NIST SPECIAL PUBLICATION 1800-11

Data Integrity

Recovering from Ransomware and Other Destructive Events

Includes Executive Summary (A); Approach, Architecture, and Security Characteristics (B), and How-To Guides (C)

Timothy McBride
Michael Ekstrom
Lauren Lusty
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Anne Townsend

DRAFT

This publication is available free of charge from:
https://nccoe.nist.gov/projects/building-blocks/data-integrity

National Institute of Standards and Technology
U.S. Department of Commerce

NCCoE
NATIONAL CYBERSECURITY CENTER OF EXCELLENCE

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September 2017

U.S. Department of Commerce
Wilbur Ross, Secretary

National Institute of Standards and Technology
Kent Rochford, Acting Undersecretary of Commerce for Standards and Technology and Director

NIST SPECIAL PUBLICATION 1800-11A

Data Integrity

Recovering from Ransomware and Other Destructive Events

Volume A:
Executive Summary

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Executive Summary

- Data integrity attacks have compromised corporate information including emails, employee records, financial records, and customer data.
- Destructive malware, ransomware, malicious insider activity, and even honest mistakes all set the stage for why organizations need to quickly recover from an event that alters or destroys data. Businesses must be confident that recovered data is accurate and safe.
- The National Cybersecurity Center of Excellence (NCCoE) at NIST built a laboratory environment to explore methods to effectively recover from a data corruption event in various Information Technology (IT) enterprise environments. NCCoE also explored auditing and reporting IT system use issues to support incident recovery and investigations.
- This NIST Cybersecurity Practice Guide demonstrates how organizations can develop and implement appropriate actions following a detected cybersecurity event. The solutions outlined in this guide encourage monitoring and detecting data corruption in commodity components—as well as custom applications and data composed of open-source and commercially available components.
- Thorough quantitative and qualitative data collection is important to organizations of all types and sizes. It can impact all aspects of a business including decision making, transactions, research, performance, and profitability, to name a few.

CHALLENGE

Organizations must be able to quickly recover from a data integrity attack and trust that any recovered data is accurate, complete, and free of malware. Data integrity attacks caused by unauthorized insertion, deletion, or modification of data have compromised corporate information including emails, employee records, financial records, and customer data. Some organizations have experienced systemic attacks that caused a temporary cessation of operations. One variant of a data integrity attack–ransomware–encrypts data and holds it hostage while the attacker demands payment for the decryption keys.

SOLUTION

The NCCoE developed and implemented a solution that incorporates appropriate actions in response to a detected cybersecurity event. If data integrity is jeopardized, multiple systems work in concert to recover from the event. The solution includes recommendations for commodity components and explores issues around auditing and reporting to support recovery and investigations.

While the NCCoE used a suite of commercial products to address this cybersecurity challenge, this guide does not endorse any particular products—nor does it guarantee compliance with any regulatory initiatives. Your organization's information security experts are responsible for identifying the available

products that will best integrate with your existing tools and IT system infrastructure. Your organization can choose to adopt this solution or one that adheres to these suggested guidelines or you can use this guide as a starting point for tailoring and implementing parts of the solution.

BENEFITS

This practice guide can help your organization:

- develop a strategy for recovering from a cybersecurity event
- facilitate a smoother recovery from an adverse event, maintain operations, and ensure the integrity and availability of data critical to supporting business operations and revenue-generating activities
- manage enterprise risk (consistent with foundations of the NIST *Framework for Improving Critical Infrastructure Cybersecurity*)

SHARE YOUR FEEDBACK

You can view or download the Practice Guide at https://nccoe.nist.gov/projects/building_blocks/data_integrity.

Help the NCCoE make this guide better by sharing your thoughts with us as you read the guide. If you adopt this solution for your own organization, please share your experience and advice with us. We recognize that technical solutions alone will not fully enable the benefits of our solution, so we encourage organizations to share lessons learned and best practices for transforming the processes associated with implementing this guide.

To provide comments or to learn more by arranging an in-person demonstration of this reference solution, email the project team at di-nccoe@nist.gov.

TECHNOLOGY PARTNERS/COLLABORATORS

Organizations participating in this project submitted their capabilities in response to an open call in the Federal Register for all sources of relevant security capabilities from academia and industry (vendors and integrators). The following respondents with relevant capabilities or product components (identified as “Technology Partners/Collaborators” herein) signed a Cooperative Research and Development Agreement to collaborate with NIST in a consortium to build this example solution.

Certain commercial entities, equipment, products, or materials may be identified by name or company logo or other insignia in order to acknowledge their participation in this collaboration or to describe an experimental procedure or concept adequately. Such identification is not intended to imply special status or relationship with NIST or recommendation or endorsement by NIST or NCCoE; neither is it

67 intended to imply that the entities, equipment, products, or materials are necessarily the best available
68 for the purpose.

The National Cybersecurity Center of Excellence (NCCoE), a part of the National Institute of Standards and Technology (NIST), is a collaborative hub where industry organizations, government agencies, and academic institutions work together to address businesses' most pressing cybersecurity challenges. Through this collaboration, the NCCoE develops modular, easily adaptable example cybersecurity solutions demonstrating how to apply standards and best practices using commercially available technology.

LEARN MORE

Visit https://nccoe.nist.gov
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NIST SPECIAL PUBLICATION 1800-11B

Data Integrity

Recovering from Ransomware and Other Destructive Events

Volume B:
Approach, Architecture, and Security Characteristics

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National Cybersecurity Center of Excellence
National Institute of Standards and Technology

Michael Ekstrom
Lauren Lusty
Julian Sexton
Anne Townsend
The MITRE Corporation
McLean, VA

September 2017

DRAFT

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DISCLAIMER

Certain commercial entities, equipment, products, or materials may be identified in this document in order to describe an experimental procedure or concept adequately. Such identification is not intended to imply recommendation or endorsement by NIST or NCCoE, nor is it intended to imply that the entities, equipment, products, or materials are necessarily the best available for the purpose.

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FEEDBACK

You can improve this guide by contributing feedback. As you review and adopt this solution for your own organization, we ask you and your colleagues to share your experience and advice with us.

Comments on this publication may be submitted to di-nccoe@nist.gov.

Public comment period: September 6, 2017 through November 6, 2017

All comments are subject to release under the Freedom of Information Act (FOIA).

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NATIONAL CYBERSECURITY CENTER OF EXCELLENCE

The National Cybersecurity Center of Excellence (NCCoE), a part of the National Institute of Standards and Technology (NIST), is a collaborative hub where industry organizations, government agencies, and academic institutions work together to address businesses' most pressing cybersecurity issues. This public-private partnership enables the creation of practical cybersecurity solutions for specific industries, as well as for broad, cross-sector technology challenges. Through consortia under Cooperative Research and Development Agreements (CRADAs), including technology partners—from Fortune 50 market leaders to smaller companies specializing in IT security—the NCCoE applies standards and best practices to develop modular, easily adaptable example cybersecurity solutions using commercially available technology. The NCCoE documents these example solutions in the NIST Special Publication 1800 series, which maps capabilities to the NIST Cyber Security Framework and details the steps needed for another entity to recreate the example solution. The NCCoE was established in 2012 by NIST in partnership with the State of Maryland and Montgomery County, Md.

To learn more about the NCCoE, visit https://nccoe.nist.gov. To learn more about NIST, visit https://www.nist.gov.

NIST CYBERSECURITY PRACTICE GUIDES

NIST Cybersecurity Practice Guides (Special Publication Series 1800) target specific cybersecurity challenges in the public and private sectors. They are practical, user-friendly guides that facilitate the adoption of standards-based approaches to cybersecurity. They show members of the information security community how to implement example solutions that help them align more easily with relevant standards and best practices and provide users with the materials lists, configuration files, and other information they need to implement a similar approach.

The documents in this series describe example implementations of cybersecurity practices that businesses and other organizations may voluntarily adopt. These documents do not describe regulations or mandatory practices, nor do they carry statutory authority.

ABSTRACT

Businesses face a near-constant threat of destructive malware, ransomware, malicious insider activities, and even honest mistakes that can alter or destroy critical data. These data corruption events could cause a significant loss to a company's reputation, business operations, and bottom line.

These types of adverse events, that ultimately impact data integrity, can compromise critical corporate information including emails, employee records, financial records, and customer data. It is imperative for organizations to recover quickly from a data integrity attack and trust the accuracy and precision of the recovered data.

The National Cybersecurity Center of Excellence (NCCoE) at NIST built a laboratory environment to explore methods to effectively recover from a data corruption event in various Information Technology (IT) enterprise environments. NCCoE also implemented auditing and reporting IT system use to support incident recovery and investigations.

This NIST Cybersecurity Practice Guide demonstrates how organizations can implement technologies to take immediate action following a data corruption event. The example solution outlined in this guide encourages effective monitoring and detection of data corruption in standard, enterprise components as well as custom applications and data composed of open-source and commercially available components.

KEYWORDS

business continuity; data integrity; data recovery; malware; ransomware

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Donna Koschalk	Veeam Software Corporation
Brian Abe	The MITRE Corporation
Sarah Kinling	The MITRE Corporation
Josh Klosterman	The MITRE Corporation
Susan Urban	The MITRE Corporation

Name	Organization
Mary Yang	The MITRE Corporation

The Technology Partners/Collaborators who participated in this build submitted their capabilities in response to a notice in the Federal Register. Respondents with relevant capabilities or product components were invited to sign a Cooperative Research and Development Agreement (CRADA) with NIST, allowing them to participate in a consortium to build this example solution. We worked with:

Technology Partner/Collaborator	Build Involvement
GreenTec USA	GreenTec WORMdisk, v151228
Hewlett Packard Enterprise	HPE ArcSight ESM, v6.9.1 HPE ArcSight Connector, v7.4.0
IBM Corporation	IBM Spectrum Protect, v8.1.0
Tripwire	Tripwire Enterprise, v8.5 Tripwire Log Center, v7.2.4.80
Veeam Software Corporation	Veeam Availability Suite, v9.5

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1 Summary

Businesses face a near-constant threat of destructive malware, ransomware, malicious insider activities, and even honest mistakes that can alter or destroy critical data. These types of adverse events ultimately impact data integrity (DI). It is imperative for organizations to recover quickly from a DI attack and trust the accuracy and precision of the recovered data.

The National Cybersecurity Center of Excellence (NCCoE) at the National Institute of Standards and Technology (NIST) built a laboratory environment to explore methods to recover from a data corruption event in various information technology (IT) enterprise environments. The example solution outlined in this guide describes the solution built in the NCCoE lab. It encourages effective monitoring and detection of data corruption in standard enterprise components as well as custom applications and data composed of open-source and commercially available components.

The goals of this NIST Cybersecurity Practice Guide are to help organizations confidently:

- restore data to its last known good configuration
- identify the correct backup version (free of malicious code and data for data restoration)
- identify altered data as well as the date and time of alteration
- determine the identity/identities of those who alter data
- identify other events that coincide with data alteration
- determine any impact of the data alteration

For ease of use, here is a short description of the different sections of this volume.

- **Section 1**: *Summary* presents the challenge addressed by the NCCoE project, with an in-depth look at our approach, the architecture, and the security characteristics we used; the solution demonstrated to address the challenge; benefits of the solution; and the technology partners that participated in building, demonstrating, and documenting the solution. The Summary also explains how to provide feedback on this guide.
- **Section 2**: *How to Use This Guide* explains how readers—business decision makers, program managers, and IT professionals (e.g., systems administrators)—might use each volume of the guide.
- **Section 3**: *Approach* offers a detailed treatment of the scope of the project and describes the assumptions on which the security platform development was based, the risk assessment that informed platform development, and the technologies and components that industry collaborators gave us to enable platform development.

- **Section 4**: *Architecture* describes the usage scenarios supported by project security platforms, including Cybersecurity Framework [1] functions supported by each component contributed by our collaborators.
- **Section 5**: *Example Implementation* provides an in-depth description of the implementation developed in the NCCoE's lab environment.
- **Section 6**: *Security Characteristics Analysis* provides details about the tools and techniques we used to perform risk assessments.
- **Section 7**: *Functional Evaluation* summarizes the test sequences we employed to demonstrate security platform services, the Cybersecurity Framework functions to which each test sequence is relevant, and the NIST Special Publication (SP) 800-53-4 controls that applied to the functions being demonstrated.
- **Section 8**: *Future Build Considerations* is a brief treatment of other DI implementations NIST is considering consistent with Framework Core Functions: Identify, Protect, Detect and Respond, System Level Recovery, and Dashboarding.

1.1 Challenge

Thorough collection of quantitative and qualitative data is important to organizations of all types and sizes. It can impact all aspects of a business, including decision making, transactions, research, performance, and profitability. When these data collections sustain a DI attack caused by unauthorized insertion, deletion, or modification of information, it can impact emails, employee records, financial records, and customer data, rendering it unusable or unreliable. Some organizations have experienced systemic attacks that caused a temporary cessation of operations. One variant of a DI attack—ransomware—encrypts data and holds it hostage while the attacker demands payment for the decryption keys.

When DI events occur, organizations must be able to recover quickly from the events and trust that the recovered data is accurate, complete, and free of malware.

1.2 Solutions

The NCCoE implemented a solution that incorporates appropriate actions in response to a detected DI event. The solution is comprised of multiple systems working together to recover from a data corruption event in standard enterprise components. These components include, but are not limited to, mail servers, databases, end user machines, virtual infrastructure, and file share servers. Essential to the recovery is an investigation into auditing and reporting records to understand the depth and breadth of the event across these systems and inclusive of user activity.

The NCCoE sought existing technologies that provided the following capabilities:

- secure storage
- logging
- virtual infrastructure
- corruption testing
- backup capability

While the NCCoE used a suite of commercial products to address this cybersecurity challenge, this guide does not endorse any particular products—nor does it guarantee compliance with any regulatory initiatives. Your organization's information security experts should identify the products that will best integrate with your existing tools and IT system infrastructure. Your organization can adopt this solution or one that adheres to these guidelines in whole, or you can use this guide as a starting point for tailoring and implementing parts of the solution. In developing our solution, we used standards and guidance from the following, which can also provide your organization relevant standards and best practices:

- NIST Framework for Improving Critical Infrastructure Cybersecurity (commonly known as the NIST CSF) [1]
- NISTIR 8050: Executive Technical Workshop on Improving Cybersecurity and Consumer Privacy [2]
- Special Publication 800-30 Rev. 1: Guide for Conducting Risk Assessments [3]
- Special Publication 800-37 Rev. 1: Guide for Applying the Risk Management Framework to Federal Information Systems: A Security Lifecycle Approach [4]
- Special Publication 800-39: Managing Information Security Risk [5]
- Special Publication 800-40 Rev. 3: Guide to Enterprise Patch Management Technologies [6]
- Special Publication 800-53 Rev. 4: Security and Privacy Controls for Federal Information Systems and Organizations [7]
- FIPS 140-2: Security Requirements for Cryptographic Modules [8]
- Special Publication 800-86: Guide to Integrating Forensic Techniques into Incident Response [9]
- Special Publication 800-92: Guide to Computer Security Log Management [10]
- Special Publication 800-100: Information Security Handbook: A Guide for Managers [11]
- Special Publication 800-34 Rev. 1: Contingency Planning Guide for Federal Information Systems [12]
- Office of Management and Budget, Circular Number A-130: Managing Information as a Strategic Resource [13]

- Special Publication 800-61 Rev. 2: Computer Security Incident Handling Guide [14]
- Special Publication 800-83 Rev. 1: Guide to Malware Incident Prevention and Handling for Desktops and Laptops [15]
- Special Publication 800-150: Guide to Cyber Threat Information Sharing [16]
- Special Publication 800-184: Guide for Cybersecurity Event Recovery [17]

1.3 Benefits

The NCCoE's practice guide can help your organization:

- develop an implementation plan for recovering from a cybersecurity event
- facilitate a smoother recovery from an adverse event and maintain operations
- maintain integrity and availability of data that is critical to supporting business operations and revenue-generating activities
- manage enterprise risk (consistent with the foundations of the NIST CSF)

2 How to Use This Guide

This NIST Cybersecurity Practice Guide demonstrates a standards-based reference design and provides users with the information they need to replicate a solution to recover from attacks on DI to a last known good. This reference design is modular and can be deployed in whole or in part.

This guide contains three volumes:

- NIST SP 1800-11a: *Executive Summary*
- NIST SP 1800-11b: *Approach, Architecture, and Security Characteristics* – what we built and why **(you are here)**
- NIST SP 1800-11c: *How-To Guides* – instructions for building the example solution

Depending on your role in your organization, you might use this guide in different ways.

Business decision makers, including chief security and technology officers, will be interested in the *Executive Summary (NIST SP 1800-11a)*, which describes the:

- challenges enterprises face in attacks on DI
- example solution built at the NCCoE
- benefits of adopting the example solution

Technology or security program managers who are concerned with how to identify, understand, assess, and mitigate risk will be interested in this part of the guide, *NIST SP 1800-11b,* which describes what we did and why. The following sections will be of particular interest:

- Section 3.4.1, Assessing Risk Posture - describes the risk analysis we performed.
- Section 3.4.2, Security Control Map - maps the security characteristics of this example solution to cybersecurity standards and best practices.

You might share the *Executive Summary, NIST SP 1800-11a,* with your leadership team members to help them understand the importance of adopting standards-based methods to recover from attacks on DI to a last known good.

IT professionals who want to implement a similar approach will find the whole practice guide useful. You can use the "how-to" portion of the guide, *NIST SP 1800-11c*, to replicate all or parts of the build created in our lab. The guide provides specific product installation, configuration, and integration instructions. We do not recreate the product manufacturers' documentation, which is generally widely available. Rather, we show how we incorporated the products together in our environment to create an example solution.

This guide assumes that IT professionals have experience implementing security products within the enterprise. While we used a suite of commercial products, this guide does not endorse these particular products. Your organization can adopt this solution or one that adheres to these guidelines in whole, or you can use this guide as a starting point for tailoring parts of it to recover from attacks on DI. Your organization's security experts should identify the products that will best integrate with your existing tools and IT system infrastructure. We hope you will seek products that are congruent with applicable standards and best practices. Section 3.5, Technologies, lists the products we used and maps them to the cybersecurity controls provided by this reference solution.

A NIST Cybersecurity Practice Guide does not describe "the" solution, but a possible solution. This is a draft guide. We seek feedback on its contents and welcome your input. Comments, suggestions, and success stories will improve subsequent versions of this guide. Please contribute your thoughts to di-nccoe@nist.gov.

2.1 Typographic Conventions

The following table presents typographic conventions used in this volume.

Typeface/ Symbol	Meaning	Example
Italics	filenames and pathnames references to documents that are not hyperlinks, new terms, and placeholders	For detailed definitions of terms, see the *NCCoE Glossary.*
Bold	names of menus, options, command buttons and fields	Choose **File > Edit**.
`Monospace`	command-line input, on-screen computer output, sample code examples, status codes	`mkdir`
`Monospace Bold`	command-line user input contrasted with computer output	**`service sshd start`**
blue text	link to other parts of the document, a web URL, or an email address	All publications from NIST's National Cybersecurity Center of Excellence are available at http://nccoe.nist.gov

3 Approach

Based on key points expressed in *NIST IR 8050: Executive Technical Workshop on Improving Cybersecurity and Consumer Privacy* (2015) [2], the NCCoE is pursuing a series of DI projects to map the core functions of the NIST Cybersecurity Framework. This initial project is centered on the core function of recovery, which is focused on recovering data to the last known good state. NCCoE engineers working with a Community of Interest (COI) defined the requirements for the DI project.

Members of the COI, which include participating vendors referenced in this document, contributed to the development of the architecture and reference design, providing technologies that meet the project requirements and assisting in the installation and configuration of those technologies. The practice guide highlights the approach used to develop the NCCoE reference solution. Elements include risk assessment and analysis, logical design, build development, test and evaluation, and security control

mapping. This guide is intended to provide practical guidance to any organization interested in implementing a solution for recovery from a cybersecurity event.

3.1 Audience

This guide is intended for individuals responsible for implementing security solutions in organizations' IT support activities. Current IT systems, particularly in the private sector, often lack integrity protection for domain name services and electronic mail. The platforms demonstrated by this project, and the implementation information provided in these practice guides, permit integration of products to implement a data recovery system. The technical components will appeal to system administrators, IT managers, IT security managers, and others directly involved in the secure and safe operation of the business IT networks.

3.2 Scope

The guide provides practical, real-world guidance on developing and implementing a DI solution consistent with the principles in the *NIST Framework for Improving Critical Infrastructure Cybersecurity Volume 1* [1], specifically the core function of recover. Recover emphasizes developing and implementing the appropriate activities to maintain plans for resilience and to restore any capabilities or services that were impaired by a cybersecurity event to a last known good state. Examples of outcomes within this function include recovery planning, improvements, and communication.

3.3 Assumptions

This project is guided by the following assumptions:

- The solution was developed in a lab environment. The environment is based on a typical organization's IT enterprise. It does not reflect the complexity of a production environment.
- An organization has access to the skill sets and resources required to implement a data recovery solution.
- A DI event has taken place and been detected. This guide does not address the actual detection function.

3.4 Risk Assessment

NIST SP 800-30 Rev. 1: Guide for Conducting Risk Assessments [3] states that the definition of risk is "a measure of the extent to which an entity is threatened by a potential circumstance or event, and typically a function of: (i) the adverse impacts that would arise if the circumstance or event occurs; and (ii) the likelihood of occurrence." The NCCoE recommends that any discussion of risk management, particularly at the enterprise level, begin with a comprehensive review of *NIST 800-37: A Guide for Applying the Risk Management Framework to Federal Information Systems* [4]. The framework proved

invaluable in giving us a baseline to assess risks, from which we developed the required security controls of the reference design and this guide.

We performed two types of risk assessment:

- Initial analysis of the risk factors that were discussed with financial, retail, and hospitality institutions. This analysis led to the creation of the DI project and the desired security posture. See *NIST IR 8050 Executive Technical Workshop* [2] for additional participant information.
- Analysis of how to secure the components within the solution and minimize any vulnerabilities they might introduce. See Section 6, Security Characteristics Analysis.

3.4.1 Assessing Risk Posture

Using the guidance in NIST's series of publications concerning risk, we worked with financial institutions and the Financial Sector Information Sharing and Analysis Center to identify the most compelling risk factors encountered by this business group. We participated in conferences and met with members of the financial sector to define the main security risks to business operations. These discussions resulted in the identification of an area of concern—the inability to recover from DI attacks. We then identified the core operational risks, as various methods exist that all lead to sustaining a DI compromise. These risks lead to two tactical risk factors:

- systems incapacitated
- DI impacted

These discussions also gave us an understanding of strategic risks for organizations with respect to DI. *NIST SP 800-39: Managing Information Security Risk* [5] focuses particularly on the business aspect of risk, namely at the enterprise level. This understanding is essential for any further risk analysis, risk response/mitigation, and risk monitoring activities. The following is a summary of the strategic risk areas we identified and their mitigations:

- Impact on system function – ensuring the availability of accurate data or sustaining an acceptable level of DI reduces the risk of systems' availability being compromised.
- Cost of implementation – implementing DI once and using it across all systems may reduce both system restoration and system continuity costs.
- Compliance with existing industry standards – contributes to the industry requirement to maintain a continuity of operations plan.
- Maintenance of reputation and public image – helps reduce level of impact, in turn helping to maintain image.
- Increased focus on DI – includes not just loss of confidentiality but also harm from unauthorized alteration of data (per NIST IR 8050 [2]).

We subsequently translated the risk factors identified to security functions and subcategories within the NIST CSF. In Table 3-1 we mapped the categories to NIST's *SP 800-53 Rev. 4* [7] controls and International Electrotechnical Commission/International Organization for Standardization (IEC/ISO) controls for additional guidance.

3.4.2 Security Control Map

As explained in Section 3.4.1, we identified the CSF security functions and subcategories that we wanted the reference design to support through a risk analysis process. This was a critical first step in designing the reference design and example implementation to mitigate the risk factors. Table 3-1 lists the addressed CSF functions and subcategories and maps them to relevant NIST standards, industry standards, and controls and best practices. The references provide solution validation points in that they list specific security capabilities that a solution addressing the CSF subcategories would be expected to exhibit. Organizations can use Table 3-1 to identify the CSF subcategories and NIST 800-53 controls that they are interested in addressing.

Note: Not all the CSF subcategories guidance can be implemented using technology. Any organization executing a DI solution would need to adopt processes and organizational policies that support the reference design. For example, some of the subcategories within the CSF function "Identify" are processes and policies that should be developed prior to implementing recommendations.

Table 3-1 Data Integrity Reference Design CSF Core Components Map

Cybersecurity Framework (CSF) v1.1				Standards & Best Practices
Function	**Category**	**Subcategory**	**SP800-53R4**	**ISO/IEC 27001:2013**
PROTECT (PR)	Data Security (PR.DS)	PR.DS-1: Data-at-rest is protected	SC-28	A.8.2.3
		PR.DS-6: Integrity checking mechanisms are used to verify software, firmware, and information integrity	SI-7	A.12.2.1, A.12.5.1, A.14.1.2, A.14.1.3

Cybersecurity Framework (CSF) v1.1				Standards & Best Practices
Function	**Category**	**Subcategory**	**SP800-53R4**	**ISO/IEC 27001:2013**
	Information Protection Processes and Procedures (PR.IP)	PR.IP-3: Configuration change control processes are in place	CM-3, CM-4, SA-10	A.12.1.2, A.12.5.1, A.12.6.2, A.14.2.2, A.14.2.3, A.14.2.4, A.14.2.7
		PR.IP-4: Backups of information are conducted, maintained, and tested periodically	CP-4, CP-6, CP-9	A.11.1.4, A.12.3.1, A.17.1.2, A.17.1.3, A.17.2.1 A. 18.1.3
		PR.IP-9: Response plans (Incident Response and Business Continuity) and recovery plans (Incident Recovery and Disaster Recovery) are in place and managed	CP-2, IR-8	A.16.1.1, A.17.1.1, A.17.1.2, A.17.2.1
	Protective Technology (PR.PT)	PR.PT-1: Audit/log records are determined, documented, implemented, and reviewed in accordance with policy	AU Family IR-5, IR-6	A.6.1.3, A.16.1.2, A.12.4.1, A.12.4.2, A.12.4.3, A.12.4.4, A.12.7.1

Cybersecurity Framework (CSF) v1.1				Standards & Best Practices
Function	**Category**	**Subcategory**	**SP800-53R4**	**ISO/IEC 27001:2013**
DETECT (DE)	Anomalies and Events (DE.AE)	DE.AE-4: Impact of events is determined	CP-2, IR-4, RA-3, SI -4	A.6.1.1, A.17.1.1, A.17.2.1, A.16.1.4, A.16.1.5, A.16.1.6, A.12.6.1
	Security Continuous Monitoring (DE.CM)	DE.CM-1: The network is monitored to detect potential cybersecurity events	AC-2, AU-12, CA-7, CM-3, SC-5, SC-7, SI-4	A.9.2.1, A.9.2.2, A.9.2.3, A.9.2.5, A.9.2.6, A.12.4.1, A.12.4.3, A.12.1.2, A.14.2.2, A.14.2.3, A.14.2.4, A.13.1.1, A.13.1.3, A.13.2.1, A.14.1.3
		DE.CM-3: Personnel activity is monitored to detect potential cybersecurity events	AC-2, AU-12, AU-13, CA-7, CM-10, CM-11	A.9.2.1, A.9.2.2, A.9.2.3, A.9.2.5, A.9.2.6, A.12.4.1, A.12.4.3, A.18.1.2, A.12.5.1, A.12.6.2s

3.5 Technologies

Table 3-2 lists all the technologies used in this project and provides a mapping between the generic application term, the specific product used, and the security control(s) that the product provides. Refer to Table 3-1 for an explanation of the CSF subcategory codes. This table describes only the product capabilities used in our example solution. Many of the products have additional security capabilities that were not used for our purposes.

Table 3-2 Products and Technologies

Component	Specific Product	Function	CSF Subcategories
Corruption Testing	ArcSight Enterprise Security Manager (ESM) v6.9.1 Tripwire Enterprise v8.5 Tripwire Log Center Manager v7.2.4.80	• provides monitoring for changes to data on a system • provides logs, detection, and reporting, in the event of changes to data on a system • provides audit capabilities for database metadata and content modifications • provides file hashing and integrity testing independent of file type (can include software files) • provides notifications for changes to configuration • provides file monitoring for cybersecurity events • provides analytic capabilities to determine the impact of integrity events	PR.DS-6, PR.PT-1, DE.AE-4
Secure Storage	Spectrum Protect and Backup and Replication v8.1.0 WORMdisk v151228	• provides write-once read-many file disk storage for secure backups of integrity information • provides immutability of backups • creates encrypted backups	PR.DS-1, PR.IP-4
Logging	ArcSight Enterprise Security Manager (ESM) v6.9.1	• provides auditing and logging capabilities configurable to corporate policy • provides logging of some user activity of monitored systems	PR.PT-1, DE.AE-4, DE.CM-1, DE.CM-3

Component	Specific Product	Function	CSF Subcategories
	Tripwire Enterprise v8.5	• provides network information about certain cybersecurity events • correlates logs of cybersecurity events with user information • provides logs of database activity and database backup operations	
	Tripwire Log Center Manager v7.2.4.80	• provides analysis capabilities for log data • provides analysis capabilities for finding anomalies in user activity • provides automation for logging • provides logs of database activity and database backup operations	
Backup Capability	Spectrum Protect and Backup and Replication v8.1.0	• provides backup and restoration capabilities for systems • provides backup and restore capabilities for configuration files • provides immutable storage • performs periodic backups of information	PR.DS-1, PR.IP-3, PR.IP-4, PR.IP-9
	WORMdisk v151228		
Virtual Infrastructure	Veeam Availability Suite 9.5	• provides backup and restoration capabilities for virtual systems • provides ability to encrypt backups • provides logs for backup and restore operations	PR.DS-1, PR.IP-4, PR.PT-1

4 Architecture

Data integrity involves the recovery of data after a ransomware or other destructive attack with the validation that the recovered data is the last known good. This section presents a high-level architecture and reference design for implementing such a solution.

4.1 Architecture Description

4.1.1 High-Level Architecture

The DI solution is designed to address the security functions and subcategories described in Table 3-1 and is composed of the capabilities illustrated in Figure 4-1.

Figure 4-1 DI High-Level Architecture

1. Secure Storage provides the capability to store data with additional data protection measures, such as Write Once Read Many (WORM) technologies or data encryption.
2. Logging stores and reports all the log files produced by the components within the enterprise.
3. Virtual Infrastructure provides virtualized capabilities, including backup capabilities for the virtual infrastructure.
4. Corruption Testing provides capabilities for testing file corruption and provides notification or logs of violations against specified policies.
5. Backup Capability establishes a capability for components within the enterprise that are not a part of the virtual infrastructure to produce a backup.

These capabilities work together to provide the recover function for DI. The secure storage is the ability to store file-such as backups, gold images, or configurations files, in a format that cannot be corrupted, since files cannot be altered or changed while in storage. The logging capability works in conjunction with the corruption testing. The corruption testing capability describes the event(s) when the attack occurs and the damage caused. Since the corruption testing describes when the event occurred, these details can be used to investigate the logs to correlate all events relative to the attack across all items

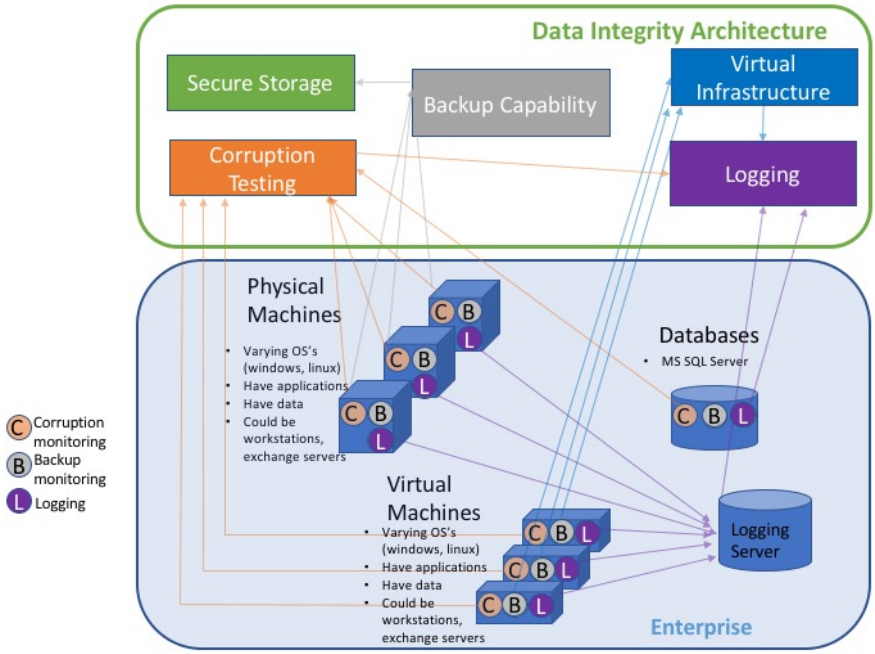
that report log files. After the last known good is determined via the logs and corruption testing, the backup capability for either the enterprise or the virtual infrastructure is employed. A backup capability is the ability to restore to the point prior to the DI event. The backup capability is supplemented by built-in backup and rollback capabilities of the database services.

The following components of the high-level architecture are not addressed in this guide: enterprise components (e.g., virtual machines, mail servers, active directory, file sharing capabilities), installation and configurations, file corruption testing policies, and event detection.

4.1.2 Reference Design

The reference design addresses the DI architecture in conjunction with its interactions with a representation of a basic enterprise.

Figure 4-2 DI Reference Design



Solid lines represent the communication of information between components within the enterprise, from the enterprise to the DI architecture, or between components within the DI architecture. The lines are color coded to correspond with the capability provided by the DI architecture.

The Secure Storage component provides a capability to store the most critical files for an enterprise. These would include backup data, configuration files, and golden images. Additional measures need to be applied to provide increased security to these files so they are not subject to attacks or corruption.

The Corruption Testing component provides the ability to test, understand, and measure the attack that occurred to files and components within the enterprise. This testing is essential to identify the last known good for the DI recovery process. For these measures to be applicable to an enterprise, appropriate triggers need to be defined and developed within the capability that look for specific events. For example, it may be very normal for end users to have encrypted files they develop during operational hours. But if every file on the end user's workstation begins to be encrypted, or an encryption begins to happen on the end user machine at hours outside of normal operational hours, these could be identifiable actions noted in the log files indicating a ransomware attack. For an enterprise, these triggers need to be defined appropriately and thoroughly to have a successful Corruption Testing capability.

The Backup Capability component supports the ability to back up each component within the enterprise as well as perform a restore that uses backup data. The configuration of this component needs to align with the tempo of the enterprise. For example, if an enterprise is performing thousands of transactions per hour per day, then a backup solution that only performs a backup once a day would not adequately provide for the enterprise. This type of configuration would allow for a potentially large data loss. If backups occur every morning and a loss of DI happened at the end of the day, then a full day's worth of transactions would be lost. The decision on what the correct configuration is determined by an organization's risk tolerance. More information pertaining to this decision can be found in Section 5.1.1.3.

The Virtual Infrastructure component straddles the line between being part of the enterprise and part of the DI architecture. It provides virtual capabilities to the enterprise as well as backup and restoration capabilities to support the DI architecture. The backup and restoration capabilities are for the virtual infrastructure itself. For data that is produced on individual virtual machines (VMs), either the VM infrastructure can provide the file-level restoration or the backup component can provide this capability. If the VM infrastructure cannot provide its own backup and restoration, then the requirements for that are levied on the backup component.

Logging from each component and sorting the logs together is imperative to understanding the ramifications of the attack across the enterprise. File, system, and configuration changes and modifications need to be logged, reported, and stored in one repository where events can be identified and understood.

Databases are necessary to support everyday operations of the enterprise architecture and to assist in backup and recovery. The chosen database software should have built-in backup and rollback methods enabled, although commercial solutions for the backup and recovery of databases exist. Often, these commercial solutions use the internal database backup/recovery capabilities. These capabilities are tied into the security architecture, as demonstrated in Section 5.1.6.2. Consult the Backup Capability paragraph above for guidance on the regularity of backups. The regularity of database backups determines the effectiveness of data recovery efforts.

5 Example Implementation

The example implementation is constructed on the NCCoE lab's infrastructure, which consists of a VMware vSphere virtualization operating environment. We used network attached storage and virtual switches, as well as internet access, to interconnect the solution components. The lab network is not connected to the NIST enterprise network. Table 5-1 lists (alphabetically) the software and hardware components we used, as well as the specific function each component.

Table 5-1 Example Implementation Component List

Product Vendor	Component Name	Function
GreenTec	WORMdisk	Secure, immutable hardware
Hewlett Packard Enterprise (HPE)	ArcSight ESM	Log analysis, correlation, management, and reporting
IBM	Spectrum Protect	File-level, disk-level, and system-level backup and recovery
Tripwire	Enterprise and Log Center	File integrity monitoring and database metadata integrity monitoring
Veeam	Availability Suite	VM backup and restore

The architecture depicted in Figure 5-1 describes a solution built around several typical infrastructure components: a Microsoft Exchange server, a Microsoft SharePoint server, a Microsoft Structured Query Language (MS SQL) server, a Microsoft Hyper-V server, and a Microsoft Active Directory server that also runs Microsoft Domain Name System service, as well as an array of client machines, primarily running Windows 10 and Ubuntu 16.04.

The solution consists of several products to comprise an enterprise DI solution.

Organizations should have backup capability that can be used to back up files, disks, and systems. Tools that provide backup capability may also provide capabilities to back up databases or email servers. These tools should include management capabilities for backups that provide configuration options such as when and how data should be backed up. IBM Spectrum Protect provides backup capability in this build. Clients are installed on all machines that need backup and restore capabilities. Furthermore, IBM Spectrum Protect uses incremental backups; essentially, this means that it stores an initial full backup of a user's system. After this initial backup, additional backups are performed only after changes occur in data.

Secure storage is important for protecting backups and other forms of data in an enterprise DI solution. Secure storage involves write-protected or write-controlled devices, which prevent data from being modified or deleted. By integrating backup infrastructure with these disks, it is possible to permanently

preserve backups and protect them from harmful malware and accidental deletion. GreenTec WORMdisks are a secure storage solution that protects data on a firmware level. WORMdisks come with software to lock disks or portions of disks permanently or temporarily. Once WORMdisks are locked, they are immutable and any data on the disk is read-only. Implementation instructions are included for backing up directly to GreenTec WORMdisks using IBM Spectrum Protect, as well as instructions for copying backup data from IBM Spectrum Protect to a WORMdisk. Other files stored on these disks can be copied over using the operating system's usual methods. WORMdisks are transparent to the operating system in terms of use, so they function as regular storage drives until they are locked.

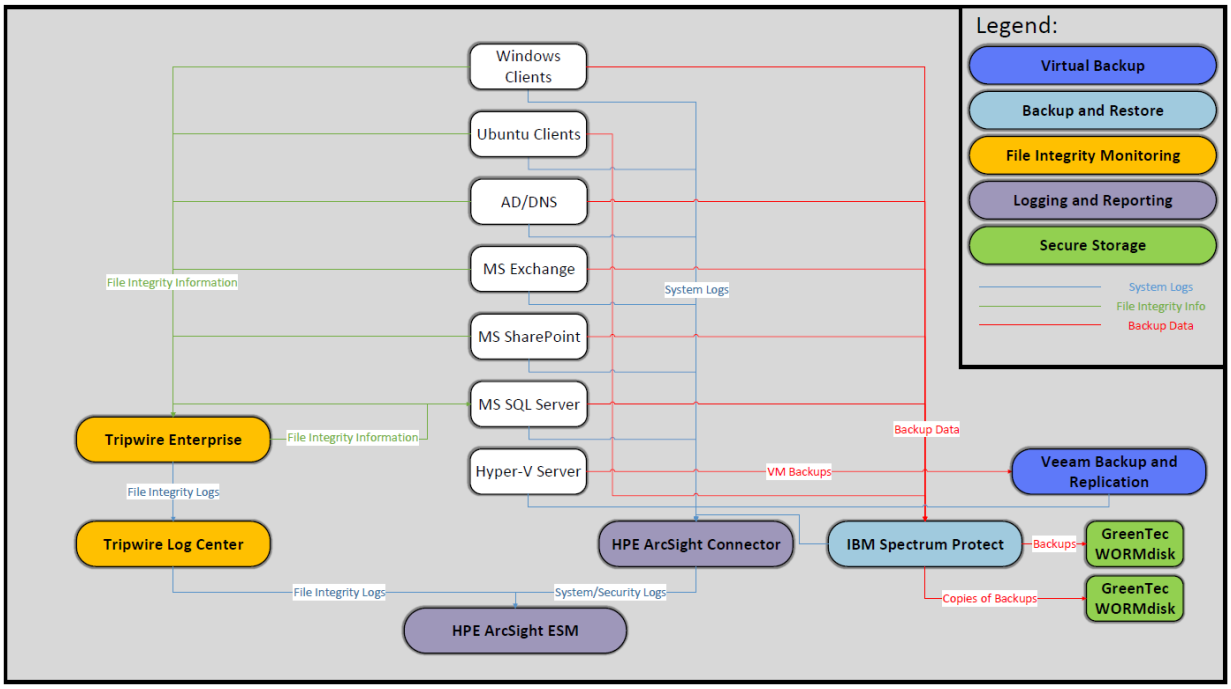
Corruption testing involves periodic or manual testing of files for modifications, deletions, additions, or other potential DI events. Tools that provide corruption testing may also test other systems, such as databases or mail servers. Tripwire Enterprise provides corruption testing for this build. By using individual agents installed on client machines, Tripwire Enterprise generates file integrity information for a set of specified files and folders. Tripwire Enterprise can also generate file integrity information for database metadata, allowing administrators to track changes made to database structure. It stores this metadata in a database. For simplicity, we use the MS SQL server to store the file integrity information, but this could be done in a separate database for processing efficiency. Tripwire Enterprise forwards logs that it generates to Tripwire Log Center. Tripwire Log Center allows for filtering and processing of Tripwire Enterprise logs as well as the ability to integrate with other log collection tools.

Many organizations have virtual infrastructure that allows them to manage the distribution of VMs across their enterprise. When implementing a DI solution, the virtual infrastructure should include the ability to granularly backup and restore VMs. Veeam Backup and Replication is a tool that can integrate with Hyper-V and VMware to jointly comprise the virtual infrastructure of our build. Veeam Backup and Replication can provide granular backup and restore capabilities. It can perform restores of entire VMs as well as restores on individual files in virtualized environments. Veeam Backup and Replication is server based and can be applied to Hyper-V machines that run on various systems across the enterprise.

Logging is another important piece of a DI solution. The collection of logs from various sources is useful in identifying the root cause of DI events, whether they are caused by accident or by malicious insiders or software. Furthermore, logs aid in identifying the time of the last known good and inform decisions regarding restoration. In this build, HPE ArcSight ESM is used to collect logs from various sources. Included in the architecture is an HPE ArcSight Connector server. Through Active Directory, the connector server acquires system and security logs from all Windows endpoints in the domain. These logs are then forwarded to HPE ArcSight ESM. Implementation instructions are included for other, non-default sources. HPE ArcSight ESM can log MS SQL queries and collect Hyper-V application logs, Veeam application logs, and Ubuntu syslogs, and provides instructions for each. In the case of Hyper-V application logs and Veeam application logs, we provide sample custom parsers for forwarding some events to HPE ArcSight ESM (see Volume 3). Additionally, ESM integrates with Tripwire Log Center to provide log collection for all file integrity monitoring logs generated by Tripwire Enterprise. HPE ArcSight ESM can sort, filter, and audit logs from all its sources. The information gathered from these logs should

provide system administrators the context they need to determine how to fully remediate systems affected by destructive malware.

Figure 5-1 Example Implementation Architecture



5.1 Use Cases

5.1.1 Ransomware

5.1.1.1 Scenario

A malicious piece of software run by the user encrypts the entire documents folder. This renders files unusable and pictures unable to be viewed, and users will only be able to see encrypted text should they attempt to open any of the files in a text editor. Though the software's scope is limited to the documents folder, the approach could be more widely applied to encrypt other folders and even system files, resulting in an attack on the availability of systems and data alike.

5.1.1.2 Resolution

This use case is resolved using a combination of several tools. The corruption testing component (Tripwire Enterprise) is used to detect changes in the file systems of various selected machines, specifically when files are modified or overwritten. The corruption testing component provides context

for these events, such as a time stamp, the user responsible, the affected files, and the program that modified the file (if applicable).

The logging component (HPE ArcSight ESM) collects logs from various sources for analysis and reporting. Logs are forwarded from the corruption testing component for analysis by a system administrator. The logging component provides search, filtering, and correlation capabilities for auditing, allowing enterprises to manage the quantity of logs generated by the corruption testing component and other sources.

These two components work together to provide information about the files encrypted by the ransomware tool: the name of the program that encrypted the files, which files were affected, when they were affected, and which user ran the program. This information aids in removing the ransomware from the system and contributes to the identification of the last known good. However, it does not actually restore the availability of the user's files. The backup capability component (IBM Spectrum Protect) is used to restore encrypted files.

5.1.1.3 Other Considerations

In the event of a system failure caused by ransomware, it is important to note that recovery requires the installation of the IBM Spectrum Protect client (if IBM Spectrum Protect is used as the backup capability). If a system failed due to ransomware and cannot be rebooted, this client may not be immediately accessible. Restoration would require the reinstallation of the operating system and then installation of the IBM Spectrum Protect client. The client could then restore all files, including system files, to their previous state. Products exist that work with IBM Spectrum Protect to automate and accelerate this process.

Also, there is a trade-off between the frequency of backups and the amount of data loss an enterprise will experience. More frequent backups require more resources, both in work performed by the client and space required on the server. More frequent backups, however, provide more granularity in recovery capabilities. This can be managed by backing up active files more frequently and dormant files less frequently. An active file will lose more data during recovery because the restoration is to a point in time and will not reflect recent changes to the file.

Another caveat of more frequent (i.e., automated) backups is that if a backup is taken after a ransomware attack, the backup infrastructure will retain backups of the encrypted data. Though this is undesirable, it is still possible to restore to previous versions. This scenario highlights the importance of file monitoring capabilities, which can guide users to restoring to the correct backup.

5.1.2 File Modification and Deletion

5.1.2.1 Scenario

A malicious piece of software is downloaded from a phishing website and run by the user. The software recursively modifies files in the directory in which it is running. It removes and replaces pieces of text files, such as numbers and common English words, sometimes removing entire lines of text. It also deletes any file it doesn't recognize as text, such as pictures, videos, and music files. This results in potentially detrimental data loss. Furthermore, since files are deleted and not just encrypted, recovery is impossible without a backup infrastructure in place. There is no option to decrypt files that were deleted from the system, so compensating the creators of the malicious software for data recovery is not an option.

5.1.2.2 Resolution

Though this use case is more destructive than ransomware, the same tools are used to recover from it. The corruption testing component (Tripwire Enterprise) is used to test sensitive files and folders, and reports information such as the time, user, and the name of the malicious software that deleted and modified the now corrupted files. Even though files are missing and not just encrypted, their deletion will still be reported.

The logs generated by the corruption testing component are forwarded to the logging component (HPE ArcSight ESM) for collection and processing by a system administrator. The administrator can use the information to determine how to respond to the event—how to remove the malicious software, how to prevent it from spreading, and which files to restore. The combination of logging in concert with corruption testing provides the ability to identify the last known good.

The backup capability (IBM Spectrum Protect) is used to restore modified, corrupted, and deleted files. Even though files are missing from the user's system, they are still present in the backup capability component, and the user need only choose which backup version to restore to.

5.1.2.3 Other Considerations

Please see Section 5.1.1.3 for a discussion of tradeoffs between the frequency of backups, resources required, and restoration granularity, as they are applicable to this use case.

Again, if a backup is taken after malicious software runs but before recovery, the corrupted data will be retained by the backup infrastructure. However, it will still be possible to restore to an older version of the data with IBM Spectrum Protect (if IBM Spectrum Protect is used). IBM Spectrum Protect will not back up deleted files, however, so in the event of file deletion, the last backup taken should be sufficient for recovery, unless the user has a specific reason to recover from an earlier version.

5.1.3 VM Deletion

5.1.3.1 Scenario

A user accidentally deleted a VM in Hyper-V. In this use case, it is assumed that the user has access to the VM. Although the deletion may not set off any red flags by detection systems since a privileged user deleted the machine, it is still undesired. Since VMs can be used for several purposes—such as access to software unavailable on the host operating system (OS), emulation of infrastructure before deployment, or simply storing files for use in the user's preferred OS—the deletion of a VM can cause significant data loss and disruption in work flow.

5.1.3.2 Resolution

The VM deletion is resolved using a combination of the logging component (HPE ArcSight ESM) and the virtual infrastructure (Veeam Backup and Restore, Hyper-V). This use case deals specifically with an accidental deletion by a benign user. Because of this, logs pertaining to the deletion are likely unnecessary for recovery. However, other use cases may require logs, especially in the event of a malicious VM deletion. Therefore, our resolution includes a method for integrating the selected virtual infrastructure tools and logging component. The integration allows for the collection of logs regarding the deletion of the VM as well as logs pertaining to the restoration of the VM once complete. The virtual infrastructure is used to restore the entire deleted VM.

5.1.3.3 Other Considerations

The chosen virtual infrastructure components (Veeam Backup and Restore, Hyper-V) allow for more granular recovery–files on the guest OS can be recovered, not just the entire VM. This extends the user's restoration capabilities in events where data corruption happens within the VM. However, it is unlikely that file change logs will be forwarded to the logging component (HPE ArcSight ESM), meaning that such recovery capabilities do not meet all the requirements of this reference design.

5.1.4 Active Directory Permission Change

5.1.4.1 Scenario

A malicious insider creates backdoors into a Microsoft Exchange server. Since the culprit is an insider, he or she is assumed to be privileged. The backdoor accounts have administrator privileges and can make changes to various settings in the Exchange infrastructure. This results in potential data leaks, which could involve forwarding emails from all users to an off-site account.

5.1.4.2 Resolution

This use case is resolved primarily using the logging component (HPE ArcSight ESM) and the built-in Microsoft Windows server recovery capabilities. Since system and security logs are reported to the

logging component, administrators will be able to find which user created the accounts, the names of all the accounts created, when they were created, and the account activities. The administrator could choose to delete the accounts manually, but Windows includes a method for restoring the system state. Since restoring the system state is more complicated in later Windows server versions, the chosen backup capability (IBM Spectrum Protect) is not used for the restoration. As stated in the product documentation, the preferred method for recovering the system state is through the Microsoft Windows System State restoration process.

This restore is performed on the Active Directory server (as opposed to the Microsoft Exchange server) since the accounts, though created from the Exchange server, are stored on the Active Directory server.

5.1.4.3 Other Considerations

IBM Spectrum Protect recommends using the Microsoft Windows System State backup and recovery tool for later Windows versions.

5.1.5 Database Transactions

5.1.5.1 Scenario

A malicious or careless insider changes database data that is necessary for enterprise operations. The user is assumed to be privileged. Through the course of interacting with the database, the user executes a query that inserts, deletes, or modifies data in a way that harms enterprise operations.

5.1.5.2 Resolution

The event is detected with the logging capability (HPE ArcSight ESM). Database integrity is restored through a system of transactional rollbacks. Since the logging capability includes database query log collection, administrators will be able to find which users modified the database, and what queries were run. Given this information, administrators can determine the harmful queries and when the database was in its desired state. Transactional rollbacks are then used to restore the database to the last known good state.

5.1.5.3 Other Considerations

Restoration need not be conducted on the database server, depending on the method of rollbacks employed. The database modification can be conducted on any machine.

Transactional rollbacks require that queries be explicitly executed within “transactions.” During the restoration process, a transactional ID is specified to restore to. An enterprise can choose to force queries to use transactions through the implementation of a proxy between all potential endpoints and the database. Through this precise processing of queries, granular restoration can be achieved, though potentially at cost to efficiency.

5.1.6 Database Metadata Modification

5.1.6.1 Scenario

A malicious or careless insider changes the metadata of the system's main database. The user is assumed to be privileged. Through the course of interacting with the database, the user executes a query that changes the name of a key table. This results in a loss of functionality of the database for any queries that wish to use that table.

5.1.6.2 Resolution

This use case is resolved through database restoration capabilities—in this case, inherent to the database. Both the corruption testing component (Tripwire Enterprise) and the logging component (HPE ArcSight ESM) are used to detect the event. Through these components, administrators will be able to find which users modified the database. It is possible to manually revert the changes, but the built-in database backup and restoration capabilities can also be used to fix the metadata.

Regardless of where the database modification query was run, recovery occurs on the database server to the last known good.

5.1.6.3 Other Considerations

Backup scheduling tied to the database is separate from the backup capability (IBM Spectrum Protect). If tools are used that require separate database backup procedures, security policies and backup schedules should be designed to accommodate this fact.

Note: The use of backups to restore databases that have had adverse changes to their metadata may result in the loss of all data since the backup was taken. Reversing the changes manually is more time-consuming but more precise.

6 Security Characteristics Analysis

This evaluation focuses on the security of the reference design itself. In addition, it seeks to understand the security benefits and drawbacks of the example solution.

6.1 Assumptions and Limitations

The security characteristic evaluation has several limitations:

- It is not a comprehensive test of all security components, nor is it a red team exercise.
- It cannot identify all weaknesses.

- It does not include the lab infrastructure. It is assumed that devices are hardened. Testing these devices would reveal only weaknesses in implementation that would not be relevant to those adopting this reference architecture.

6.2 Analysis of the Reference Design's Support for CSF Subcategories

Table 3-2 lists the reference design functions and the security characteristics, along with products that we used to instantiate each capability. The focus of the security evaluation is not on these specific products but on the CSF subcategories, because, in theory, any number of commercially available products could be substituted to provide the CSF support represented by a given reference design capability.

This section discusses how the reference design supports each of the CSF subcategories listed in Table 3-1. Using the CSF subcategories as a basis for organizing our analysis allowed us to systematically consider how well the reference design supports specific security activities and provides structure to our security analysis.

6.2.1 PR.IP-3: Configuration Change Control Processes Are in Place

The reference design protects the configuration from change and detects changes in the configuration using secure hardware and file integrity monitoring. It does not include processes for change control, however, which the adopting organization should implement.

6.2.2 PR. IP-4: Backups of Information Are Conducted, Maintained, and Tested Periodically

The reference design includes capabilities for creating backups of information from various sources:

- file systems
- disks
- virtualized environments
- databases

It also describes scheduling capabilities for each of these backup targets, allowing for periodic backups as well as manual backups. The design provides the capability to test and maintain backups, but planning schedules, maintenance, and testing of backups are left to the adopting organization.

By adopting this reference design, organizations gain the capability to conduct, maintain, and test backups, and in doing so, the organizations will support the technical requirements of CSF subcategory PR.IP-4.

6.2.3 PR.DS-1: Data-at-Rest Is Protected

The reference design supports the protection of data-at-rest through:

- secure hardware as protection against data corruption
- encryption of backups as protection against unauthorized access

Through these combined capabilities, the reference design can protect data-at-rest from both unauthorized reads and writes. This protection only applies to data that is stored using the capability of the reference design. Utilization of the reference design is necessary for data protection; implementation alone is not sufficient.

By adopting this reference design, organizations gain the capability to protect data-at-rest, and in doing so, the organizations will support the technical requirements of CSF subcategory PR.DS-1.

6.2.4 PR.DS-6: Integrity Checking Mechanisms Are Used to Verify Software, Firmware, and Information Integrity

The reference design supports integrity checking for various types of data, including:

- files stored in file systems
- database metadata
- logs
- software

Firmware that is stored on special hardware may be out of the scope of the design. It should be possible to monitor firmware stored as files; however, this reference design does not include firmware or software integrity verification against online resources.

By adopting this reference design, organizations gain the capability to monitor file integrity within their system. This partially supports the technical requirements of CSF subcategory PR.DS-6, but the verification of integrity for firmware and software against verified sources is out of scope.

6.2.5 PR.PT-1: Audit/Log Records Are Determined, Documented, Implemented, and Reviewed in Accordance with Policy

The reference design supports auditing, log collection, log analysis, and log correlation. It includes mechanisms for collecting logs from:

- Microsoft event logs
- Windows application logs
- Linux system logs

- file integrity logs
- custom log sources
- database query history

Logs are aggregated into a single interface, which allows for searching, correlating, and analyzing logs from across an enterprise. Reviewing these logs is left to the individual organization.

By adopting this reference design, organizations gain the technical capability to aggregate, correlate, and analyze logs as well as perform audits across an enterprise. In doing so, the organizations will support the technical requirements of CSF subcategory PR.PT-1.

6.2.6 DE.CM-3: Personnel Activity Is Monitored to Detect Potential Cybersecurity Events

The reference design supports log collection for various activities across an enterprise, including:

- file creation, deletion, modification, and renaming
- account creation, deletion, and modification
- database queries and other activity

These collected logs, where possible, have users and programs associated with them. The design does not support active monitoring of user activity or monitoring of network activity. However, logs are provided for relevant activities, so that informed decisions can be made when an organization decides how to recover from destructive malware.

By adopting this reference design, organizations will gain the technical capability to review some personnel activity after a cybersecurity event has occurred, and in doing so, partially support the technical requirements of CSF subcategory DE.CM-3.

6.2.7 DE.CM-1: The Network Is Monitored to Detect Potential Cybersecurity Events

The reference design supports the monitoring of some network activity in the enterprise. Network information is correlated with all logged cybersecurity events to determine:

- Source Internet Protocol (IP) of event (if applicable)
- Destination IP of event (if applicable)
- Port (if applicable)

Though these collected logs have network information associated with them, network activity is not directly monitored for anomalies. Since the focus of this project is recovery, the reference design supports enough network information to recover from a cybersecurity event, but will not attempt to detect cybersecurity events based on network traffic or packet analysis.

By adopting this reference design, organizations will gain the technical capability to associate DI events with network information, and in doing so, will partially support the technical requirements of CSF subcategory DE.CM-1.

6.2.8 DE.CM-2: The Physical Environment Is Monitored to Detect Potential Cybersecurity Events

The reference design supports the monitoring of physical machines in the enterprise through the real-time monitoring of:

- file integrity
- database metadata integrity
- database queries

This reference design does not include monitoring for physical cybersecurity events, such as the insertion of potentially malicious flash drives.

By adopting this reference design, organizations will only partially gain the technical capability required to fully monitor the physical environment, and in doing so, partially support the technical requirements of CSF subcategory DE.CM-2.

6.2.9 PR.IP-9: Response Plans and Recovery Plans Are in Place and Managed

The reference design supports notification after a DI event as well as the infrastructure required for recovery, including:

- logs for analysis and auditing events after they happen
- backup and restore capabilities for successful recovery

The design supports the technical requirements of a recovery plan; however, the details of the plan should be put in place by the adopting organizations.

By adopting this reference design, organizations will gain the technical capability required to recover from a DI event, and in doing so, support the technical requirements of CSF subcategory PR.IP-9.

6.2.10 DE.AE-4: Impact of Events Is Determined

The reference design supports an infrastructure to determine the scope of DI events as well as create plans of action for remediation. This infrastructure includes:

- logs that identify impacted files and systems
- auditing to determine responsible parties after an event occurs

The design provides the forensic ability to determine affected systems and responsible parties but does not act on this information without human intervention. Adopting organizations should create plans to use this information for remediation.

By adopting the design, organizations will only partially gain the technical capability required to determine the impact of events, and in doing so, partially support the technical requirements of CSF subcategory DE.AE-4.

6.3 Security of the Reference Design

The list of reference design capabilities in Table 3-2 focuses on the capabilities needed to ensure the integrity of system data. Table 3-2 does not focus on capabilities that are needed to manage and secure the reference design. However, the reference design itself must be managed and secured. To this end, this security evaluation focuses on the security of the reference design itself.

Measures implemented to protect the reference design from outside attack include:

- isolating certain capabilities on separate subnetworks protected by firewalls
- Implementing a management network to isolate log and management traffic from the production (business operations) networks
- securing critical user access information and logs to protect them from unauthorized insertion, modification, or deletion
- logging all privileged user access activities
- using encryption and integrity protection of user access information and logs while this information is in transit between capabilities

Table 6-1, Capabilities for Managing and Securing the DI Reference Design, describes the security protections each capability provides and lists the corresponding products that were used to instantiate each capability. The security evaluation focuses on the capabilities rather than the products. The NCCoE is not assessing or certifying the security of the products included in the example implementation. We assume that the enterprise already deploys network security capabilities such as firewalls and intrusion detection devices that are configured per best practices. The focus here is on securing capabilities introduced by the reference design and minimizing their exposure to threats.

6.3.1 Deployment Recommendations

When deploying the reference design in an operational environment, organizations should follow security best practices to address potential vulnerabilities and ensure that all solution assumptions are valid to minimize any risk to the production network. Organizations leveraging the reference design should adhere to the following list of recommended best practices that are designed to reduce risk. Note that the laboratory instantiation of the reference design did not implement every security

recommendation. Organizations should not, however, consider this list to be comprehensive; merely following this list will not guarantee a secure environment. Organizations must also take into consideration items such as user access controls, continuity of operations planning, and environmental elements that are not addressed in this document. Planning for design deployment gives an organization the opportunity to go back and audit the information in its system and get a more global, correlated, and disambiguated view of the DI controls that are in effect.

6.3.1.1 Patch, Harden, Scan, and Test [6]

- Keep OSs up-to-date by patching, version control, and monitoring indicators of compromise (e.g., performing virus and malware detection as well as keeping anti-virus signatures up-to-date).
- Harden all capabilities by deploying on securely configured OSs that use long and complex passwords and are configured per best practices.
- Scan OSs for vulnerabilities.
- Test individual capabilities to ensure that they provide the expected CSF subcategory support and that they do not introduce unintended vulnerabilities.
- Evaluate reference design implementations before going operational with them.

6.3.1.2 Other Security Best Practices [7]

- Install, configure, and use each capability of the reference design per the security guidance provided by the capability vendor.
- Change the default password when installing software.
- Identify and understand which predefined administrative and other accounts each capability comes with by default to eliminate any inadvertent backdoors into these capabilities. Disable all unnecessary predefined accounts and, even though they are disabled, change the default passwords in case a future patch enables these accounts.
- Segregate reference design capabilities on their own subnetwork, separate from the production network, either physically or using virtual private networks and port-based authentication or similar mechanisms.
- Protect the various reference design subnetworks from each other and from the production network using security capabilities such as firewalls and intrusion detection devices that are configured per best practices.
- Configure firewalls to limit connections between the reference design network and the production network, except for connections needed to support required inter-network communications to specific IP address and port combinations in certain directions.

- Configure and verify firewall configurations to ensure that data transmission to and from reference design capabilities is limited to interactions that are needed. Restrict all permitted communications to specific protocols and IP address and port combinations in specific directions.
- Monitor the firewalls that separate the various reference design subnetworks from one another.
- NIST SP 1800-9C: *How-To Guides* contains the firewall configurations that show the rules implemented in each of the firewalls for the example implementation. These configurations are provided to enable the reader to reproduce the traffic filtering/blocking that was achieved in the implementation.
- Apply encryption or integrity-checking mechanisms to all information exchanged between reference design capabilities (i.e., to all user access, policy, and log information exchanged) so that tampering can be detected. Use only encryption and integrity mechanisms that conform to most recent industry best practices. Note that in the case of directory reads and writes, protected mode is defined as the use of Lightweight Directory Access Protocols (Request for Comments 2830).
- Strictly control physical access to both the reference design and the production network.
- Deploy a configuration management system to serve as a "monitor of monitors" to ensure that any changes made to the list of information are logged and reported to the monitoring system or to the analytics in the monitoring system and notifications are generated. Such a system could also monitor whether reference design monitoring capabilities, such as log integrity capabilities or the monitoring system itself, go offline or stop functioning, and generate alerts when these capabilities become unresponsive.
- Deploy a system that audits and analyzes directory content to create a description of who has access to what resources and validate that these access permissions correctly implement the enterprise's intended business process and access policies.

6.3.1.3 Policy Recommendations

- Define the access policies to enforce the principles of least privilege and separation of duties.
- Equip the monitoring capability with a complete a set of rules to take full advantage of the ability to identify anomalous situations that can signal a cyber event. Define enterprise-level work flows that include business and security rules to determine each user's access control authorizations and ensure that enterprise access control policy is enforced as completely and accurately as possible.
- Develop an attack model to help determine the type of events that should generate alerts.
- Grant only a very few users (e.g., human resource administrators) the authority to modify (initiate, change, or delete) employee access information. Require the approval of more than

one individual to update employee access information. Log all employee access information modifications. Define work flows to enforce these requirements.

- Grant only a very few users (e.g., access rules administrators) the authority to modify (initiate, change, or delete) access rules. Require the approval of more than one individual to update access rules. Log all access rule modifications. Define work flows to enforce these requirements.
- Grant only a very few users (e.g., security analyst) the authority to modify (initiate, change, or delete) the analytics that are applied to log information by the monitoring capability to determine what constitutes an anomaly and generates an alert. Any changes made to the analytics should, by policy, require the approval of more than one individual, and these changes should themselves be logged, with the logs sent to a monitor-of-monitors system other than the monitoring system and to all security analysts and other designated individuals. Define work flows to enforce these requirements.

Table 6-1 Capabilities for Managing and Securing the DI Reference Design

This table describes only the product capabilities and CSF subcategory support used in the reference architecture. Many of the products have significant additional security capabilities that are not listed here.

Capability	Specific Product	Function	CSF Subcategories
Subnetting	N/A	Technique of segmenting the network on which the reference design is deployed so that capabilities on one subnetwork are isolated from capabilities on other subnetworks. If an intruder gains access to one segment of the network, this technique limits the intruder's ability to monitor traffic on other segments of the network. For example, the enterprise's production network, on which user access information and decisions are conveyed, is separate from the reference design's monitoring and management subnetwork.	PR.DS-1: Data-at-rest is protected. PR.PT-4: Communications and control networks are protected.
Privileged Access Management	Active Directory	Manages privileged access to the OSs of all physical reference design capabilities. This is the single portal into which all users with administrator privileges must log in; it defines what systems these administrators are authorized to access based on their role and attributes. It also logs every login that is performed by users with administrator privileges, creating an audit trail of privileged	PR.AC-3: Remote access is managed. PR.AC-4: Access permissions are managed, incorporating the principles of least privilege and separation of duties. PR.PT-3: Access to systems and assets is controlled, incorporating the principle of least functionality.

Capability	Specific Product	Function	CSF Subcategories
		user access to the OSs of the physical systems that are hosting reference design capabilities.	DE.CM-3: Personnel activity is monitored to detect potential cybersecurity events.
Virtual Environment Privileged Access Management	Hyper-V VEEAM Active Directory	Manages privileged access to the virtual environment (including machines, switches, and host hardware) that host reference design capabilities. Hyper-V defines what VMs users are authorized to access based on the user's role. It logs activity that administrators perform on VMs, but it does not log operations that are performed on the OSs that are installed on those VMs. These logs create an audit trail of privileged user access to the virtual environment that is hosting the reference design capabilities.	PR.AC-3: Remote access is managed. PR.AC-4: Access permissions are managed, incorporating the principles of least privilege and separation of duties. PR.PT-3: Access to systems and assets is controlled, incorporating the principle of least functionality. DE.CM-3: Personnel activity is monitored to detect potential cybersecurity events.
Log Integrity	Tripwire Enterprise HPE ArcSight ESM	Forwards log information from each reference design capability to the monitoring capability. If an alternative product were used to instantiate this capability, it could add a time stamp and hash/integrity seal to each log file, thereby providing the file with integrity, but not confidentiality, protections. However, if the hash/integrity seal were to continue to be stored with the log file at the monitoring capability, it would provide a mechanism to	PR.DS-6: Integrity checking mechanisms are used to verify software, firmware, and information integrity. PR.PT-1: Audit/log records are determined, documented, implemented, and reviewed in accordance with policy. DE.AE-3: Event data is aggregated and correlated from multiple sources and sensors. PR.DS-2: Data-in-transit is protected.

Capability	Specific Product	Function	CSF Subcategories
		detect unauthorized modifications made to the log file while stored there.	

7 Functional Evaluation

A functional evaluation of the DI example implementation, as constructed in our laboratory, was conducted to verify that it meets its objective of demonstrating the ability to recover from DI attack. The evaluation verified that the example implementation could perform the following functions:

- recover from an identified ransomware attack
- recover from a data destruction event
- recover from a data manipulation event

Section 7.1 describes the format and components of the functional test cases. Each functional test case is designed to assess the capability of the example implementation to perform the functions listed above and detailed in Section 7.1.1.

7.1 Data Integrity Functional Test Plan

One aspect of our security evaluation involved assessing how well the reference design addresses the security characteristics it was intended to support. The CSF subcategories were used to provide structure to the security assessment by consulting the specific sections of each standard that are cited in reference to that subcategory. The cited sections provide validation points that the example solution is expected to exhibit. Using the CSF subcategories as a basis for organizing our analysis allowed us to systematically consider how well the reference design supports the intended security characteristics.

This plan includes the test cases necessary to conduct the functional evaluation of the DI example implementation, which is currently deployed in a lab at the NCCoE. The implementation tested is described in Section 5.

Each test case consists of multiple fields that collectively identify the goal of the test, the specifics required to implement the test, and how to assess the results of the test. Table 7-1 describes each field in the test case.

Table 7-1 Test Case Fields

Test Case Field	Description
Parent requirement	Identifies the top-level requirement or the series of top-level requirements leading to the testable requirement.
Testable requirement	Drives the definition of the remainder of the test case fields. Specifies the capability to be evaluated.
Associated security controls	Lists the NIST SP 800-53 rev 4 controls addressed by the test case.

Test Case Field	Description
Description	Describes the objective of the test case.
Associated test cases	In some instances, a test case may be based on the outcome of another test case(s). For example, analysis-based test cases produce a result that is verifiable through various means (e.g., log entries, reports, and alerts).
Preconditions	The starting state of the test case. Preconditions indicate various starting state items, such as a specific capability configuration required or specific protocol and content.
Procedure	The step-by-step actions required to implement the test case. A procedure may consist of a single sequence of steps or multiple sequences of steps (with delineation) to indicate variations in the test procedure.
Expected results	The expected results for each variation in the test procedure.
Actual results	The observed results.
Overall result	The overall result of the test as pass/fail. In some test case instances, the determination of the overall result may be more involved, such as determining pass/fail based on a percentage of errors identified.

7.1.1 Data Integrity Use Case Requirements

Table 7-2 identifies the DI functional evaluation requirements that are addressed in the test plan and associated test cases.

957 **Table 7-2 Data Integrity Functional Requirements**

Capability Requirement (CR) ID	Parent Requirement	Sub-requirement 1	Test Case
CR 1	The DI example implementation shall respond/recover from malware that encrypts files and displays notice demanding payment.		
CR 1.a		Produce notification of security event	Data Integrity -1
CR 1.b		Provide file integrity monitor	Data Integrity -1
CR 1.c		Revert to last known good	Data Integrity -1
CR 2	The DI example implementation shall recover when malware destroys data on user's machine.		
CR 2.a		Provide file integrity monitor	Data Integrity -2
CR 2.b		Revert to last known good	Data Integrity -2
CR 3	The DI example implementation shall recover when a user modifies a configuration file in violation of established baselines.		
CR 3.a		Provide file integrity monitor	Data Integrity -3 Data Integrity -6
CR 3.b		Revert to last known good	Data Integrity -3 Data Integrity -6
CR 3.c		Provide user activity auditing	Data Integrity -6

Capability Requirement (CR) ID	Parent Requirement	Sub-requirement 1	Test Case
CR 4	The DI example implementation shall recover when an administrator modifies a user's file.		
CR 4.a		Provide file integrity monitor	Data Integrity -4
CR-4.b		Provide user activity auditing	Data Integrity -4
CR 4.c		Revert to last known good	Data Integrity -4
CR-5	The DI example implementation shall recover when an administrator and/or script modifies data in a database.		
CR 5.a		Use database transaction auditing	Data Integrity -5
CR 5.b		Roll back to last known good	Data Integrity -5
CR-6	The DI example implementation shall recover when a user modifies a configuration file in violation of established baselines.		
CR 6.a		Provide file integrity monitor	Data Integrity -6
CR 6.b		Revert to last known good	Data Integrity -6
CR 6.c		Provide user activity auditing	Data Integrity -6

7.1.2 Test Case: Data Integrity-1

Table 7-3 Test Case ID: Data Integrity -1

Parent requirement	(CR 1) The **DI** example implementation shall respond/recover from malware that encrypts files and displays notice demanding payment.
Testable requirement	(CR 1.a) Logging, (CR 1.b) Corruption Testing, (CR 1.c) Backup Capability
Description	Show that the DI solution can recover from a DI attack that was initiated via ransomware.
Associated test cases	N/A
Associated CSF Subcategories	DE.DP-4, RS.CO-2, DE.EA-5, PR.DS-1, PR.DS-6, PR.PT-1
Preconditions	User downloaded and ran an executable from the internet that is ransomware. The user's files are then encrypted by the ransomware.
Procedure	1. Open the Tripwire Enterprise interface. 2. Click on the **Tasks** Section, enable the associated rule box, and click **Run.** 3. Open HPE ArcSight ESM. 4. Under Events, select **Active Channels**, then select **Audit Events.** 5. Find the Tripwire Enterprise event logs associated with the event. Select **Fields** in the **Customize** dropdown and enable the following fields: a. **End Time** b. **Attacker Address** c. **File Name** d. **Device Action** e. **Source User Name** f. **Device Custom String6** 6. Open IBM Spectrum Protect. 7. Click on **Restore.** 8. Select missing files and click **Restore to original location.**
Expected Results (pass)	Event identified (CR 1.a) Details of the event are understood and moment of last known good is identified.

	Provide file Integrity monitor (CR 1.b). Modified files are correctly identified. Recovery complete (CR 1.c). System was restored to pre-DI event version.
Actual Results	Details of the event were understood and the moment of last known good was identified for the file in question. All the files affected within that timeframe were correctly identified, and a full and successful restore was executed.
Overall Result	Pass. All metrics of success were met to satisfaction.

7.1.3 Test Case Data Integrity-2

Table 7-4 Test Case ID: Data Integrity -2

Parent requirement	(CR 2) The **DI** example implementation shall recover when malware destroys data on user's machine.
Testable requirement	(CR 2.a) Corruption Testing, (CR 2.b) Backup Capability
Description	Show that the DI solution can recover from a DI attack that destroys data via a malware attack.
Associated test cases	N/A
Associated CSF Subcategories	PR.DS-1, PR.IP-4, PR-DS-6, PR.PT1
Preconditions	User downloads a malicious executable that modifies critical data.
Procedure	1. Open the Tripwire Enterprise interface. 2. Click on the **Tasks** Section, enable the associated rule box, and click **Run.** 3. Open HPE ArcSight ESM. 4. Under Events, select **Active Channels**, then select **Audit Events.** 5. Find the Tripwire event logs associated with the event. Select **Fields** in the **Customize** dropdown and enable the following fields: a. **End Time** b. **Attacker Address** c. **File Name** d. **Device Action** e. **Source User Name** f. **Device Custom String** 6. Open IBM Spectrum Protect. 7. Click on **Restore.** 8. Select missing files and click **Restore to original location.**
Expected Results (pass)	Provide file integrity monitor (CR 2.a). Modified files are correctly identified. Recovery complete (CR 2.b).

	System was restored to pre-DI event version.
Actual Results	Details of the event were understood and the moment of last known good was identified for the file in question. All the files affected within that timeframe were correctly identified, and a full and successful restore was executed.
Overall Result	Pass. All metrics of success were met to satisfaction.

7.1.4 Test Case Data Integrity-3

Table 7-5 Test Case ID: Data Integrity -3

Parent requirement	(CR 3) The **DI** example implementation shall recover when a user modifies a configuration file in violation of established baselines.
Testable requirement	(CR 3.a) Corruption Testing, (CR 3.b) Backup Capability
Description	Show that the DI solution can recover from a DI event that modifies system configurations.
Associated test cases	N/A
Associated CSF Subcategories	PR.DS-1, PR.DS-6, PR.PT-1, DE.CM-3, DE.AE-1, DE.CM-1
Preconditions	Run a script that would simulate the effects of a configuration modification event.
Procedure	1. Open HP ArcSight ESM. 2. Under **Events**, select **Event Search.** 3. Use the search bar to search for the keyword “created” to find associated event logs for account creation. 4. After determining the point in time of a malicious event, restart the Active Directory server, holding down the **F2** and **F8** keys while restarting to enter the **Advanced Boot Options** menu. 5. Select **Directory Services Repair Mode.** 6. Log in as the machine administrator. 7. Open a command prompt. 8. View visible backup versions with the following command: ▪ **`wbadmin get versions`** 9. Restore to a selected backup target with the following command. Note that the selected date should reflect the last known good backup: ▪ **`wbadmin start systemstaterecovery -version:<Version Number> -backupTarget:<Backup Location>`** ▪ Replace **`<Version Number>`** with the desired version’s version identifier, and **`<Backup Location>`** with the version’s corresponding backup location.

	10. Provide a username (with domain if applicable) and password for a privileged user to the backup location. 11. Acknowledge the remaining prompts and wait for the backup to complete. The system will automatically restart.
Expected Results (pass)	Provide file integrity monitor (CR 3.a). Modified files are correctly identified. Recovery complete (CR 3.b). Modified files are restored to their original state.
Actual Results	The fake accounts were successfully identified and deleted. The remaining accounts were restored to their original states at the time of the backup.
Overall Result	Pass. All metrics of success were met to satisfaction.

7.1.5 Test Case Data Integrity-4

Table 7-6 Test Case ID: Data Integrity -4

Parent requirement	(CR 4) The **DI** example implementation shall recover when an administrator modifies a user's file.
Testable requirement	(CR 4.a) Corruption Testing, (CR 4.b) Logging, (CR 4.c) Backup Capability
Description	Show that the DI solution can recover from when an administrator modifies a user's file.
Associated test cases	N/A
Associated CSF Subcategories	DE.AE-1, DE.AE-3, DE.AE-5
Preconditions	Two VMs on Microsoft Hyper-V have been backed up. Administrator accidentally runs a command that deletes a critical VM. `Remove-VM -Name "<VMName>" -Force`
Procedure	1. Open HP ArcSight ESM. 2. Under **Events**, select **Event Search.** 3. Use the search bar to search for the deleted VM's name and then find the associated event log. 4. Locate previous logins from that machine by searching for the VM host machine's domain and name in the search bar. Look for logins before the time of the deletion incident, without an associated logout before the event. User logins (as opposed to automated ones that occur constantly in the machine) will have a non-null value for the **Source Address** field, typically 127.0.0.1. 5. Open the VEEAM console. 6. Navigate to the **Backups** menu. 7. Right-click on deleted VM and click **Restore**, and then **Entire VM.** 8. When prompted, search for the deleted VM's name and select it for restoration. 9. When prompted, enter reason for VM restoration.
Expected Results (pass)	Provide file integrity monitor (CR 4.a). Missing files are correctly identified.

	Provide user activity auditing (CR 4.b). User who initiated deletion is correctly identified. Revert to last known good (CR 4.c). VM is fully restored to original functionality.
Actual Results	The VEEAM system functioned as expected. Deleted VM is restored to its original functionality. Any user logged in during the deletion event was identified.
Overall Result	Pass (partial). The file integrity monitoring and reversion to last known good requirements were met. User activity was audited, but it is not possible to determine which user caused the deletion event if multiple users were logged in to the machine at the time of the event.

7.1.6 Test Case Data Integrity-5

Table 7-7 Test Case ID: Data Integrity -5

Parent requirement	(CR 5) The **DI** example implementation shall recover when an administrator and/or script modifies data in a database.
Testable requirement	(CR 5.a) Logging, (CR 5.b) Backup Storage
Description	Show that the DI solution can recover when data in a database has been altered in error by an administrator or script.
Associated test cases	N/A
Associated CSF Subcategories	DE.AE-3, DE.AE-5
Preconditions	Run a script that would simulate the effects of an administrator or script modification within a database.
Procedure	1. Open HP ArcSight ESM. 2. Under **Events**, select **Event Search.** 3. Use the search bar to search for the affected database and then find the associated event log. Use the field **cs1** to find the affected table name and **cs2** to find the undesired database transaction query string. Modify time parameters for the search to narrow the desired transaction. 4. Use the **duser** field of the event to find the name of the user who executed the transaction event. 5. Determine the number of transactions that occurred and then use a transactional rollback tool to restore the database to the last known good state.
Expected Results (pass)	Use database transaction auditing (CR 5.a). Bad database transaction is correctly identified. Roll back to last known good (CR 5.b). Database is restored to full functionality.

Actual Results	The database data was successfully restored to its last known good state. The user responsible for the event was identified and the time of the event was determined.
Overall Result	Pass. All metrics of success were met to satisfaction.

7.1.7 Test Case Data Integrity-6

Table 7-8 Test Case ID: Data Integrity -6

Parent requirement	(CR 6) The **DI** example implementation shall recover when a user modifies a configuration file in violation of established baselines.
Testable requirement	(CR 6.a) Corruption Testing, (CR 6.b) Backup Capability (CR 6.c). Provide user activity auditing.
Description	Show that the DI solution can recover when the database schema has been altered in error by an administrator or script.
Associated test cases	N/A
Associated CSF Subcategories	PR.DS-1, PR.DS-6, PR.PT-1, DE.CM-3, DE.AE-1, DE.CM-1
Preconditions	Run a script that would simulate the effects of an administrator or script modifying the database schema.
Procedure	1. Open the Tripwire Enterprise interface. 2. Click on the **Tasks** Section, enable the associated rule box, and click **Run.** 3. Open HP ArcSight ESM. 4. Under Events, select **Active Channels**, then select **Audit Events.** 5. Find the Tripwire event logs associated with the event. Select **Fields** in the **Customize** dropdown and enable the following fields: a. **End Time** b. **Attacker Address** c. **File Name** d. **Device Action** e. **Source User Name** f. **Device Custom String6** 6. Open SQL Server Management Studio and locate the affected database(s).

	7. Right-click on the database name and select **Tasks > Restore > Database...** 8. Verify that the **Restore To:** location is a backup from before the time of the incident. 9. Under **Options,** select **Overwrite the existing database (WITH REPLACE)** 10. Click **OK** and wait for the restoration to complete.
Expected Results (pass)	Provide file integrity monitor (CR 6.a). Modified table is correctly identified. Revert to last known good (CR 6.b). Database fully restored to previous functionality. Provide user activity auditing (CR 6.c). User who initiated the modification is correctly identified.
Actual Results	The database schema was successfully restored to its last known good state. The user responsible for the event was identified and the time of the event was determined.
Overall Result	Pass. All metrics of success were met to satisfaction.

8 Future Build Considerations

The NCCoE is considering additional DI projects that map to the Cybersecurity Framework Core Functions of Identify, Protect, Detect and Respond. This reference design focuses largely on the Recover aspect of the CSF. The functions of the CSF lead into each other and act as a cycle. Identifying vulnerabilities leads to protection against them. Protecting against vulnerabilities allows enterprises to detect cybersecurity events. Detection of events gives enterprises the information needed to respond and recover from these events as well as reshape their policy to identify and protect against events in the future. Though this project deals primarily with an organization's capabilities to recover from DI events, future NCCoE projects may look at capabilities for meeting the requirements of the other functions in the CSF.

This project does not include instructions for automated full system recovery. If malicious software manages to affect critical system files, recovery becomes more difficult. The backup software used is client-based, so the system must be able to run the client to restore, which may not be possible in some instances. Solutions exist to help automate the process to fully restore a failed system and integrate with existing backup solutions. A future build might include the use of a product to address these types of attacks.

This project uses built-in database capabilities to achieve transactional rollbacks as well as database metadata restoration. The restoration process is granular and uses built-in mechanisms; however, automating the process is more difficult. Products exist that use the built-in restoration mechanisms and implement their own database backup functionality. These products add varying degrees of latency to database transactions, depending on the mechanisms used and the granularity of recovery the organization desires.

Appendix A List of Acronyms

COI	Community of Interest
CR	Capability Requirement
CSF	Cybersecurity Framework
DI	Data Integrity
ESM	Enterprise Security Manager
HPE	Hewlett Packard Enterprise
IEC/ISO	International Electrotechnical Commission/International Organization for Standardization
IP	Internet Protocol
IT	Information Technology
MS SQL	Microsoft Structured Query Language
NCCoE	National Cybersecurity Center of Excellence
NIST	National Institute of Standards and Technology
OS	Operating System
SP	Special Publication
VM	Virtual Machine
WORM	Write Once Read Many

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[16] C. Johnson *et al.*, *Guide to Cyber Threat Information Sharing*, NIST Special Publication (SP) 800-150, National Institute of Standards and Technology, Gaithersburg, Maryland, October 2016, 42pp. http://dx.doi.org/10.6028/NIST.SP.800-150

[17] M. Bartock *et al.*, *Guide for Cybersecurity Event Recovery*, NIST Special Publication (SP) 800-184, National Institute of Standards and Technology, Gaithersburg, Maryland, December 2016, 52pp. http://dx.doi.org/10.6028/NIST.SP.800-184

NIST SPECIAL PUBLICATION 1800-11C

Data Integrity

Recovering from Ransomware and Other Destructive Events

Volume C:
How-to Guides

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September 2017

DRAFT

This publication is available free of charge from:
https://nccoe.nist.gov/projects/building-blocks/data-integrity

DISCLAIMER

Certain commercial entities, equipment, products, or materials may be identified in this document in order to describe an experimental procedure or concept adequately. Such identification is not intended to imply recommendation or endorsement by NIST or NCCoE, nor is it intended to imply that the entities, equipment, products, or materials are necessarily the best available for the purpose.

National Institute of Standards and Technology Special Publication 1800-11c, Natl. Inst. Stand. Technol. Spec. Publ. 1800-11c, 384 pages, (September 2017), CODEN: NSPUE2

FEEDBACK

You can improve this guide by contributing feedback. As you review and adopt this solution for your own organization, we ask you and your colleagues to share your experience and advice with us.

Comments on this publication may be submitted to di-nccoe@nist.gov.

Public comment period: September 6, 2017 through November 6, 2017

All comments are subject to release under the Freedom of Information Act (FOIA).

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NATIONAL CYBERSECURITY CENTER OF EXCELLENCE

The National Cybersecurity Center of Excellence (NCCoE), a part of the National Institute of Standards and Technology (NIST), is a collaborative hub where industry organizations, government agencies, and academic institutions work together to address businesses' most pressing cybersecurity issues. This public-private partnership enables the creation of practical cybersecurity solutions for specific industries, as well as for broad, cross-sector technology challenges. Through consortia under Cooperative Research and Development Agreements (CRADAs), including technology partners—from Fortune 50 market leaders to smaller companies specializing in IT security—the NCCoE applies standards and best practices to develop modular, easily adaptable example cybersecurity solutions using commercially available technology. The NCCoE documents these example solutions in the NIST Special Publication 1800 series, which maps capabilities to the NIST Cyber Security Framework and details the steps needed for another entity to recreate the example solution. The NCCoE was established in 2012 by NIST in partnership with the State of Maryland and Montgomery County, Md.

To learn more about the NCCoE, visit https://nccoe.nist.gov. To learn more about NIST, visit https://www.nist.gov.

NIST CYBERSECURITY PRACTICE GUIDES

NIST Cybersecurity Practice Guides (Special Publication Series 1800) target specific cybersecurity challenges in the public and private sectors. They are practical, user-friendly guides that facilitate the adoption of standards-based approaches to cybersecurity. They show members of the information security community how to implement example solutions that help them align more easily with relevant standards and best practices and provide users with the materials lists, configuration files, and other information they need to implement a similar approach.

The documents in this series describe example implementations of cybersecurity practices that businesses and other organizations may voluntarily adopt. These documents do not describe regulations or mandatory practices, nor do they carry statutory authority.

ABSTRACT

Businesses face a near-constant threat of destructive malware, ransomware, malicious insider activities, and even honest mistakes that can alter or destroy critical data. These data corruption events could cause a significant loss to a company's reputation, business operations, and bottom line.

These types of adverse events, that ultimately impact data integrity, can compromise critical corporate information including emails, employee records, financial records, and customer data. It is imperative for organizations to recover quickly from a data integrity attack and trust the accuracy and precision of the recovered data.

The National Cybersecurity Center of Excellence (NCCoE) at NIST built a laboratory environment to explore methods to effectively recover from a data corruption event in various Information Technology (IT) enterprise environments. NCCoE also implemented auditing and reporting IT system use to support incident recovery and investigations.

This NIST Cybersecurity Practice Guide demonstrates how organizations can implement technologies to take immediate action following a data corruption event. The example solution outlined in this guide encourages effective monitoring and detection of data corruption in standard, enterprise components as well as custom applications and data composed of open-source and commercially available components.

KEYWORDS

business continuity; data integrity; data recovery; malware; ransomware

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Donna Koschalk	Veeam Software Corporation
Brian Abe	The MITRE Corporation
Sarah Kinling	The MITRE Corporation
Josh Klosterman	The MITRE Corporation

Name	Organization
Susan Urban	The MITRE Corporation
Mary Yang	The MITRE Corporation

The Technology Partners/Collaborators who participated in this build submitted their capabilities in response to a notice in the Federal Register. Respondents with relevant capabilities or product components were invited to sign a Cooperative Research and Development Agreement (CRADA) with NIST, allowing them to participate in a consortium to build this example solution. We worked with:

Technology Partner/Collaborator	Build Involvement
GreenTec USA	GreenTec WORMdisk, v151228
Hewlett Packard Enterprise	HPE ArcSight ESM, v6.9.1 HPE ArcSight Connector, v7.4.0
IBM Corporation	IBM Spectrum Protect, v8.1.0
Tripwire	Tripwire Enterprise, v8.5 Tripwire Log Center, v7.2.4.80
Veeam Software Corporation	Veeam Availability Suite, v9.5

Contents

1 Introduction

The following guides show IT professionals and security engineers how we implemented this data integrity solution example. We cover all the products employed in this reference design. We do not recreate the product manufacturers' documentation, which is presumed to be widely available. Rather, these guides show how we integrated the products into our environment.

Note: These are not comprehensive tutorials. There are many possible service and security configurations for these products that are out of scope for this reference design.

1.1 Practice Guide Structure

This NIST Cybersecurity Practice Guide demonstrates a standards-based reference design and provides users with the information they need to replicate the data integrity solution. This reference design is modular and can be deployed in whole or in parts.

This guide contains three volumes:

- NIST SP 1800-11a: *Executive Summary*
- NIST SP 1800-11b: *Approach, Architecture, and Security Characteristics* – what we built and why
- NIST SP 1800-11c: *How-To Guides* – instructions for building the example solution **(you are here)**

Depending on your role in your organization, you may use this guide in different ways:

Business decision makers, including chief security and technology officers, will be interested in the *Executive Summary (NIST SP 1800-11a)*, which describes the:

- challenges enterprises face in protecting their data from loss or corruption
- example solution built at the National Cybersecurity Center of Excellence (NCCoE)
- benefits of adopting the example solution

Technology or security program managers who are concerned with how to identify, understand, assess, and mitigate risk will be interested in this part of the guide, *NIST SP 1800-11b,* which describes what we did and why. The following sections will be of particular interest:

- Section 3.4.1, Assessing Risk Posture, provides a description of the risk analysis we performed.
- Section 3.4.2, Security Control Map, maps the security characteristics of the example solution to cybersecurity standards and best practices.

Consider sharing the *Executive Summary (NIST SP 1800-11a)* with your leadership team to help them understand the importance of adopting standards-based data integrity solutions.

IT professionals who want to implement an approach like this will find the whole practice guide useful. You can use the How-To portion of the guide (*NIST SP 1800-11c)* to replicate all or parts of the build created in our lab. The guide provides specific product installation, configuration, and integration instructions for implementing the example solution. We do not recreate the product manufacturers' documentation, which is generally widely available. Rather, we show how we integrated the products in our environment to create an example solution.

This guide assumes that IT professionals have experience implementing security products within the enterprise. While we used a suite of commercial products to address this challenge, this guide does not endorse these particular products. Your organization can adopt this solution or one that adheres to these guidelines in whole, or you can use this guide as a starting point for tailoring and implementing parts of the data integrity solution. Your organization's security experts should identify the products that will best integrate with your existing tools and IT system infrastructure. We hope you will seek products that are congruent with applicable standards and best practices.

A NIST cybersecurity practice guide does not describe "the" solution, but a possible solution. This is a draft guide. We seek feedback on its contents and welcome your input. Comments, suggestions, and success stories will improve subsequent versions of this guide. Please contribute your thoughts to di-nccoe@nist.gov.

1.2 Build Overview

The NCCoE built a hybrid virtual-physical laboratory environment to explore methods to effectively recover from a data corruption event in various Information Technology (IT) enterprise environments. NCCoE also explored the issues of auditing and reporting that IT systems use to support incident recovery and investigations. The servers in the virtual environment were built to the hardware specifications of their specific software components.

The NCCoE worked with members of the Data Integrity Community of Interest to develop a diverse (but non-comprehensive) set of use case scenarios against which to test the reference implementation. These are detailed in Volume B, Section 5.1. For a detailed description of our architecture, see Volume B, Section 4.

1.3 Typographical Conventions

The following table presents typographic conventions used in this volume.

Typeface/ Symbol	Meaning	Example
Italics	filenames and pathnames references to documents that are not hyperlinks, new terms, and placeholders	For detailed definitions of terms, see the *NCCoE Glossary.*
Bold	names of menus, options, command buttons and fields	Choose **File > Edit**.
`Monospace`	command-line input, on-screen computer output, sample code examples, status codes	`mkdir`
`Monospace Bold`	command-line user input contrasted with computer output	**`service sshd start`**
blue text	link to other parts of the document, a web URL, or an email address	All publications from NIST's National Cybersecurity Center of Excellence are available at http://nccoe.nist.gov

2 Product Installation Guides

This section of the practice guide contains detailed instructions for installing, configuring, and integrating all the products used to build an instance of the example solution.

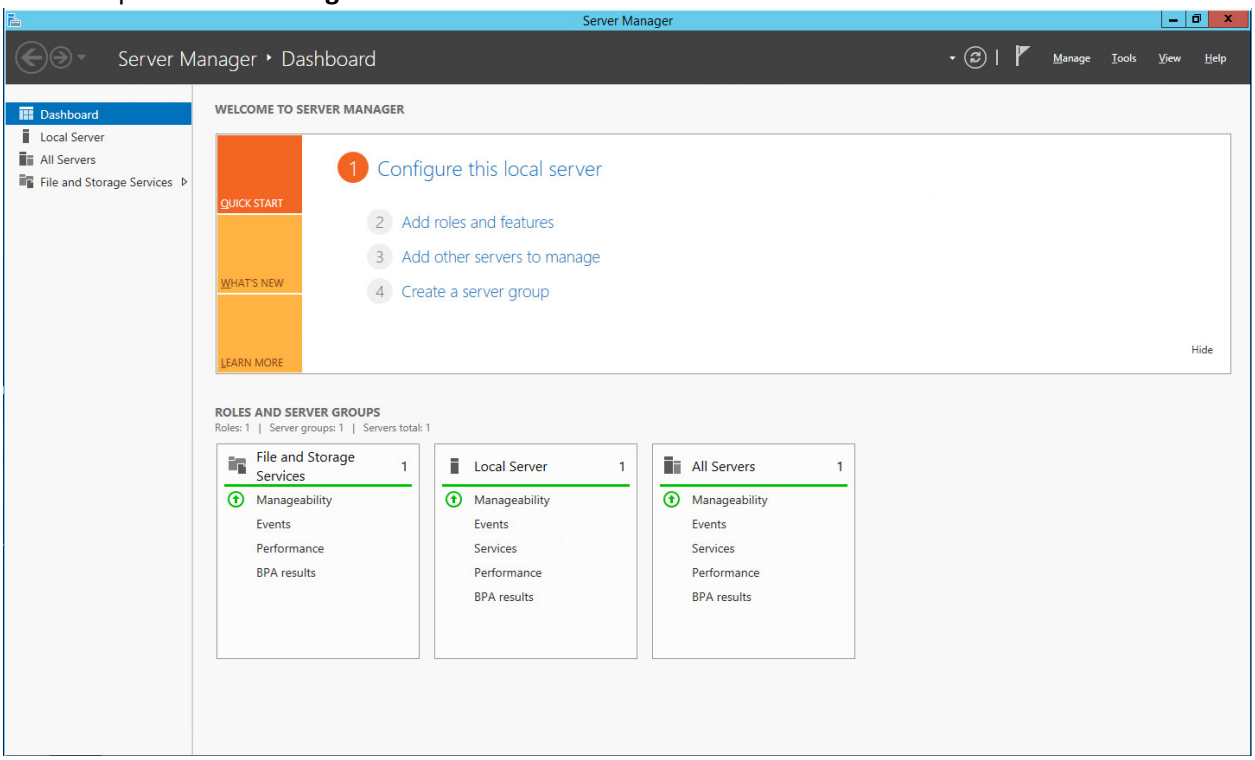
The products presented in this document have the potential to quickly change both interfaces and functionality. This document aims to highlight the core configurations an organization could use along with visual representations of those configurations.

2.1 Active Directory and Domain Name System (DNS) Server

As part of our enterprise emulation, we included an Active Directory server that doubles as a DNS server. This section covers the installation and configuration process used to set up Active Directory and DNS on a Windows Server 2012 R2 machine.

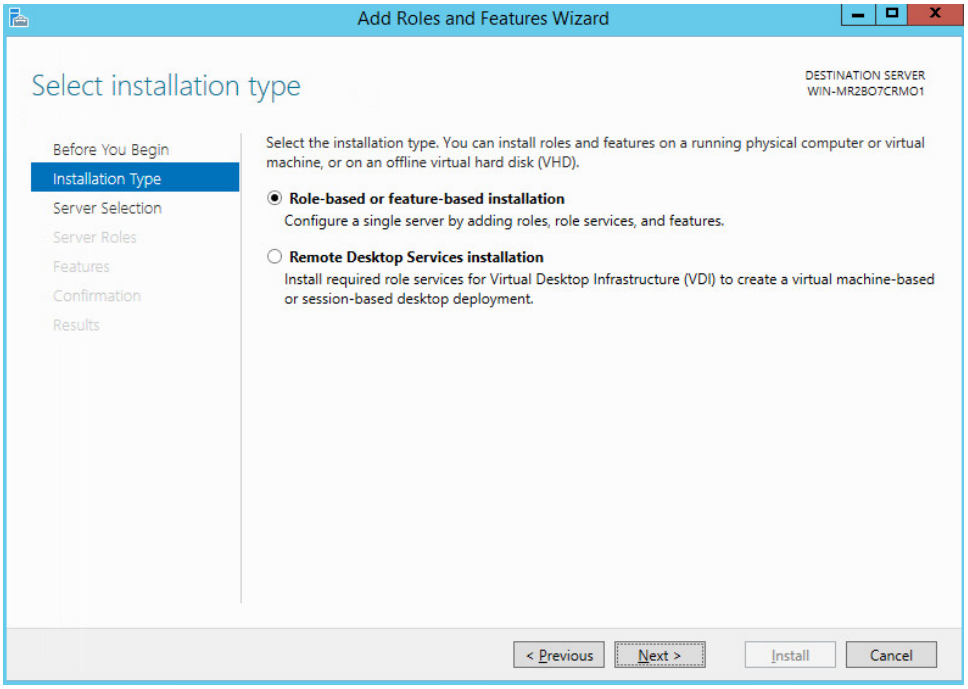
2.1.1 Installing Features

1. Open **Server Manager**.

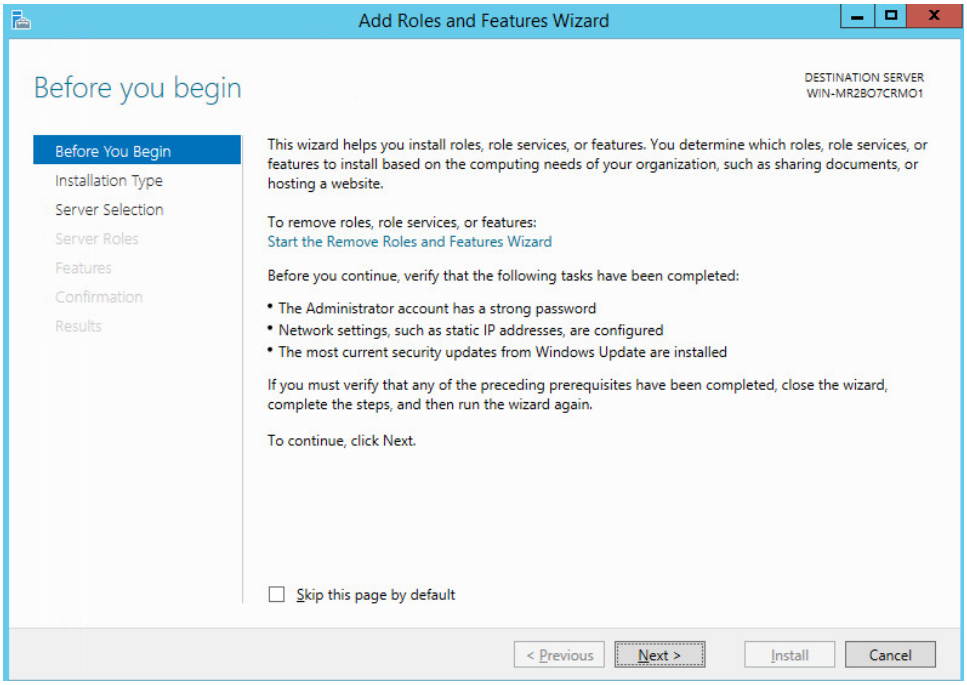


2. Click the link **Add Roles and Features**.

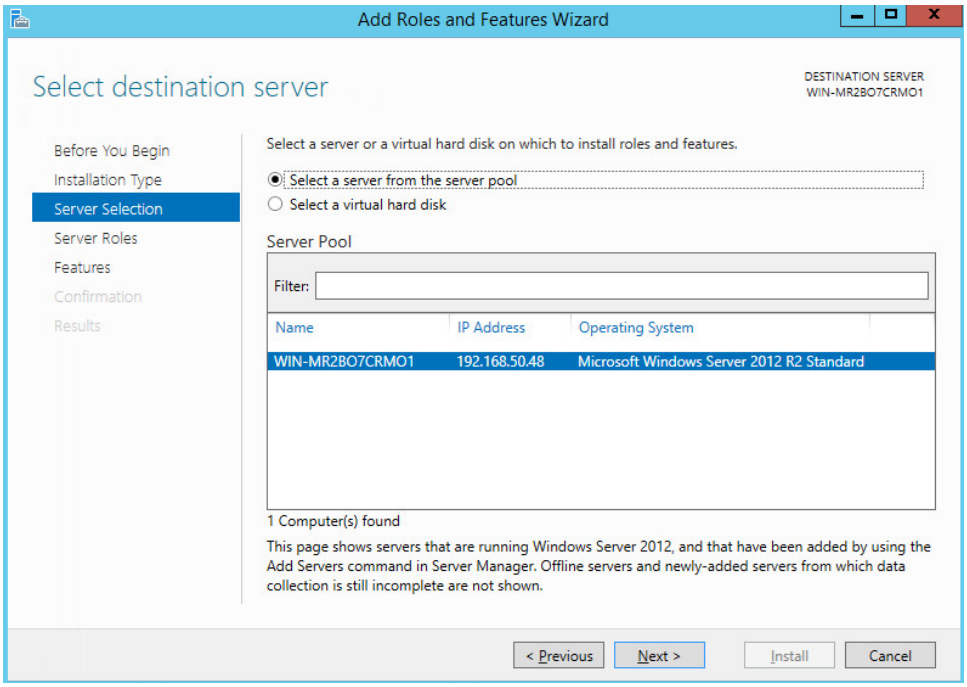
3. Click **Next**.



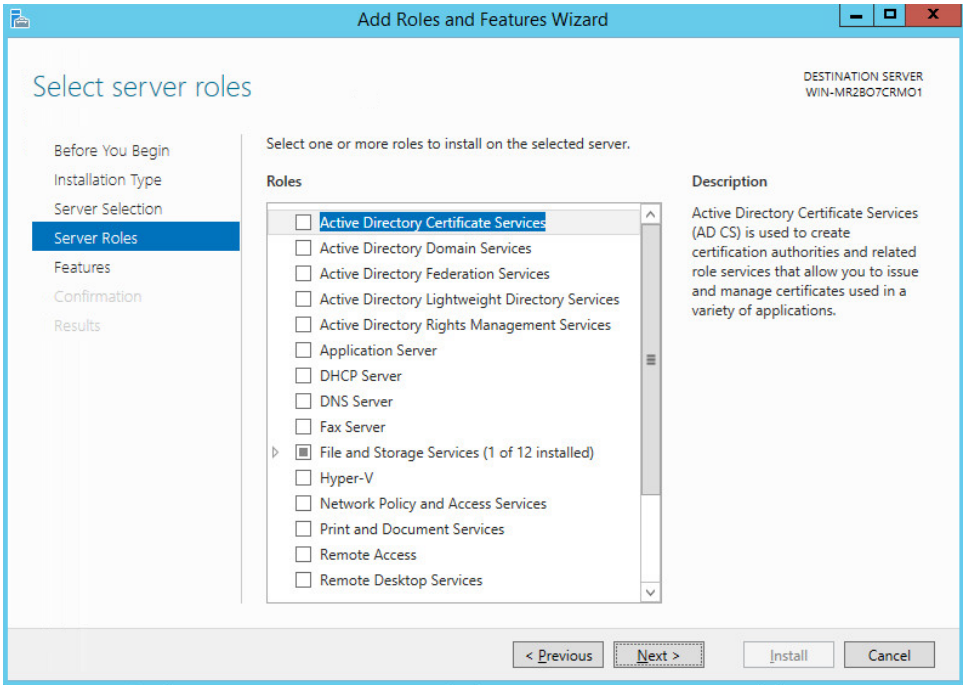
4. Select **Role-based or feature-based installation**.



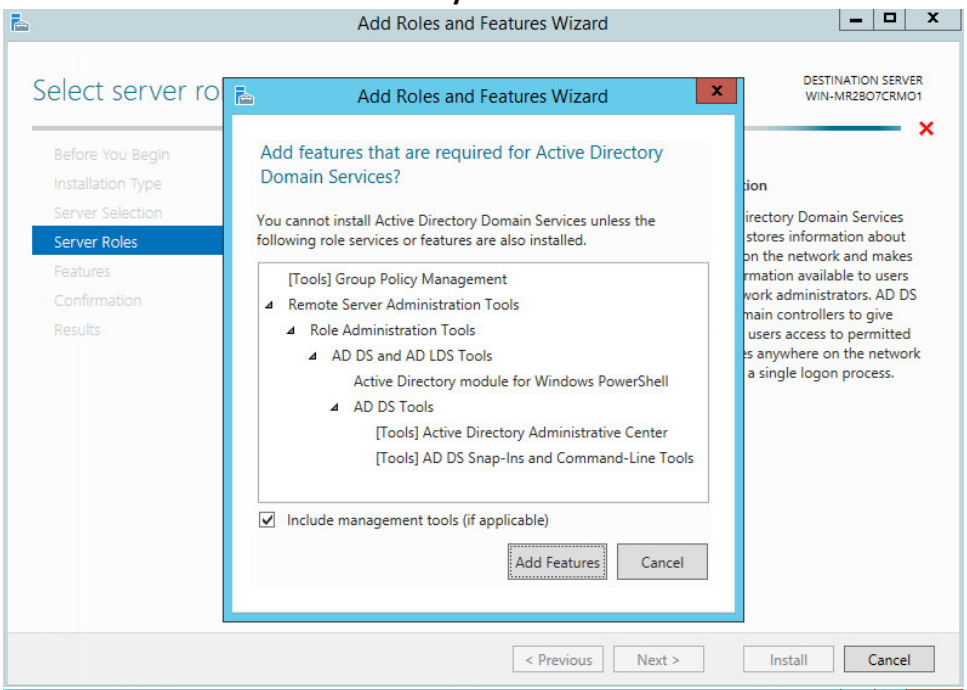
5. Click **Next**.

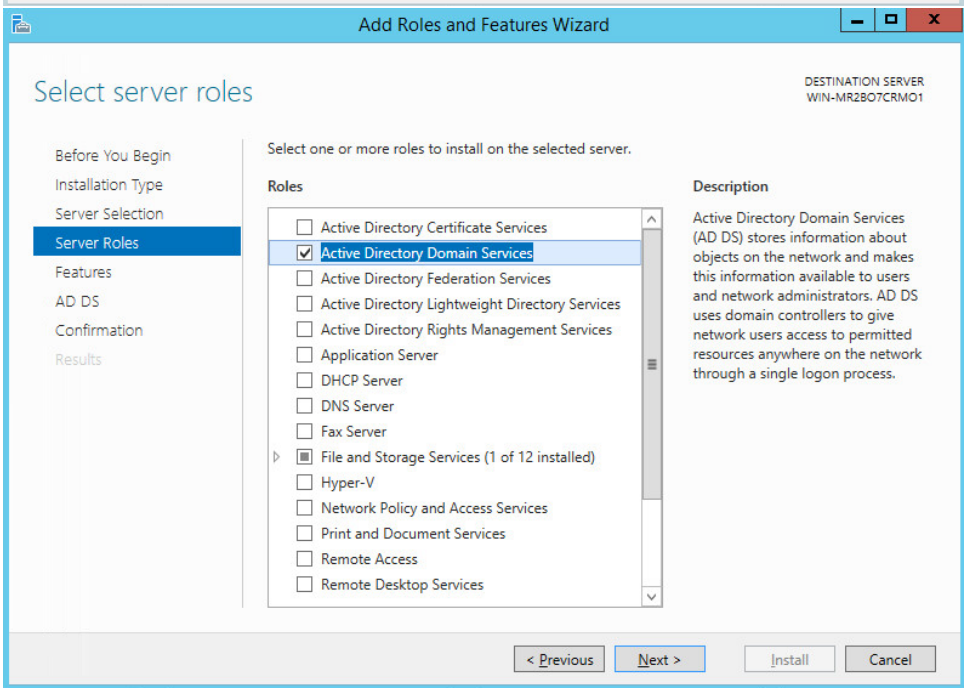


6. Select **ADDNS** (or the correct Windows Server name) from the list.
7. Click **Next**.

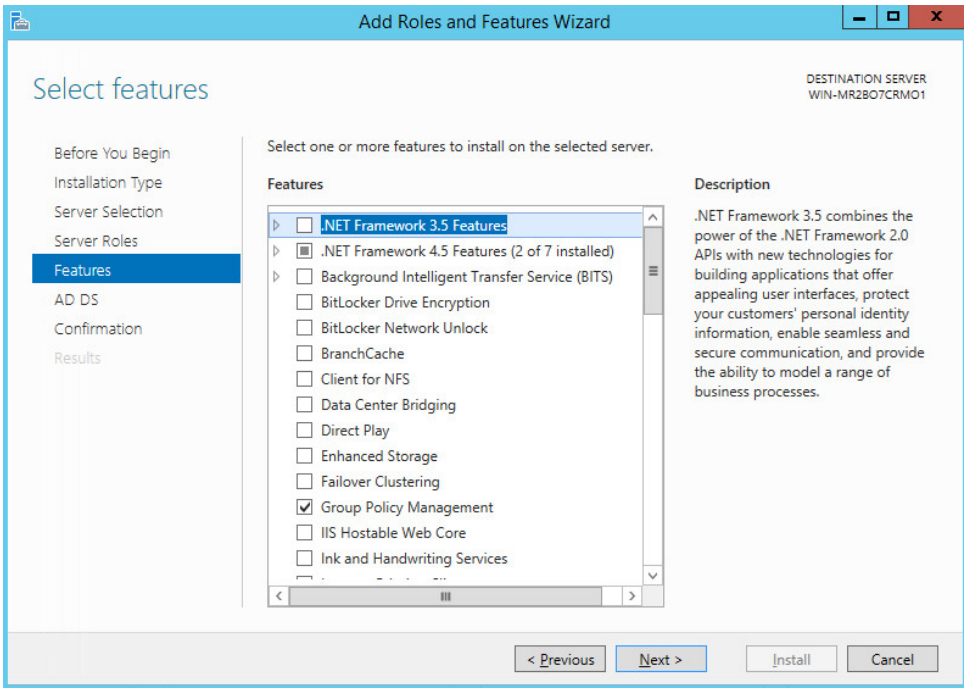


8. Check the box next to **Active Directory Domain Services**.

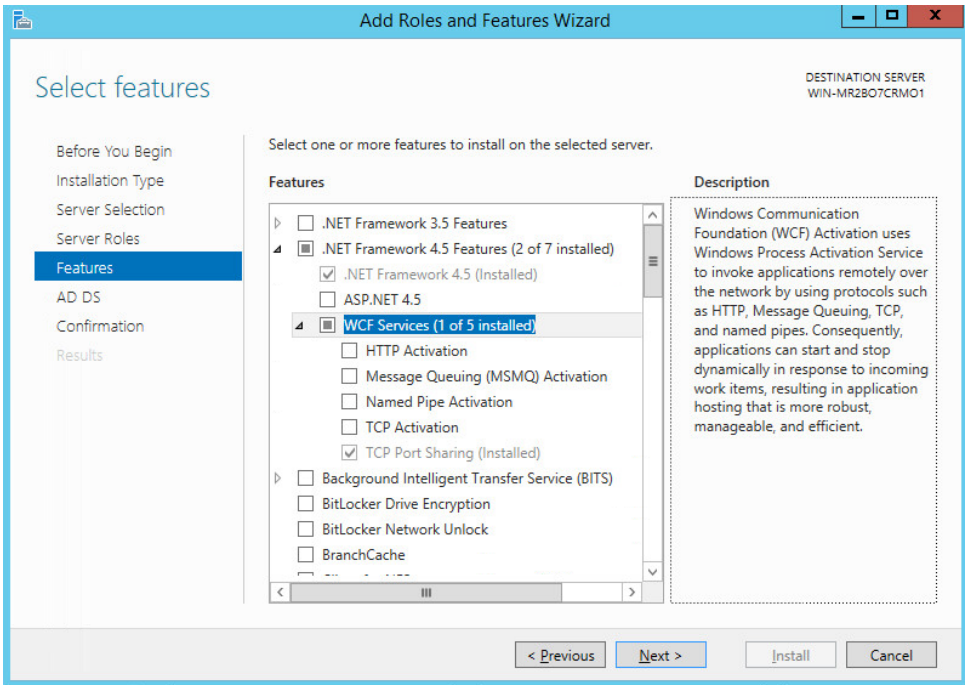




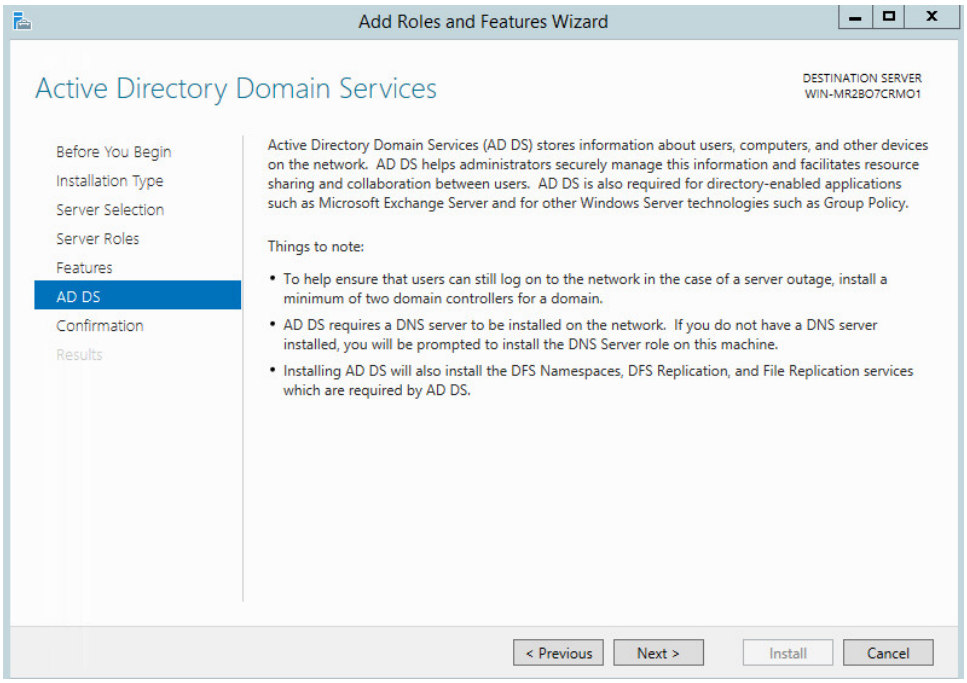
9. Click **Add Features**.
10. Click **Next**.



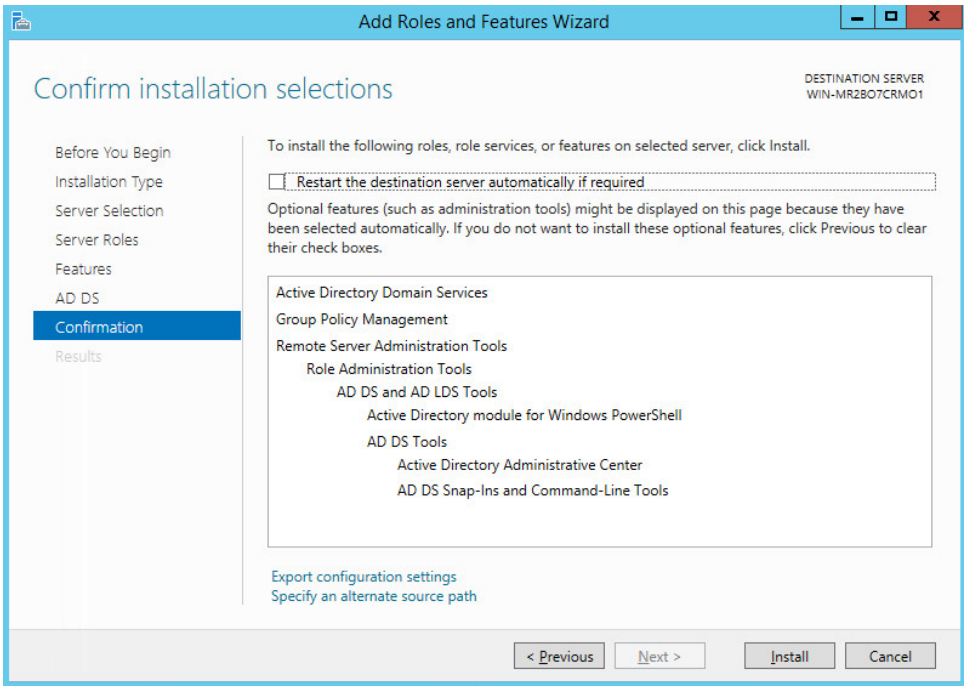
11. Ensure that **Group Policy Management**, **.NET Framework 4.5**, **TCP Port Sharing**, **Remote Server Administration Tools**, and **Windows PowerShell** are selected.

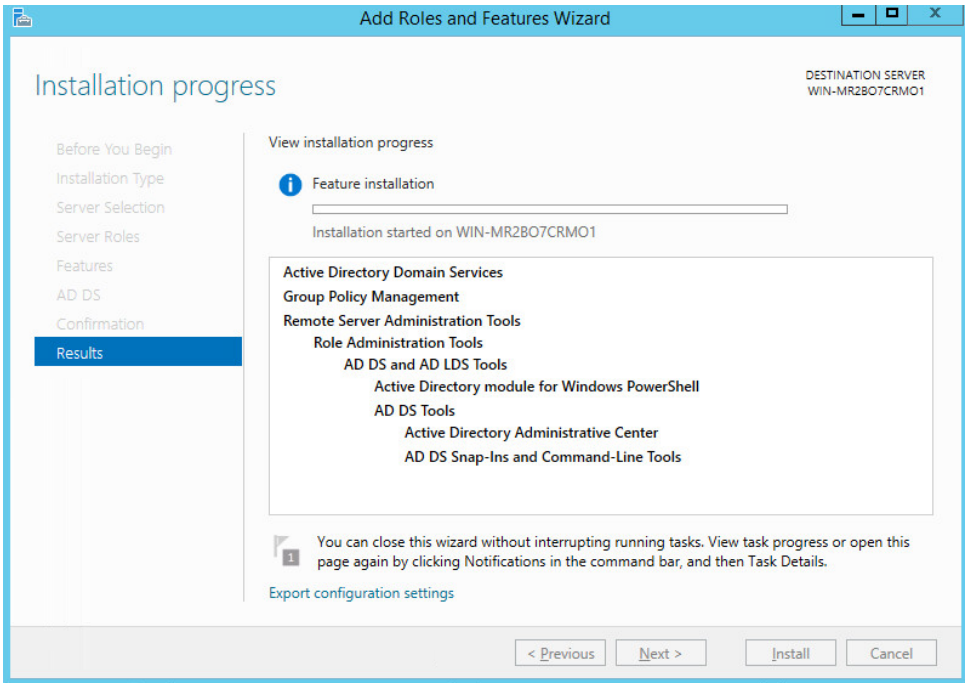


12. Select any additional features and click **Add Features** on the popup.
13. Click **Next**.

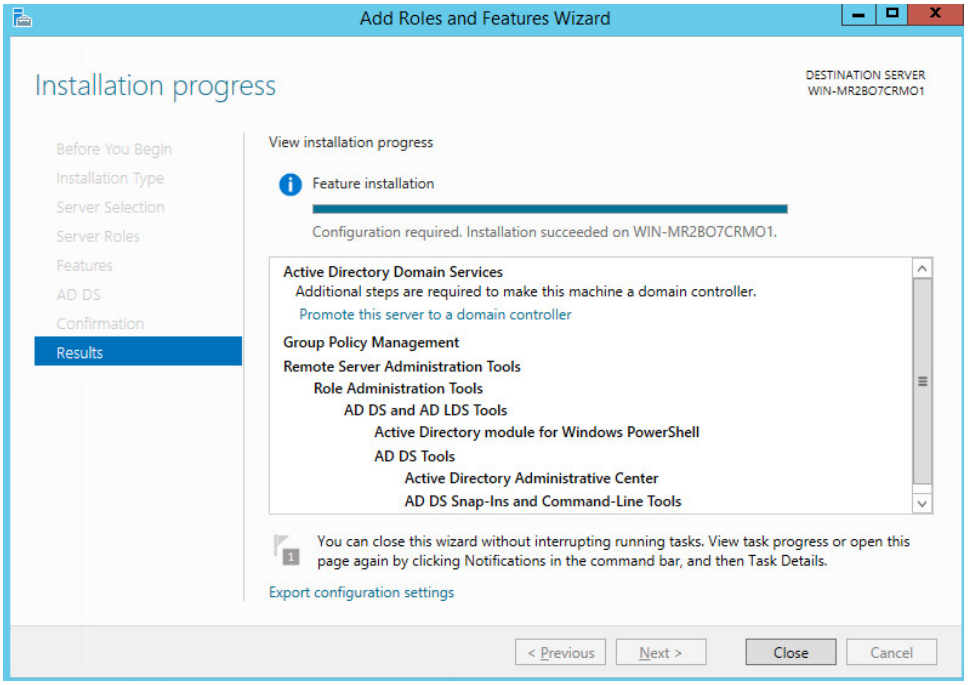


14. Click **Next**.

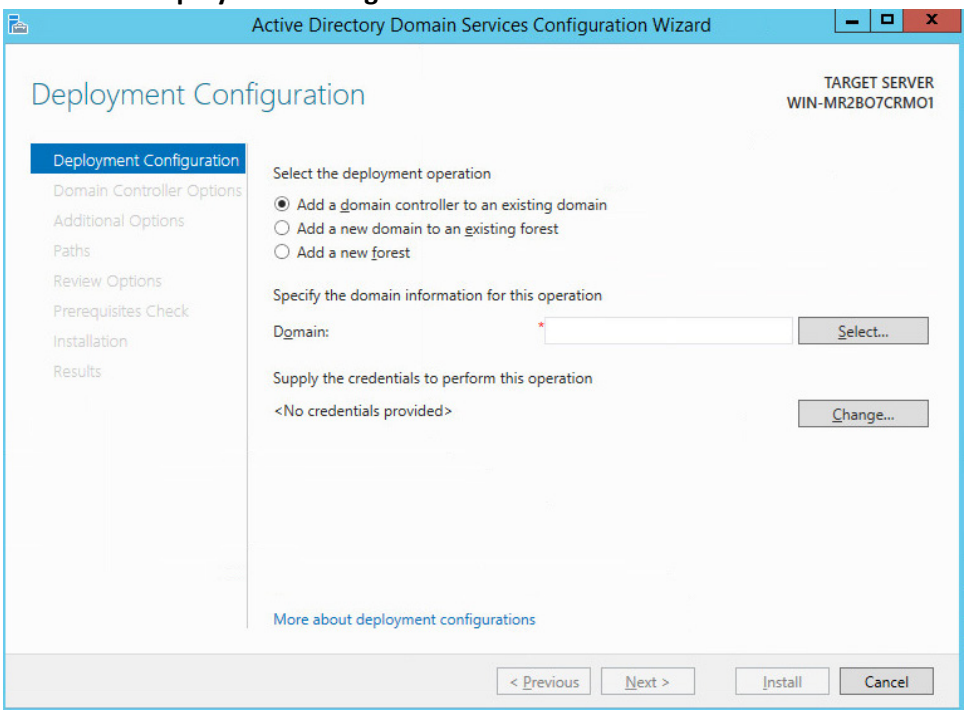




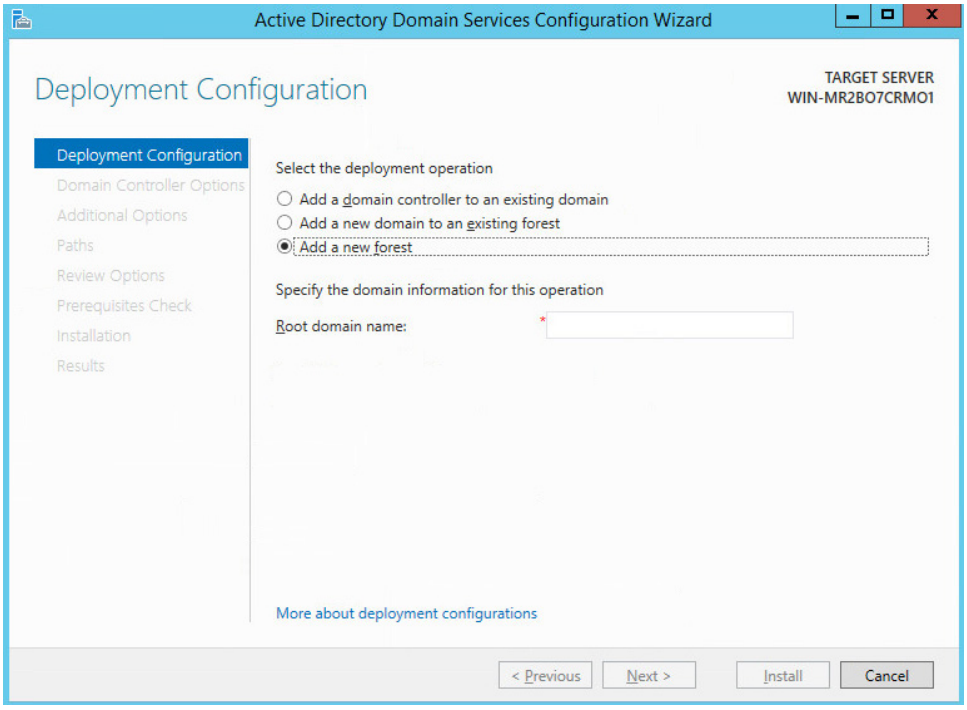
15. Click **Install**.
16. Wait for the installation to complete.



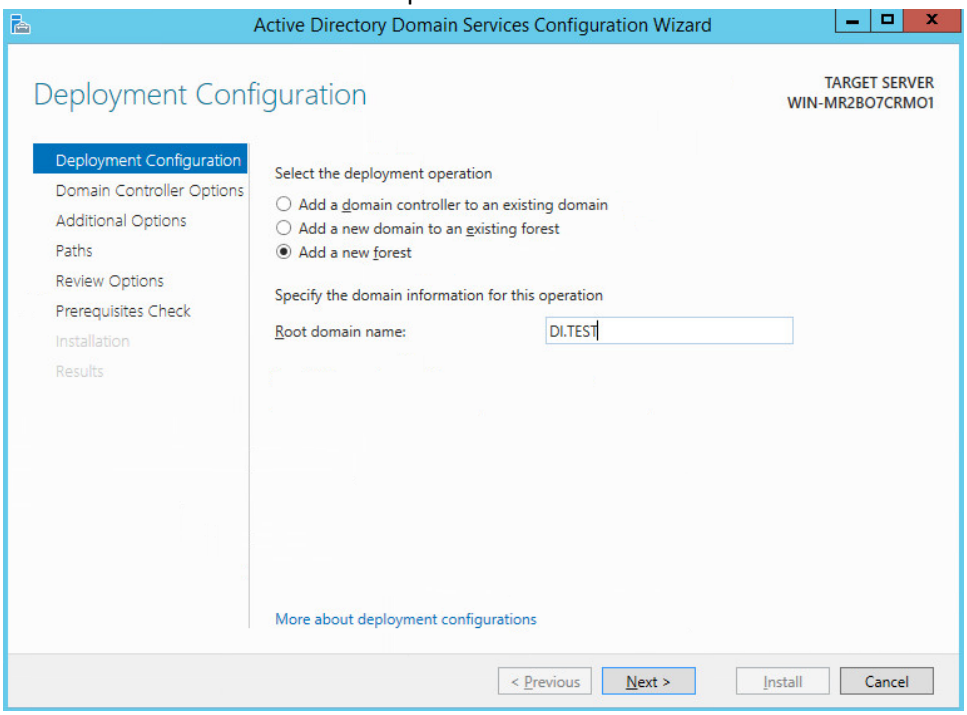
17. Select **Post-Deployment Configuration** or **Promote this server to a domain controller**.



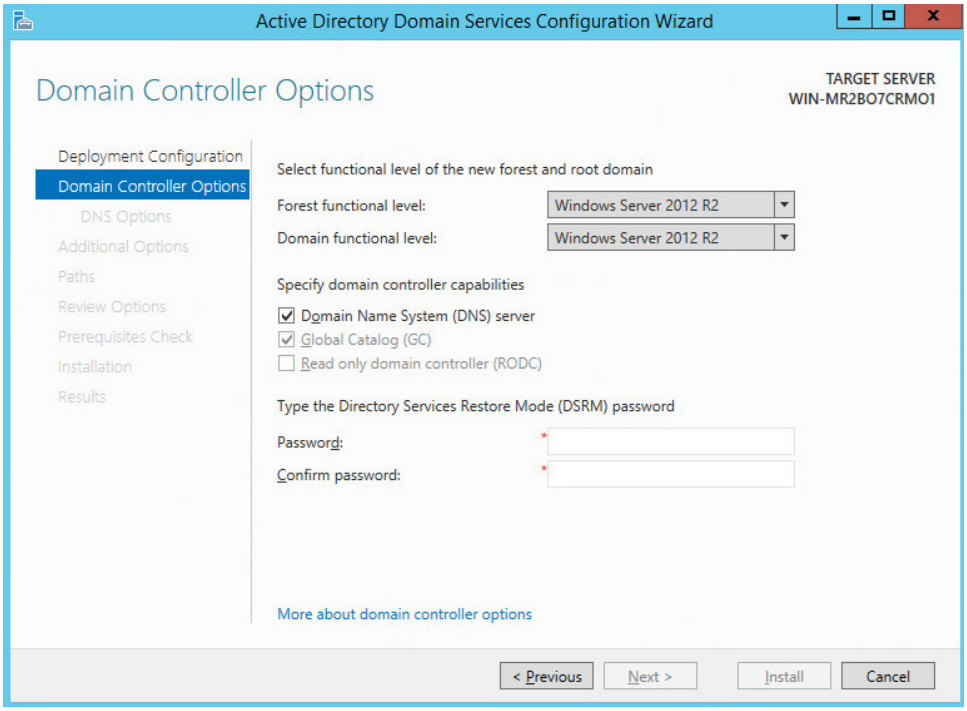
18. Select **Add a new forest**.



19. Enter a **Root domain name**. Example: DI.TEST.

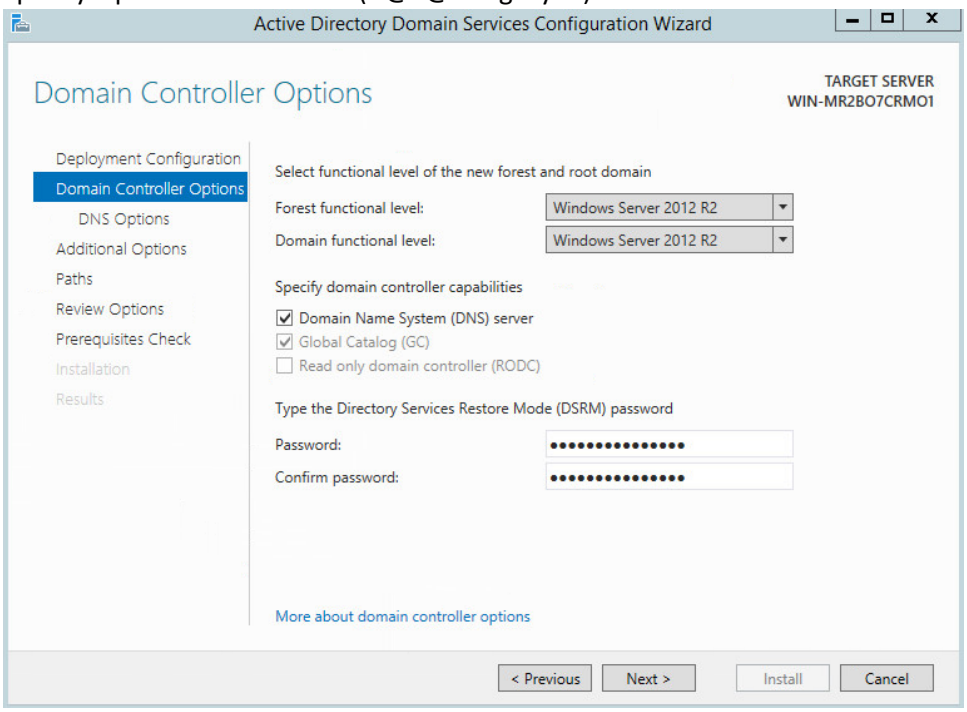


20. Click **Next.**

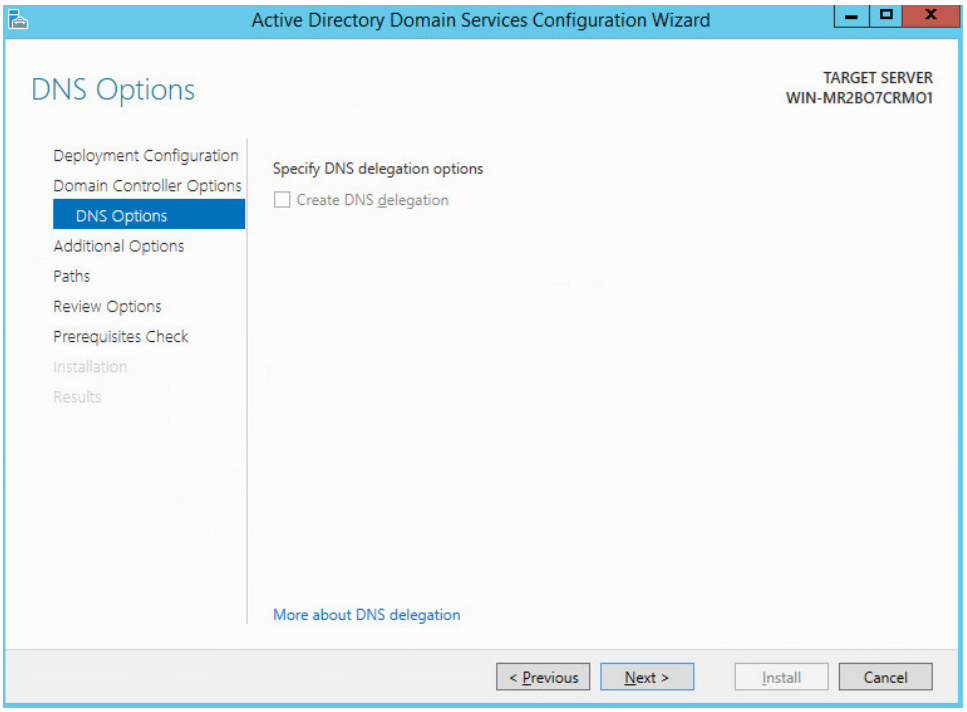


21. Select **Windows Server 2012 R2** for the **Forest Functional Level**.

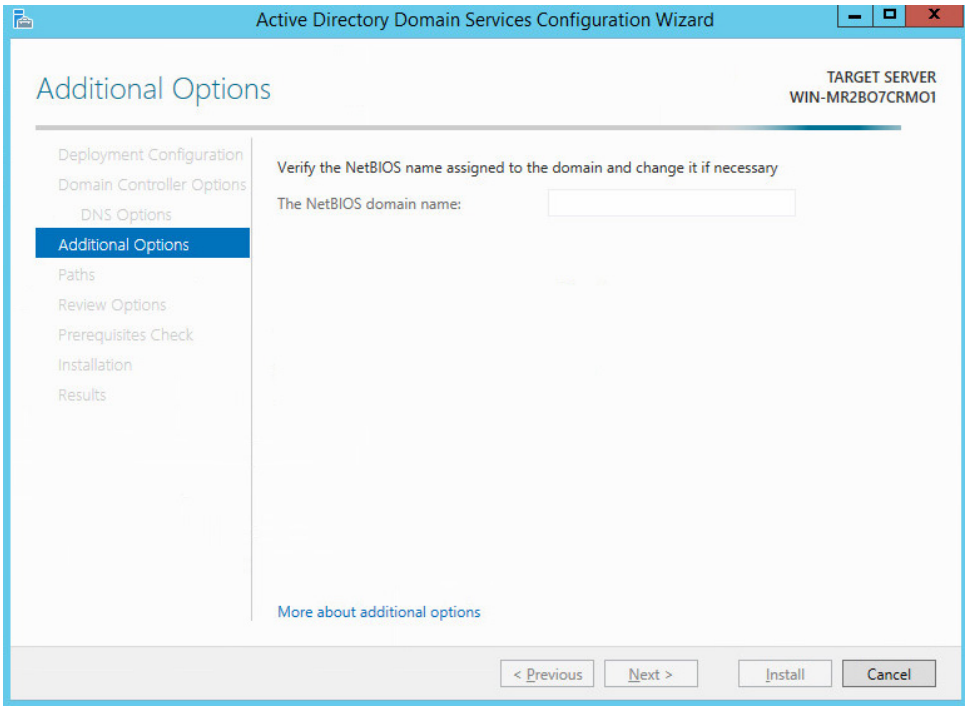
22. Select **Windows Server 2012 R2** for the **Domain Functional Level**.
23. Check the box next to **DNS server** and **Global Catalog**.
24. Do not check the box next to **read-only domain controller**.
25. Specify a password for **DSRM** (D@T@Integrity#1).



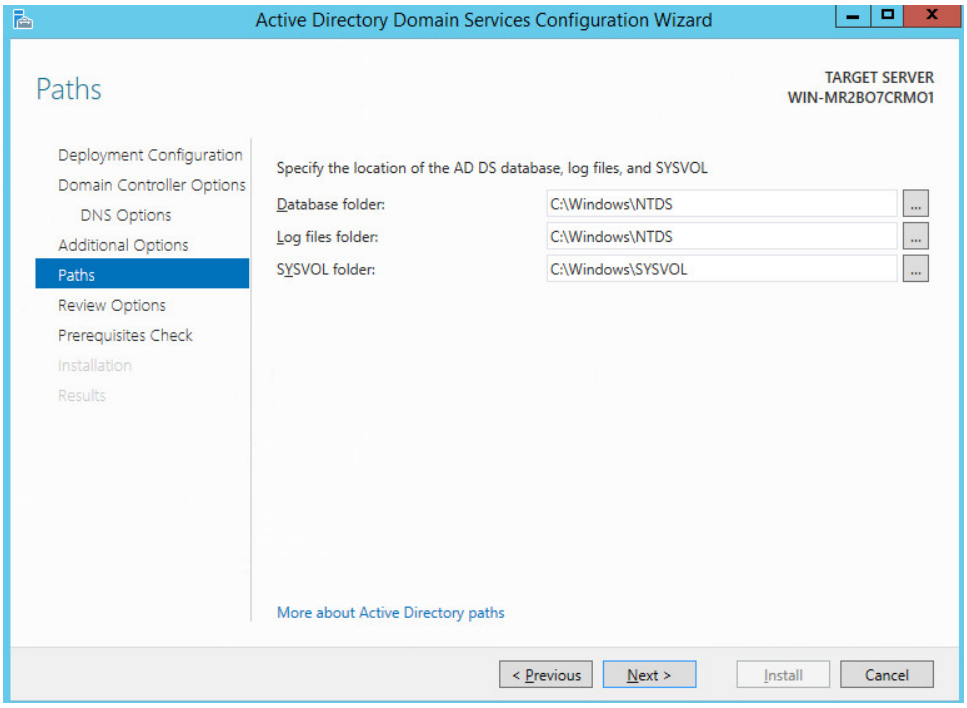
26. Click **Next**.



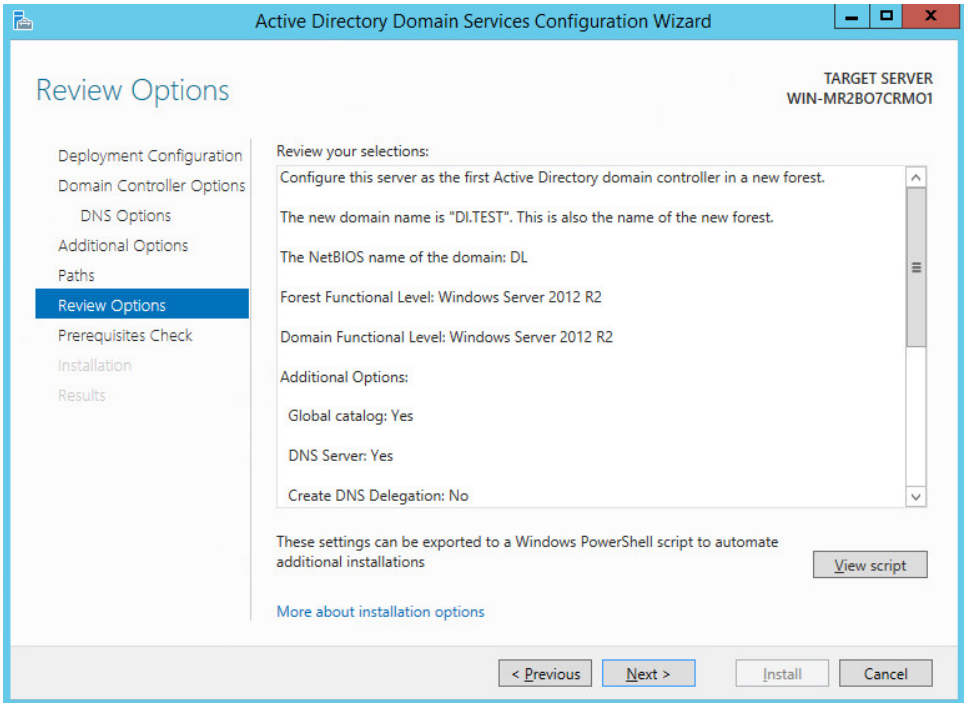
27. Click **Next**.



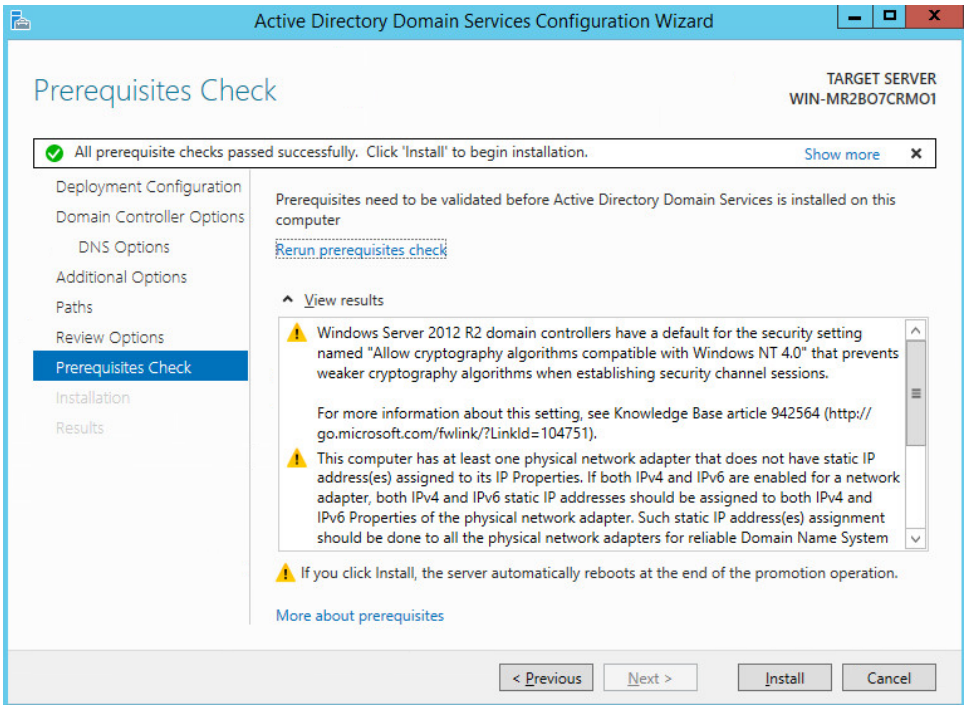
28. Verify the NetBIOS name.
29. Click **Next**.



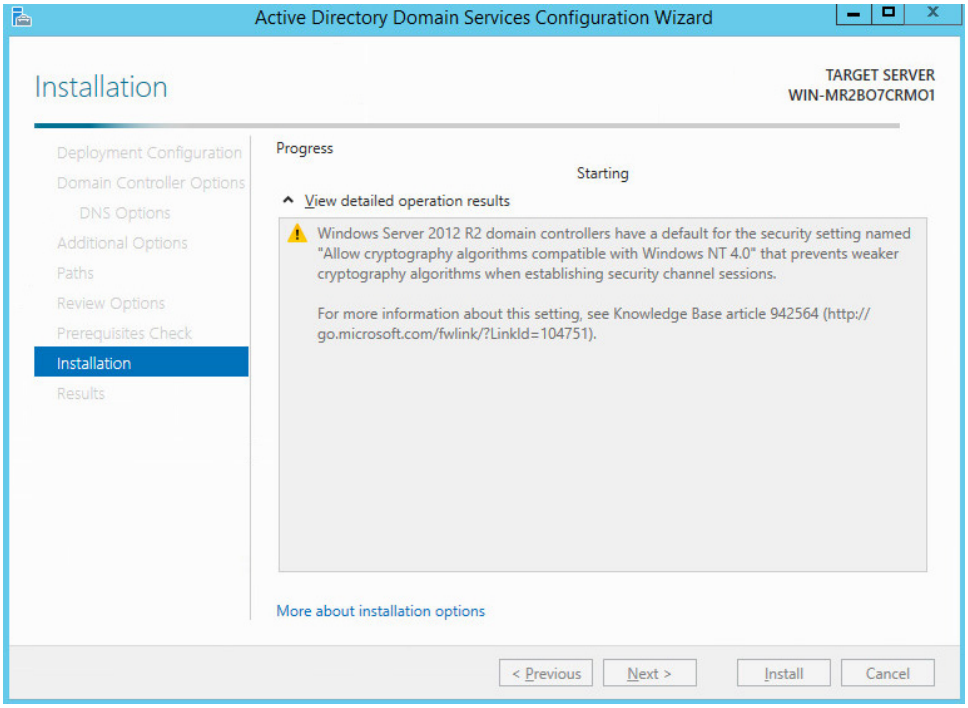
30. Click **Next**.



31. Click **Next**.



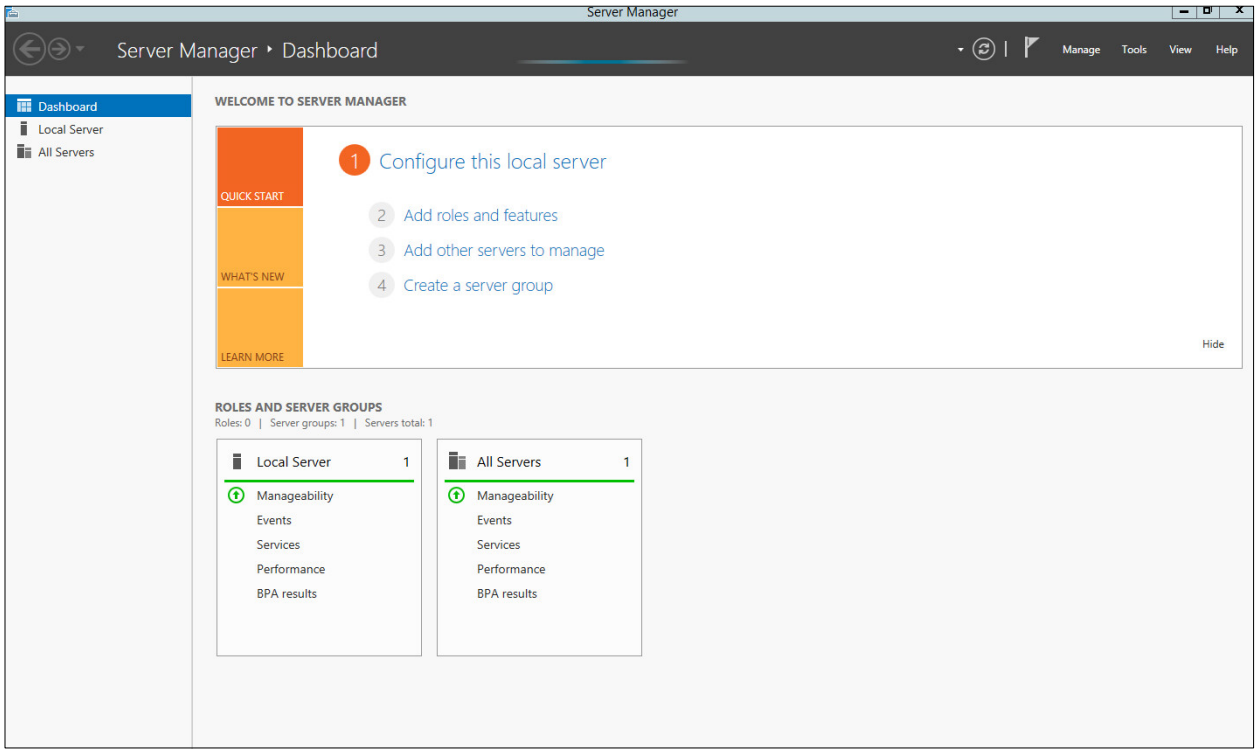
32. Click **Install**.



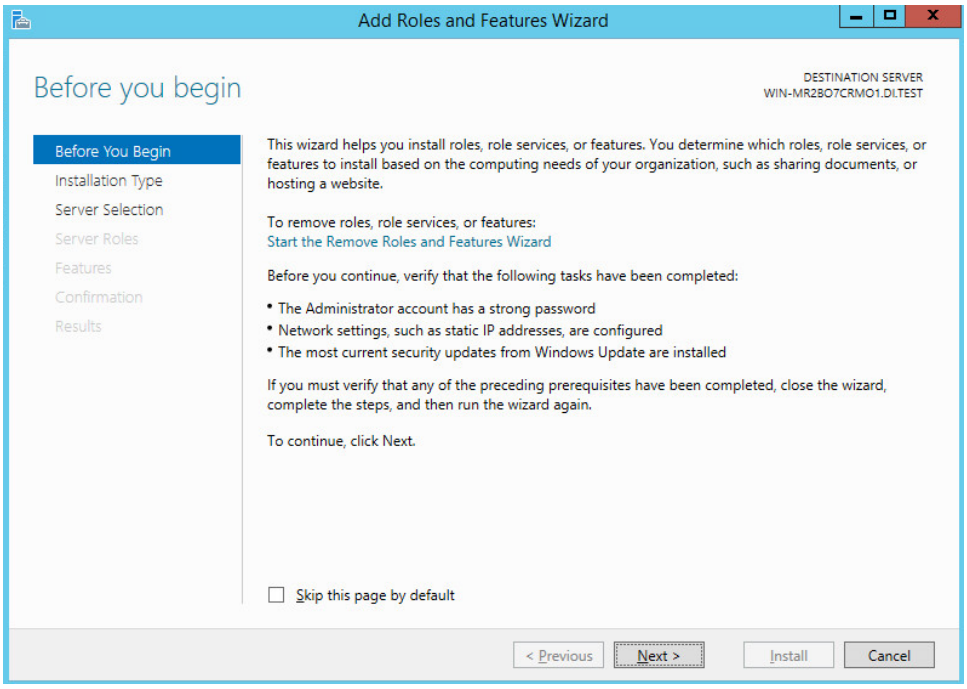
33. The server automatically reboots.

2.1.2 Creating a Certificate Authority

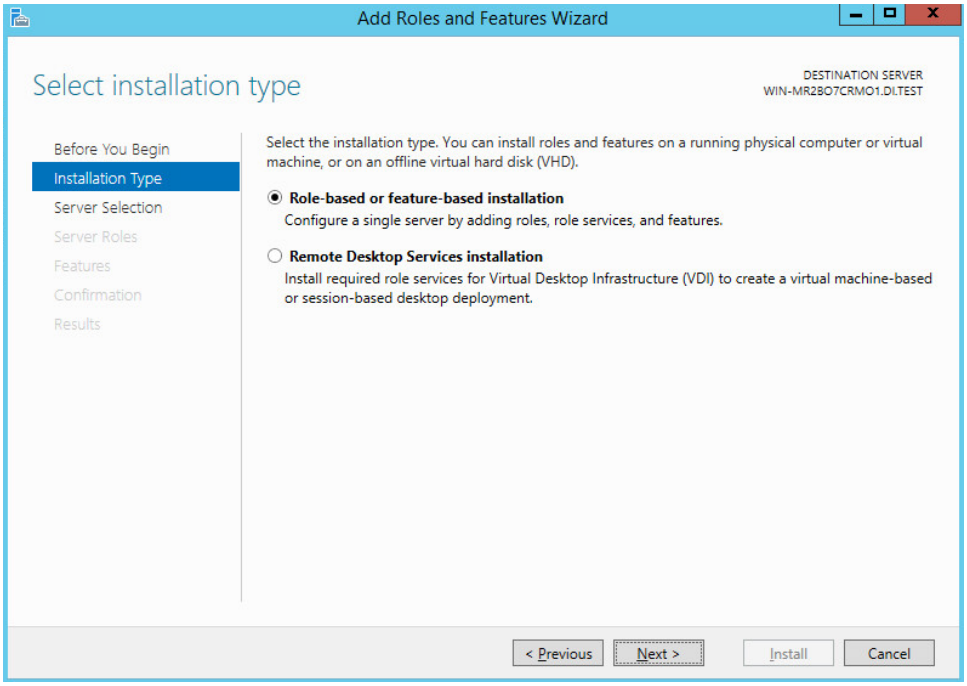
1. Open **Server Manager**.



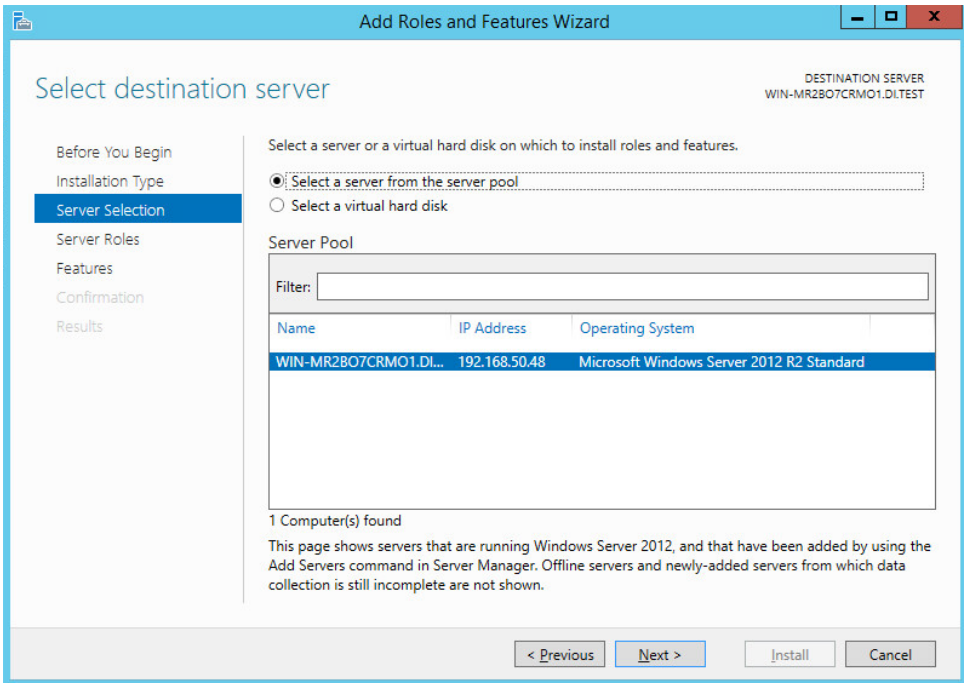
2. Click the link **Add Roles and Features**.



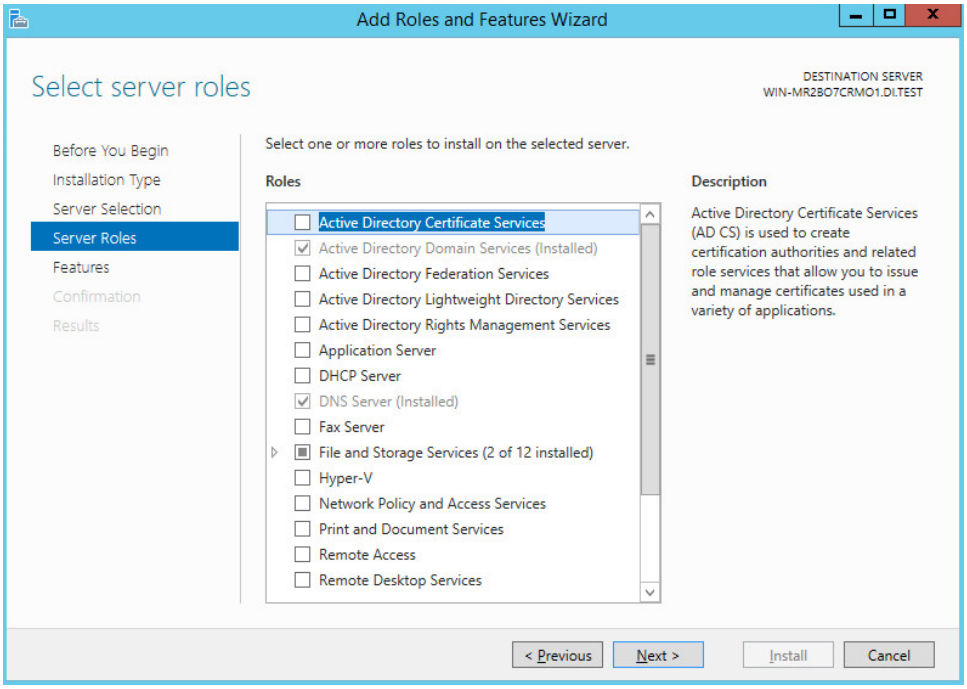
3. Click **Next**.



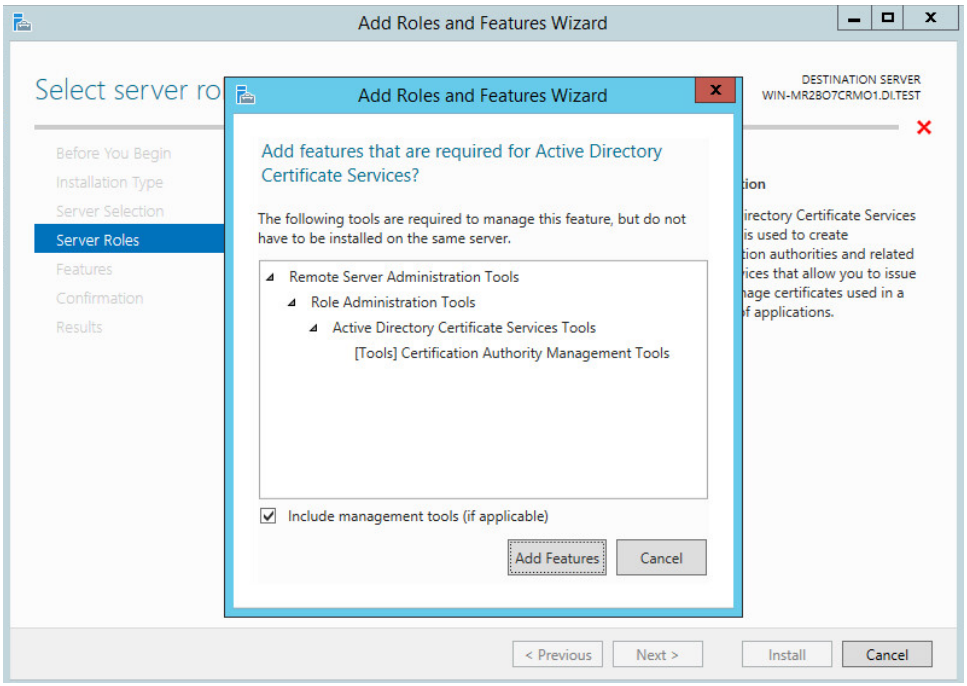
4. Select **Role-based or feature-based installation**.
5. Click **Next**.



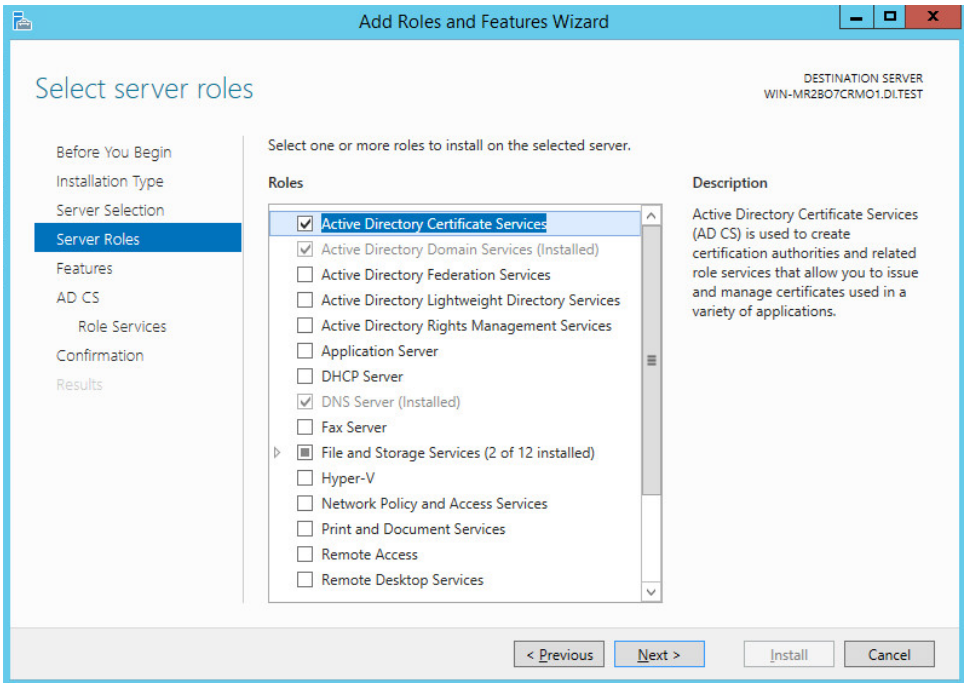
6. Select **ADDNS** (or the correct Windows Server name) from the list.
7. Click **Next**.



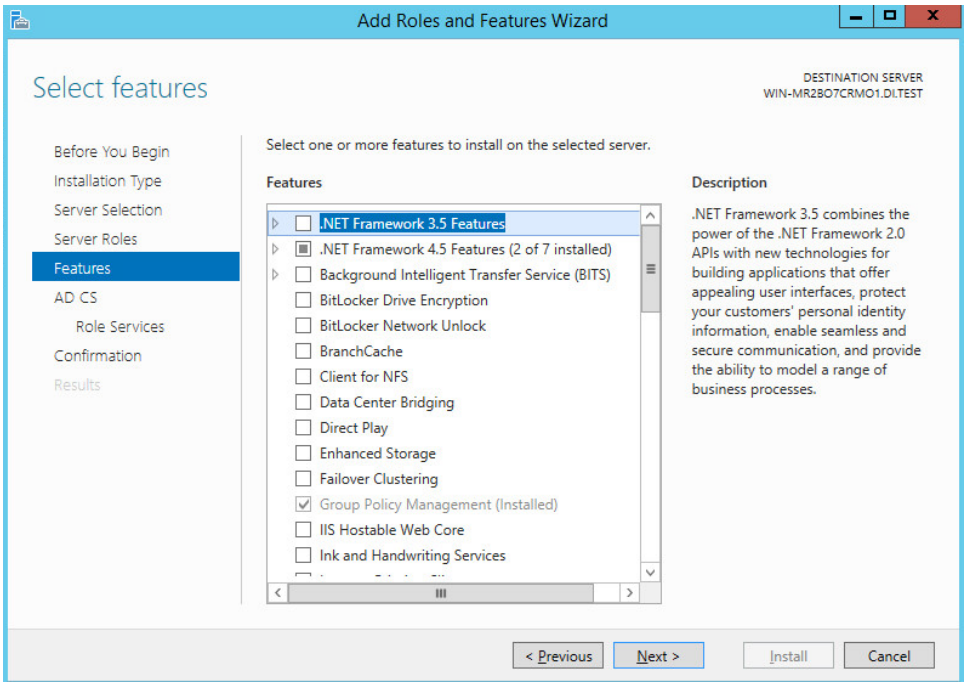
8. Check the box next to **Active Directory Certificate Services**



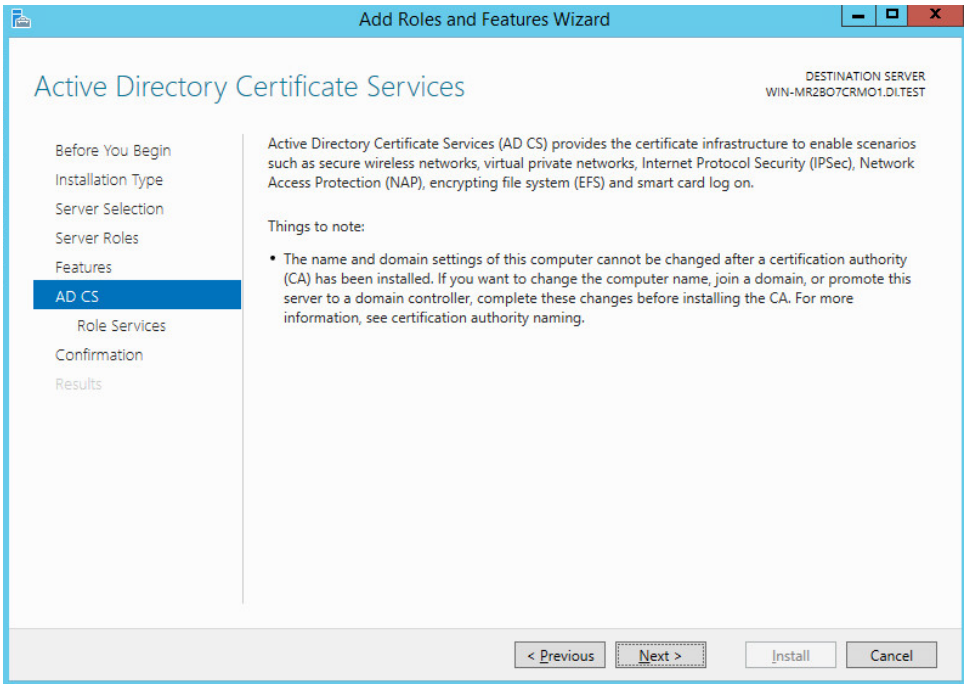
9. Click **Add Features**.



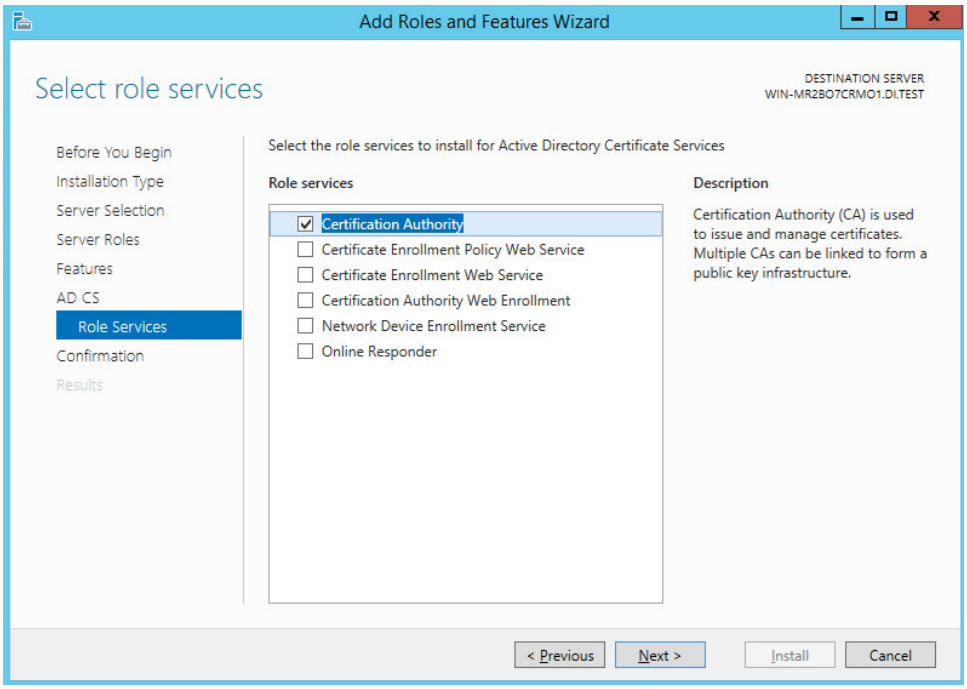
10. Click **Next**.



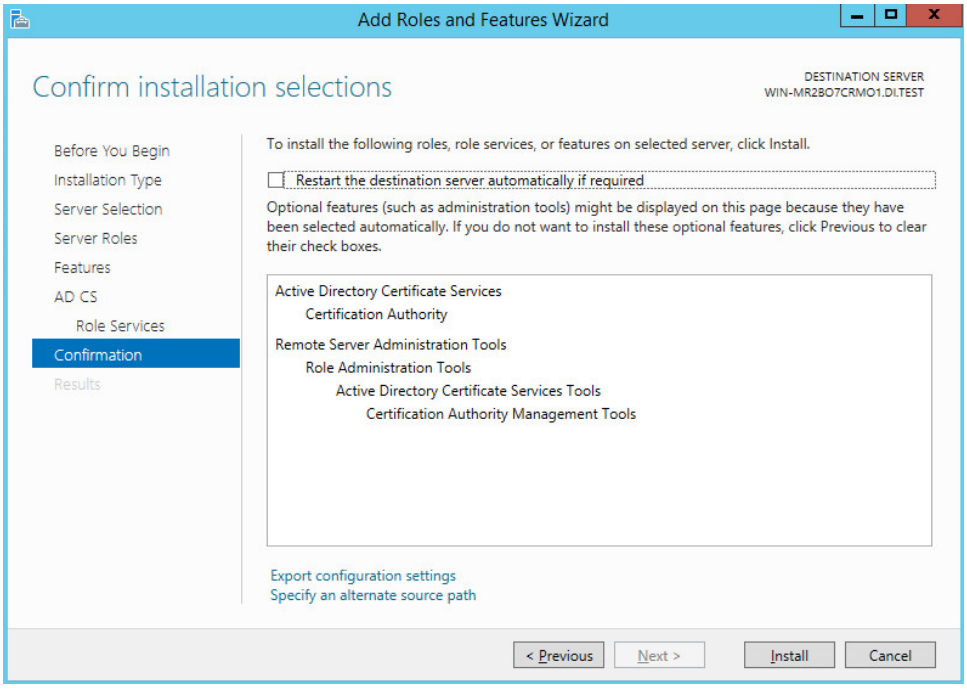
11. Click **Next**.

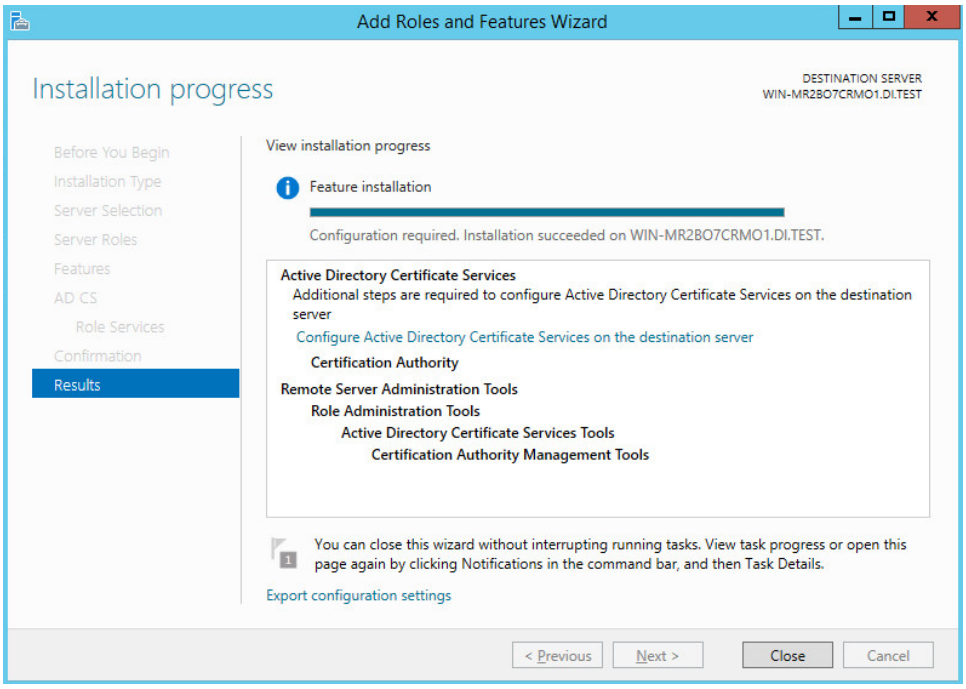


12. Click **Next**.

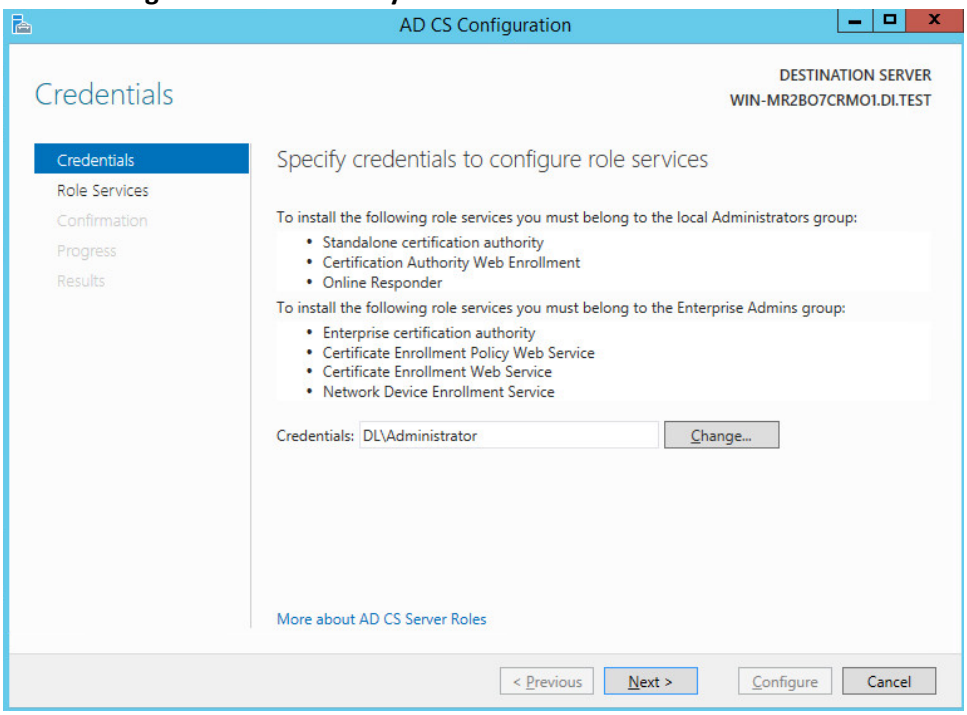


13. Select **Certification Authority** on the **Role Services** list.
14. Click **Next**.



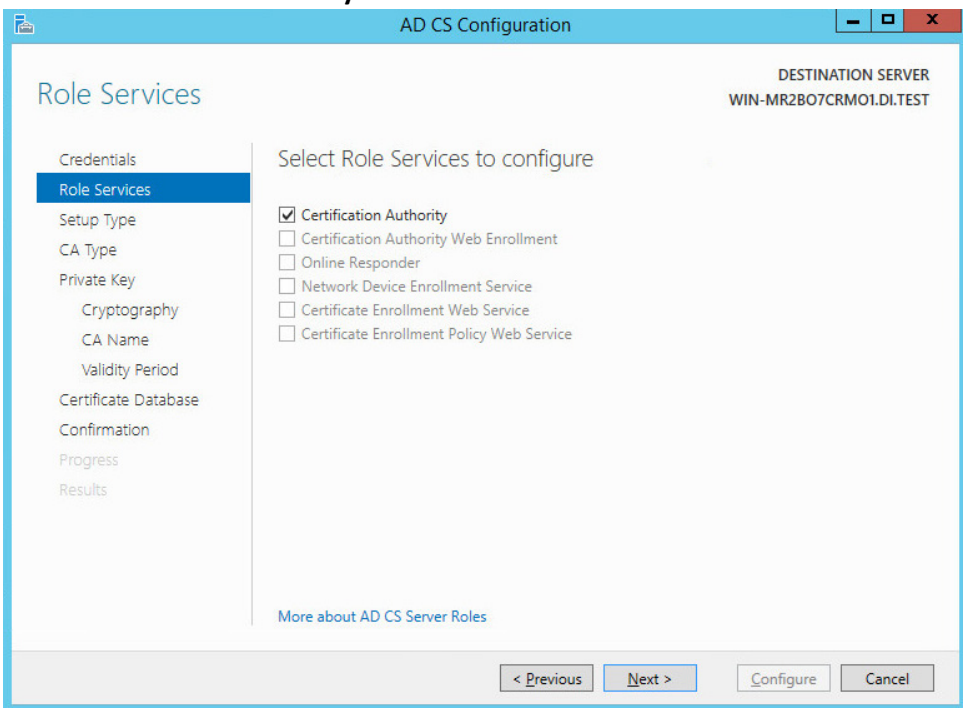


15. Click **Install**.
16. Select **Configure Active Directory Certificate Services on the destination server**.

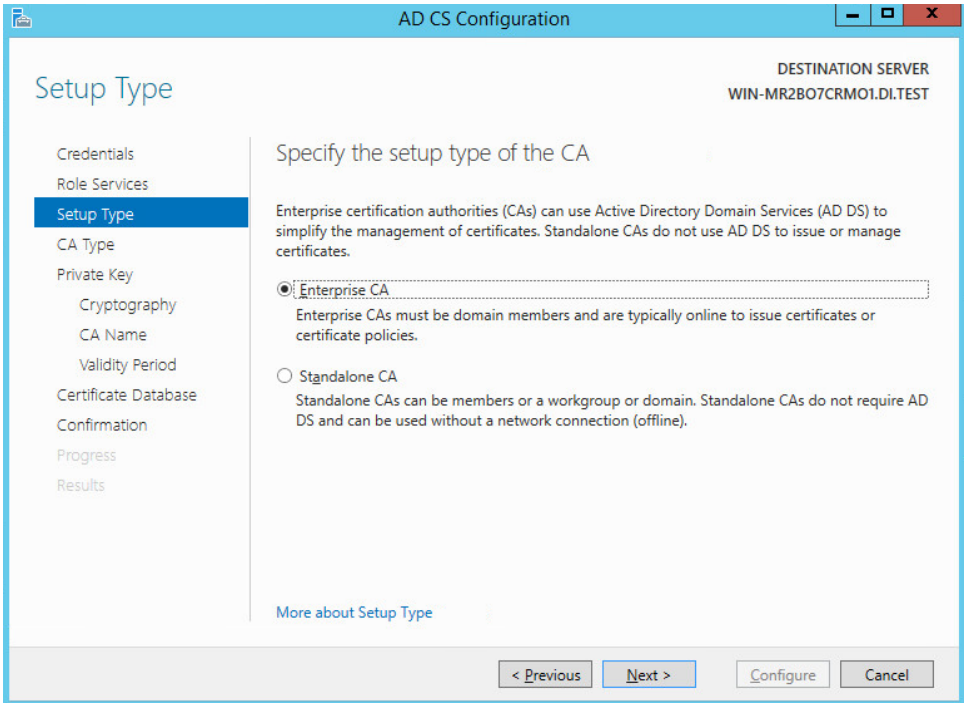


17. Click **Next**.

18. Select **Certification Authority**.

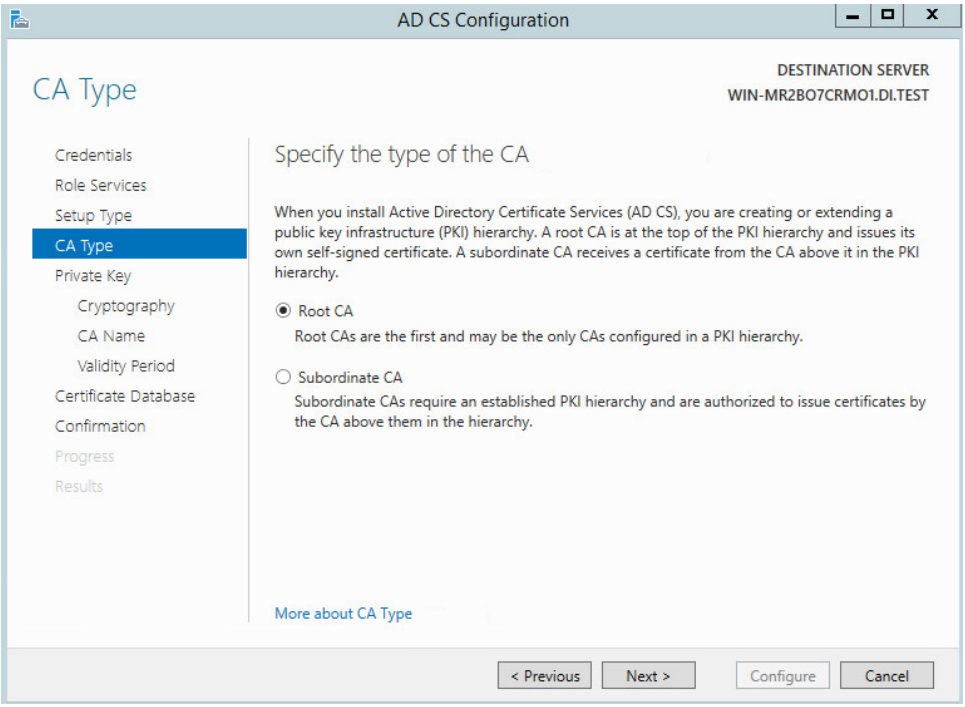


19. Click **Next**.



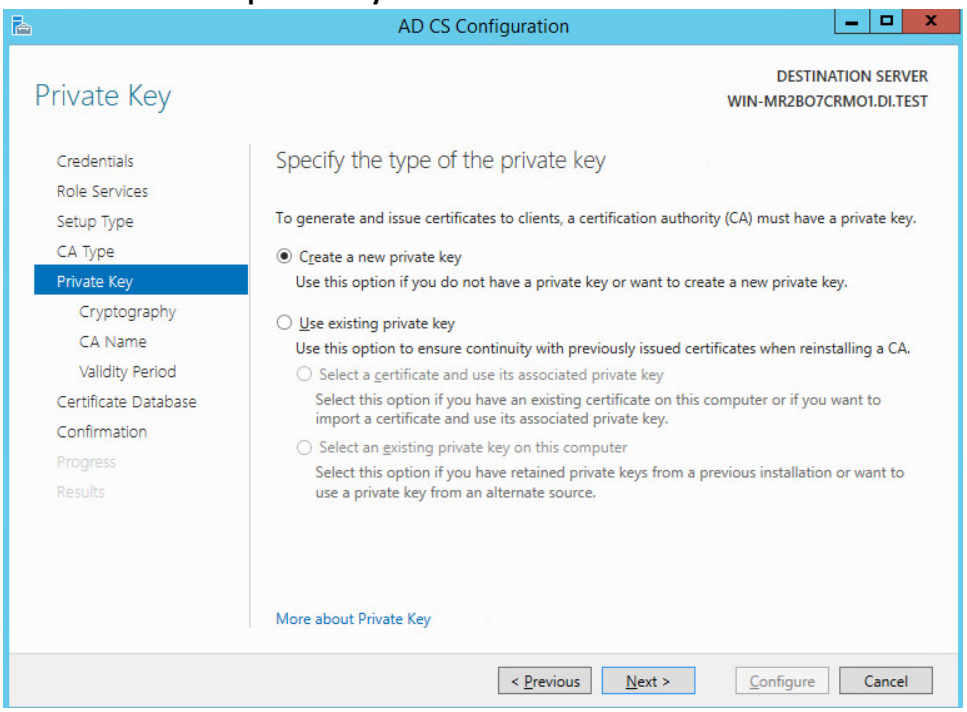
20. Select **Enterprise CA**.

21. Click **Next**.



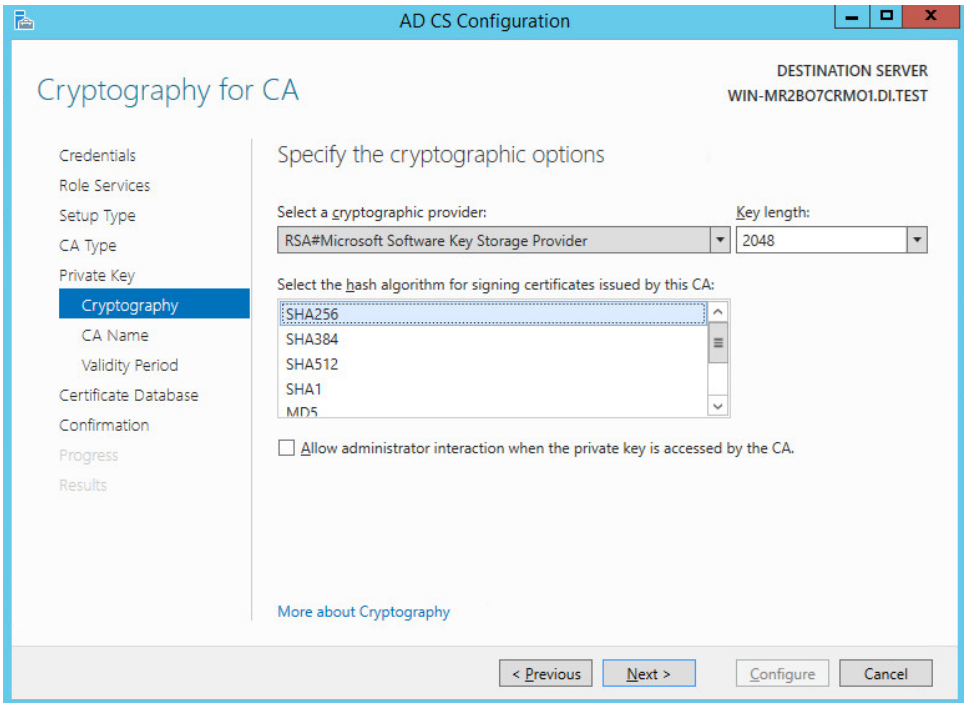
22. Select **Root CA**.
23. Click **Next**.

24. Select **Create a new private key**.

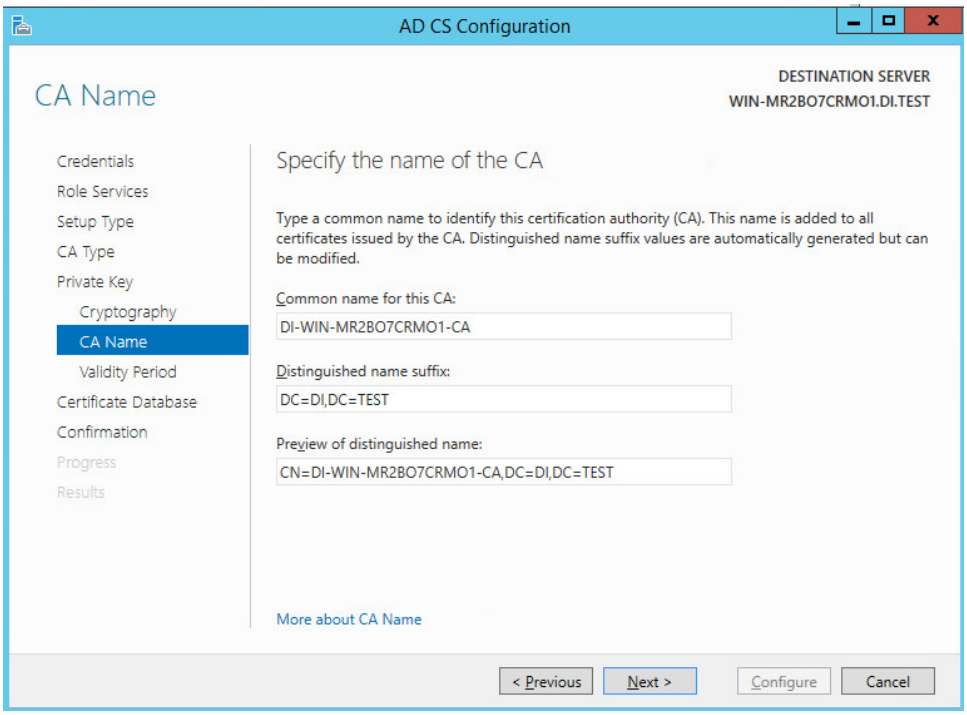


25. Click **Next**.
26. Select **RSA#Microsoft Software Key Storage Provider**.
27. Enter **2048** in the box.

28. Select **SHA256** from the list.

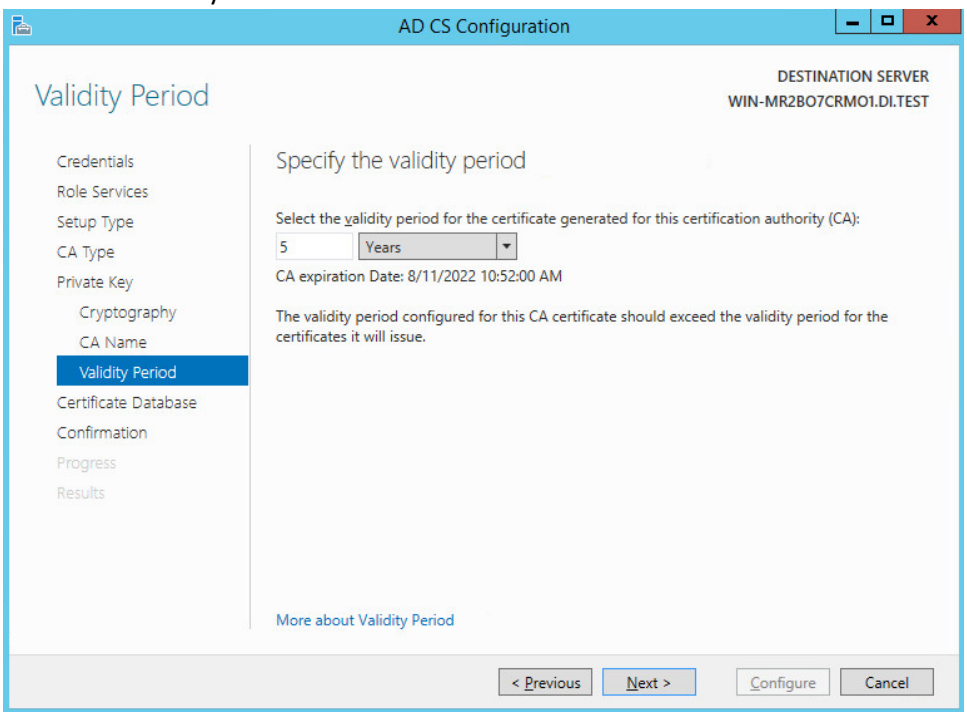


29. Click **Next**.

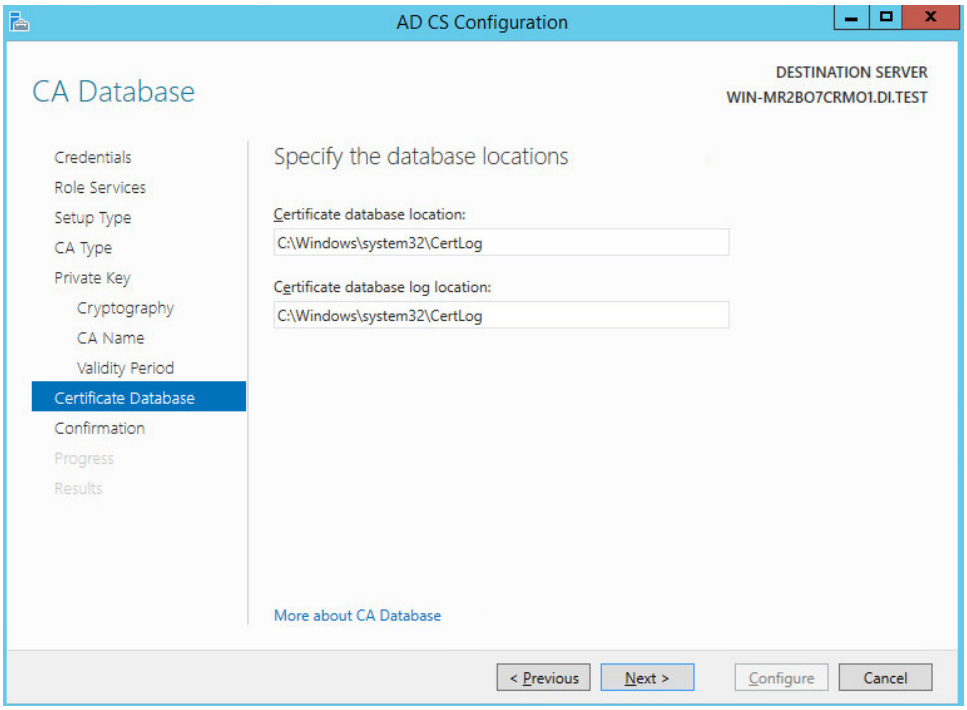


30. Click **Next**.

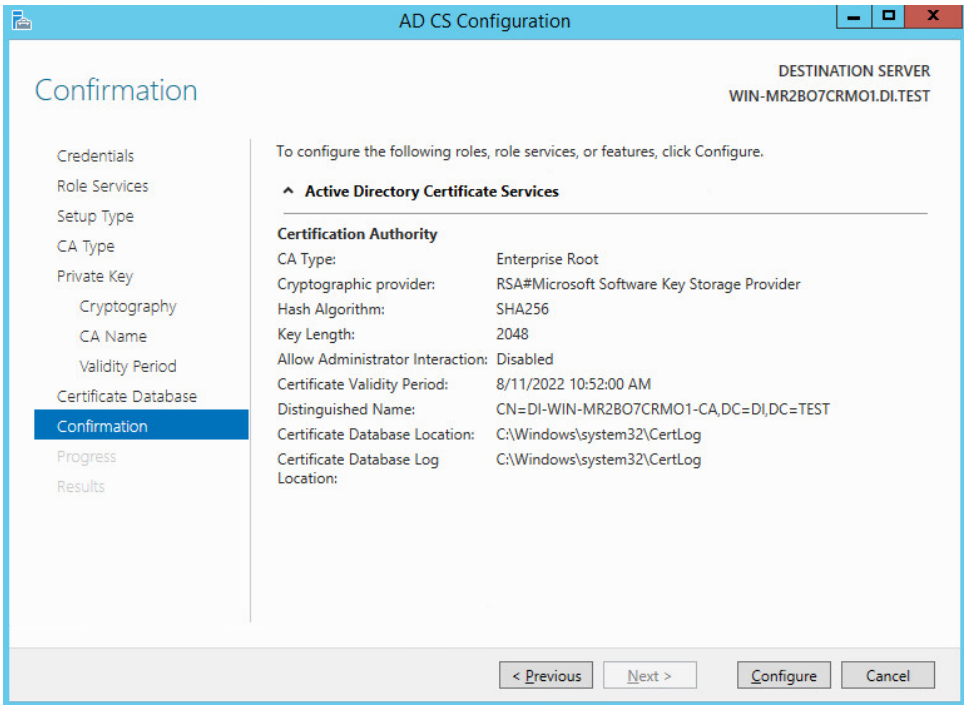
31. Set the time to 5 years.



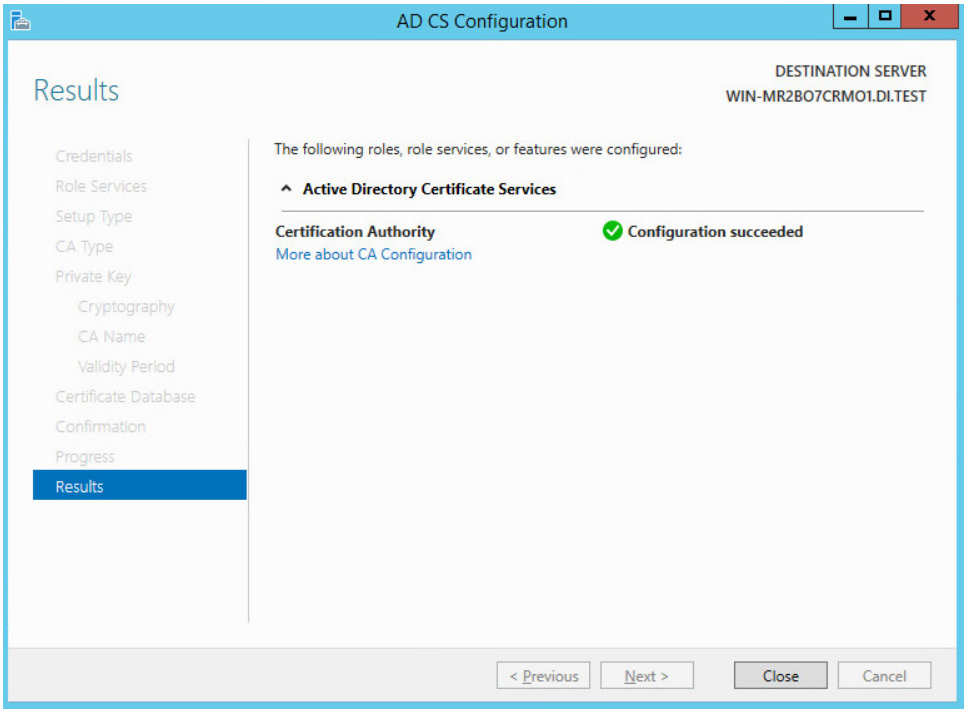
32. Click **Next**.



33. Click **Next**.

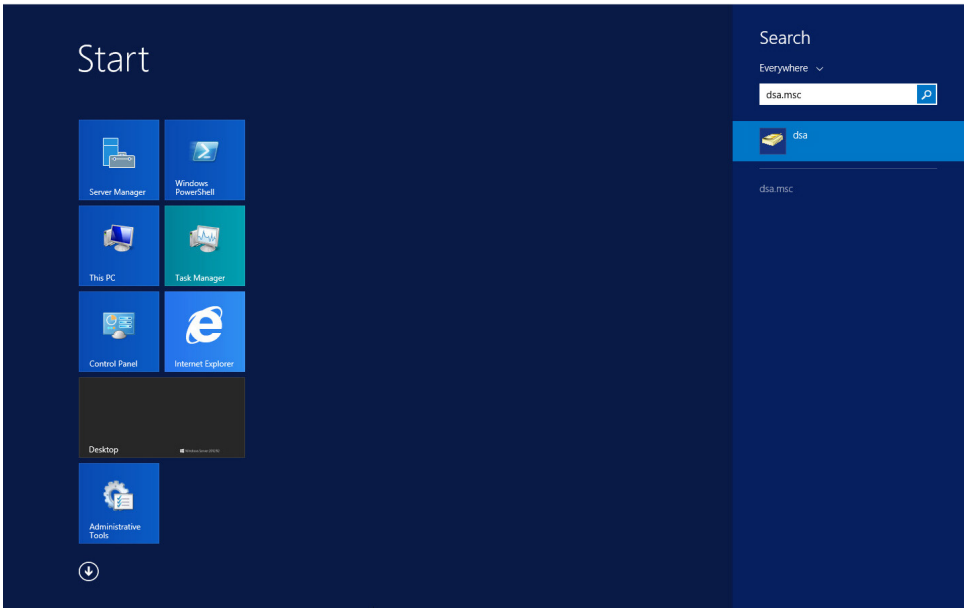


34. Click **Configure**.

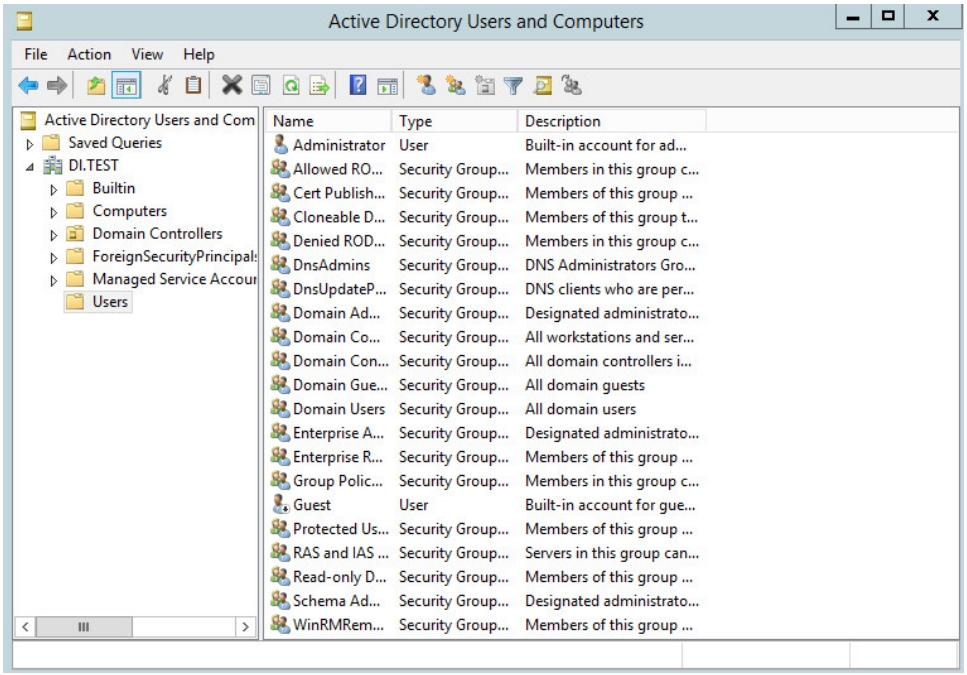


2.1.3 Configure Account to Add Computers to Domain

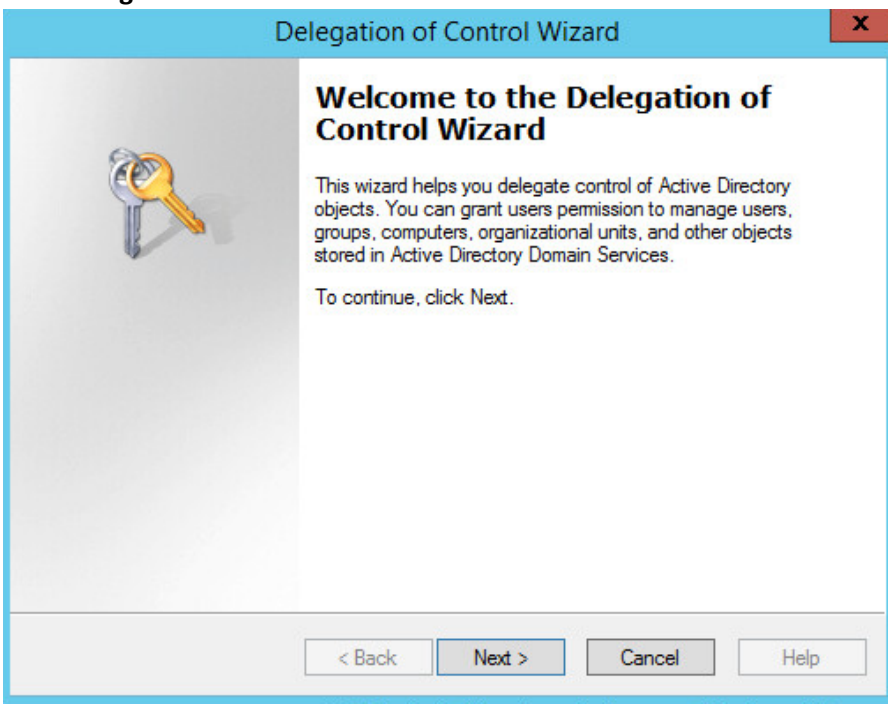
1. Open the **start menu**.
2. Type **dsa.msc** and run the program.



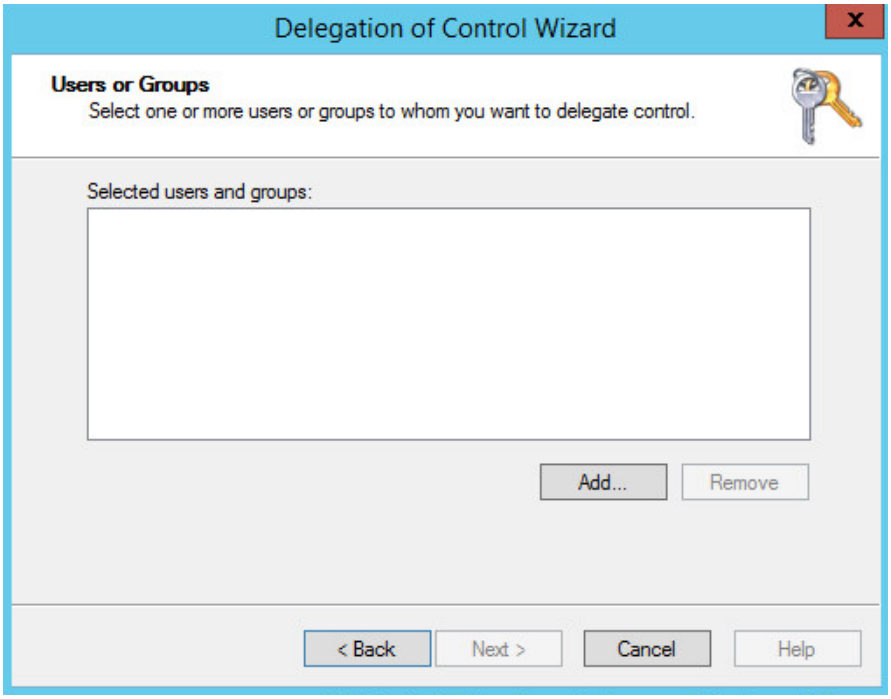
3. Right click on **Users** in the left pane.



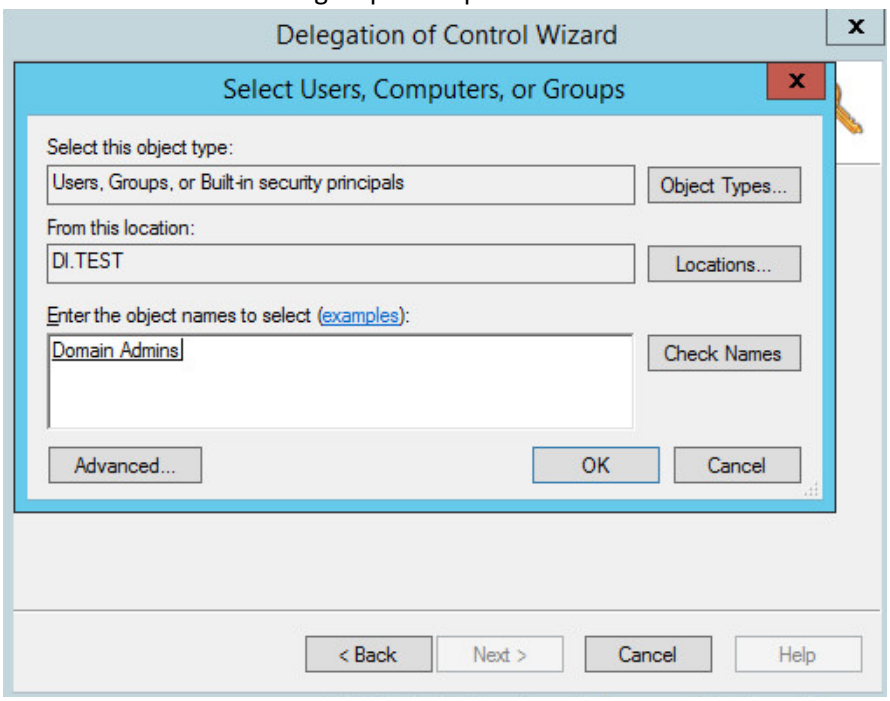
4. Click **Delegate Control**.



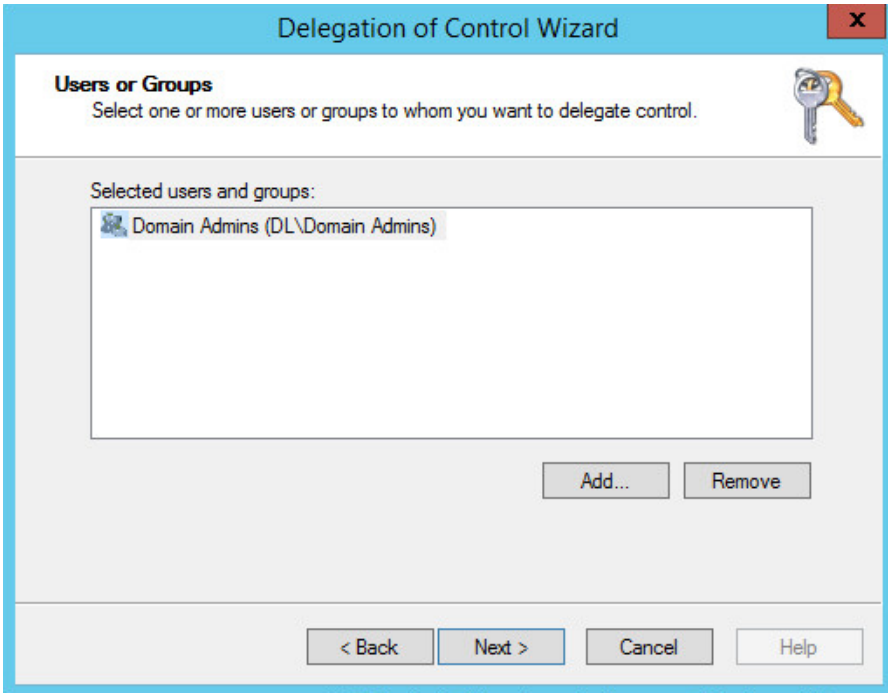
5. Click **Next**.



6. Click **Add** to add a user or group. Example: **Domain Admins**.

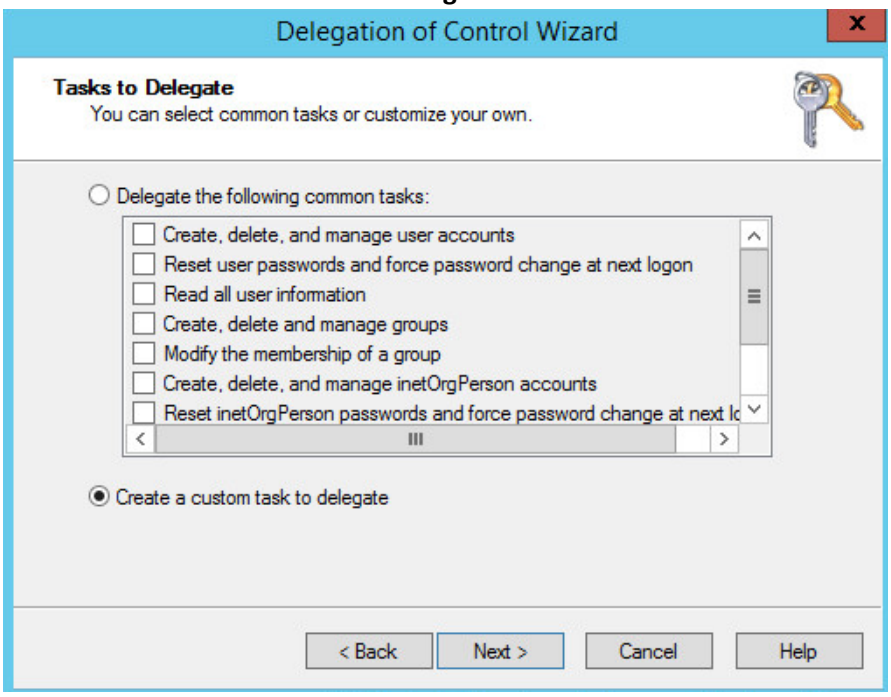


7. When finished adding users or groups, click **OK**.

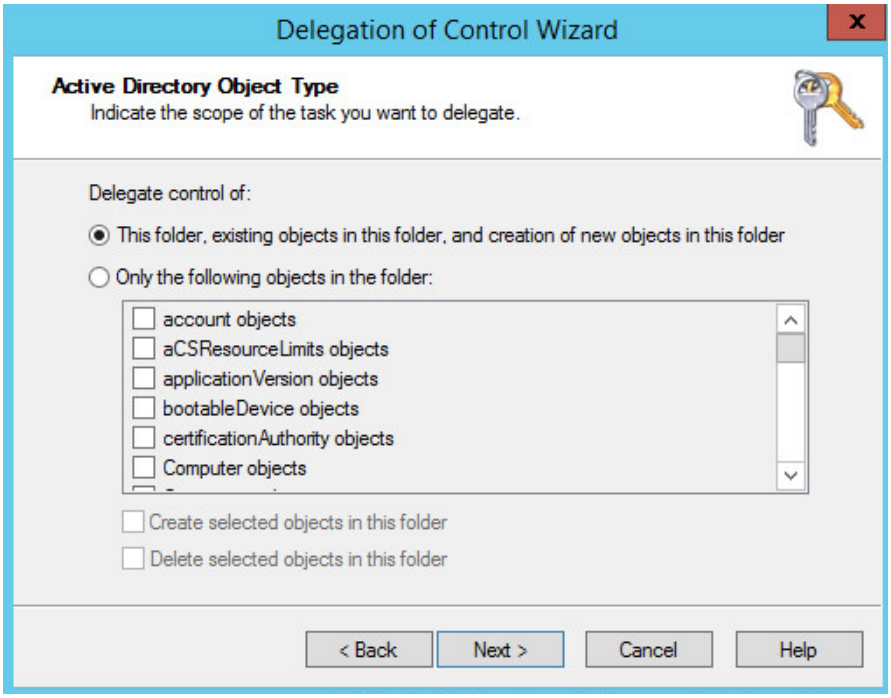


8. Click **Next**.

9. Choose **Create a custom task to delegate**.

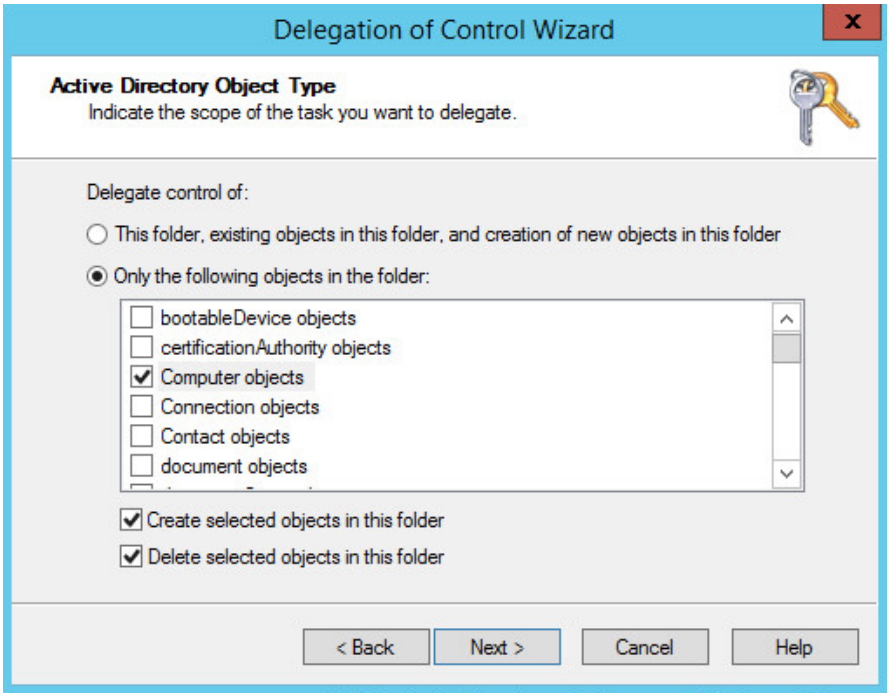


10. Click **Next**.



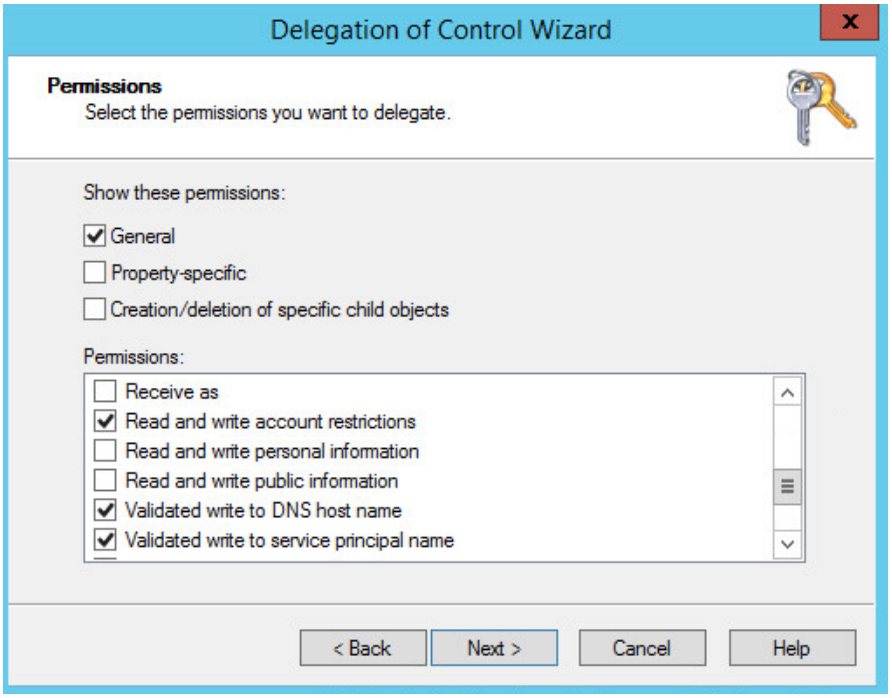
11. Choose **Only the following objects in the folder**.
12. Select the **Computer Objects** check box.

13. Check the box for **Create selected objects in this folder**.
14. Check the box for **Delete selected objects in this folder**.

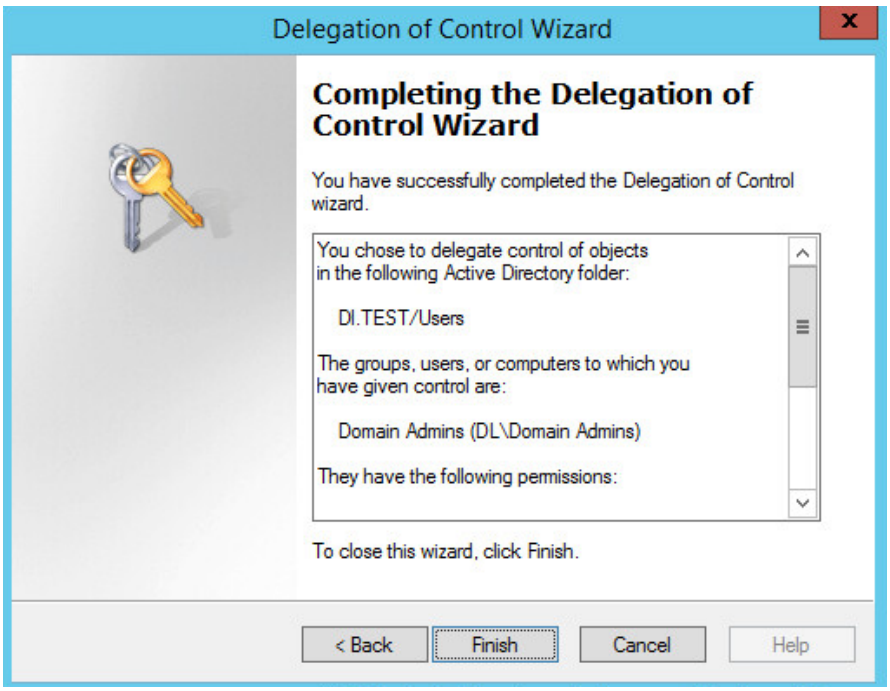


15. Click **Next**.

16. In the **Permissions List**, choose **Reset Password**, **Read and write Account Restrictions**, **Validated write to DNS host name**, **Validated write to service principal name.**



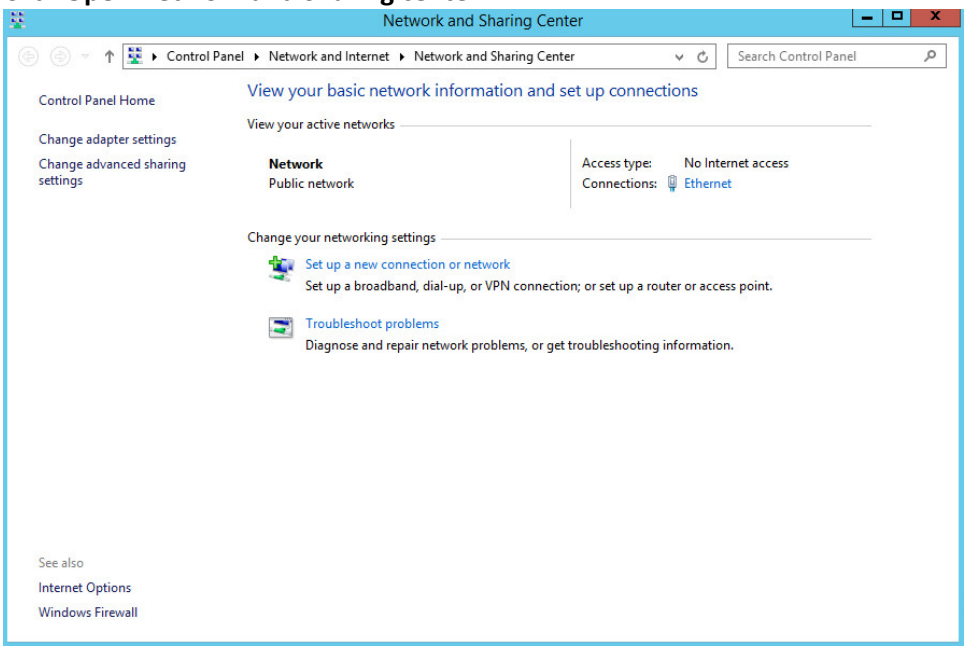
17. Click **Next**.



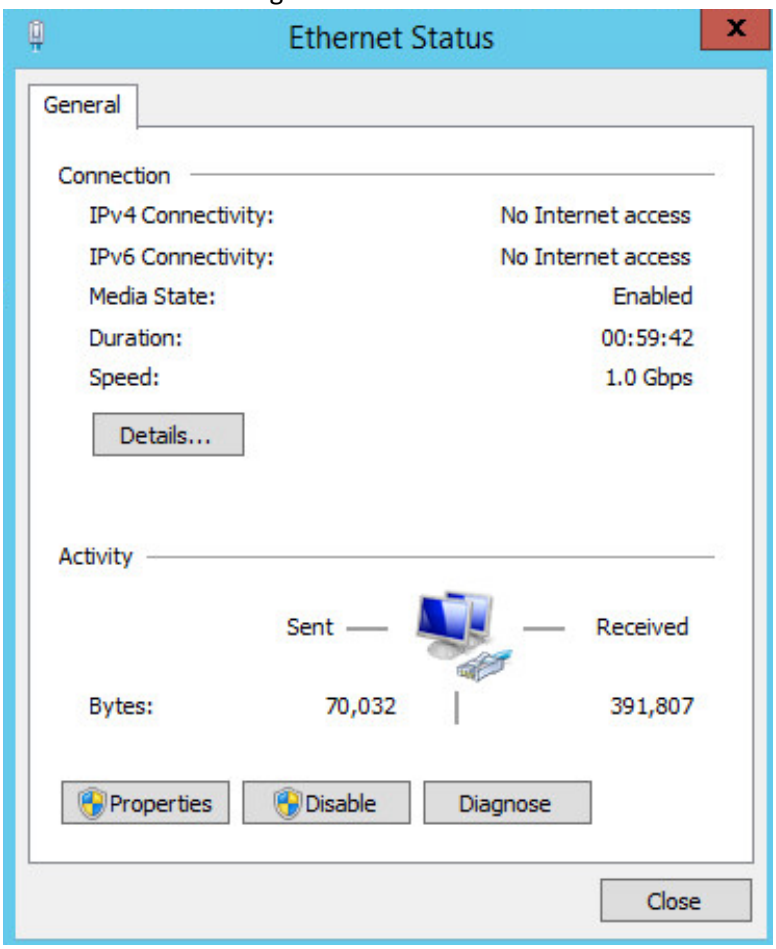
18. Observe the successful installation and click **Finish**.

2.1.4 Adding Machines to the Correct Domain

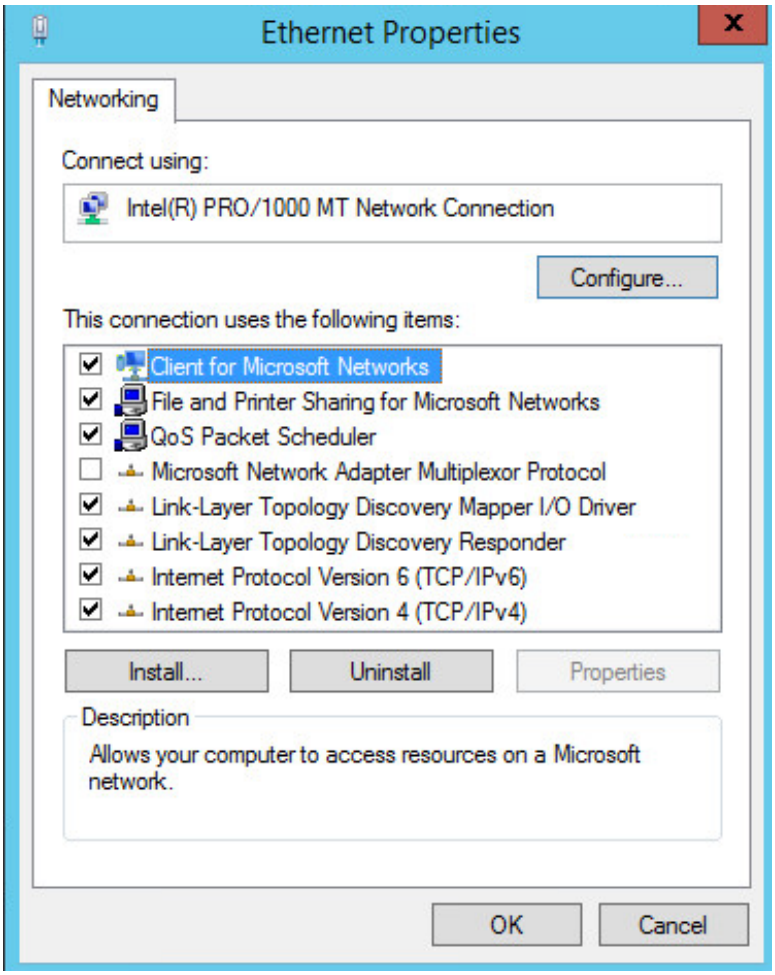
1. Right click network icon in task bar.
2. Click **Open Network and Sharing center**.



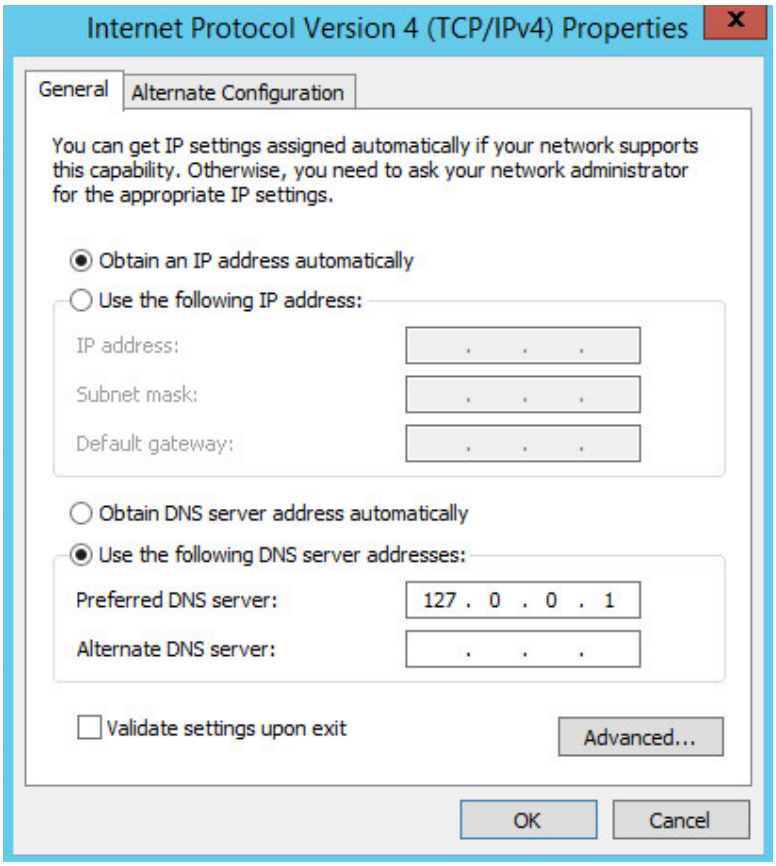
3. Click the link for editing the network interface under **Connections**.



4. Click **Properties**.

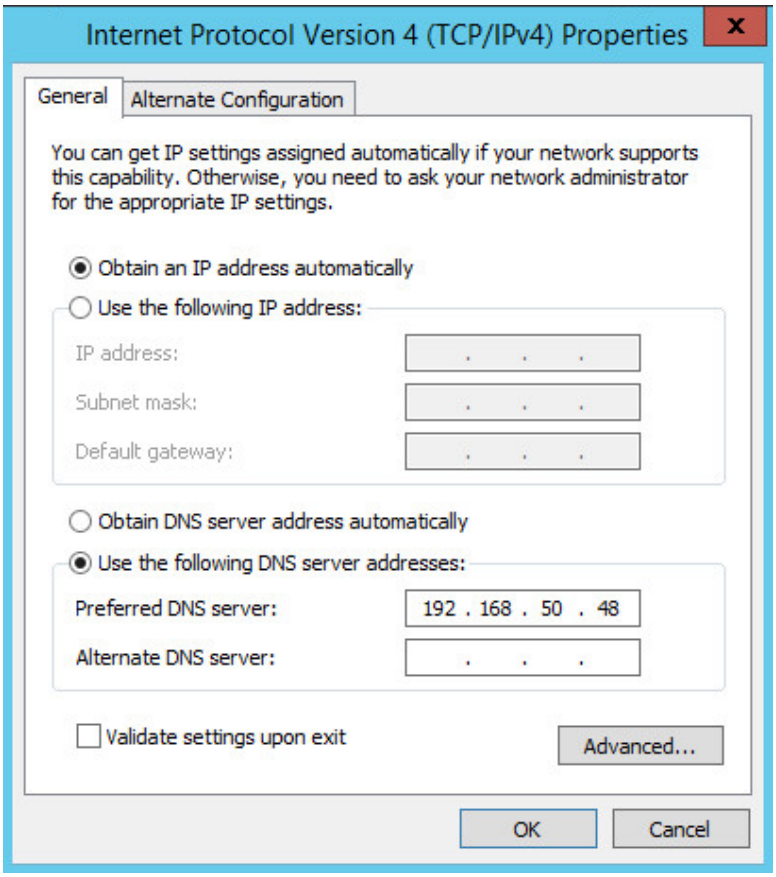


5. Click **Internet Protocol Version 4**.

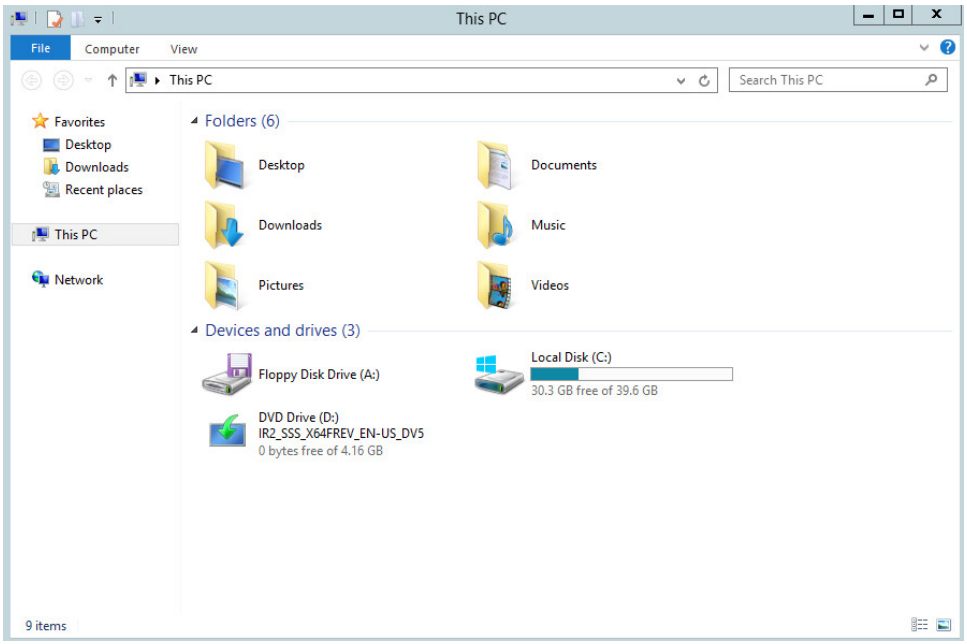


6. Click **Properties**.

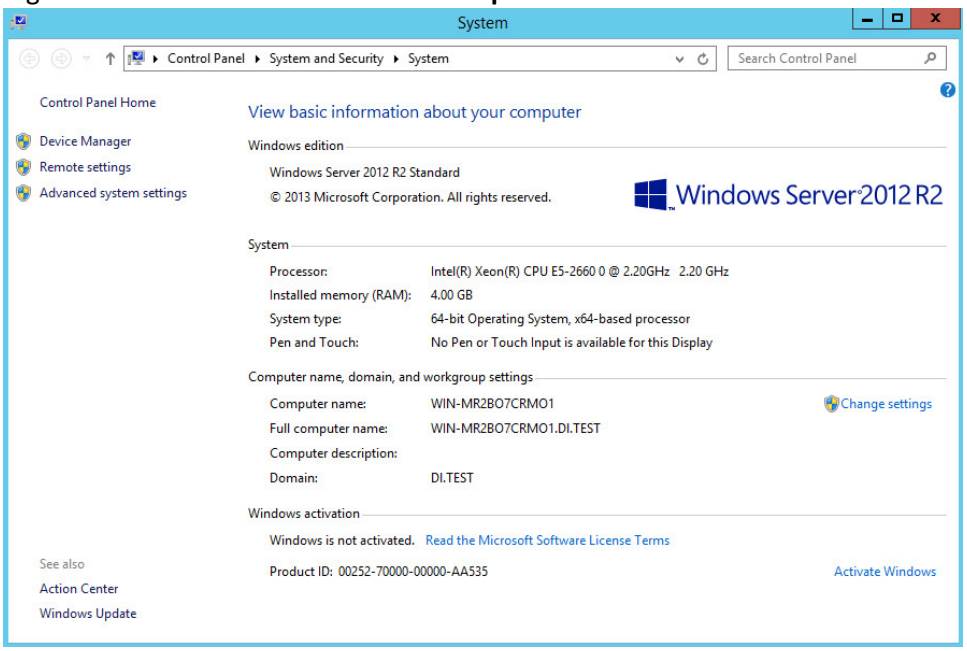
7. Set the **DNS** field to the field of the AD/DNS server.



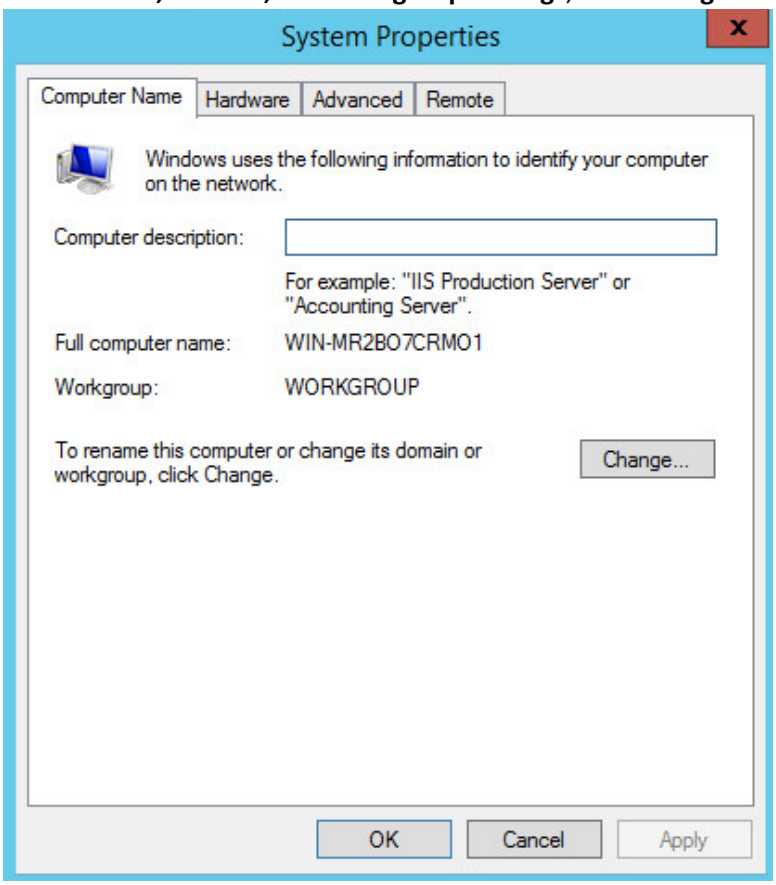
8. Click **OK**.
9. Exit out of the **Network and Sharing Center**
10. Push the **start menu** button.



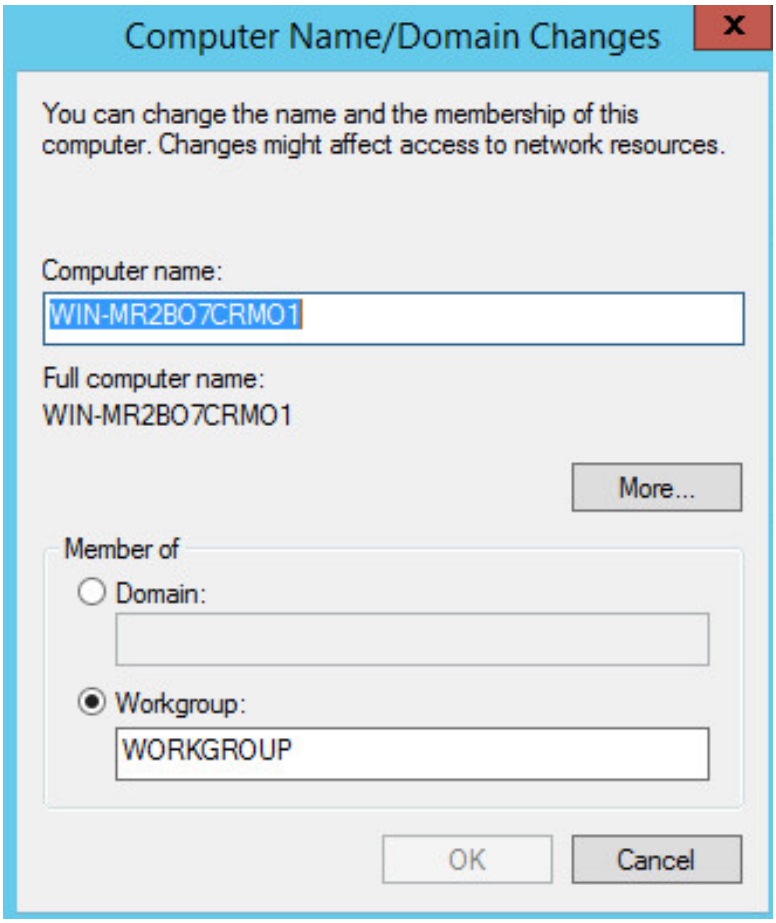
11. Go to **This PC**.
12. Right click in the window and choose **Properties**.



13. Under **Name, domain, and workgroup settings**, click **Change settings**.



14. Click **Change...**.


Computer Name/Domain Changes
You can change the name and the membership of this computer. Changes might affect access to network resources.
Computer name:
WIN-MR2BO7CRMO1
Full computer name:
WIN-MR2BO7CRMO1
More...
Member of
Domain:
Workgroup:
WORKGROUP
OK
Cancel

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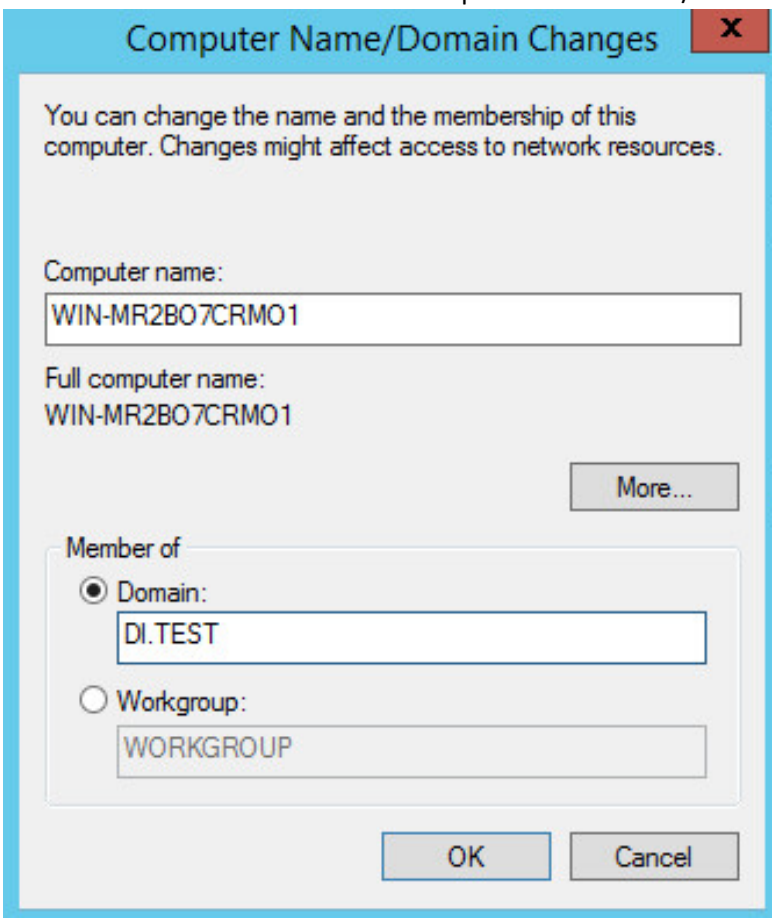
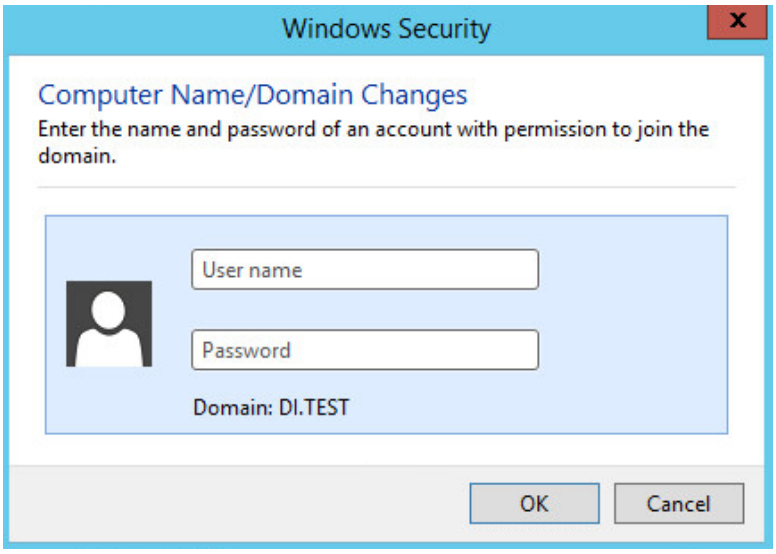
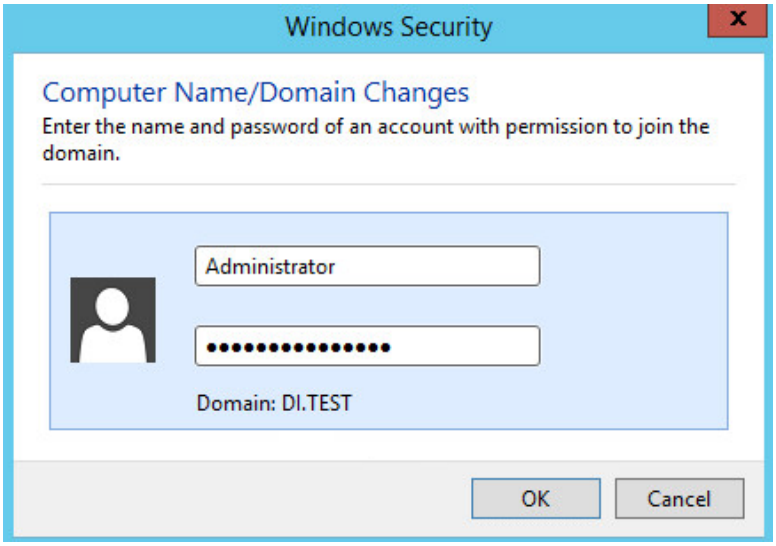
15. Select **Domain** and enter the domain specified on the AD/DNS server.



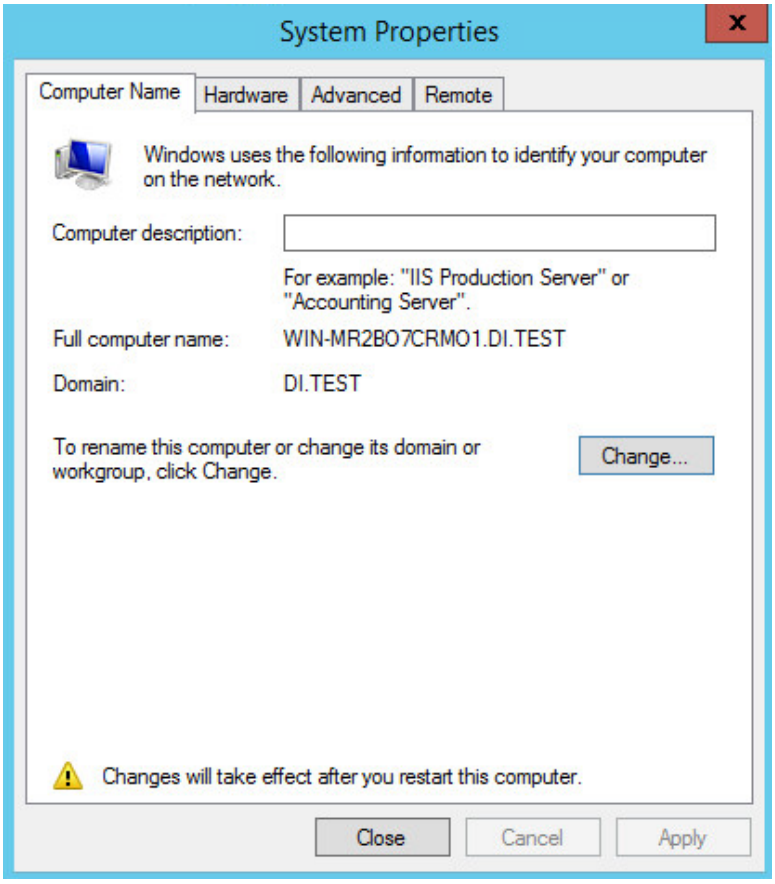
16. Click **OK**.



17. Enter the credentials of an account in AD which has the right permissions to add a group to the domain.

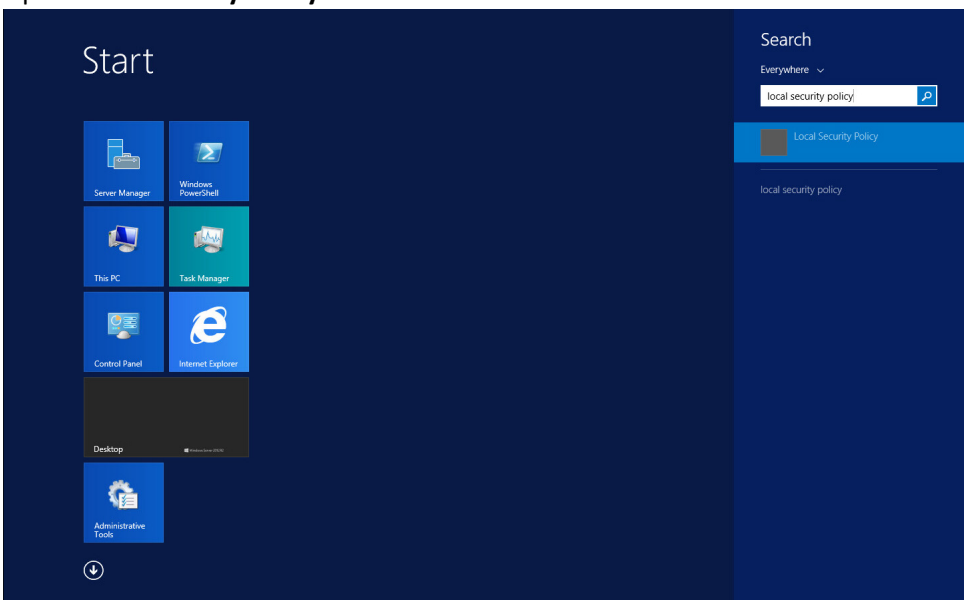


18. Click **OK** a few times and restart the server when prompted.

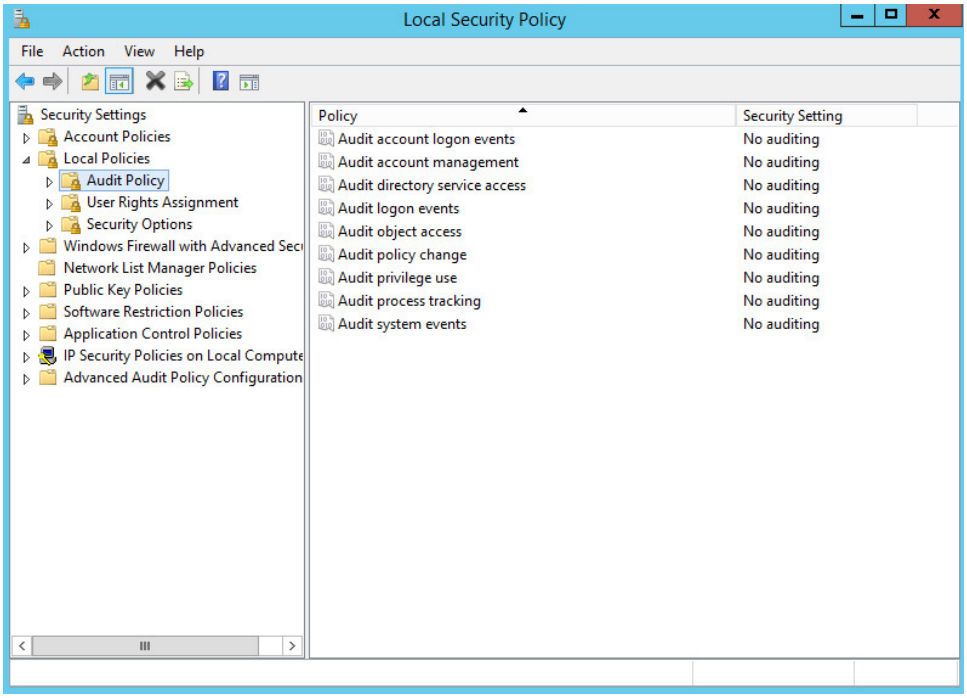


2.1.5 Configuring Active Directory to Audit Account Activity

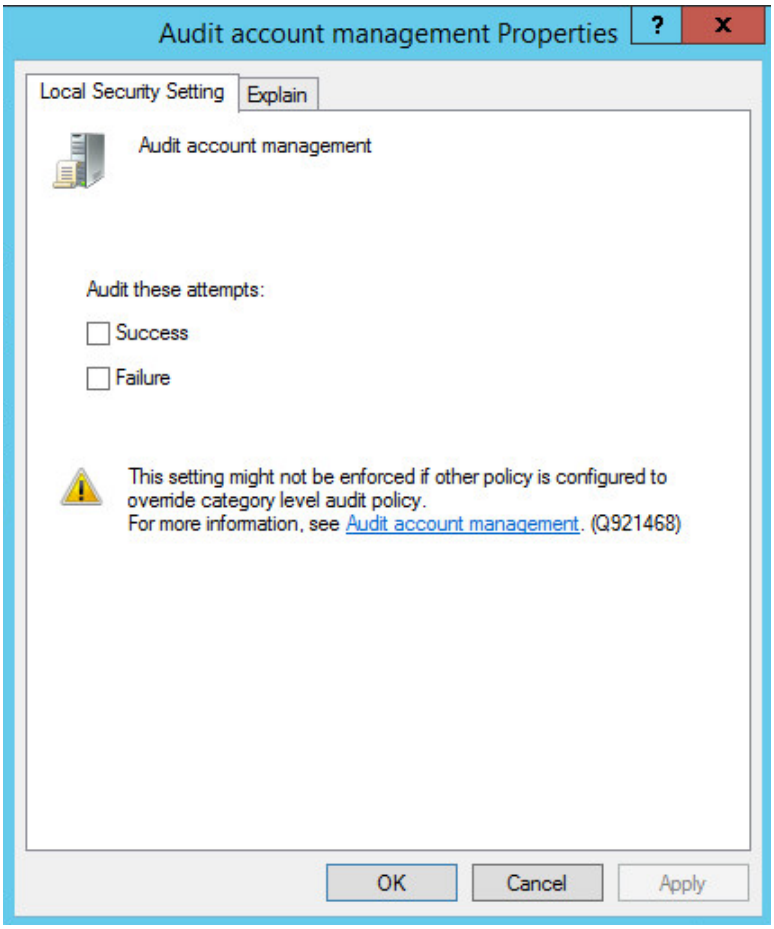
1. Open **Local Security Policy** from the Start Menu.



2. Open **Local Policies** > **Audit Policy**.



3. Right click **Audit account management**.
4. Select **Properties**.


Audit account management Properties
Local Security Setting
Explain
Audit account management
Audit these attempts:
Success
Failure
This setting might not be enforced if other policy is configured to override category level audit policy.
For more information, see Audit account management. (Q921468)
OK
Cancel
Apply

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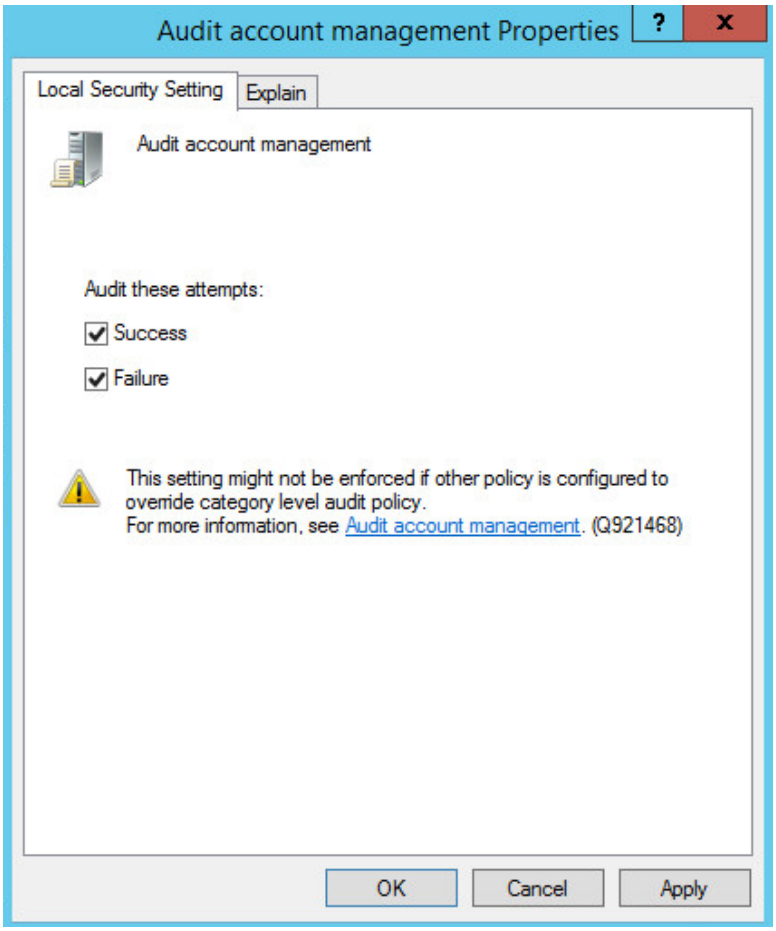


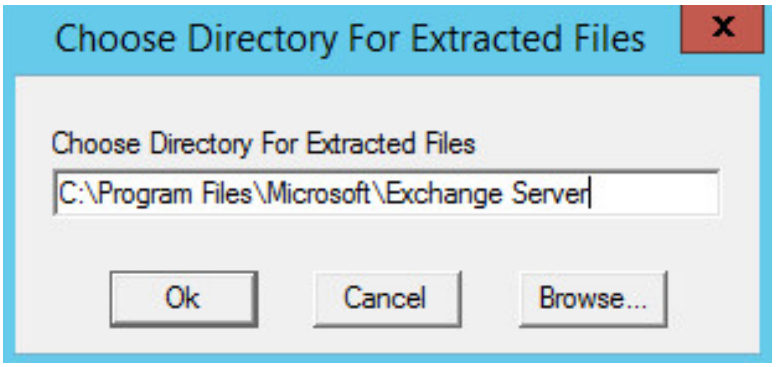
5. Check the boxes next to **Success** and **Failure**.
6. Click **OK**.
7. Account management activities will now be reported to **Windows Event Log – Security**.

2.2 Microsoft Exchange Server

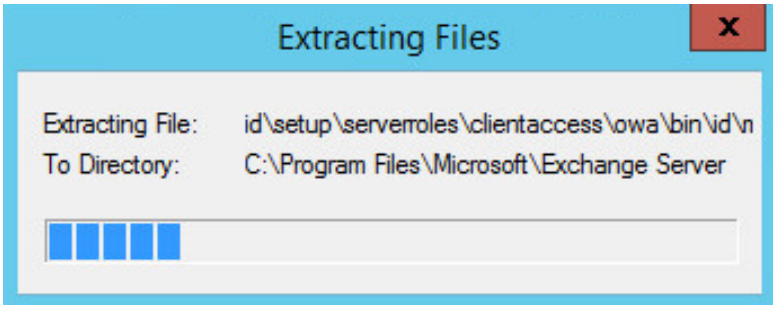
As part of our enterprise emulation, we include a Microsoft Exchange server. This section covers the installation and configuration process used to set up Microsoft Exchange on a Windows Server 2012 R2 machine.

2.2.1 Install Microsoft Exchange

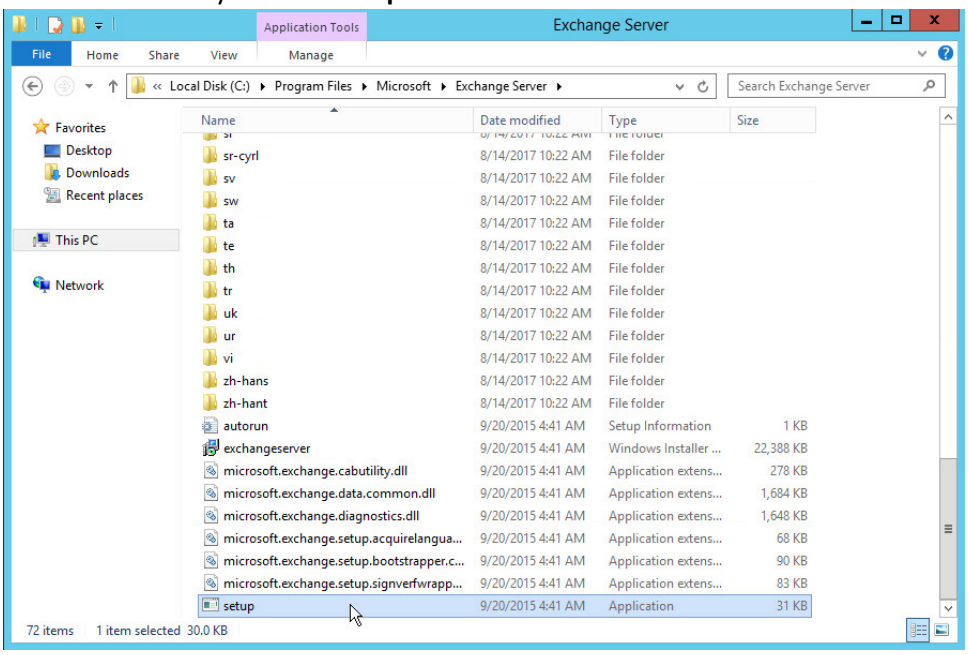
1. Run **Exchange2016-x64.exe**.



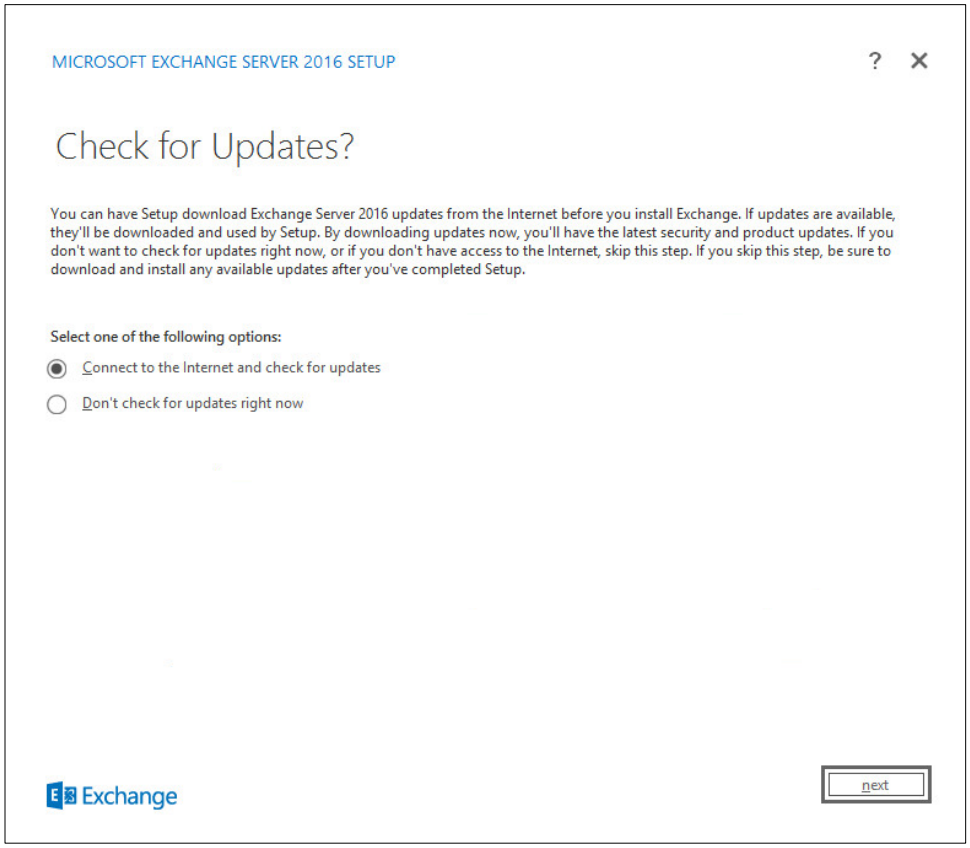
2. Choose the directory for the extracted files and press **OK**.



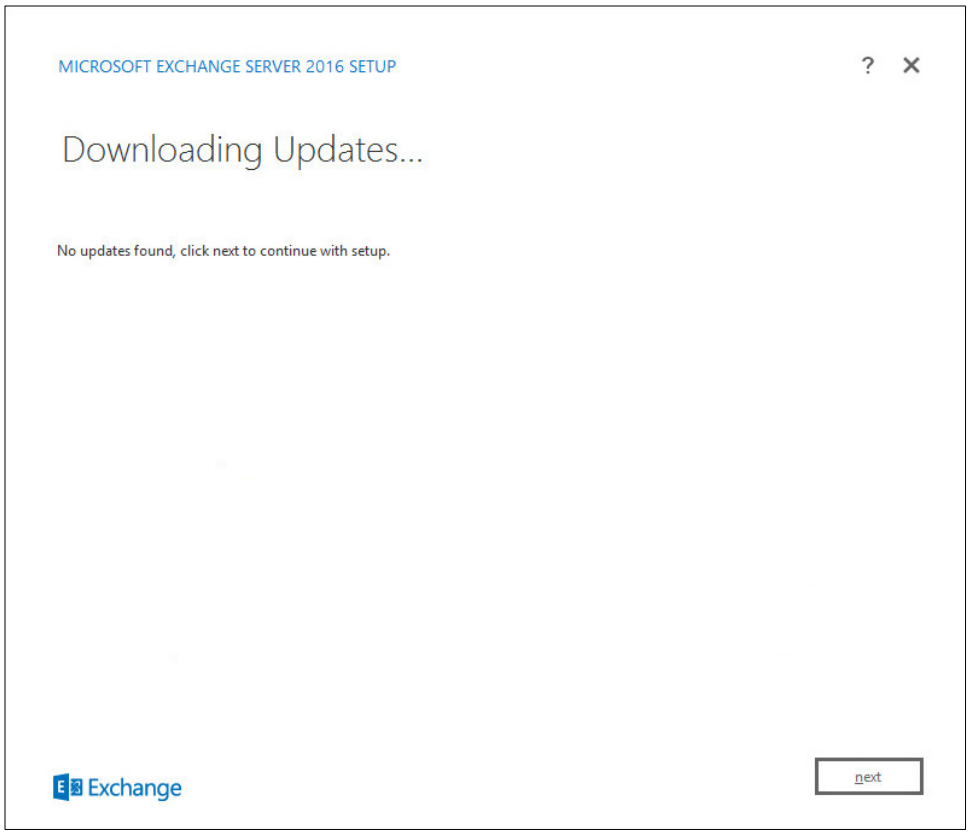
3. Enter the directory and run **setup.exe**.



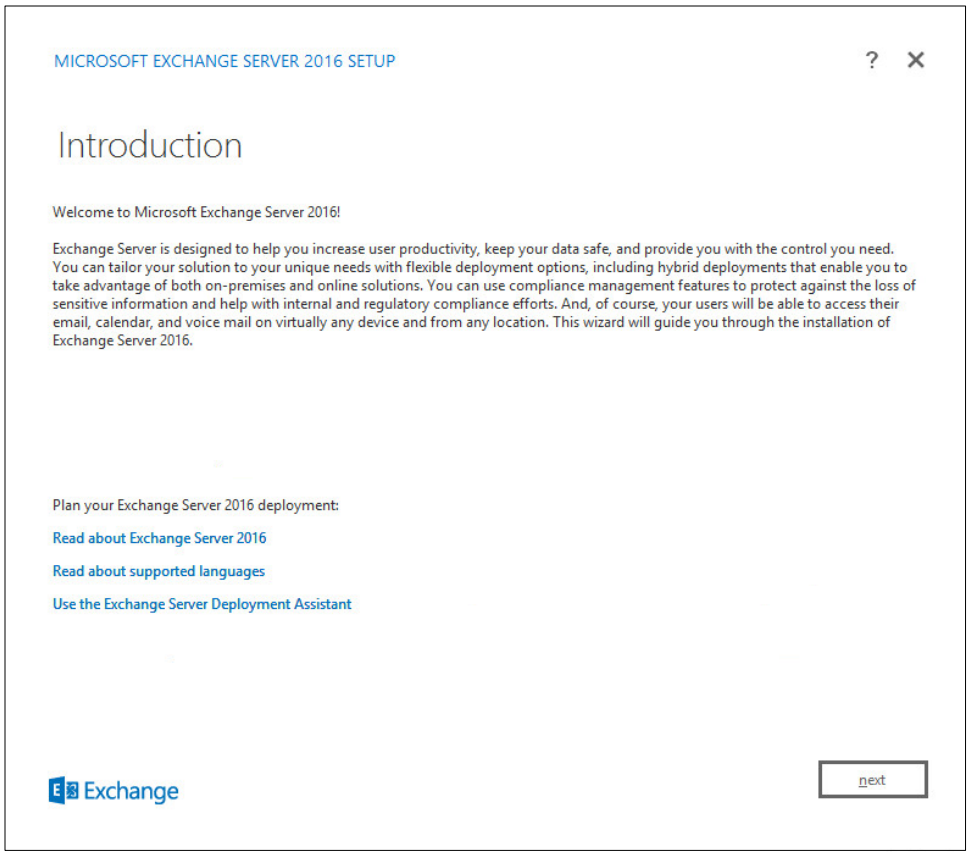
4. Select **Connect to the Internet and check for updates**.



5. Wait for the check to finish.

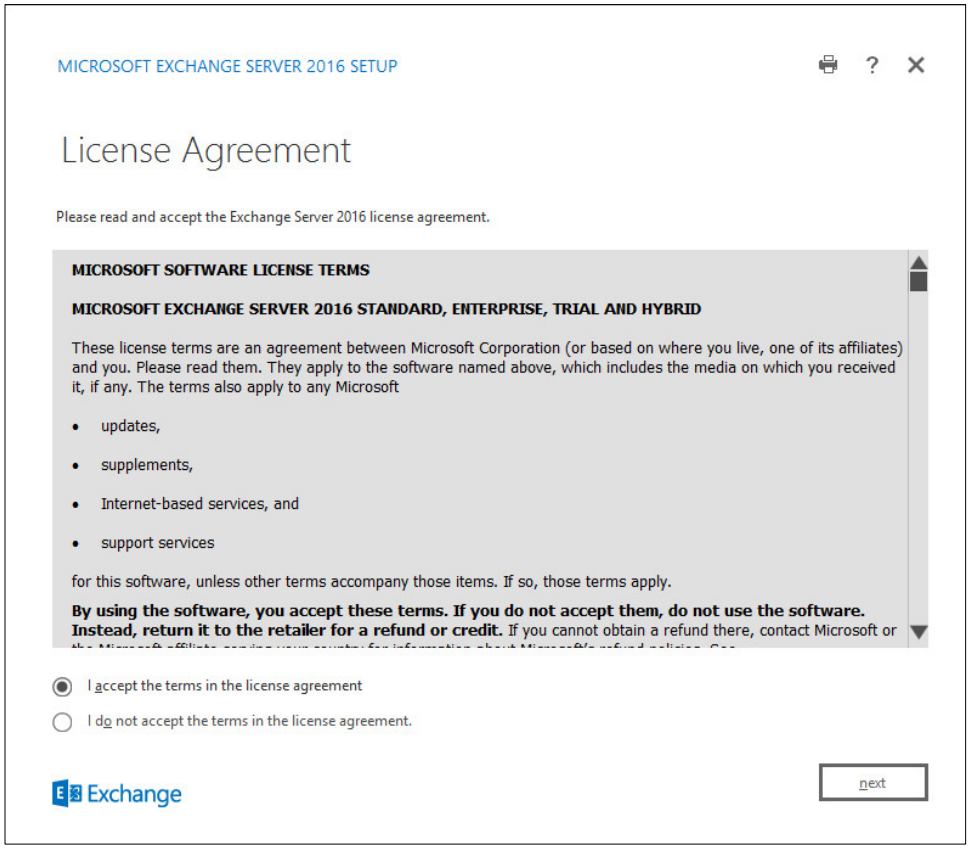

MICROSOFT EXCHANGE SERVER 2016 SETUP
Downloading Updates...
No updates found, click next to continue with setup.
Exchange
next

6. Click **Next**.

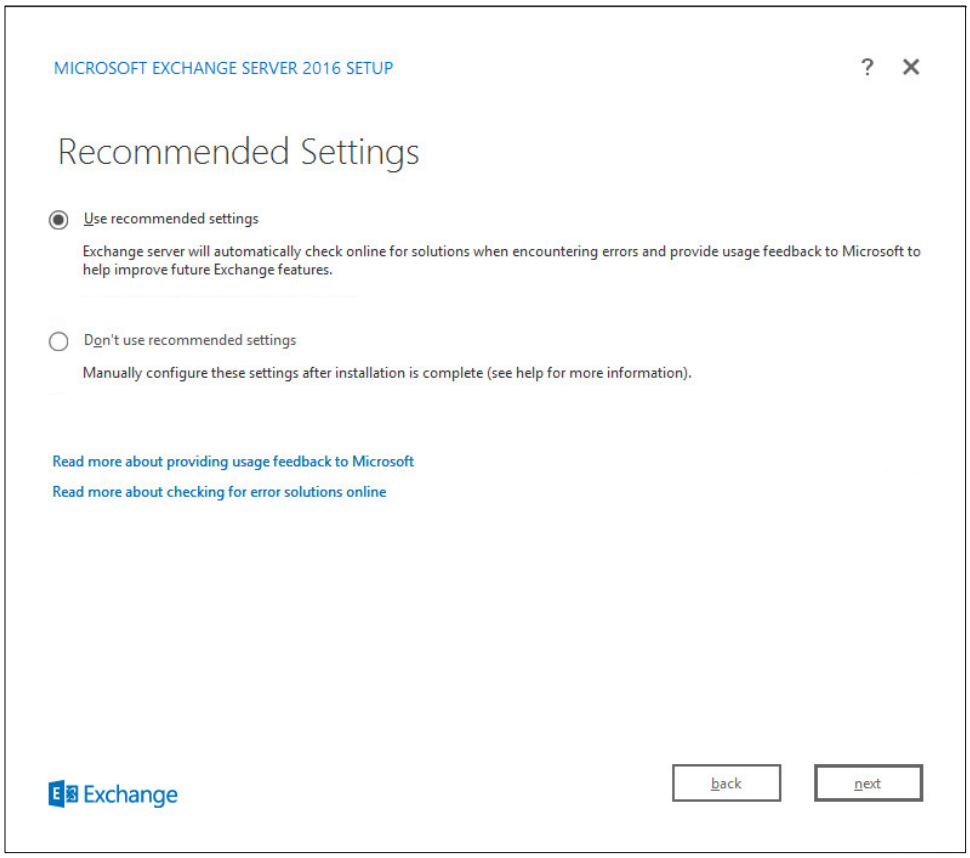


7. Wait for the copying to finish.
8. Click **Next**.

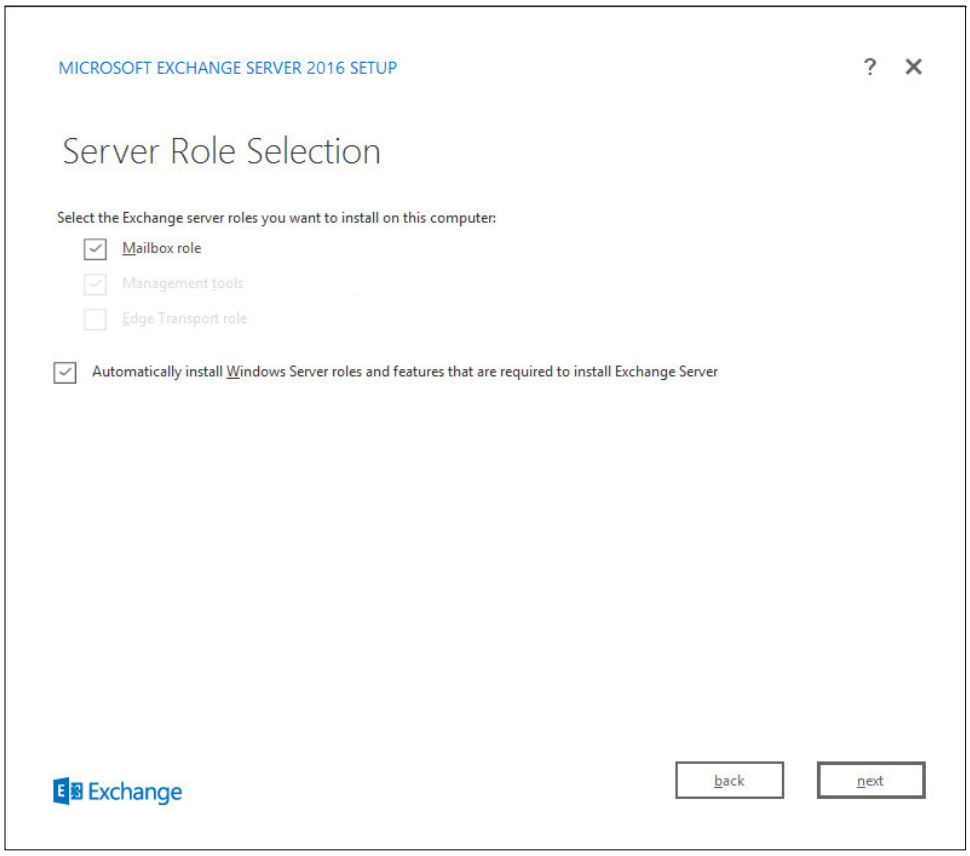
9. Click **I accept the terms in the license agreement**.



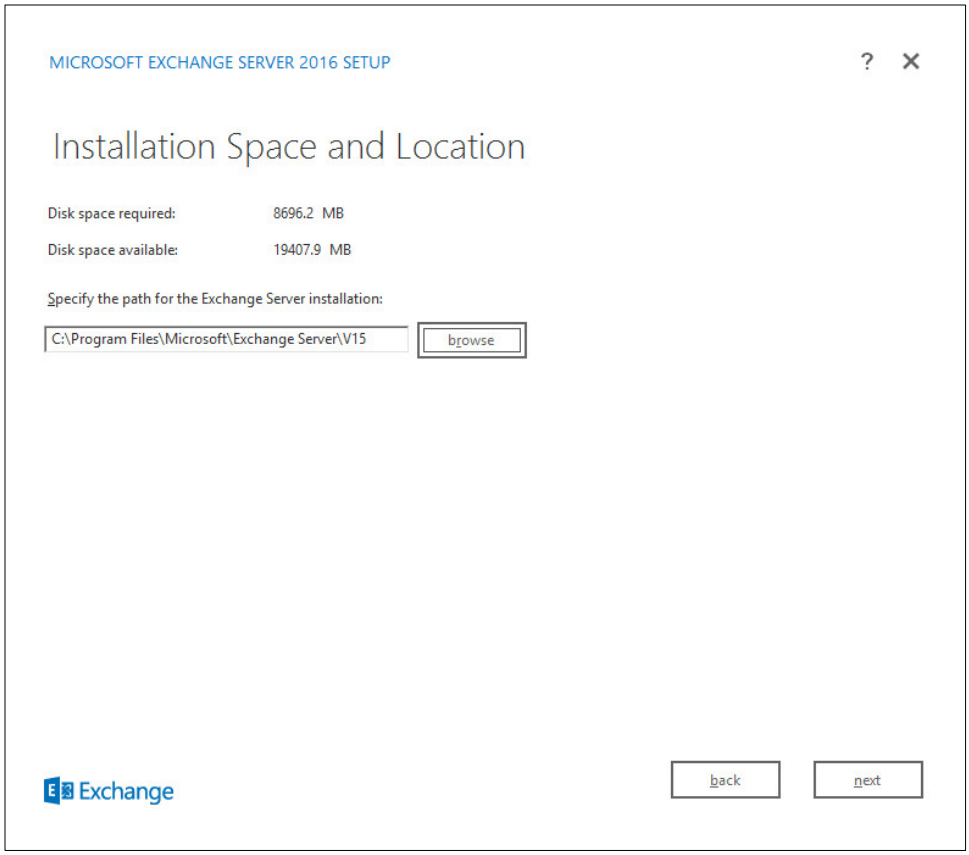
10. Click **Next**.



11. Click **Use Recommended Settings**.
12. Click **Next**.
13. Check **Mailbox role**.
14. Check **Automatically install Windows Server roles and features that are required to install Exchange Server**.

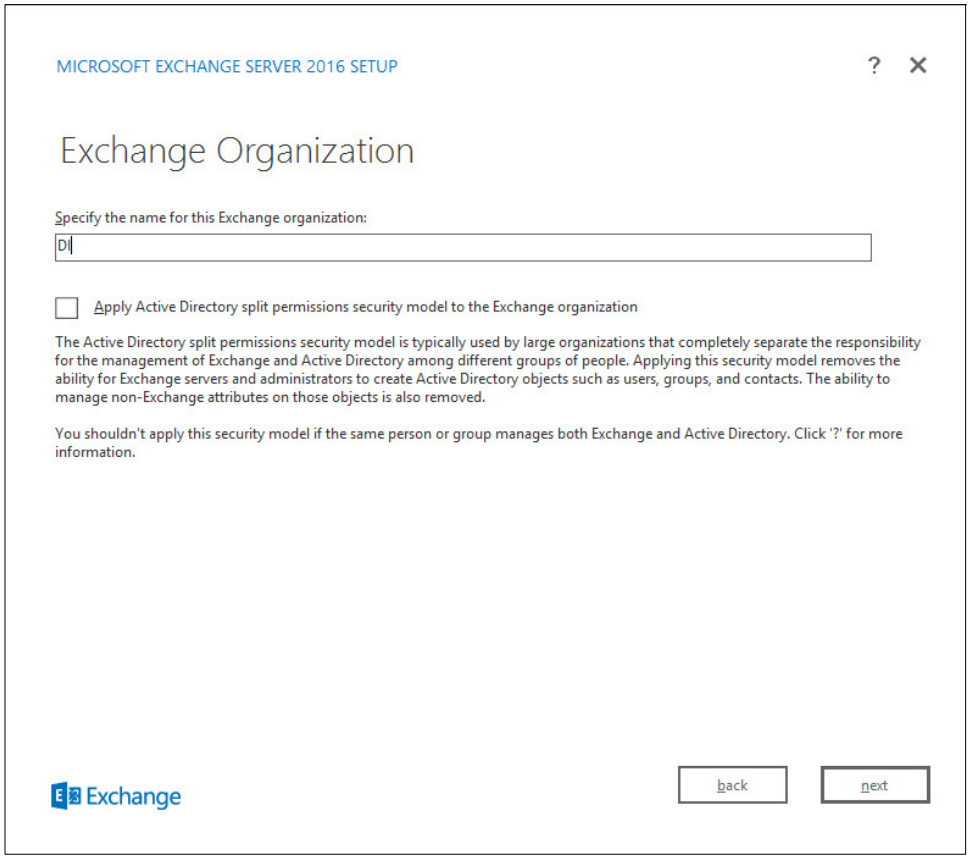


15. Click **Next**.
16. Specify the installation path for MS Exchange.

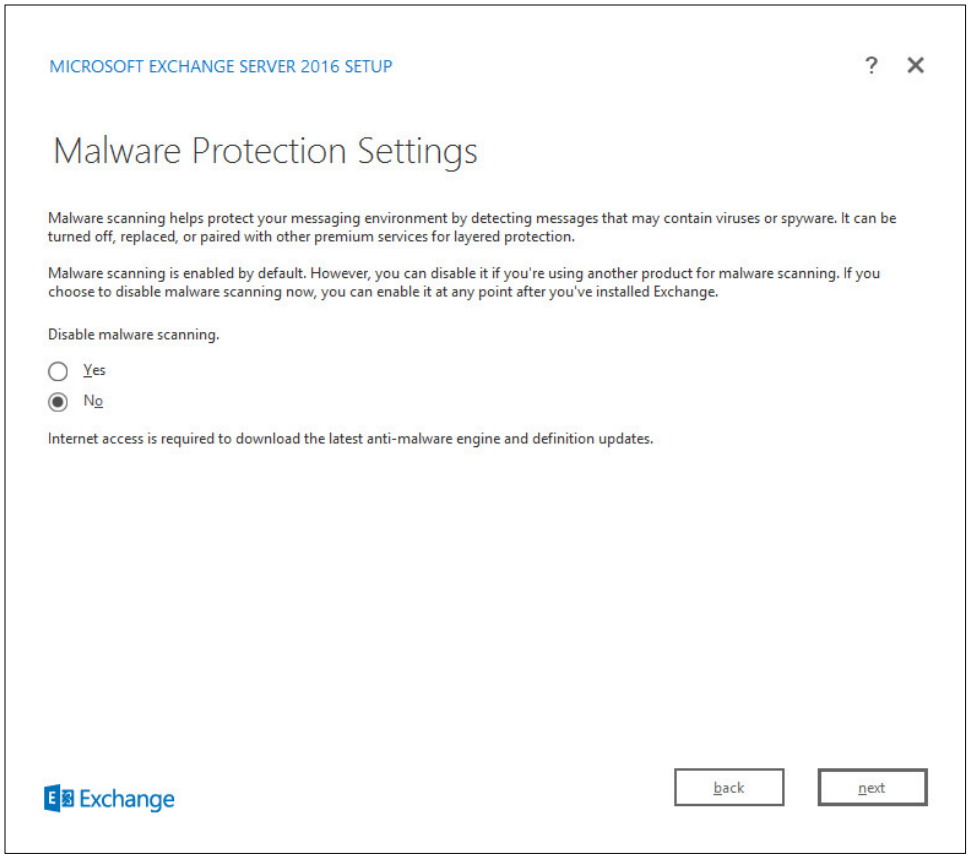


17. Click **Next**.
18. Specify the name for the Exchange organization. Example: DI.

19. Decide whether to apply split permissions based on the needs of the enterprise.

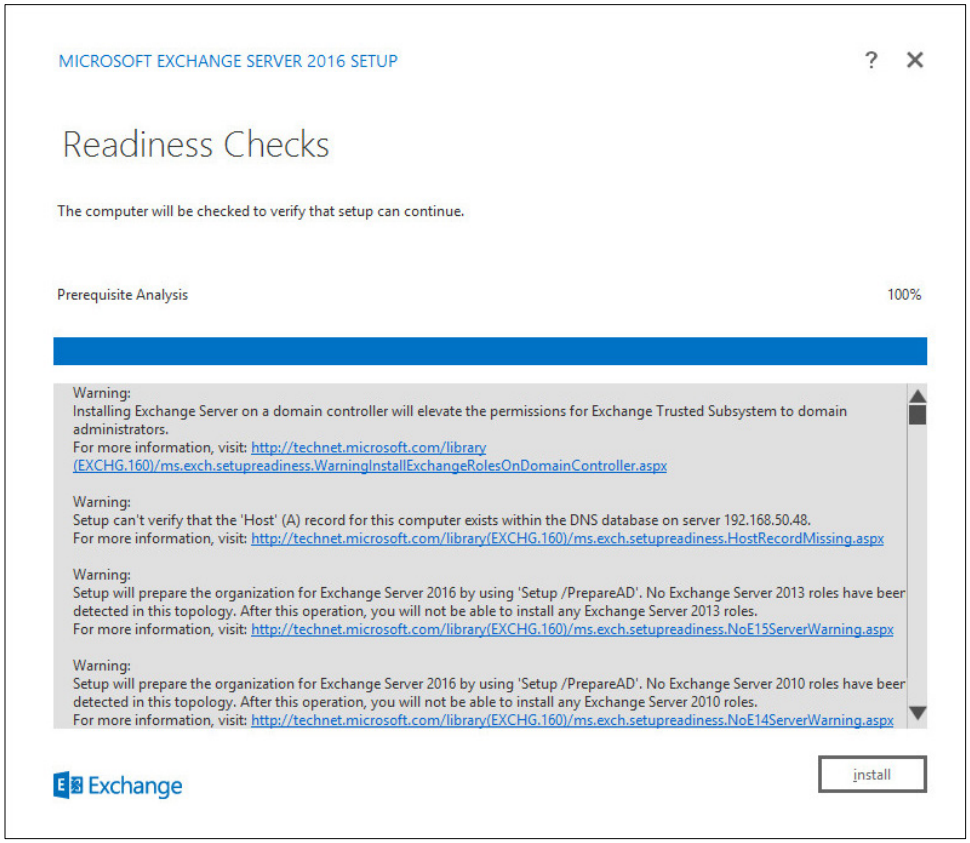


20. Click **Next**.
21. Click **No**.

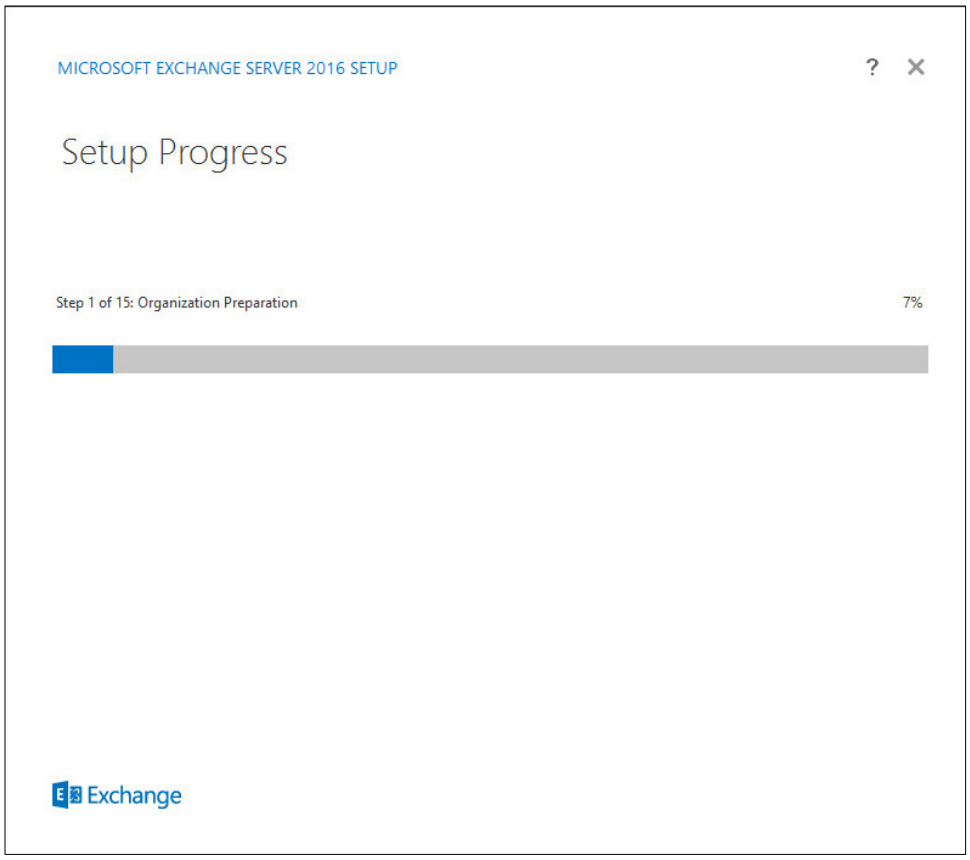


22. Click **Next**.
23. Install any **prerequisites** listed.

24. If necessary, restart the server and re-run **setup.exe**, following through steps 3-22 again.



25. Click **Install**.



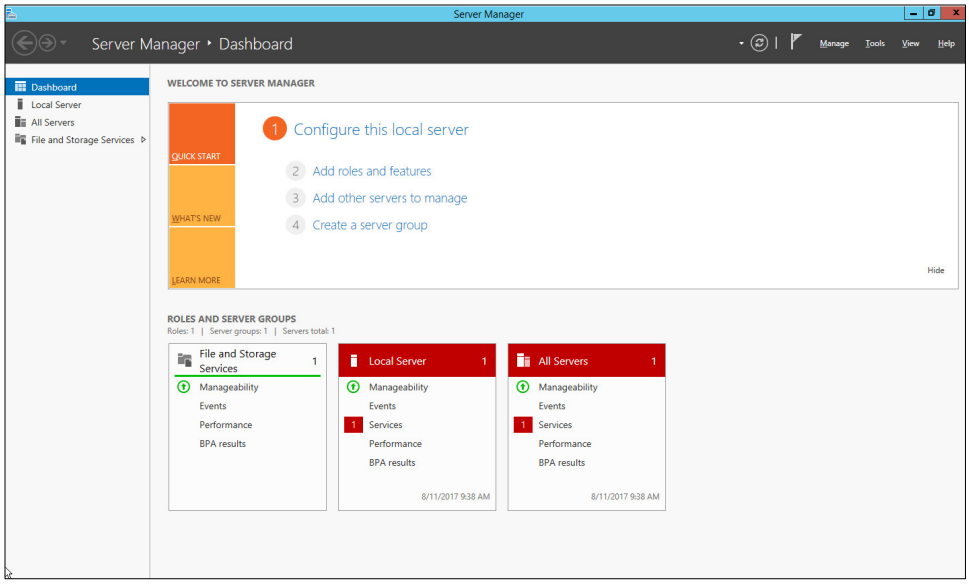
26. Wait for setup to complete.

2.3 SharePoint Server

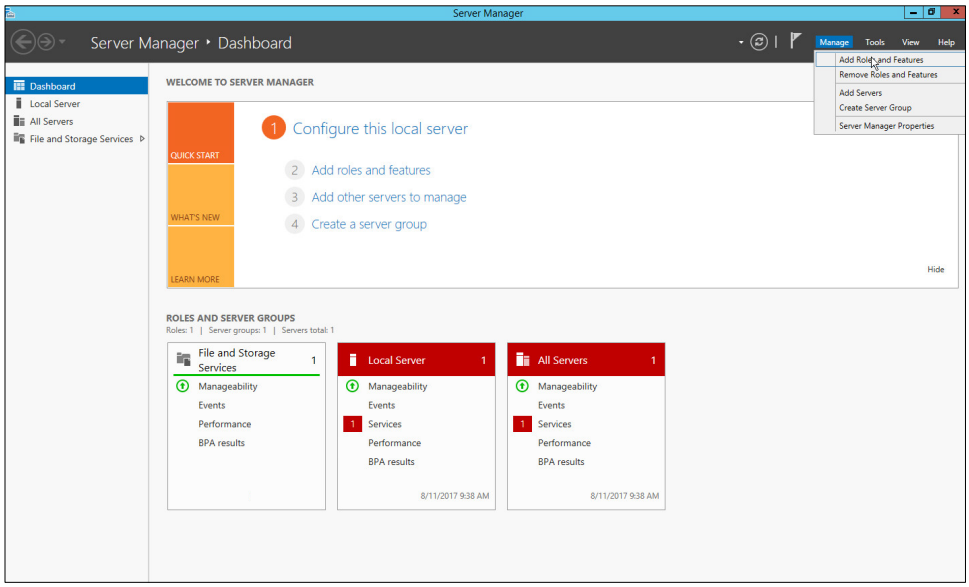
As part of our enterprise emulation, we include a Microsoft SharePoint server. This section covers the installation and configuration process used to set up SharePoint on a Windows Server 2012 R2 machine.

2.3.1 Install Roles and Features

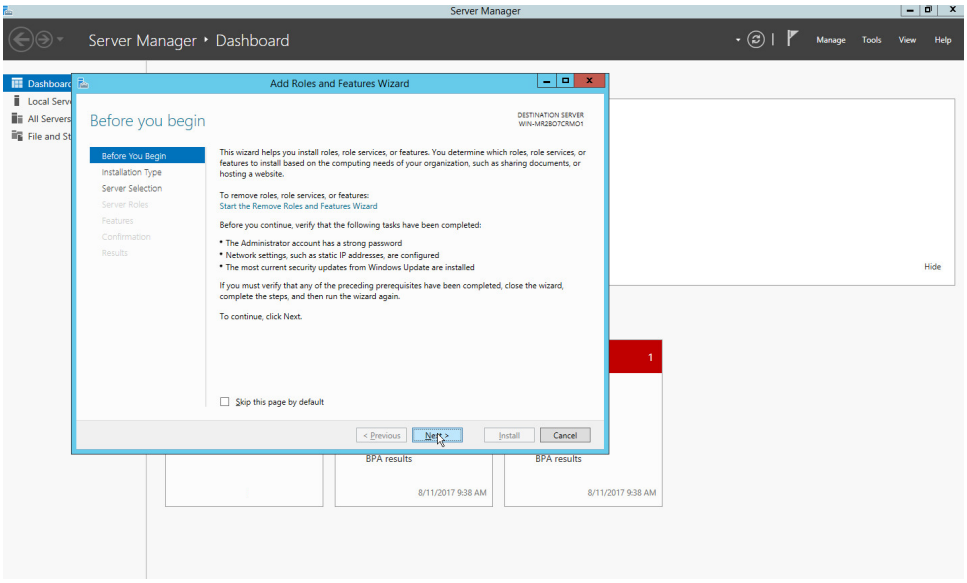
1. Open **Server Manager**.



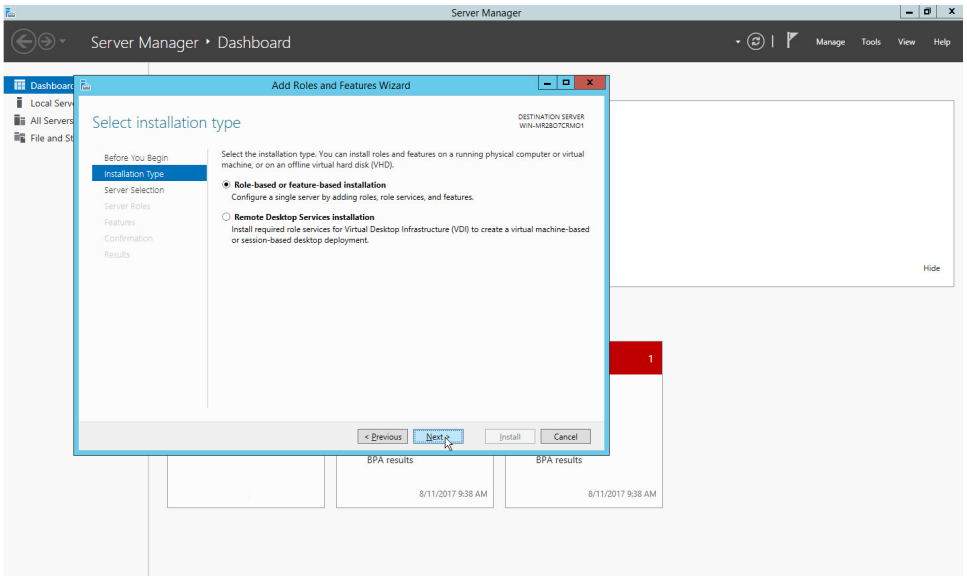
2. Click **Manage**.



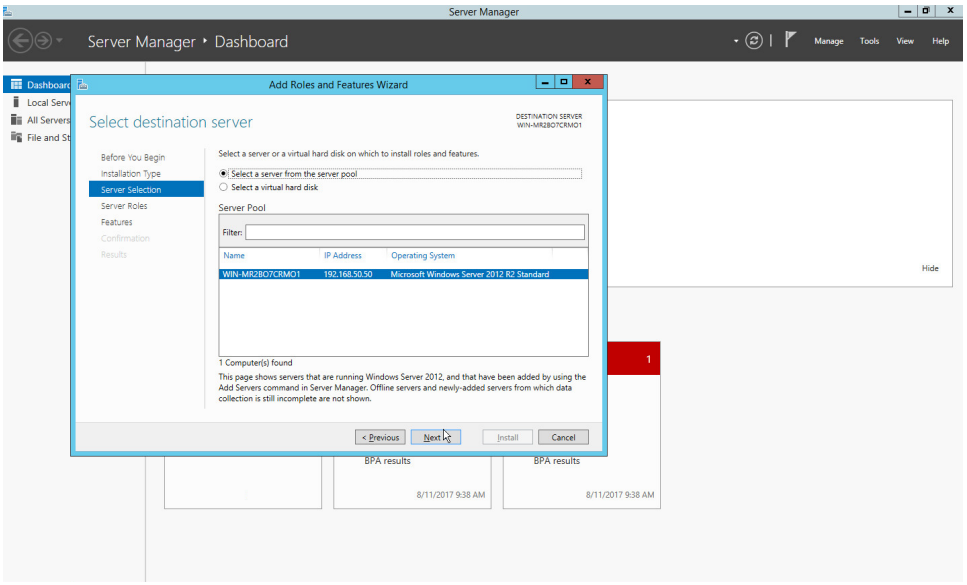
3. Click **Add Roles and Features**.



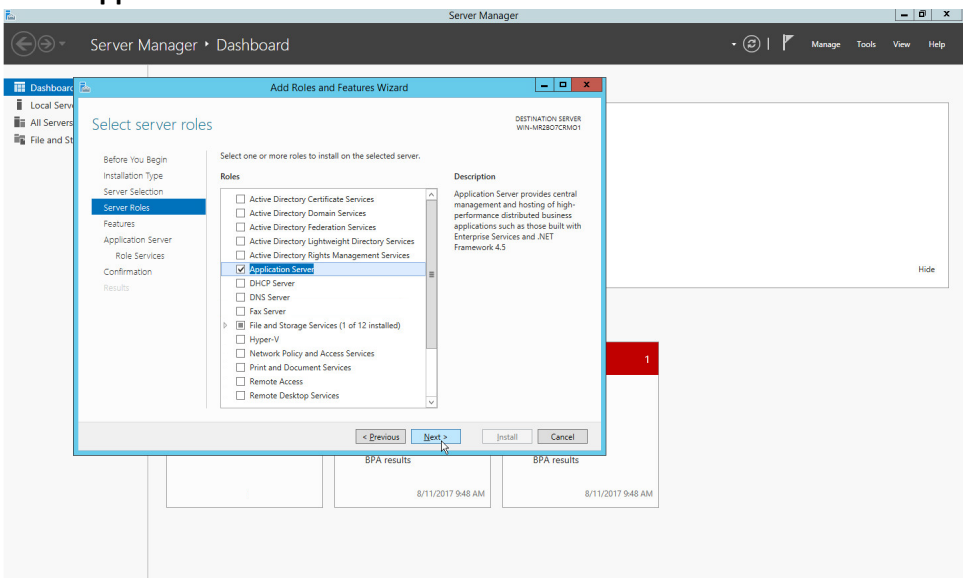
4. Click **Next**.
5. Choose **Role-based or feature-based installation**.



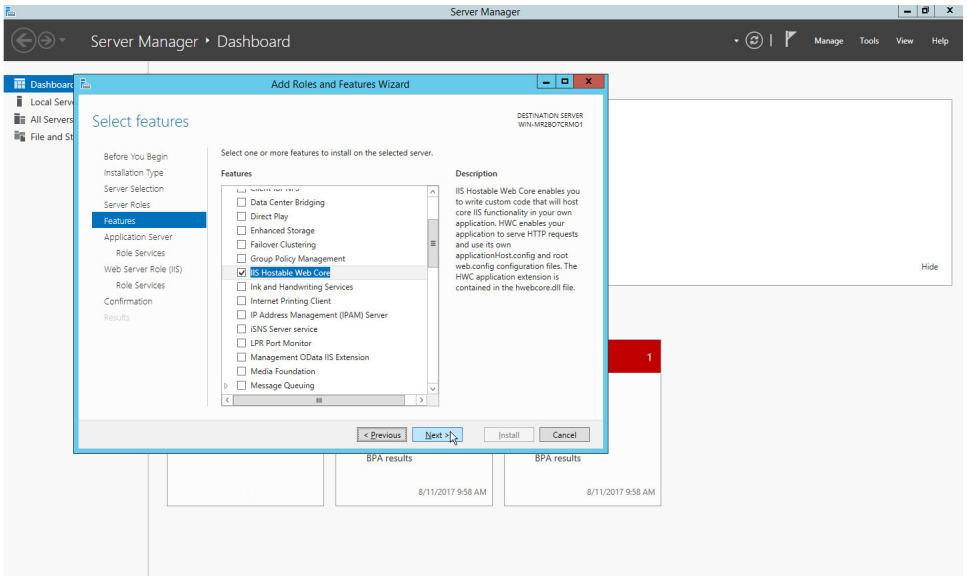
6. Click **Next**.
7. Choose **Select a server from the server pool**.
8. Choose the SharePoint server from the list.



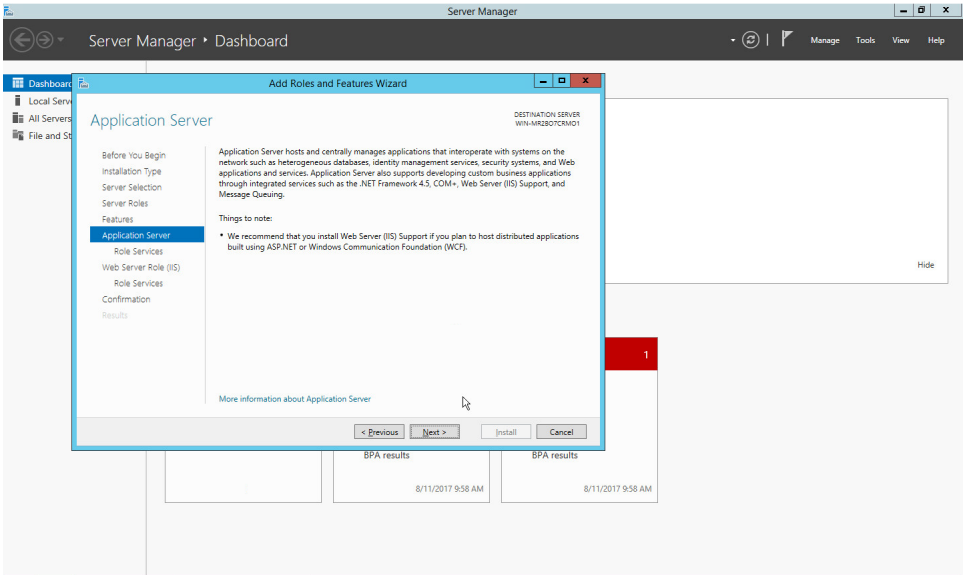
9. Click **Next**.
10. Check **Application Server Role**.



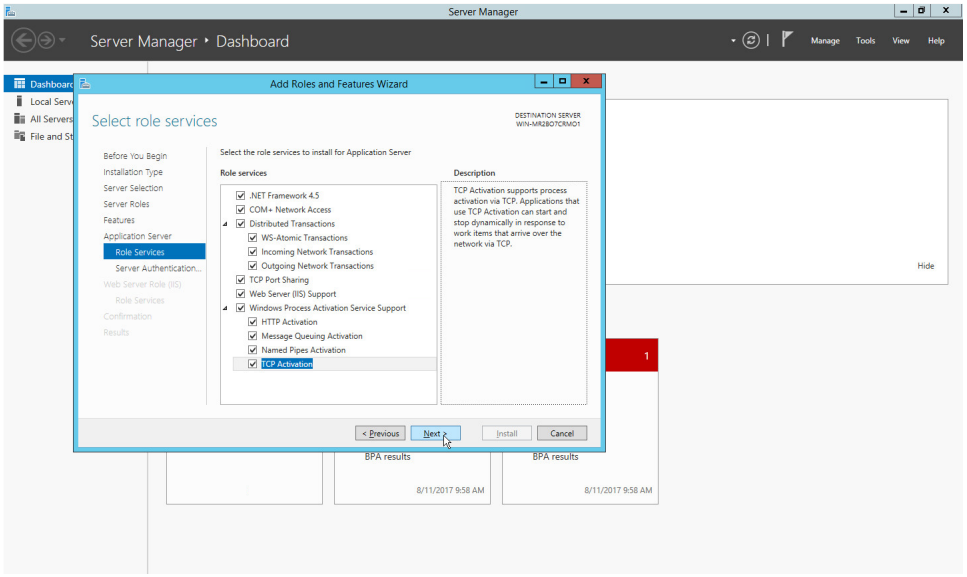
11. Click **Next**.
12. Check **IIS Hostable Web Core**.



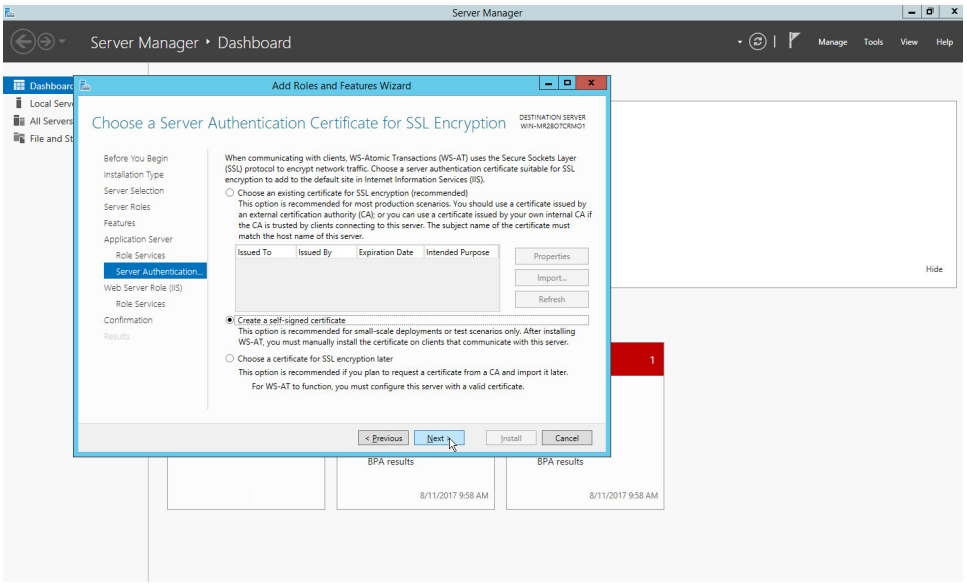
13. Click **Next**.



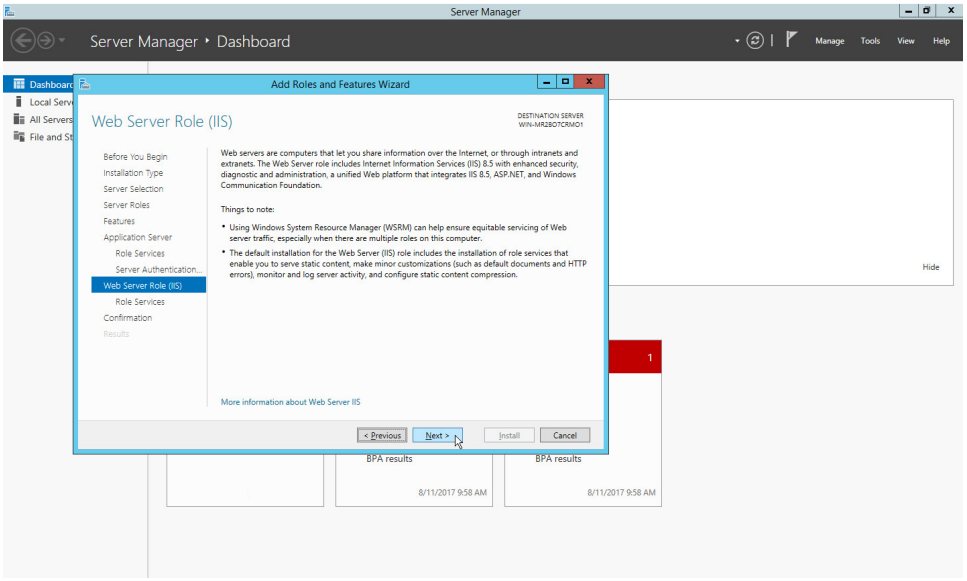
14. Click **Next**.
15. Check all boxes under **Application Server Role Services**.



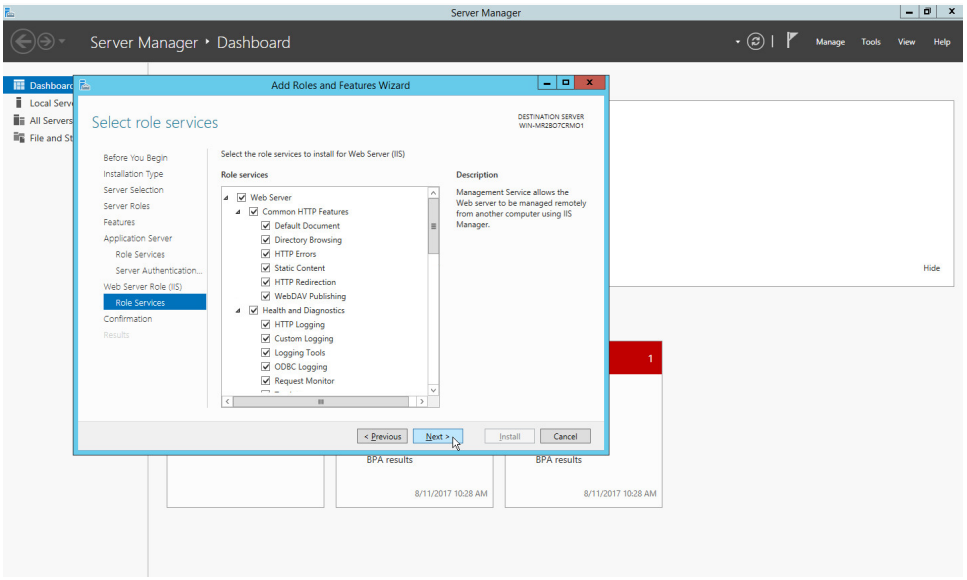
16. Click **Next**.
17. Choose **Create a self-signed certificate**.



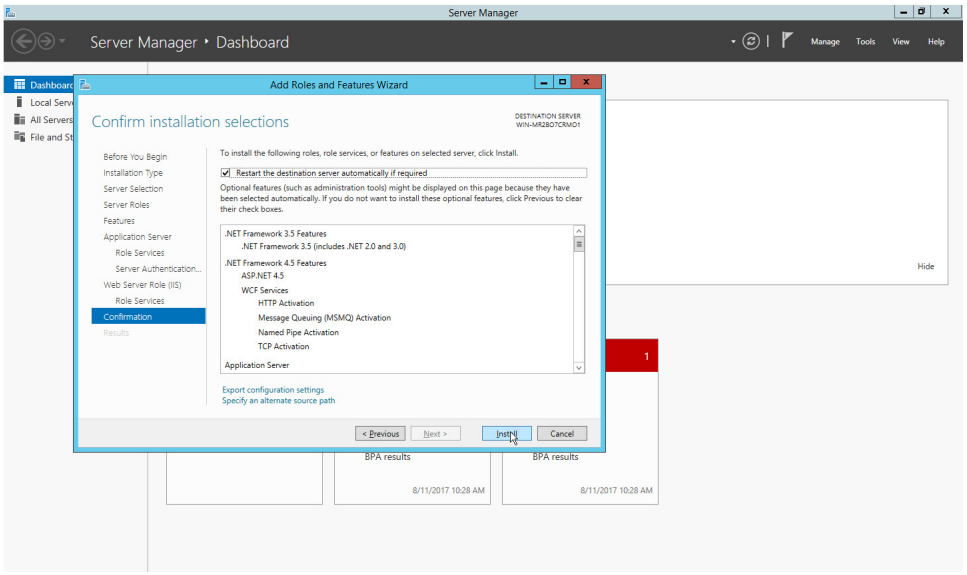
18. Click **Next**.



19. Click **Next**.
20. Check all boxes under **Web Server (IIS) Role Services**.



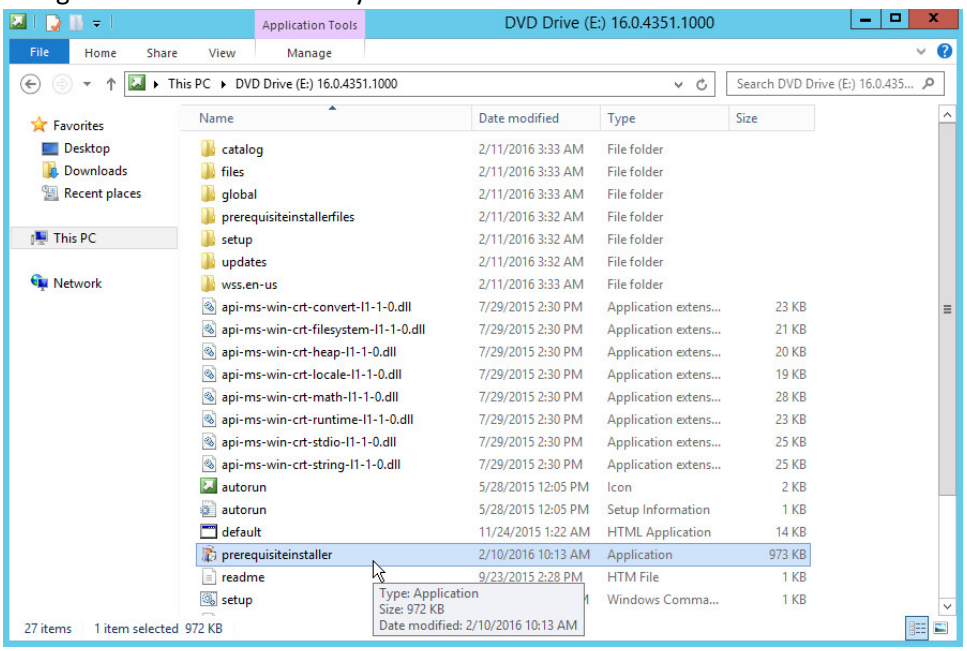
21. Click **Next**.
22. Check **Restart the destination server automatically if required**.



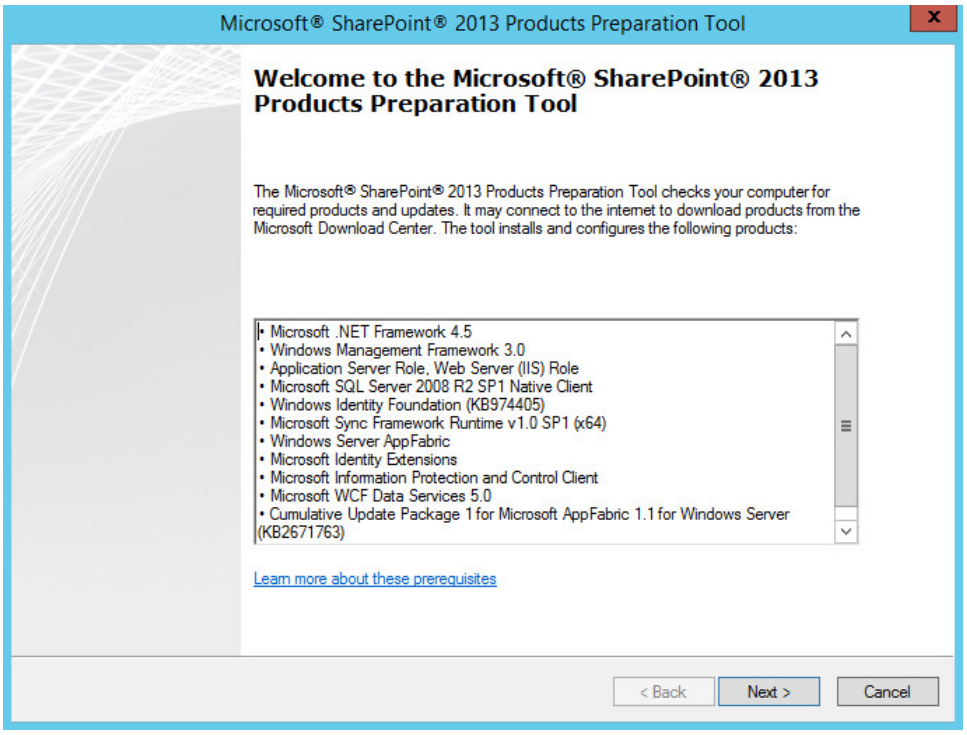
23. Click **Install**.
24. The server may automatically restart.
25. Right click the **.ISO file** for **SharePoint Server**.
26. Choose **Mount**.

2.3.2 Install SharePoint

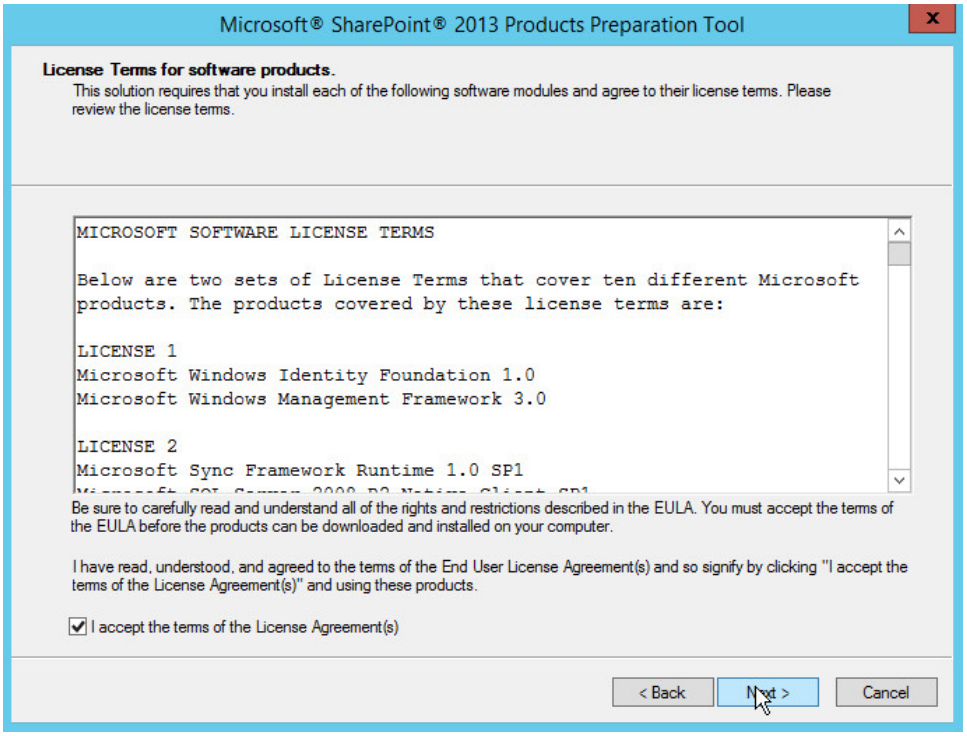
1. Navigate to the main directory of the ISO.



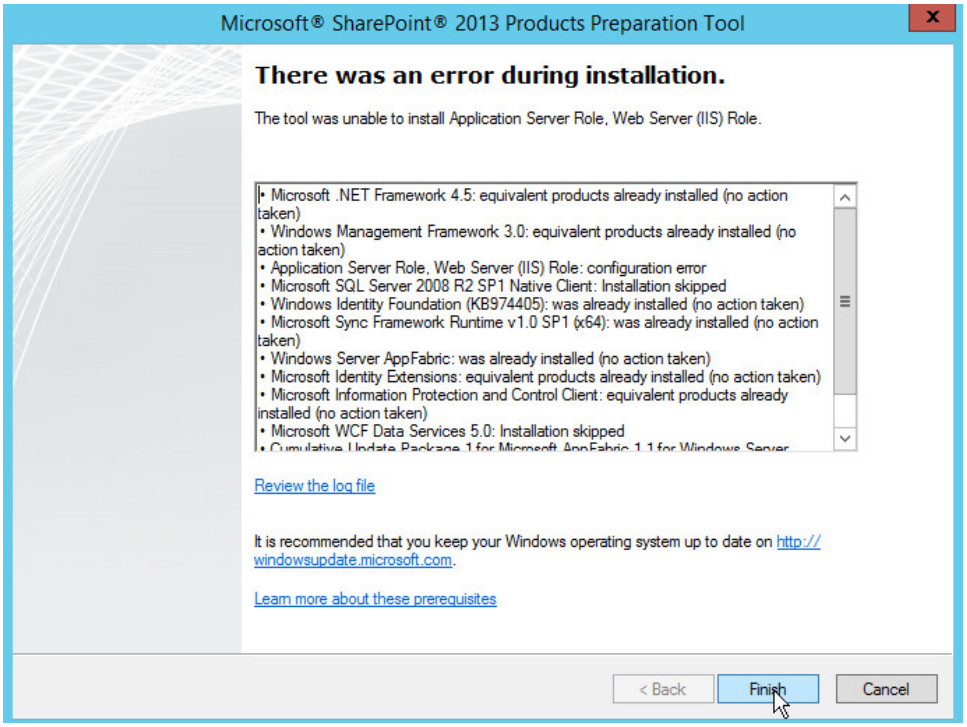
2. Double click **pre-requisite installer**.



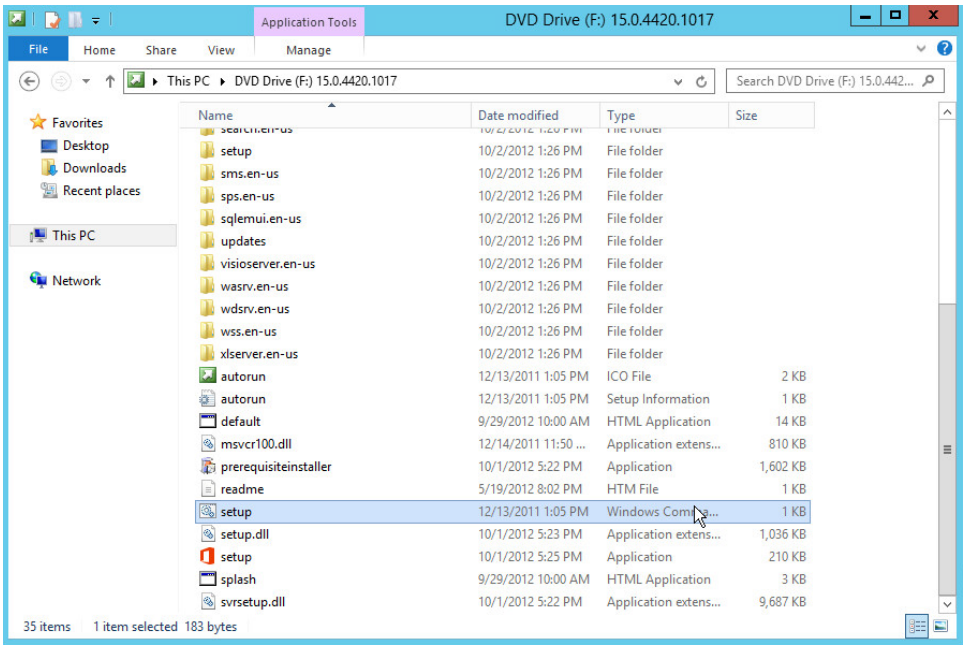
3. Click **Next**.
4. Click **I accept the terms of the License agreement**.



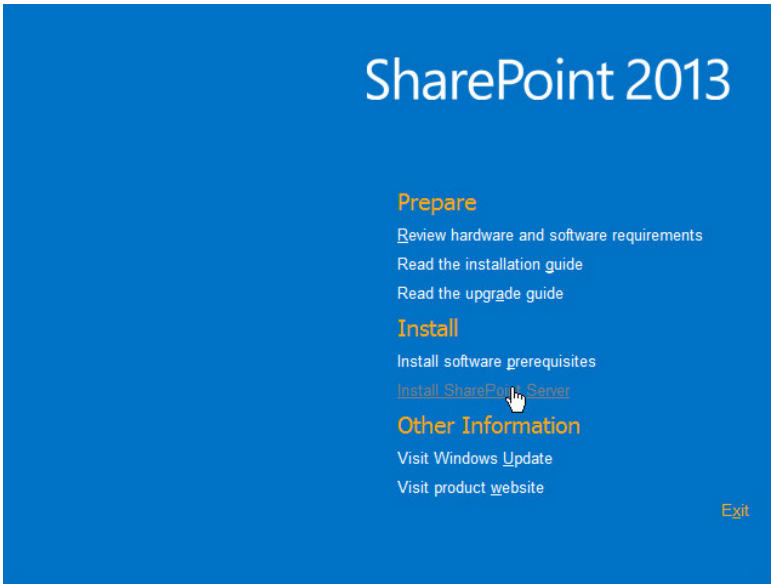
5. Click **Next**.
6. Resolve any dependencies and repeat steps 2-5.



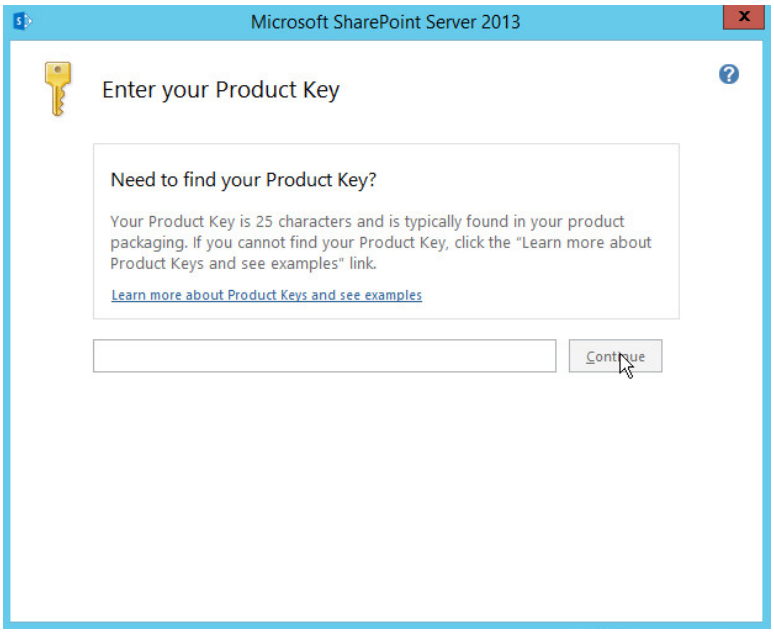
7. After the successful installation, click **Finish**.
8. The server may automatically restart.
9. Remount the **.ISO file** for **SharePoint Server**.
10. Navigate to the main directory of the **.ISO file**.



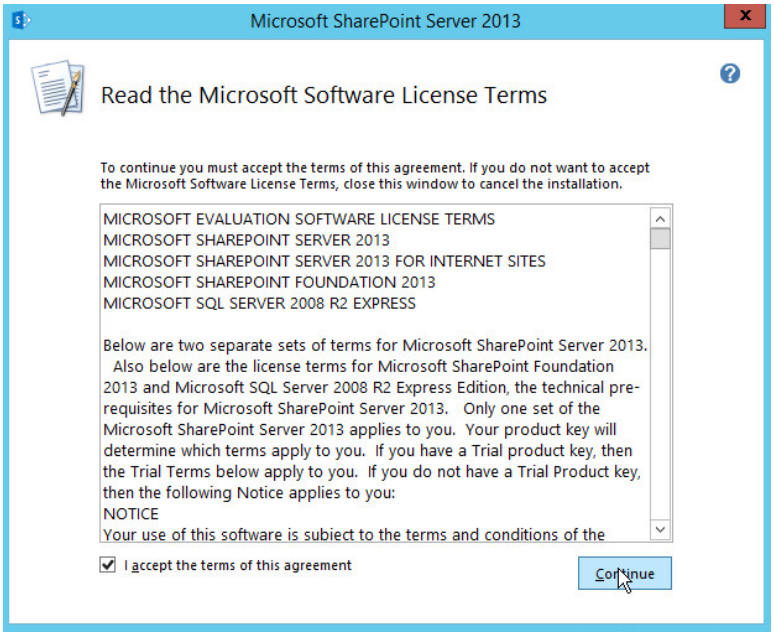
11. Double click the program called **setup**.



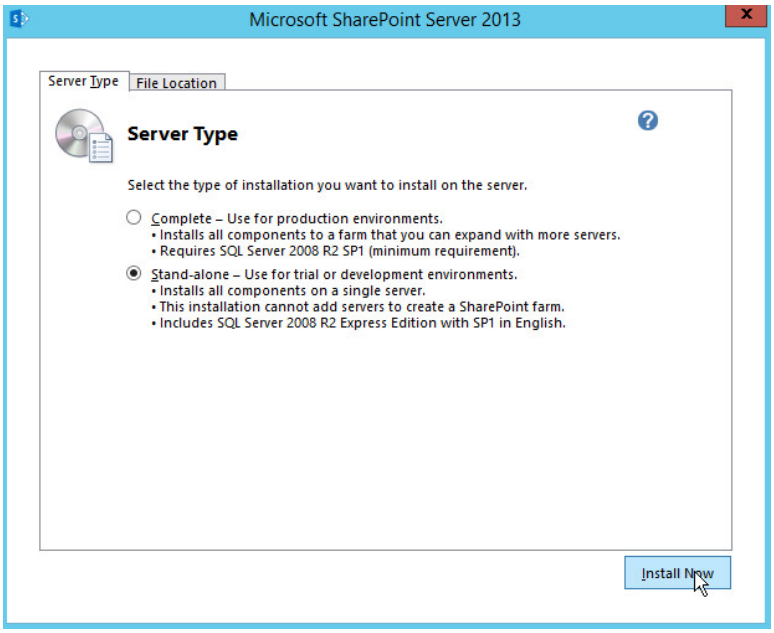
12. Click **Install SharePoint Server**.
13. Enter your product key when prompted.



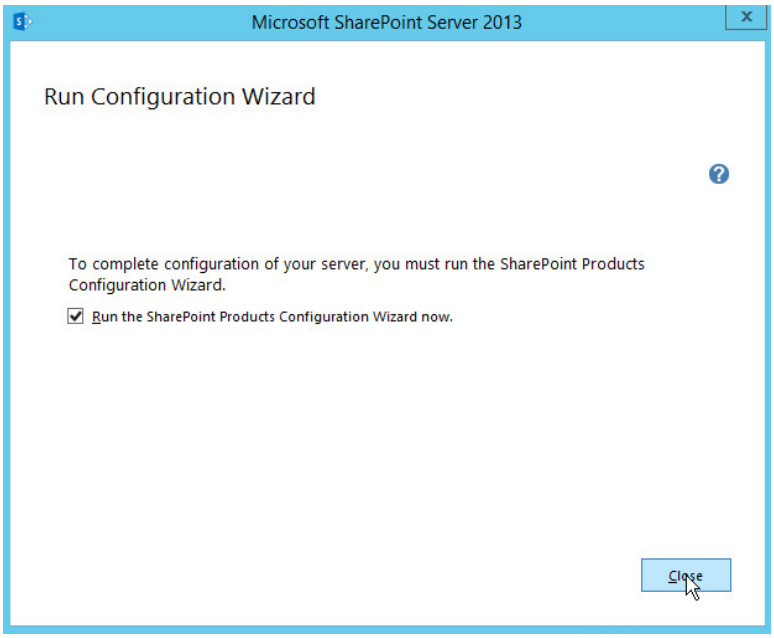
14. Click **Continue**.
15. Check **I accept the terms of this agreement**.



16. Click **Continue**.
17. Choose which **Server Type** fits your organization's purposes.

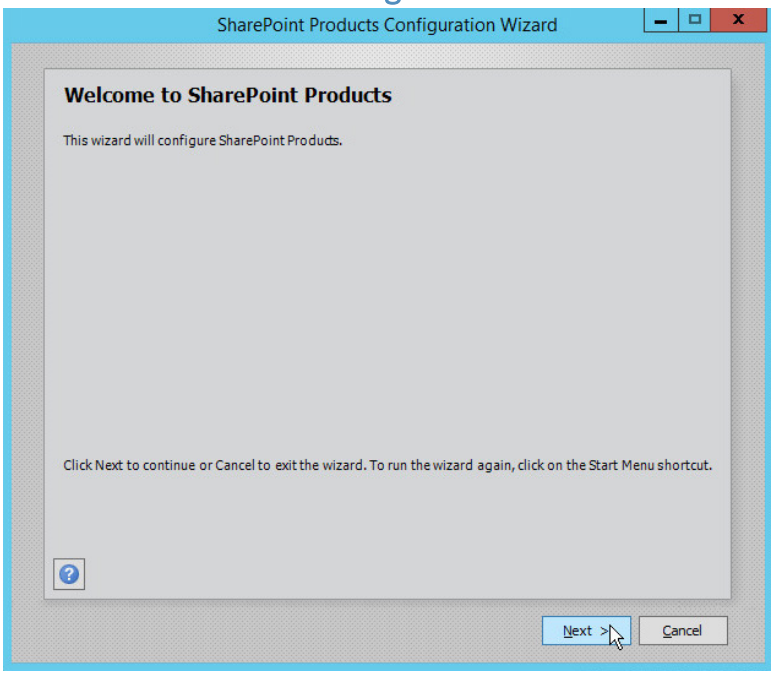


18. Click **Install Now**.
19. Wait for the installation to finish.
20. Check **Run the SharePoint Products Configuration Wizard now**.

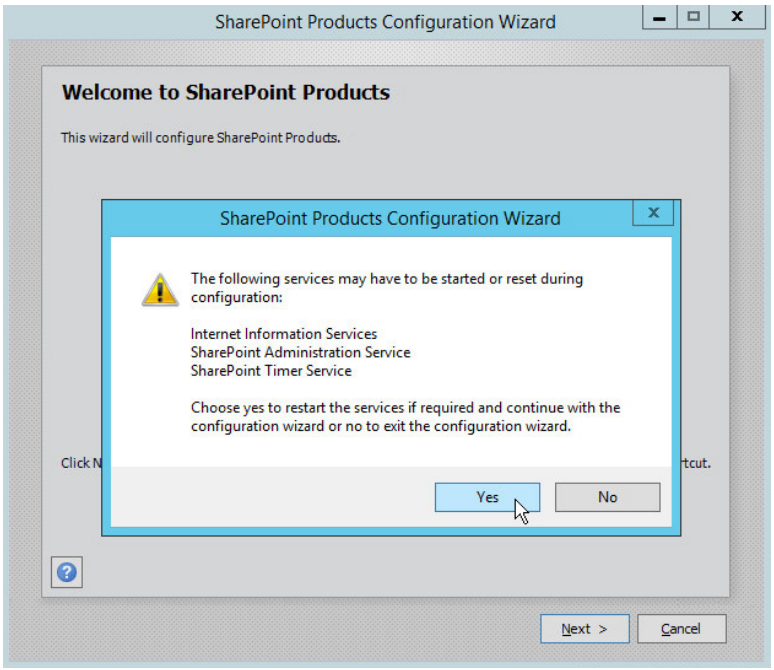


21. Click **Close**.

2.3.3 SharePoint Products Configuration Wizard

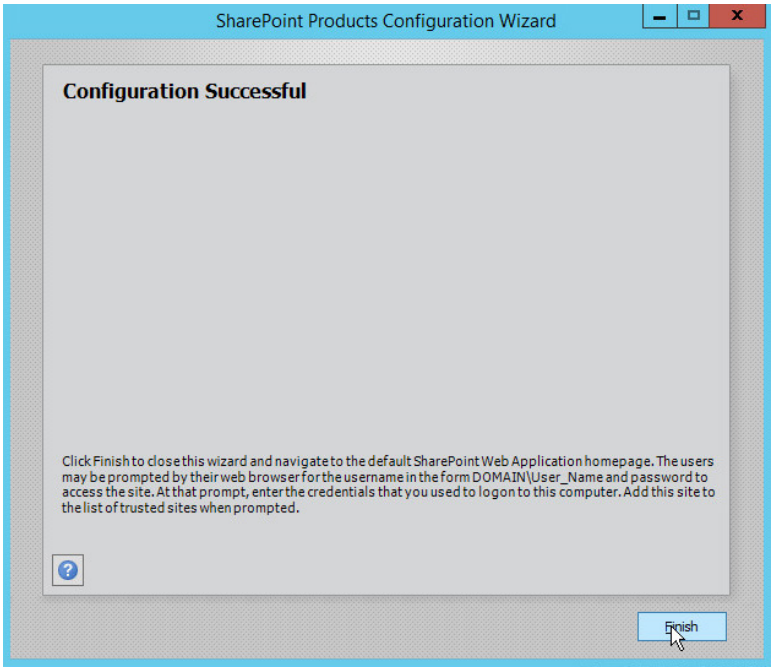


1. Click **Next**.



2. Click **Yes**.
3. Click **Next**.

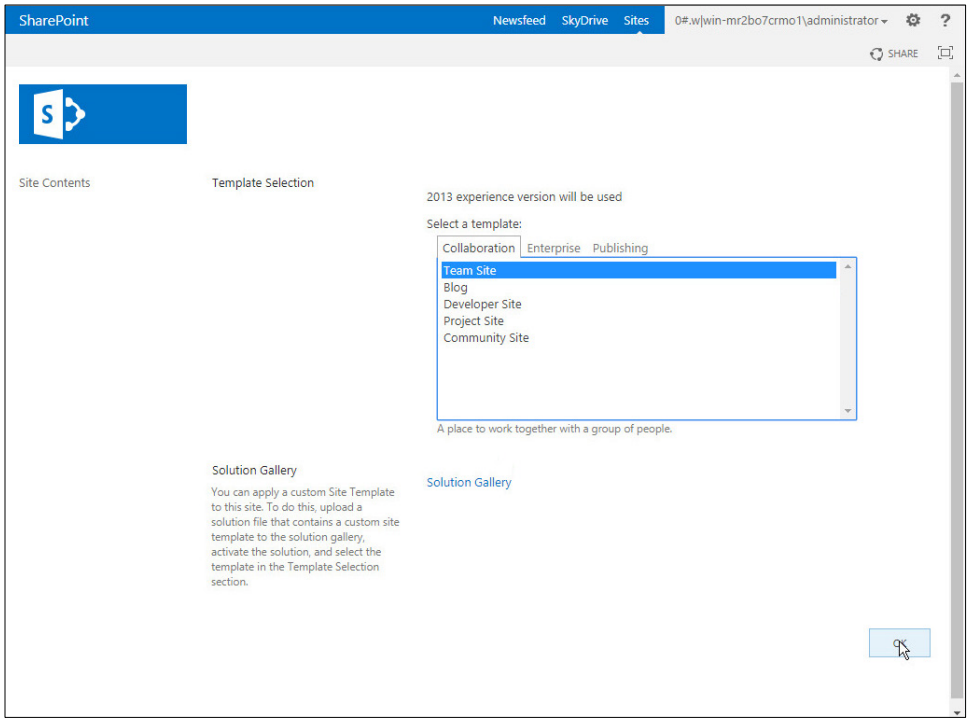
4. Wait for the configuration to complete (it may take up to 30 minutes depending on your system).



5. Click **Finish**.

2.3.4 Configure SharePoint

1. **Open** a browser and navigate to *http://sharepoint* (replace **sharepoint** with the hostname or IP address of the SharePoint server)**.**
2. Choose the type of SharePoint template that fits your business needs. Example: Enterprise > Document Center.



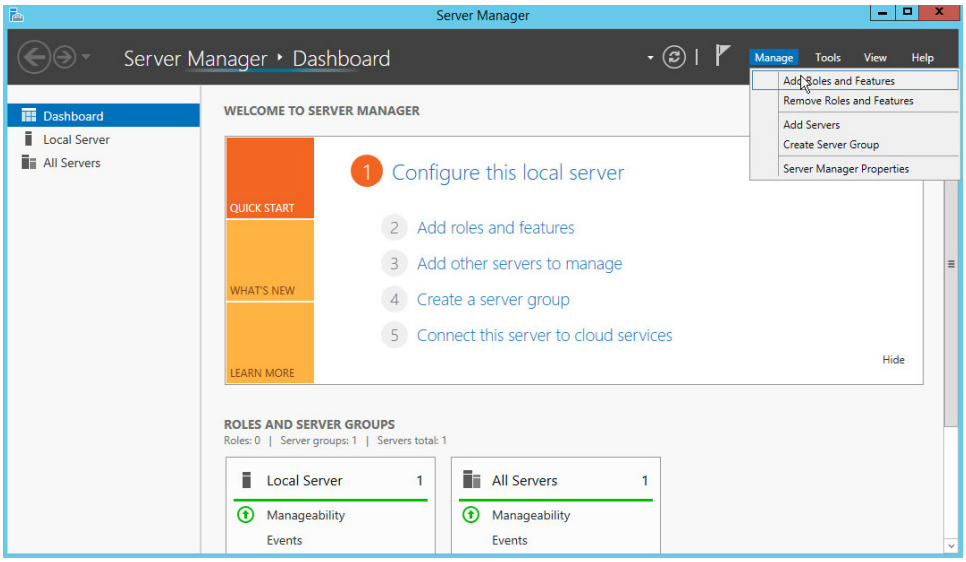
2.4 Windows Server Hyper-V Role

As part of our simulated enterprise, we include a Windows Hyper-V server. This section covers the instructions for installing Windows Server Hyper-V on a Windows Server 2012 R2 machine.

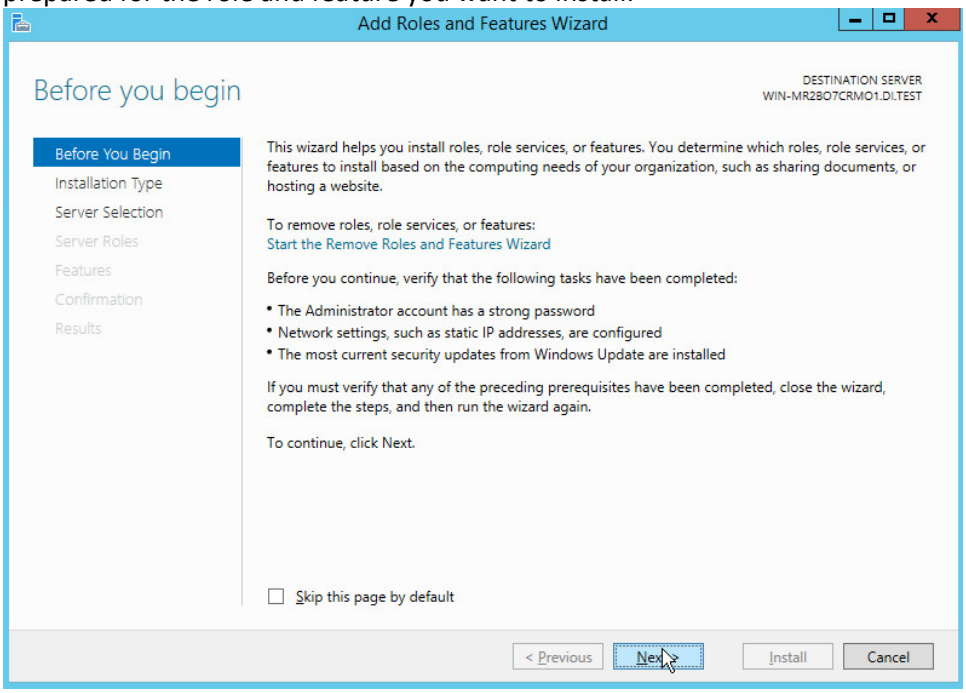
The instructions for enabling the Windows Server Hyper-V Role are retrieved from https://technet.microsoft.com/en-us/library/hh846766(v=ws.11).aspx and are replicated below for preservation and ease of use.

2.4.1 Production Installation

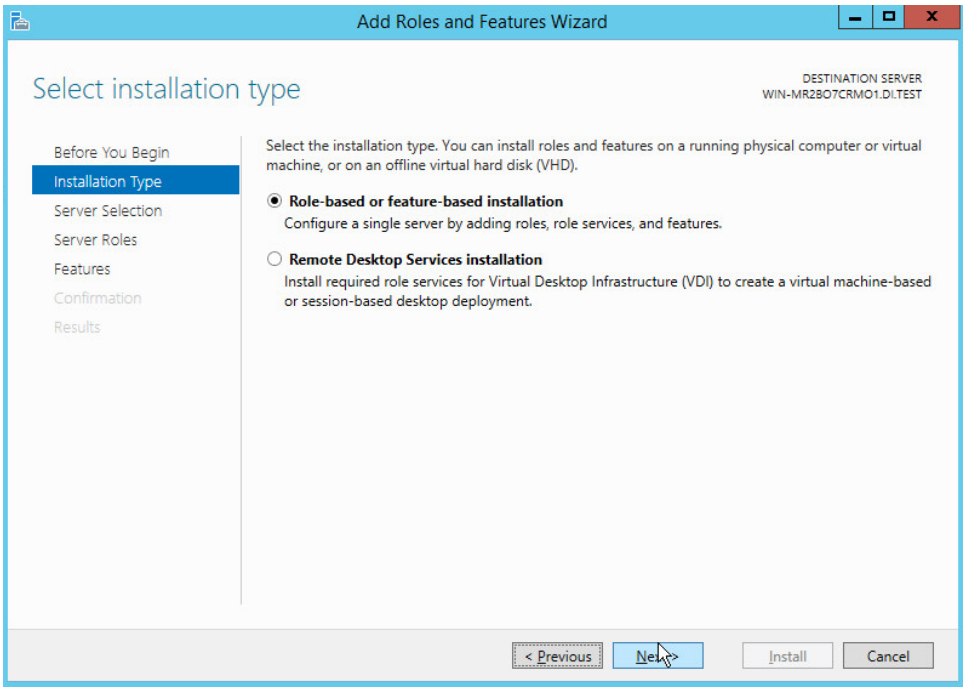
1. In **Server Manager**, on the **Manage** menu, click **Add Roles and Features**.



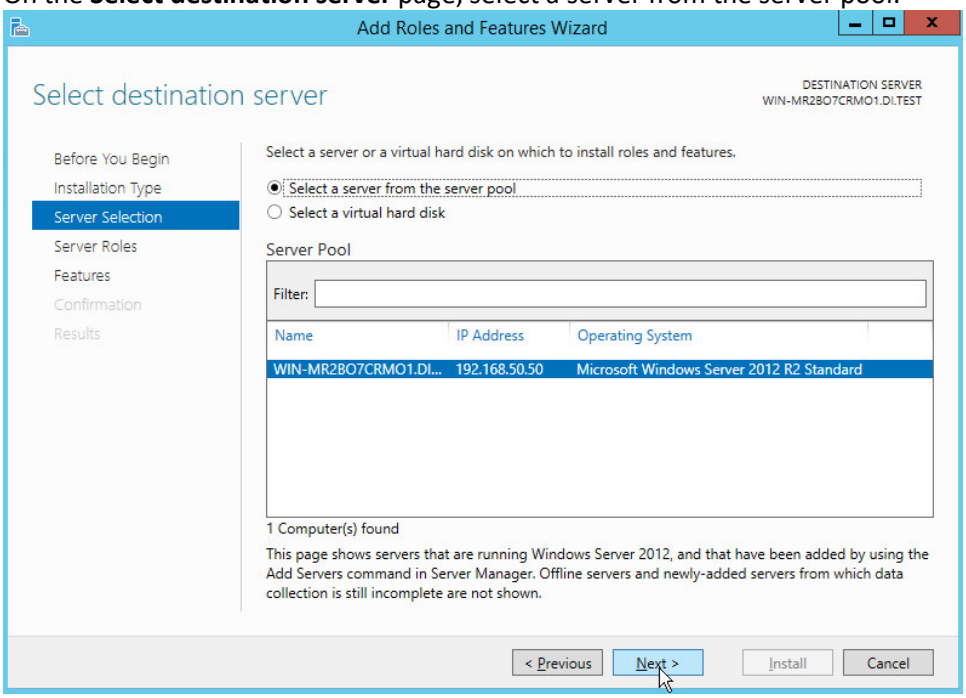
2. On the **Before you begin** page, verify that your destination server and network environment are prepared for the role and feature you want to install.



3. Click **Next**.
4. On the **Select installation type** page, select **Role-based or feature-based installation**.

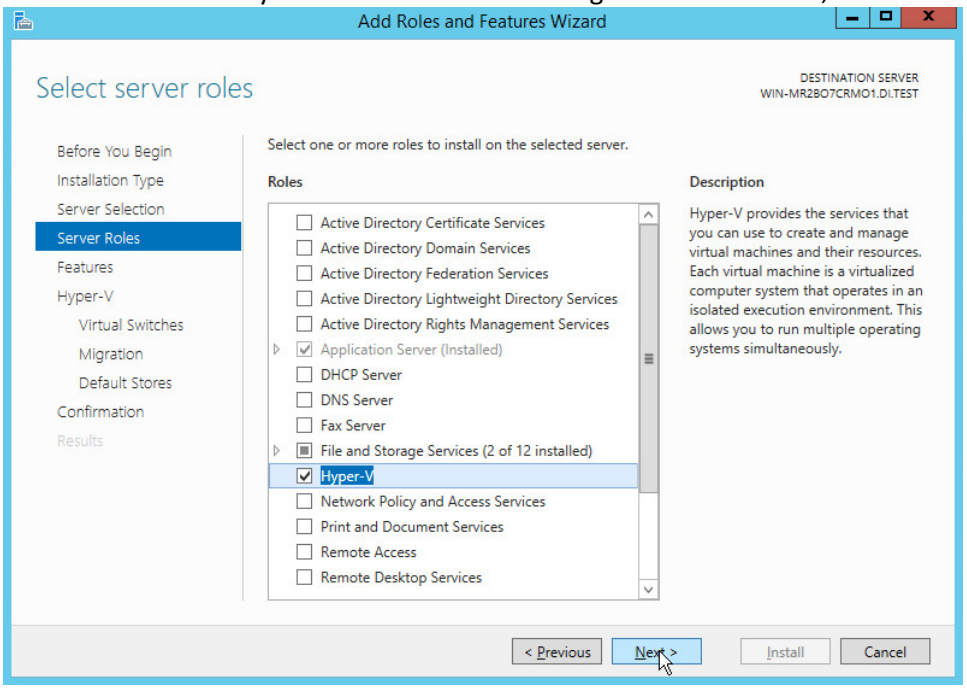


5. Click **Next**.
6. On the **Select destination server** page, select a server from the server pool.

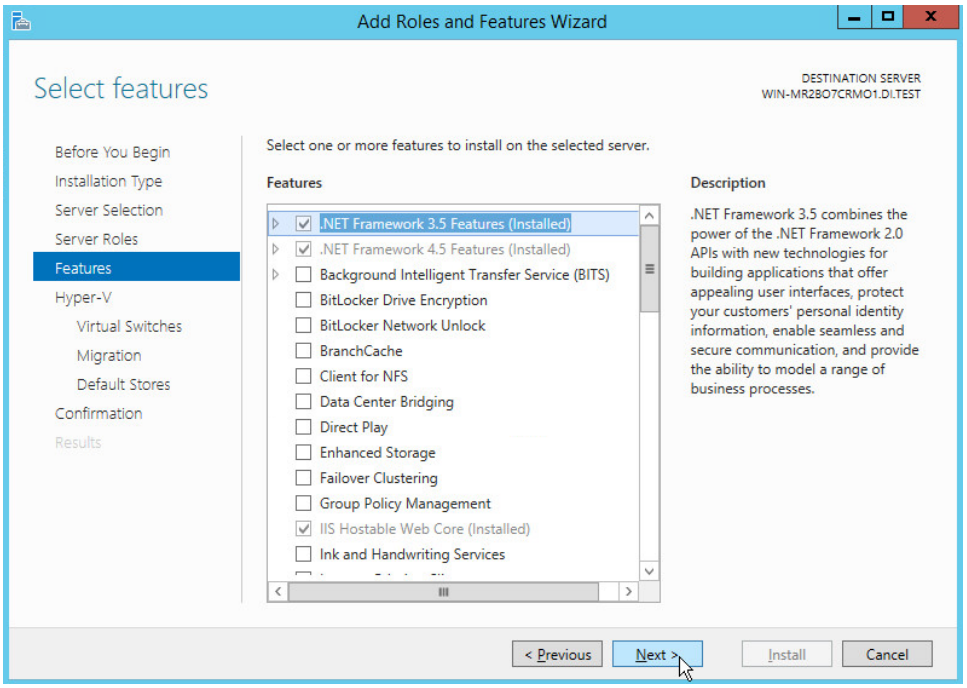


7. Click **Next**.
8. On the **Select server roles** page, select **Hyper-V**.

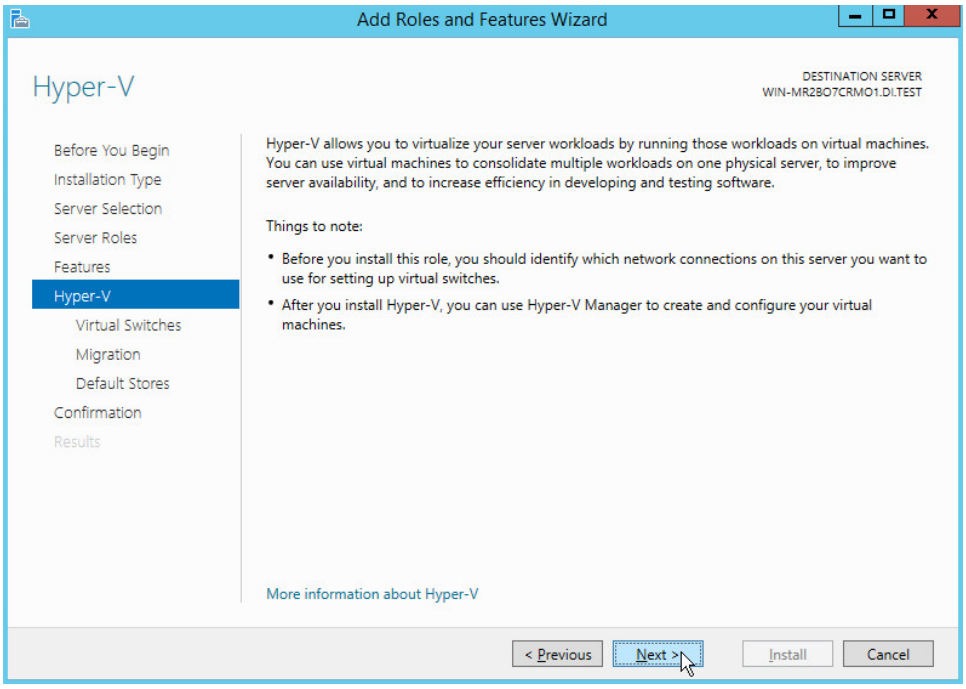
9. To add the tools that you use to create and manage virtual machines, click **Add Features**.



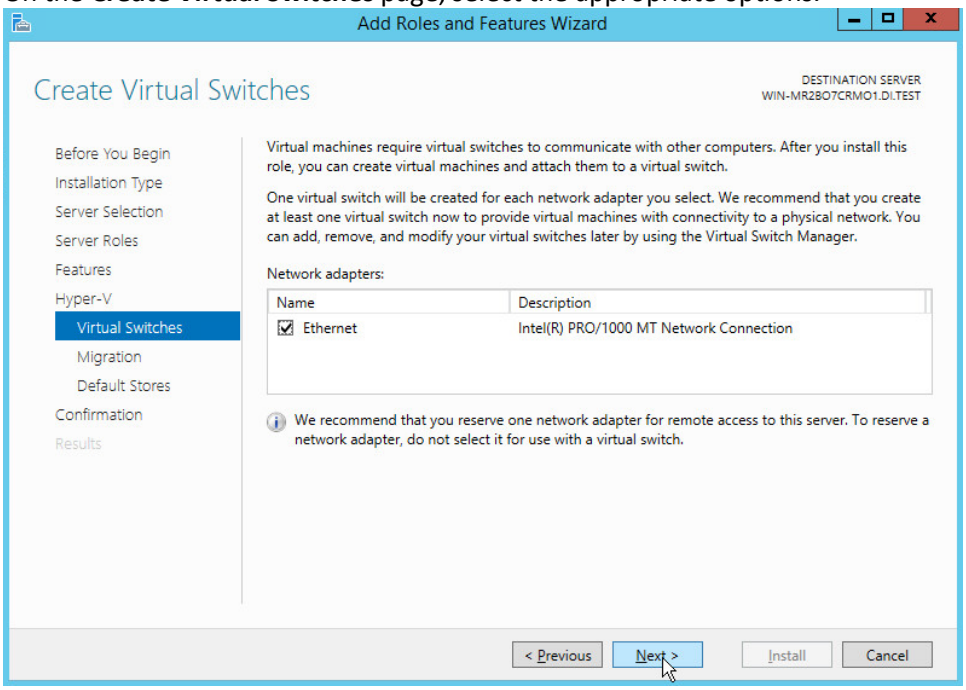
10. Click **Next**.



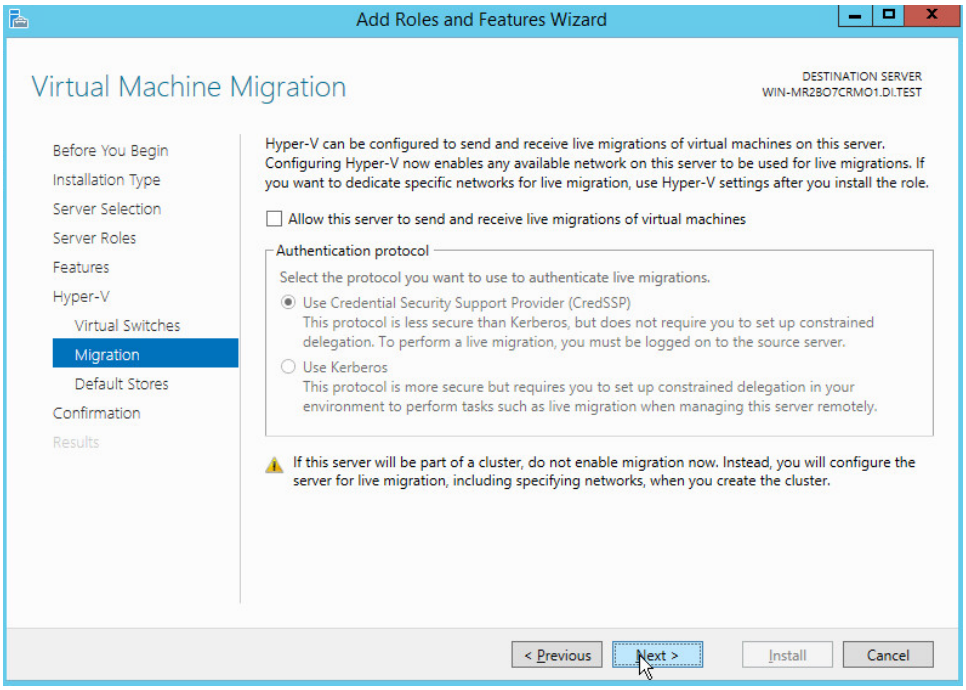
11. Click **Next**.



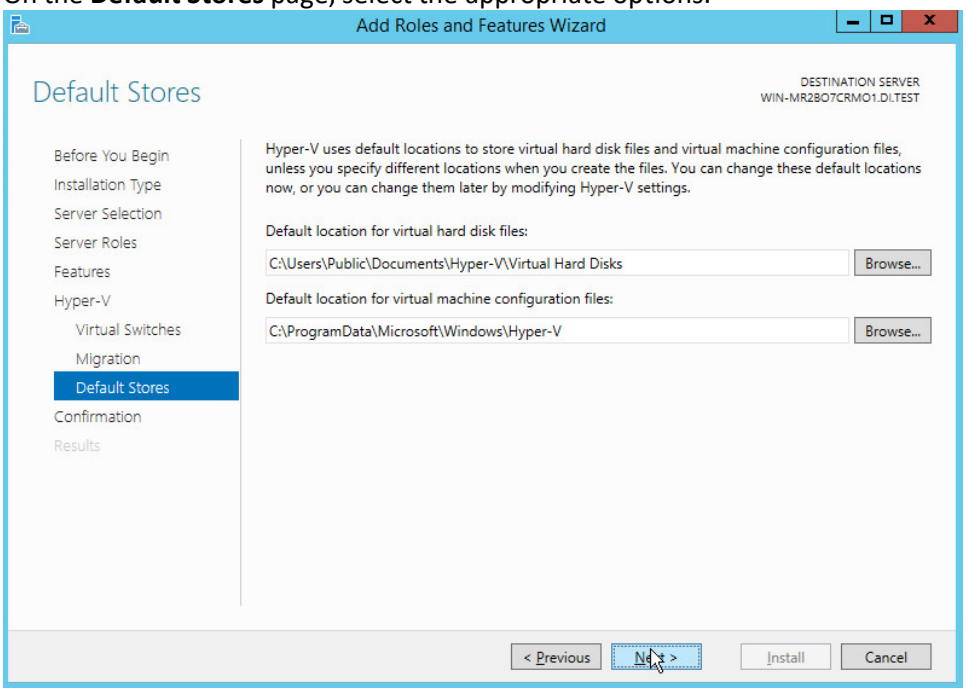
12. Click **Next**.
13. On the **Create Virtual Switches** page, select the appropriate options.



14. Click **Next**.
15. On the **Virtual Machine Migration** page, select the appropriate options.

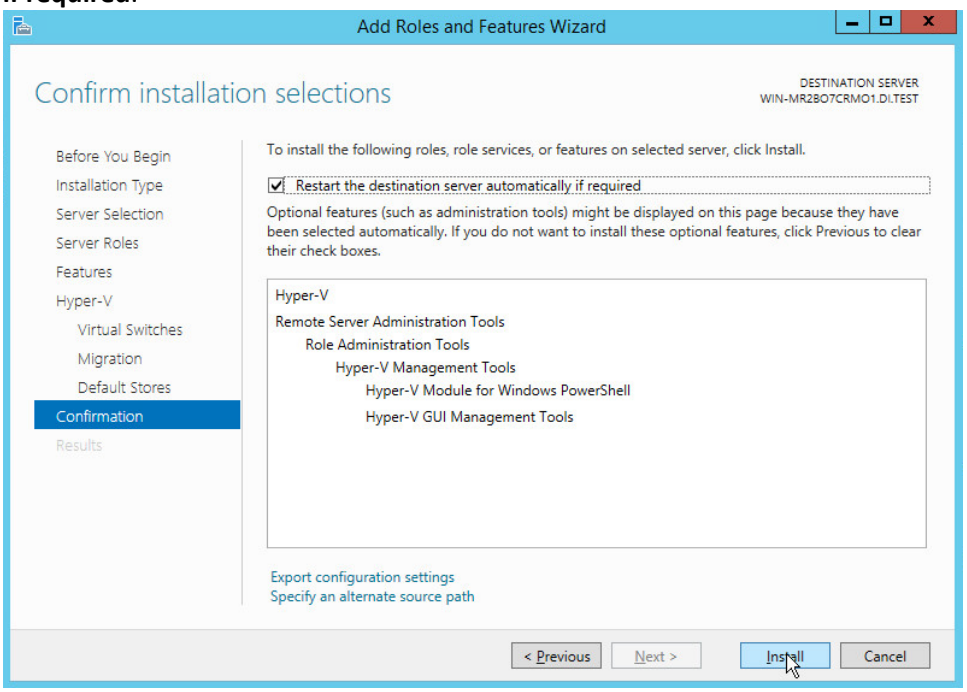


16. Click **Next**.
17. On the **Default Stores** page, select the appropriate options.



18. Click **Next**.

19. On the **Confirm installation selections** page, select **Restart the destination server automatically if required**.



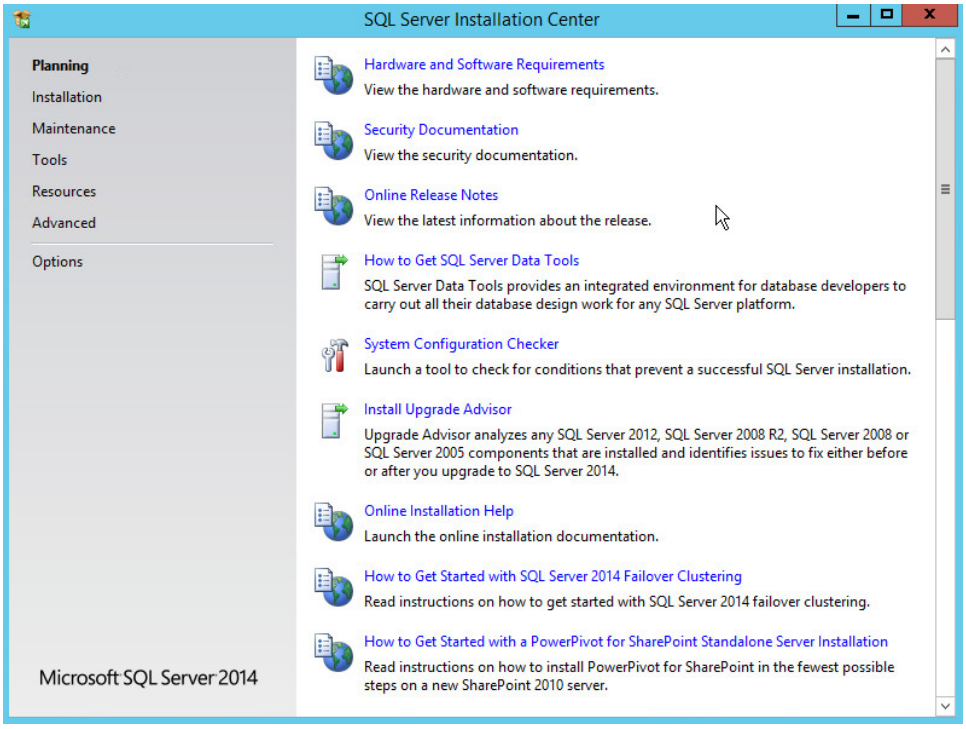
20. Click **Install**.
21. When installation is finished, verify that Hyper-V installed correctly. Open the **All Servers** page in Server Manager, select a server on which you installed Hyper-V. Check the **Roles and Features** tile on the page for the selected server.

2.5 MS SQL Server

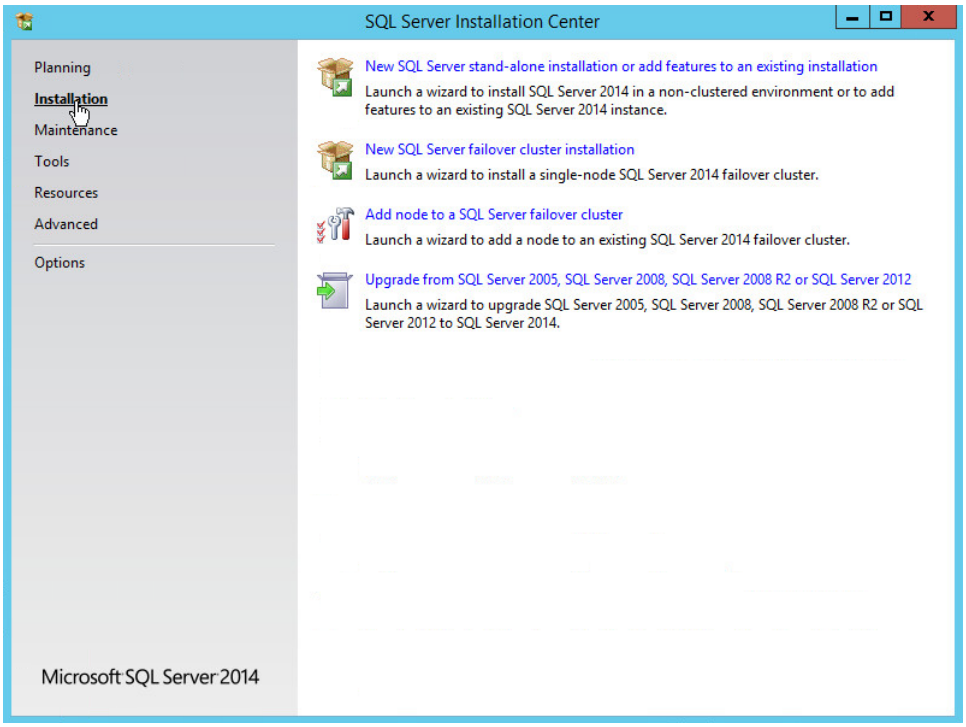
As part of both our enterprise emulation and data integrity solution, we include a Microsoft SQL Server. This section covers the installation and configuration process used to set up Microsoft SQL Server on a Windows Server 2012 R2 machine.

2.5.1 Install and Configure MS SQL

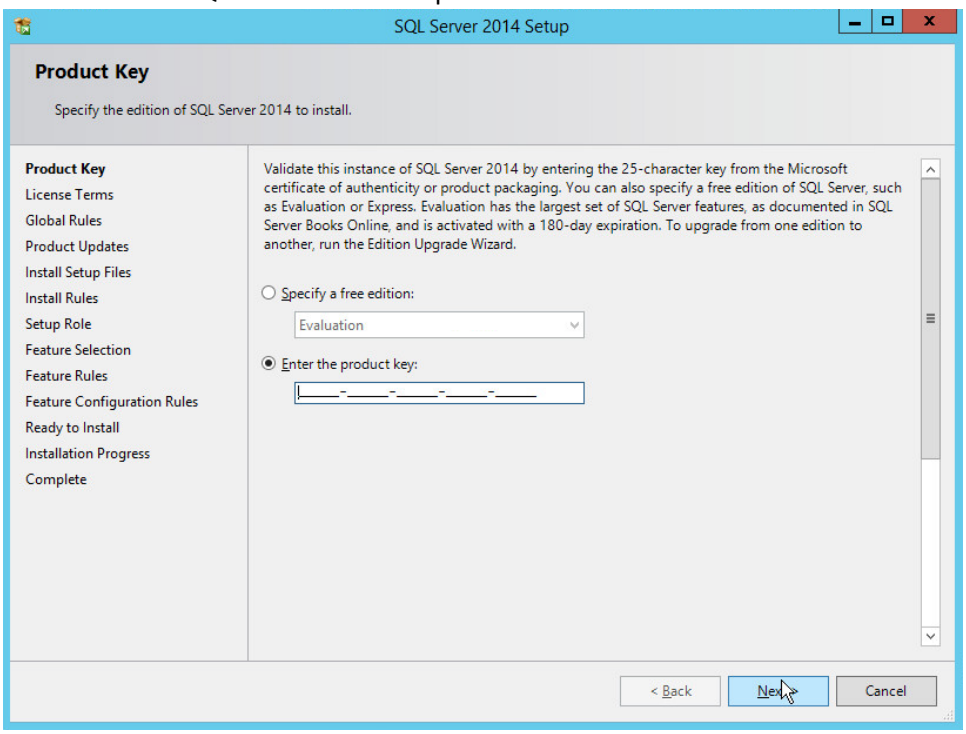
1. Acquire **SQL Server 2014 Installation Media**.
2. Locate the installation media in the machine and click on **SQL2014_x64_ENU** to launch **SQL Server Installation Center.**



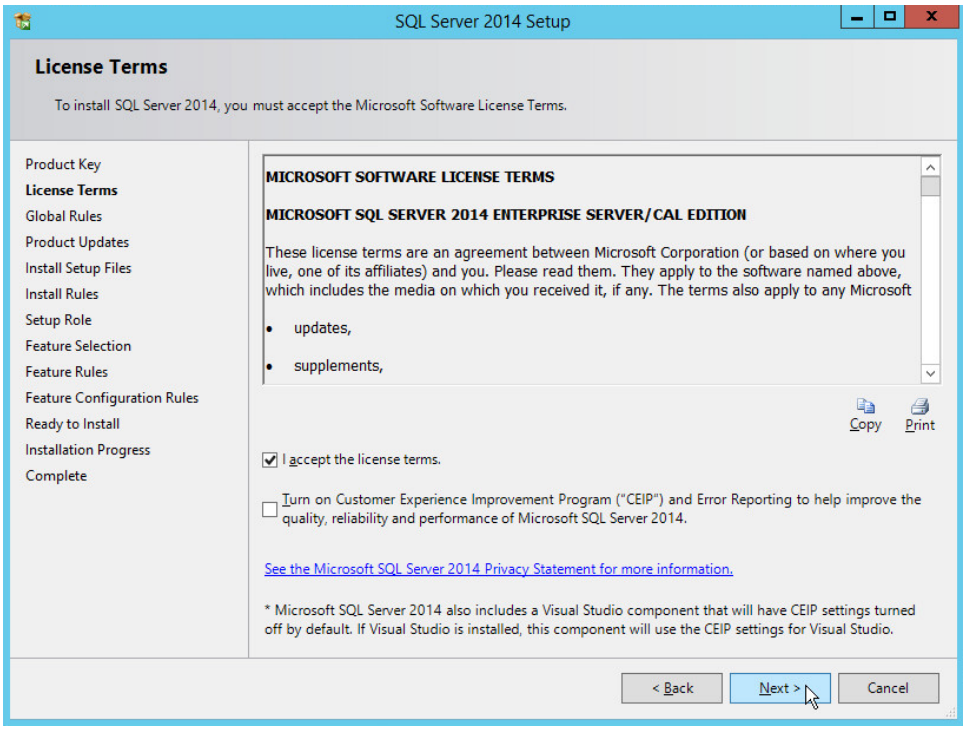
3. On the left menu, select **Installation**.



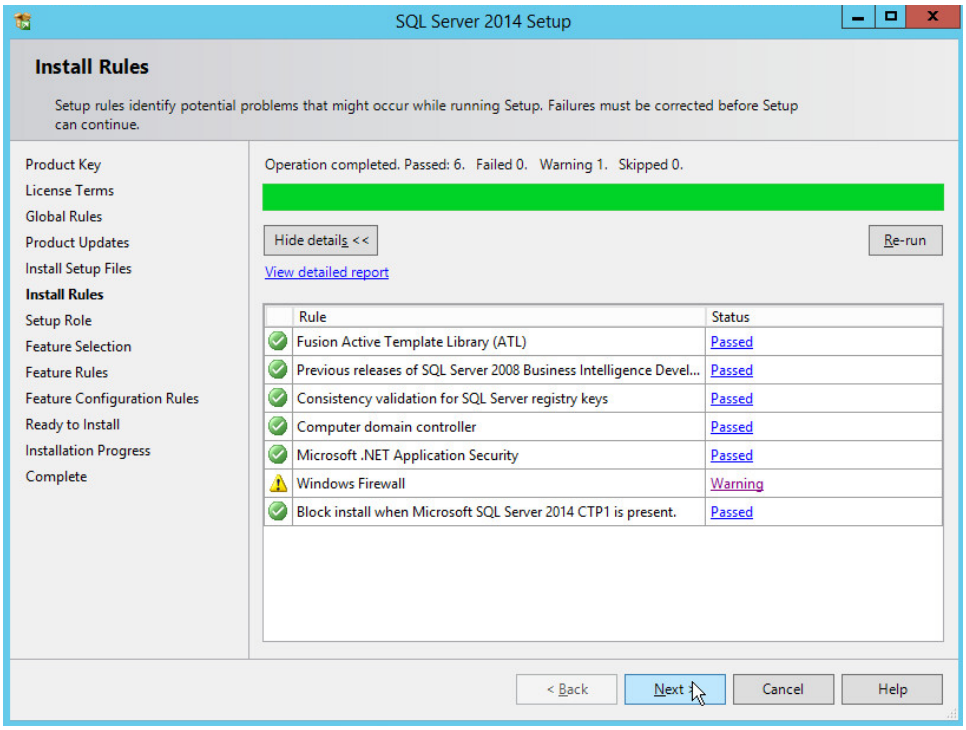
4. Select **New SQL Server stand-alone installation or add features to an existing installation**. This will launch the SQL Server 2014 setup.



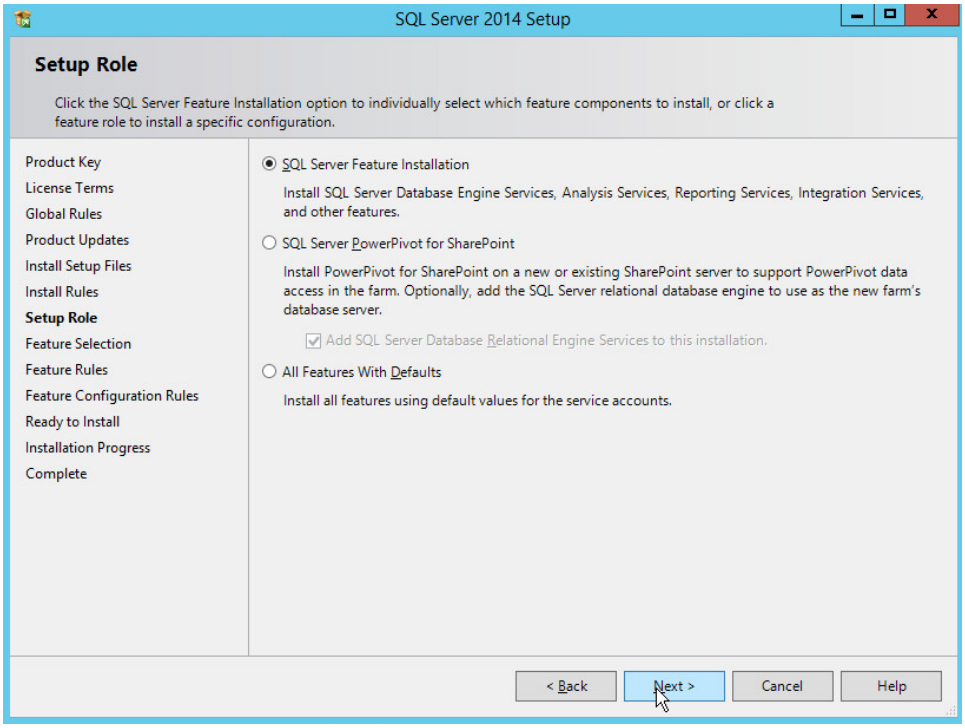
5. In the **Product Key** section, enter your product key.
6. Click **Next**.



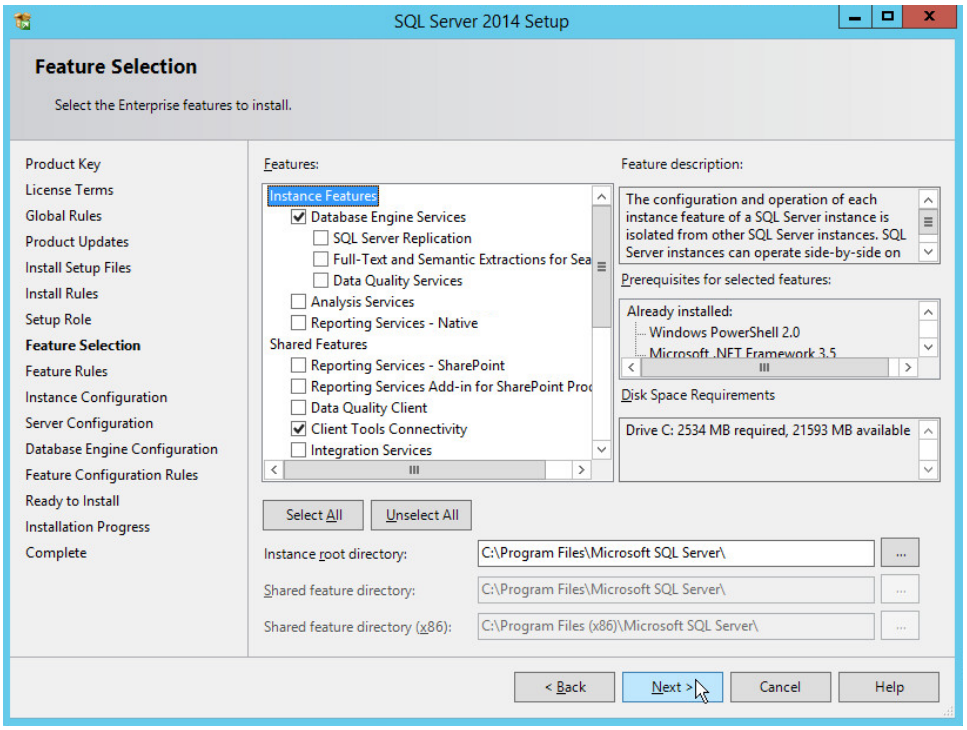
7. In the **License Terms** section, read and click **I accept the license terms**.
8. Click **Next**.
9. In the **Install Rules** section, note and resolve any further conflicts.



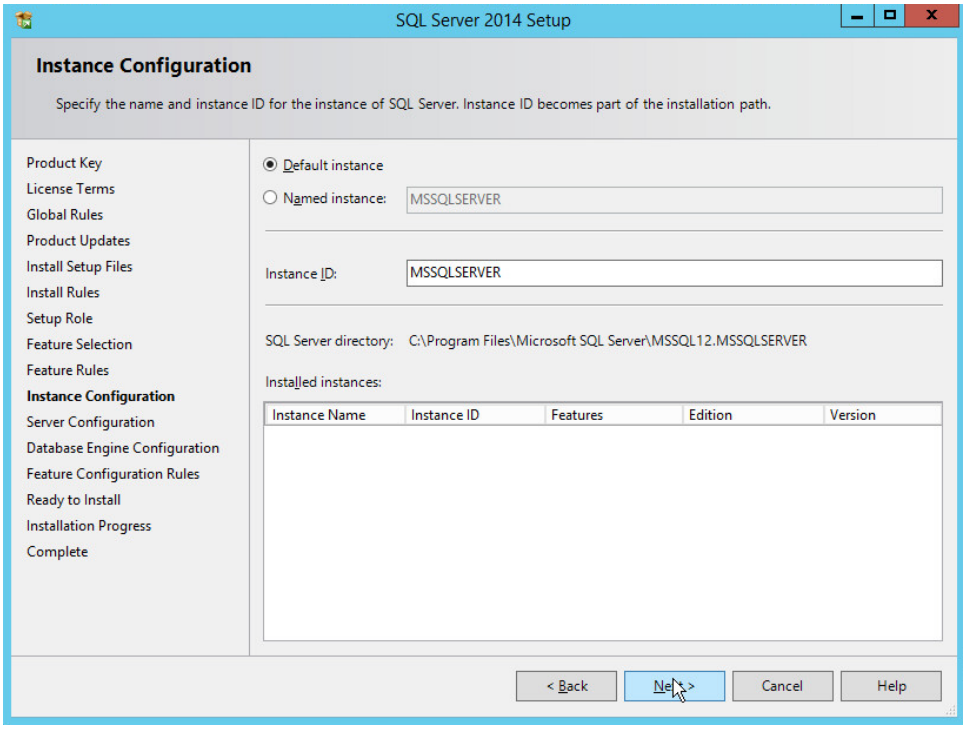
10. Click **Next**.
11. In the **Setup Role** section, select **SQL Server Feature Installation**.



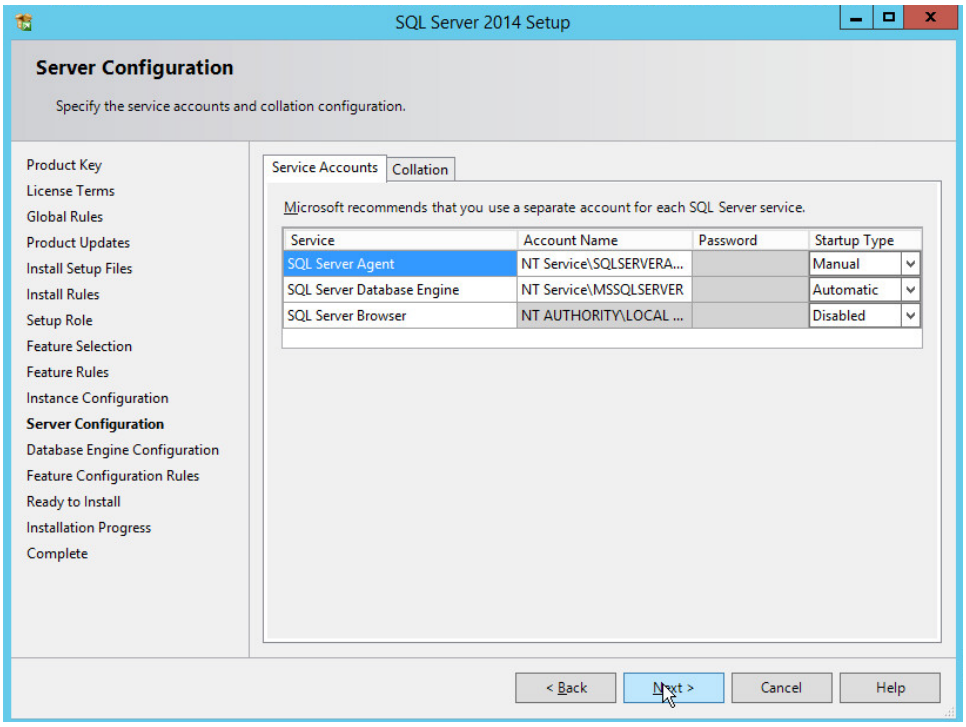
12. Click **Next**.
13. In the **Feature Selection** section, select the following:
    a. **Database Engine Services**
    b. **Client Tools Connectivity**
    c. **Client Tools Backwards Compatibility**
    d. **Client Tools SDK**
    e. **Management Tools – Basic**
    f. **Management Tools – Complete**
    g. **SQL Client Connectivity SDK**
    h. **Any other desired features**



14. Click **Next**.
15. In the **Instance Configuration** section, select **Default instance**.

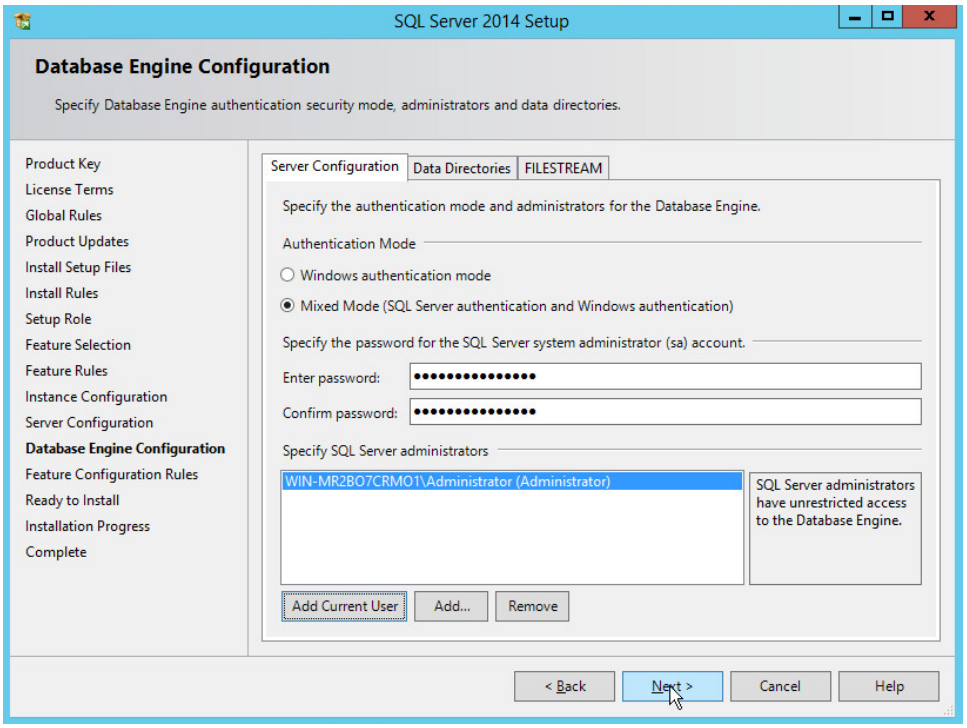


16. Click **Next**.

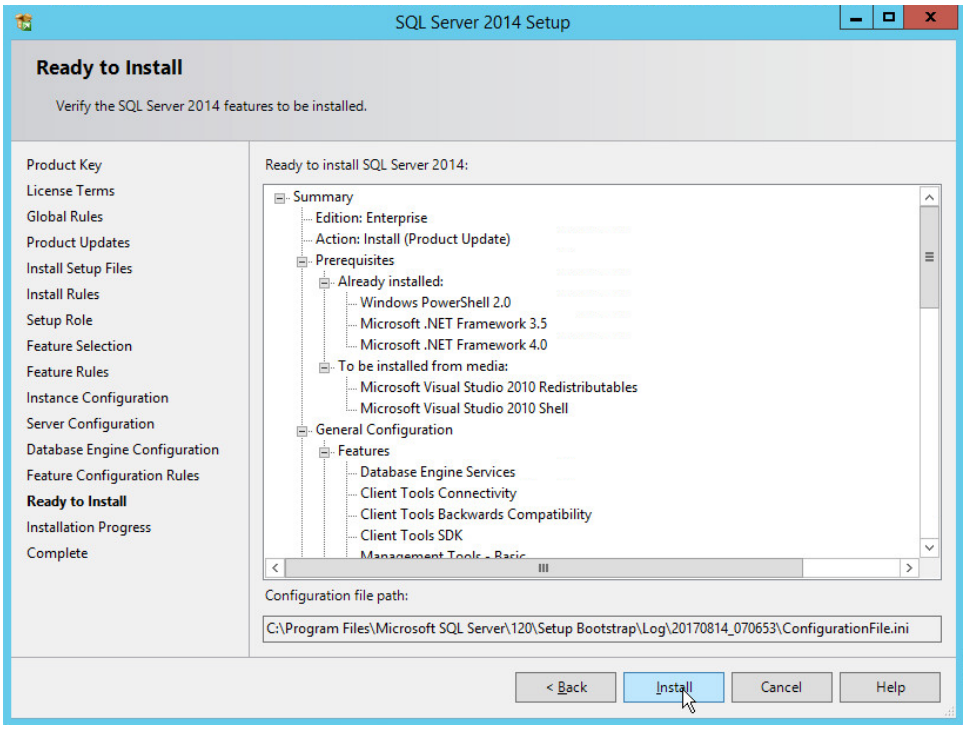


17. In the **Server Configuration** section, click **Next**.

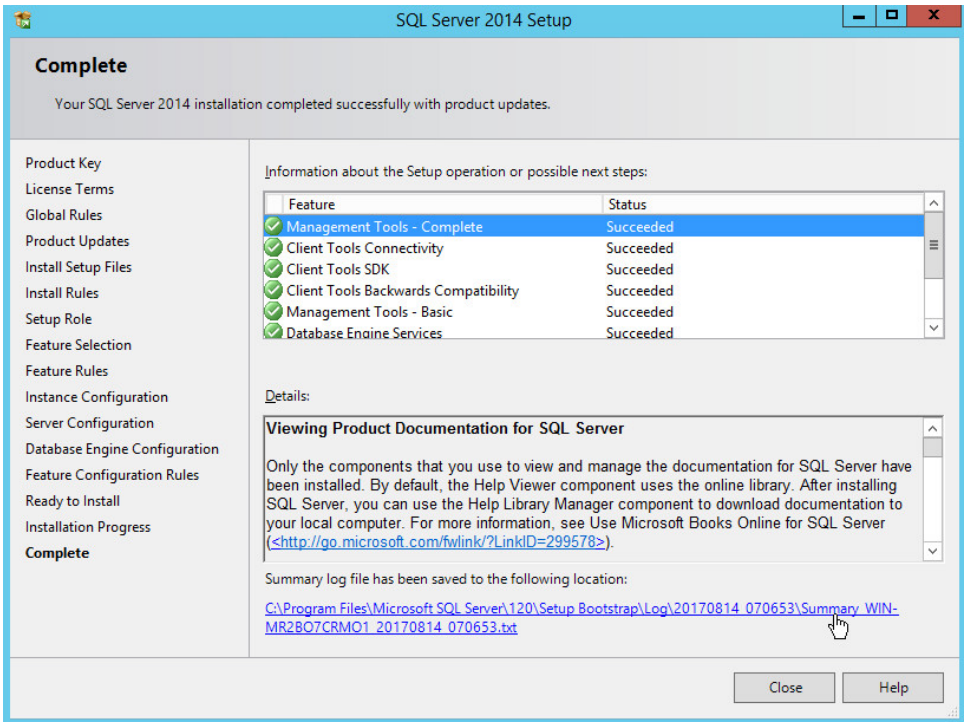
18. In the **Database Engine Configuration** section, make sure **Mixed Mode** is selected.
19. Add all desired users as Administrators under **Specify SQL Server Administrators** by pressing **Add Current User.**
    a. For Domain accounts, simply type in **$DOMAINNAME\$USERNAME** into **Enter the object names to select** textbox.
    b. Click **OK**.
    c. For local computer accounts, click on **locations** and select the computers name.
    d. Click **OK**.
    e. Type the username into the **Enter the object names to select** textbox.
    f. Once you are finished adding users, click **Next**.



20. In the **Ready to install** section, verify the installation and click **Install**.

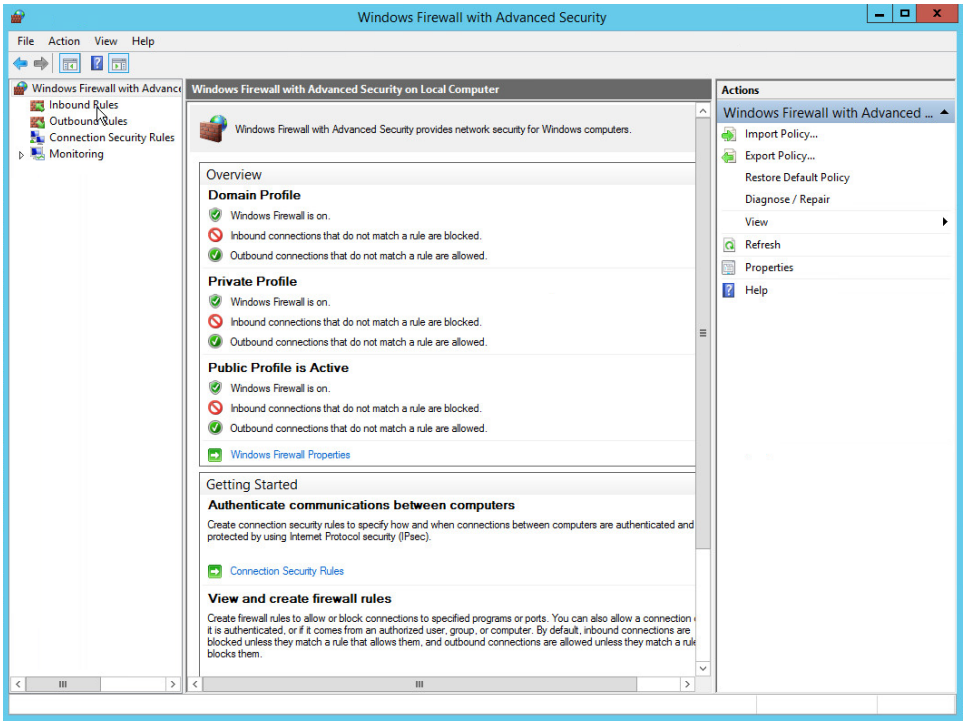


21. Wait for the install to finish.

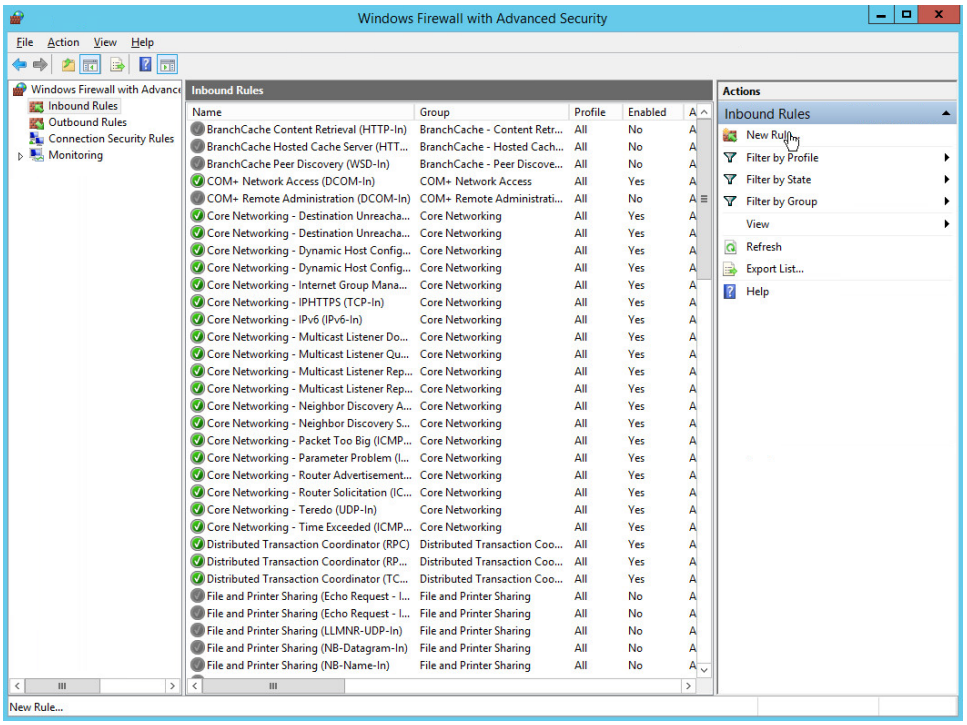


2.5.2 Open Port on Firewall

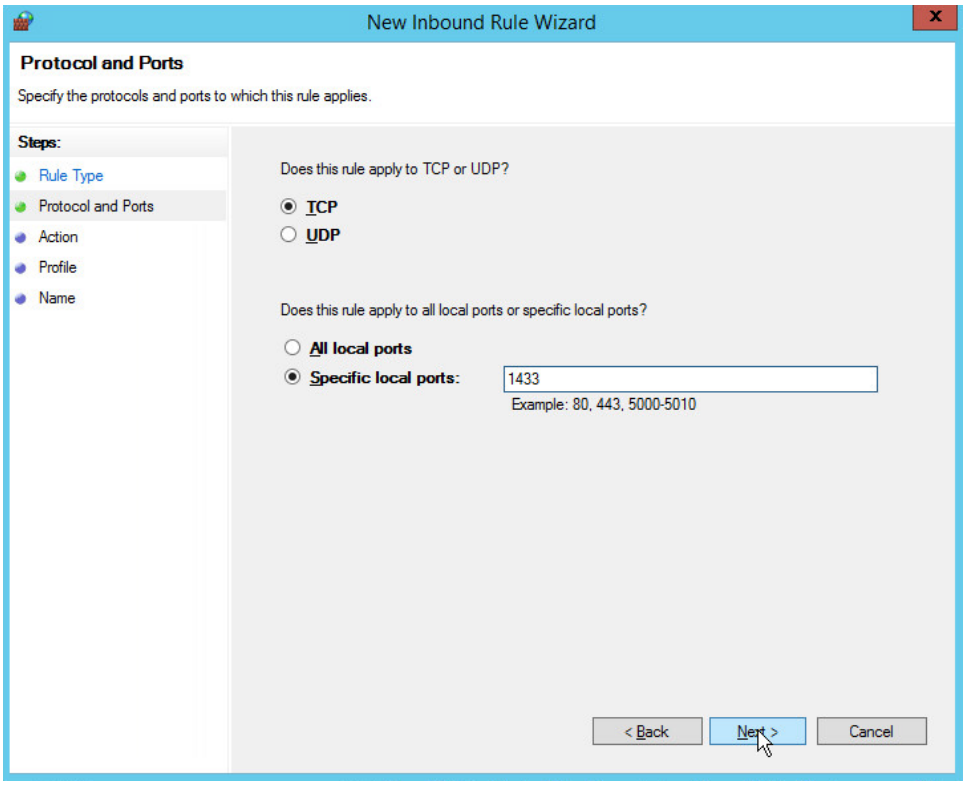
1. Open **Windows Firewall with Advanced Security**.



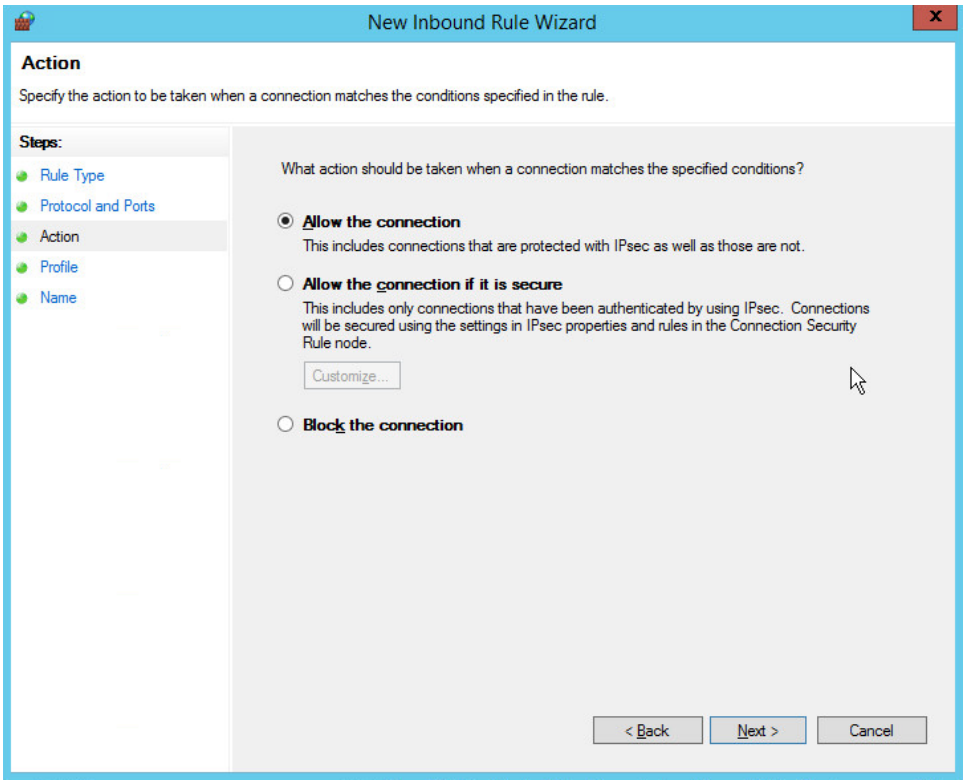
2. Click **Inbound Rules** and then **New Rule.**



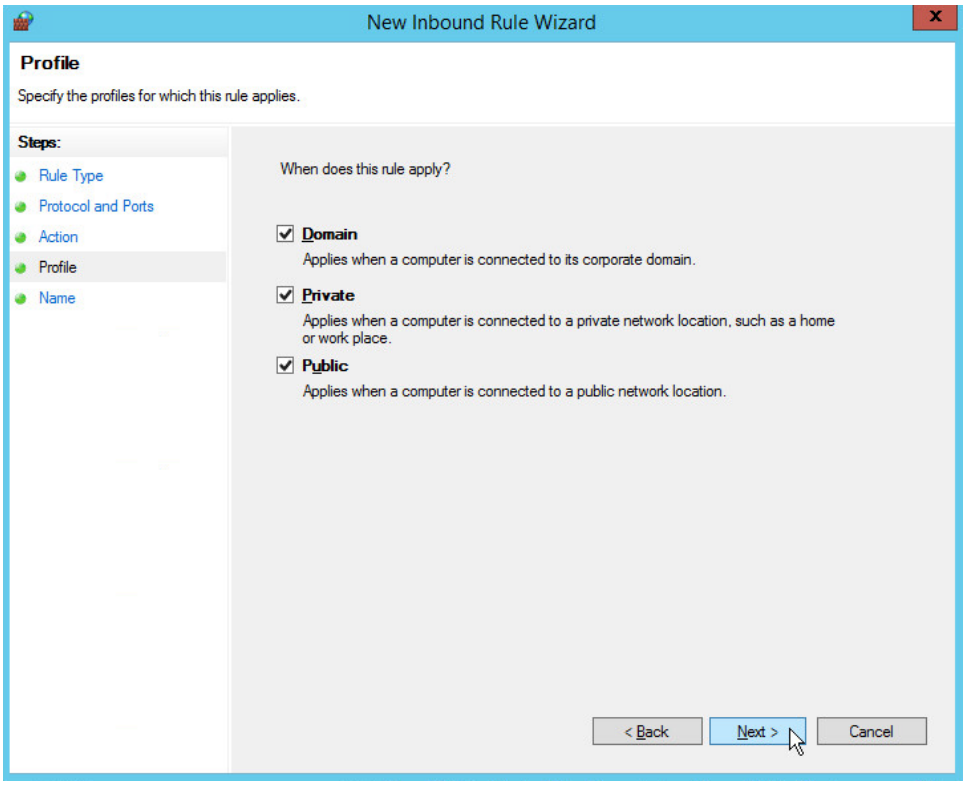
3. Select **Port**.
4. Click **Next**.
5. Select **TCP** and **Specific local ports.**
6. Type **1433** into the text field.



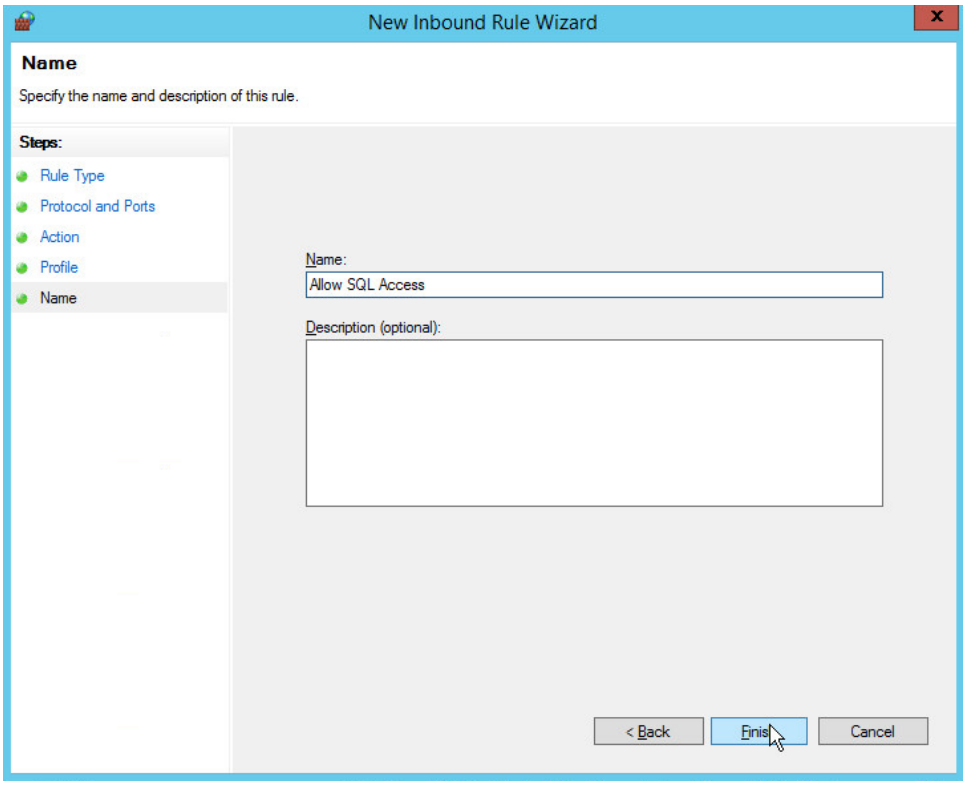
7. Click **Next**.
8. Select **Allow the connection**.



9. Click **Next**.
10. Select all applicable locations.



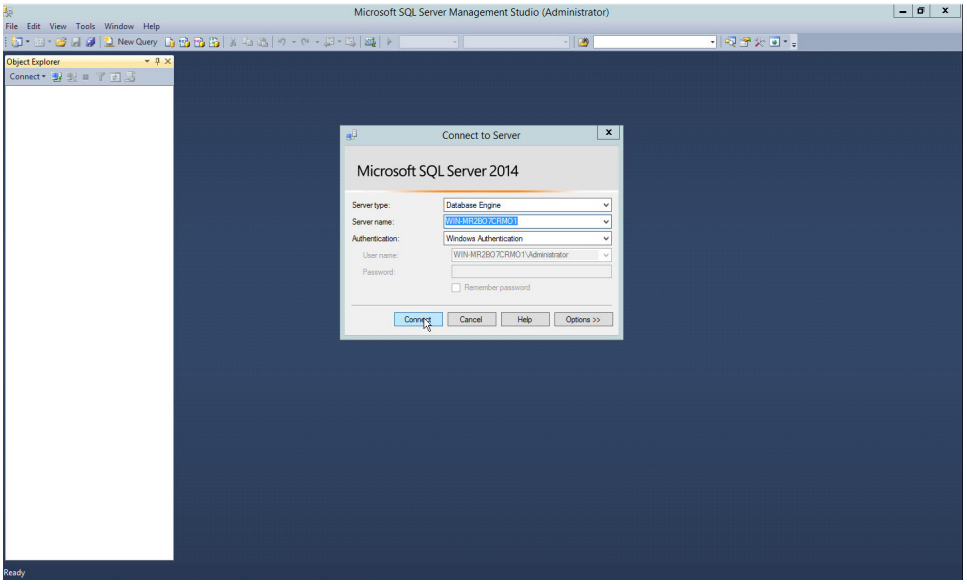
11. Click **Next**.
12. Name the rule **Allow SQL Access**.



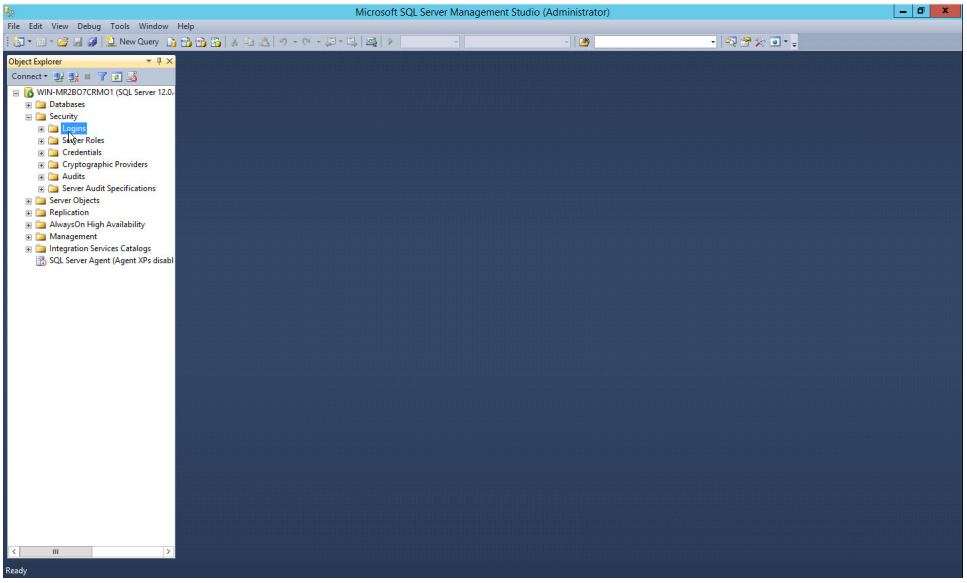
13. Click **Finish**.

2.5.3 Add a New Login to the Database

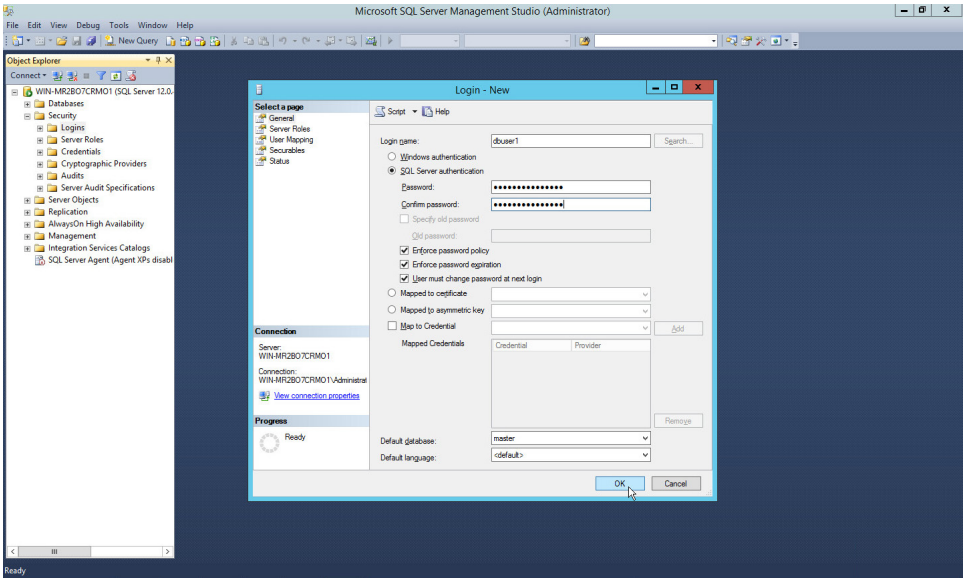
1. Open **SQL Server Management Studio.**



2. Hit **Connect** to connect to the database.
3. In the **Object Explorer** window, expand the **Security** folder.



4. Right click on the **Logins** folder and click **New Login…**.
5. Input the desired user.



6. Click **OK**.

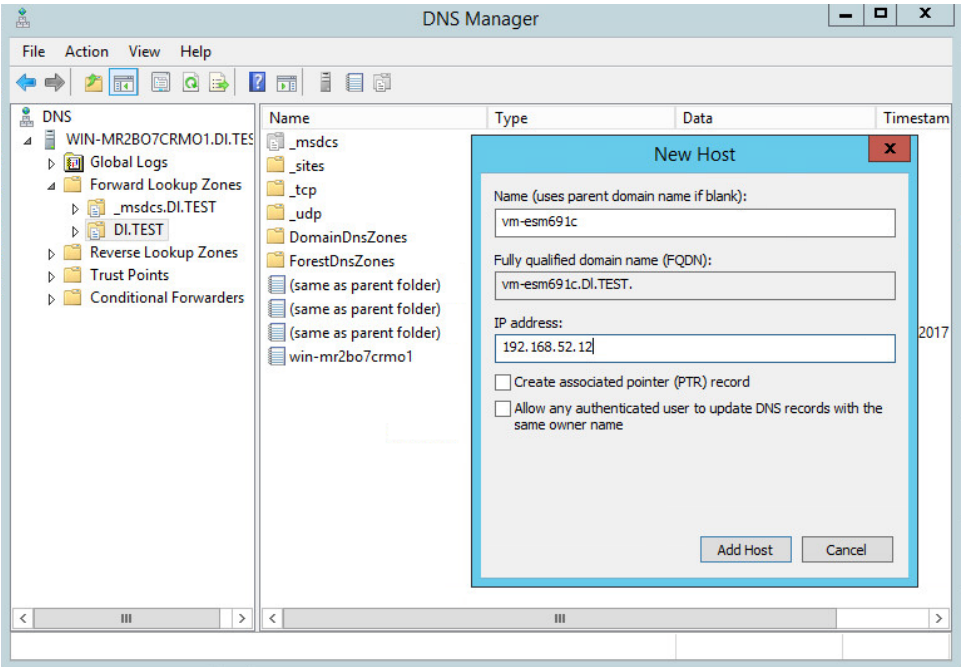
2.6 HPE ArcSight Enterprise Security Manager (ESM)

HPE ArcSight Enterprise Security Manager is primarily a log collection/analysis tool with features for sorting, filtering, correlating, and reporting information from logs. It is adaptable to logs generated by various systems, applications, and security solutions.

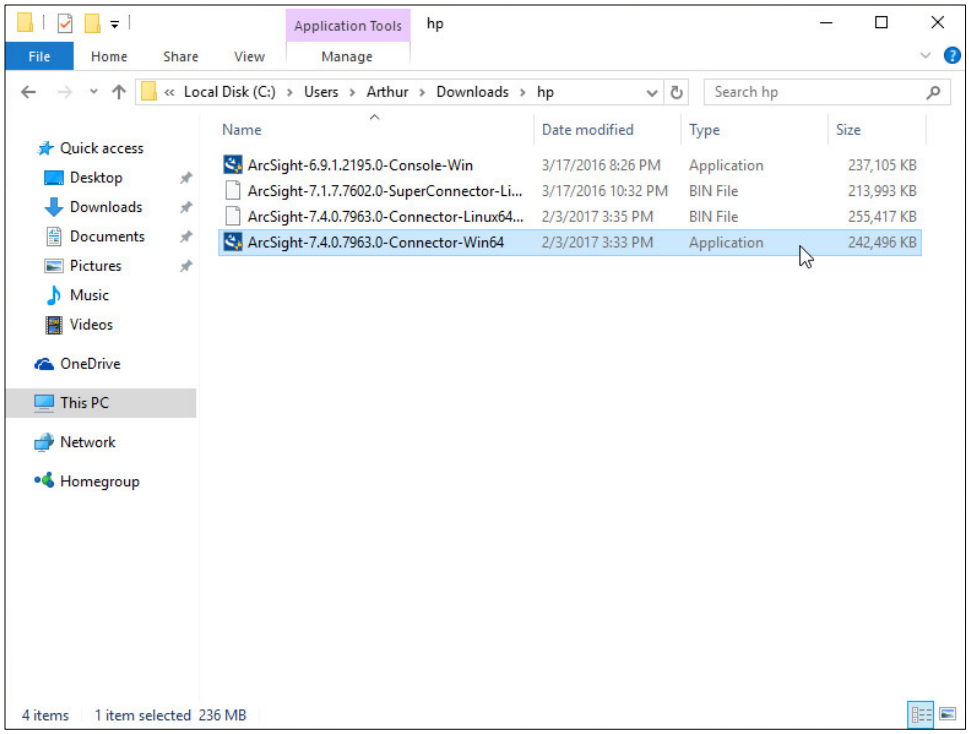
This installation guide assumes a pre-configured CentOS 7 Virtual Machine with ESM already installed and licensed. This section covers the installation and configuration process used to set up ArcSight agents on various machines.

2.6.1 Install Individual ArcSight Windows Connectors

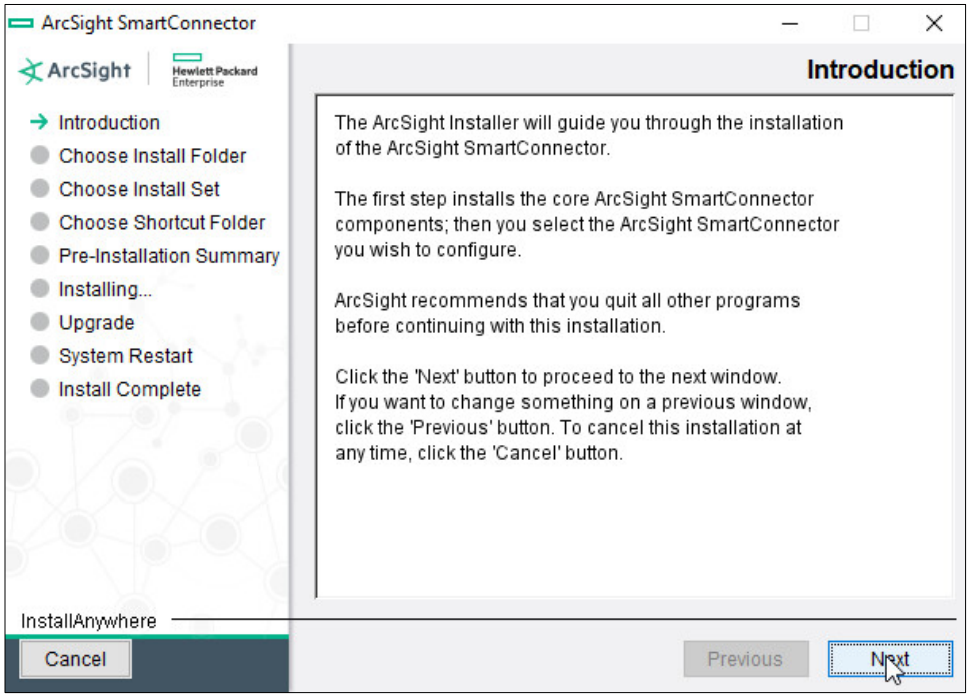
1. Log in to your DNS server.



2. Add the host name of the ESM server *vm-esm691c* to the DNS list and associate it with the IP address of the ESM server.
3. Run the installation file **ArcSight-7.4.0.7963.0-Connector-Win64**.

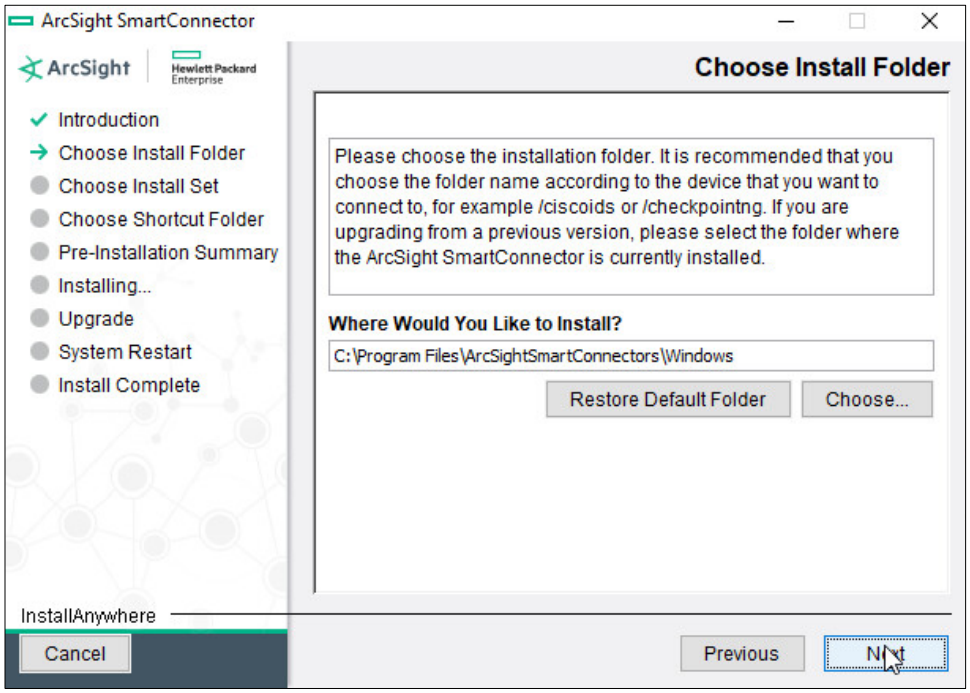


4. Wait for the initial setup to finish.

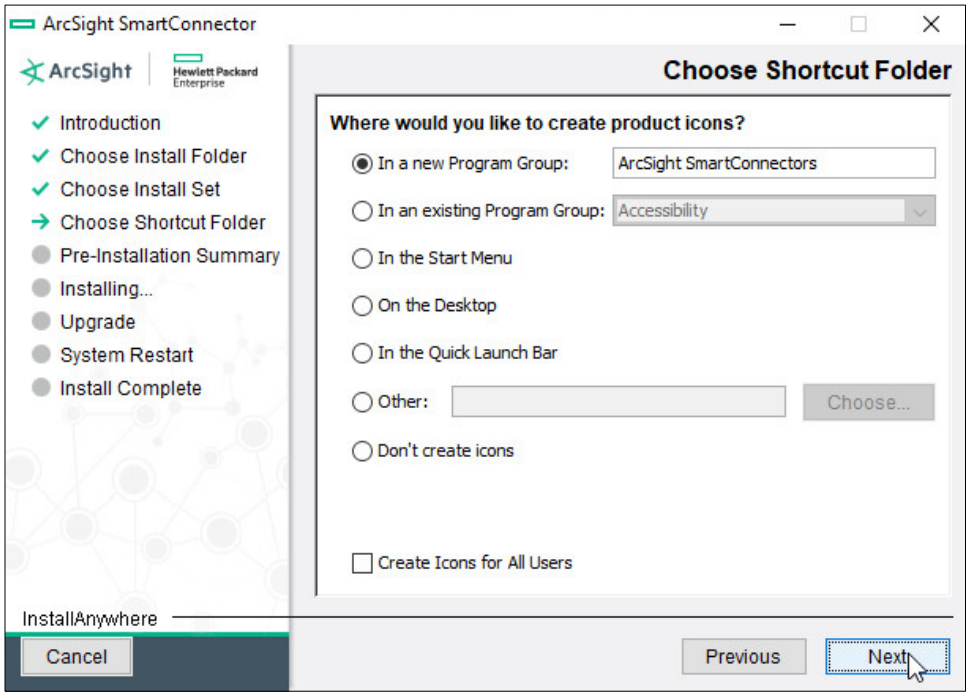


5. Click **Next**.

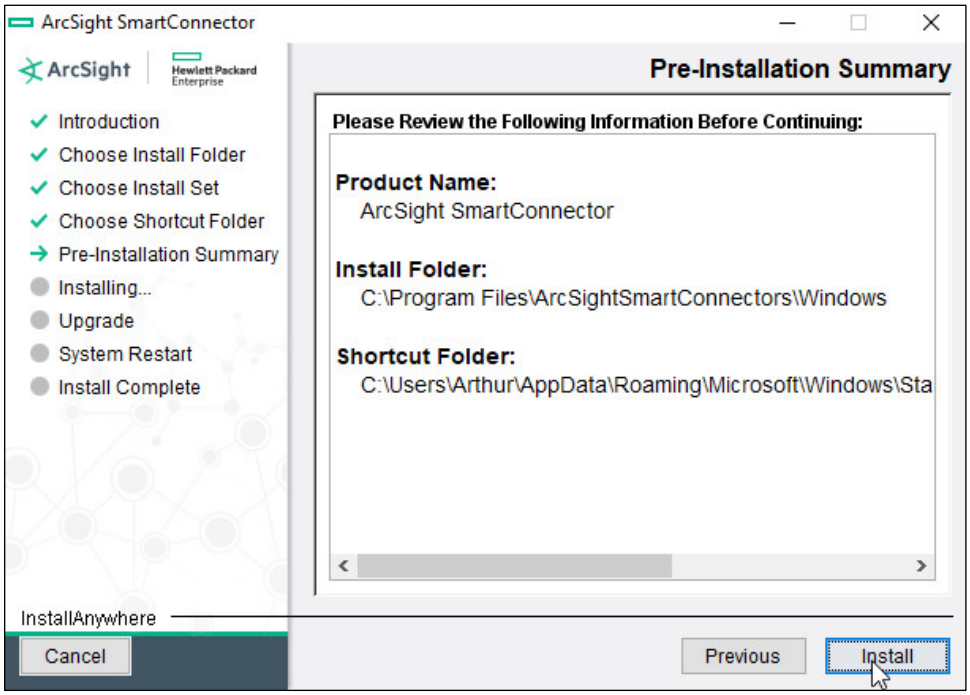
6. Choose a destination folder. Note: It is recommended to change the default destination folder to `<default>\Windows`. This is to avoid conflicts if you wish to install more than one connector.



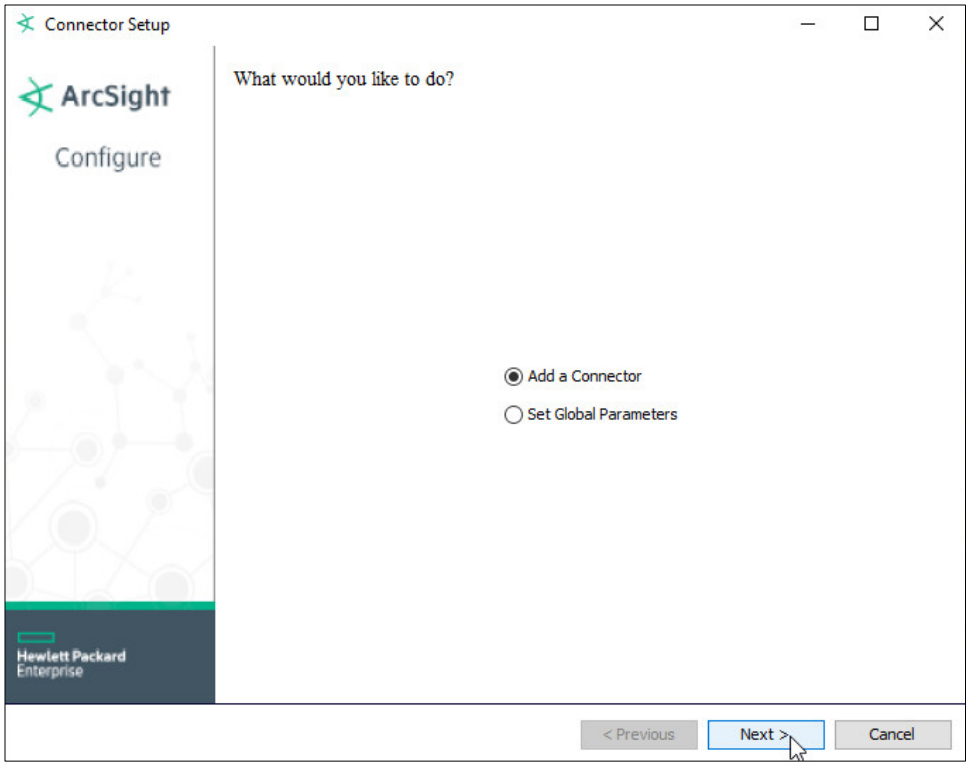
7. Click **Next**.



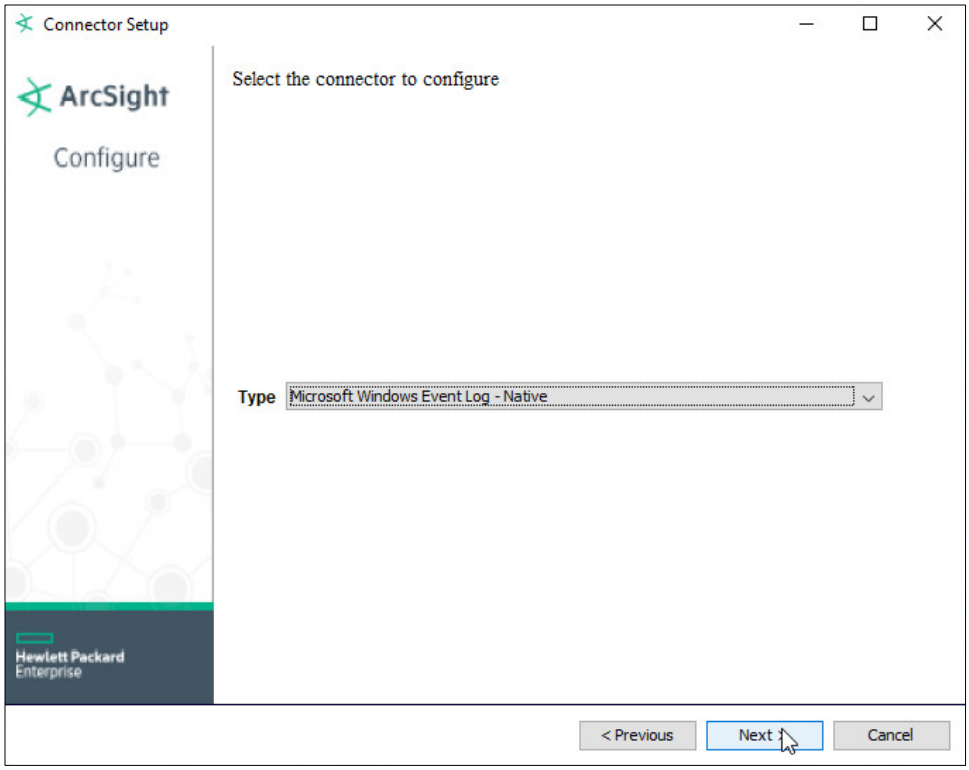
8. Click **Next**.



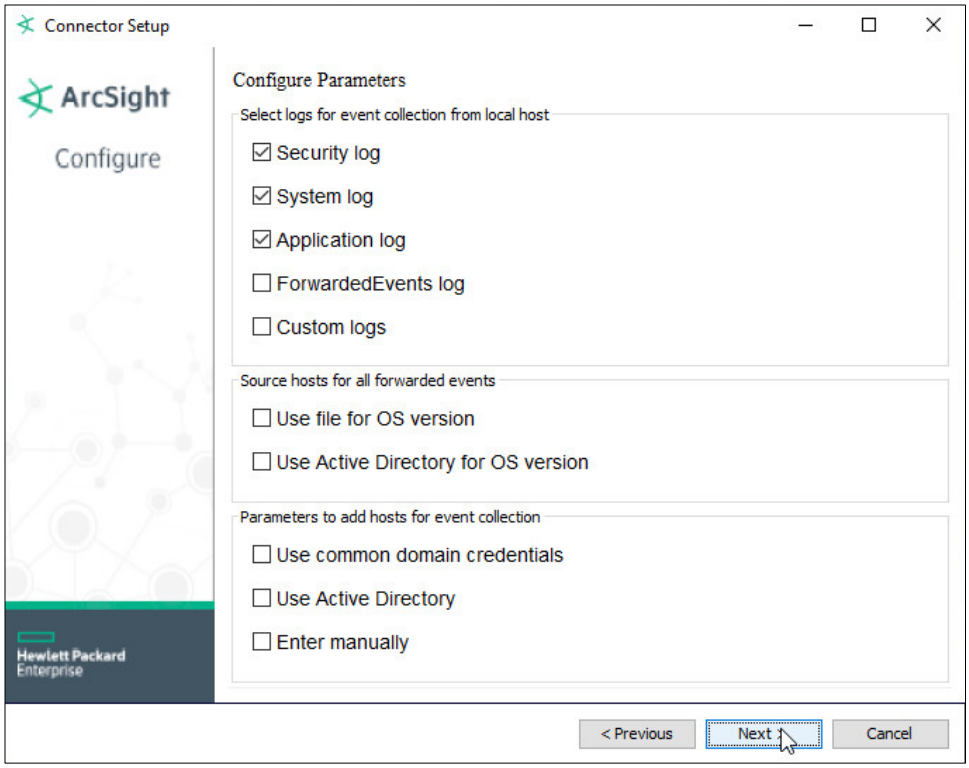
9. Click **Install**.
10. Wait for the installation to finish.



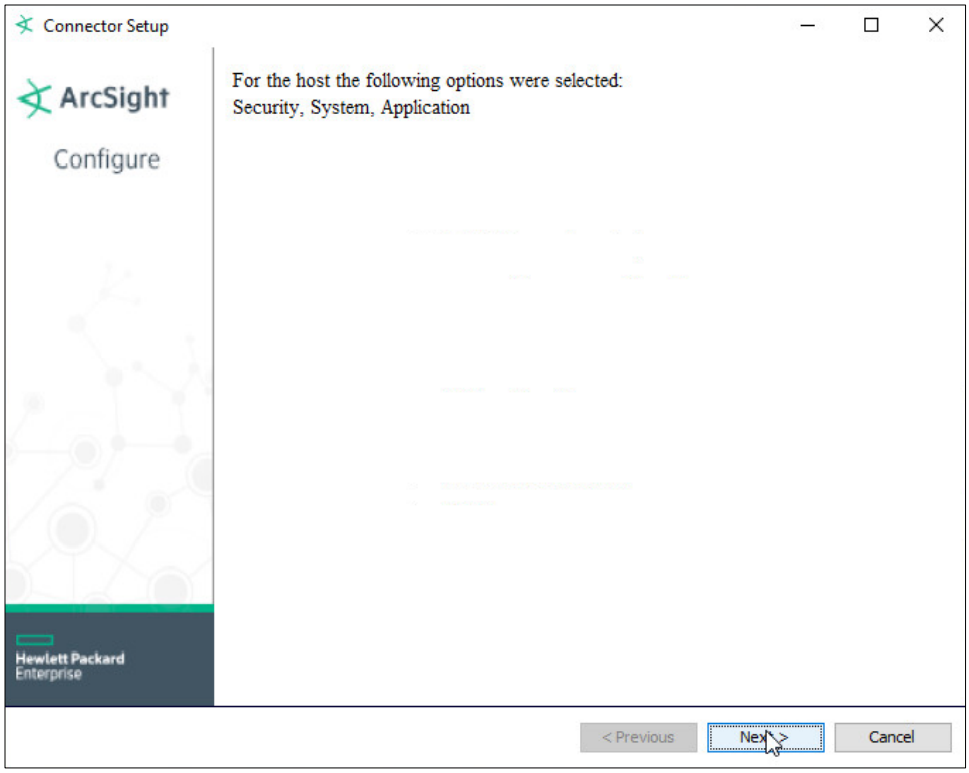
11. Select **Add a Connector**.
12. Click **Next**.
13. Choose **Microsoft Windows Event Log - Native** from the list.



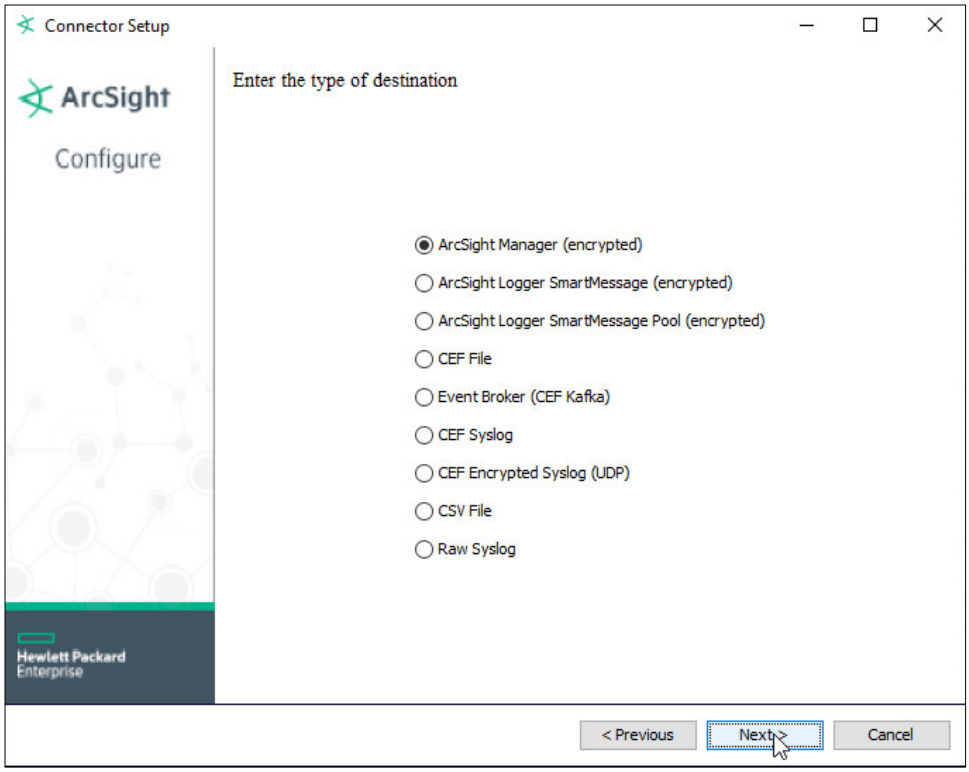
14. Click **Next**.
15. Check **Security log**, **System log**, and **Application Log**.



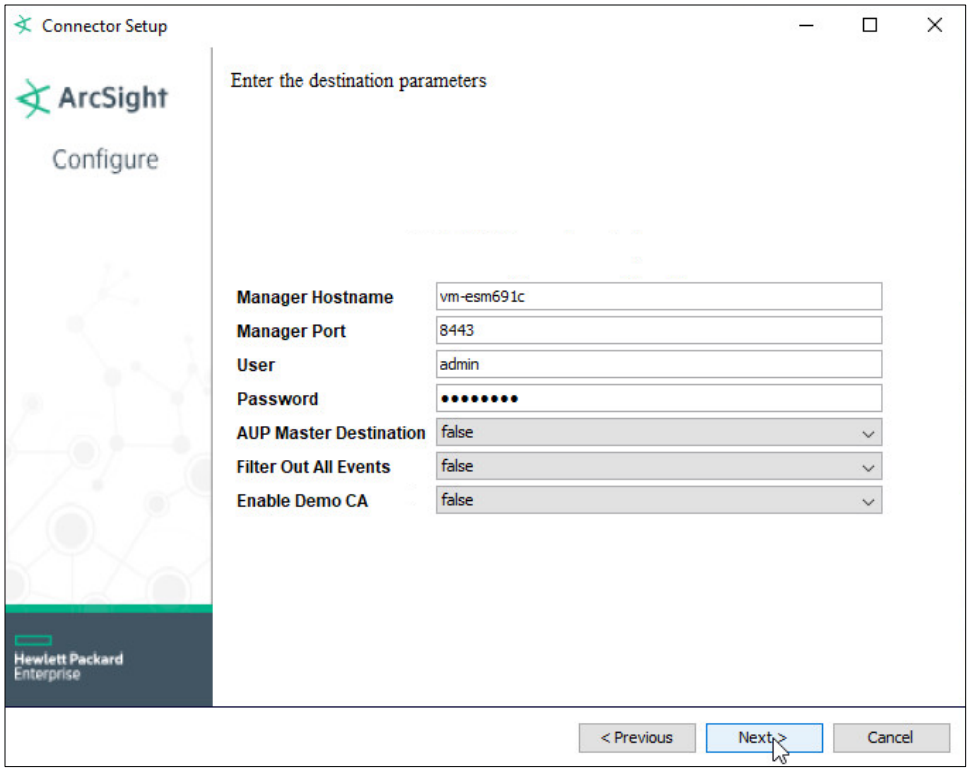
16. Click **Next**.



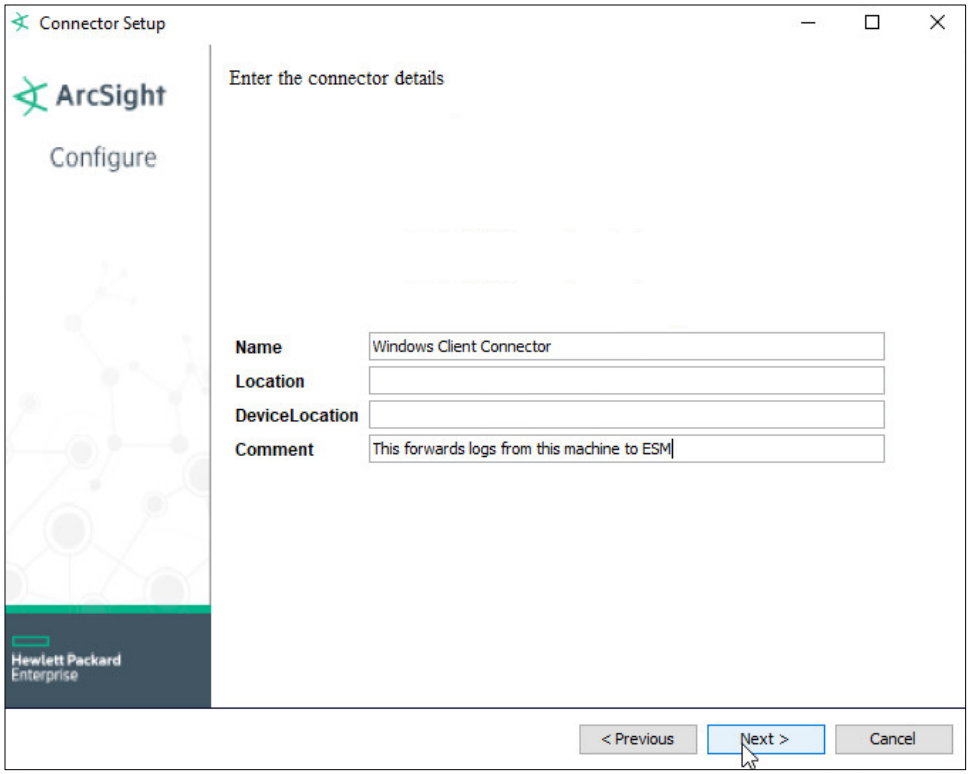
17. Click **Next**.
18. Choose **ArcSight Manager (encrypted)**.



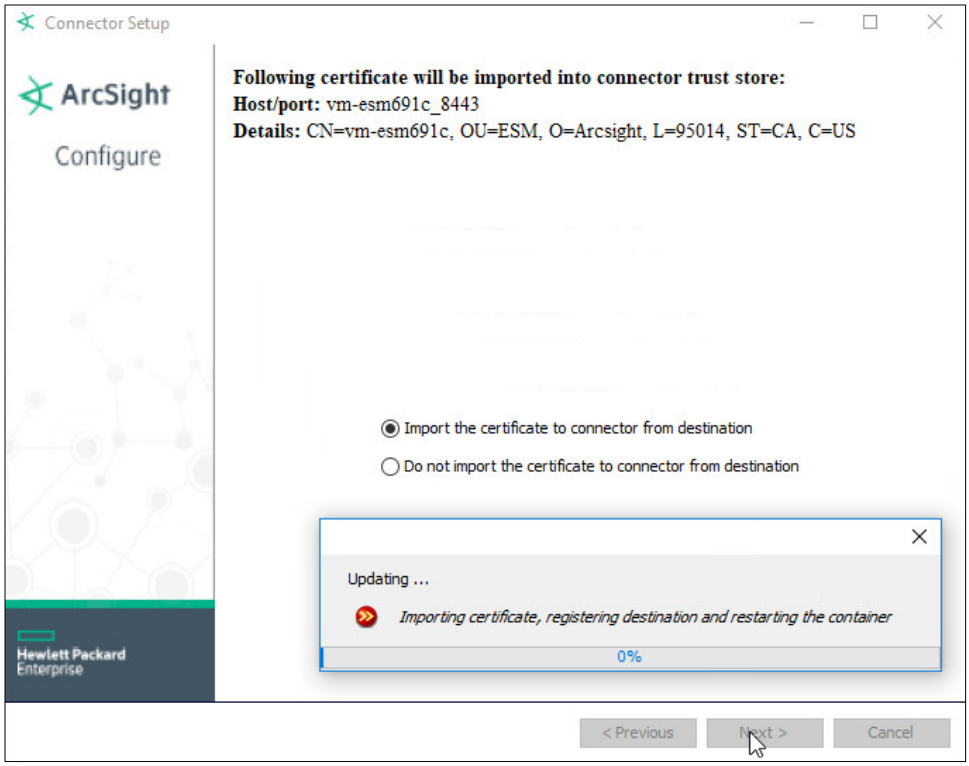
19. Click **Next**.
20. For **Manager Hostname**, put **vm-esm691c**, or the hostname of your ESM server.
21. For **Manager Port**, put **8443** (or the port that ESM is running on) on the ESM server.
22. Enter the username and password used for logging into **ArcSight Command Center**. Default: (admin/password)



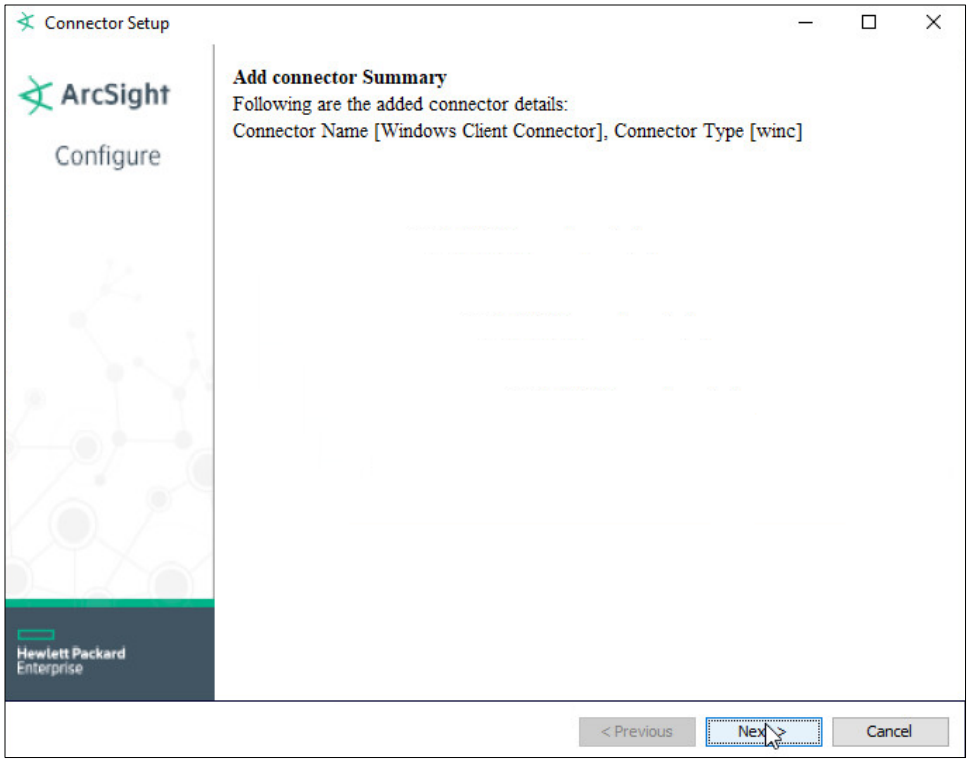
23. Click **Next**.
24. Set identifying details about the system to help identify the connector (include a value for **Name**; the rest is optional).



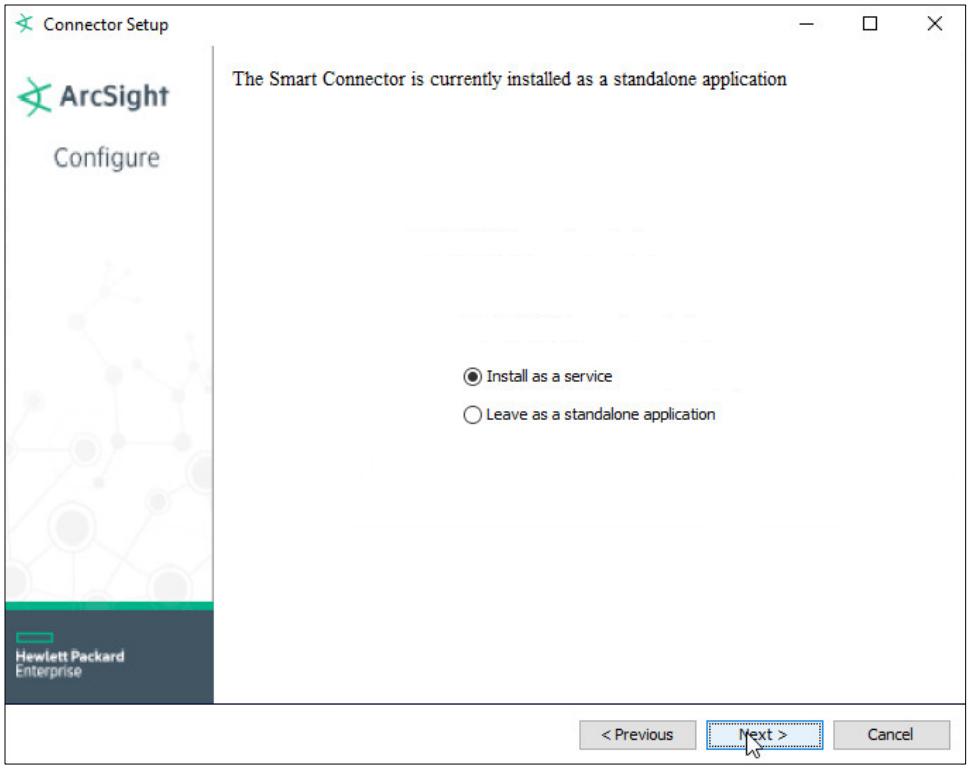
25. Click **Next**.
26. Select **Import the certificate to connector from destination**. This will fail if the **Manager Hostname** does not match the hostname of the Virtual Machine.



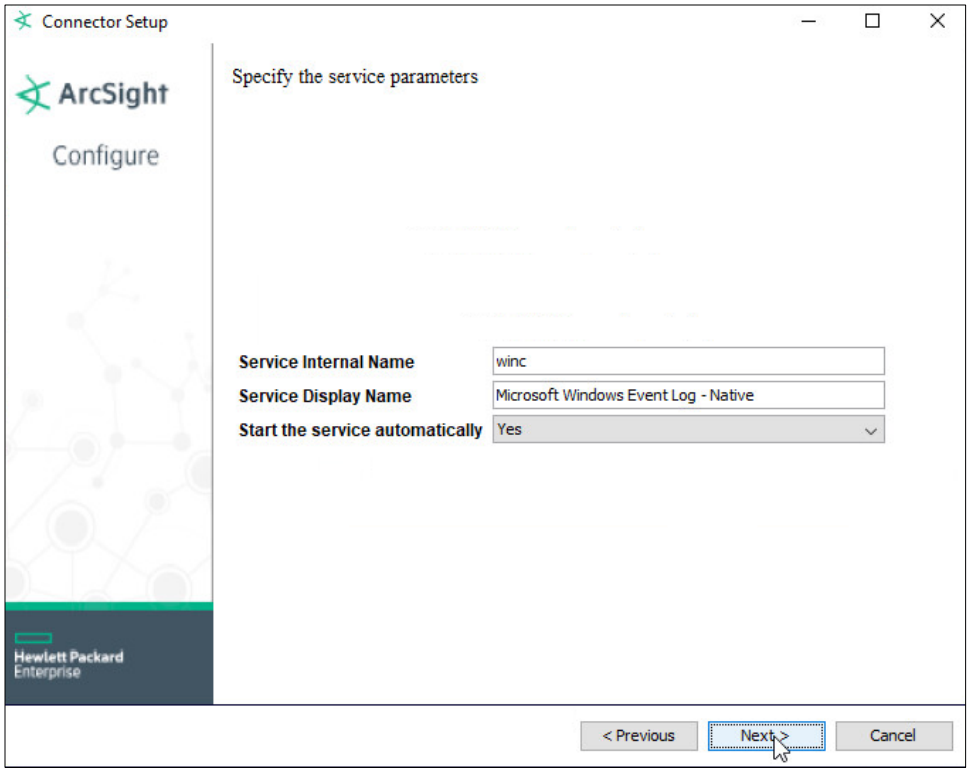
27. Click **Next**.



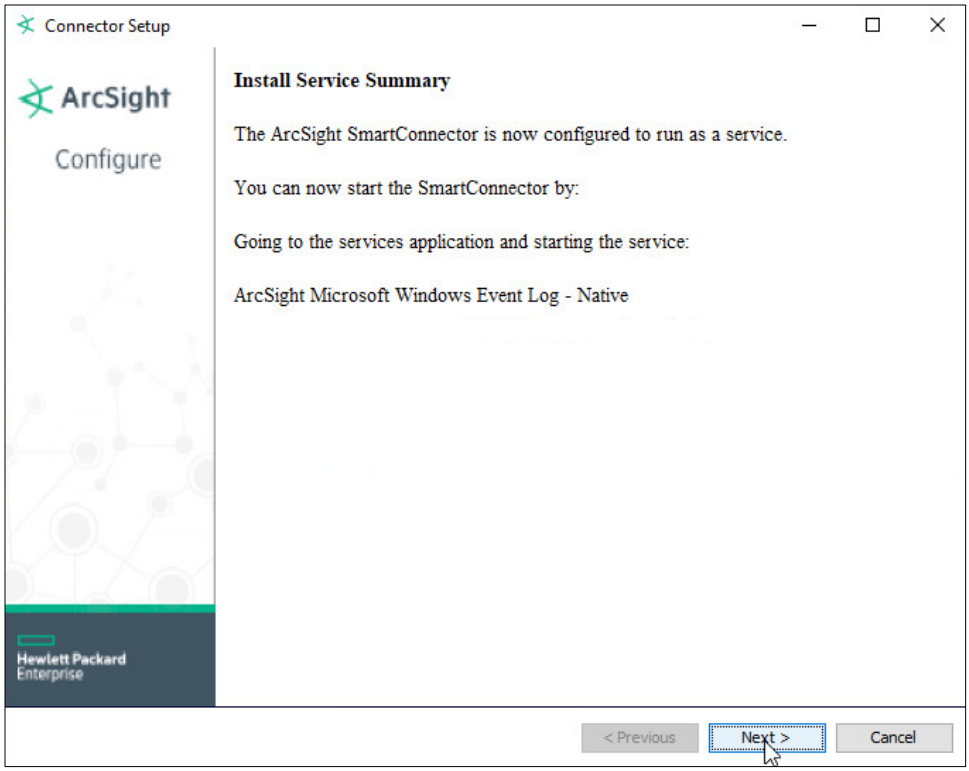
28. Click **Next**.
29. Choose **Install as a service**.



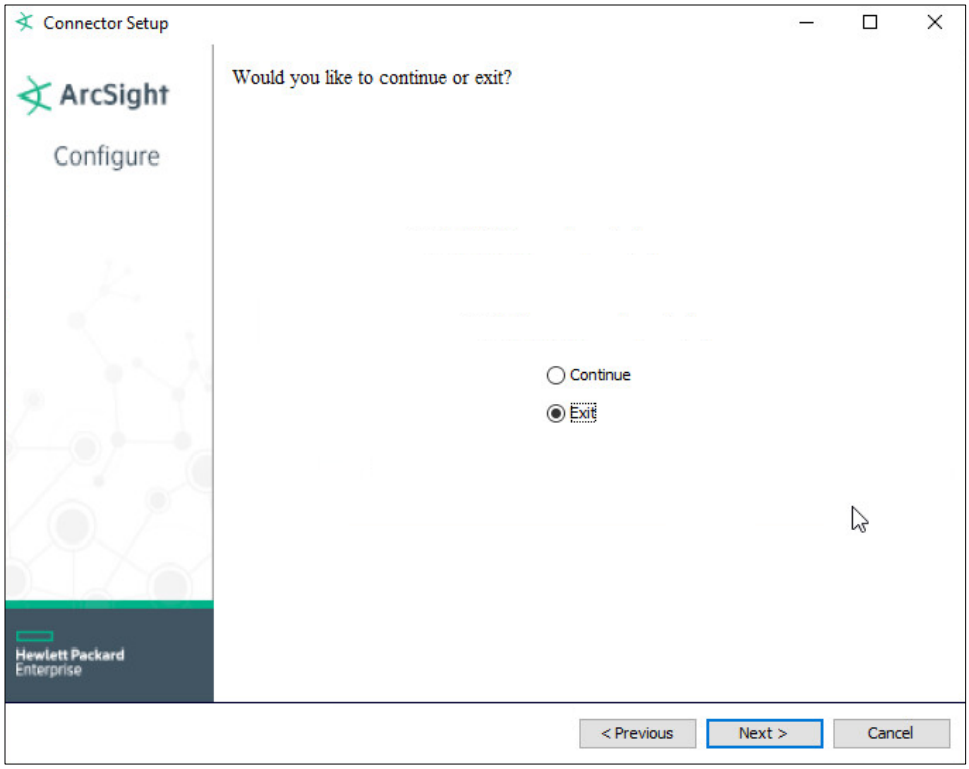
30. Click **Next**.



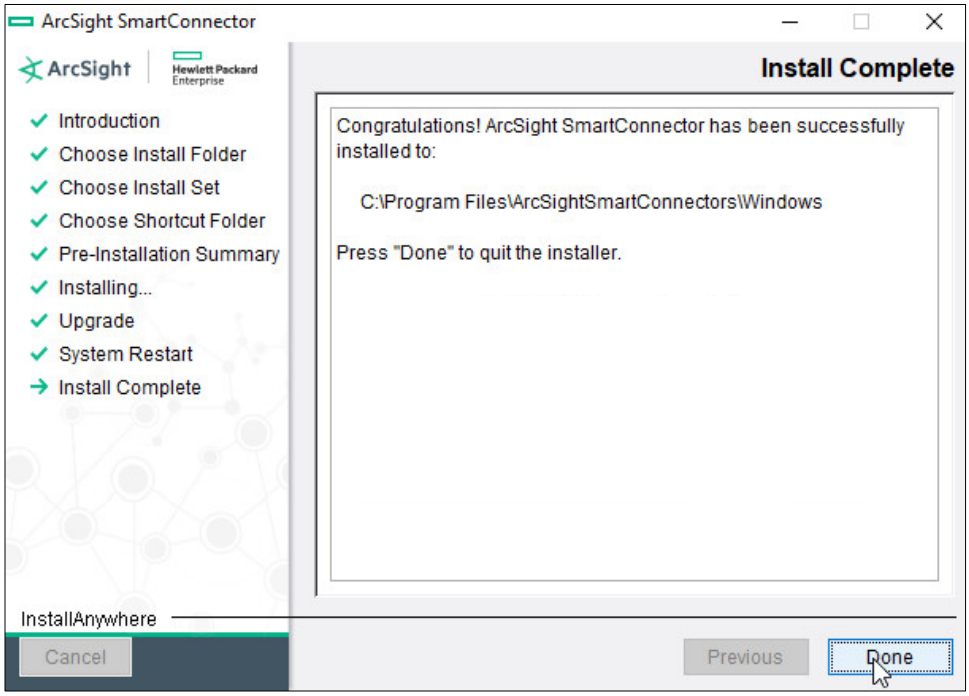
31. Click **Next**.



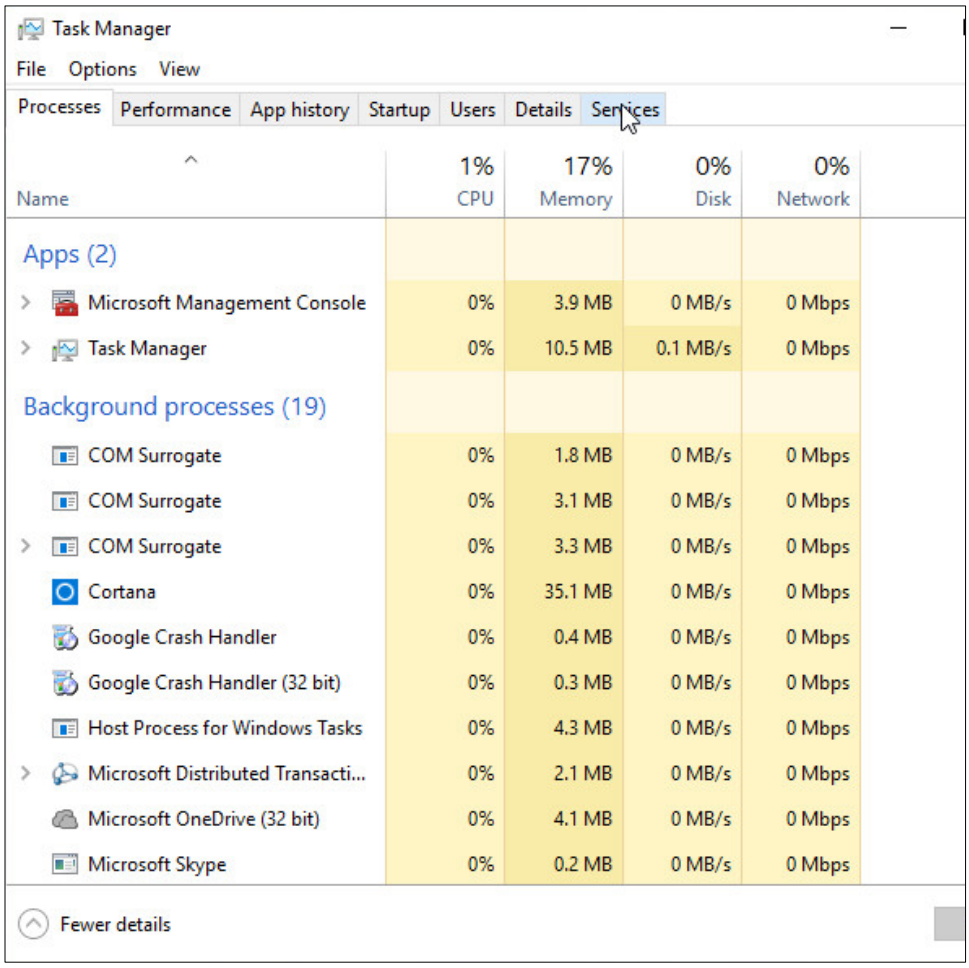
32. Click **Next**.
33. Choose **Exit**.



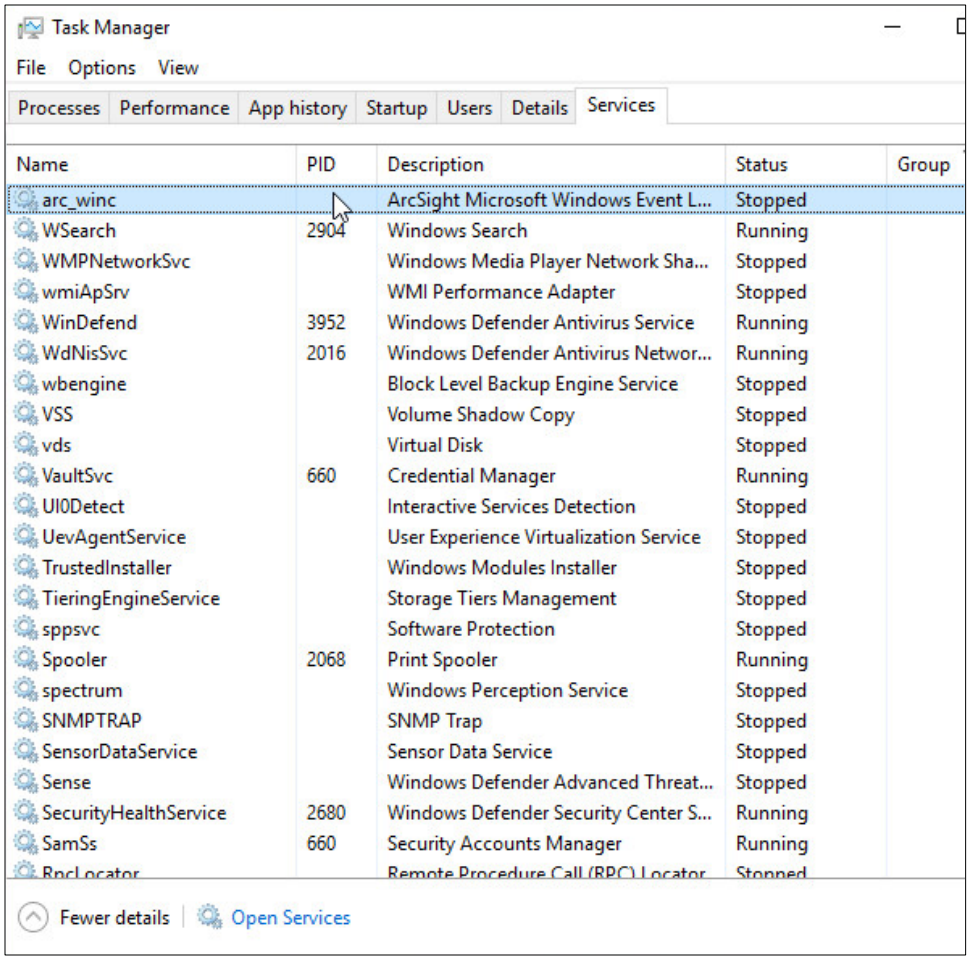
34. Click **Next**.



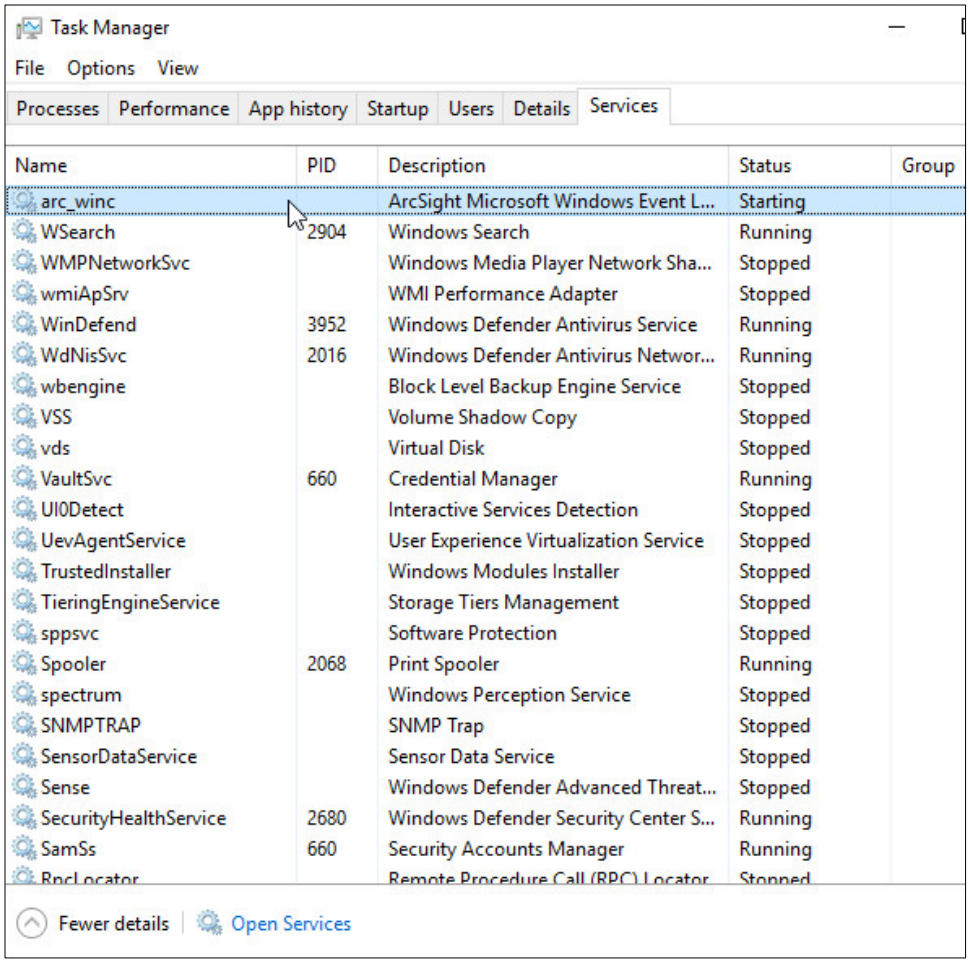
35. Click **Done**.
36. Open **Task Manager**.
37. Click **More Details**.



38. Go to the **Services** tab.
39. Find the service just created for ArcSight and right click it.



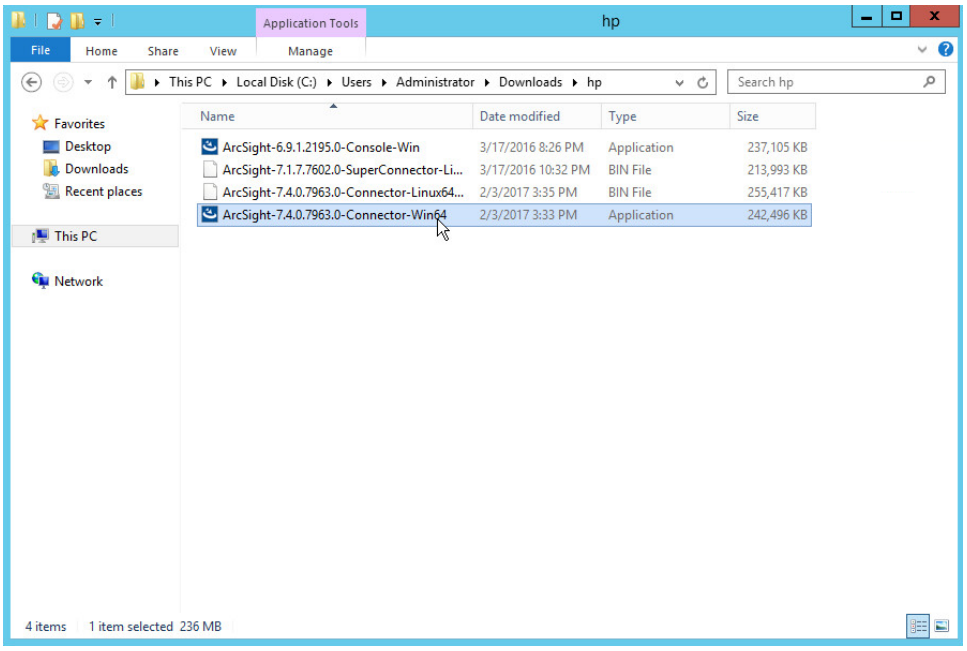
40. Choose **Start**.



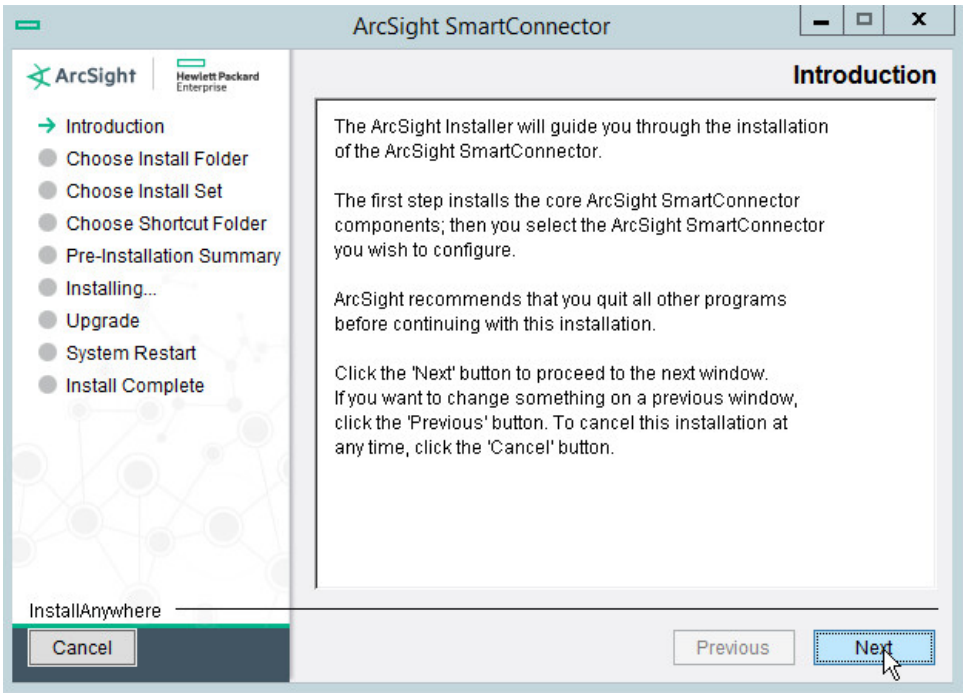
41. The machine will now report its logs to ArcSight ESM.

2.6.2 Install a Connector Server for ESM on Windows 2012 R2

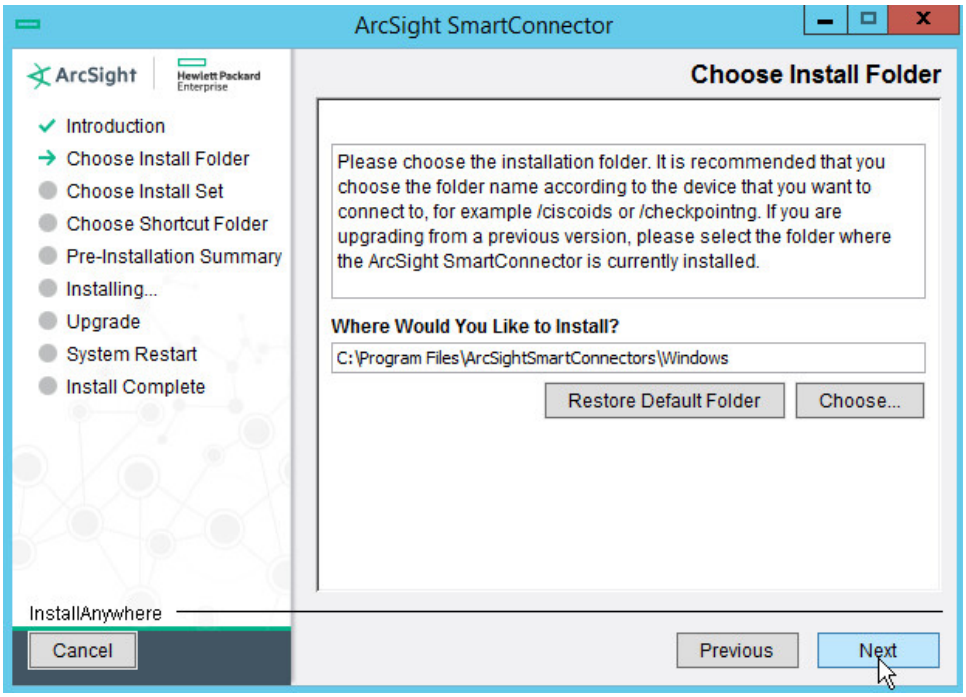
1. Run the installation file **ArcSight-7.4.0.7963.0-Connector-Win64**.



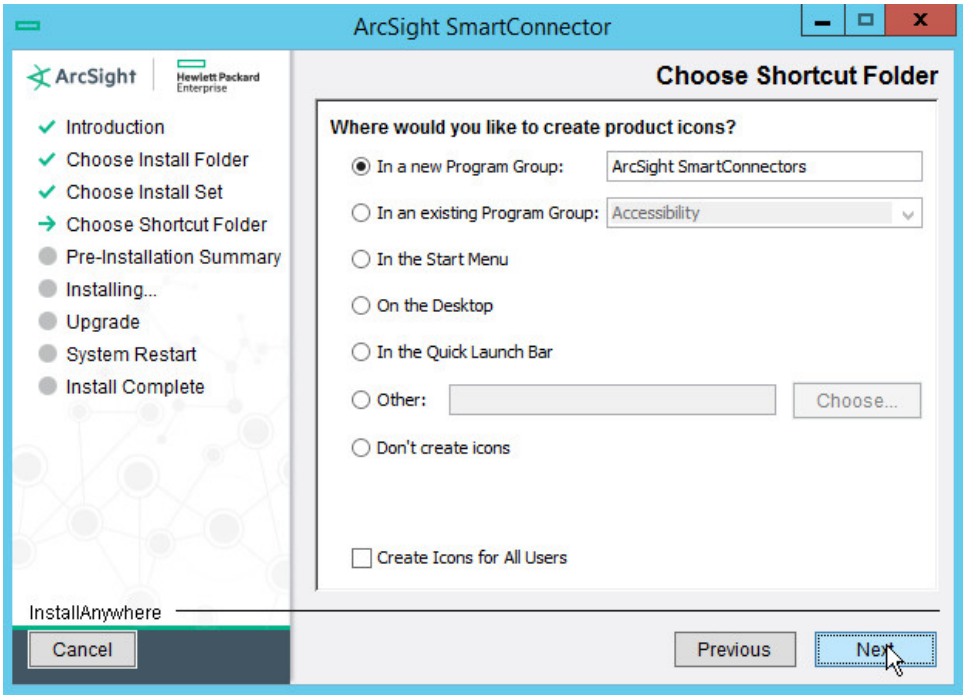
2. Wait for the initial setup to finish.



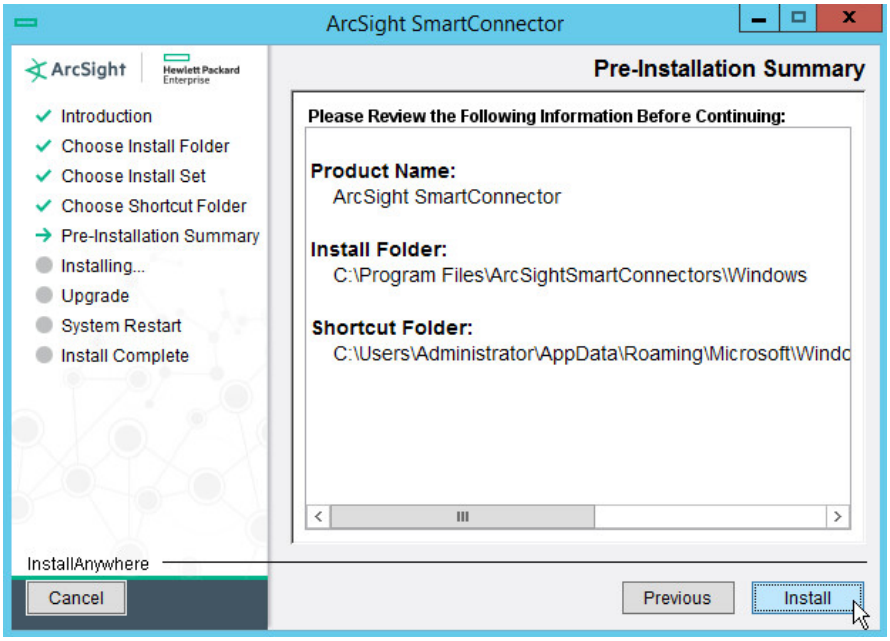
3. Click **Next**.
4. Choose a destination folder. Note: It is recommended to change the default destination folder to `<default>\Windows`. This is to avoid conflicts if you wish to install more than one connector.



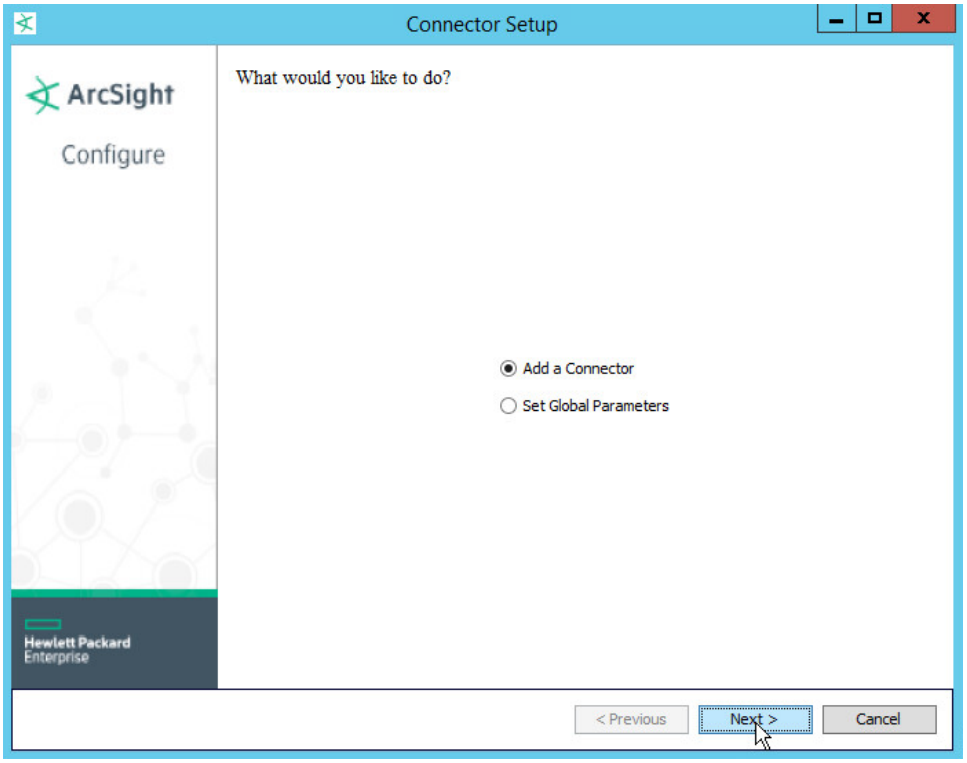
5. Click **Next**.



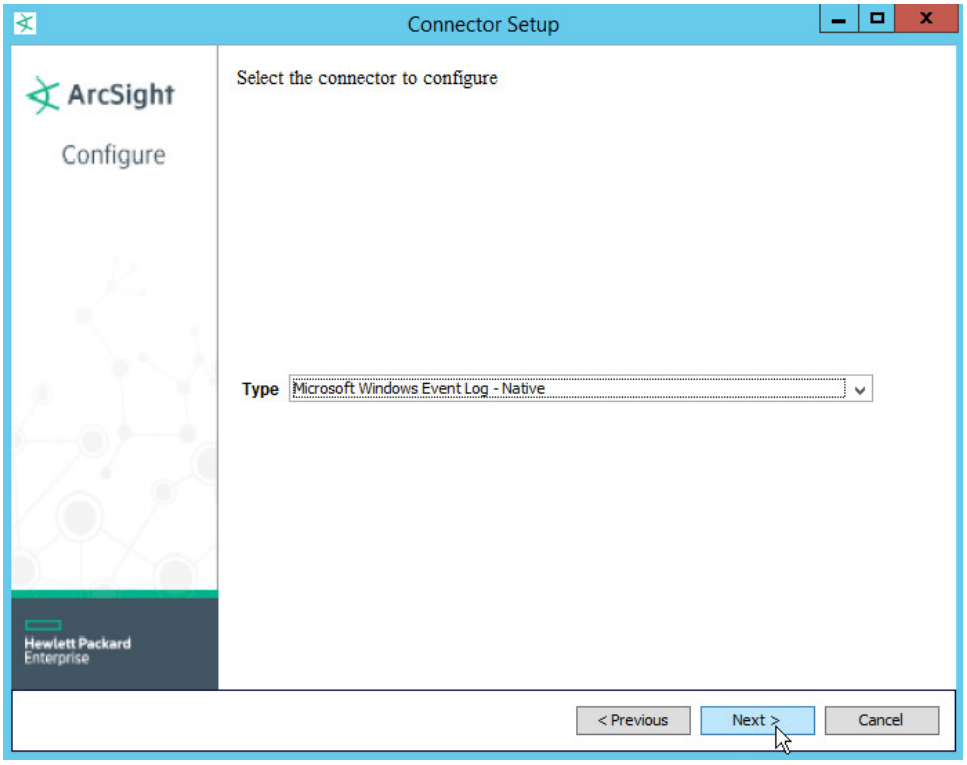
6. Click **Next**.



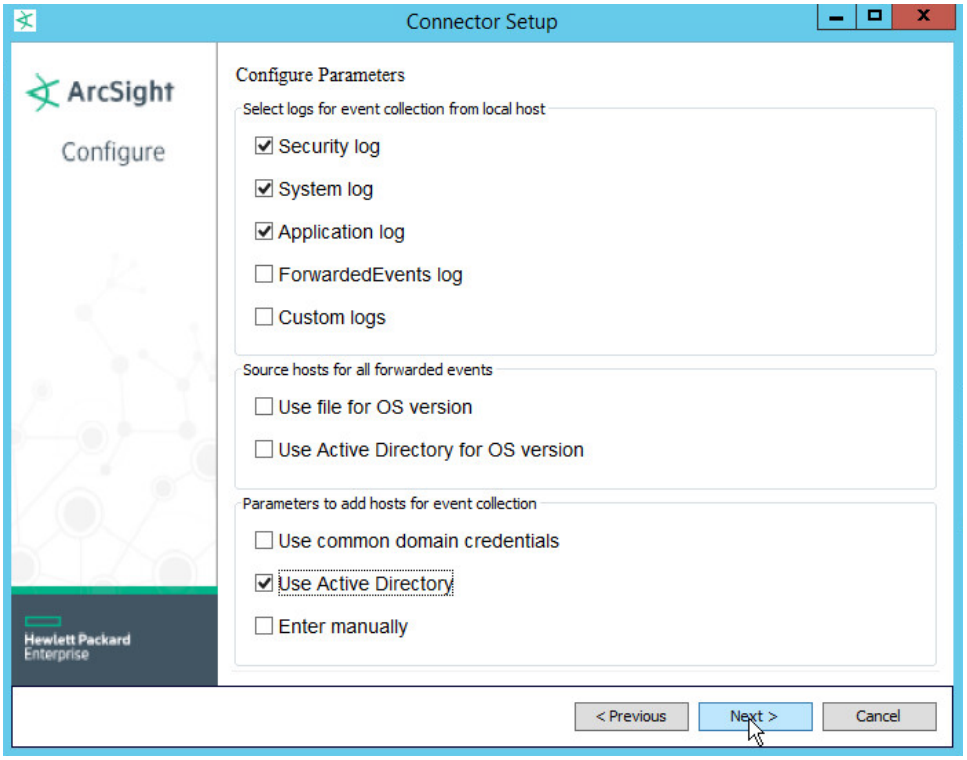
7. Click **Install**.
8. Wait for the installation to finish.
9. Select **Add a Connector**.



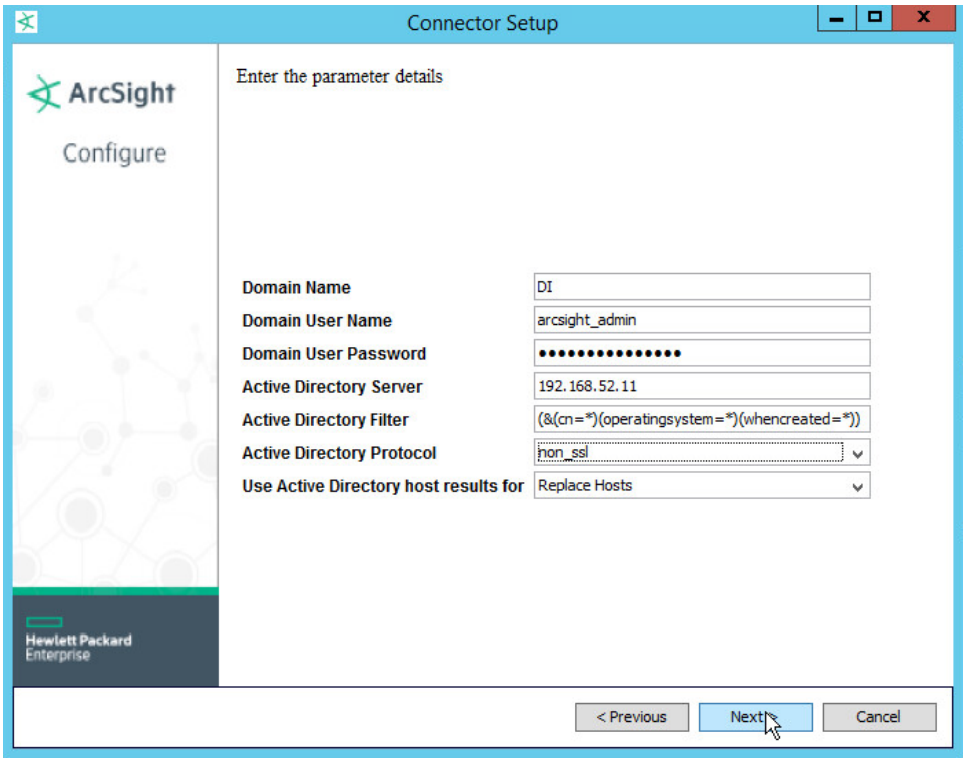
10. Click **Next**.
11. Choose **Microsoft Windows Event Log - Native** from the list.



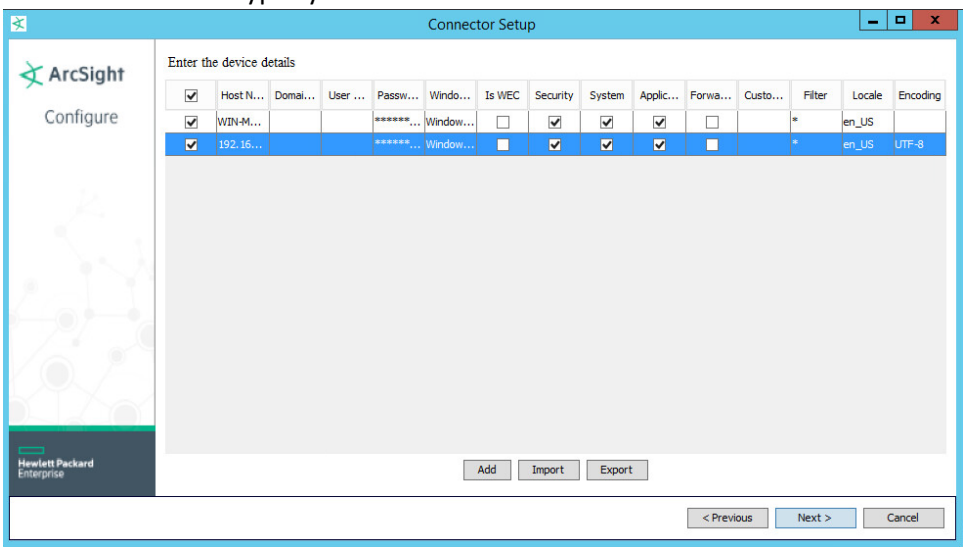
12. Click **Next**.
13. Check **Security log**, **System log**, **Application Log**.
14. Check **Use Active Directory**.



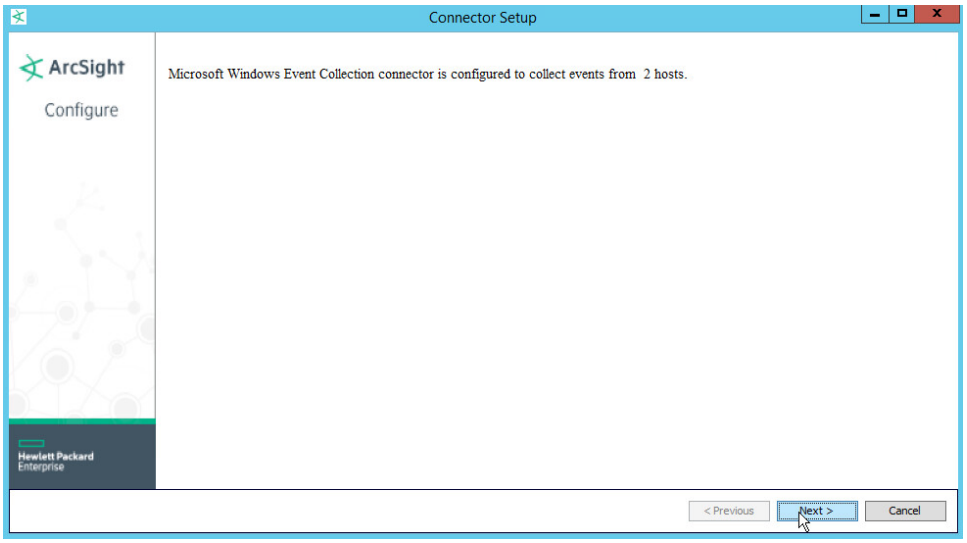
15. Click **Next**.
16. Fill out the form with the appropriate information for your Active Directory server. It is recommended to create an account on Active Directory specifically for ArcSight.
17. Select **Replace Hosts** for **Use Active Directory host results for**.



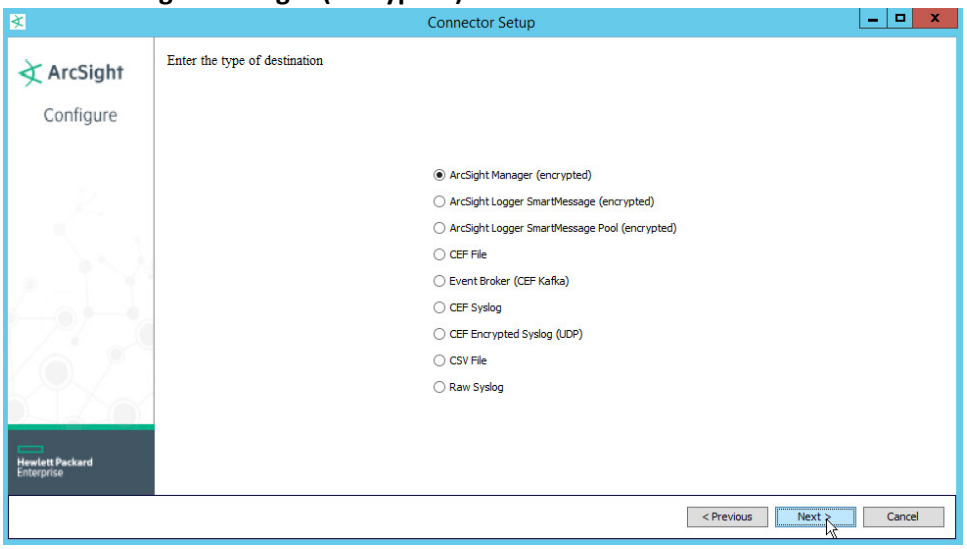
18. Click **Next**.
19. Select all the event types you would like forwarded from each machine.



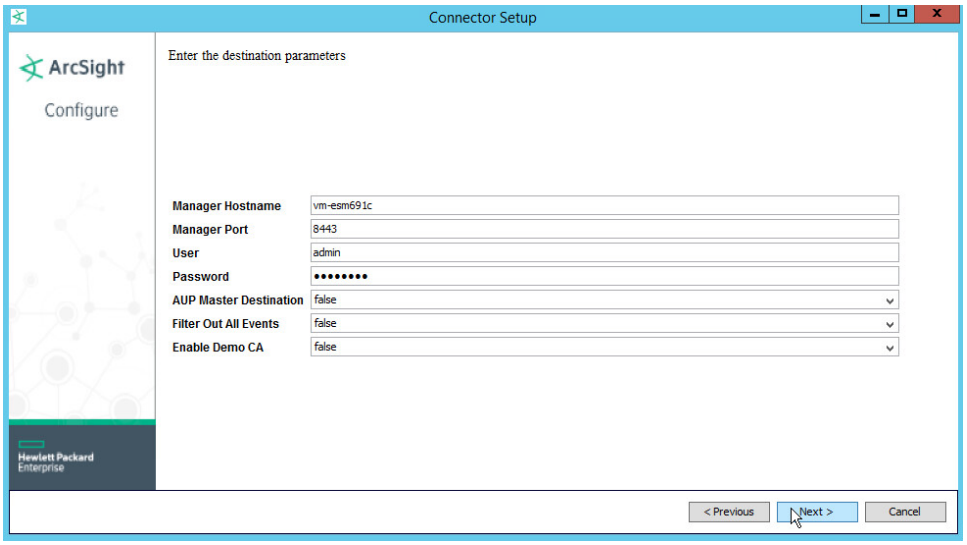
20. Click **Next**.



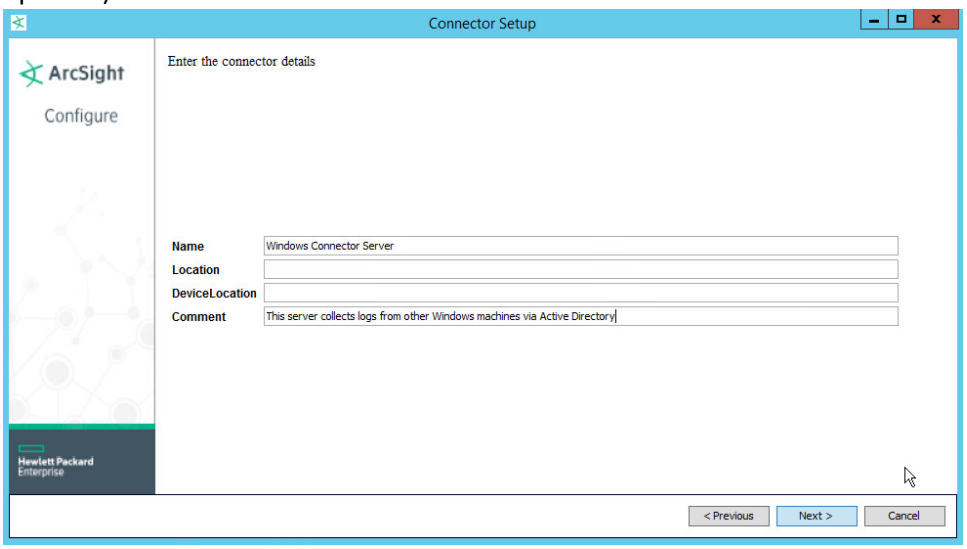
21. Click **Next**.
22. Choose **ArcSight Manager (encrypted)**.



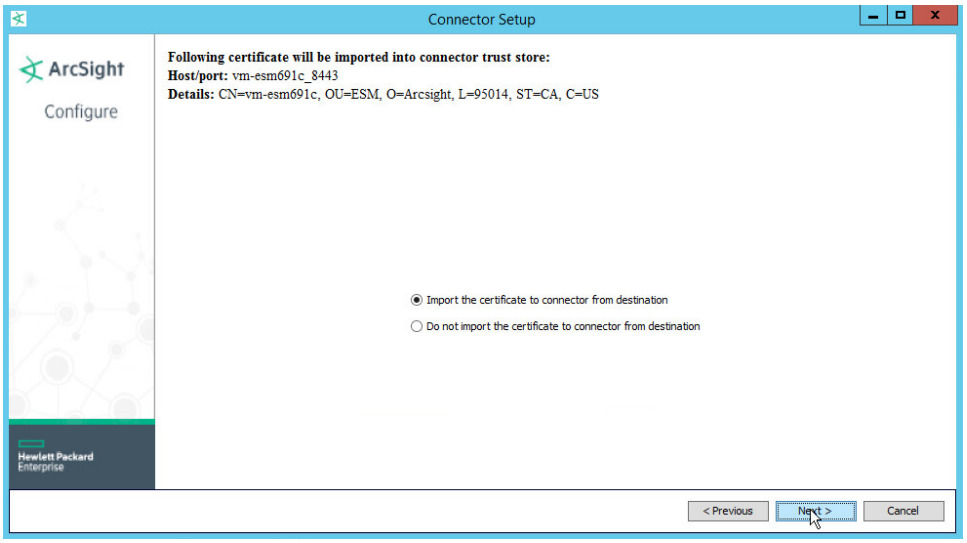
23. Click **Next**.
24. For **Manager Hostname**, use **vm-esm691c** or the hostname of your ESM server.
25. For **Manager Port**, use **8443** (or the port that ESM is running on) on the ESM server.
26. Enter the username and password used for logging into **ArcSight Command Center**. Default: (admin/password)



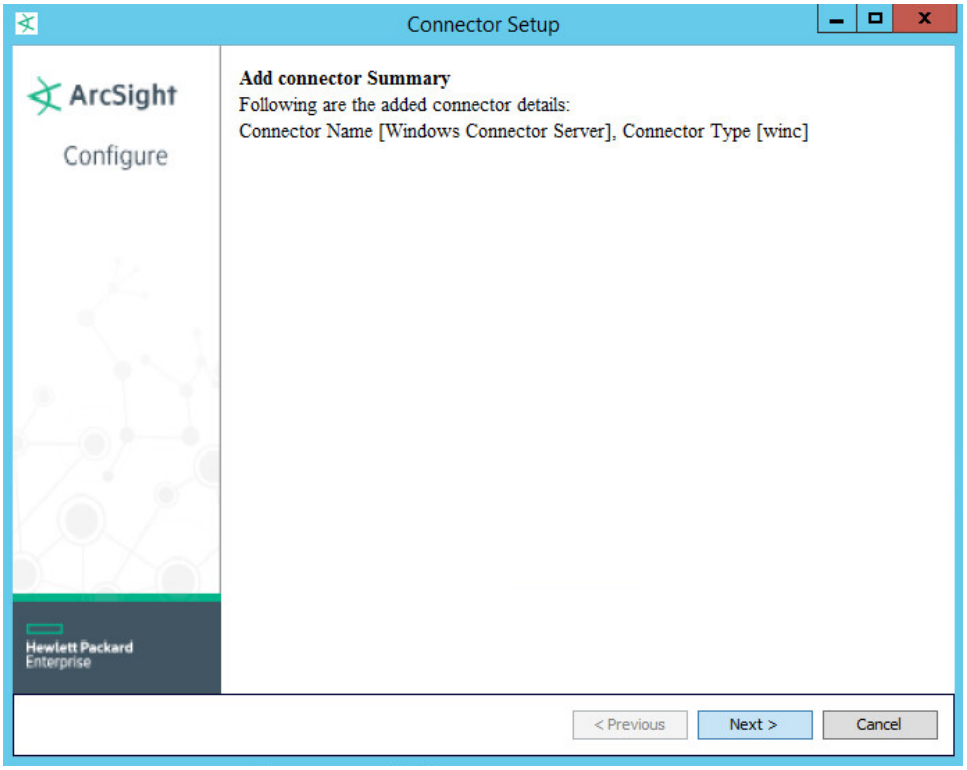
27. Click **Next**.
28. Set identifying details about the system to help identify the connector (include **Name;** the rest is optional).



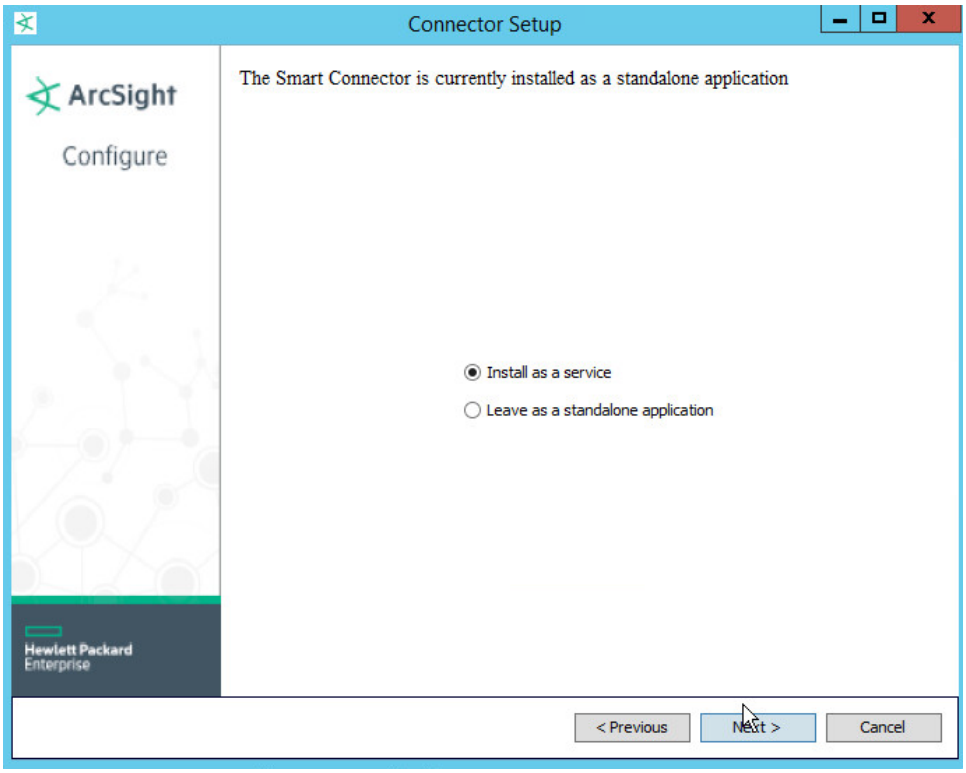
29. Click **Next**.
30. Select **Import the certificate to connector from destination**. This will fail if the **Manager Hostname** does not match the hostname of the VM.



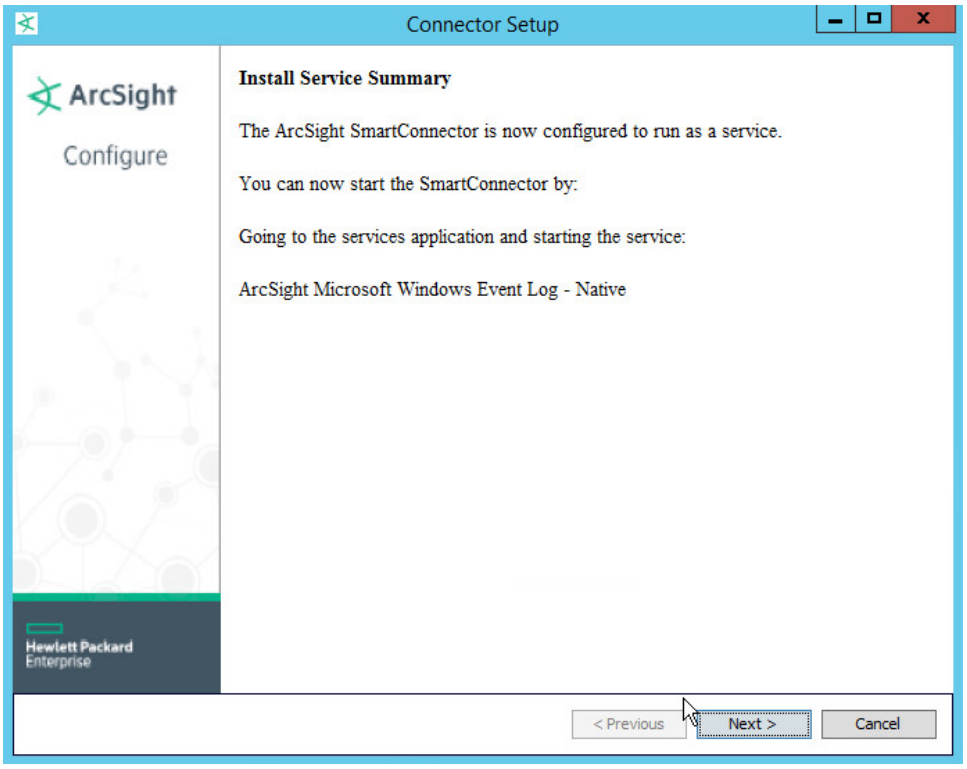
31. Click **Next**.



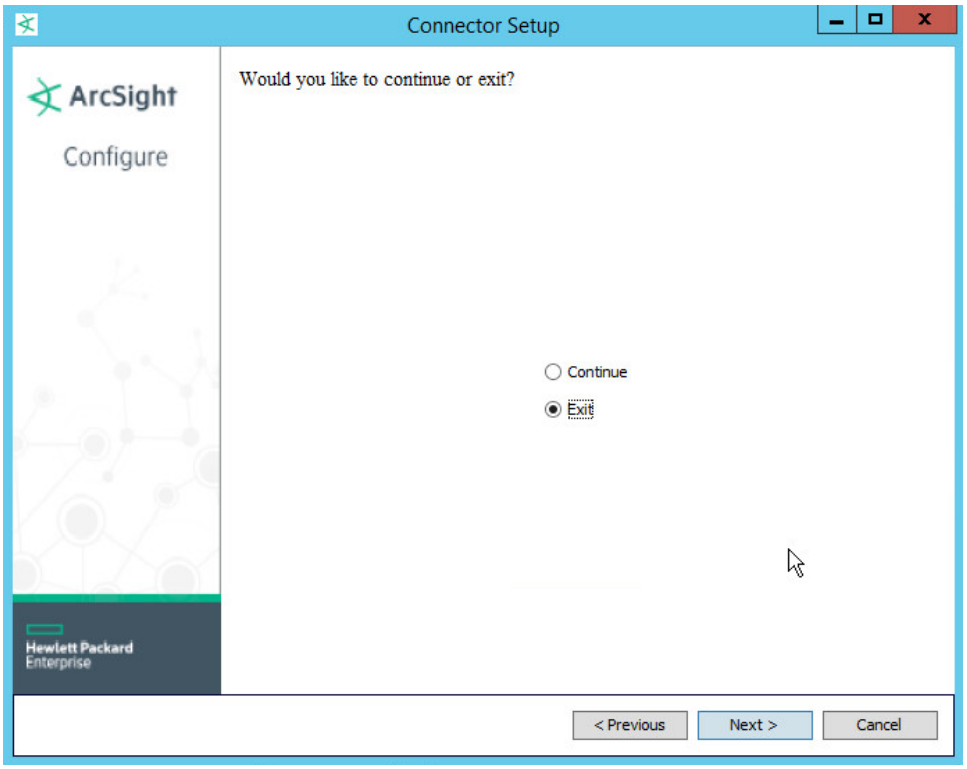
32. Click **Next**.
33. Choose **Install as a service**.



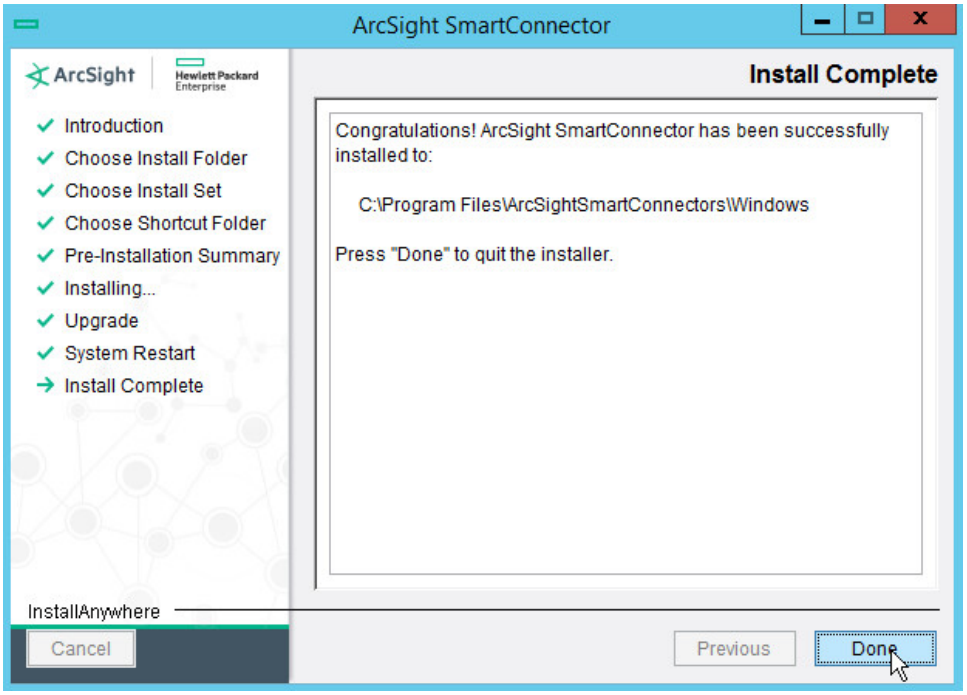
34. Click **Next**.



35. Click **Next**.
36. Choose **Exit**.

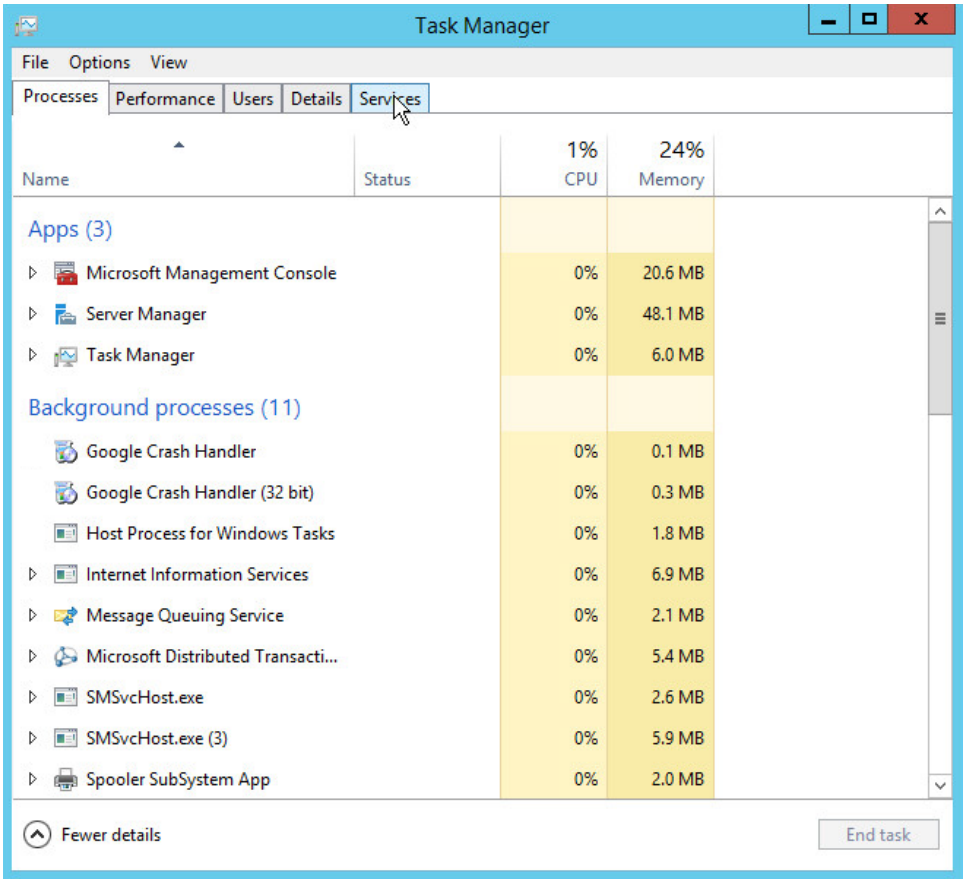


37. Click **Next**.

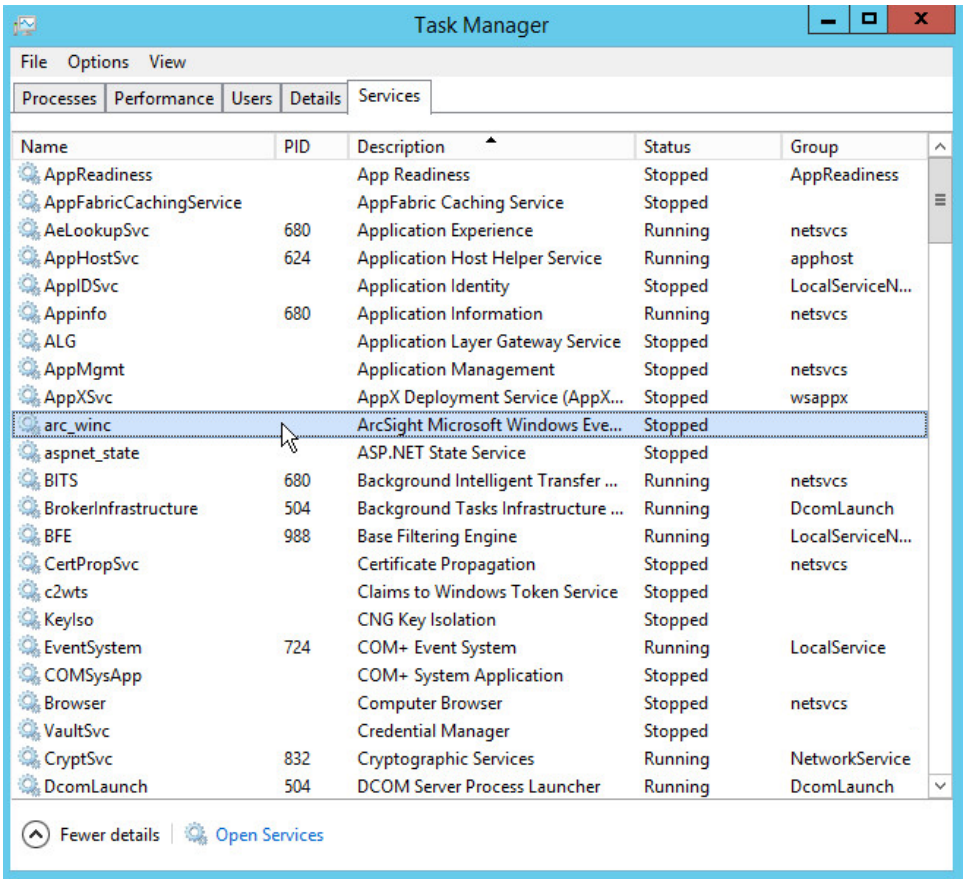


38. Click **Done**.

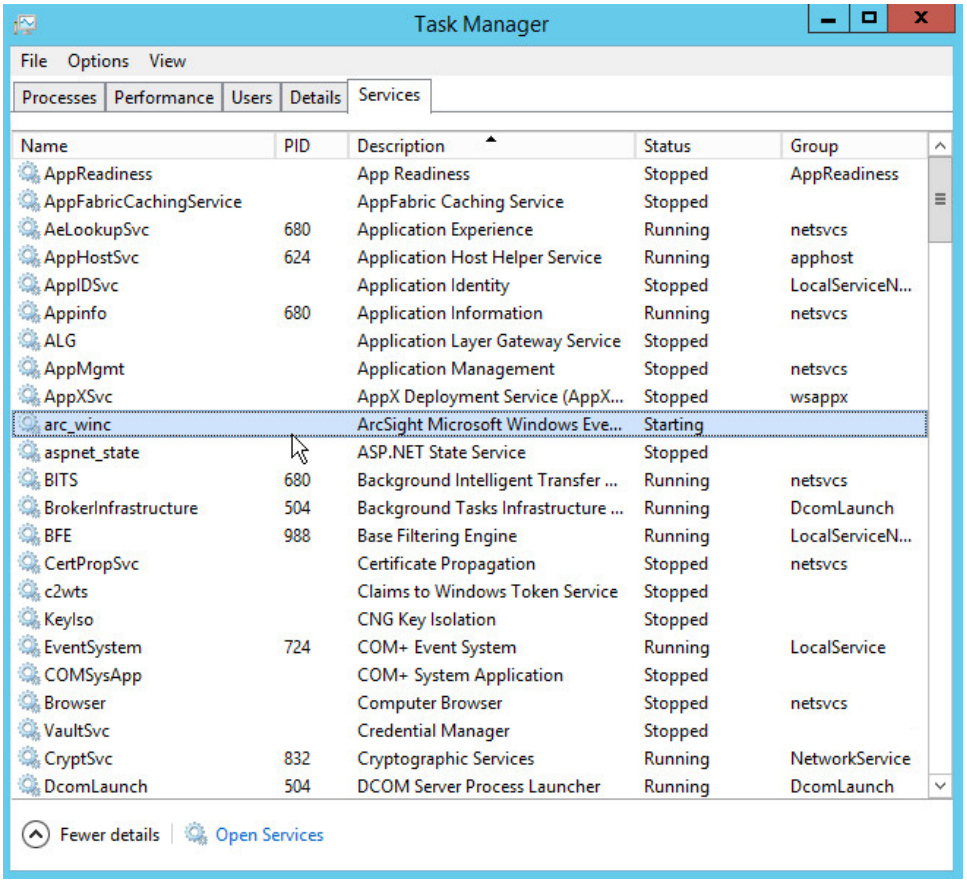
39. Open **Task Manager**.
40. Click **More Details**.



41. Go to the **Services** tab.
42. Find the service just created for ArcSight and right click it.



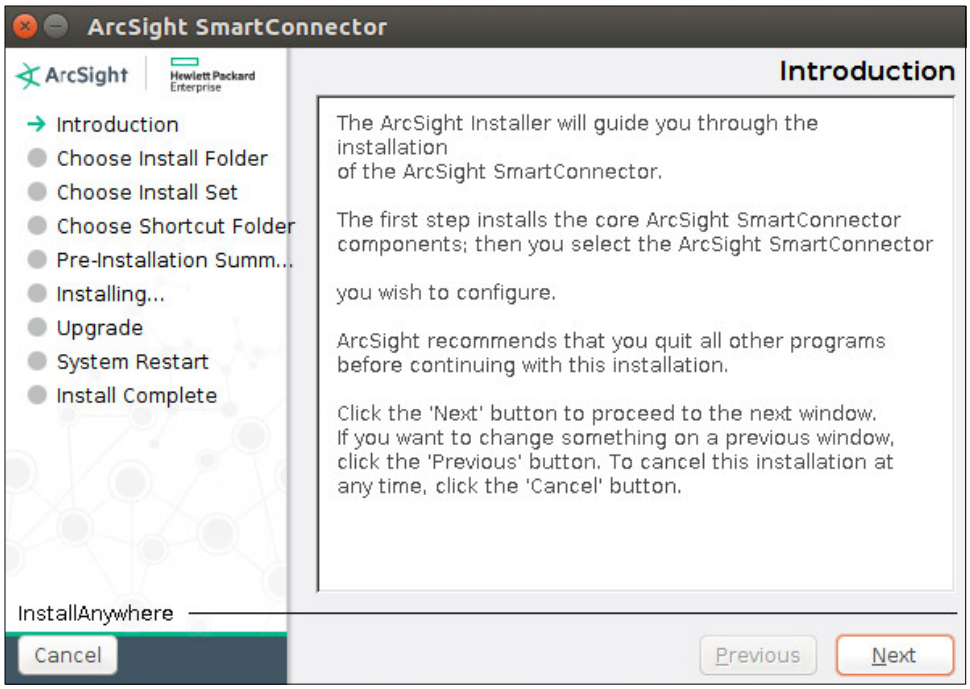
43. Choose **Start**.



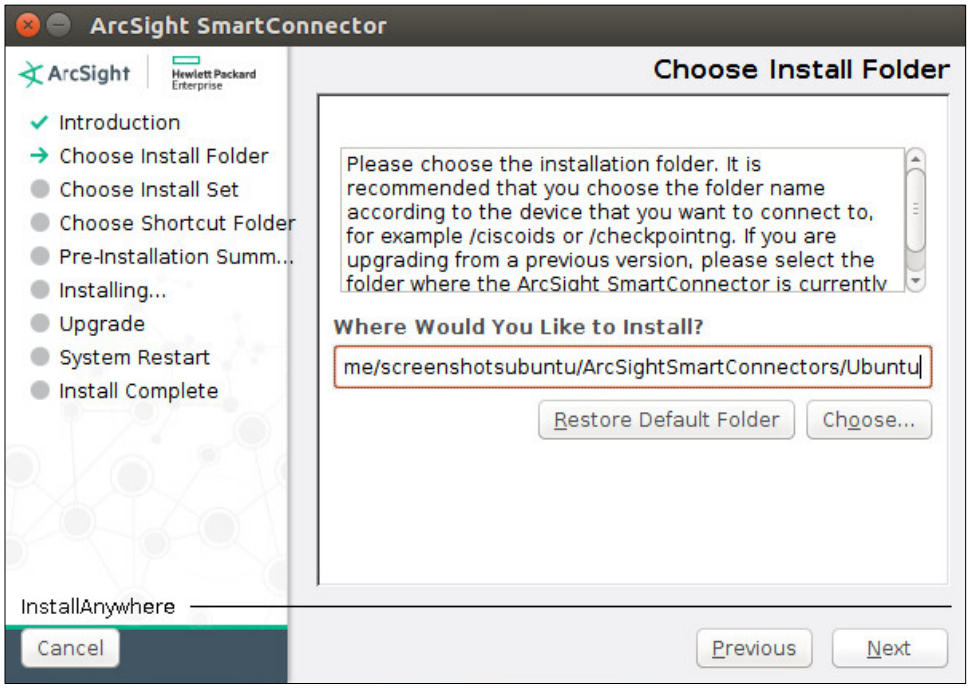
44. The machine will now report all collected Windows logs to ArcSight ESM.

2.6.3 Install Syslog Connector for Ubuntu

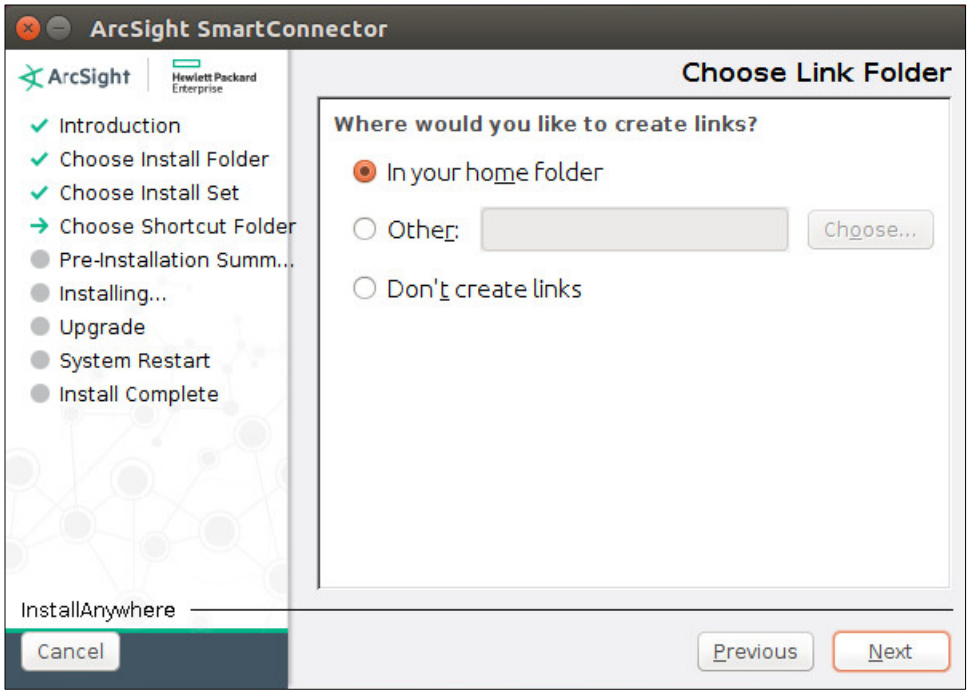
1. Run `./ArcSight-7.4.0.7963.0-Connector-Linux64.bin`.



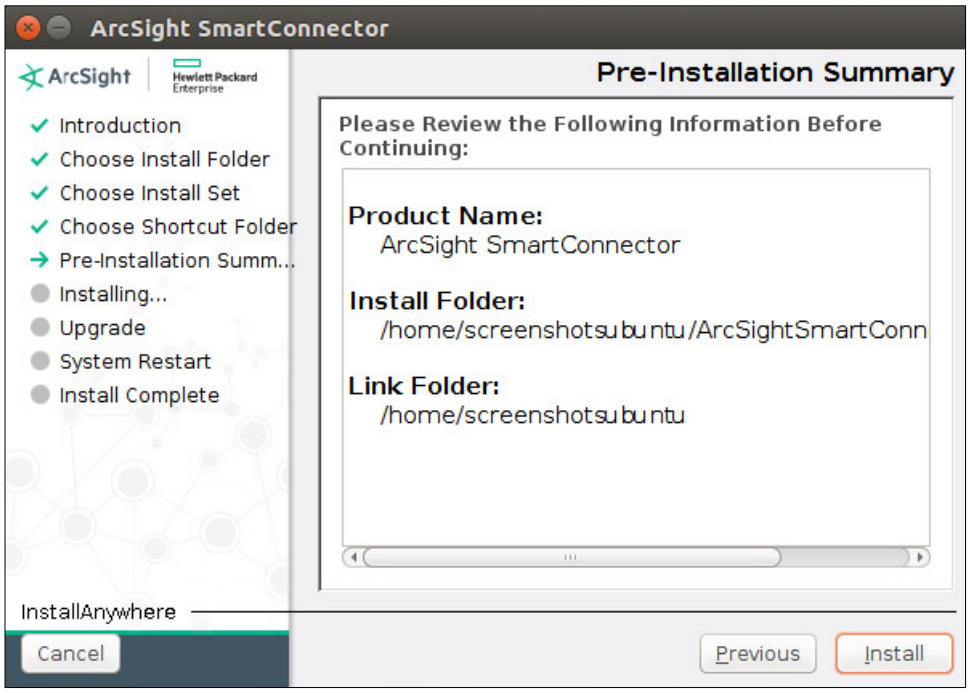
2. Click **Next**.
3. Choose a folder to install the connector in.



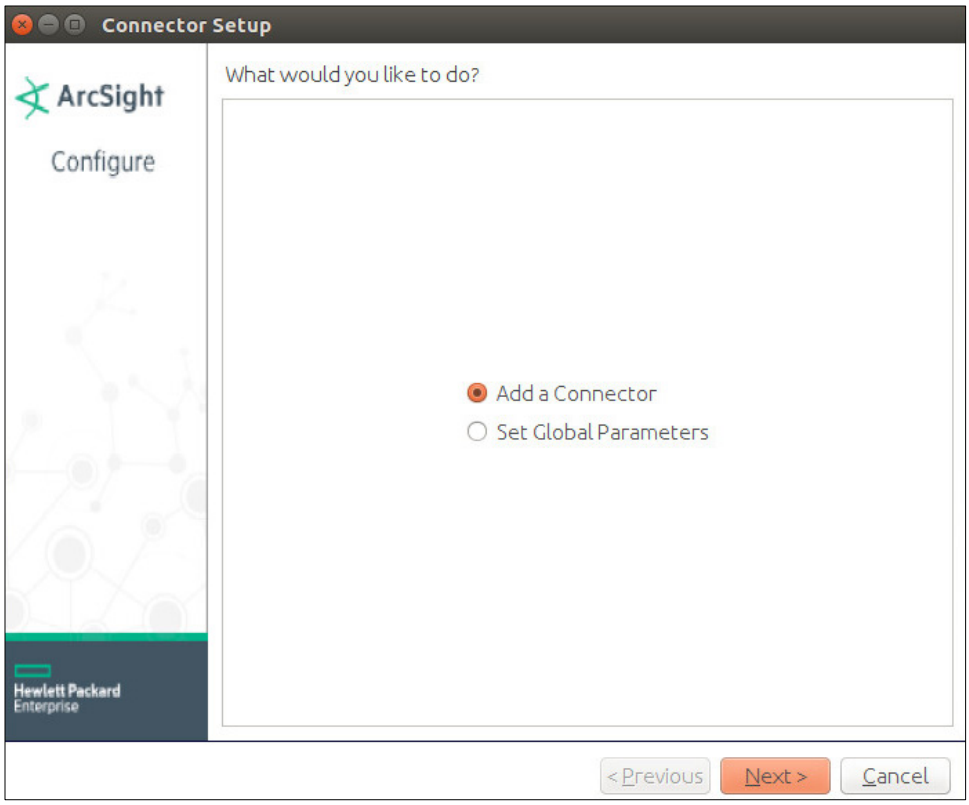
4. Click **Next**.



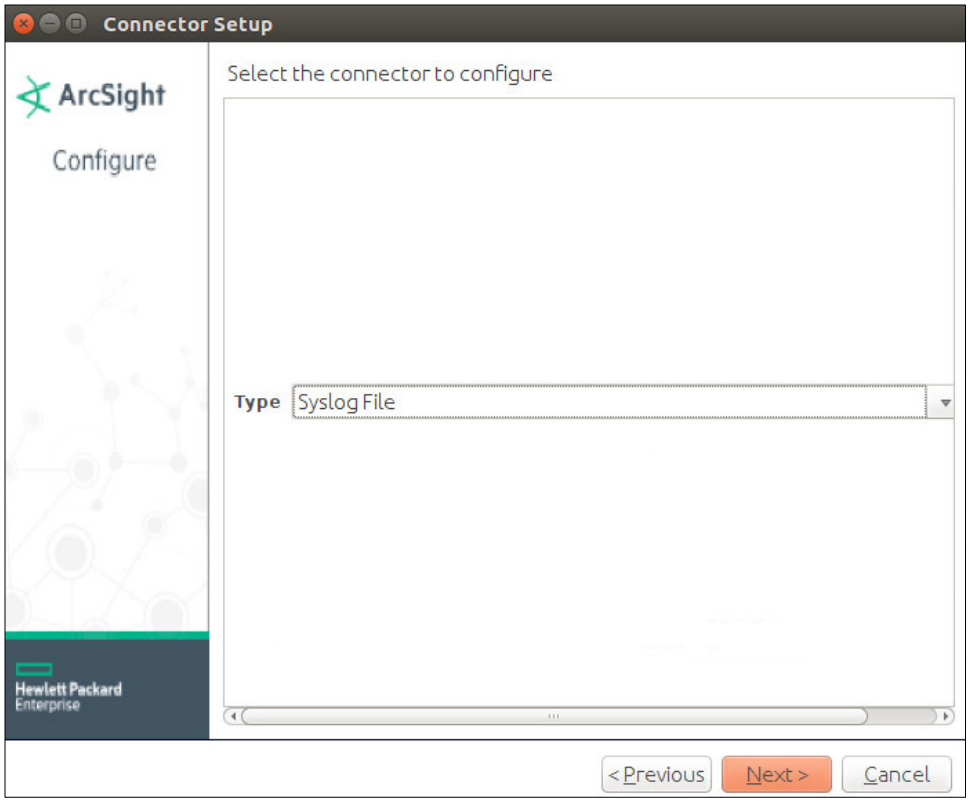
5. Click **Next**.



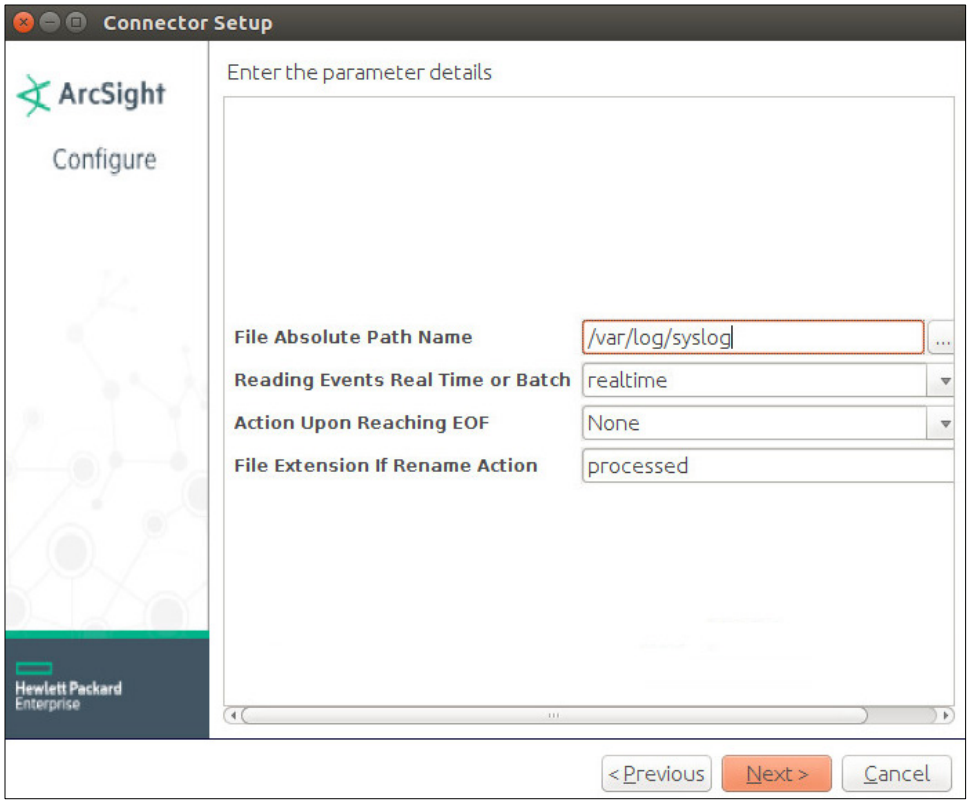
6. Click **Install**.
7. Choose **Add a Connector.**



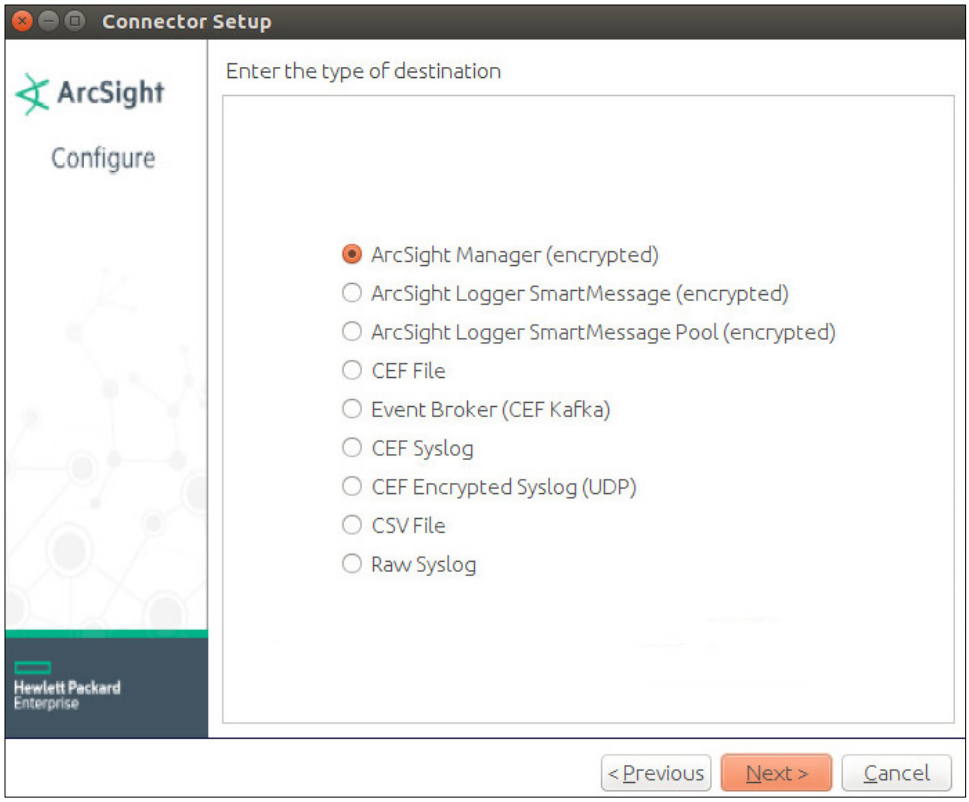
8. Click **Next**.
9. Choose **Syslog File.**



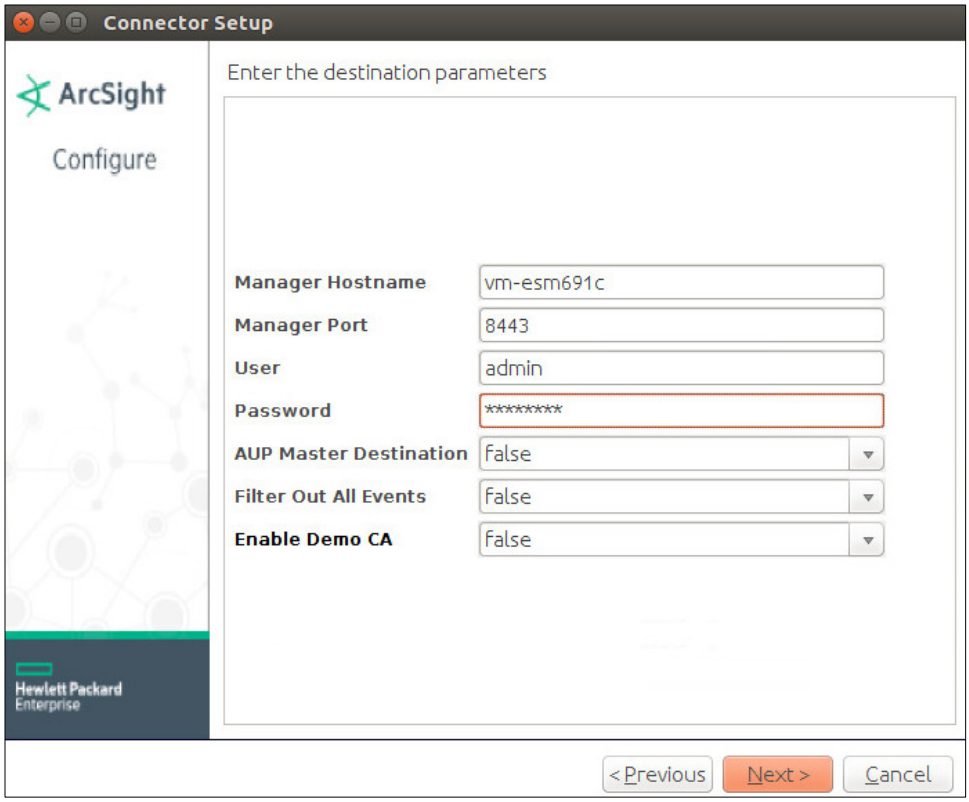
10. Click **Next**.
11. For **File Absolute Path Name**, select a log file from which to forward events to ESM. Example: */var/log/syslog*
12. Select **realtime** to have events be streamed or **batch** to have events sent over in sets.
13. For **Action upon Reaching EOF**, select **None**.



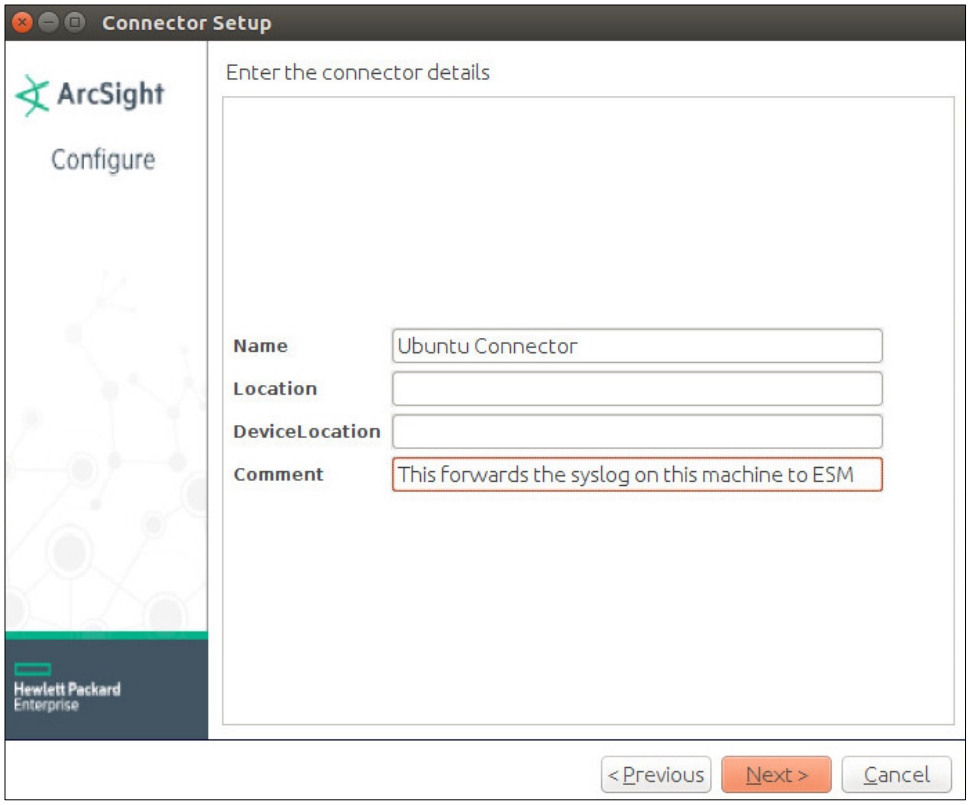
14. Click **Next**.
15. Select **ArcSight Manager (encrypted)**.



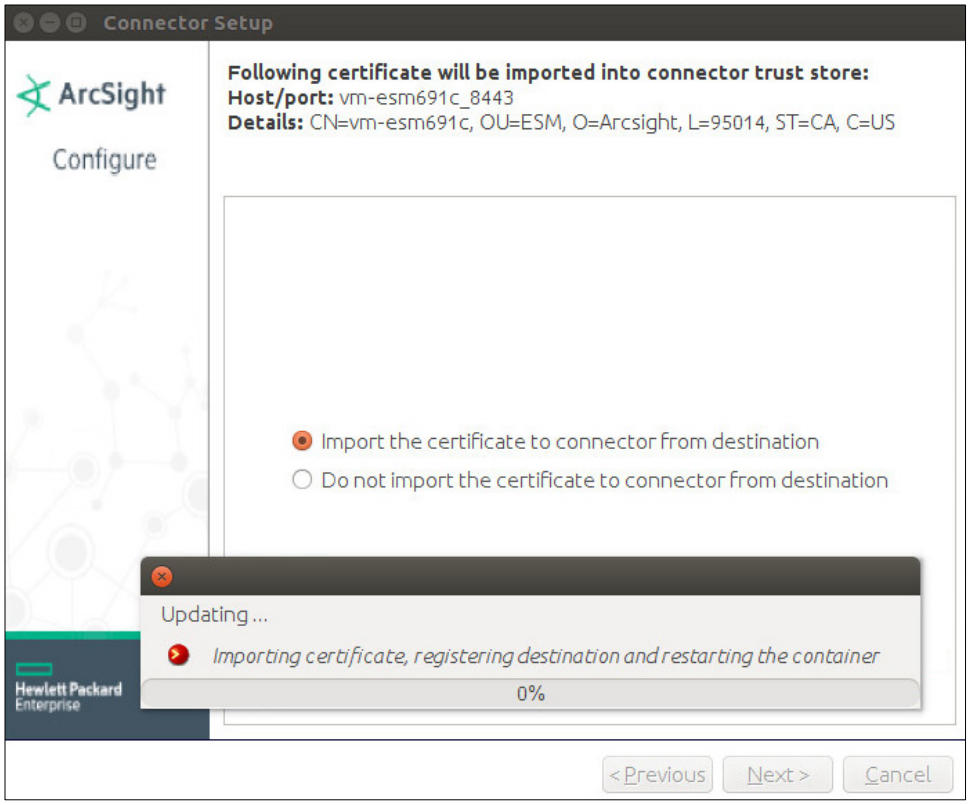
16. Click **Next**.
17. For **Manager Hostname**, put **vm-esm691c** or the hostname of your ESM server. (You may need to add *dns-search.di.test* to */etc/network/interfaces* if the hostname does not resolve on its own. For example, vm-esm691c.di.test may resolve but vm-esm691c may not.)
18. For **Manager Port**, put **8443** (or the port that ESM is running on) on the ESM server.
19. Enter the username and password used for logging into **ArcSight Command Center**. Default: (admin/password)



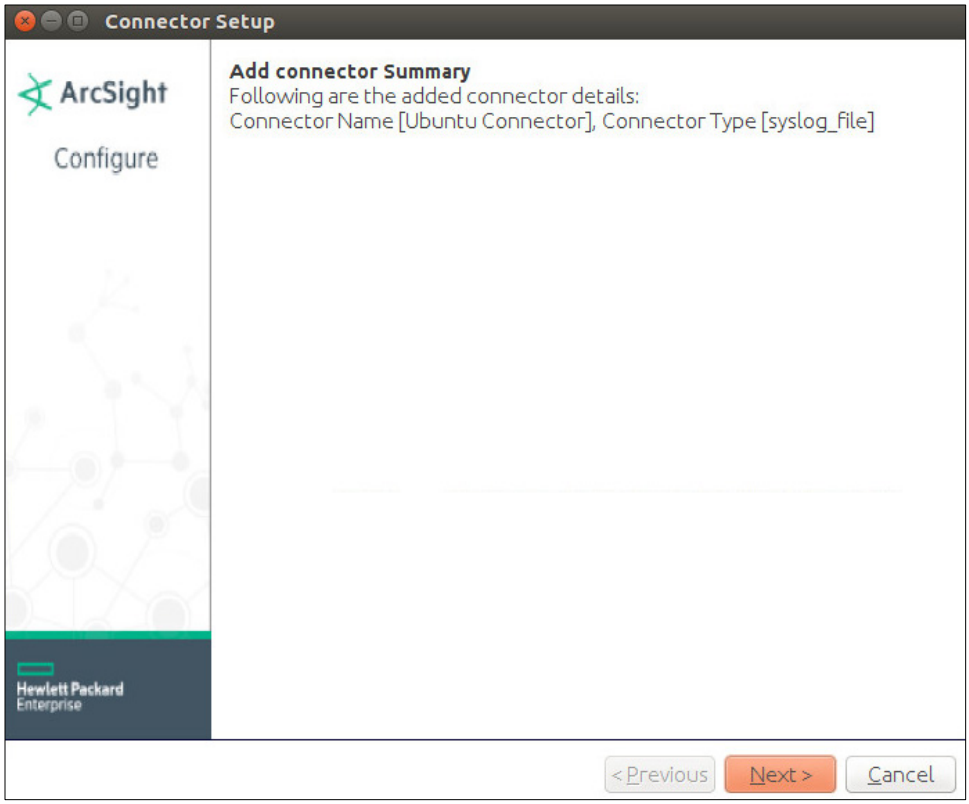
20. Click **Next**.
21. Set identifying details about the system to help identify the connector (include **Name;** the rest is optional).



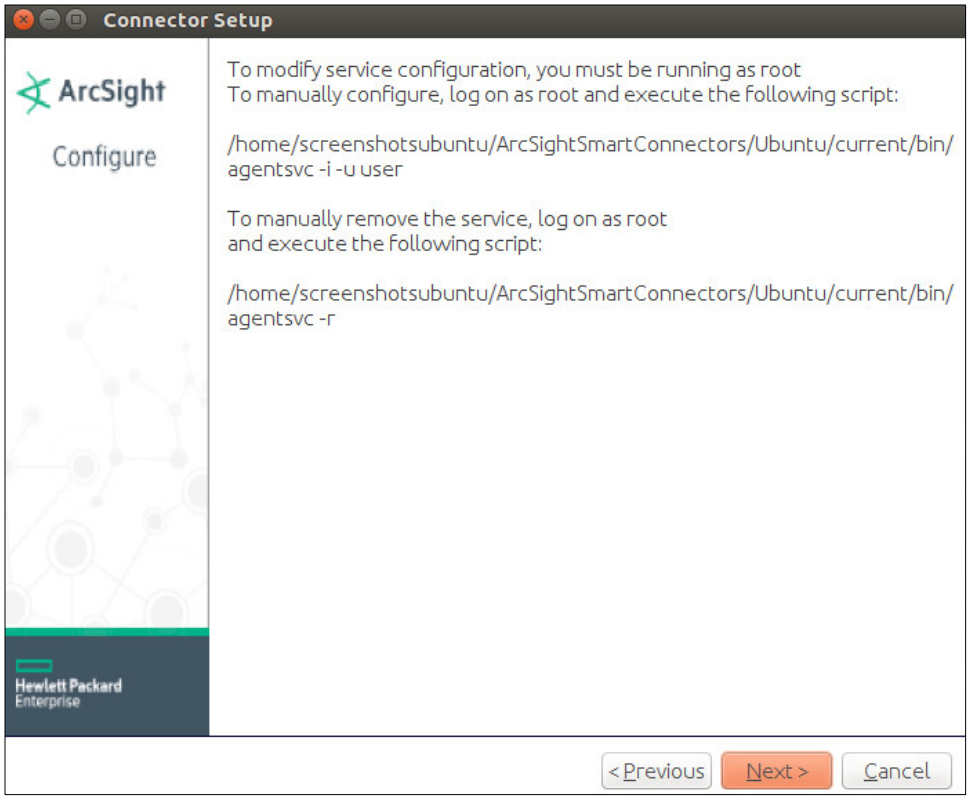
22. Click **Next**.
23. Choose **Import the certificate to connector from destination**.



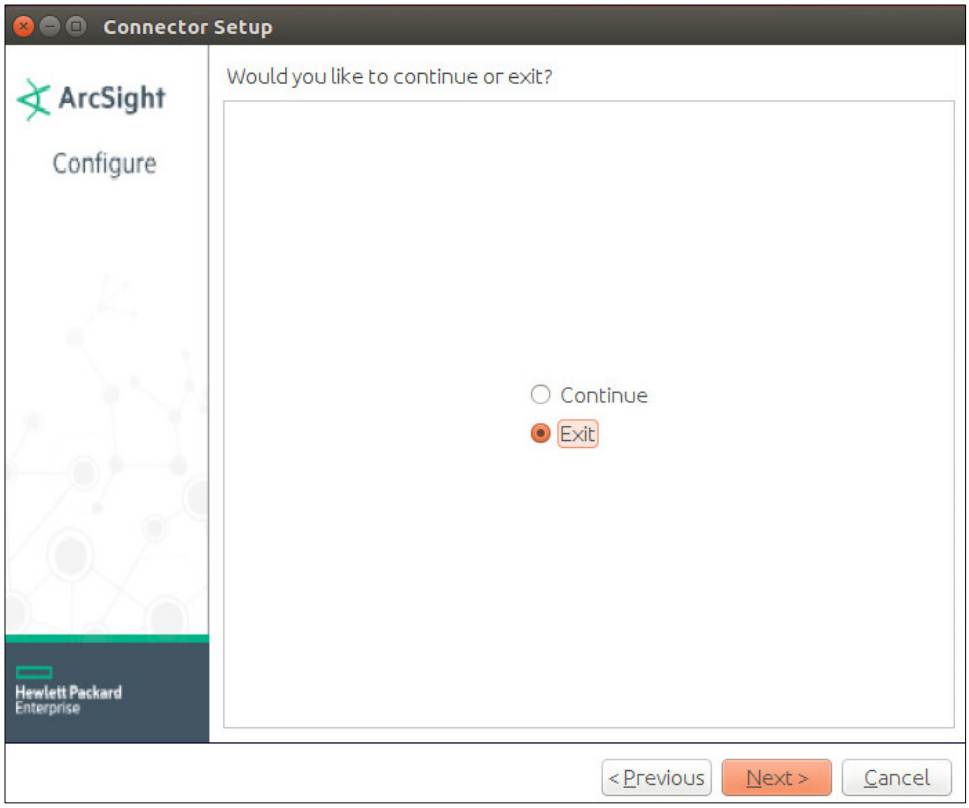
24. Click **Next**.



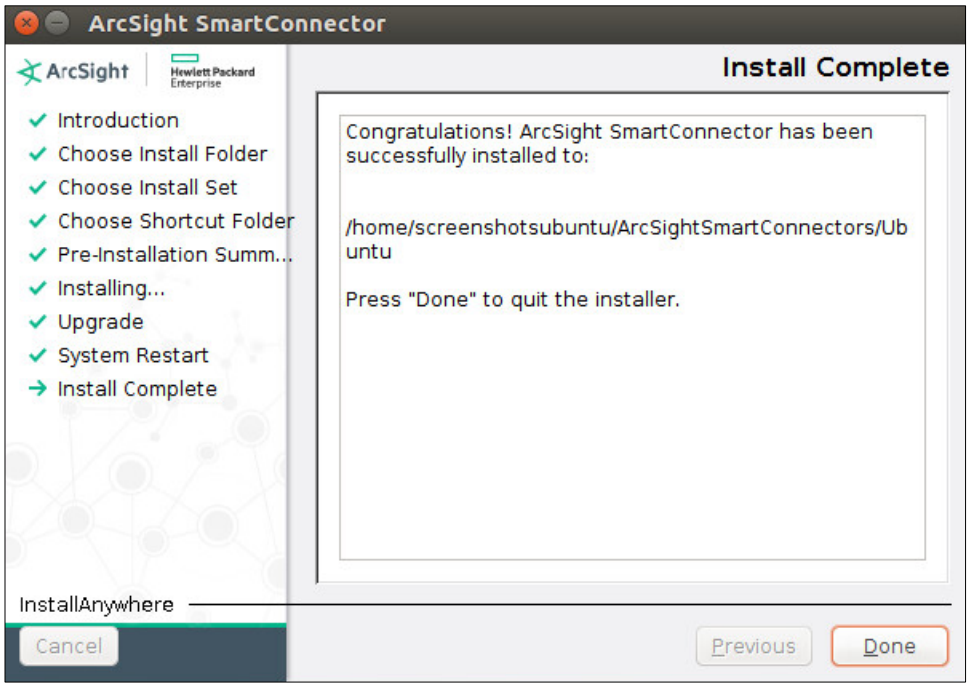
25. Click **Next**.



26. Click **Next**.
27. Choose **Exit**.



28. Click **Next**.



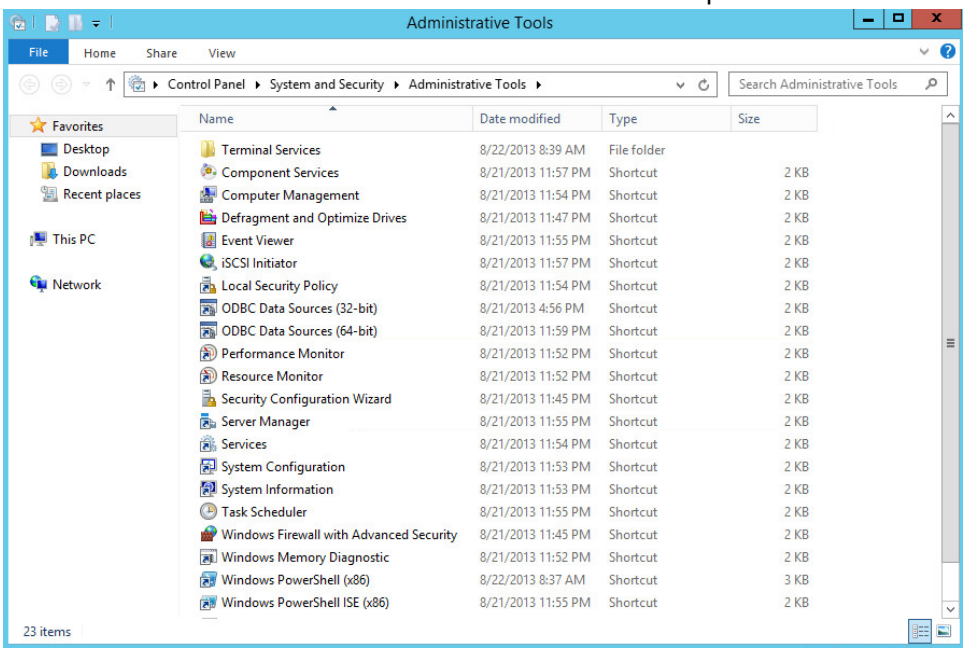
29. Click **Done**.

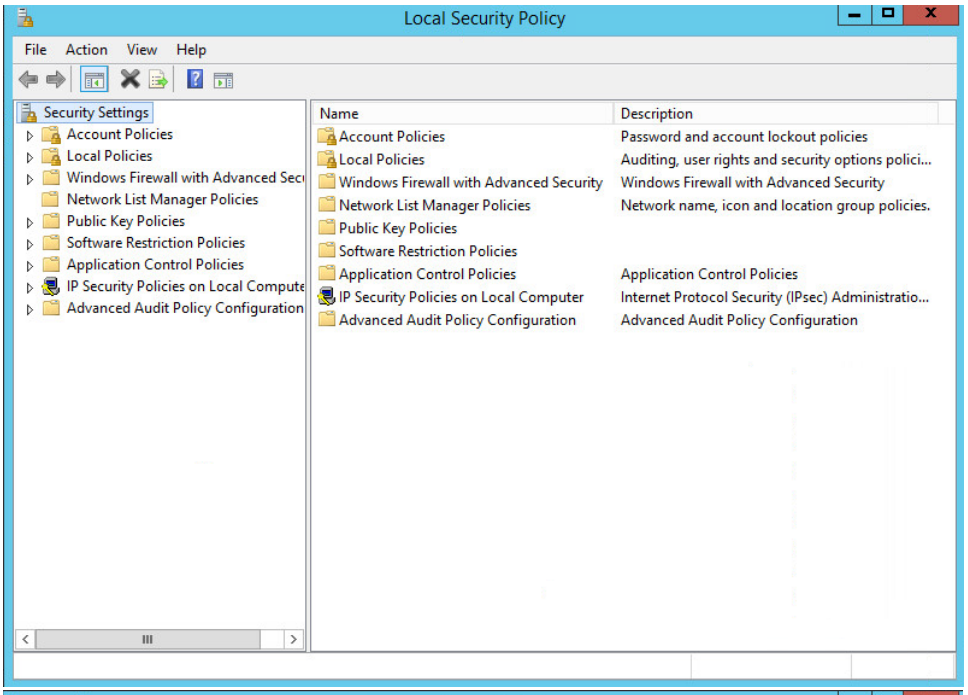
2.7 IBM Spectrum Protect

IBM Spectrum Protect is a backup/restore solution that makes use of cloud-based object storage. It allows for administrative management of backups across an enterprise, providing users with mechanisms to restore their data on a file level. This section covers the installation and configuration process used to set up IBM Spectrum Protect on a Windows Server 2012 R2 machine, as well as the installation and configuration processes required for installing the backup/archive client on various machines.

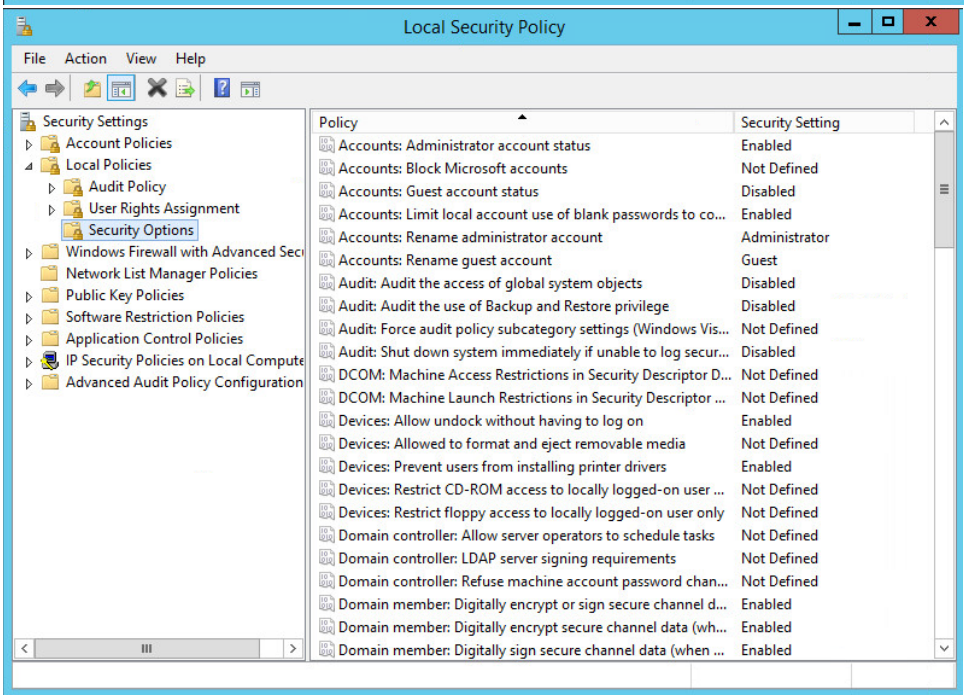
2.7.1 Install IBM Spectrum Protect Server

1. You may need to disable **Run all administrators in Admin Approval Mode**. To do this go to **Control Panel > Administrative Tools > Local Security Policy > Local Policies > Security Options**. Double click the **User Account Control: Run all administrators in Admin Approval Mode** section. Select **Disable** and click **OK**. Restart the computer.

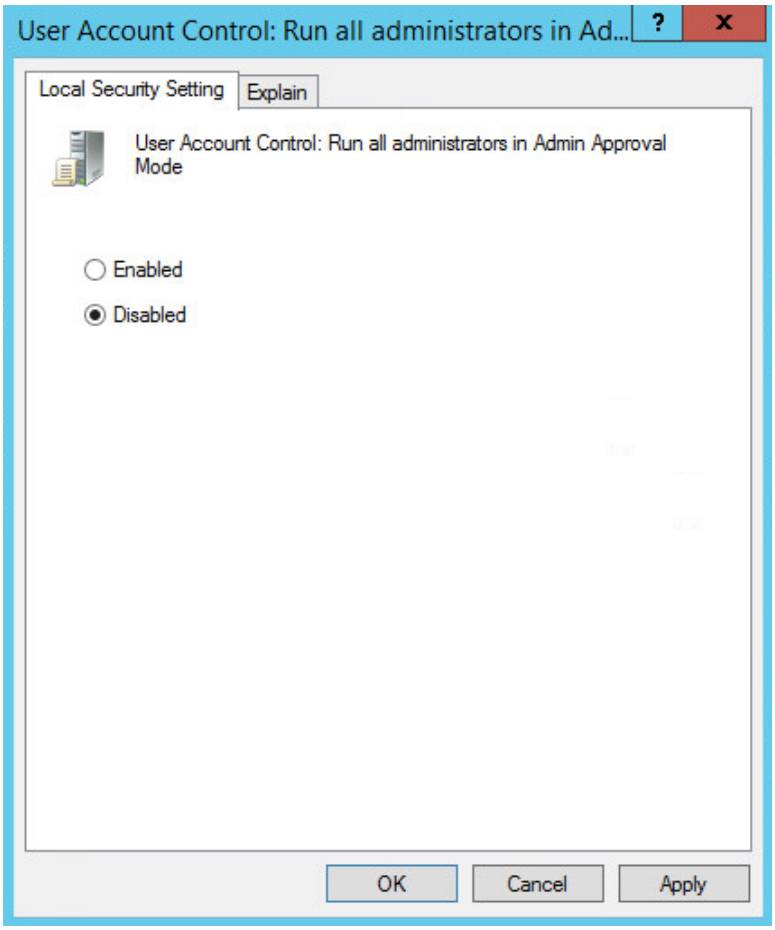



Local Security Policy
File Action View Help
Security Settings
Account Policies
Local Policies
Windows Firewall with Advanced Sec
Network List Manager Policies
Public Key Policies
Software Restriction Policies
Application Control Policies
IP Security Policies on Local Compute
Advanced Audit Policy Configuration
Name
Description
Account Policies
Password and account lockout policies
Local Policies
Auditing, user rights and security options polici...
Windows Firewall with Advanced Security
Windows Firewall with Advanced Security
Network List Manager Policies
Network name, icon and location group policies.
Public Key Policies
Software Restriction Policies
Application Control Policies
Application Control Policies
IP Security Policies on Local Computer
Internet Protocol Security (IPsec) Administratio...
Advanced Audit Policy Configuration
Advanced Audit Policy Configuration

864

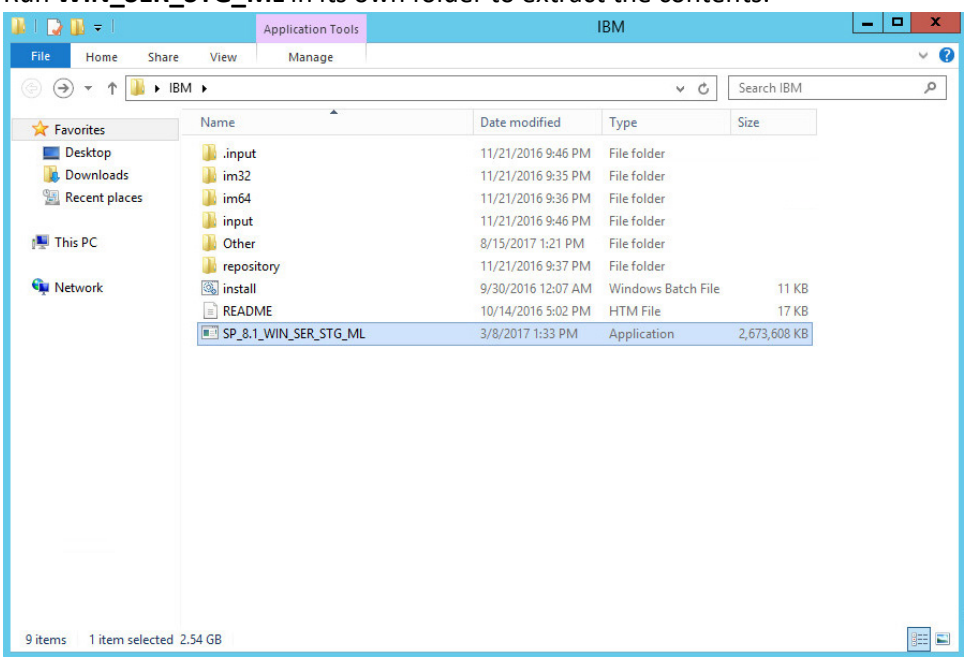

Local Security Policy
File Action View Help
Security Settings
Account Policies
Local Policies
Audit Policy
User Rights Assignment
Security Options
Windows Firewall with Advanced Sec
Network List Manager Policies
Public Key Policies
Software Restriction Policies
Application Control Policies
IP Security Policies on Local Compute
Advanced Audit Policy Configuration
Policy
Security Setting
Accounts: Administrator account status
Enabled
Accounts: Block Microsoft accounts
Not Defined
Accounts: Guest account status
Disabled
Accounts: Limit local account use of blank passwords to co...
Enabled
Accounts: Rename administrator account
Administrator
Accounts: Rename guest account
Guest
Audit: Audit the access of global system objects
Disabled
Audit: Audit the use of Backup and Restore privilege
Disabled
Audit: Force audit policy subcategory settings (Windows Vis...
Not Defined
Audit: Shut down system immediately if unable to log secur...
Disabled
DCOM: Machine Access Restrictions in Security Descriptor D...
Not Defined
DCOM: Machine Launch Restrictions in Security Descriptor ...
Not Defined
Devices: Allow undock without having to log on
Enabled
Devices: Allowed to format and eject removable media
Not Defined
Devices: Prevent users from installing printer drivers
Enabled
Devices: Restrict CD-ROM access to locally logged-on user ...
Not Defined
Devices: Restrict floppy access to locally logged-on user only
Not Defined
Domain controller: Allow server operators to schedule tasks
Not Defined
Domain controller: LDAP server signing requirements
Not Defined
Domain controller: Refuse machine account password chan...
Not Defined
Domain member: Digitally encrypt or sign secure channel d...
Enabled
Domain member: Digitally encrypt secure channel data (wh...
Enabled
Domain member: Digitally sign secure channel data (when ...
Enabled

865

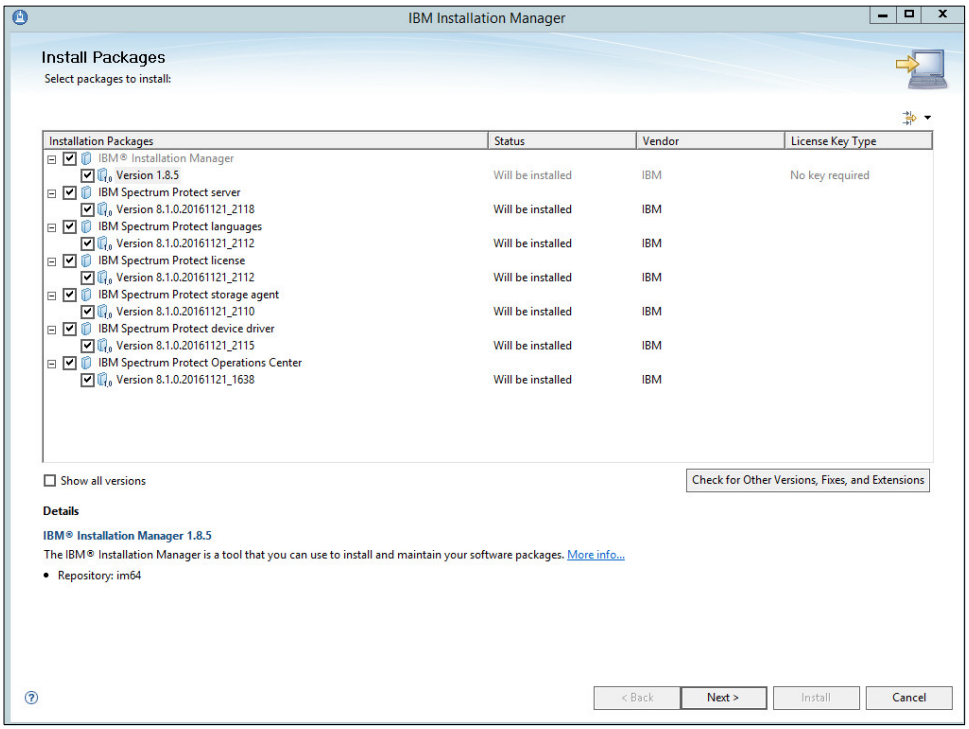

User Account Control: Run all administrators in Ad...
Local Security Setting
Explain
User Account Control: Run all administrators in Admin Approval Mode
Enabled
Disabled
OK
Cancel
Apply

866

2. Run **WIN_SER_STG_ML** in its own folder to extract the contents.

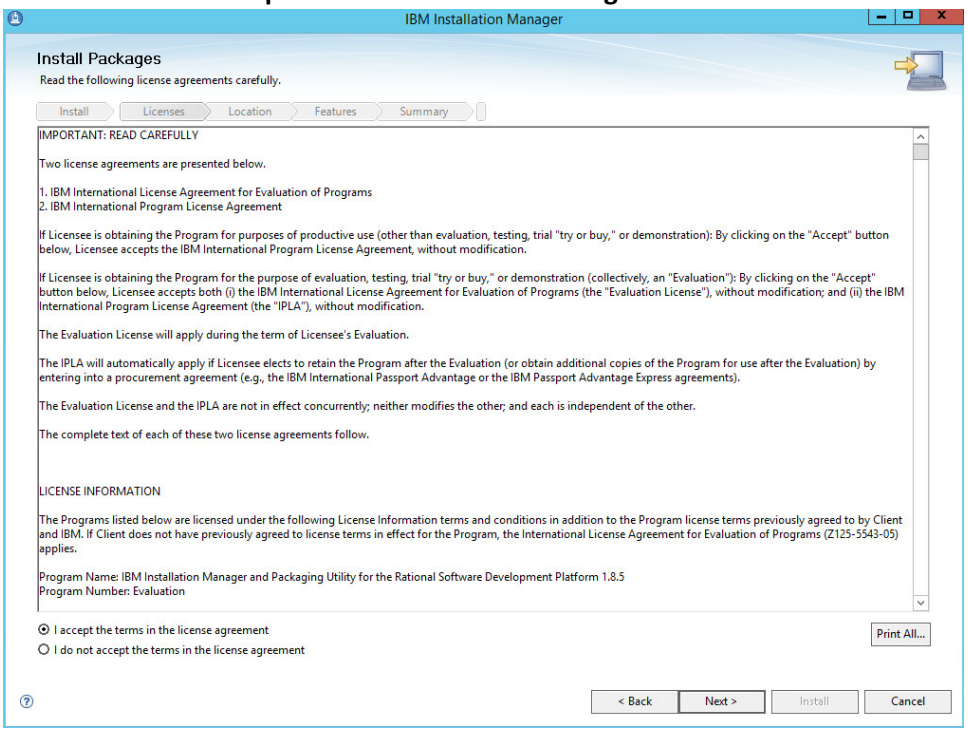


3. Run the **install** script.
4. Make sure all the boxes are checked.



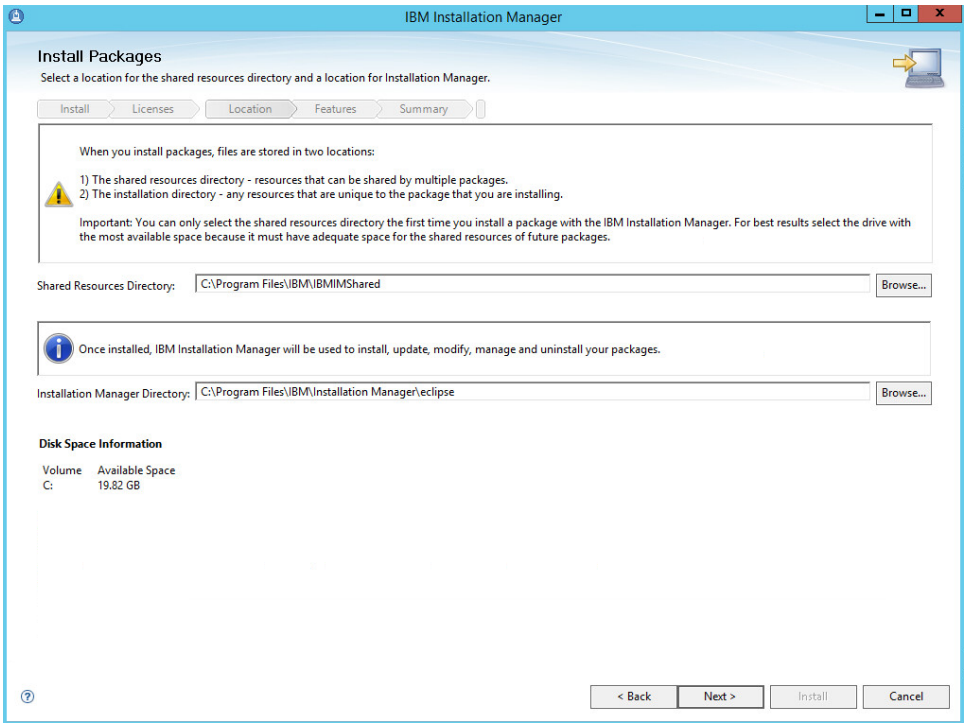
5. Click **Next**.

6. Read and select **I accept the terms in the license agreement**.

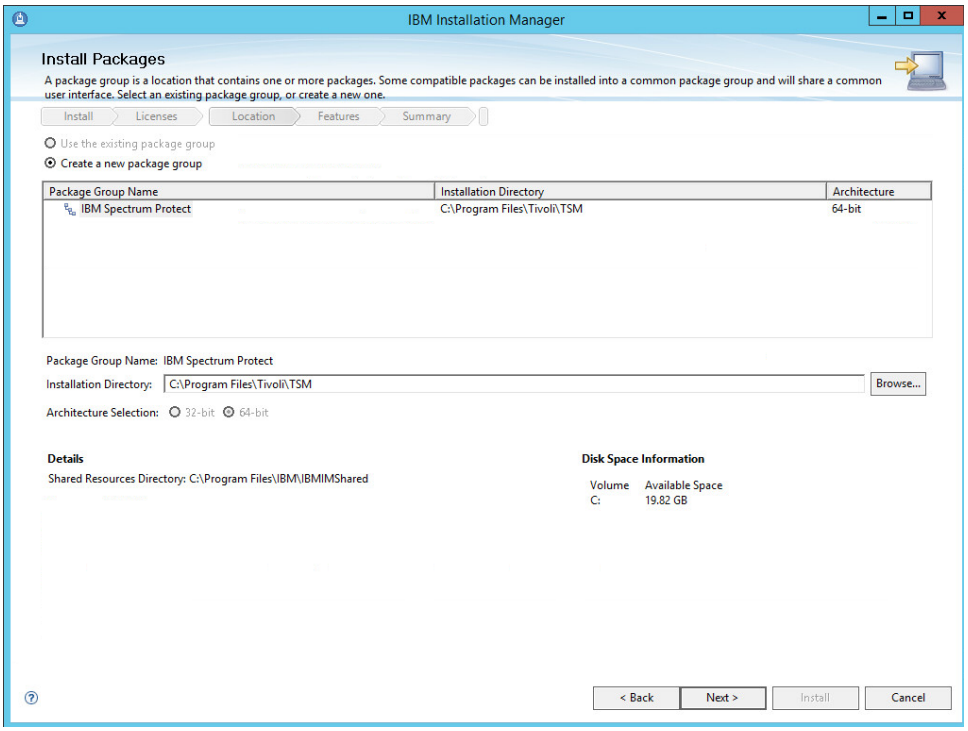


7. Click **Next**.

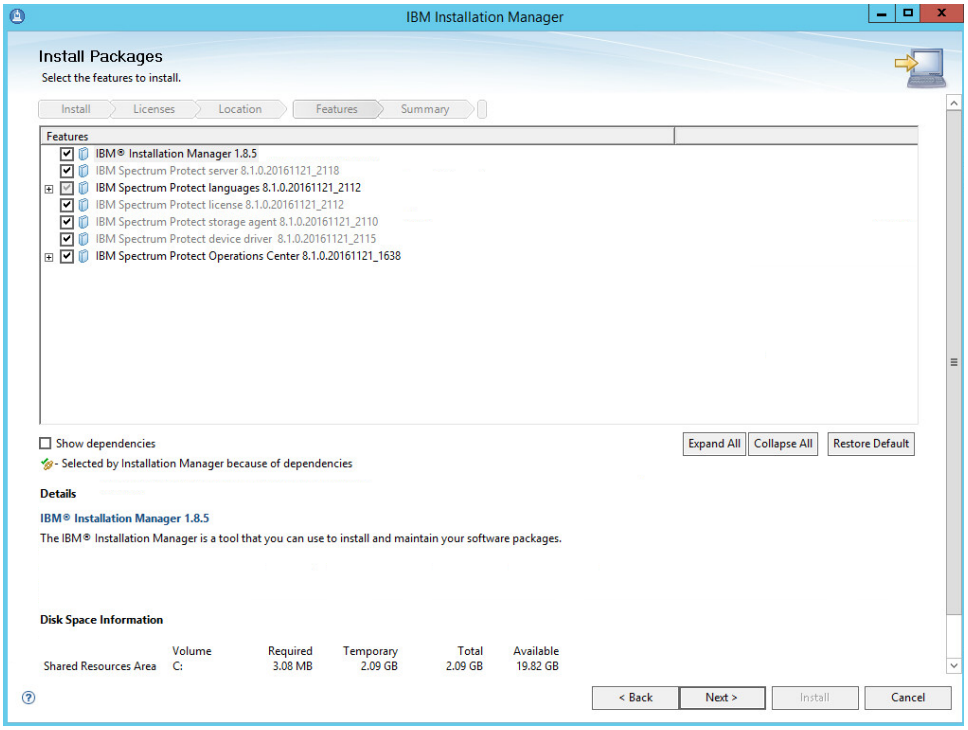
8. Select the location for files to be installed to.



9. Click **Next**.

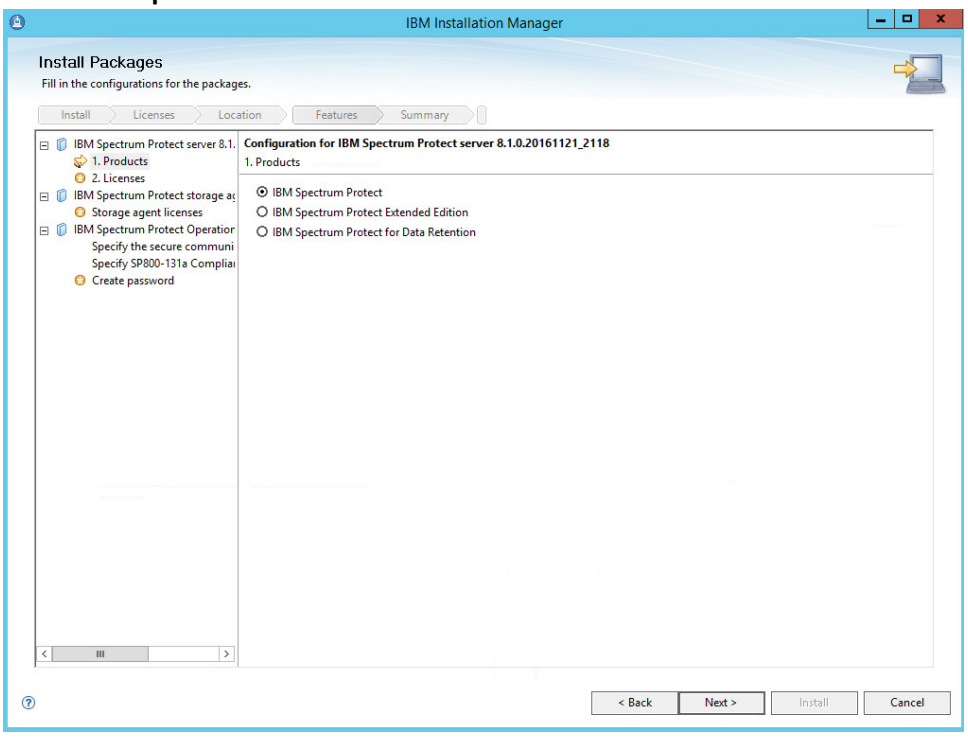


10. Click **Next**.
11. Make sure all the packages are checked.



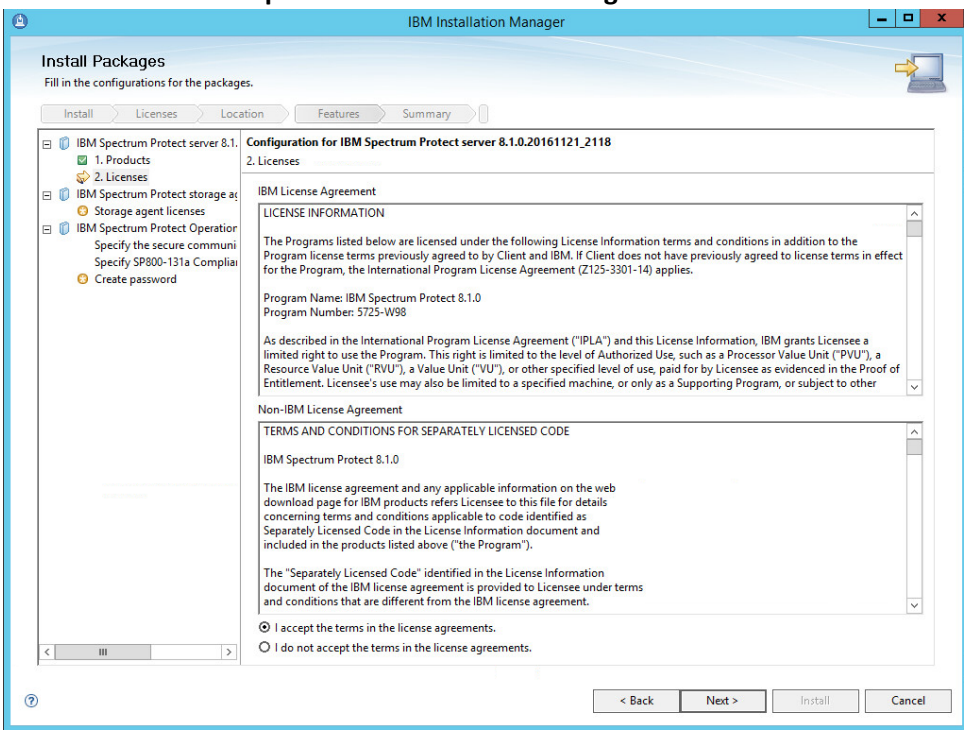
12. Click **Next**.

13. Select **IBM Spectrum Protect**.



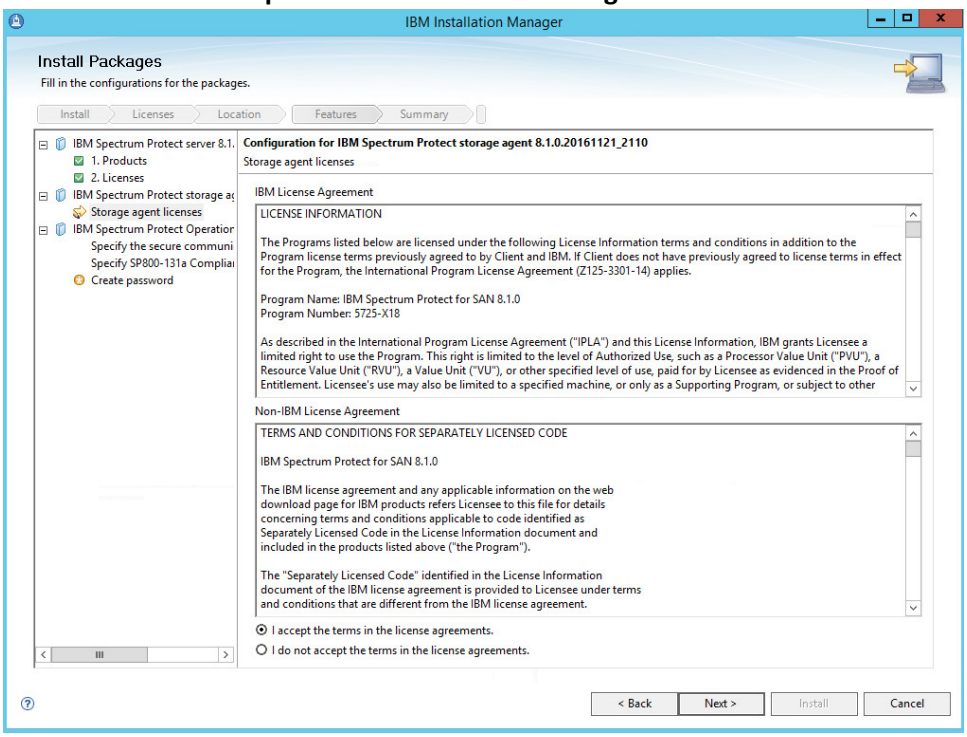
14. Click **Next**.

15. Read and select **I accept the terms in the license agreement**.



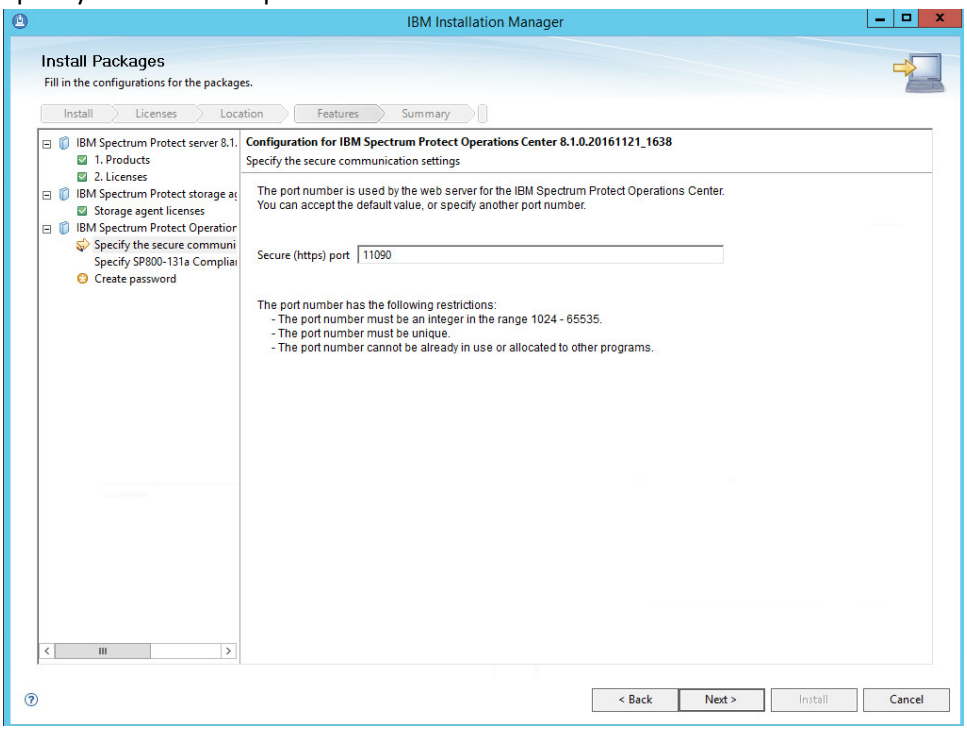
16. Click **Next**.

17. Read and select **I accept the terms in the license agreement**.



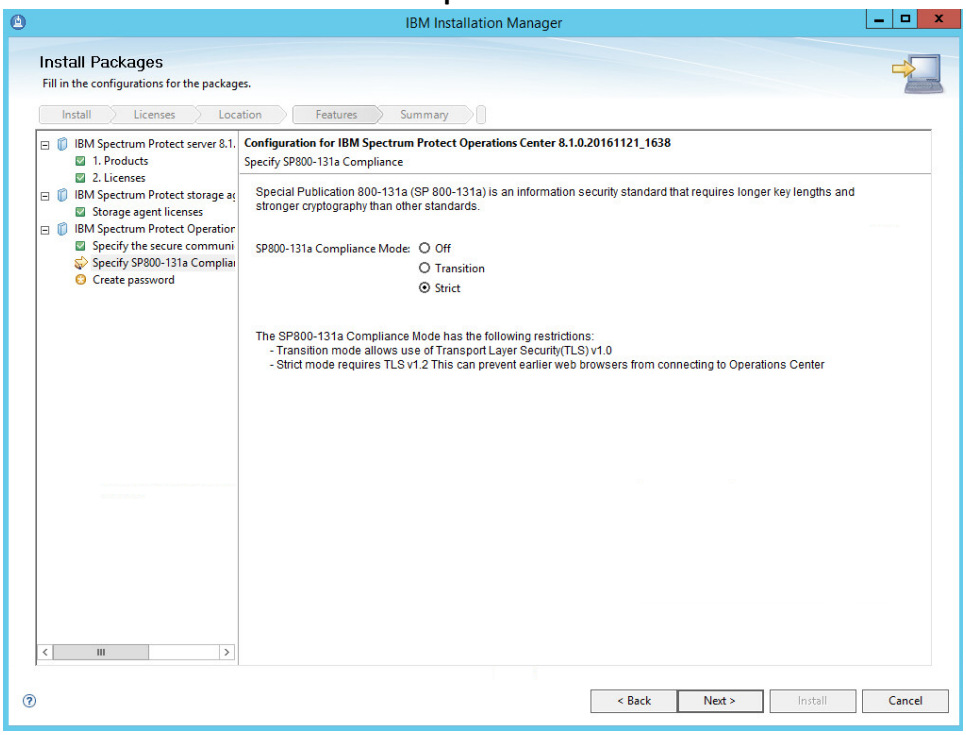
18. Click **Next**.

19. Specify **11090** for the port.

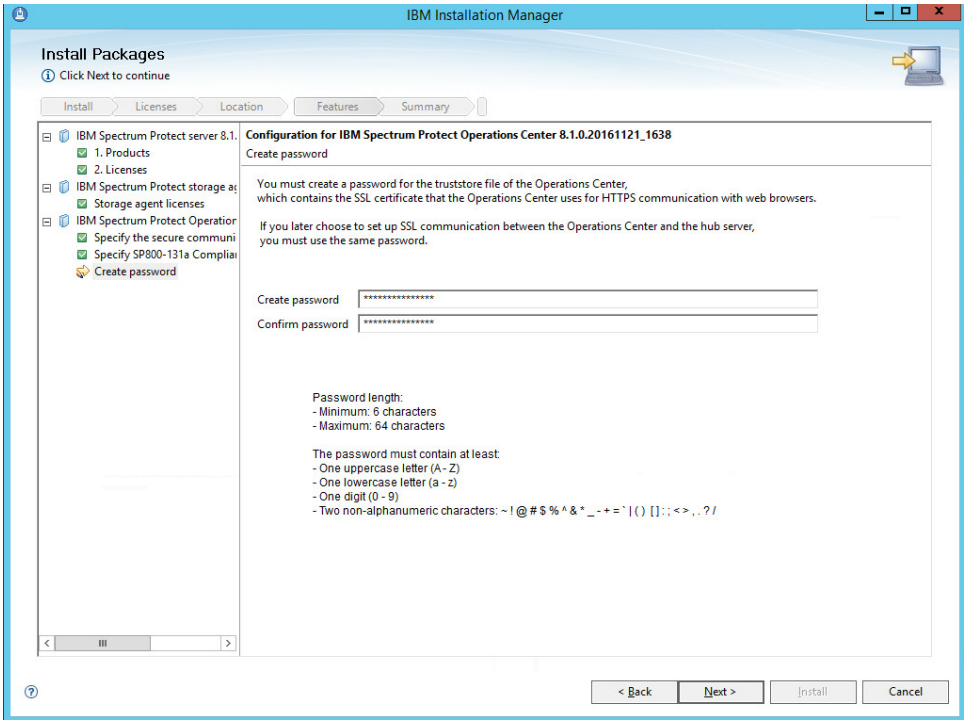


20. Click **Next**.

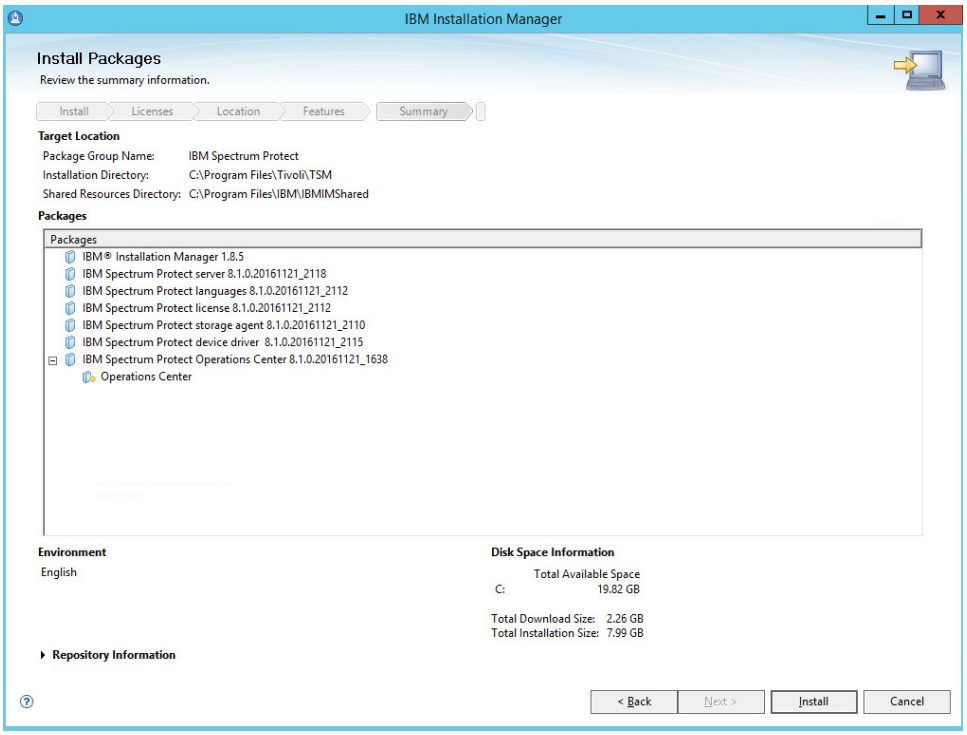
21. Select **Strict** for the **SP800-131a Compliance**.



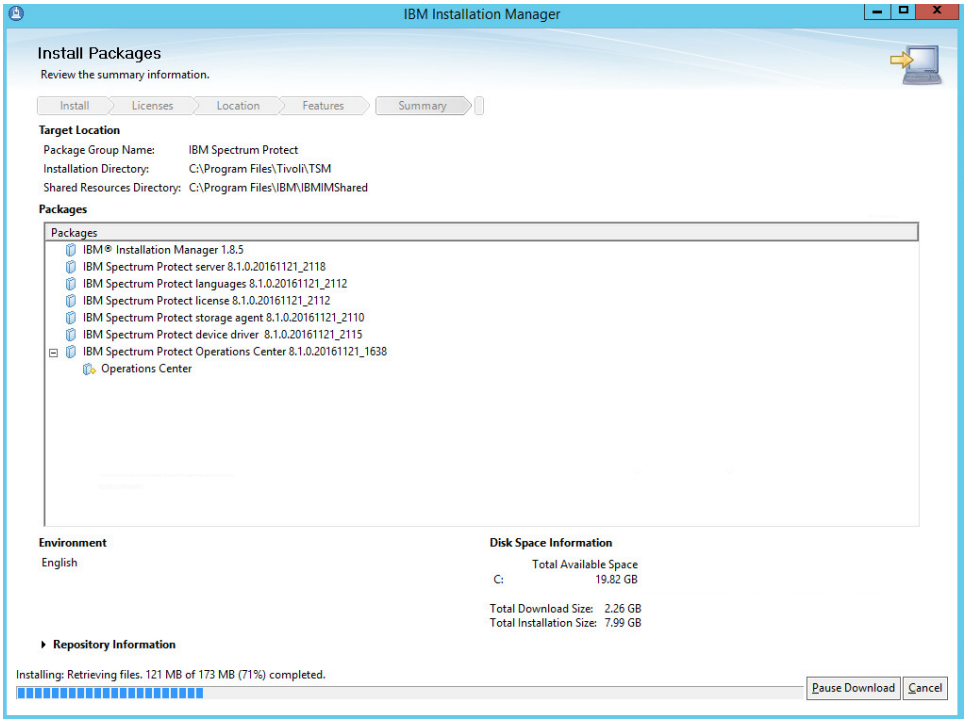
22. Click **Next**.
23. Create a password.



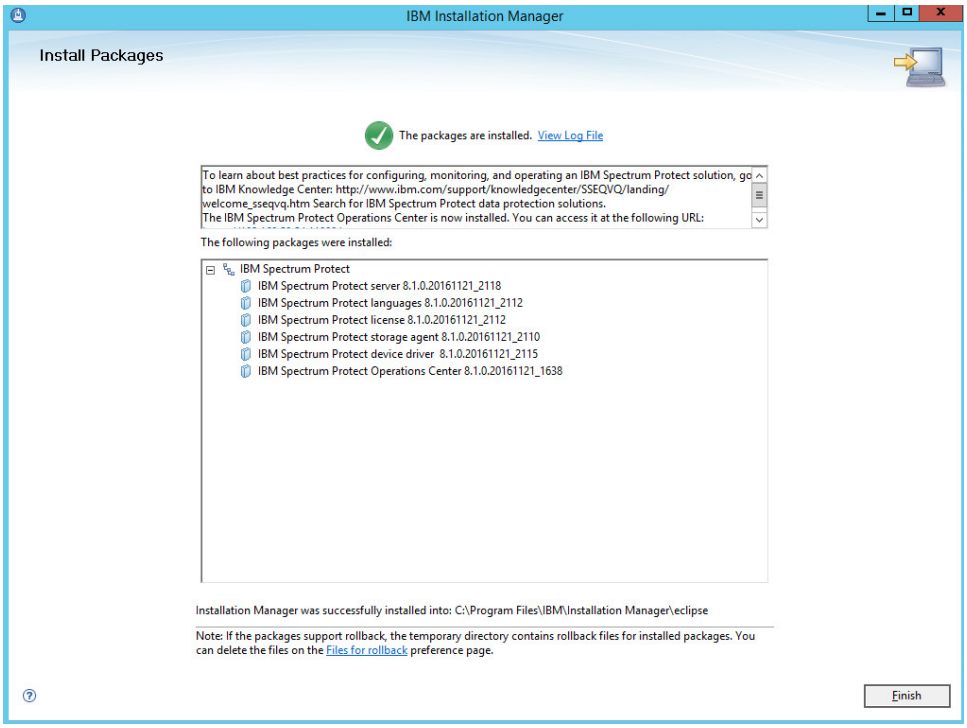
24. Click **Next**.



25. Click **Install**.
26. Wait for the **install** to finish.

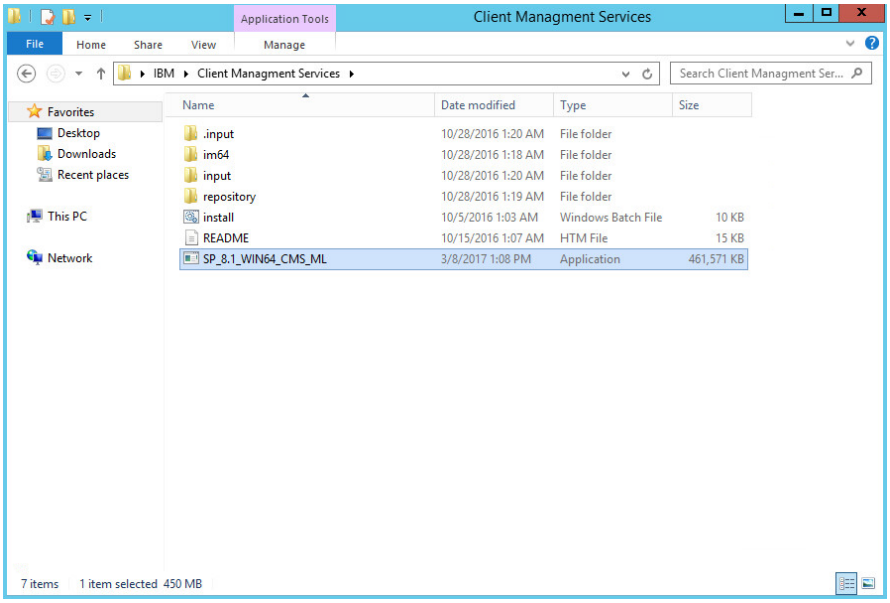


27. Click **Finish**.

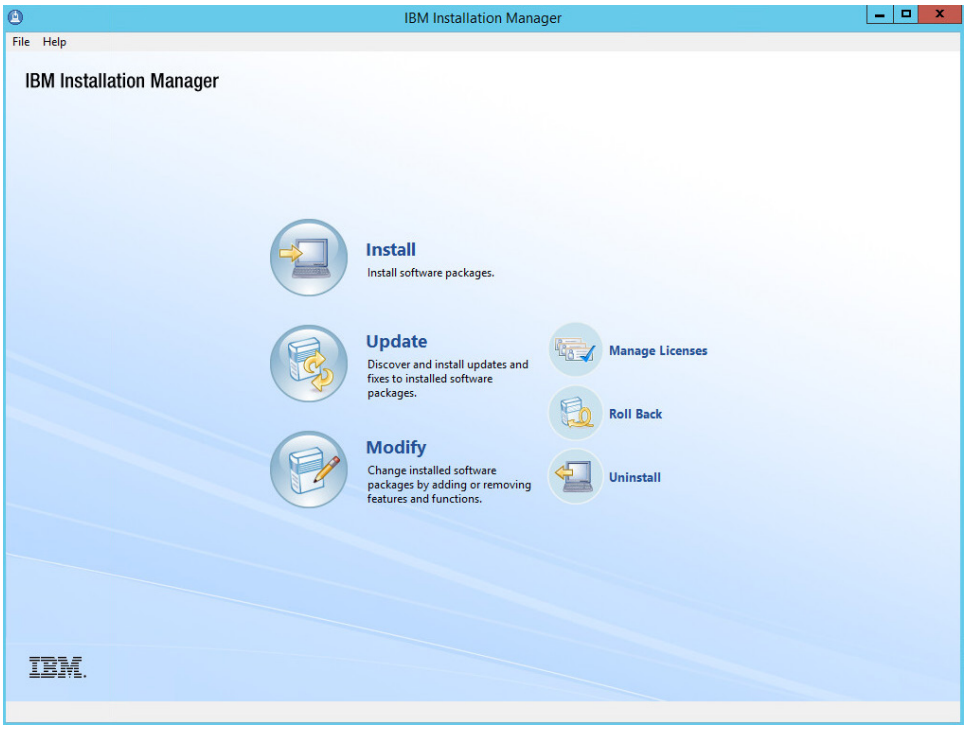


2.7.2 Install IBM Spectrum Protect Client Management Services

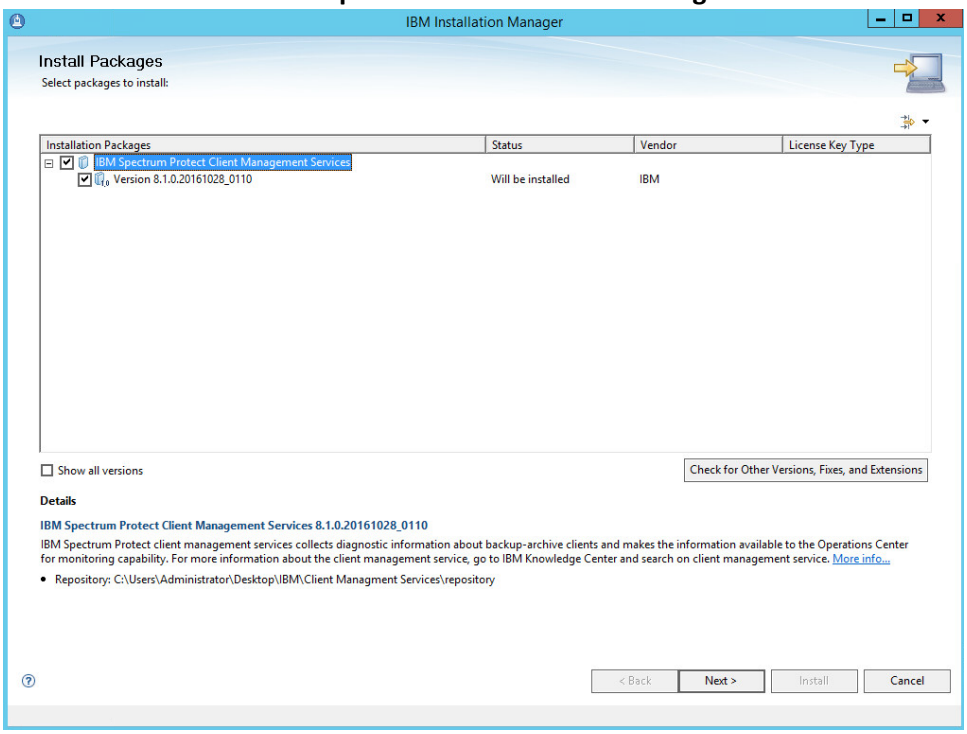
1. Run **WIN64_CMS_ML** in its own folder to extract the contents.



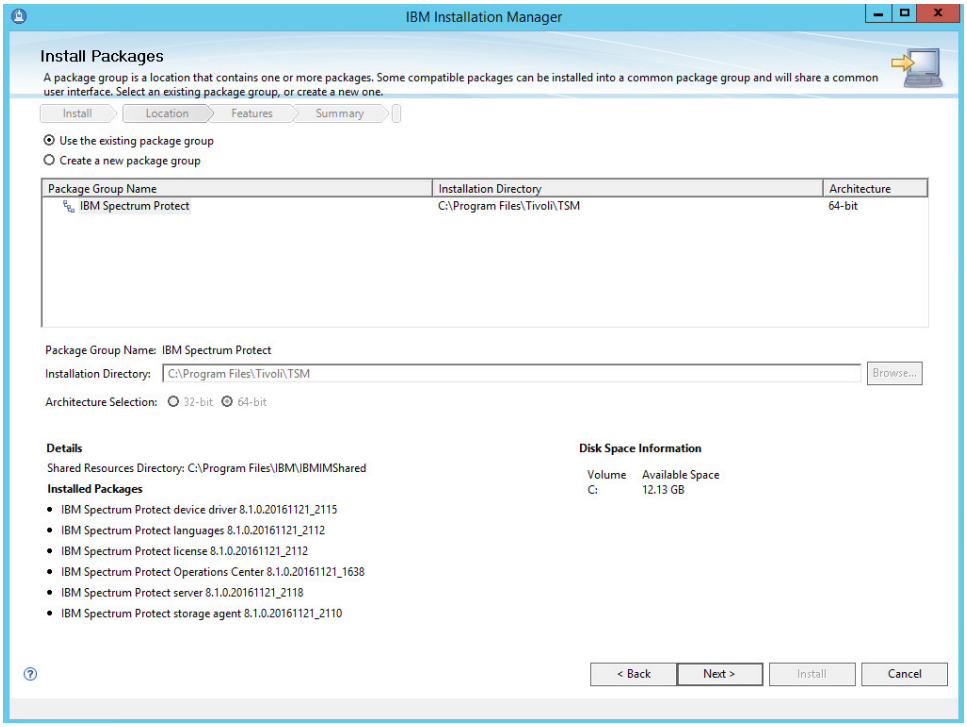
2. Run the install script.



3. Click **Install**.
4. Check the box next to **IBM Spectrum Protect Client Management Services**.

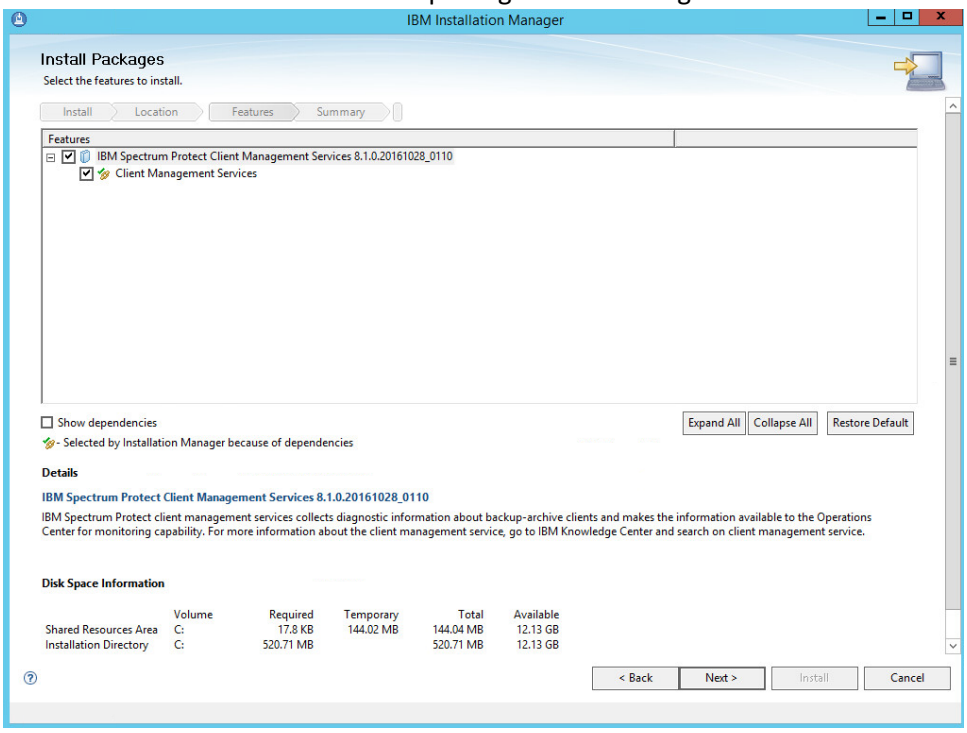


5. Click **Next**.
6. Select **Use the existing package group**.



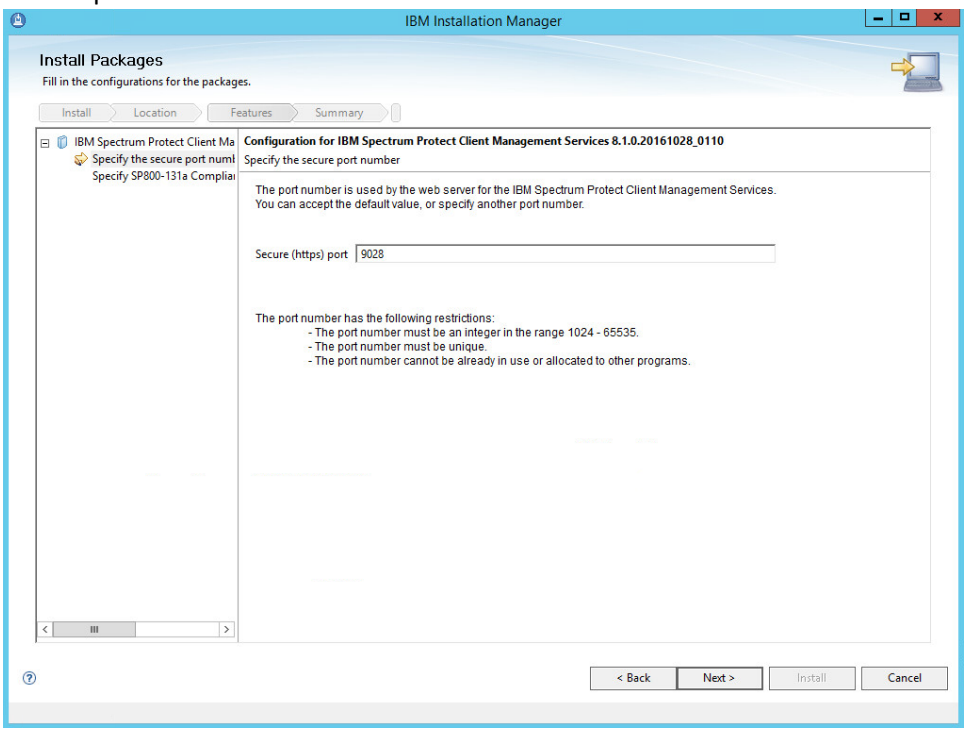
7. Click **Next**.

8. Make sure all the boxes next to the package Client Management Services are checked.



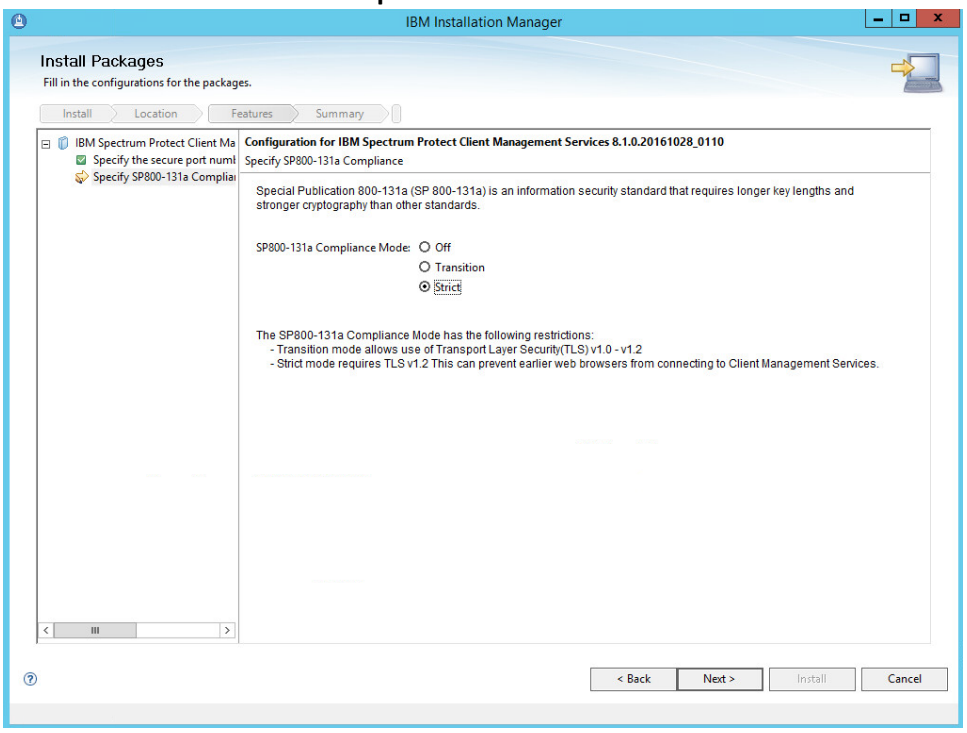
9. Click **Next**.

10. Set the port to **9028**.

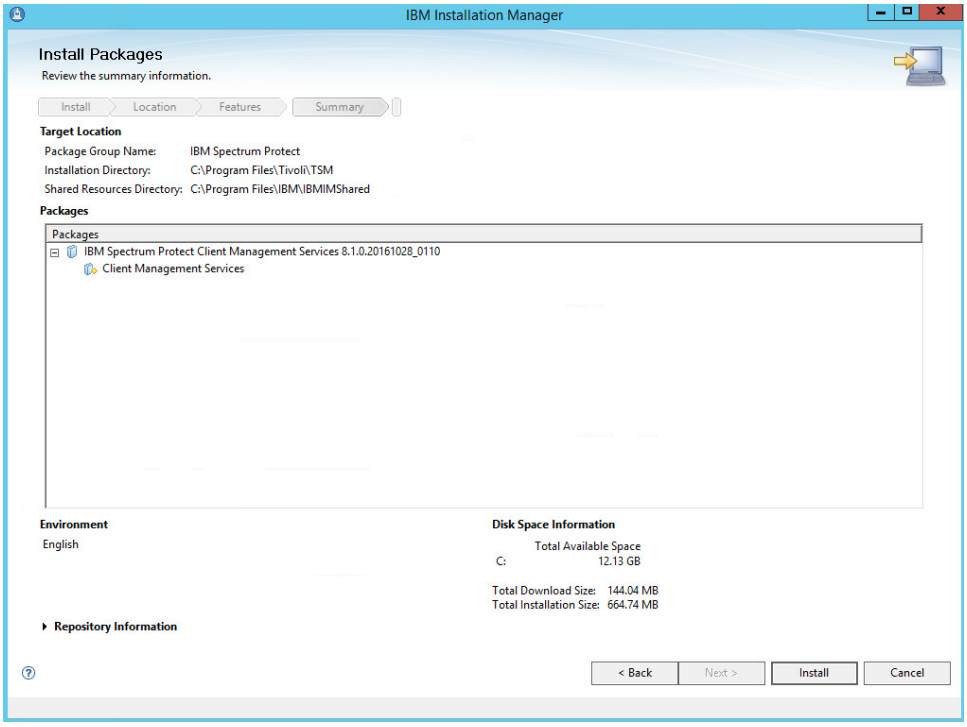


11. Click **Next**.

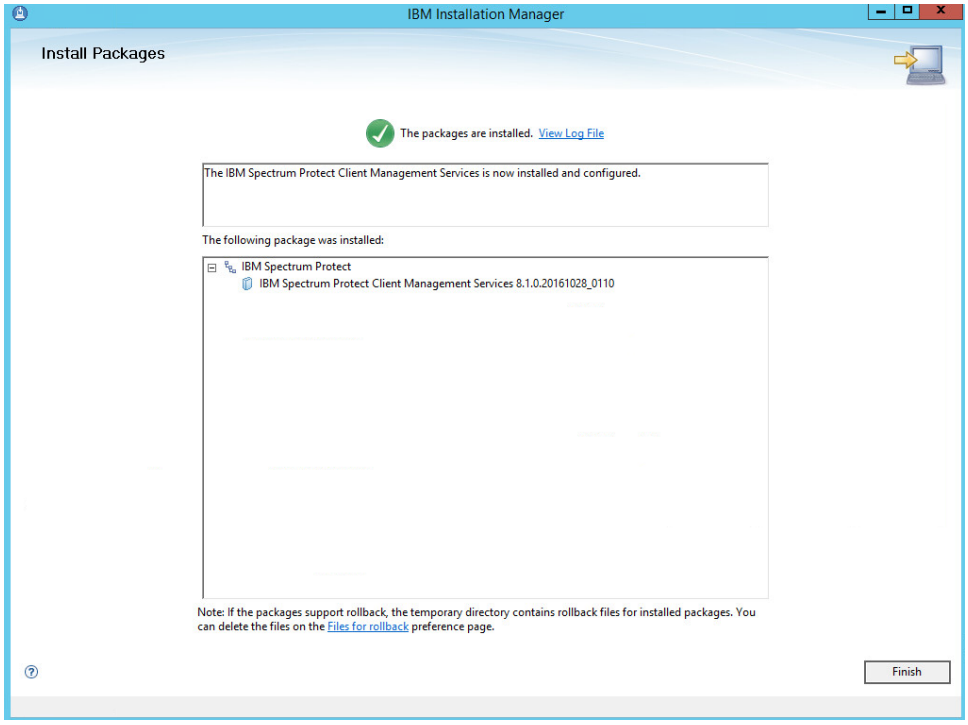
12. Click **Strict** for **SP800-131a compliance**.



13. Click **Next**.



14. Click **Install**.

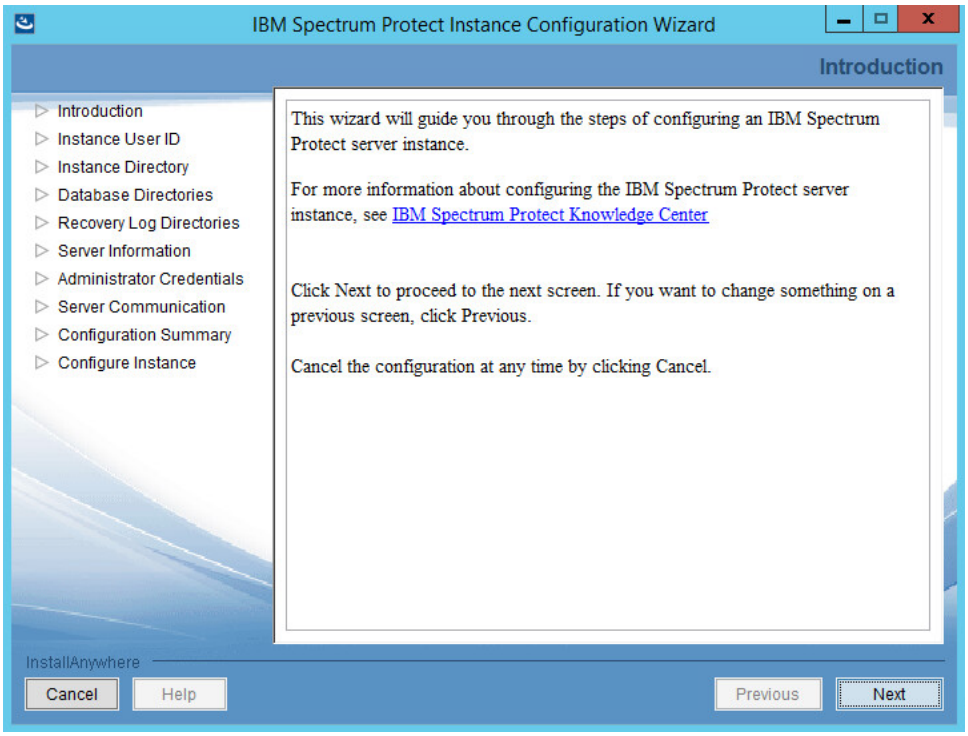


15. Observe the successful installation and click **Finish**.

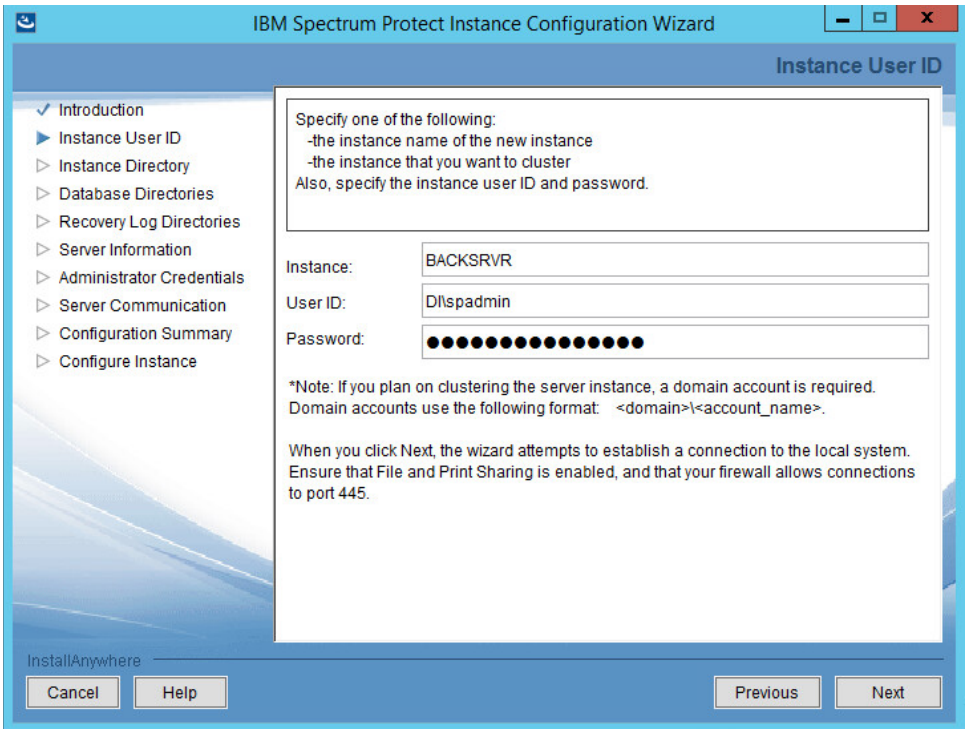
2.7.3 Configure IBM Spectrum Protect

1. Go to **Start > IBM Spectrum Protect Configuration Wizard**.

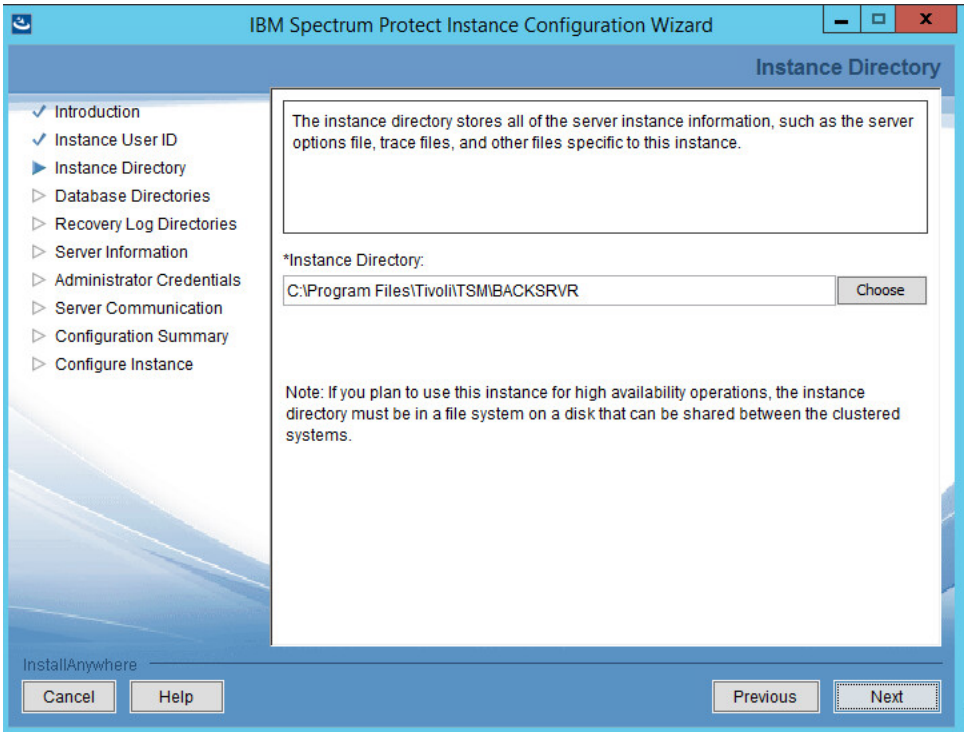
2. Click **OK**.



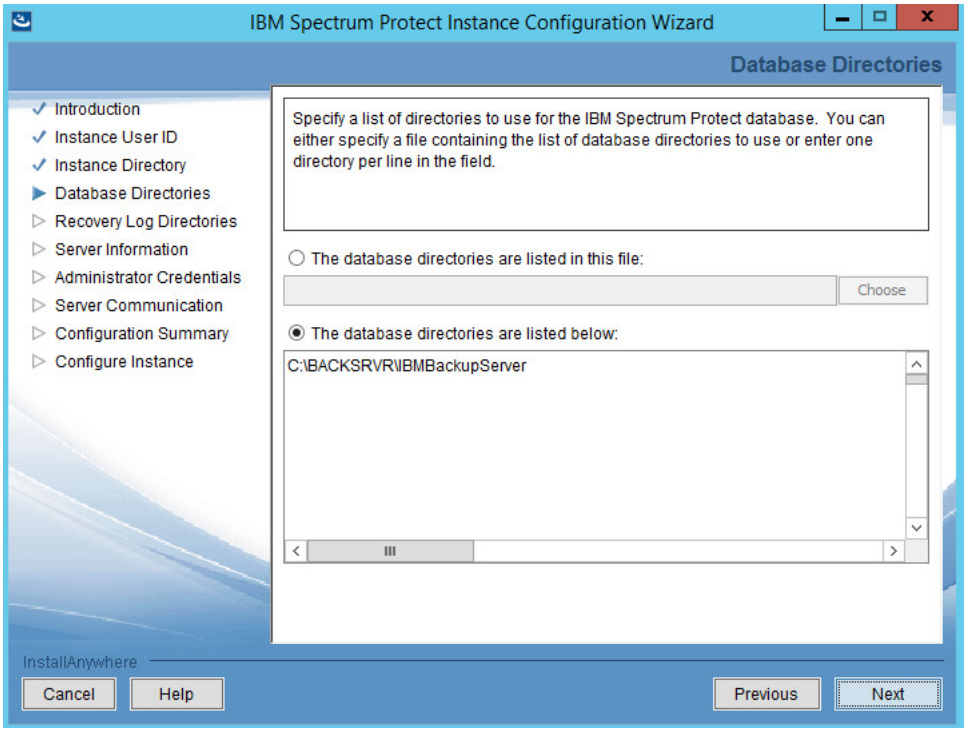
3. Click **Next**.
4. Specify a name and an account for the IBM server to use. Example: (name: BACKSRVR, User ID: DI\spadmin).



5. Click **Next**.
6. Choose a directory.

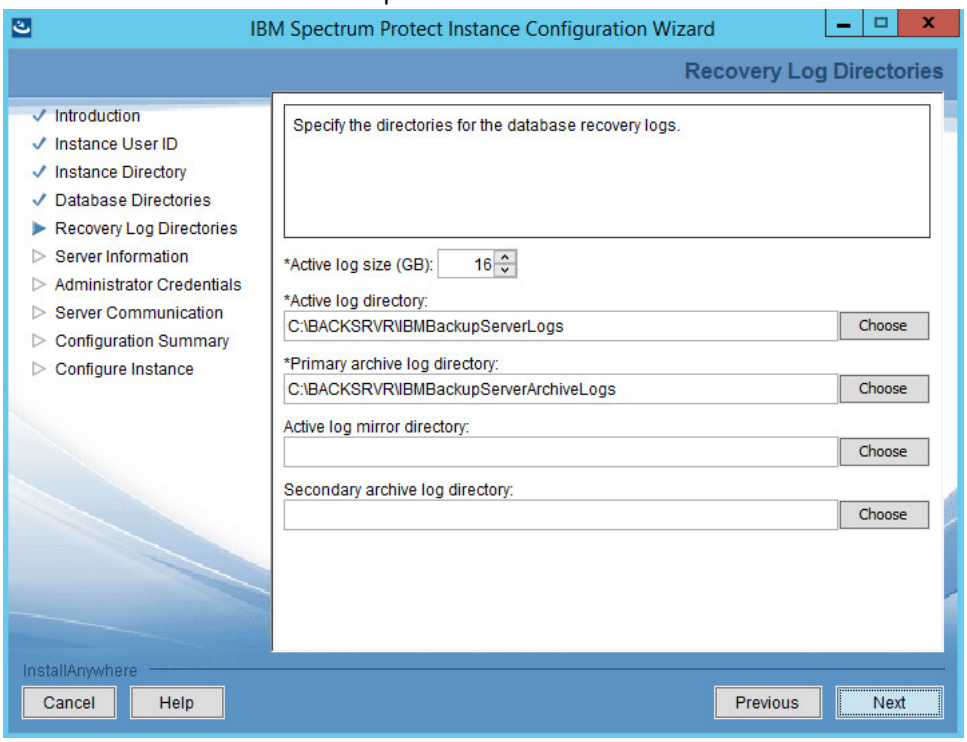


7. Click **Next**.
8. Click **Yes** if prompted to create the directory.
9. Choose **The database directories are listed below**.
10. Create a directory to contain the database. Example: *C:\BACKSRVR\IBMBackupServer.*
11. Enter the directory in the space provided.



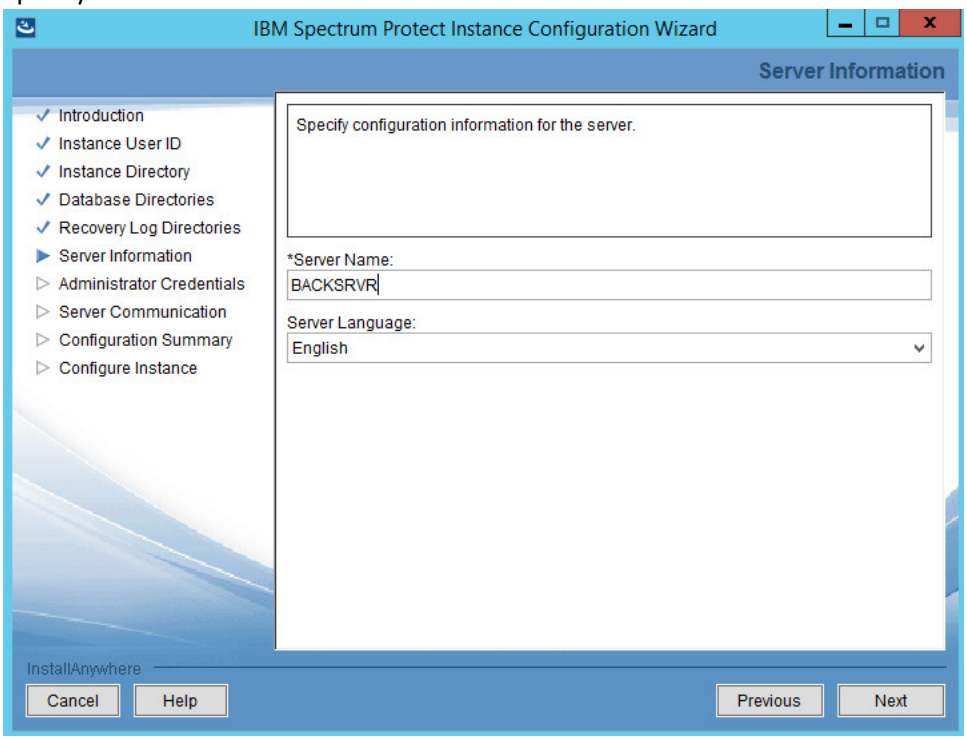
12. Click **Next**.
13. Create directories for **logs** and **archive logs**. Example: *C:\BACKSRVR\IBMBackupServerLogs*, *C:\BACKSRVR\IBMBackupServerArchiveLogs*.

14. Enter the directories in their respective fields.



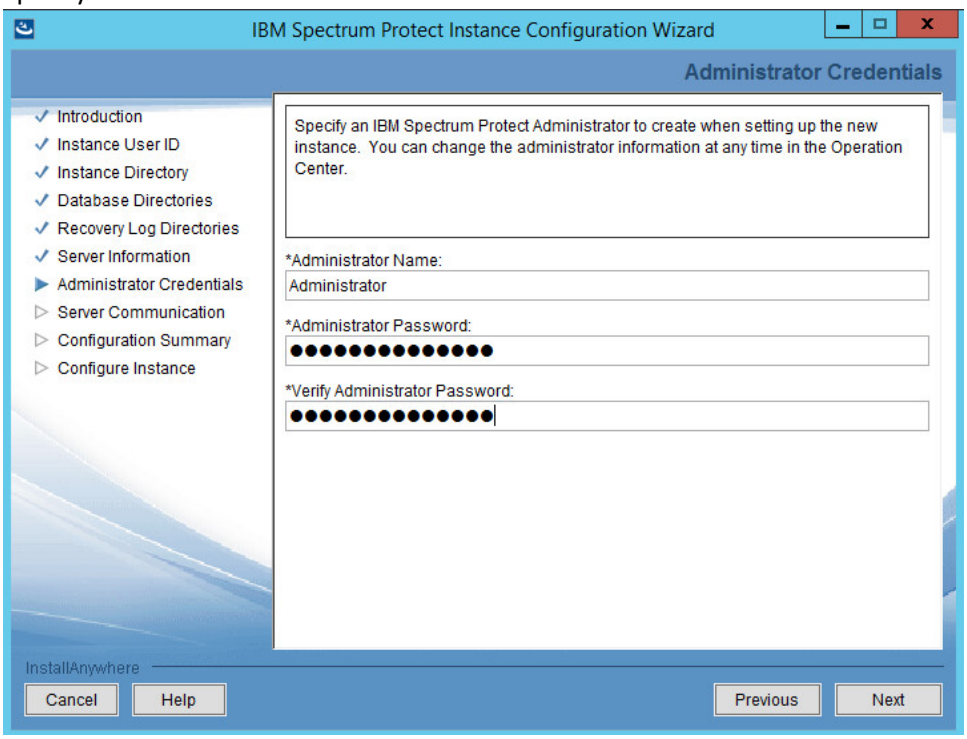
15. Click **Next**.

16. Specify the **server name**.



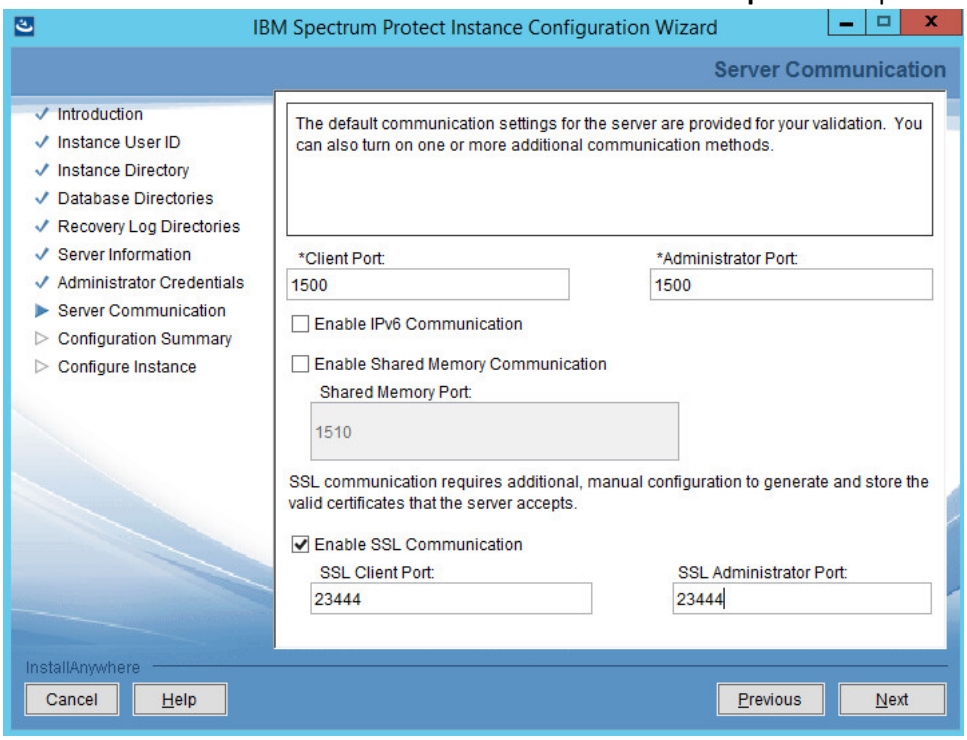
17. Click **Next**.

18. Specify an **Administrator account**.

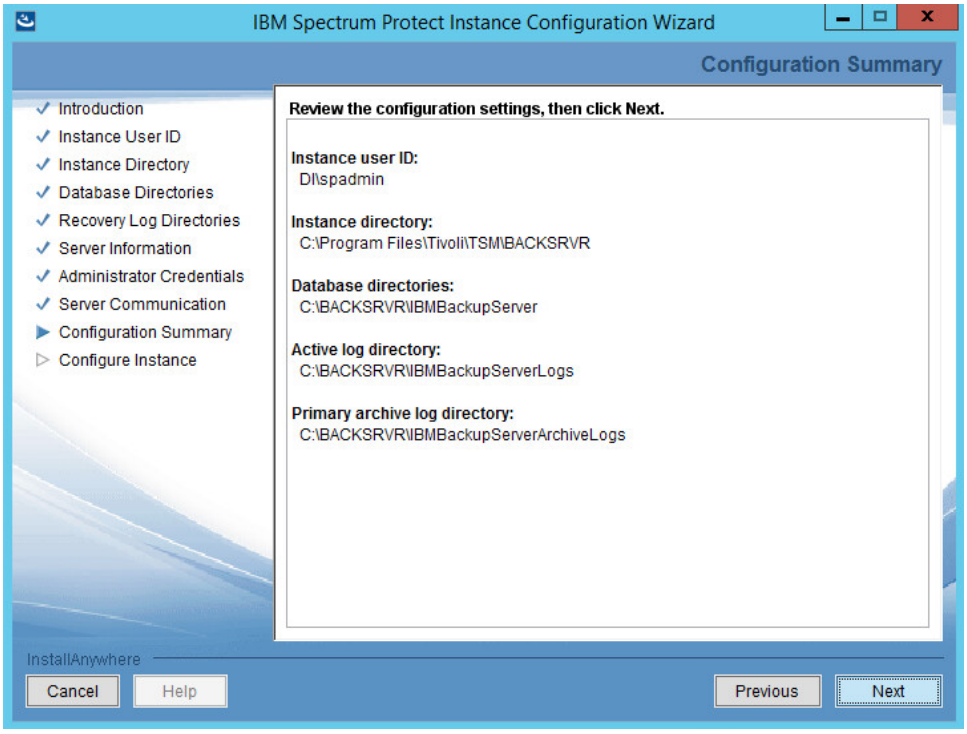


19. Click **Next**.
20. Select a **port.** Example: 1500.

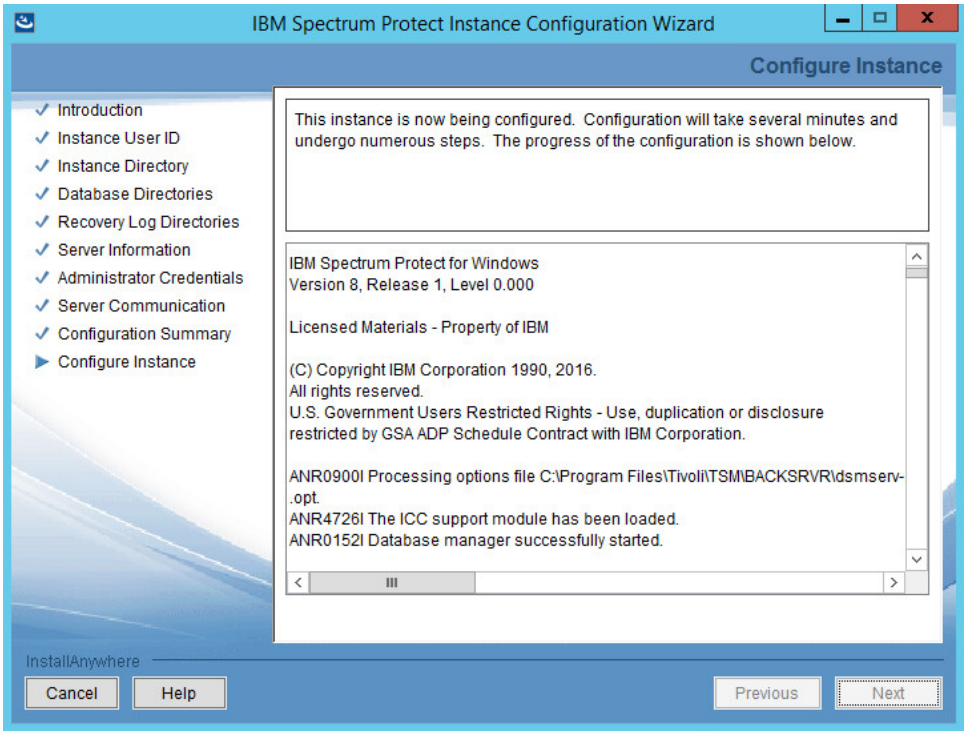
21. Check the box next to **Enable SSL Communication** and enter a **port**. Example: 23444.



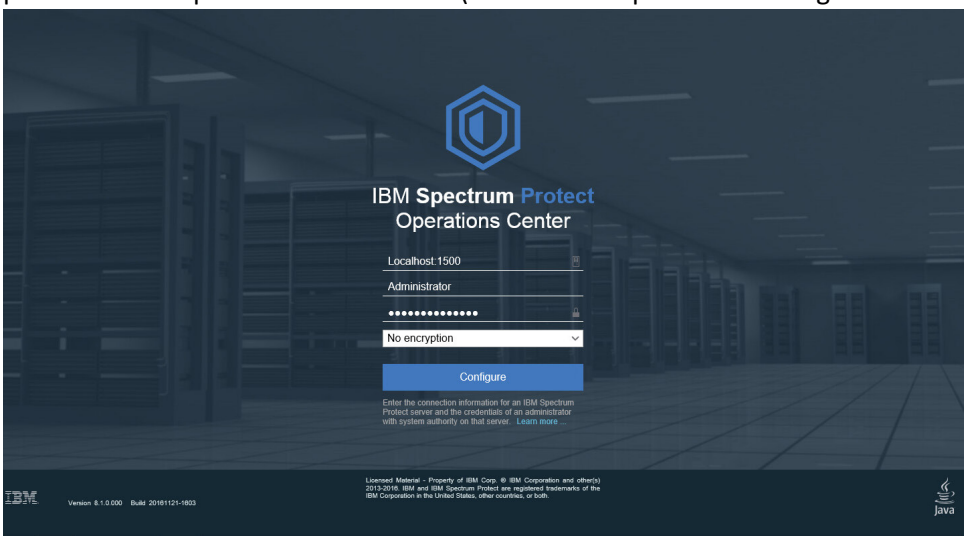
22. Click **Next**.



23. Click **Next**.
24. Wait for the installation to finish.

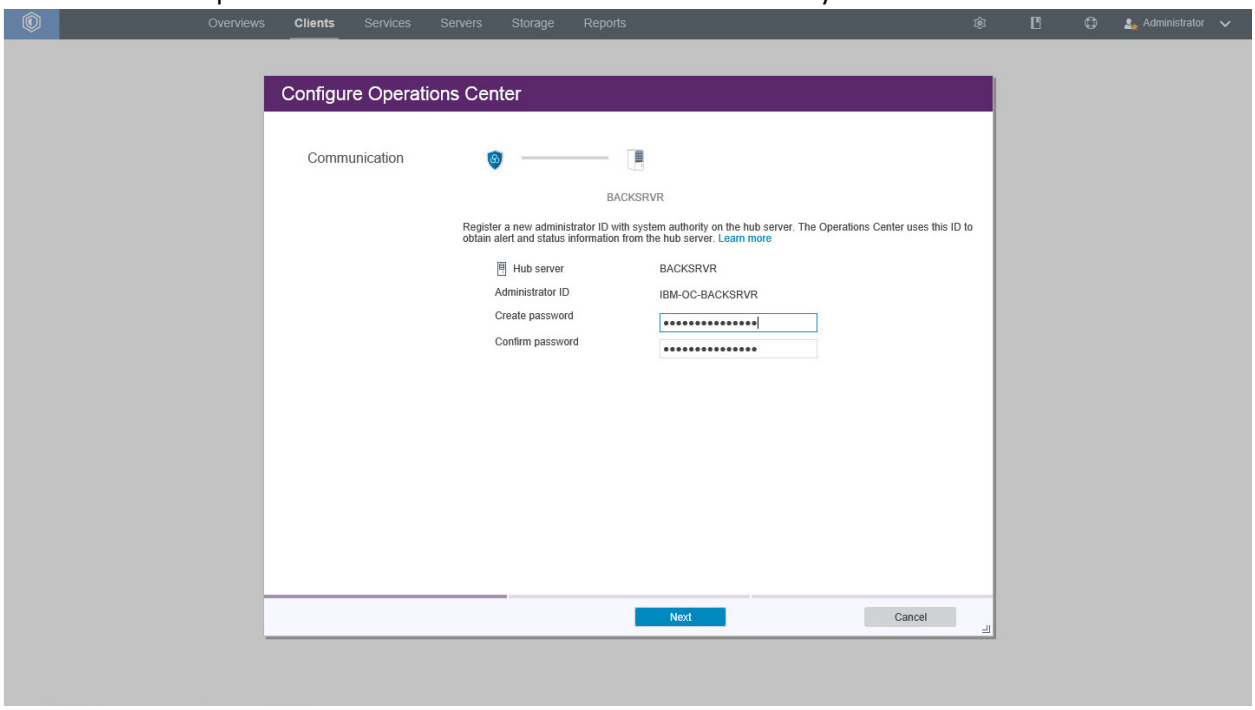


25. Click **Next**.
26. Click **Done**.
27. Log in to **Operations Center** by going to **localhost:11090/oc/**. If issues occur, check firewall permissions for ports 1500 and 23444 (or whichever ports were designated in steps 20 and 21).

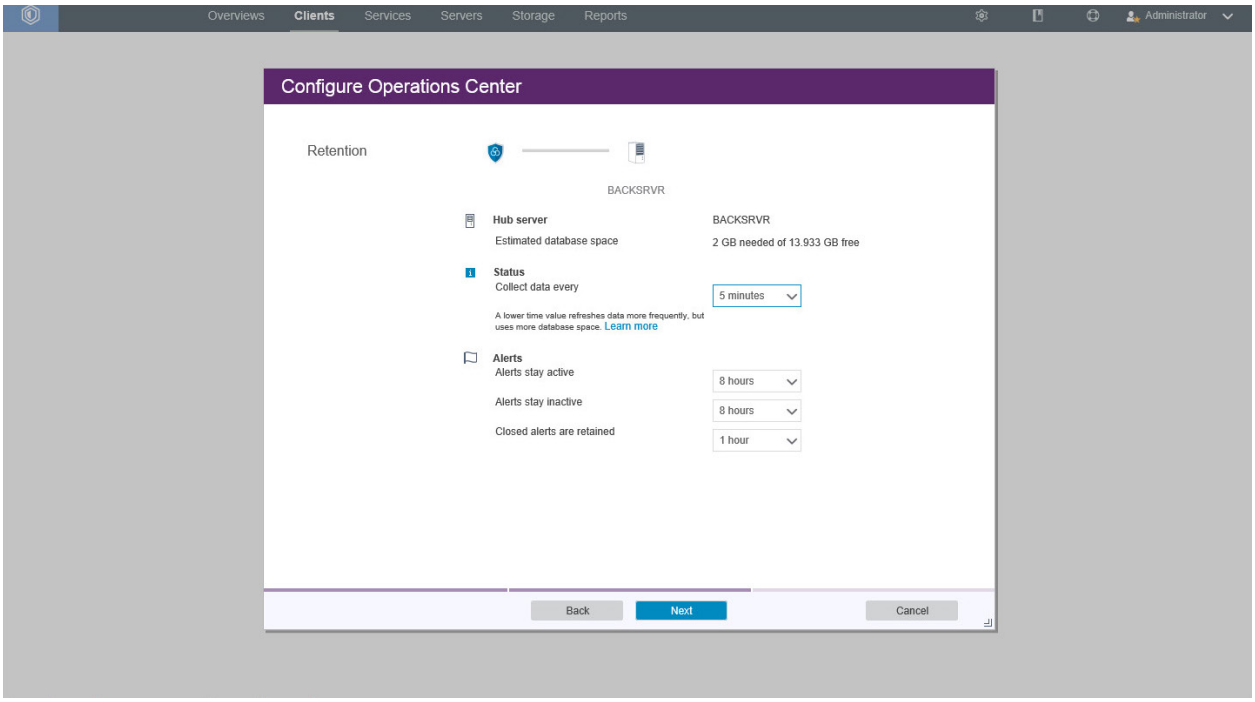


28. Log in using the credentials provided in the **Configuration Wizard**.

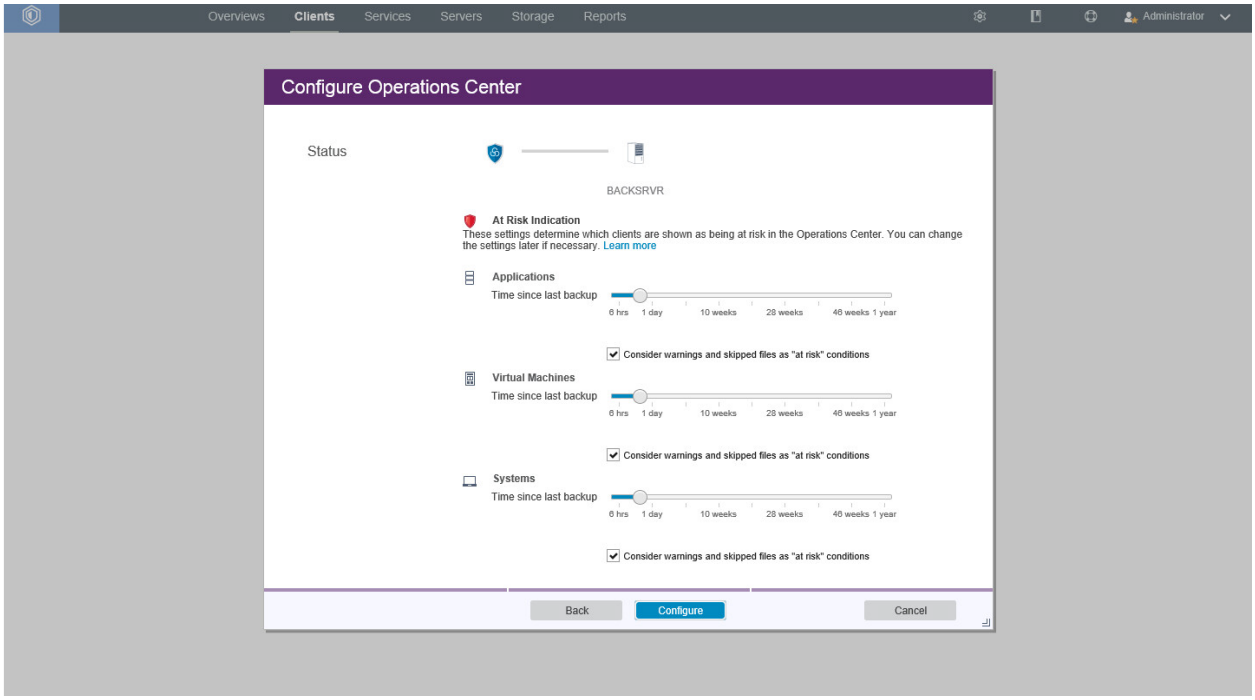
29. Enter the password for a new account to be created on the system.



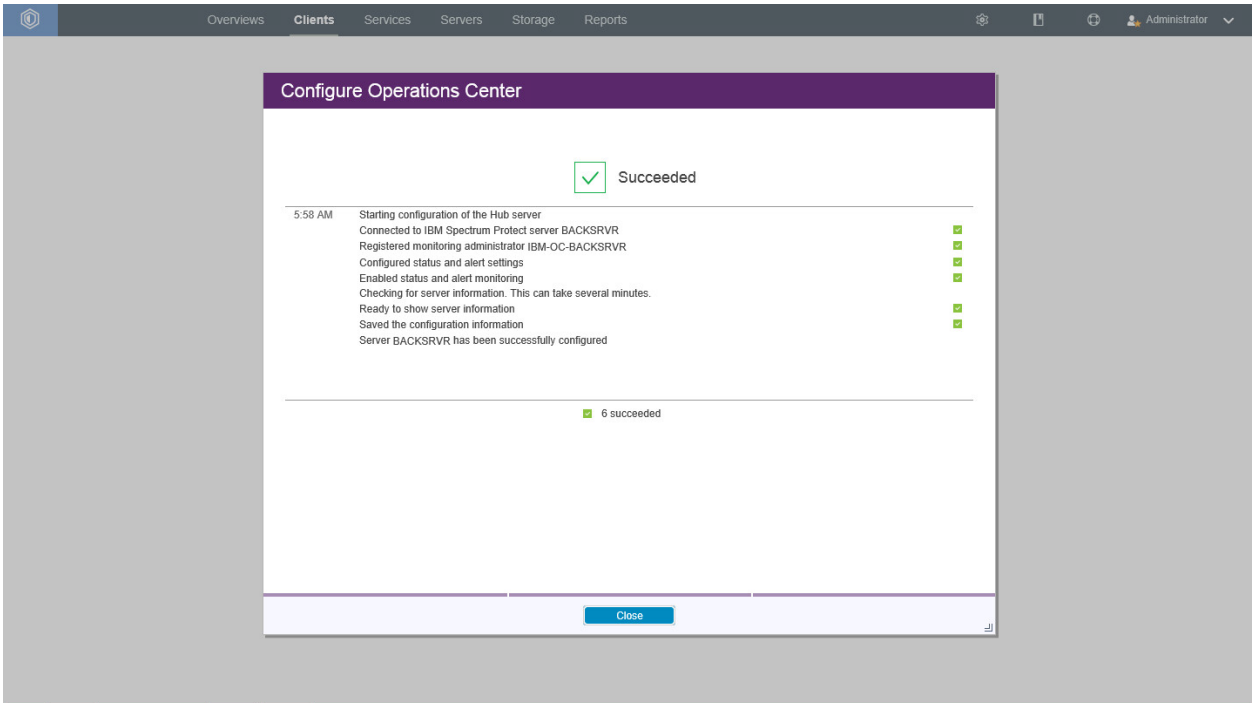
30. Click **Next**.
31. Select the time interval for data collection.



32. Click **Next**.
33. Select time intervals that suit your organization's needs.

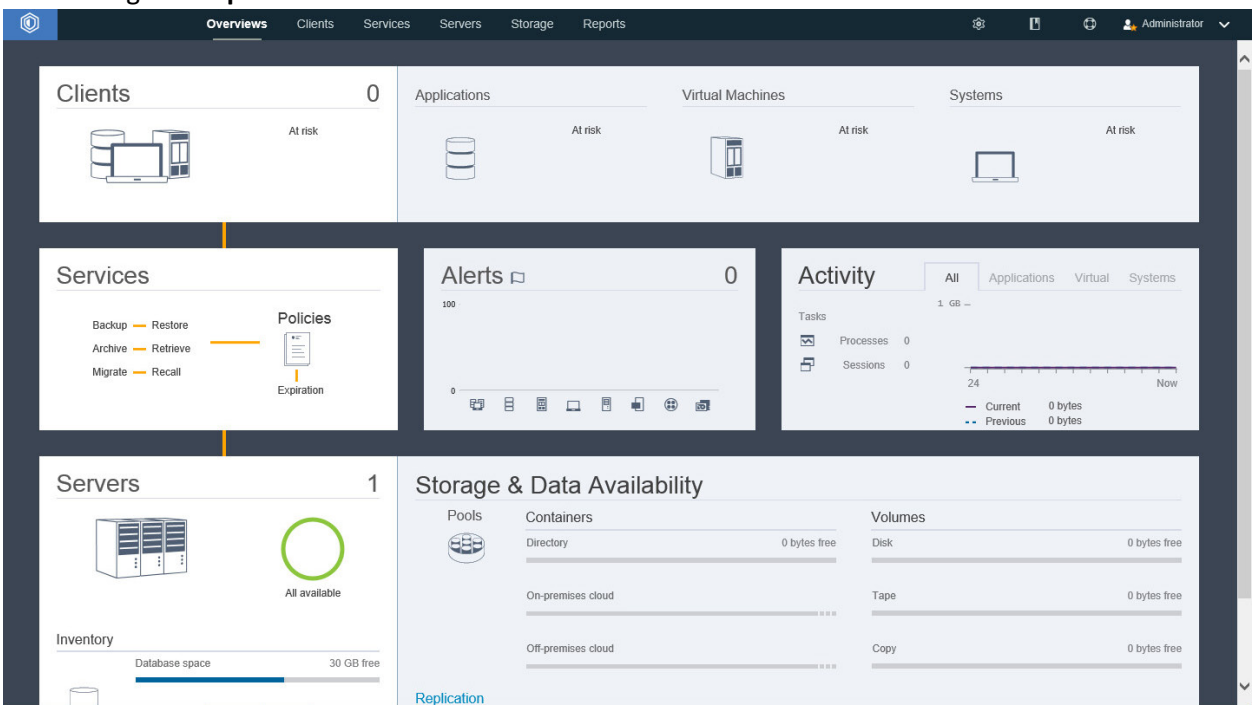


34. Click **Configure**.

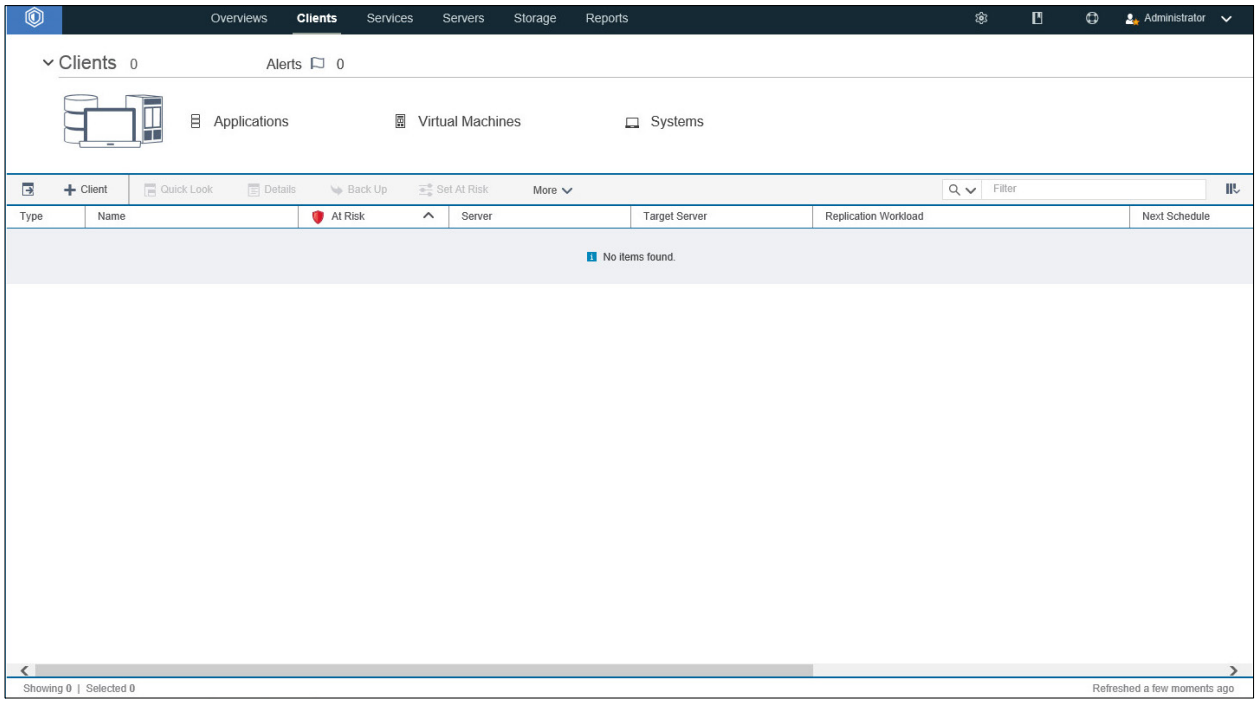


2.7.4 Adding Clients to IBM Spectrum Protect

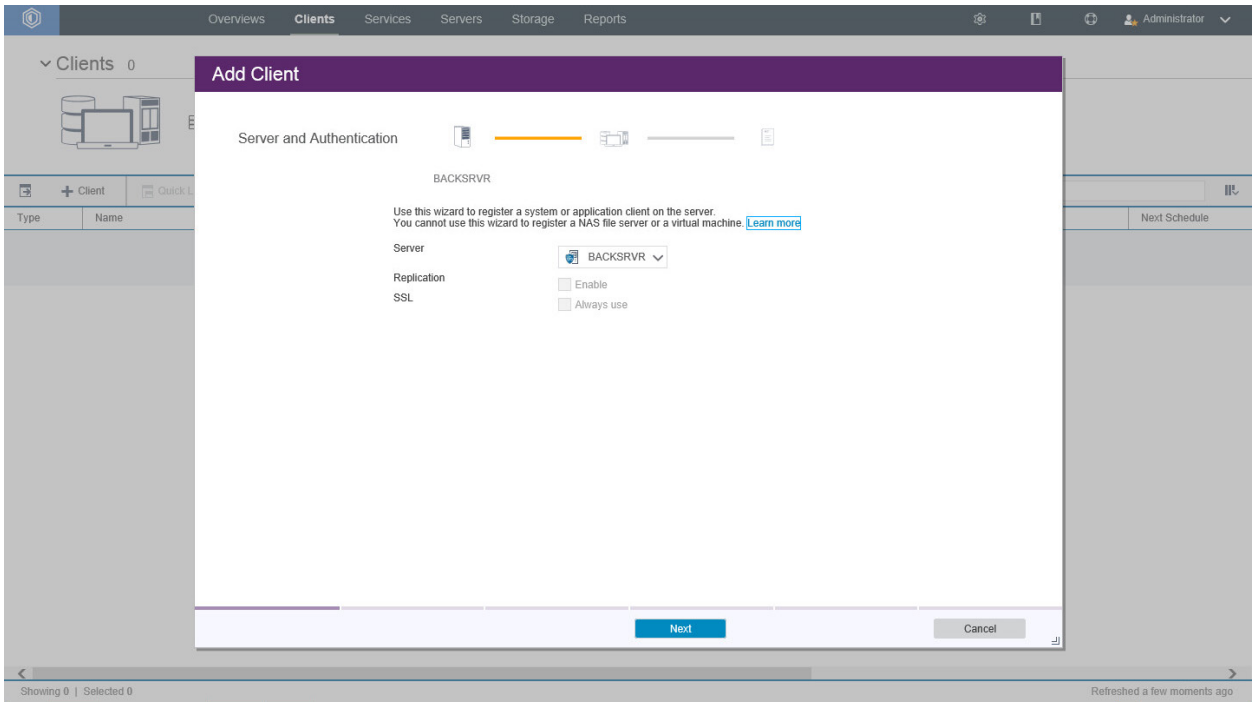
1. Log in to **Operations Center**.



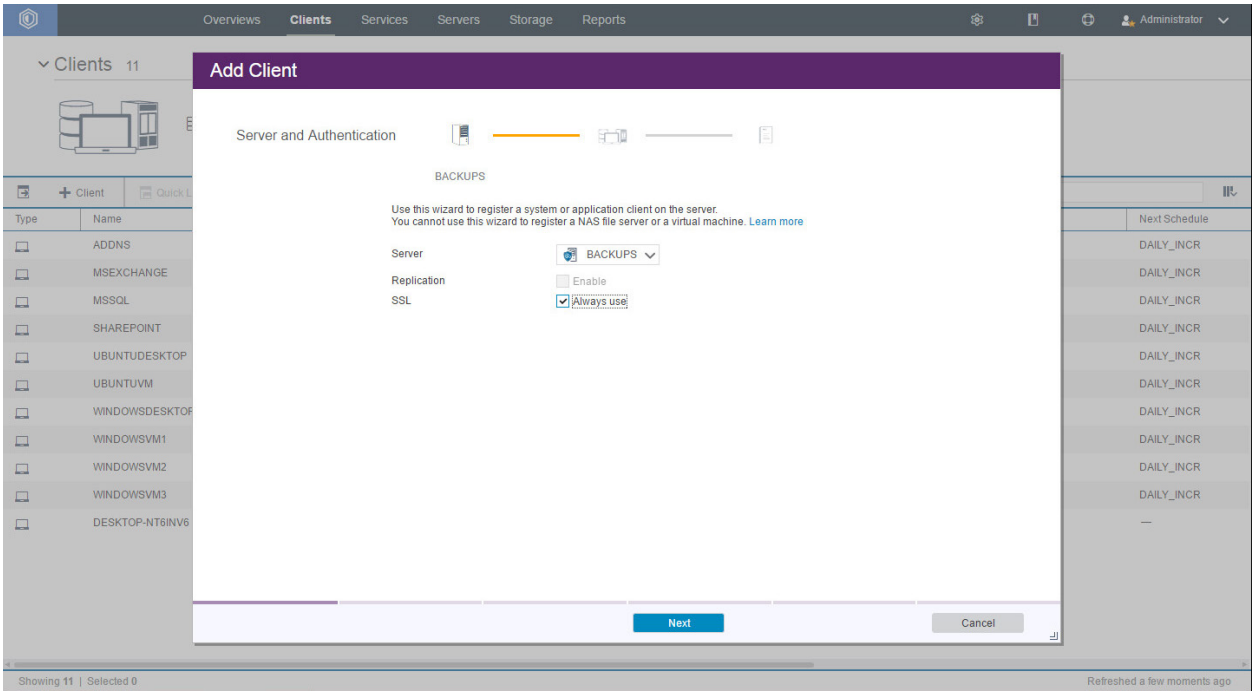
2. Add clients by clicking the **Clients** tab.



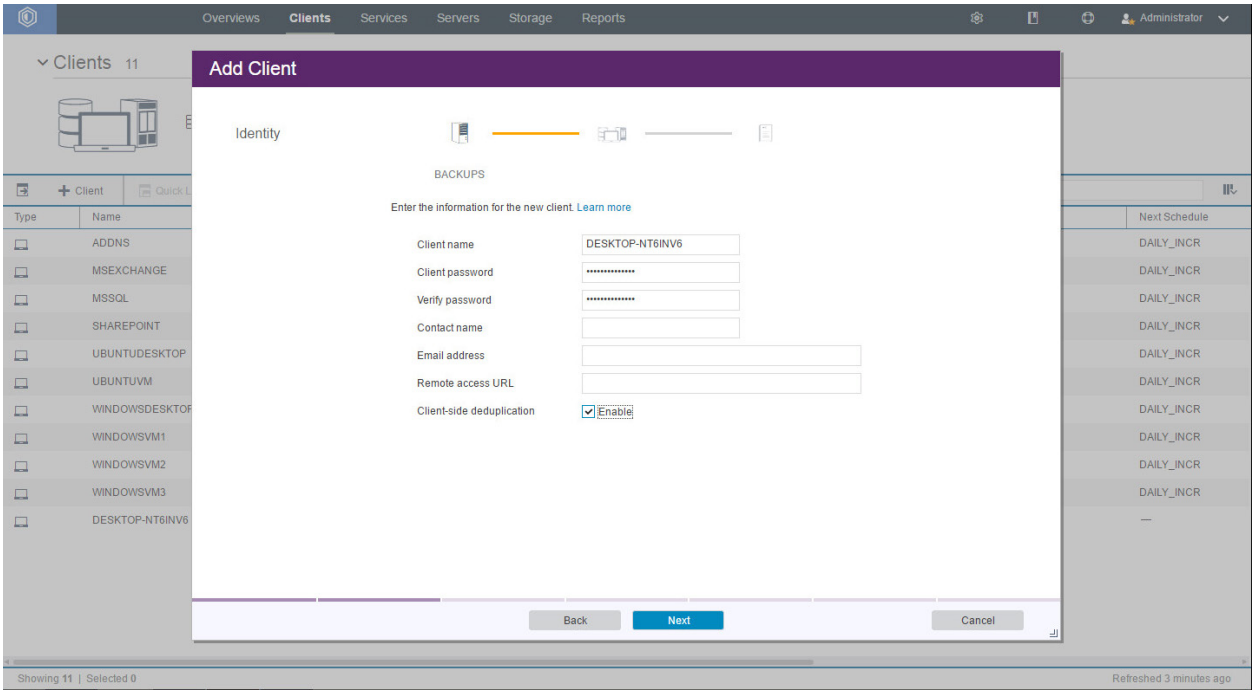
3. Click **+Client**.\



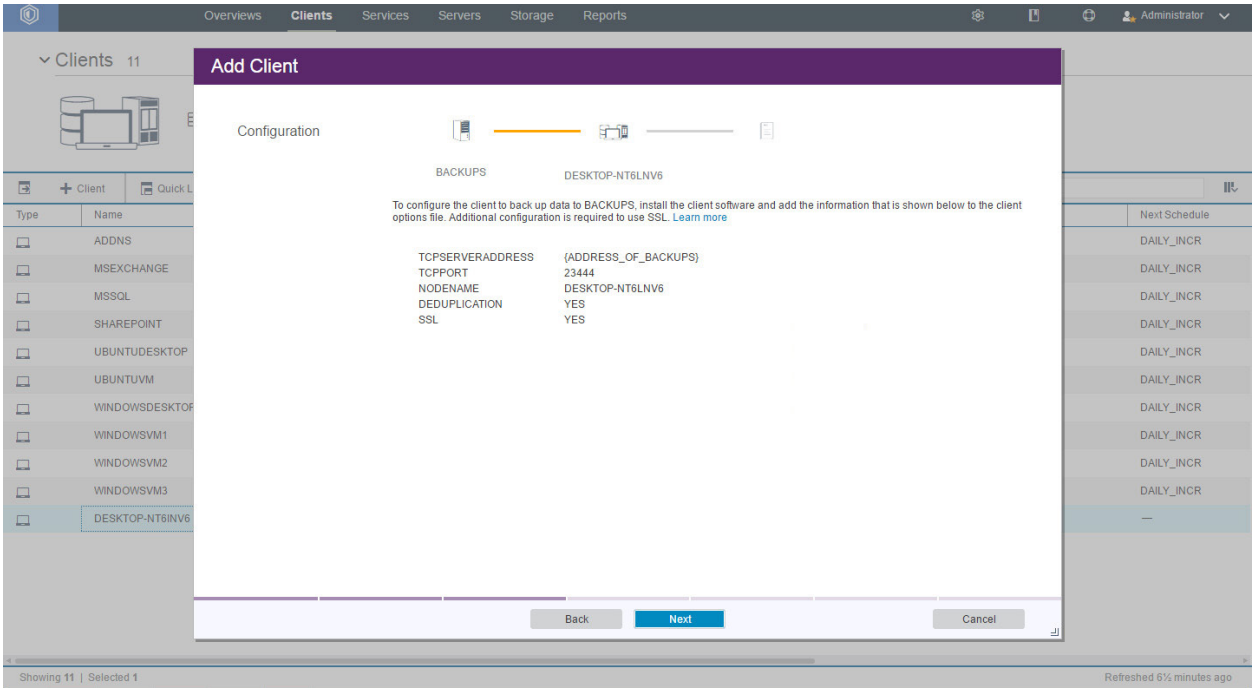
4. Select the server running the IBM backup capabilities.
5. Check the box next to **Always use** for **SSL**.



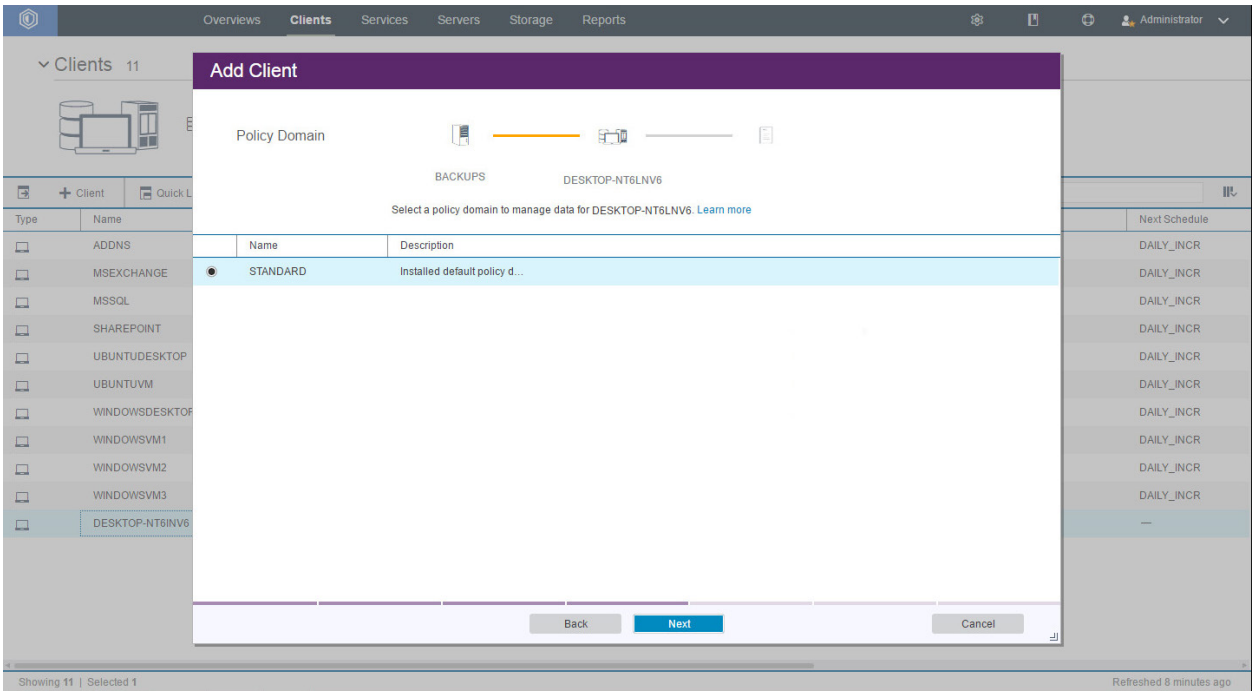
6. Click **Next**.
7. Enter the name of a client machine that you want to be able to backup data from and a password.
8. Decide whether to use **Client-side deduplication** (it reduces the required storage space for backups).



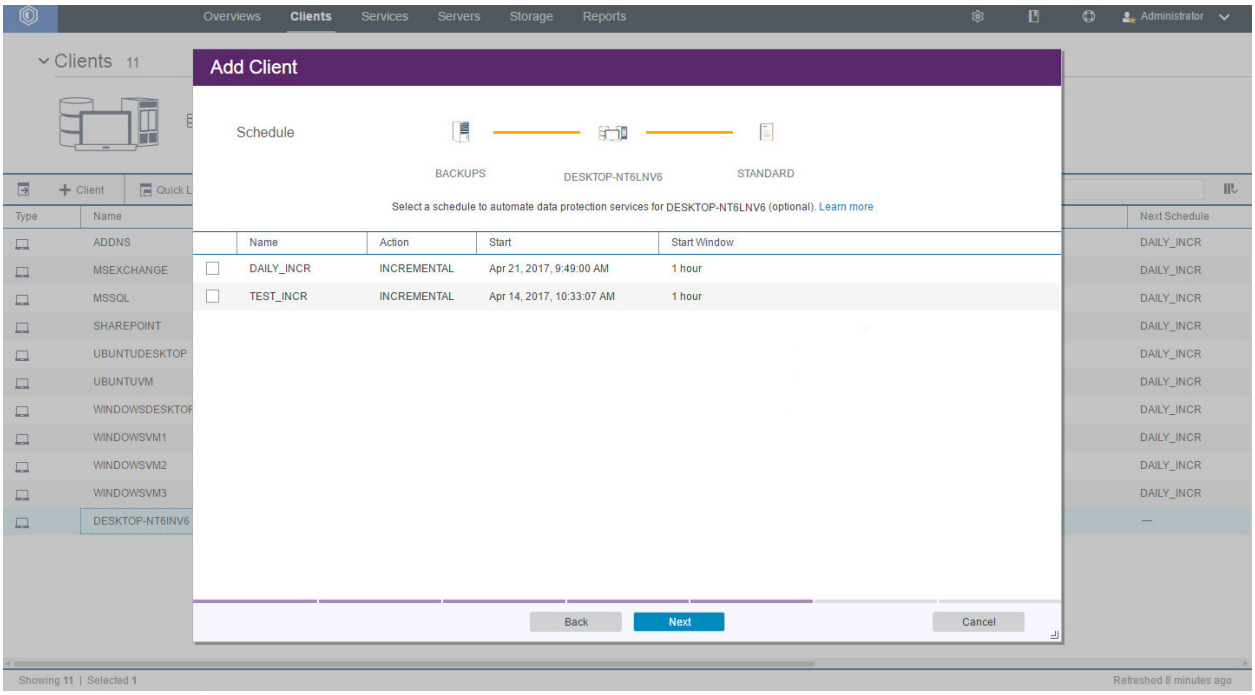
9. Click **Next**. Note the information on the next page as it is required to connect the server to the client.



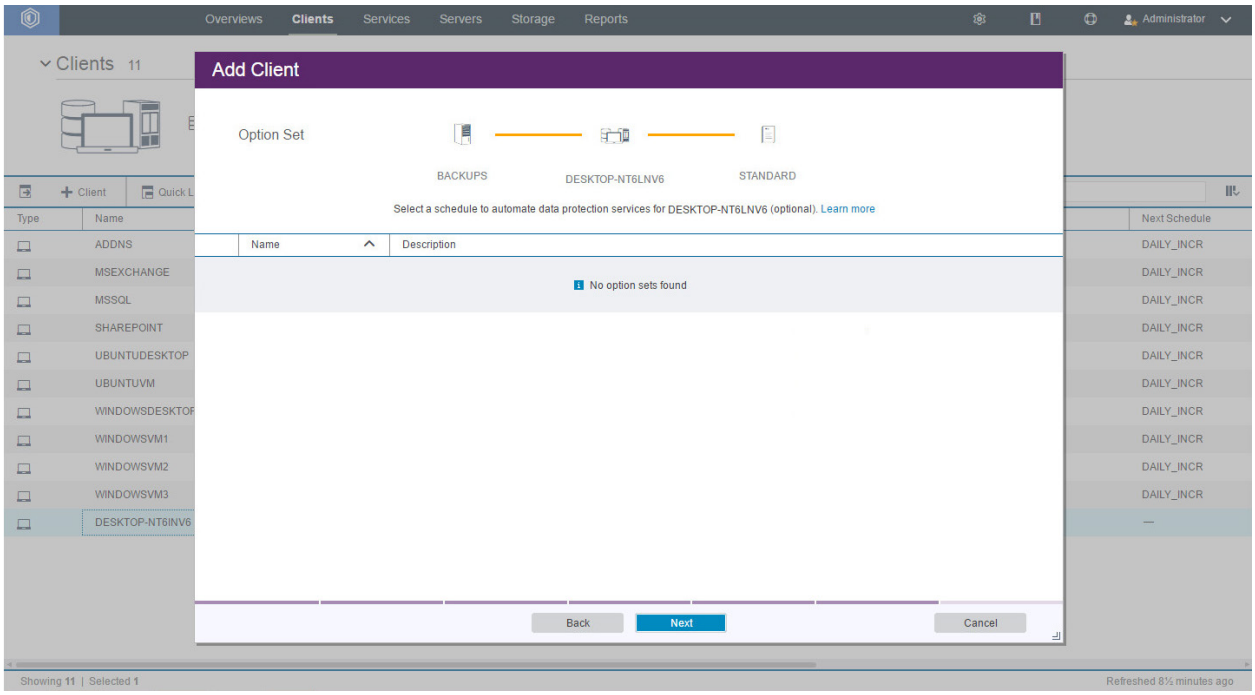
10. Click **Next**.



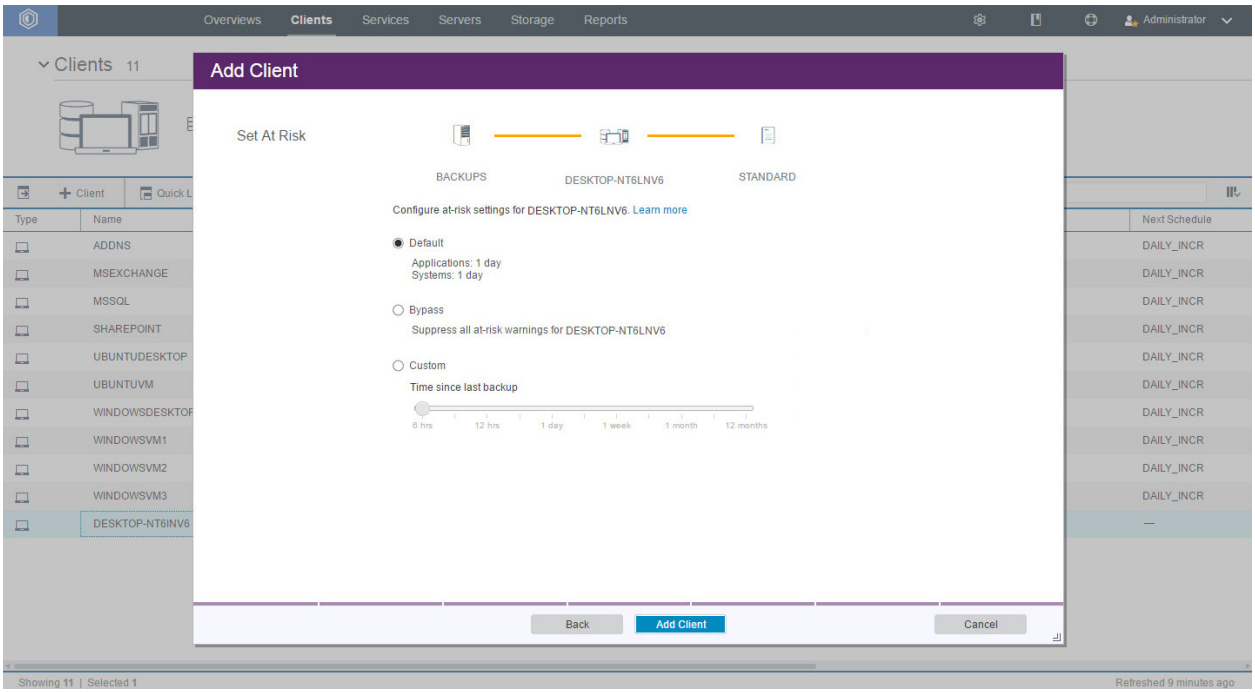
11. Click **Next**.



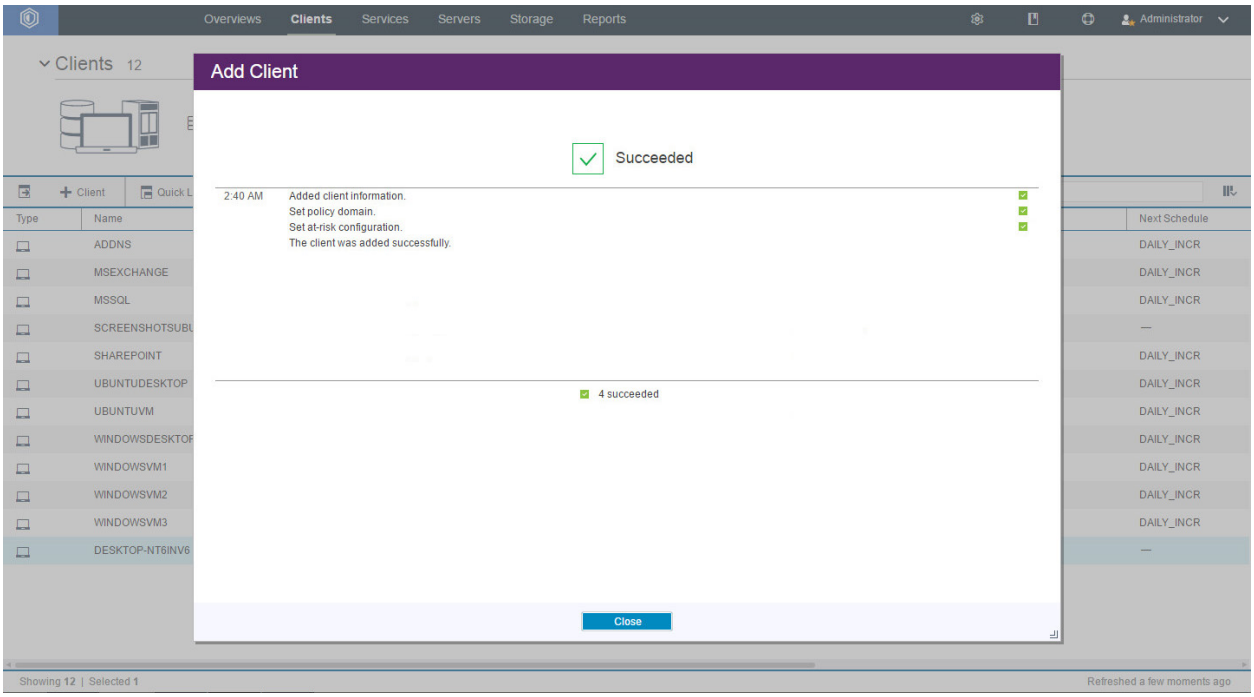
12. Click **Next**.



13. Click **Next**.
14. Select **Default**.



15. Click **Add Client**.

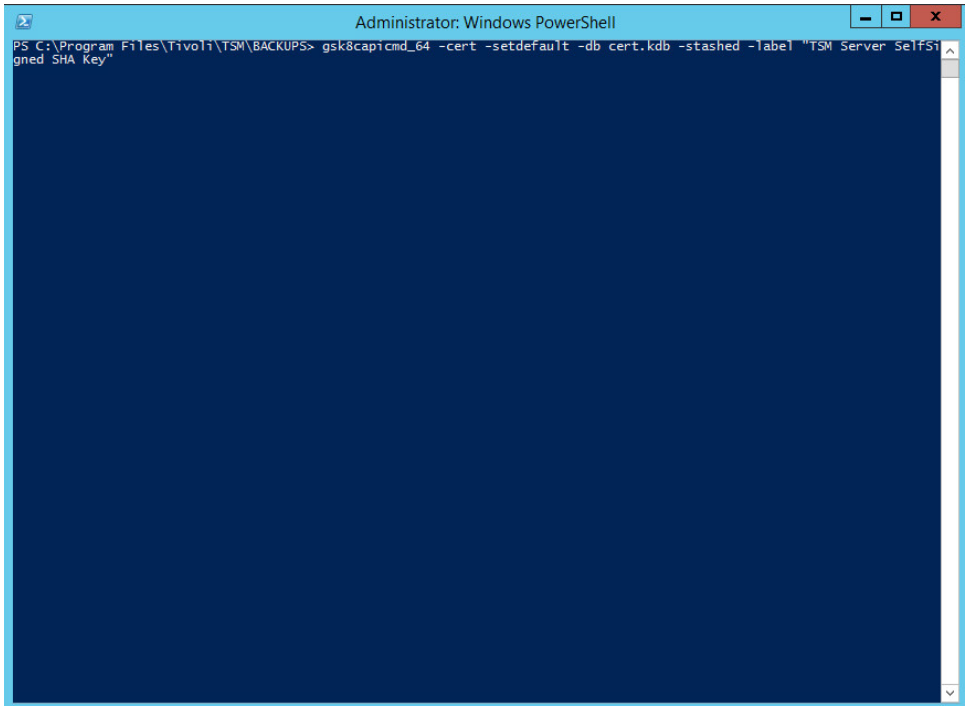


16. Make sure to allow the ports for SSL and TCP traffic through the firewall (23444, 1500).

17. Run the following command to set **cert256.arm** as the default certificate on the IBM Backup server. Execute this command from the root server directory. Example: *C:\Program Files\Tivoli\TSM\BACKSRVR*

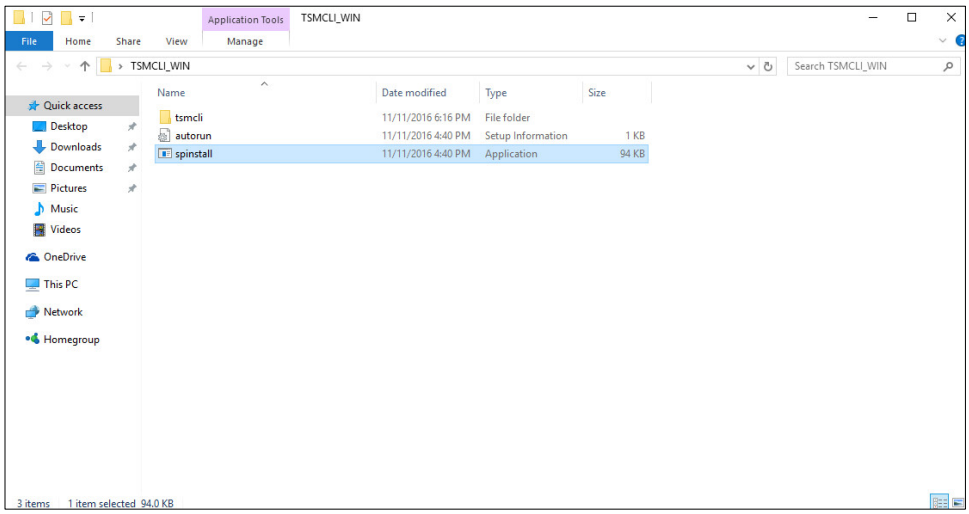
```
> gsk8capicmd_64 -cert -setdefault -db cert.kdb -stashed -label "TSM Server SelfSigned SHA Key"
```

Note: By default, gsk8capicmd_64 is located at *C:\Program Files\Common Files\Tivoli\TSM\api64\gsk8\bin.*



2.7.5 Install the Spectrum Protect Client on Windows

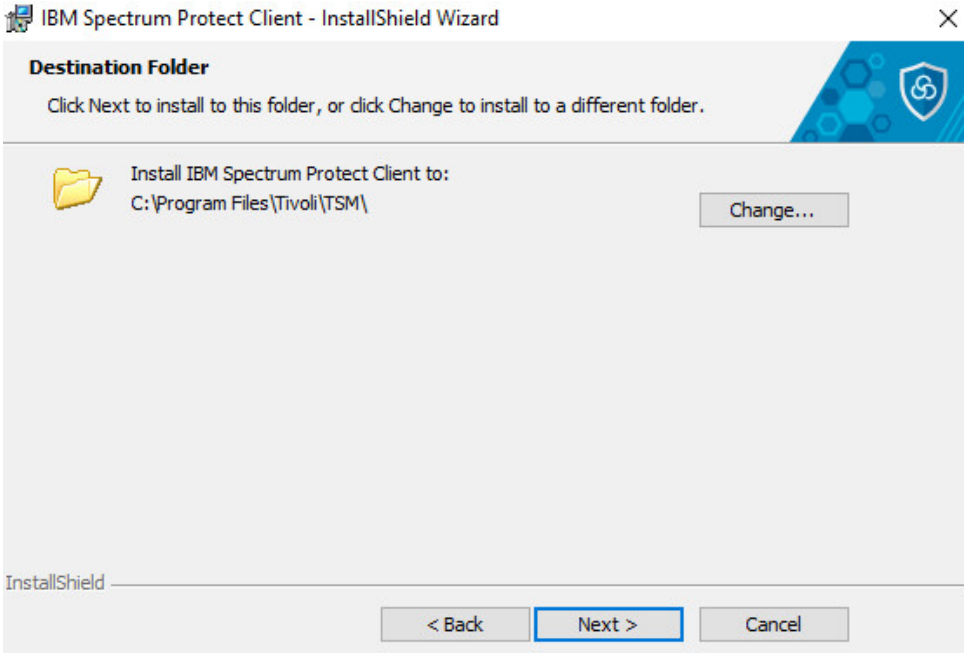
1. Extract **SP_CLIENT_8.1_WIN_ML**



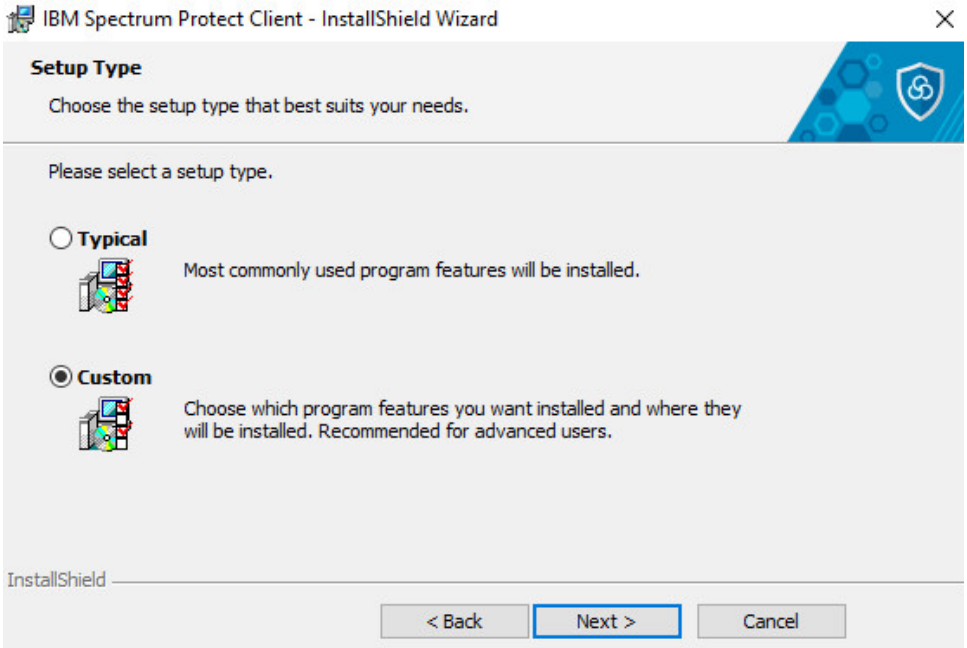
2. Run the **spinstall** script (install any prerequisites required).

3. Click **Next**.

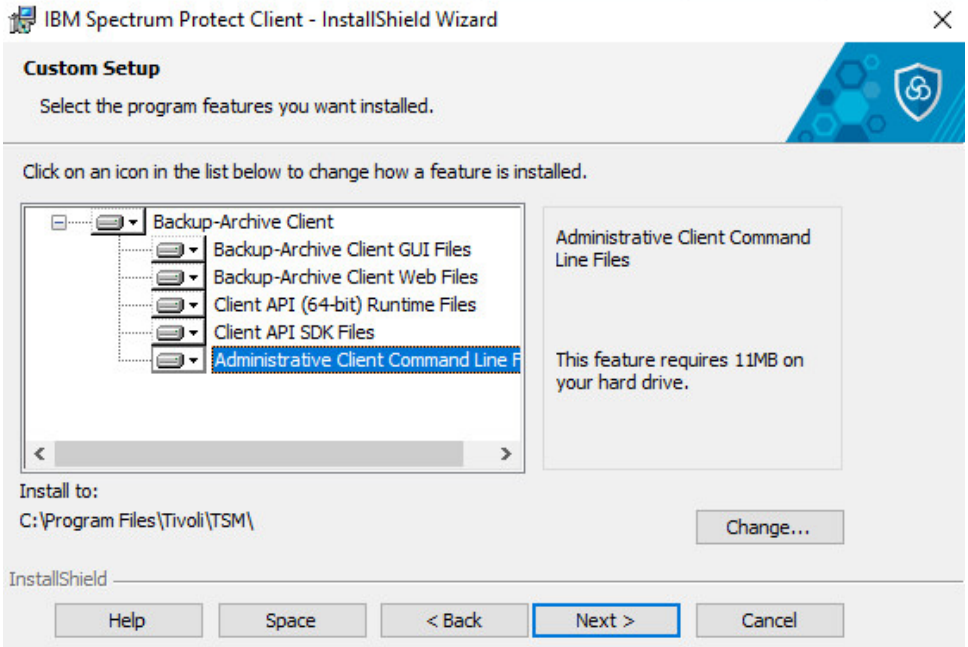
4. Specify an installation path.



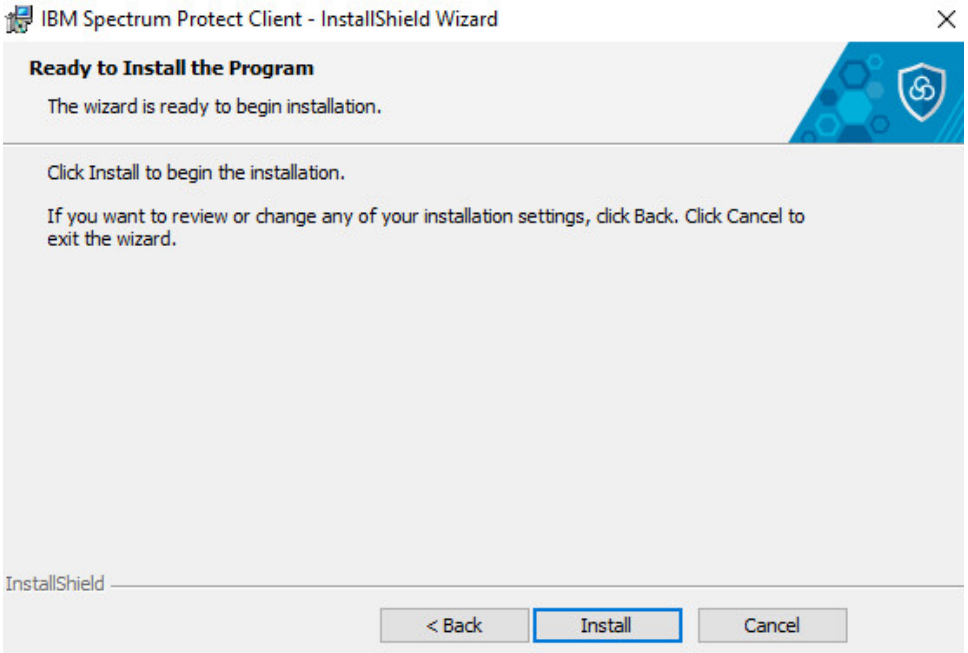
5. Click **Next**.
6. Select **Custom Install**.



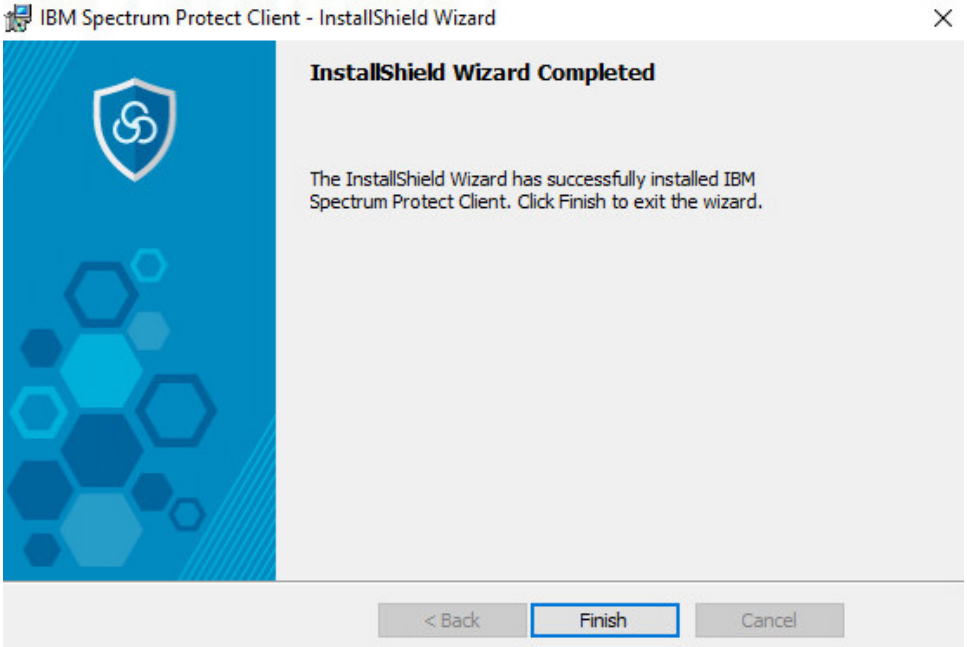
7. Click **Next**. Make sure that all packages are selected for installation.



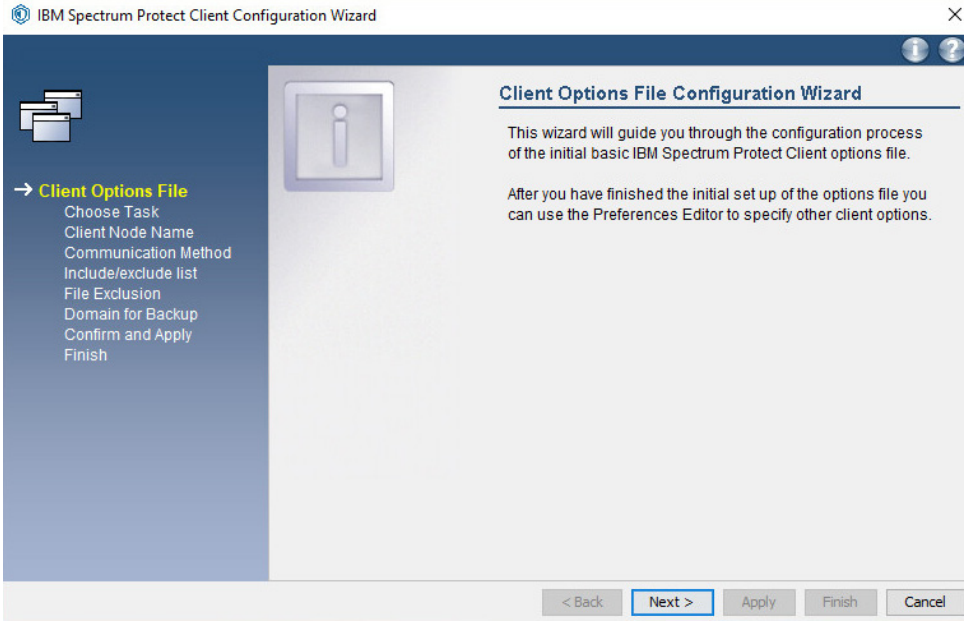
8. Click **Next**.



9. Click **Install**.

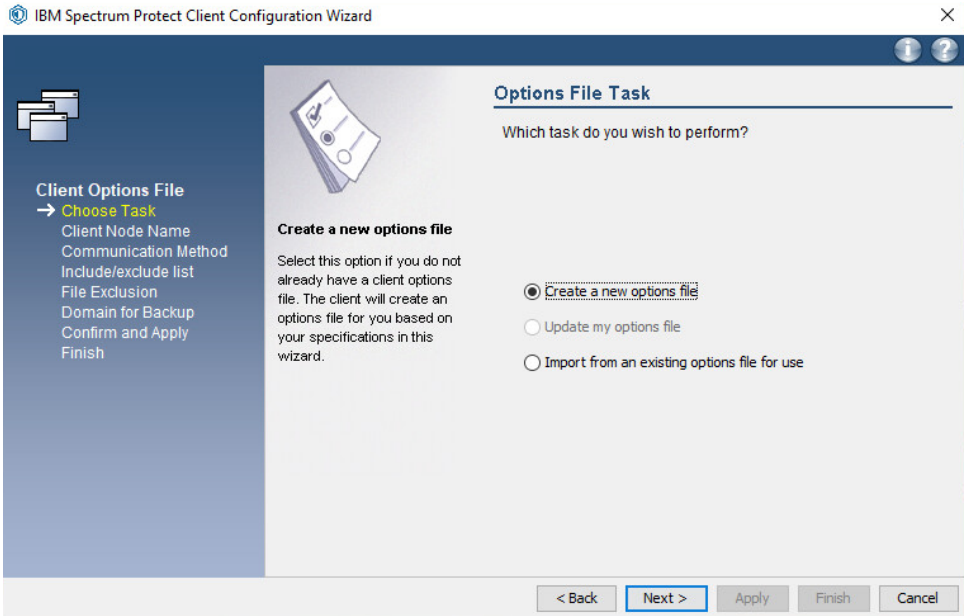


10. Click **Finish**.
11. Run **Backup-Archive GUI** from the **Start menu**. This should open the **IBM Spectrum Protect Client Configuration Wizard**.

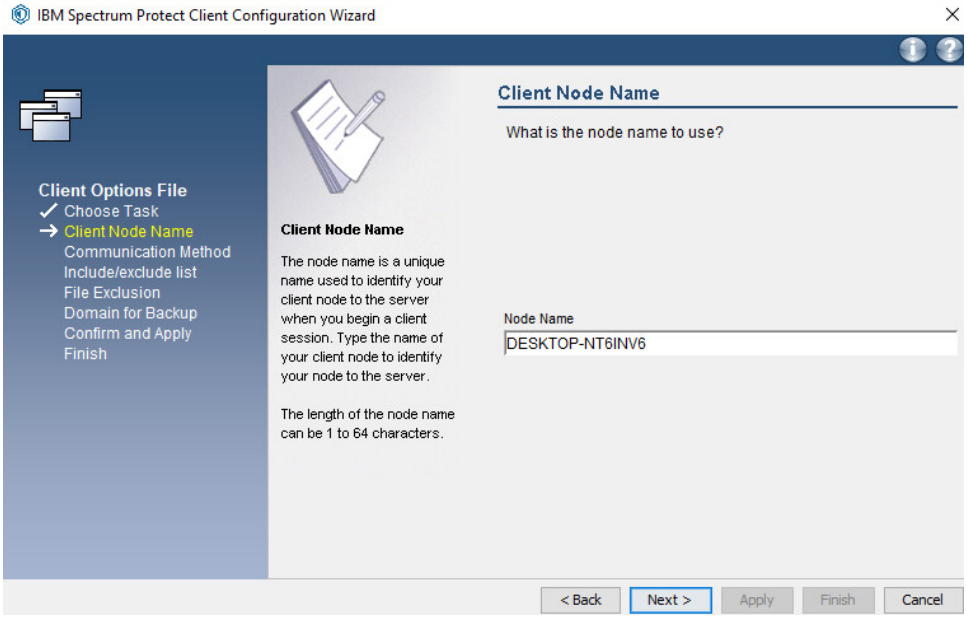


12. Click **Next**.

13. Select **Create a new options file**.

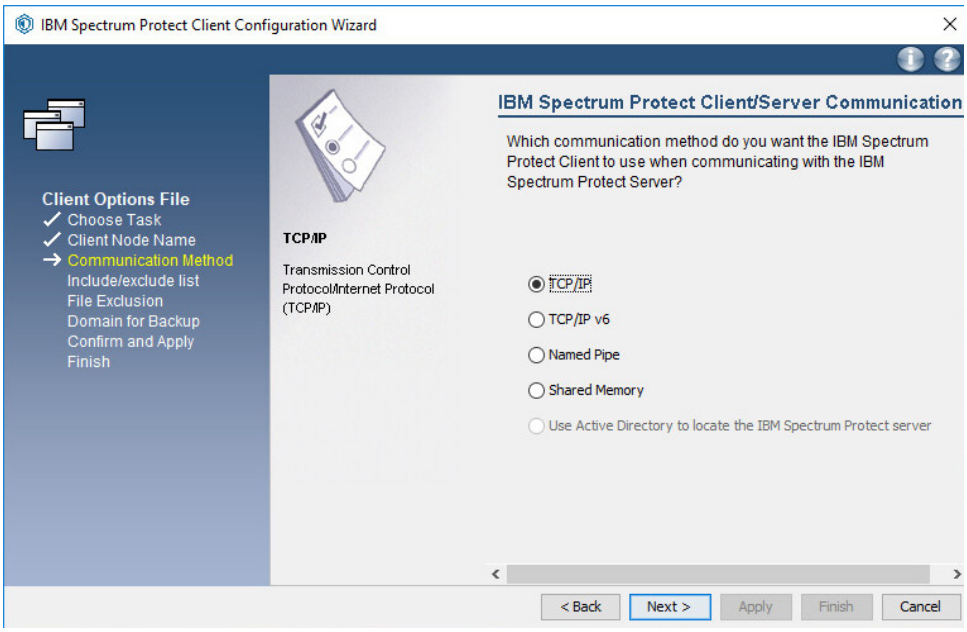


14. Click **Next**.
15. Enter the **Node Name** that you created in the **Operations Center**.

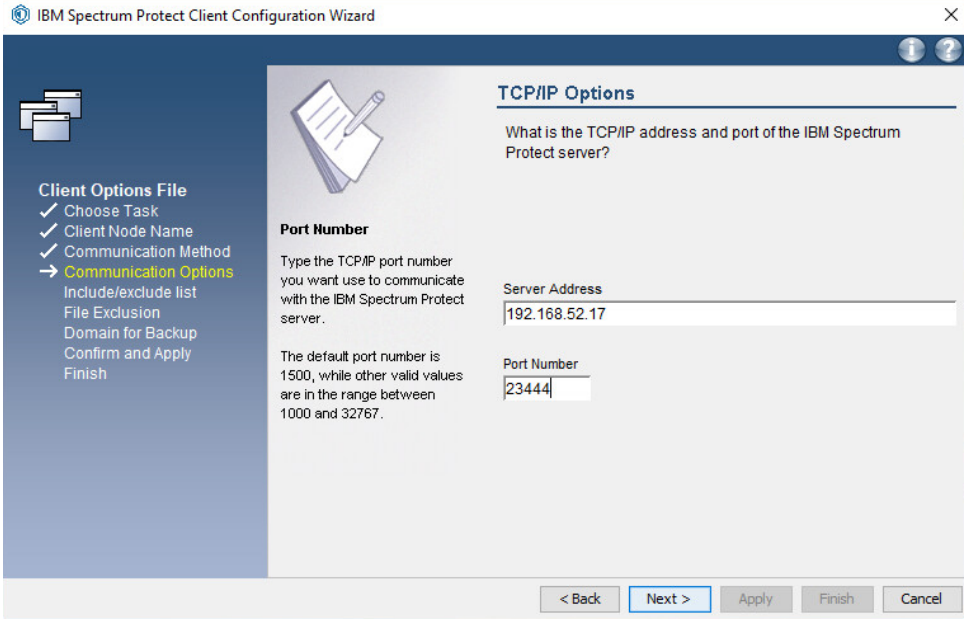


16. Click **Next**.
17. If prompted, allow the program through the firewall.

18. Select **TCP/IP** for the communication method.

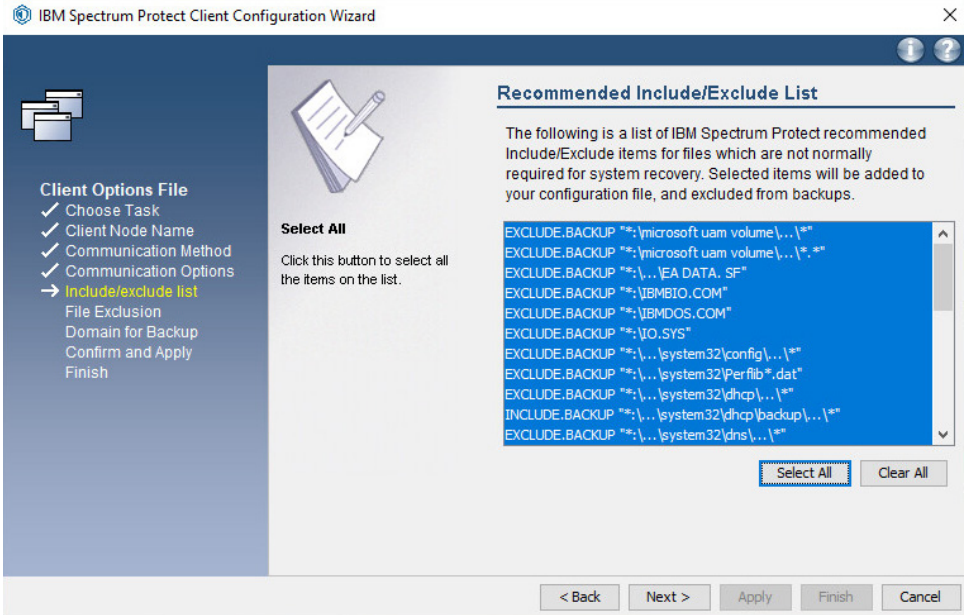


19. Click **Next**.
20. Specify the **IP address** of the server running the IBM backup server.
21. Specify the **port** that the server is accepting connections on (Example: 23444).

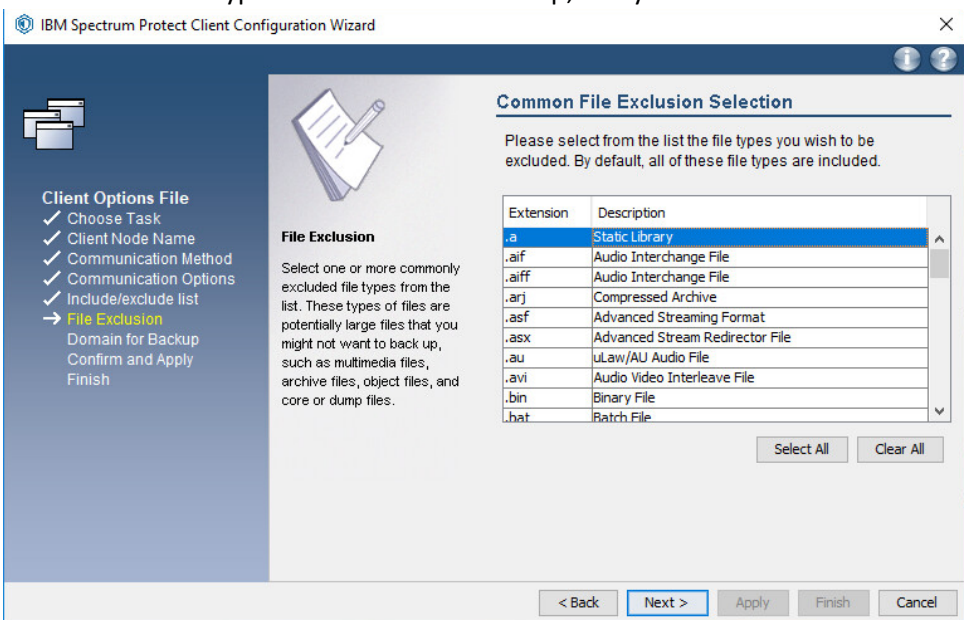


22. Click **Next**.

23. Click **Select All** or choose specific items from the recommended list of inclusions/exclusions.

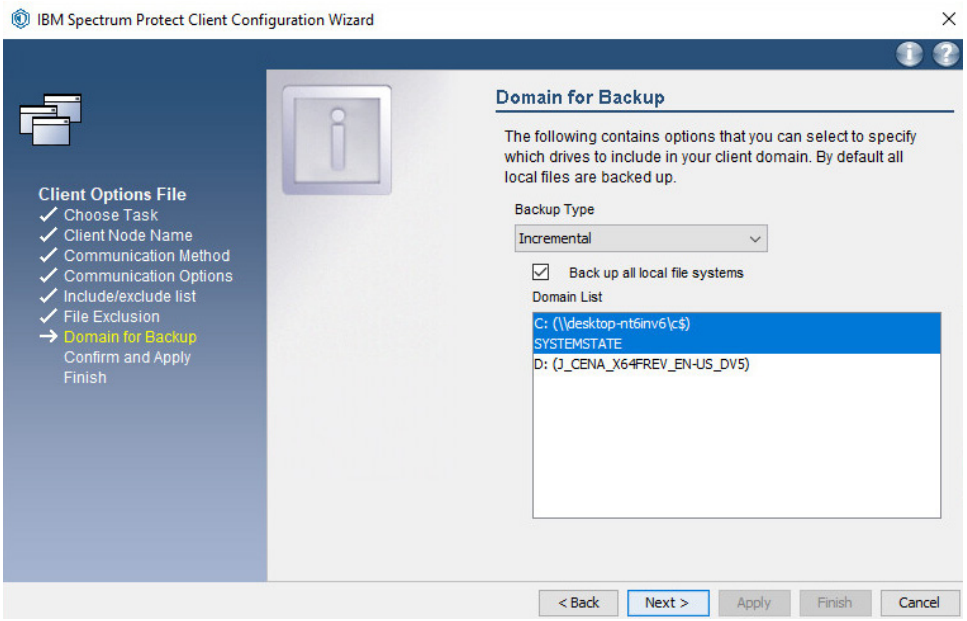


24. Click **Next**.
25. Select certain file types to exclude from backup, if any.

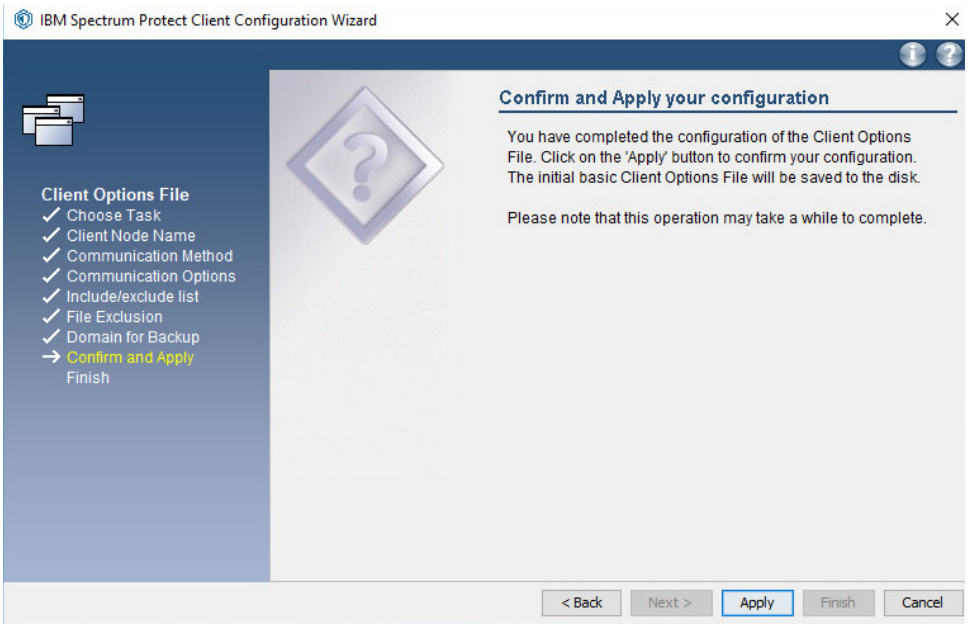


26. Click **Next**.
27. Check the box next to **Backup all local file systems**.

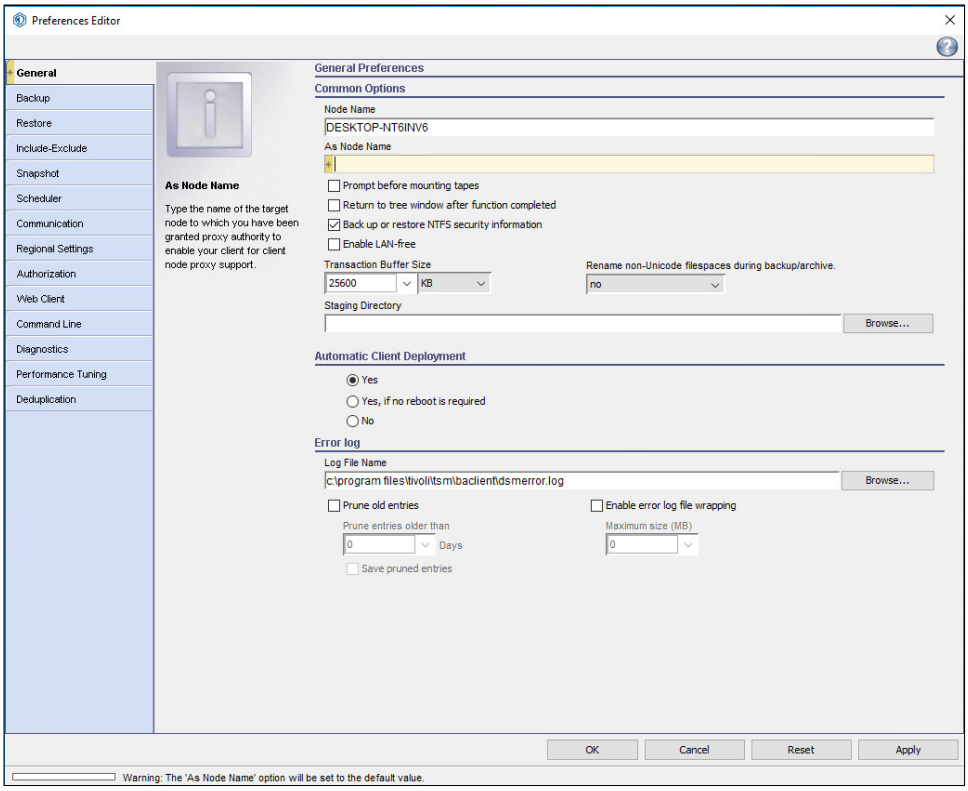
28. Select **Incremental** for the **Backup Type**.



29. Click **Next**.

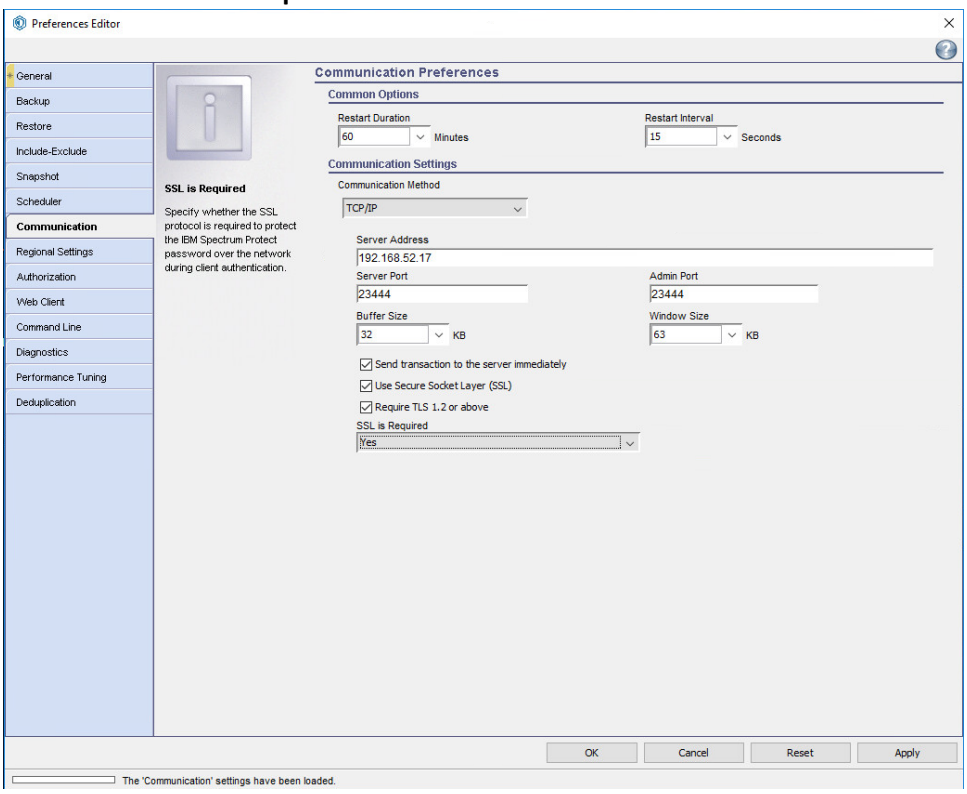


30. Click **Apply**.
31. Click **Finish**.
32. In the **Backup-Archive GUI** (you may have to log in using the credentials specified on the server or you may have to choose to ignore a warning that you couldn't connect), go to **Edit > Client Preferences**.



33. Click **Communication**.
34. Ensure that the **server address** is correct and that the **ports** point to your SSL port (23444).
35. Check the boxes next to **Send transaction to the server immediately**, **Use Secure Sockets Layer (SSL)**, and **Require TLS 1.2 or above**.

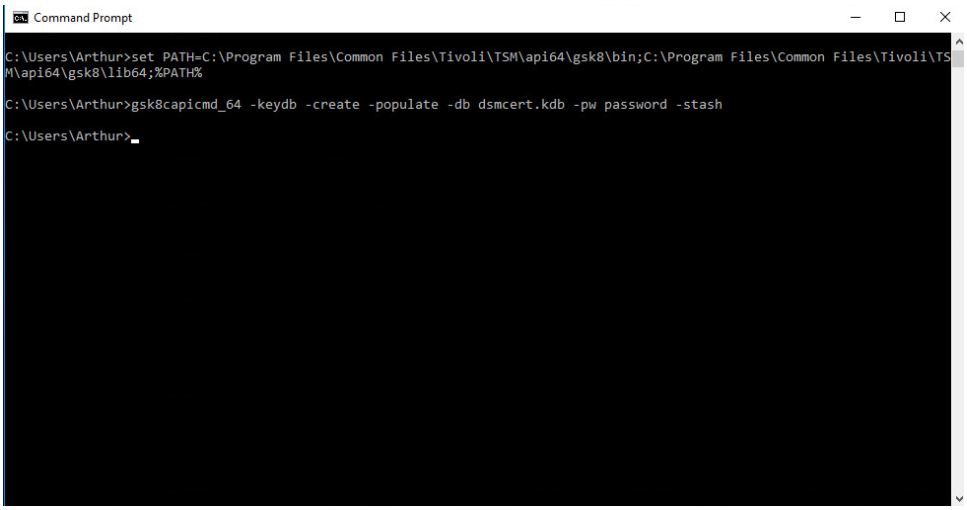
36. Select **Yes** for **SSL is Required**.



37. Click **OK.**
38. Retrieve **cert256.arm** from the server.
39. On the client machine, create a new key database by running the following commands:

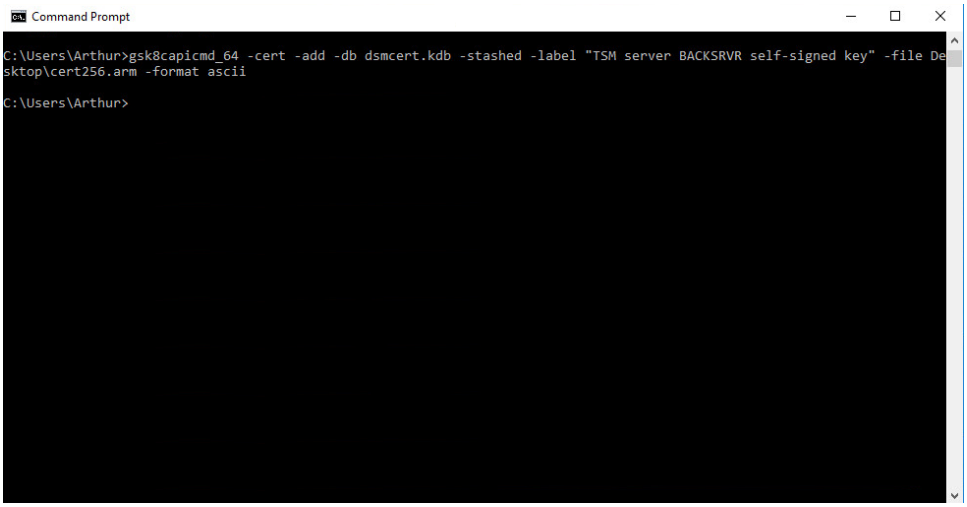
```
> set PATH=C:\Program Files\Common
Files\Tivoli\TSM\api64\gsk8\bin\;C:\Program Files\Common
Files\Tivoli\TSM\api64\gsk8\lib64;%PATH%
```

```
> gsk8capicmd_64 -keydb -create -populate -db dsmcert.kdb -pw password -
stash
```

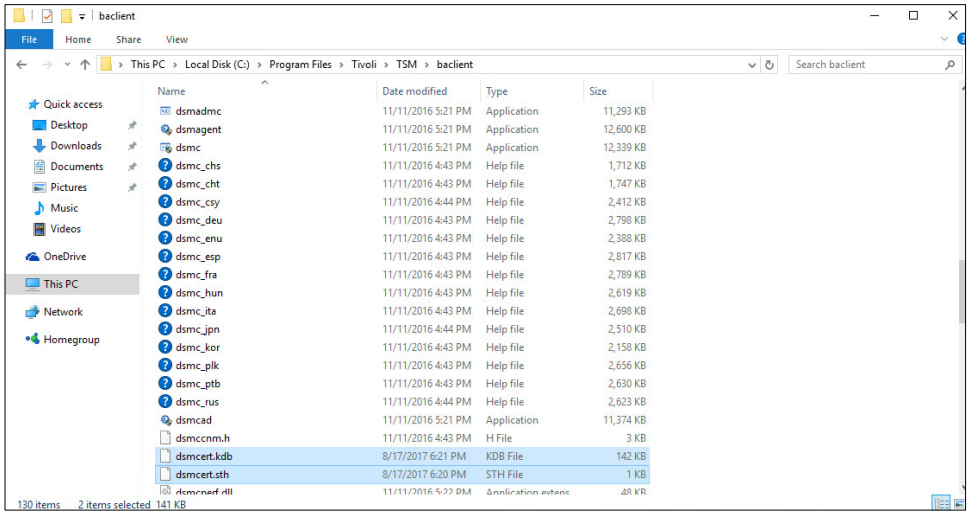


40. Import **cert256.arm** by running the command:

```
> gsk8capicmd_64 -cert -add -db dsmcert.kdb -stashed -label "TSM server
BACKSRVR self-signed key" -file <path-to-cert256.arm> -format asci
```

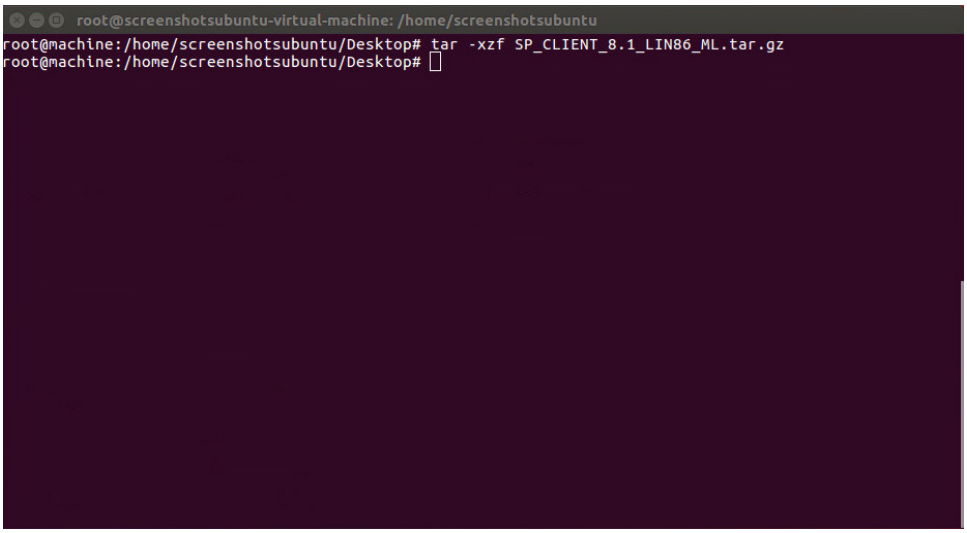


41. Copy the resulting *dsmcert.kdb* and *dsmcert.sth* to *C:\Program Files\Tivoli\TSM\baclient*.

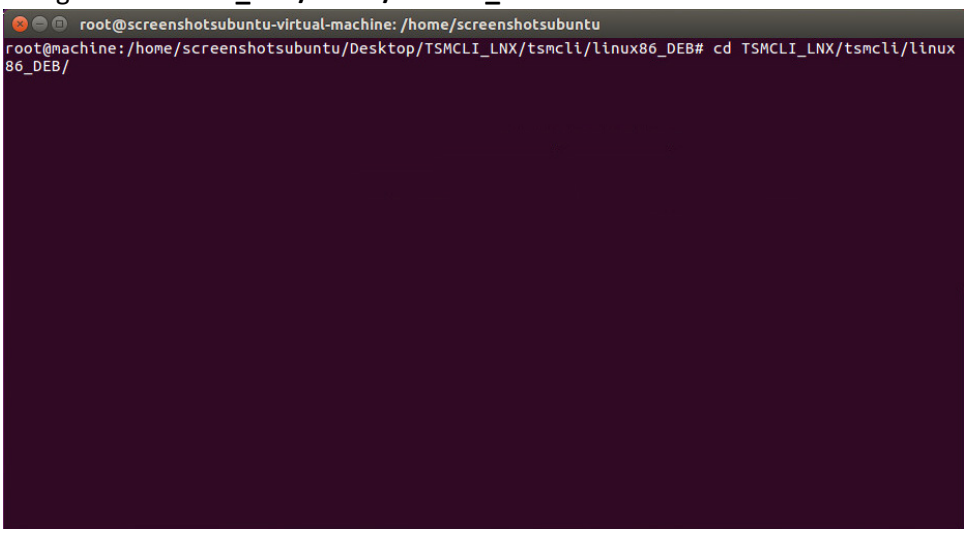


2.7.6 Install the Spectrum Protect Client on Ubuntu

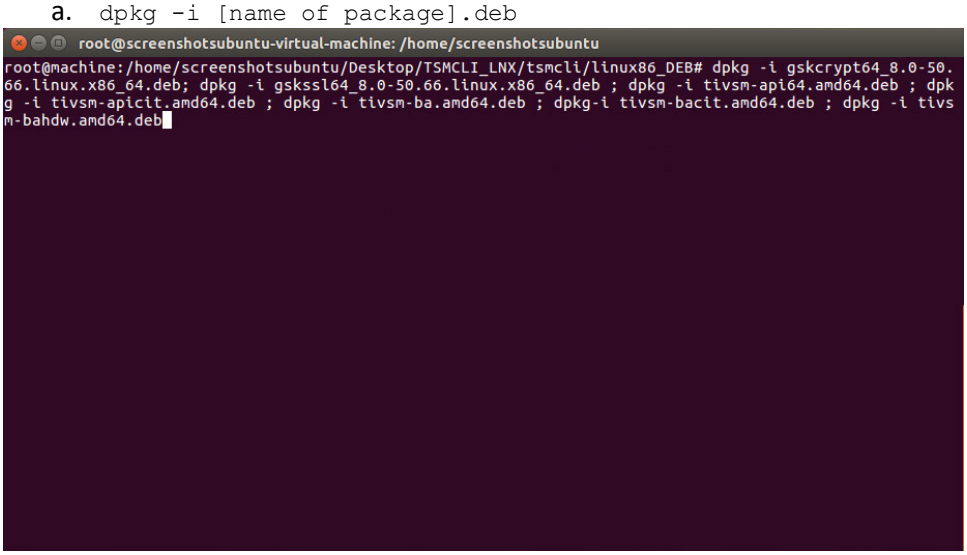
1. Extract **SP_CLIENT_8.1_LIN86_ML.tar.gz**.



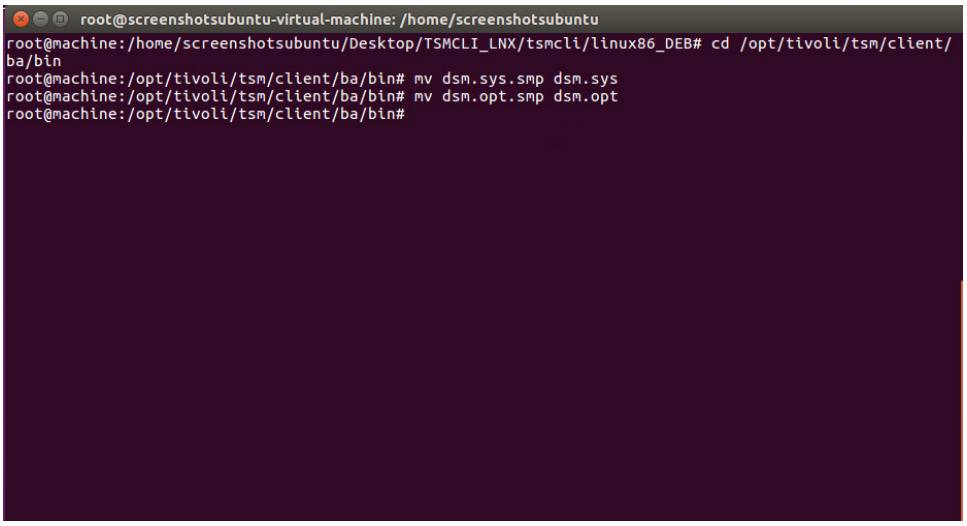
2. Navigate to **TSMCLI_LNX/tsmcli/linux86_DEB**.



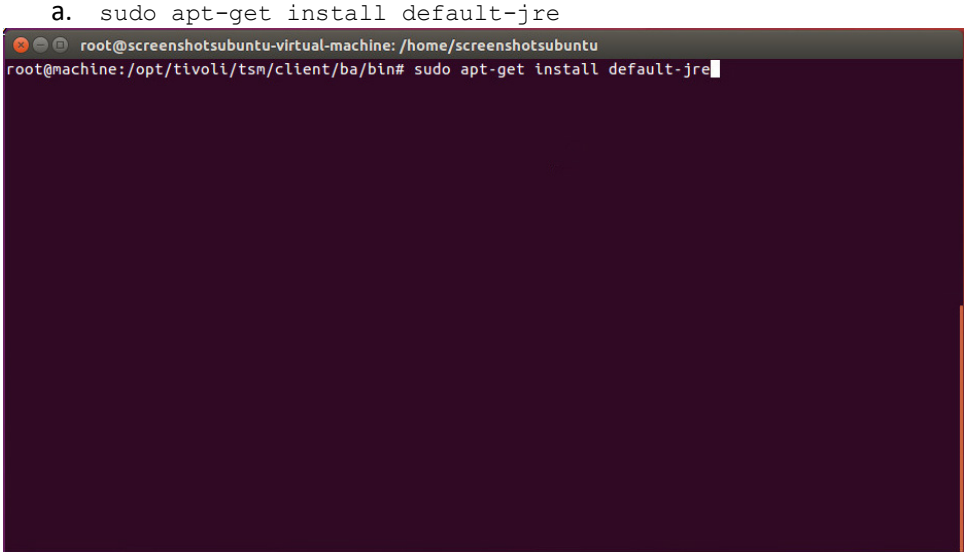
3. Install all the **.deb** files in this directory, except tivsm-jbb.amd64.deb, by running the following command (they must be dpkg'd individually since they have interdependencies):
   a. `dpkg -i [name of package].deb`



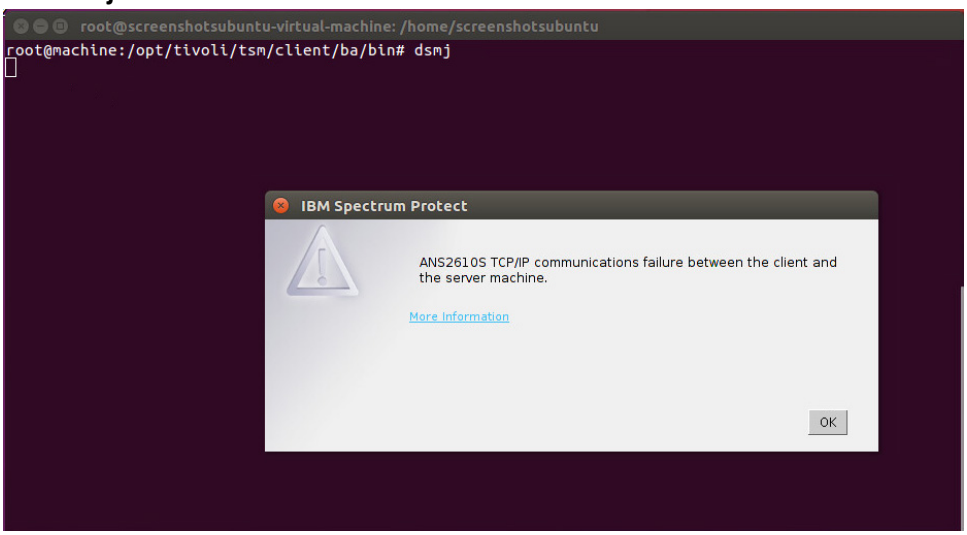
4. Issue the following commands to setup the options files:
   a. `cd /opt/tivoli/tsm/client/ba/bin`
   b. `mv dsm.sys.smp dsm.sys`
   c. `mv dsm.opt.smp dsm.opt`



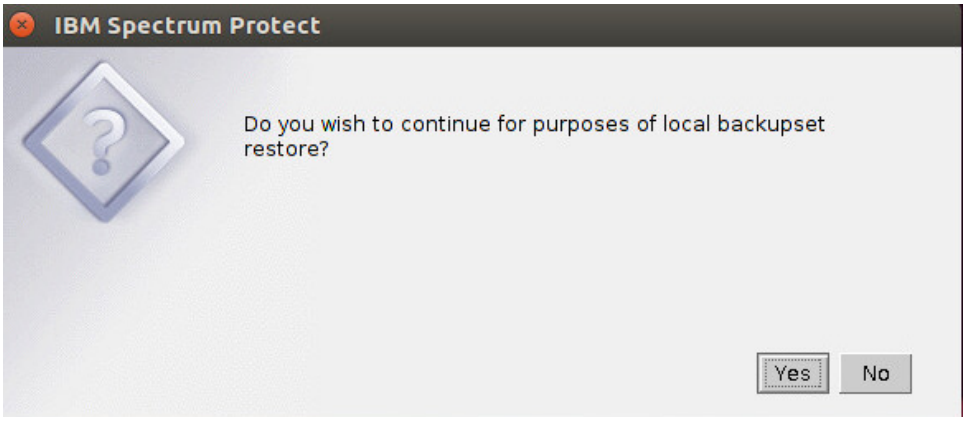
5. Install Java with:
   a. `sudo apt-get install default-jre`



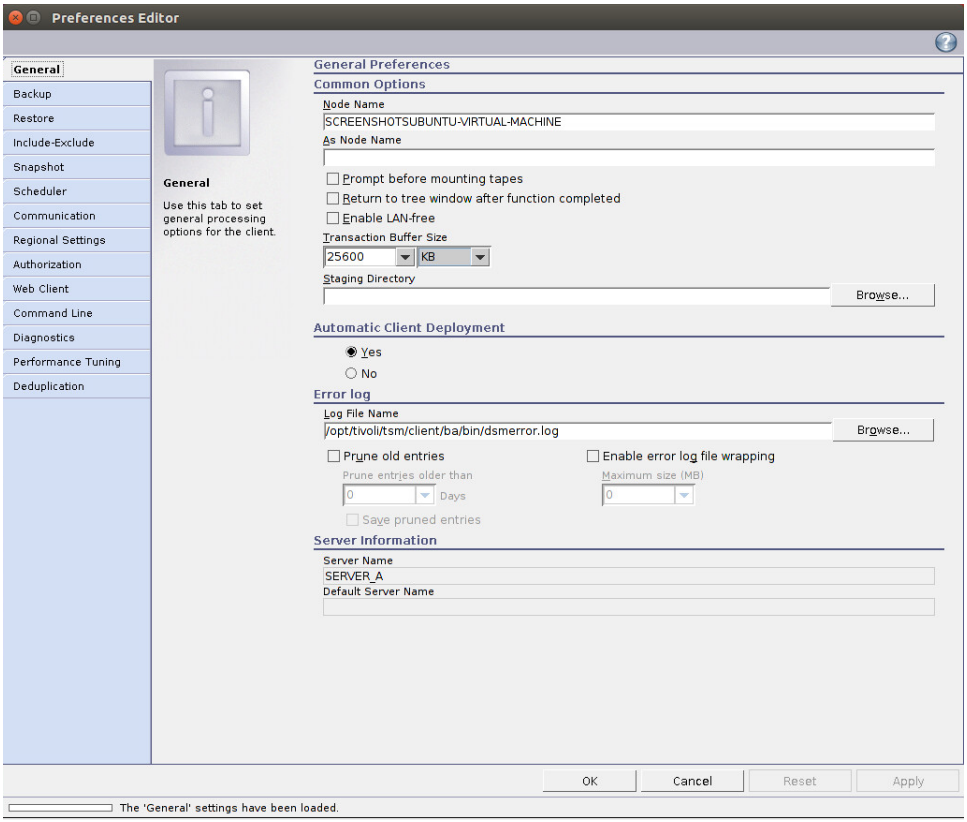
6. Run **dsmj** to start the Java **BAClient**.



7. After about 5 minutes, it will be unable to connect and will ask if you wish to start the client anyway. Click **Yes**.

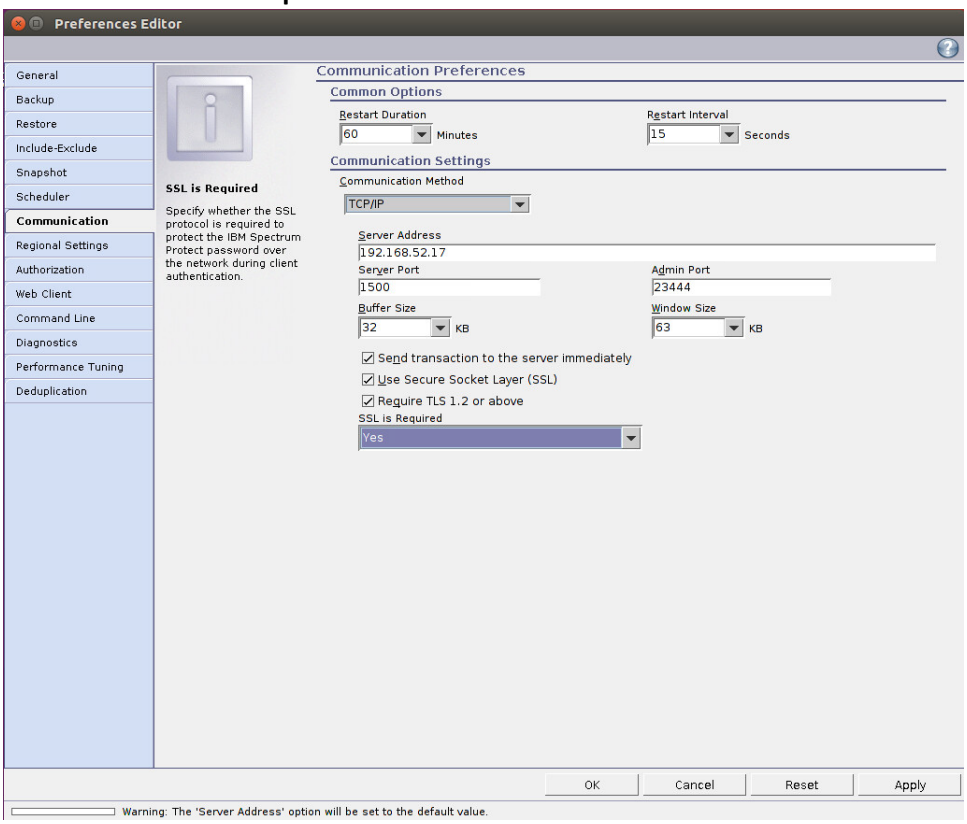


8. Open **Edit > Client Preferences**. Enter the node name as the name of the client you added to the Spectrum Protect server.



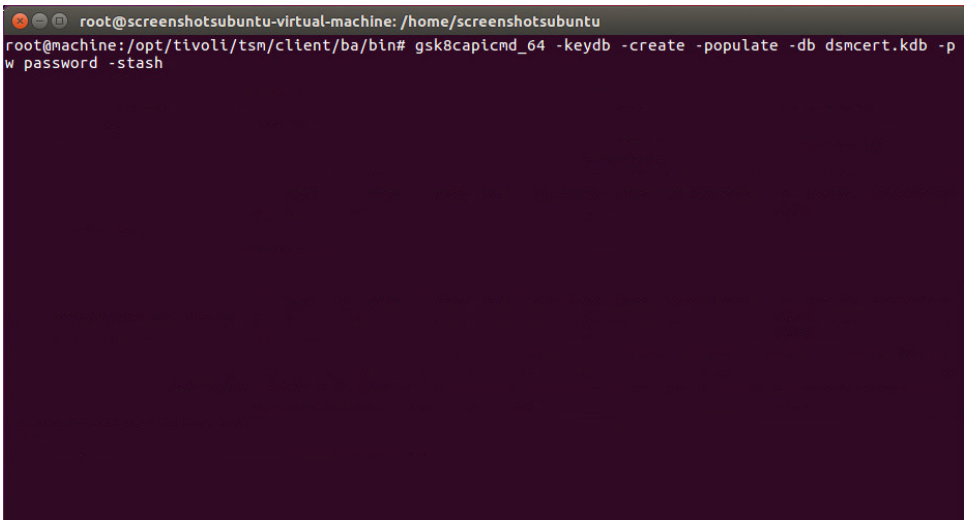
9. Click the **Communication** tab.
10. Enter the **IP Address** for the server.
11. Enter the **Server port** and **Admin port** (23444).
12. Check the boxes next to **Send transaction to the server immediately**, **Use Secure Sockets Layer (SSL)**, and **Require TLS 1.2 or above.**

13. Select **Yes** for **SSL is Required**.



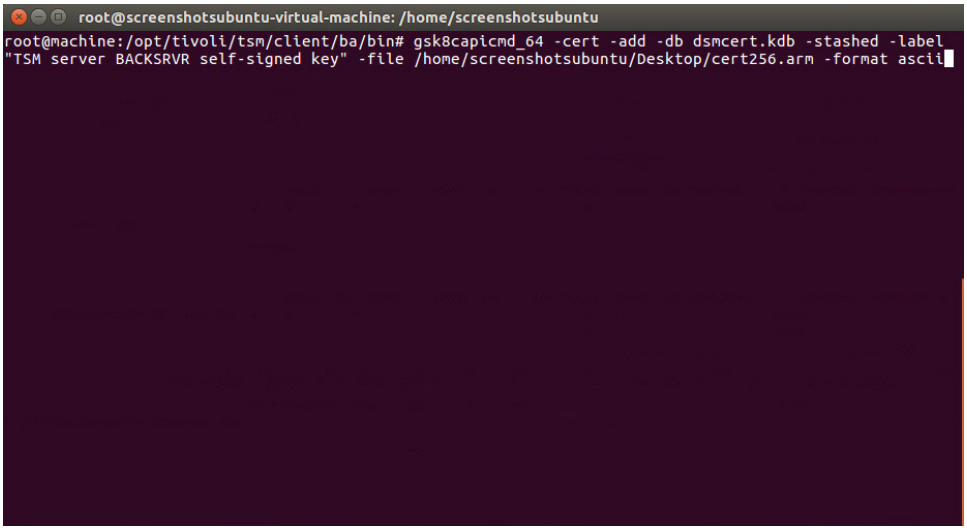
14. Click **OK**.
15. Retrieve **cert256.arm** from the server.
16. On the client machine create a new key database by running the following commands:

```
> gsk8capicmd_64 -keydb -create -populate -db dsmcert.kdb -pw password -
stash
```

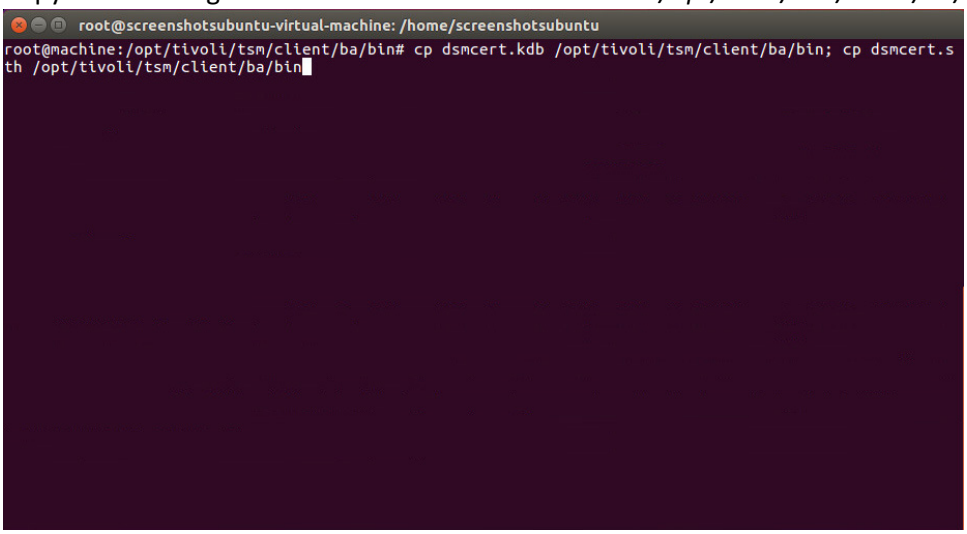


17. Import **cert256.arm** by running the command:

```
> gsk8capicmd_64 -cert -add -db dsmcert.kdb -stashed -label "TSM server
BACKSRVR self-signed key" -file <path-to-cert256.arm> -format asci
```

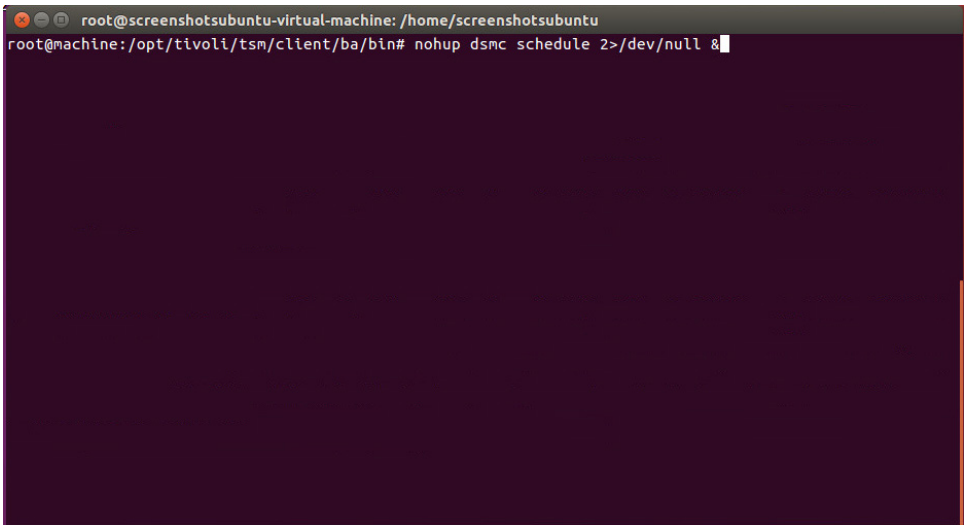


18. Copy the resulting "dsmcert.kdb" and "dsmcert.sth" to */opt/tivoli/tsm/client/ba/bin*.



19. You may be asked to reconfigure the **dsm.opt** file when setting up the scheduler but the options should be filled out already.
20. To start the scheduler as a background process, run the following command:

```
> nohup dsmc schedule 2>/dev/null &
```



21. You can add this command to the startup programs in Ubuntu to make it start automatically.

2.8 GreenTec WORMdisks

See the *Installation of GreenTec Command Line Utilities* document, that should accompany the installation disk, for a detailed guide on how to install the GreenTec command line utilities.

Furthermore, refer to the *GT_WinStatus User Guide* , that should also accompany the installation disk, for instructions on how to effectively use GreenTec disks to preserve data. Read these instructions *carefully*, as locking GreenTec WORMdisks can result in making some or all of the disk or the entire disk unusable. Having portions of the disk, or the entire disk, permanently locked is sometimes desirable but it is dependent on the needs of your organization. For example, if you want to store backup information or logs securely.

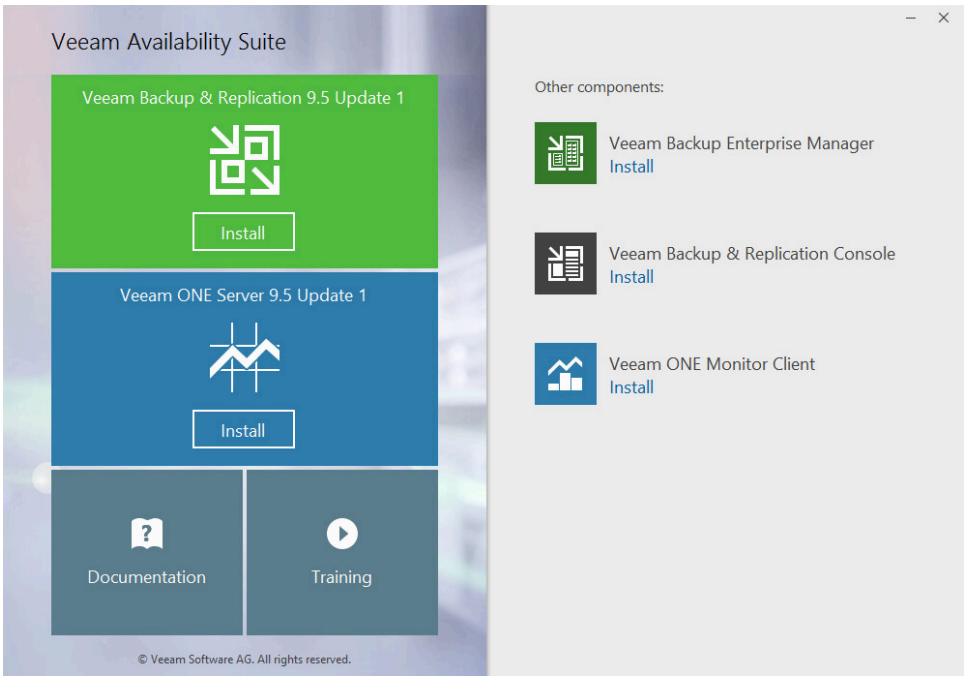
The *GT_WinStatus User Guide* provides instructions for locking and temporarily locking disk sectors. In this practice guide, we will not include instructions on when or how to lock GreenTec disks. However, in some cases, we will provide instructions detailing how to save data to these disks and leave locking them to the implementing parties.

2.9 Veeam Backup & Replication

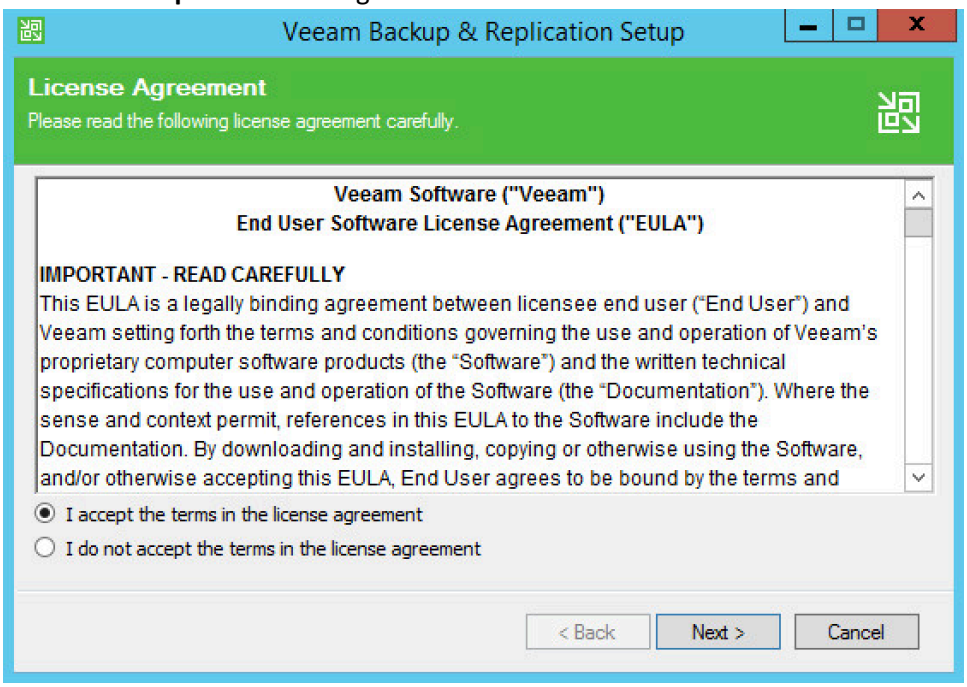
Veeam's Backup & Replication tool provides backup and restore capabilities. In the data integrity solution, Veeam is used to backup and restore virtual machines residing within Windows Server Hyper-V. In this section is the installation and configuration process for Veeam Backup & Replication on a Windows Server 2012 R2 machine. Additional installation and configuration instructions can be found at https://helpcenter.veeam.com/docs/backup/hyperv/install_vbr.html?ver=95.

2.9.1 Production Installation

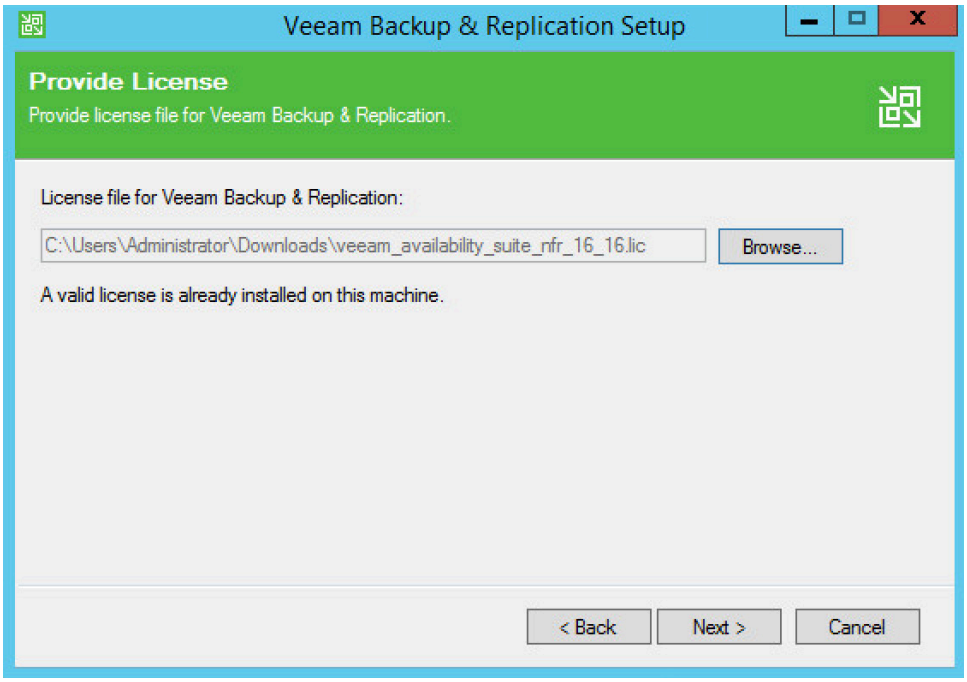
1. Start the **Veeam Setup Wizard** and click to begin the installation process for **Veeam Backup & Replication** with the appropriate version number.



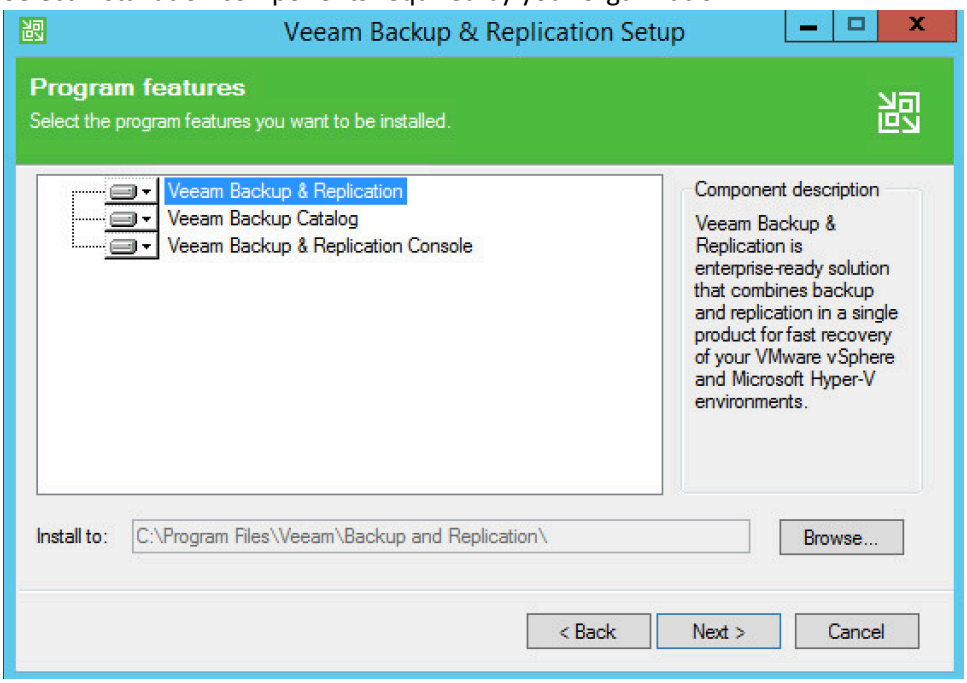
2. Read and **accept** the license agreement.



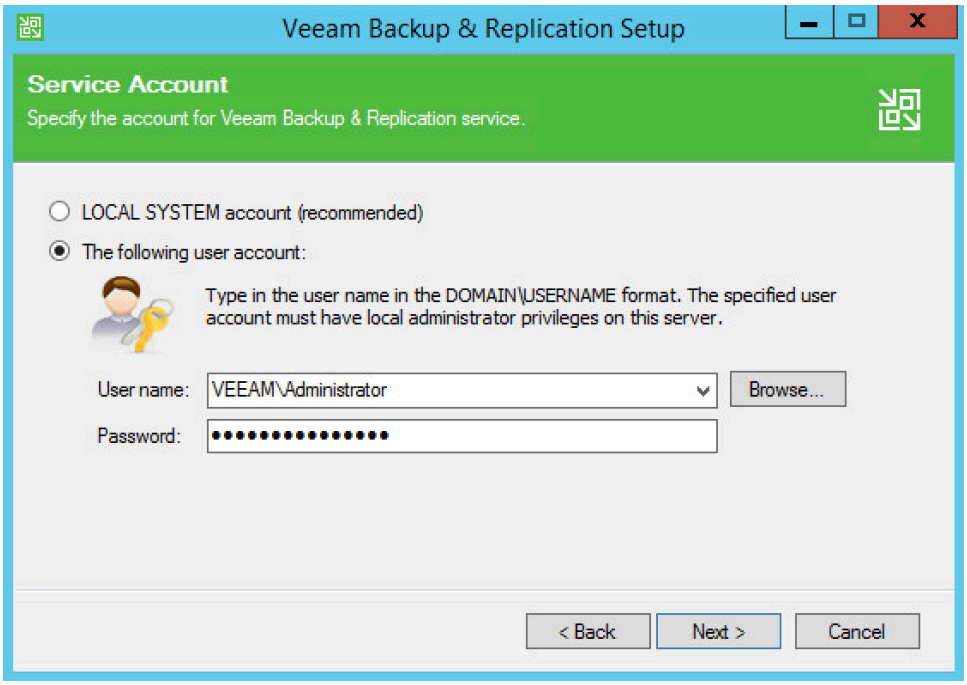
3. Click **Next**.
4. **Browse** to the location of the license file.



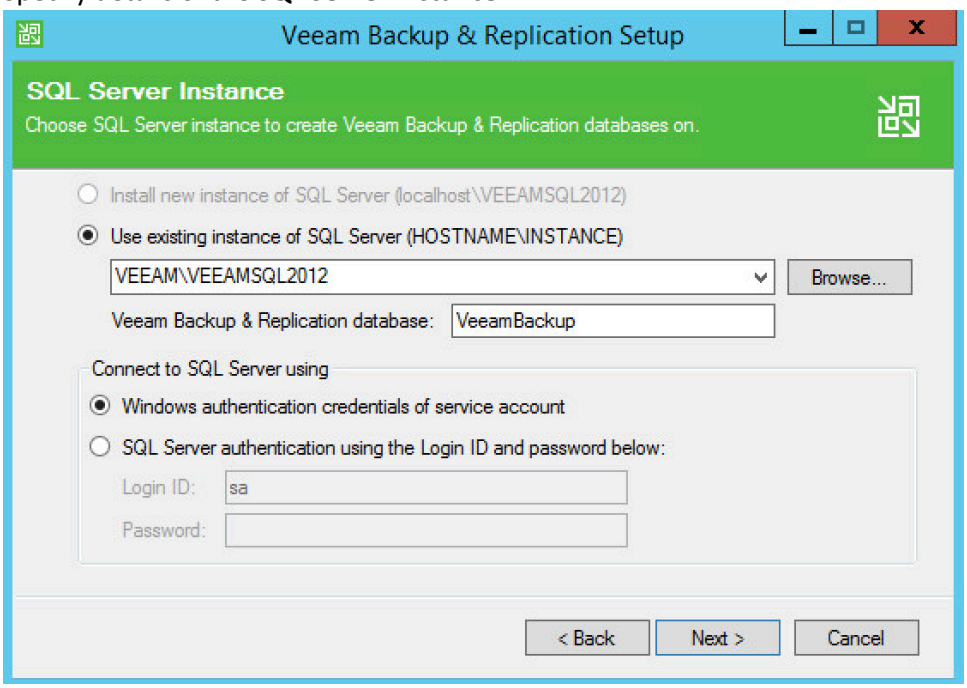
5. Click **Next**.
6. Select installation components required by your organization.



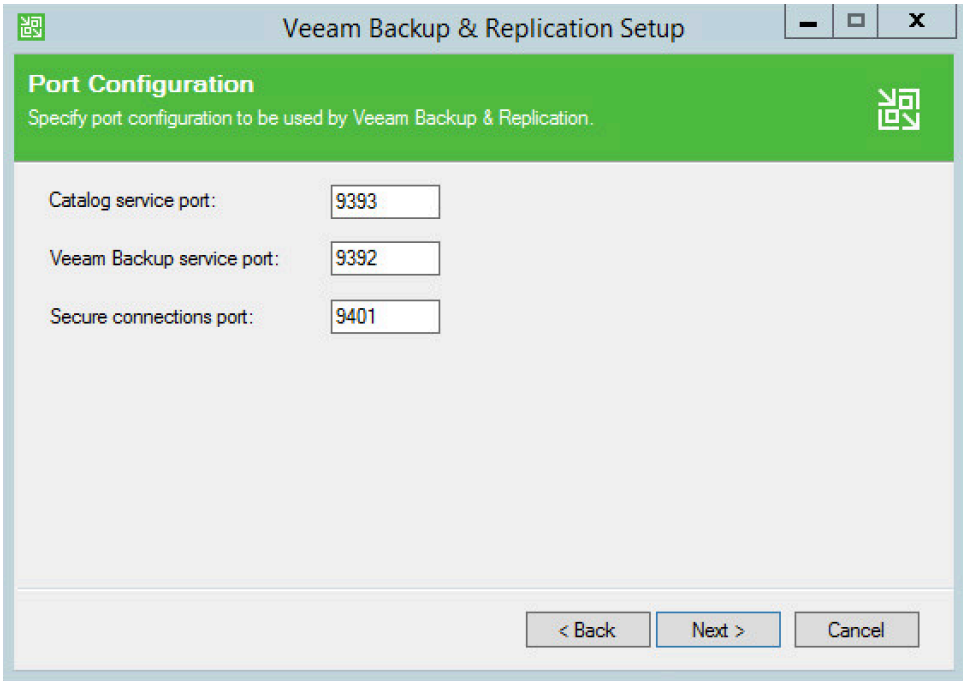
7. Click **Next**.
8. Specify account credentials for **Service** account.



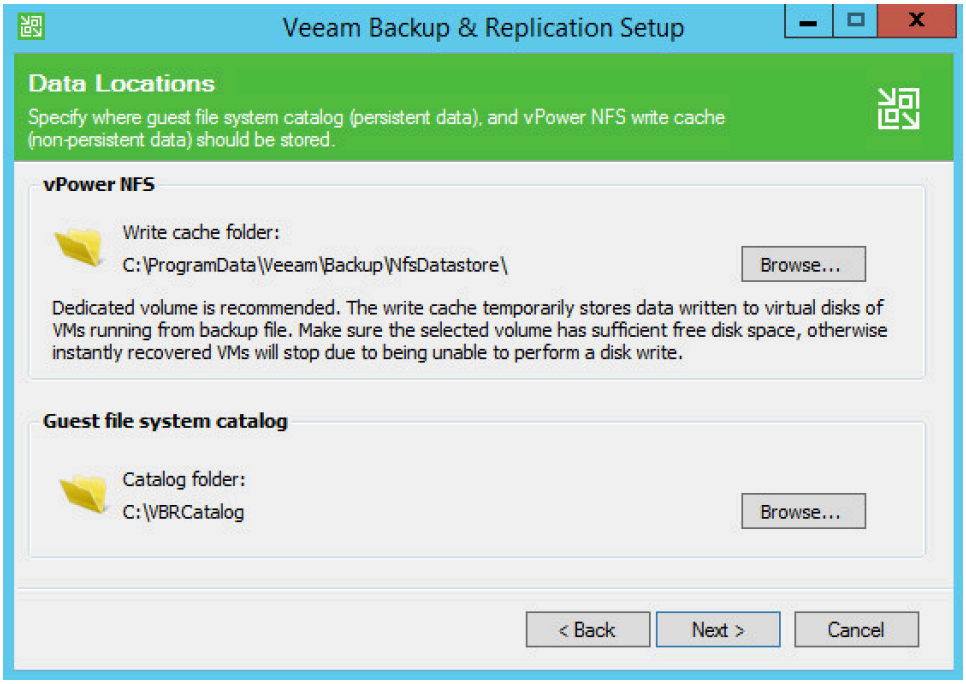
9. Click **Next**.
10. Specify details of the **SQL Server Instance**.



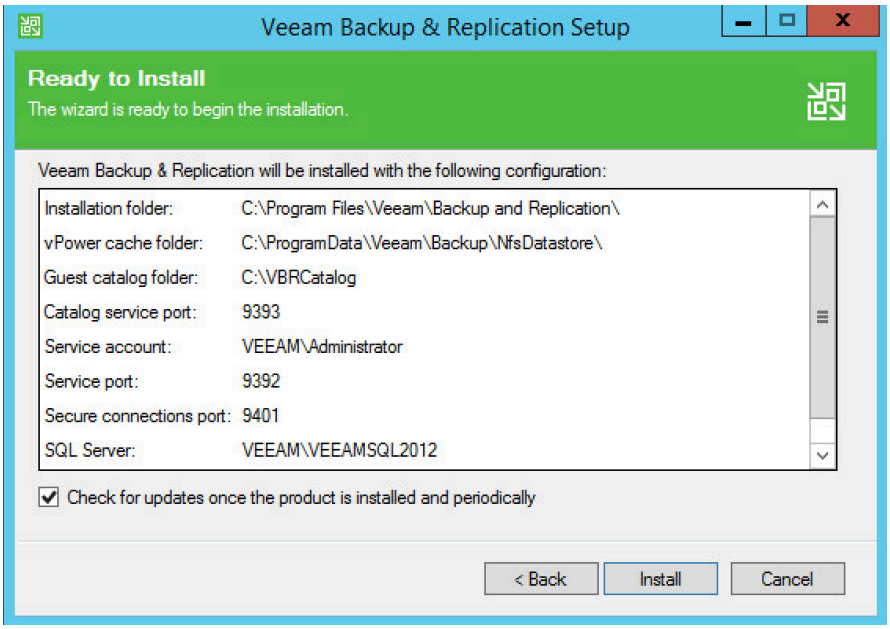
11. Click **Next**.
12. Specify **port numbers** for **Veaam Backup & Replication** services.



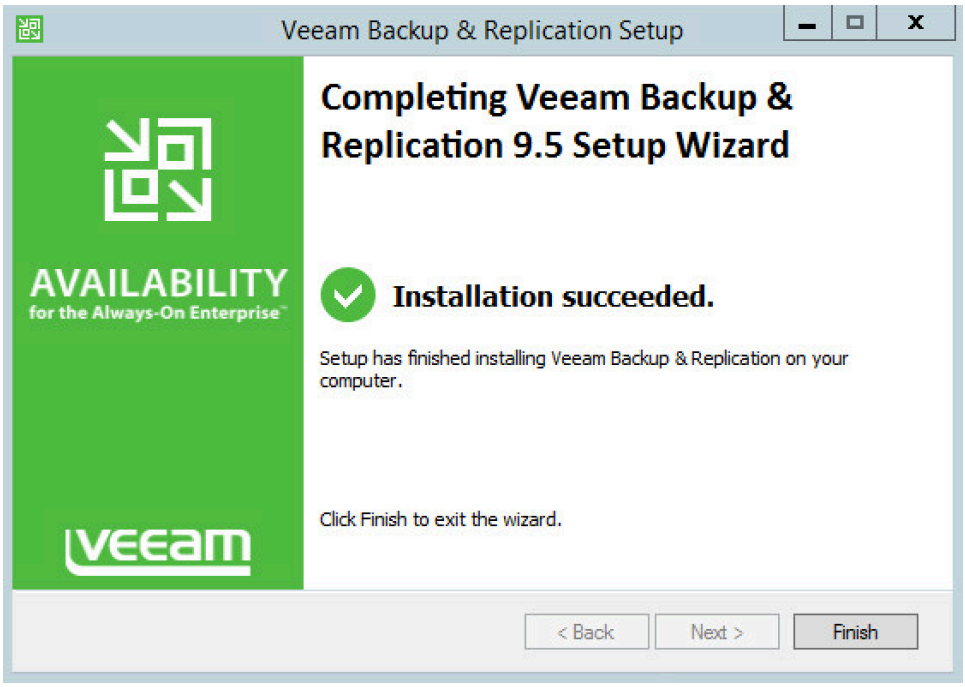
13. Click Next.
14. Specify **data storage locations.**



15. Click **Next**.
16. Review installation and configuration details and click **Install.**



17. Observe the successful installation and click **Finish.**



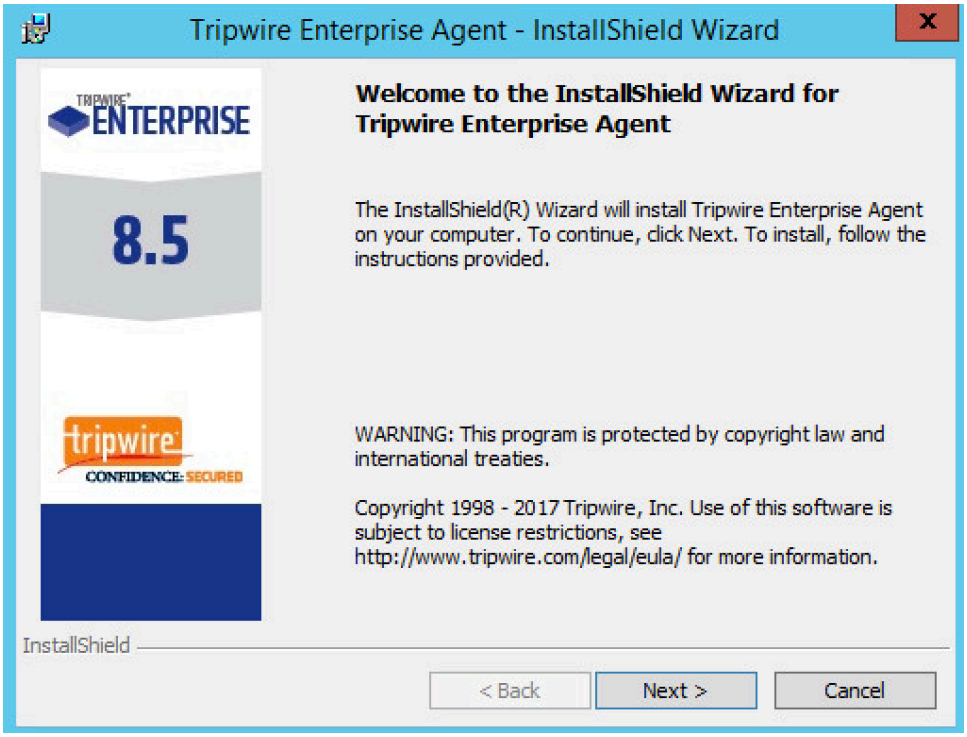
2.10 Tripwire Enterprise and Tripwire Log Center (TLC)

Tripwire Enterprise is a data integrity solution that monitors file activity and associated information across an enterprise. In this solution, we use it to monitor both a MS SQL database and file changes in certain folders. Tripwire Log Center allows for the collection and standardization of logs produced by Tripwire Enterprise.

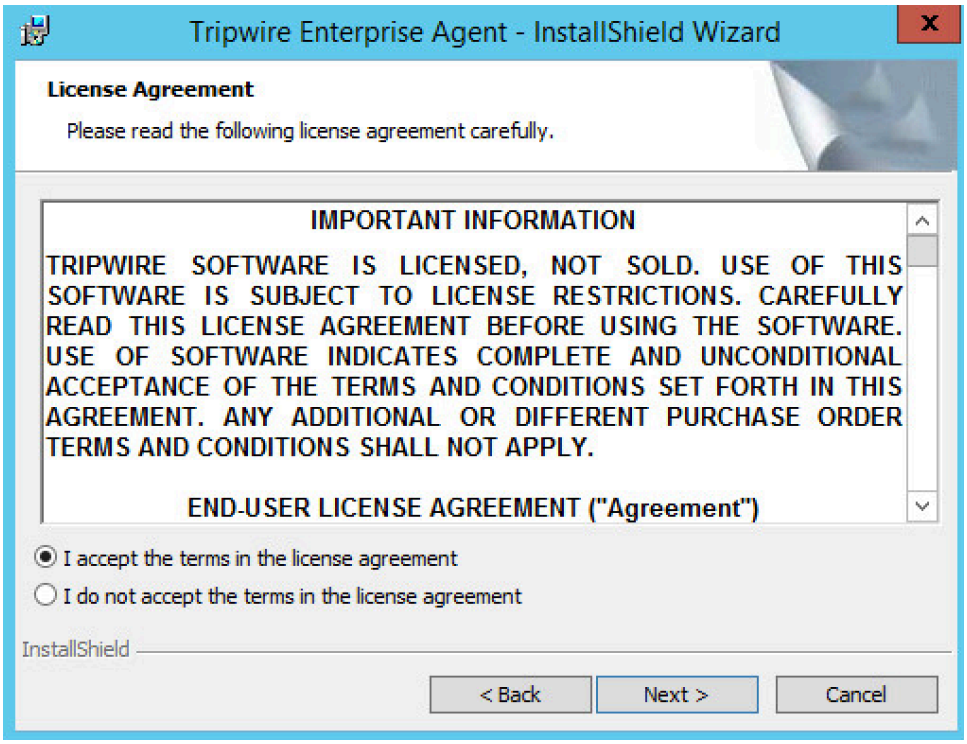
Please see the *Tripwire Enterprise Install and Maintenance Guide*, accessible at http://download.tripwire.com/te_en/docs852/te_install_and_maint_guide.pdf?V2ymLyYUTw_9Yx-EB3c3uKKO7JcgvOihm3YK_zuCGJtyYm5c9NPiogn8hIakZL3NlLqa, for a detailed, illustrated guide to the installation. The only addition to this documentation is that the MS SQL Server should be in "Mixed Mode" for authentication purposes. This section covers the installation and configuration process we used to set up Tripwire Agents on various machines as well as the installation and integration of Tripwire Log Center with Tripwire Enterprise. The result of this integration is the generation and forwarding of events from Tripwire Enterprise to Tripwire Log Center.

2.10.1 Install Tripwire Agent on Windows

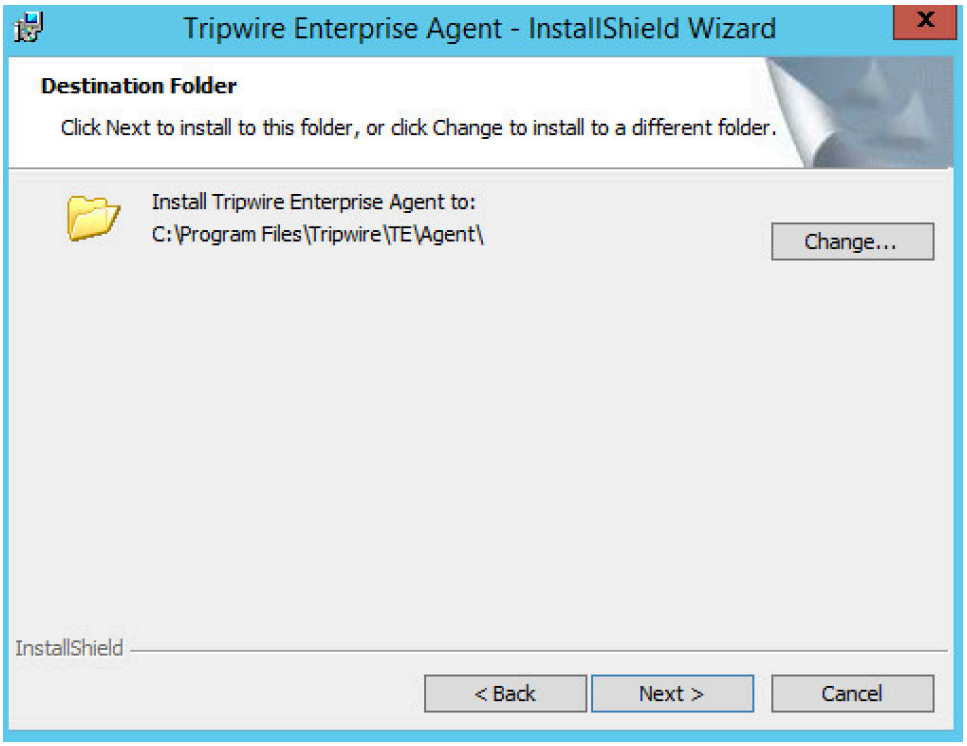
1. Run **te_agent.msi** on the client machine.



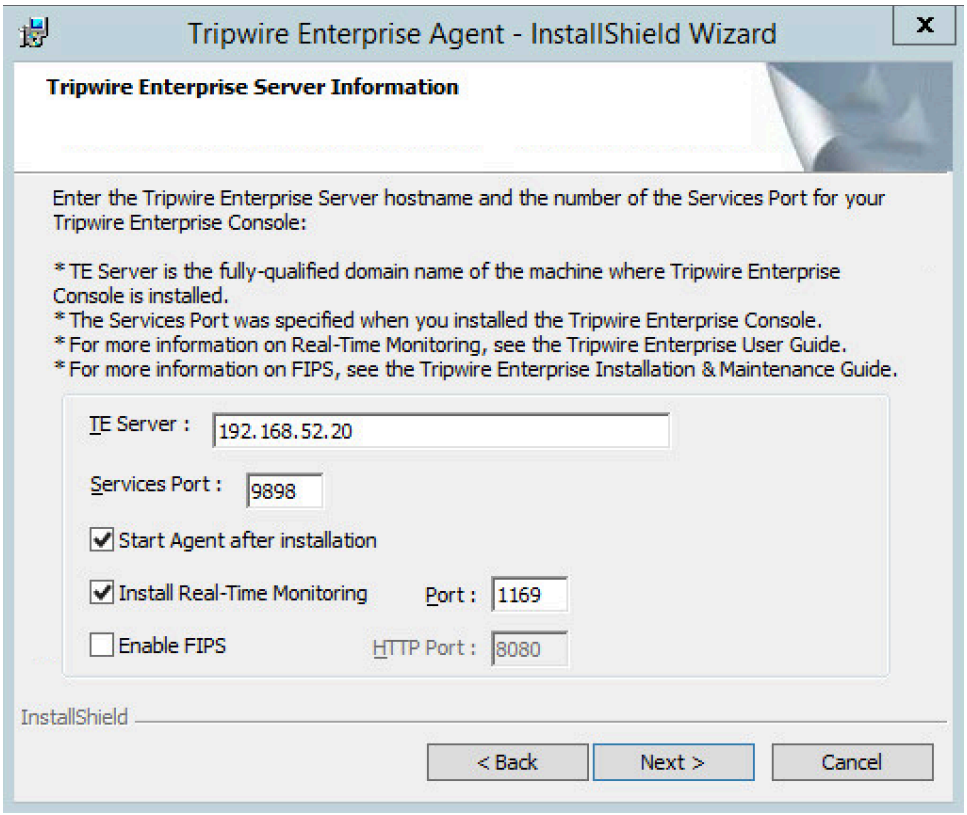
2. Click **Next**.
3. **Accept** the license agreement.



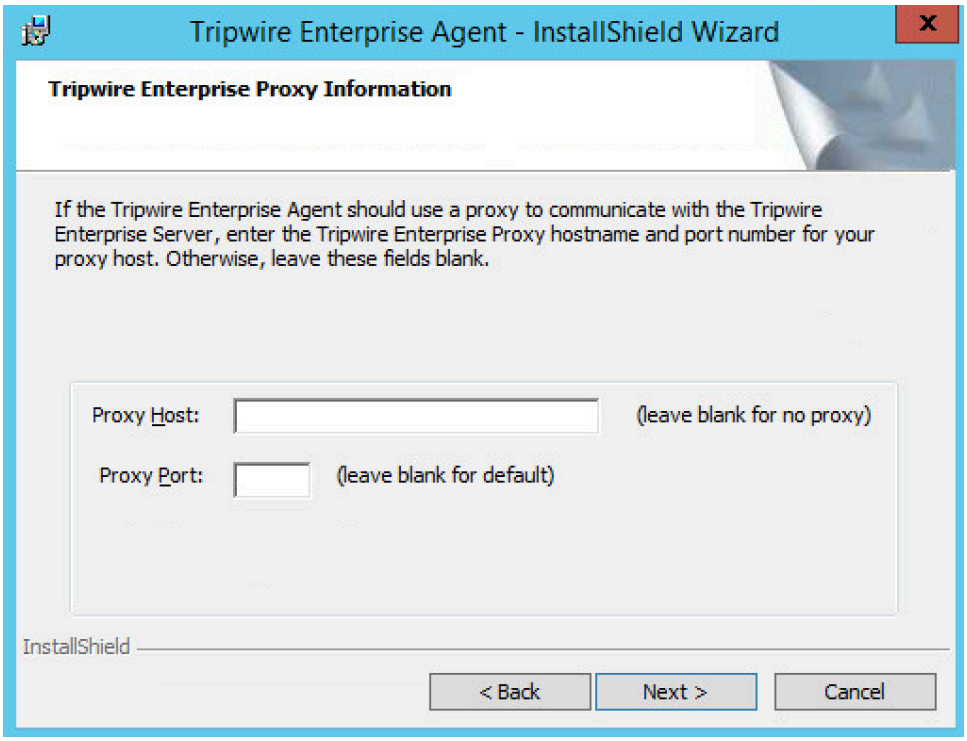
4. Click **Next**.
5. Specify the installation path.



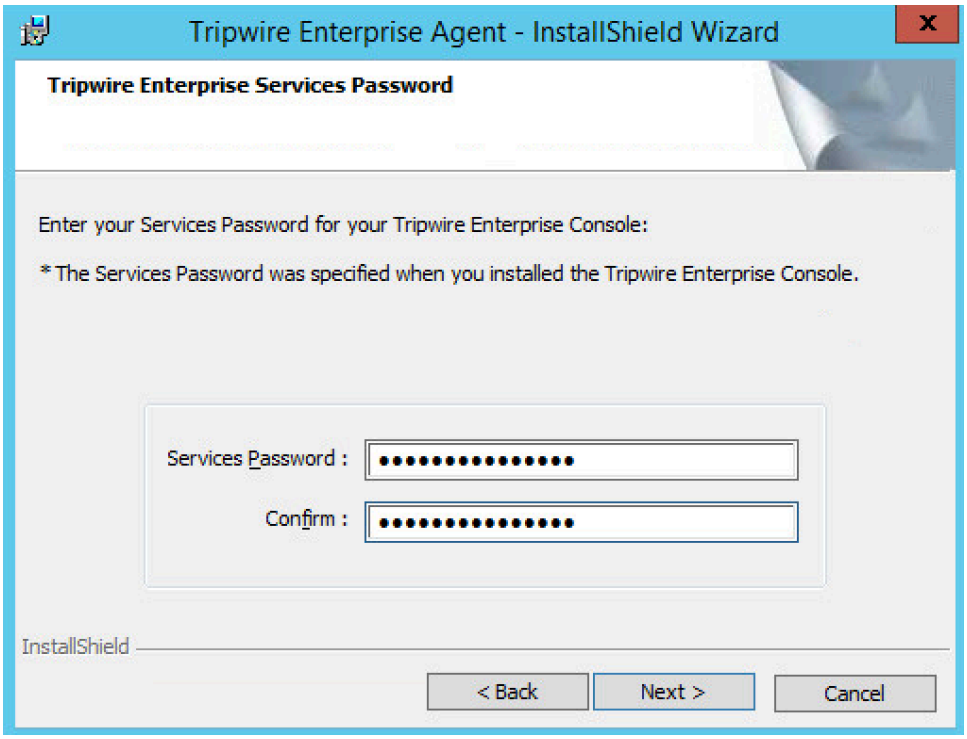
6. Click **Next**.
7. Enter the **IP address** of the Tripwire server.



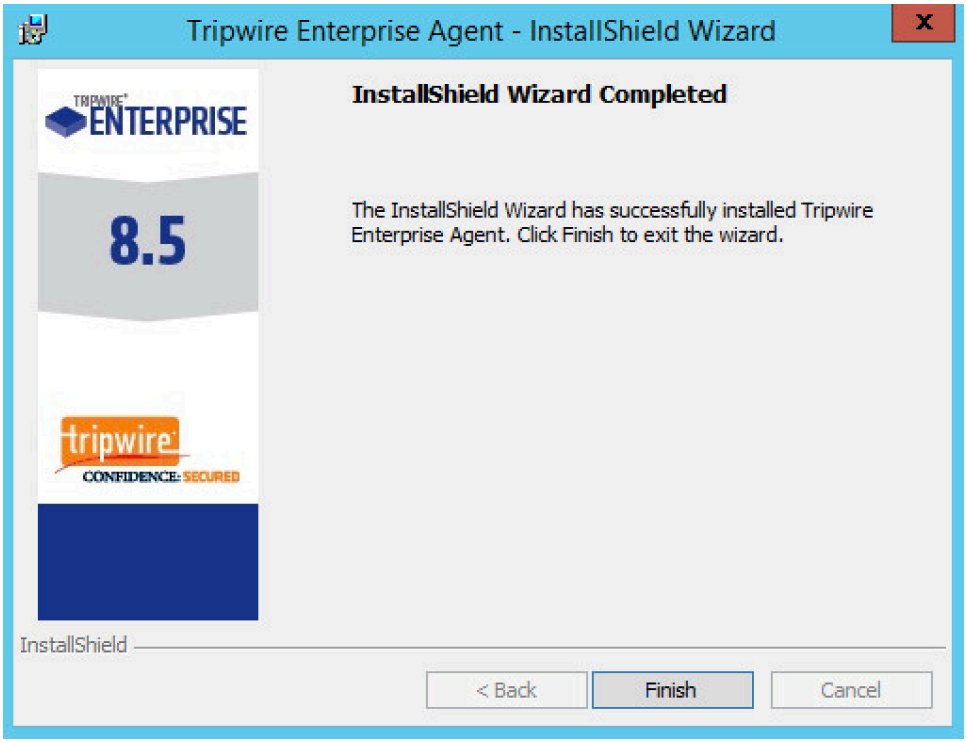
8. Click **Next**.
9. Leave the proxy settings blank.



10. Click **Next**.
11. Enter the **services password** specified in the server upon installation twice.



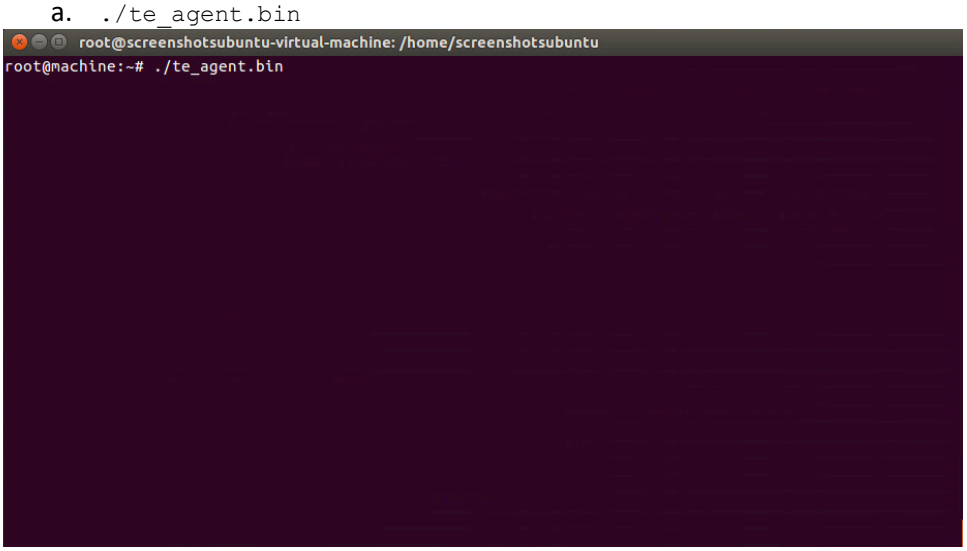
12. Click **Next**.



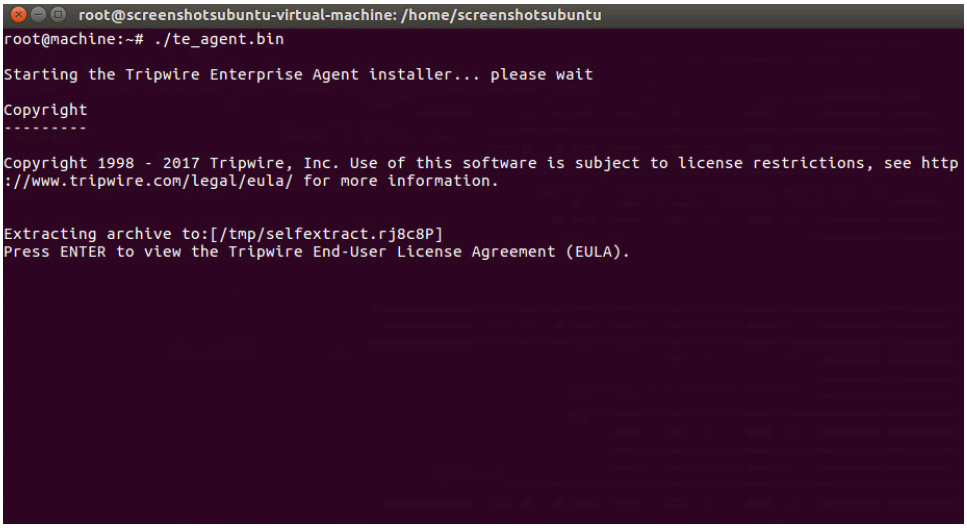
13. Click **Install**.
14. Start **Tripwire Agent** from the start menu (on some systems it may start automatically - check **services.msc** to verify that it is running).

2.10.2 Install Tripwire Agent on Ubuntu

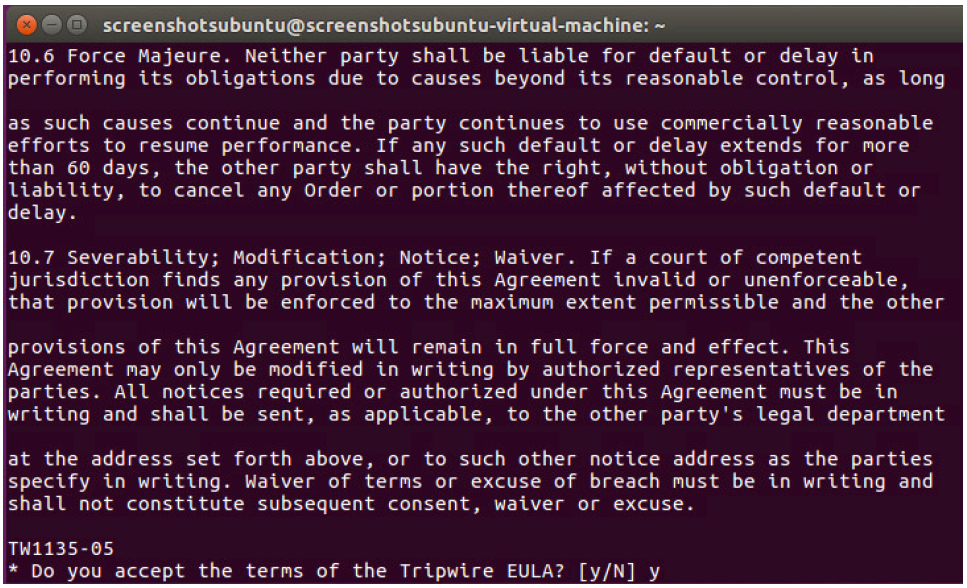
1. Execute the following commands as root.
2. Run **te_agent.bin** by issuing the command:
    a. `./te_agent.bin`



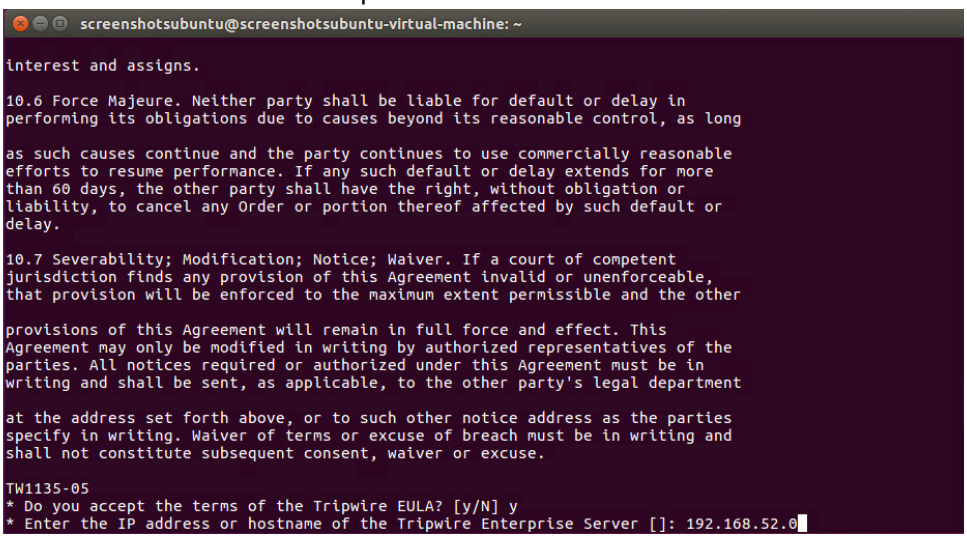
3. Press **Enter** repeatedly to read through the EULA.



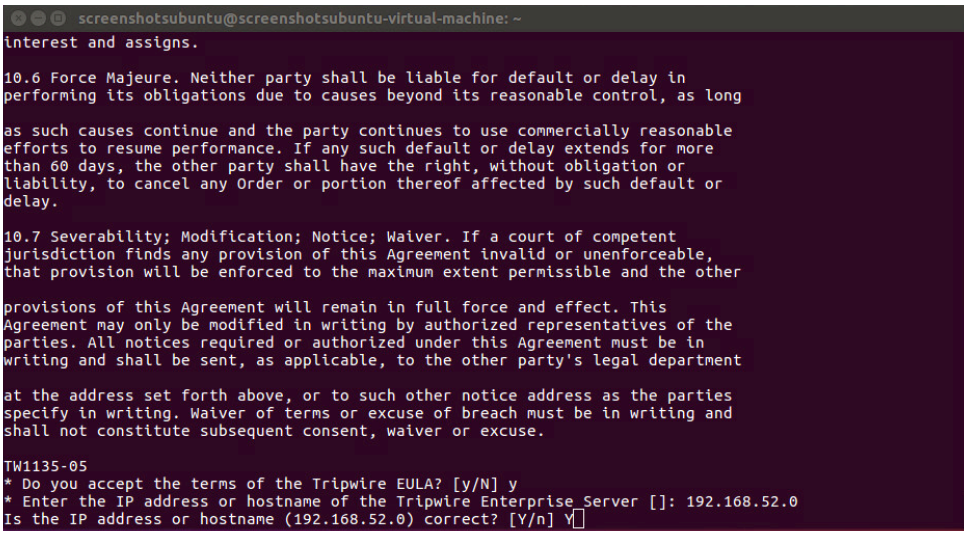
4. Enter **Y** to accept the EULA.



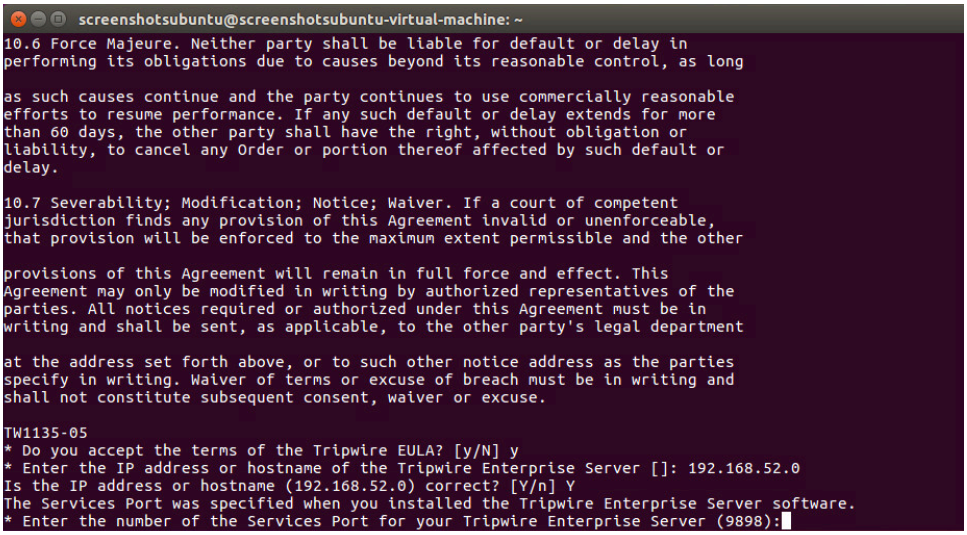
5. Press **Enter**.
6. Enter the **IP address** of the Tripwire server.



7. Press **Enter**.
8. Enter **Y** if the address was entered correctly.



9. Press **Enter**.



10. Press **Enter**.
11. Enter **Y** to use the default port number.

```
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performing its obligations due to causes beyond its reasonable control, as long

as such causes continue and the party continues to use commercially reasonable
efforts to resume performance. If any such default or delay extends for more
than 60 days, the other party shall have the right, without obligation or
liability, to cancel any Order or portion thereof affected by such default or
delay.

10.7 Severability; Modification; Notice; Waiver. If a court of competent
jurisdiction finds any provision of this Agreement invalid or unenforceable,
that provision will be enforced to the maximum extent permissible and the other

provisions of this Agreement will remain in full force and effect. This
Agreement may only be modified in writing by authorized representatives of the
parties. All notices required or authorized under this Agreement must be in
writing and shall be sent, as applicable, to the other party's legal department

at the address set forth above, or to such other notice address as the parties
specify in writing. Waiver of terms or excuse of breach must be in writing and
shall not constitute subsequent consent, waiver or excuse.

TW1135-05
* Do you accept the terms of the Tripwire EULA? [y/N] y
* Enter the IP address or hostname of the Tripwire Enterprise Server []: 192.168.52.0
Is the IP address or hostname (192.168.52.0) correct? [Y/n] Y
The Services Port was specified when you installed the Tripwire Enterprise Server software.
* Enter the number of the Services Port for your Tripwire Enterprise Server (9898):
Is the Services Port (9898) correct? [Y/n] Y
```

12. Press **Enter**.
13. Enter **N** to disable the use of the Federal Information Processing Standard (FIPS), unless your system requires the use of FIPS.

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as such causes continue and the party continues to use commercially reasonable
efforts to resume performance. If any such default or delay extends for more
than 60 days, the other party shall have the right, without obligation or
liability, to cancel any Order or portion thereof affected by such default or
delay.

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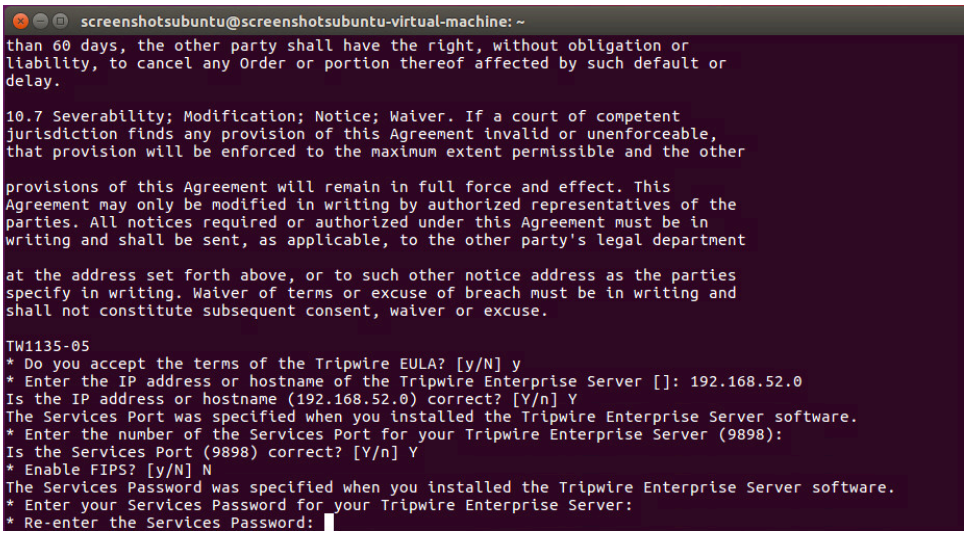
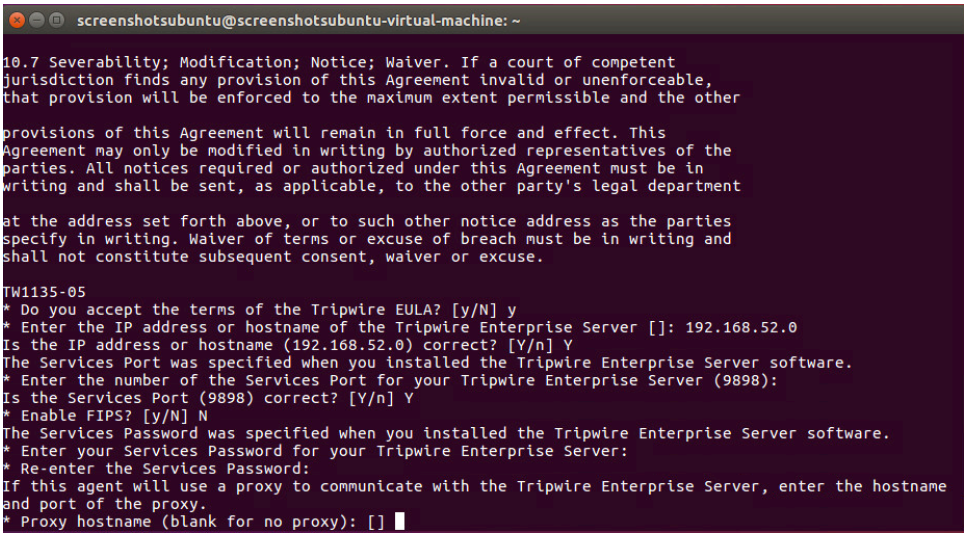
shall not constitute subsequent consent, waiver or excuse.

TW1135-05
* Do you accept the terms of the Tripwire EULA? [y/N] y
* Enter the IP address or hostname of the Tripwire Enterprise Server []: 192.168.52.0
Is the IP address or hostname (192.168.52.0) correct? [Y/n] Y
The Services Port was specified when you installed the Tripwire Enterprise Server software.
* Enter the number of the Services Port for your Tripwire Enterprise Server (9898):
Is the Services Port (9898) correct? [Y/n] Y
* Enable FIPS? [y/N] N
```

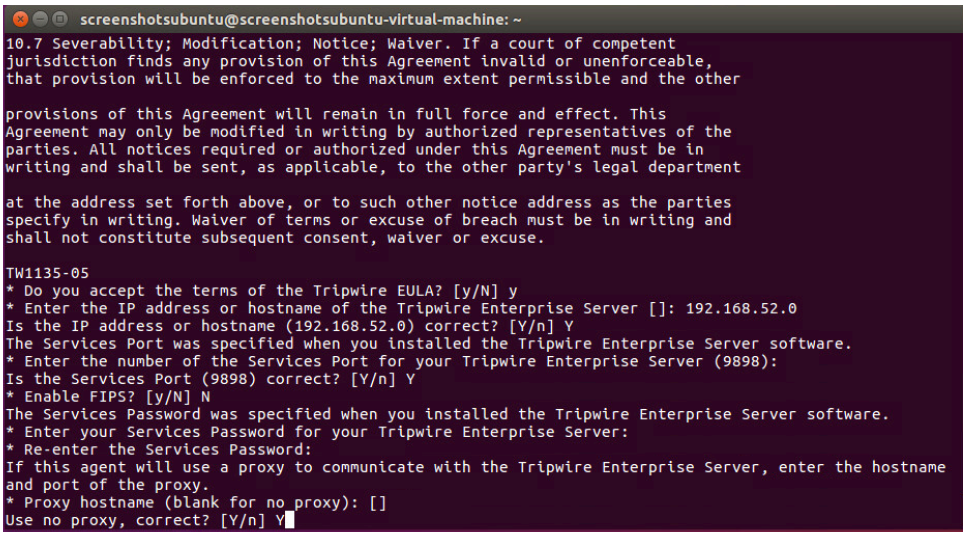
14. Press **Enter**.
15. Enter the **services password** twice, pressing **Enter** after each time. Note that no text will appear while typing the password.



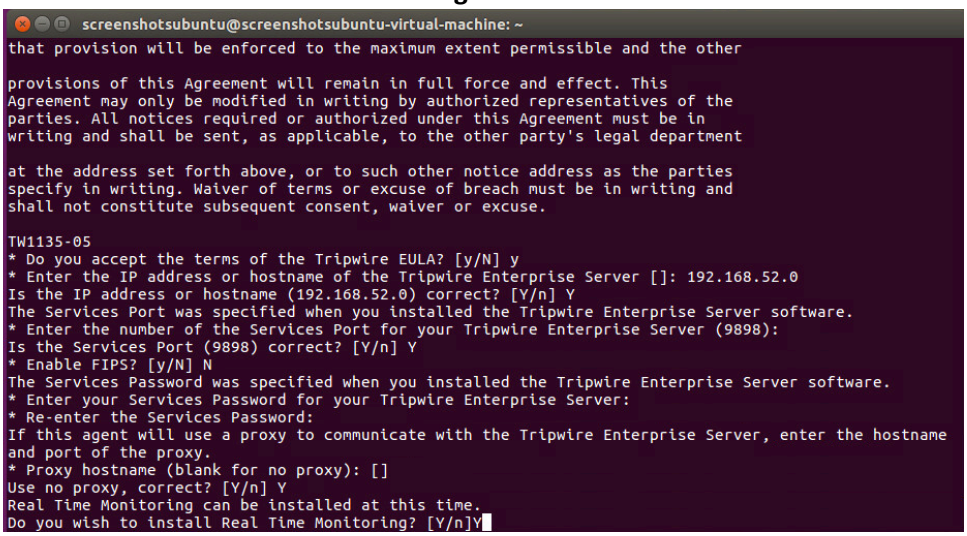
16. Press **Enter** to skip using a proxy.



17. Press **Y**.



18. Press **Enter**.
19. Press **Y** to install **Real Time Monitoring**.



20. Press **Enter**.

```
screenshotsubuntu@screenshotsubuntu-virtual-machine: ~

provisions of this Agreement will remain in full force and effect. This
Agreement may only be modified in writing by authorized representatives of the
parties. All notices required or authorized under this Agreement must be in
writing and shall be sent, as applicable, to the other party's legal department

at the address set forth above, or to such other notice address as the parties
specify in writing. Waiver of terms or excuse of breach must be in writing and
shall not constitute subsequent consent, waiver or excuse.

TW1135-05
* Do you accept the terms of the Tripwire EULA? [y/N] y
* Enter the IP address or hostname of the Tripwire Enterprise Server []: 192.168.52.0
Is the IP address or hostname (192.168.52.0) correct? [Y/n] Y
The Services Port was specified when you installed the Tripwire Enterprise Server software.
* Enter the number of the Services Port for your Tripwire Enterprise Server (9898):
Is the Services Port (9898) correct? [Y/n] Y
* Enable FIPS? [y/N] N
The Services Password was specified when you installed the Tripwire Enterprise Server software.
* Enter your Services Password for your Tripwire Enterprise Server:
* Re-enter the Services Password:
If this agent will use a proxy to communicate with the Tripwire Enterprise Server, enter the hostname
and port of the proxy.
* Proxy hostname (blank for no proxy): []
Use no proxy, correct? [Y/n] Y
Real Time Monitoring can be installed at this time.
Do you wish to install Real Time Monitoring? [Y/n]Y
* Enter the number of the Real Time Monitoring Port for your Tripwire Enterprise Agent (1169):
```

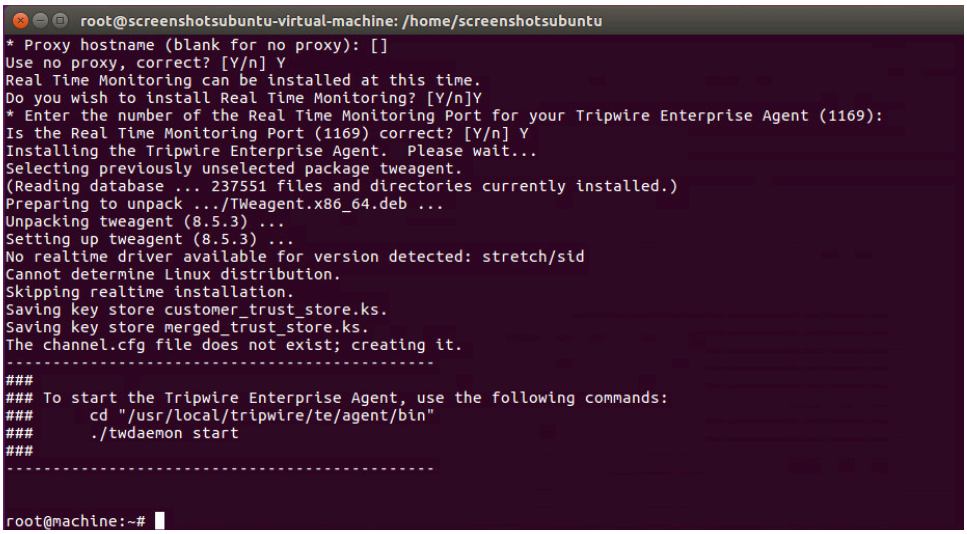
21. Press **Enter** to accept the default port.
22. Press **Y**.

```
screenshotsubuntu@screenshotsubuntu-virtual-machine: ~
provisions of this Agreement will remain in full force and effect. This
Agreement may only be modified in writing by authorized representatives of the
parties. All notices required or authorized under this Agreement must be in
writing and shall be sent, as applicable, to the other party's legal department

at the address set forth above, or to such other notice address as the parties
specify in writing. Waiver of terms or excuse of breach must be in writing and
shall not constitute subsequent consent, waiver or excuse.

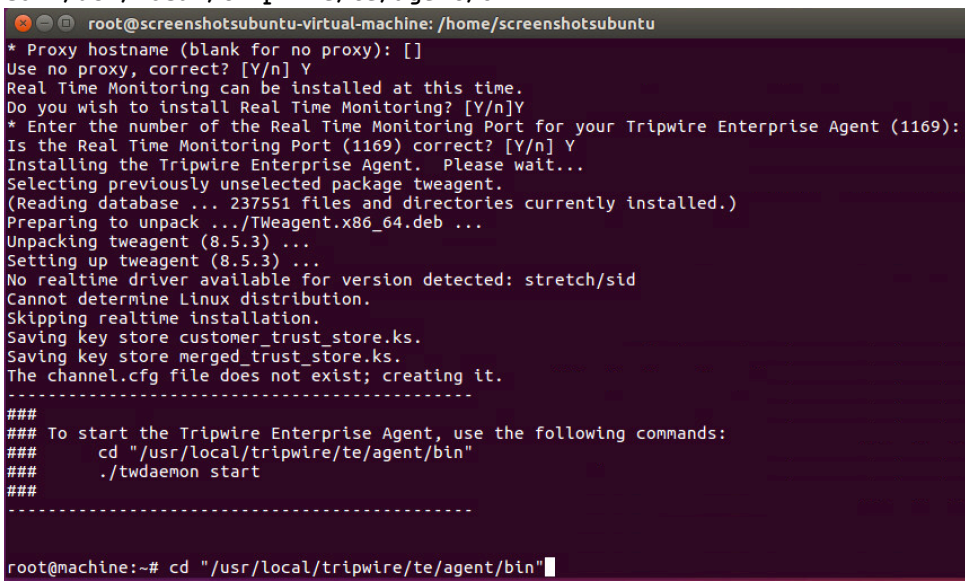
TW1135-05
* Do you accept the terms of the Tripwire EULA? [y/N] y
* Enter the IP address or hostname of the Tripwire Enterprise Server []: 192.168.52.0
Is the IP address or hostname (192.168.52.0) correct? [Y/n] Y
The Services Port was specified when you installed the Tripwire Enterprise Server software.
* Enter the number of the Services Port for your Tripwire Enterprise Server (9898):
Is the Services Port (9898) correct? [Y/n] Y
* Enable FIPS? [y/N] N
The Services Password was specified when you installed the Tripwire Enterprise Server software.
* Enter your Services Password for your Tripwire Enterprise Server:
* Re-enter the Services Password:
If this agent will use a proxy to communicate with the Tripwire Enterprise Server, enter the hostname
and port of the proxy.
* Proxy hostname (blank for no proxy): []
Use no proxy, correct? [Y/n] Y
Real Time Monitoring can be installed at this time.
Do you wish to install Real Time Monitoring? [Y/n]Y
* Enter the number of the Real Time Monitoring Port for your Tripwire Enterprise Agent (1169):
Is the Real Time Monitoring Port (1169) correct? [Y/n] Y
```

23. Press **Enter**.
24. The agent should install.

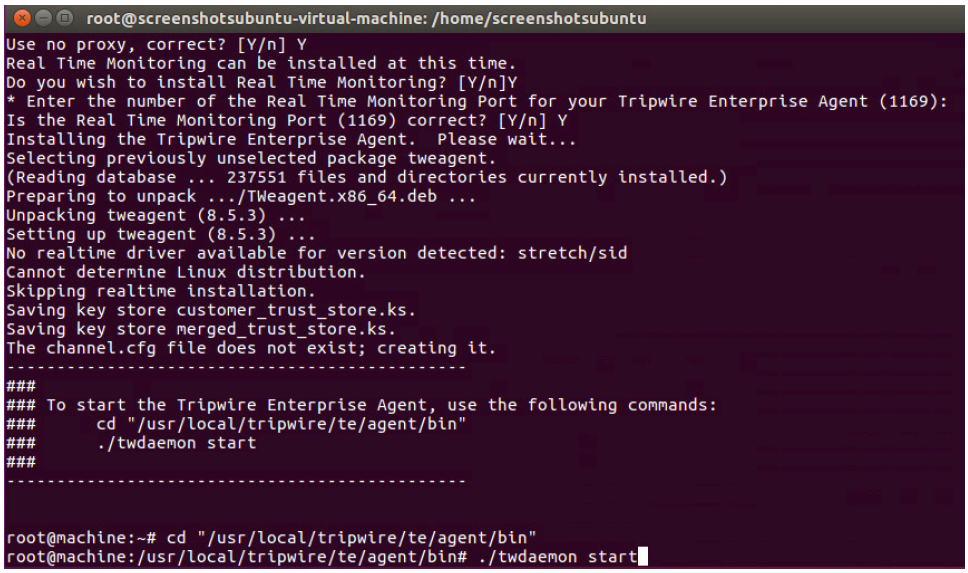


25. Run the following commands as root:

    b. **`cd "/usr/local/tripwire/te/agent/bin"`**



    c. **`./twdaemon start`**



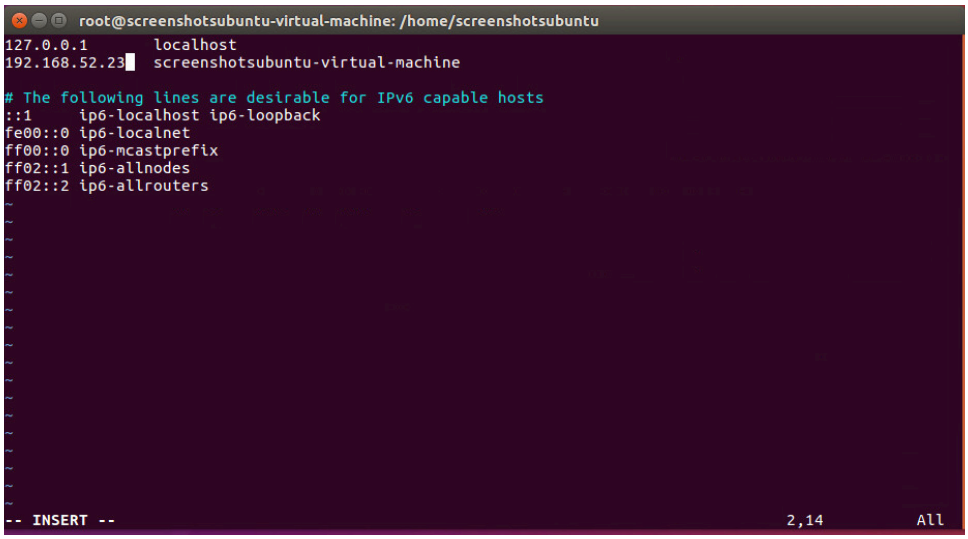
26. You may need to change /etc/hosts in Debian systems if there is a line which looks like this:

    127.0.1.1 <hostname>

    Change this to:

    <IP of machine> <hostname>

    Otherwise, Tripwire Enterprise may consider multiple Debian machines as the same machine in the assets view of Tripwire Enterprise.



2.10.3 Install Tripwire Log Center

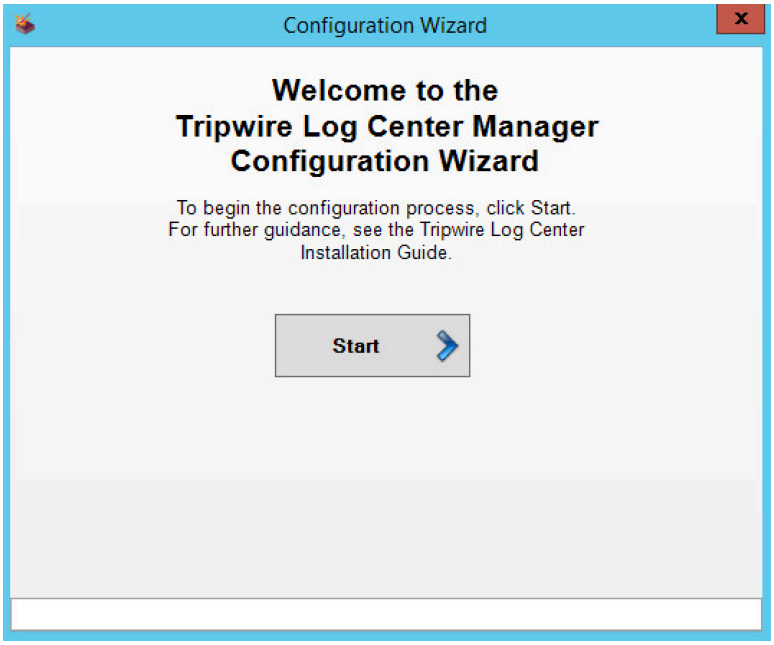
See the *Tripwire Log Center 7.2.4 Installation Guide* that should accompany the installation media for instructions on how to install TLC. Use the Tripwire Log Center Manager installer.

Notes:

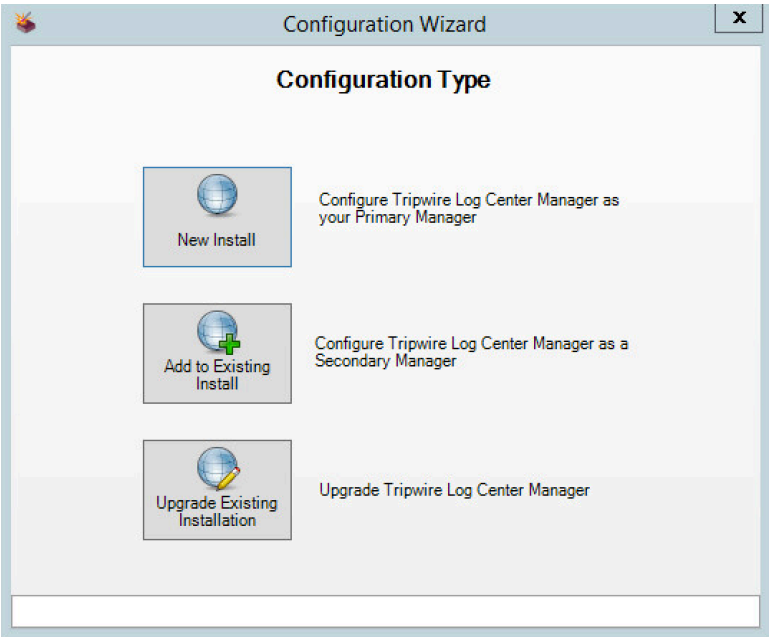
a. It is recommended that you install Tripwire Log Center on a separate system from Tripwire Enterprise.
b. You will need to install **JRE8** and the **Crypto** library. Instructions are also in the *Tripwire Log Center Installation Guide.*
c. You may need to unblock port 9898 on your firewall for the Tripwire enterprise agents.
d. Do not install PostgreSQL if you wish to use a database on another system.
e. When it finishes installing there should be a configuration wizard.

2.10.4 Configure Tripwire Log Center

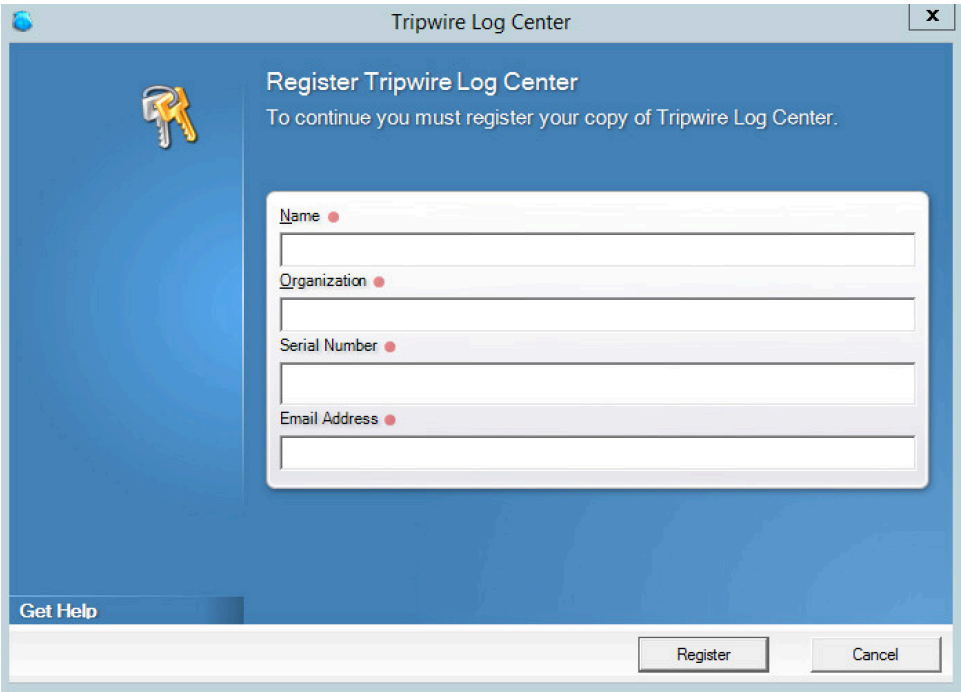
1. Click **Start**.



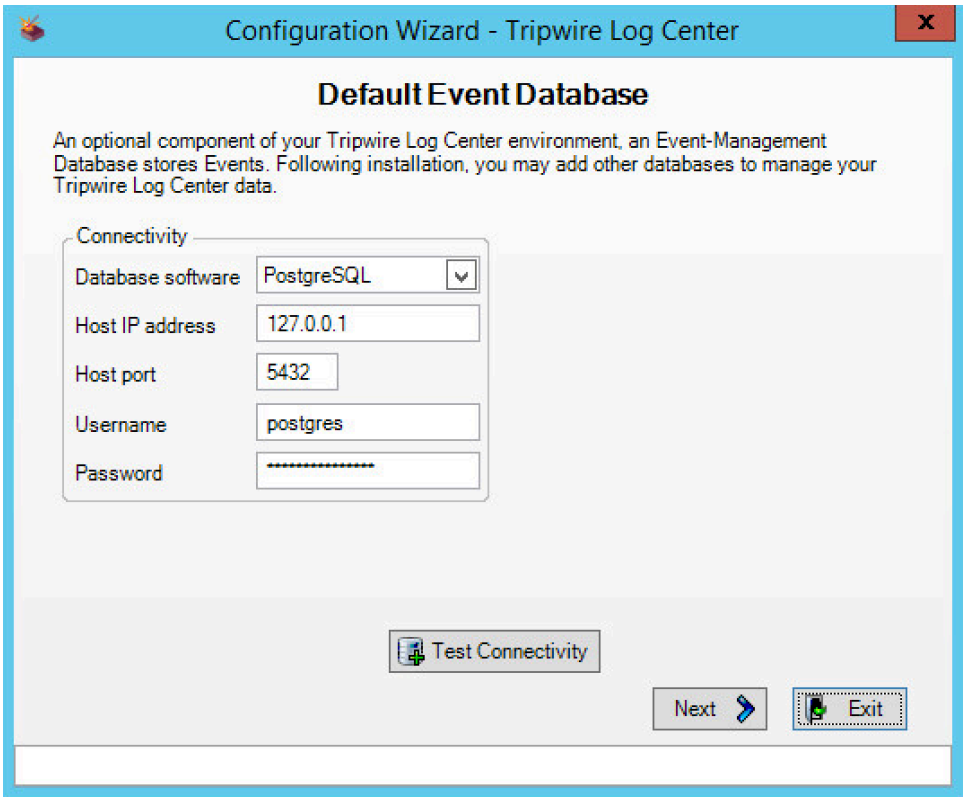
2. Click **New Install**.



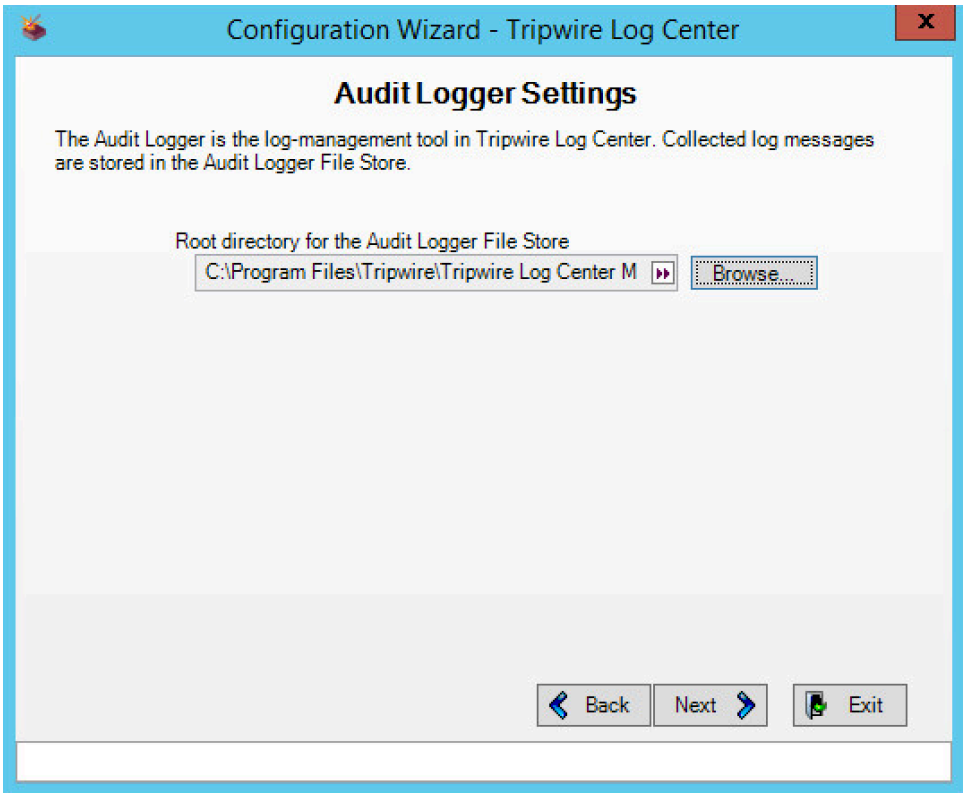
3. Click **Authorize**.
4. An error may appear asking you to install **.NET 3.5**.
5. To do this, open **Server Manager**.
6. Click **Manage**.
7. Click **Add Roles and Features**.
8. Click **Next**.
9. Select **Role-based or feature-based installation**.
10. Click **Next**.
11. Select the current server from the list.
12. Click **Next**.
13. Click **Next**.
14. Check the box next to **.NET Framework 3.5 Features**.
15. Click **Install**.
16. Wait for the installation to finish.
17. If prompted, enter **Name**, **Organization**, **Serial Number**, and **email address** in the fields. Click **Register**. This step will not appear if the software has already been registered



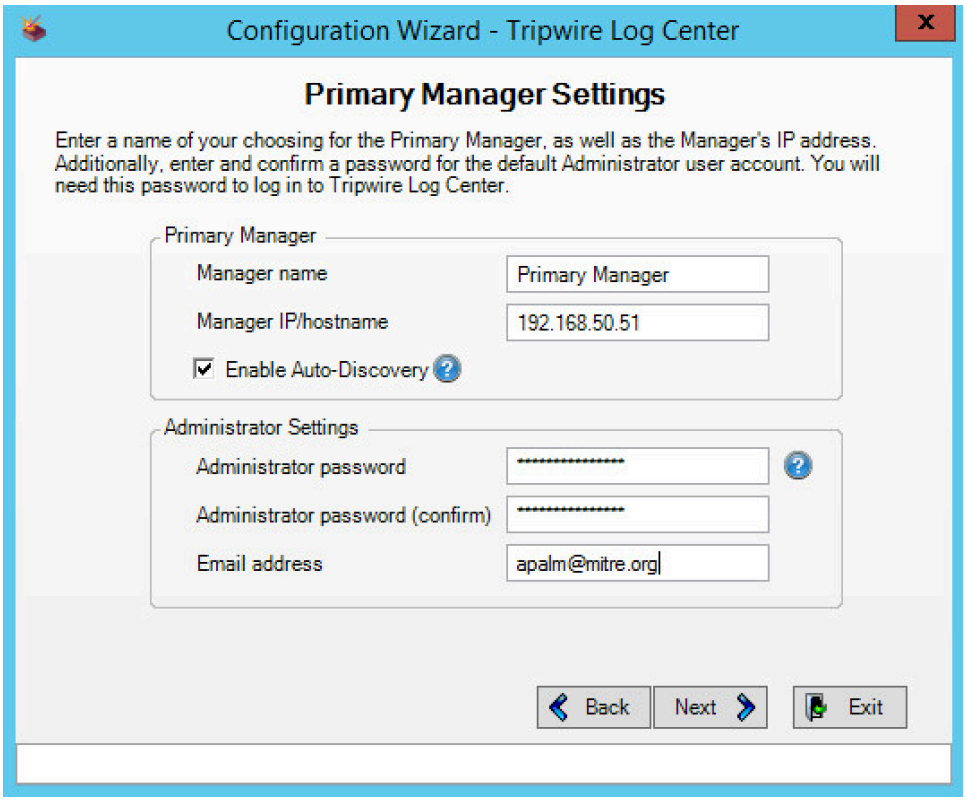
18. Click **Close**.
19. Continue with the **configuration wizard**.
20. Enter appropriate details for your **Database Software**.



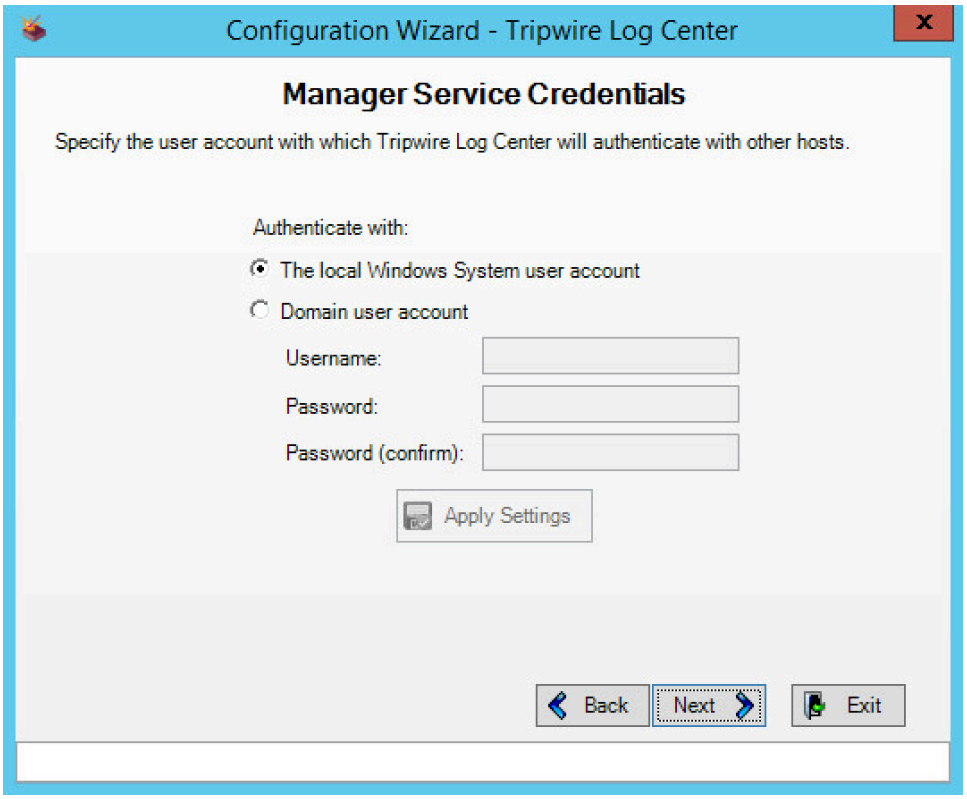
21. Select **Use Windows Authentication**.
22. Click **Next**.
23. Select a directory to store log messages in. Example*: C:\Program Files\Tripwire\Tripwire Log Center Manager\Logs\AUDIT*



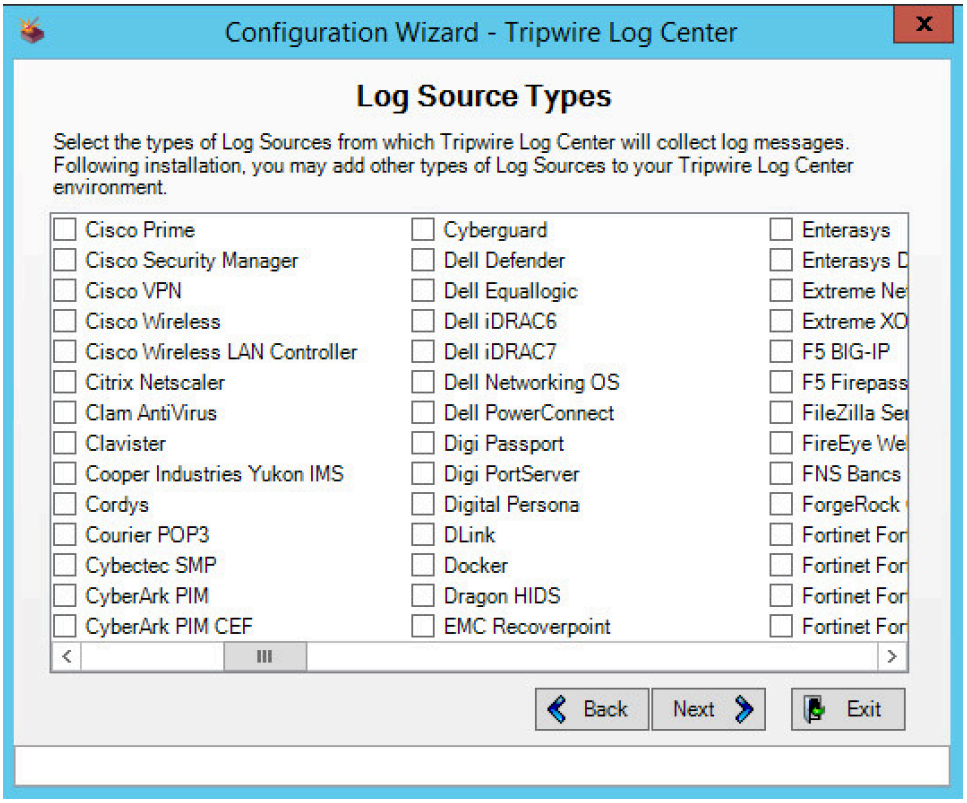
24. Click **Next**.
25. Create an Administrator password and enter it twice.
26. Enter your **email address**.



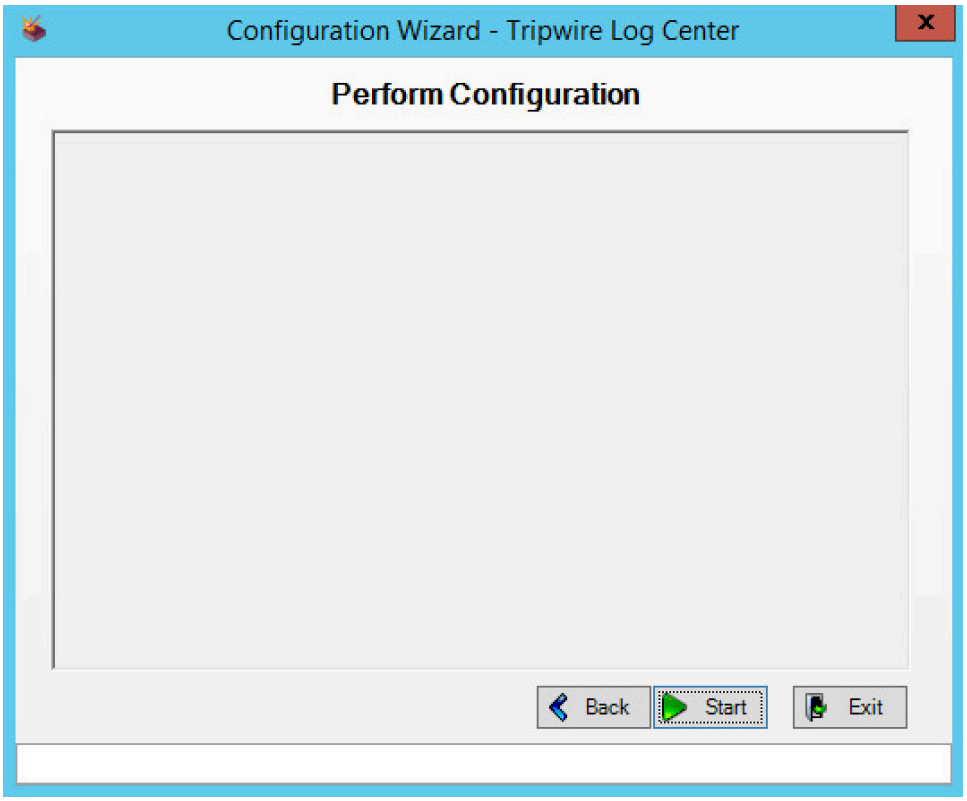
27. Click **Next**.
28. Select **authenticate with the local windows system user account**.



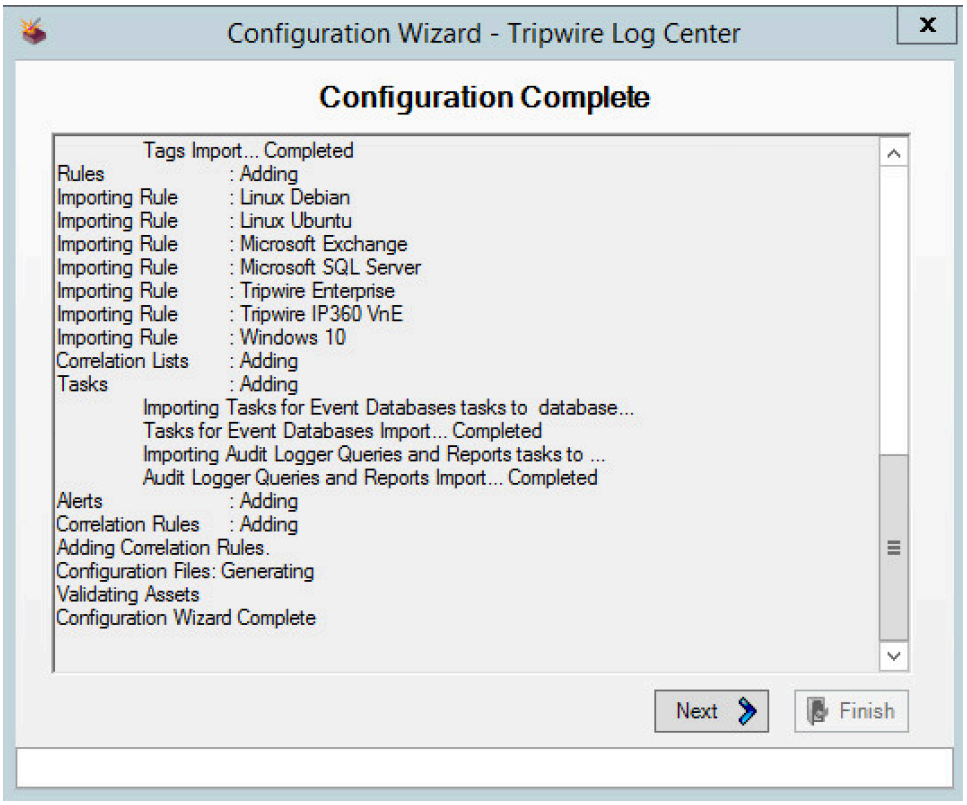
29. Click **Next**.
30. Select any log sources that you expect to collect using **Tripwire Log Center**. Examples: Tripwire Enterprise, Windows 10, Tripwire IP360 VnE, Linux Debian, Linux Ubuntu, Microsoft Exchange, Microsoft SQL Server.



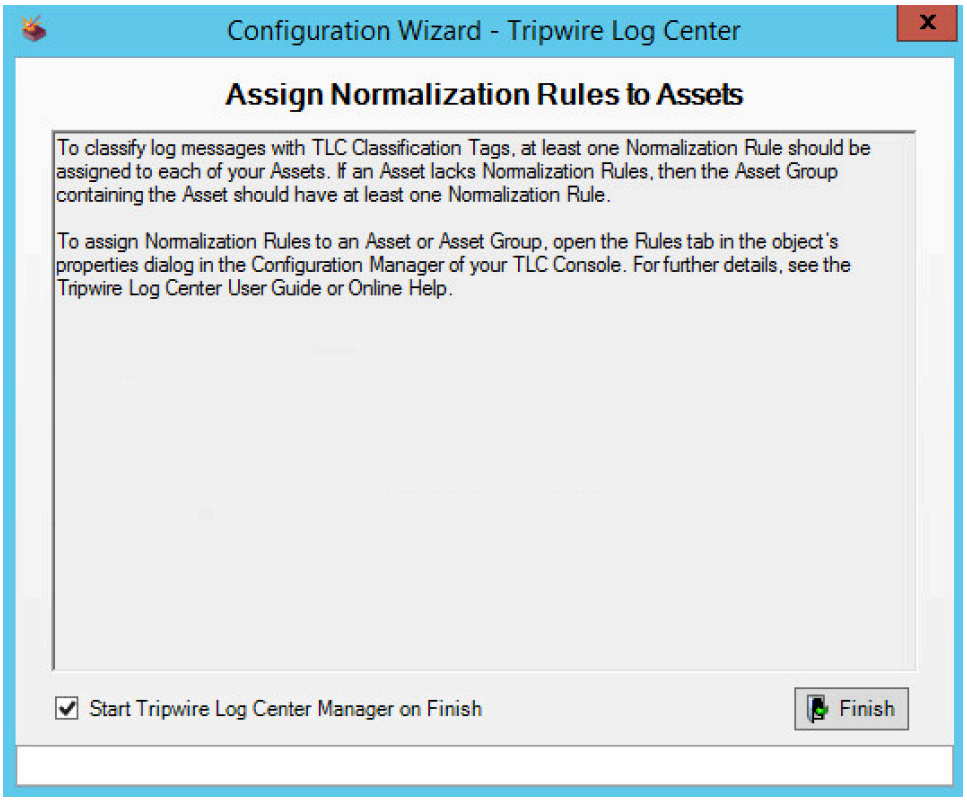
31. Click **Next**.



32. Click **Start**.



33. Click **Next** when the configuration finishes.



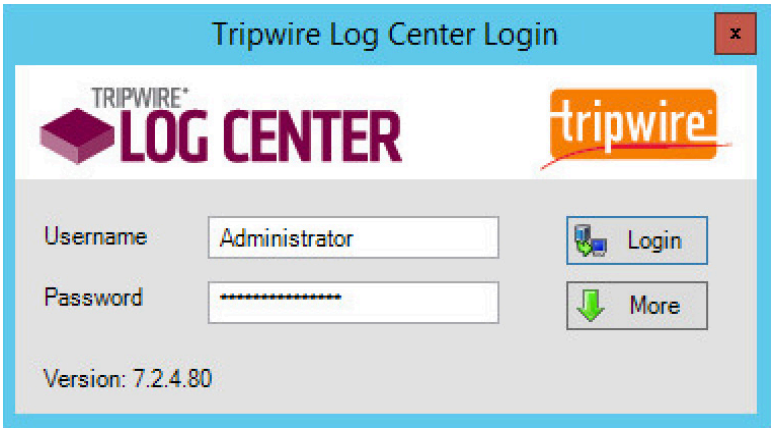
34. Observe the successful installation and click **Finish**.

2.10.5 Install Tripwire Log Center Console

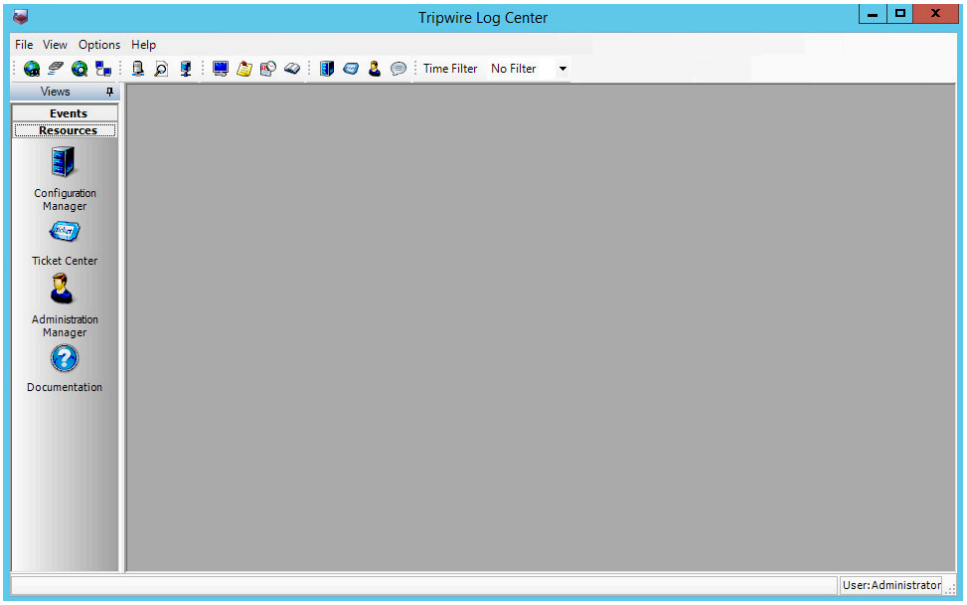
See chapter 4 of Tripwire Log Center 7.2.4 installation guide for instructions on how to install **Tripwire Log Center Console**. Use the **Tripwire Log Center Console installer**. This can be done on any system, even the system running.

2.10.6 Integrate Tripwire Log Center Tripwire Log Center with Tripwire Enterprise

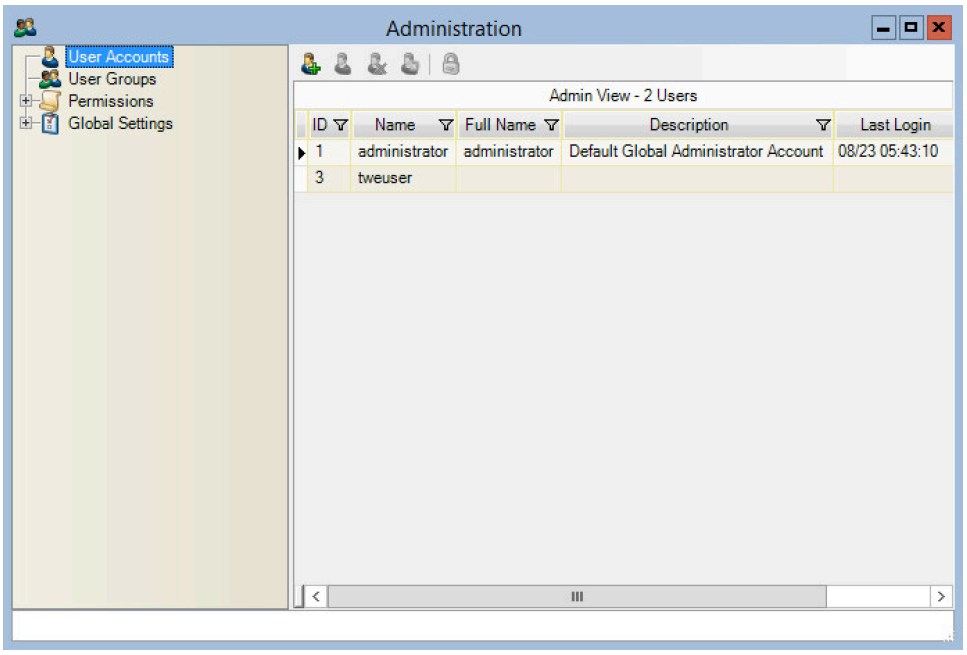
1. Create a user account in **Tripwire Log Center** by logging into **Tripwire Log Center Console**.



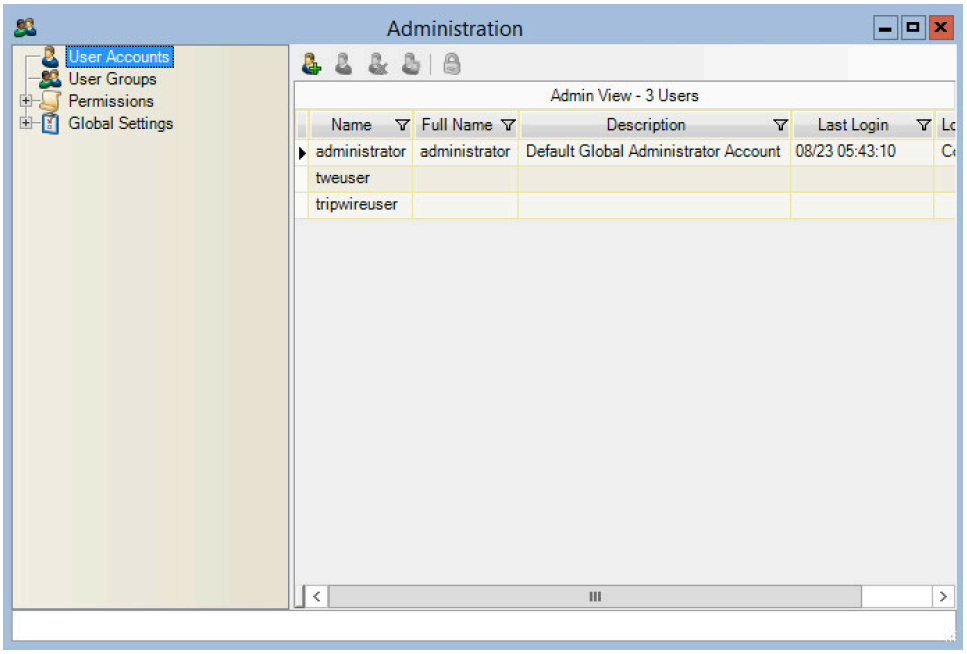
2. Click the **Administration Manager** button.



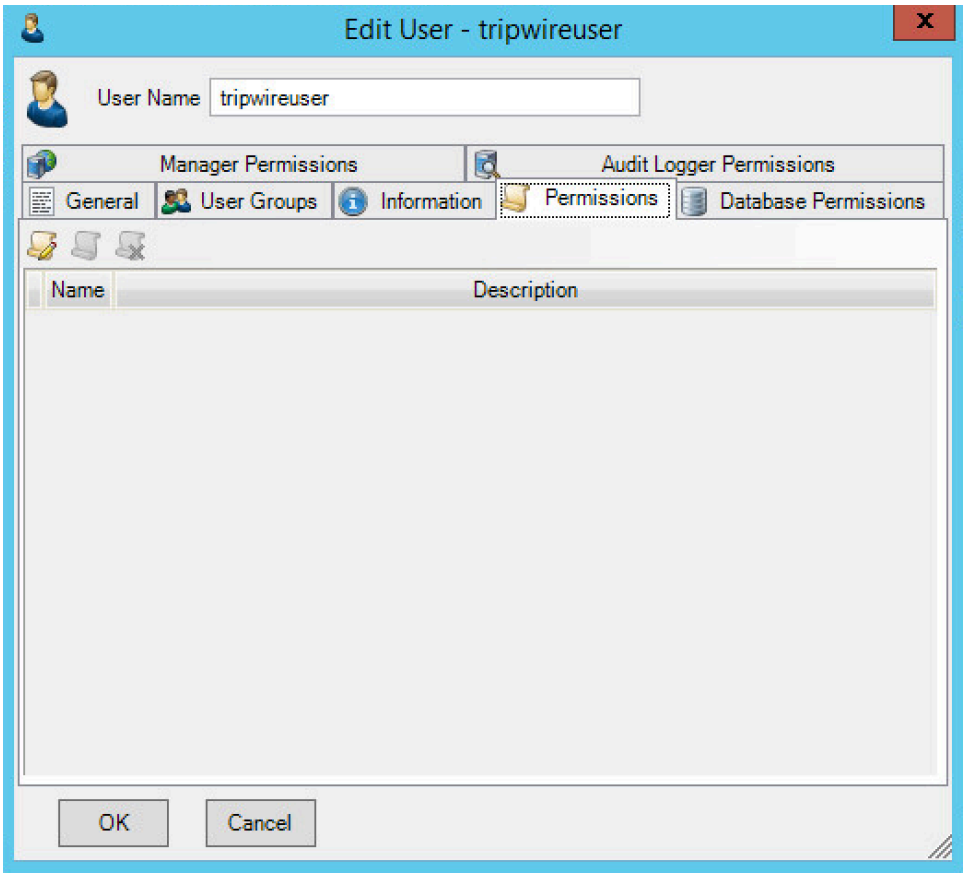
3. On the side bar, click **User Accounts**.



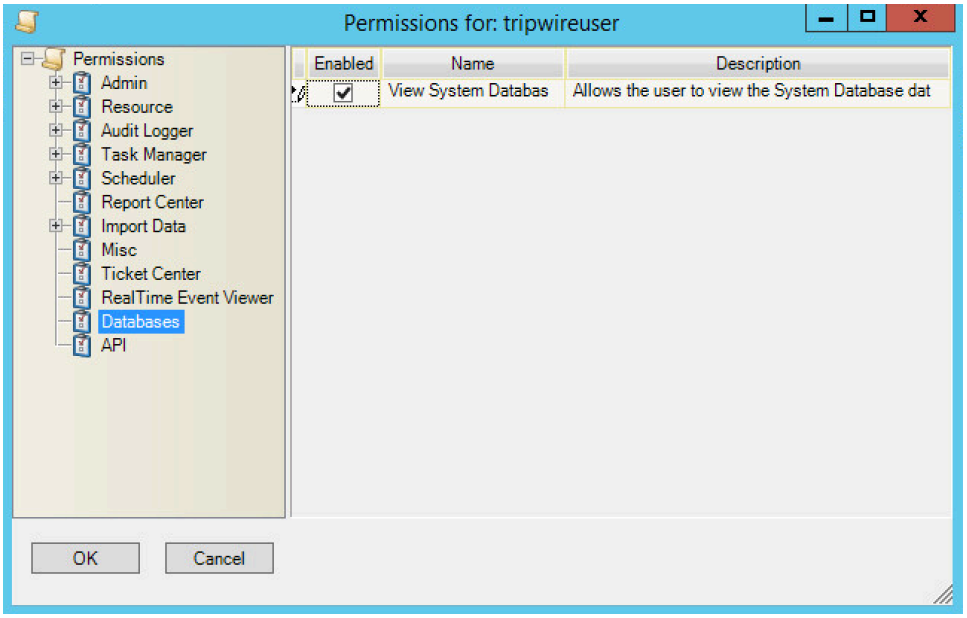
4. Click the **Add** button.
5. Enter the details of the user.



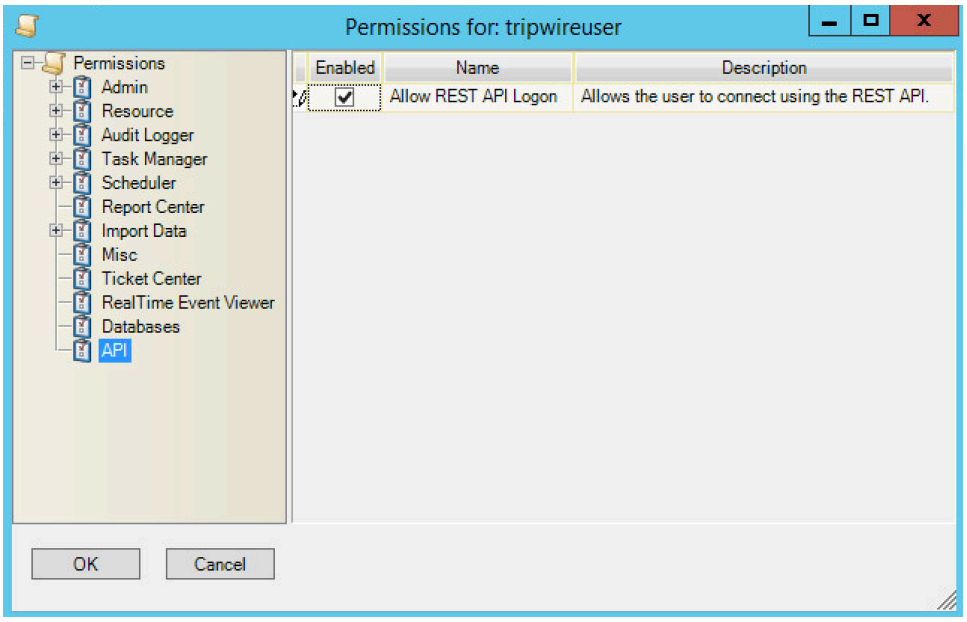
6. Double click the user account.
7. Select the **Permissions** tab.



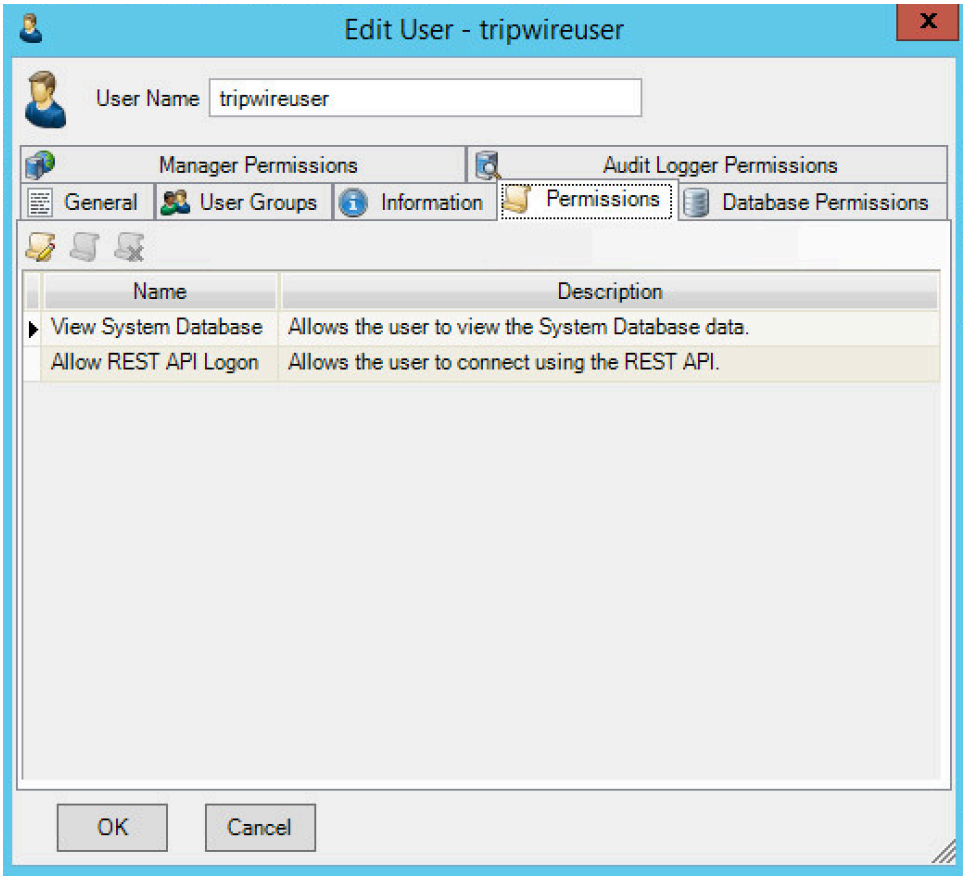
8. Click **Change User Permissions**.
9. Select **Databases** and check the box.



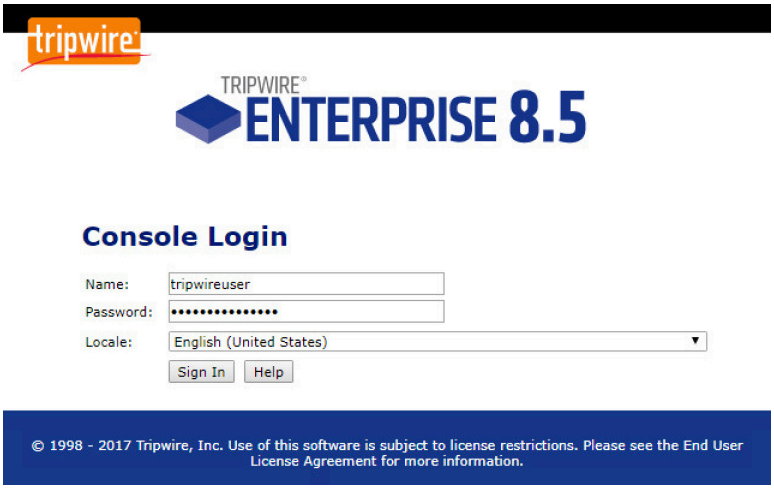
10. Select **API** and check the box.



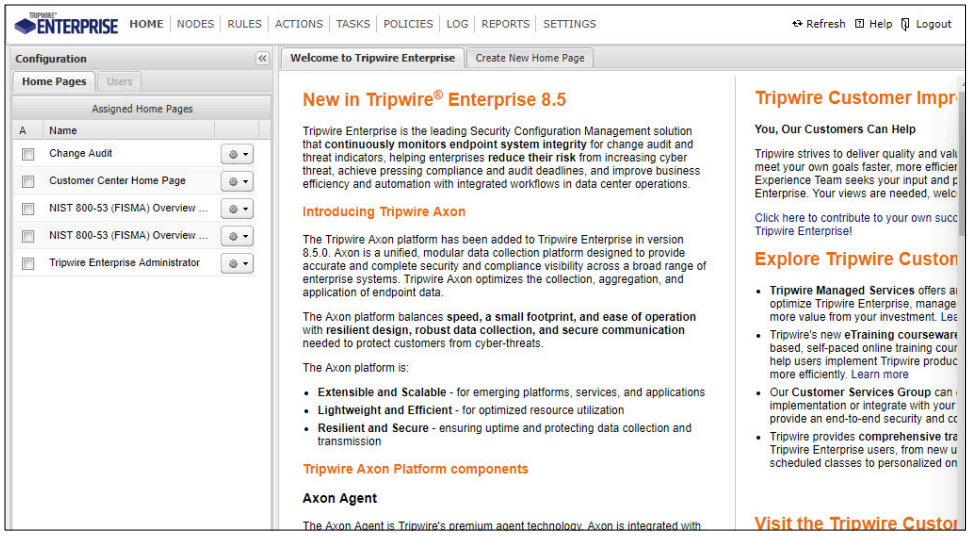
11. Click **OK**.
12. Click **OK**.
13. Click **OK**.



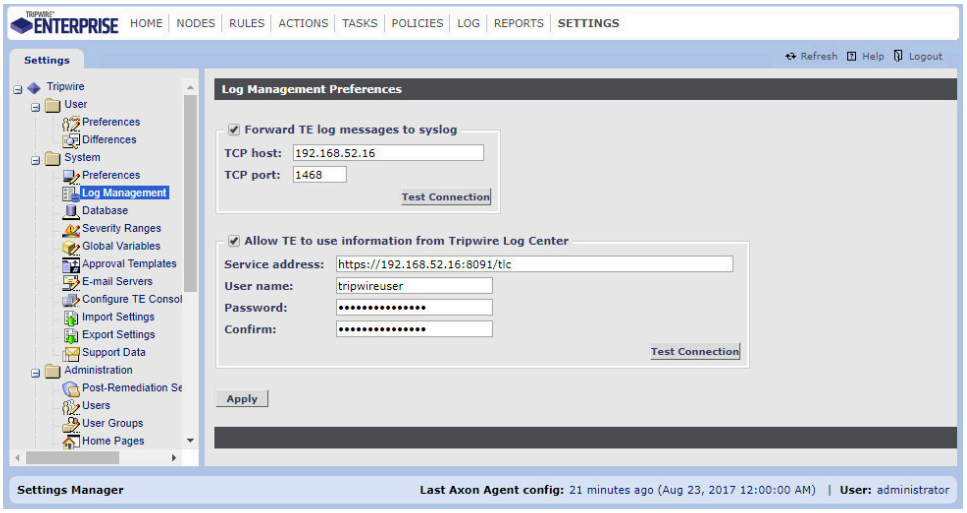
14. Open **Tripwire Enterprise** by going to https://tripwire/.
15. Log in to the **Tripwire Enterprise Console**.



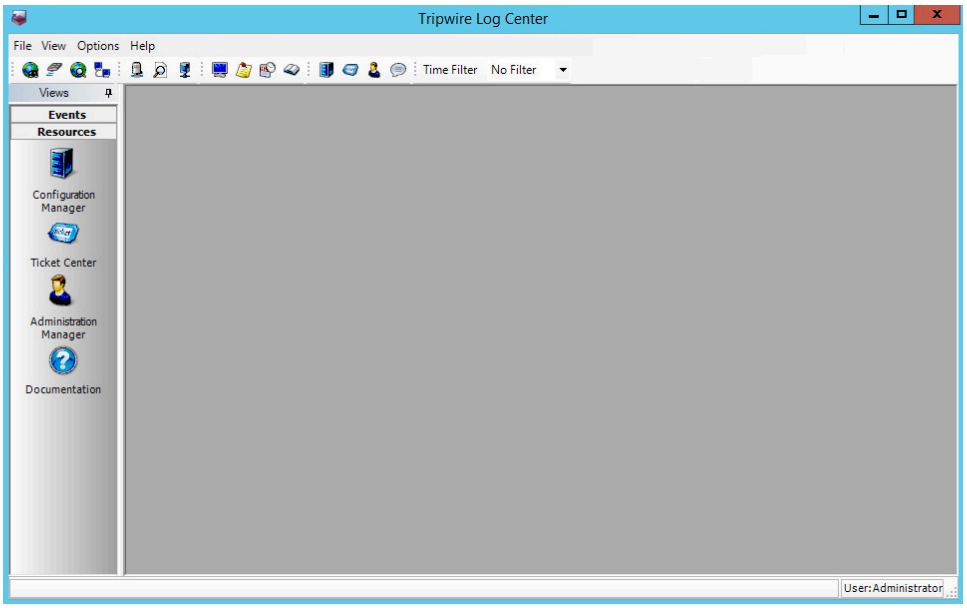
16. Click **Settings**.



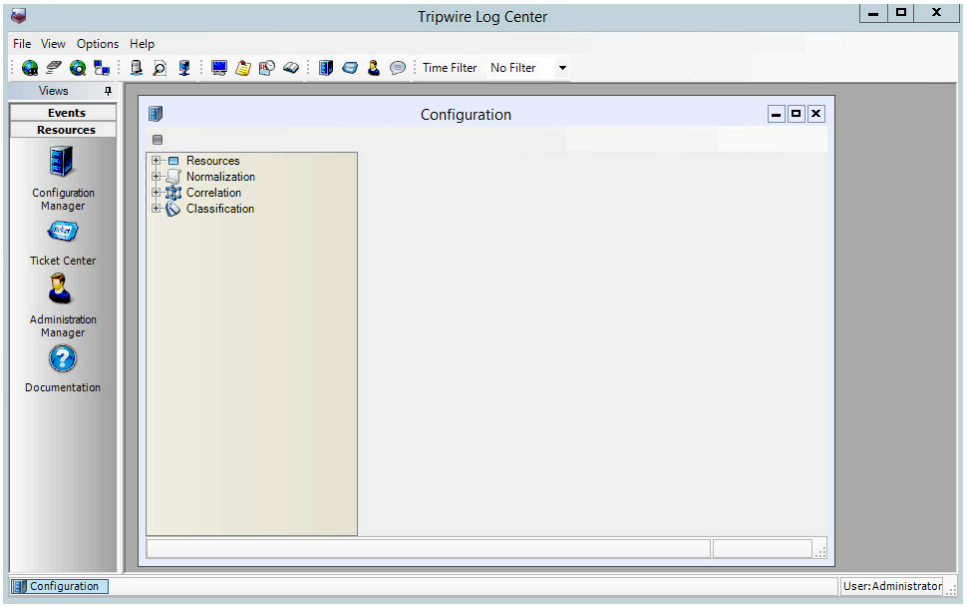
17. Go to **System > Log Management.**
18. Check the box next to **Forward TE log messages to syslog**.
19. Enter the **IP address** and **port** of the Tripwire Log Center server. The default port is 1468.
20. Check the box next to **Allow TE to use information from Tripwire Log Center**.
21. Enter the **service address** like this: *https://192.168.50.44:8091/tlc*, replacing the IP address with the IP address of the Tripwire Log Center server.
22. Enter the account information for the account created with the **Databases** and **API** permissions.



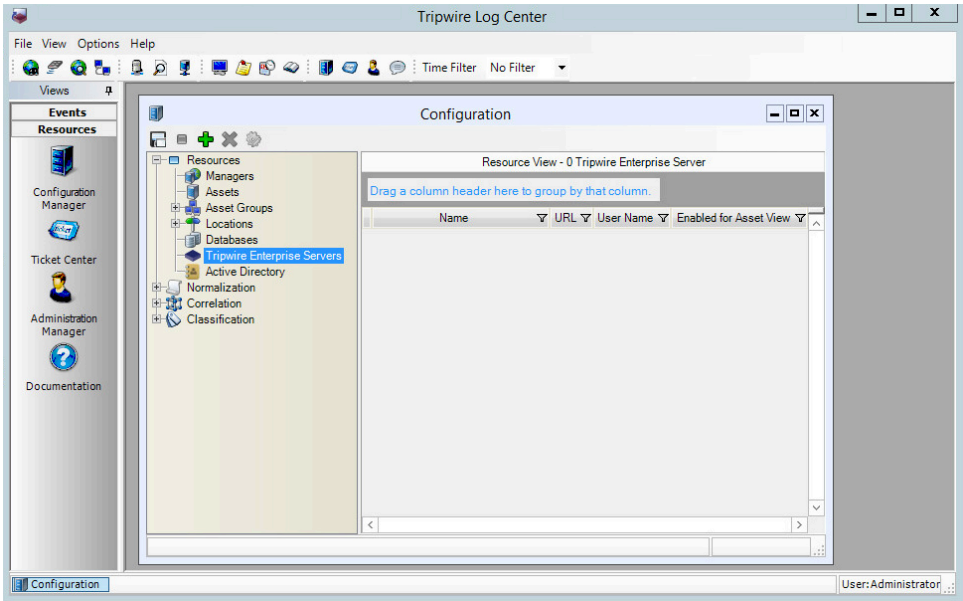
23. Click **Apply**.
24. Click **OK**.
25. Go back to the **Tripwire Log Center Console**.



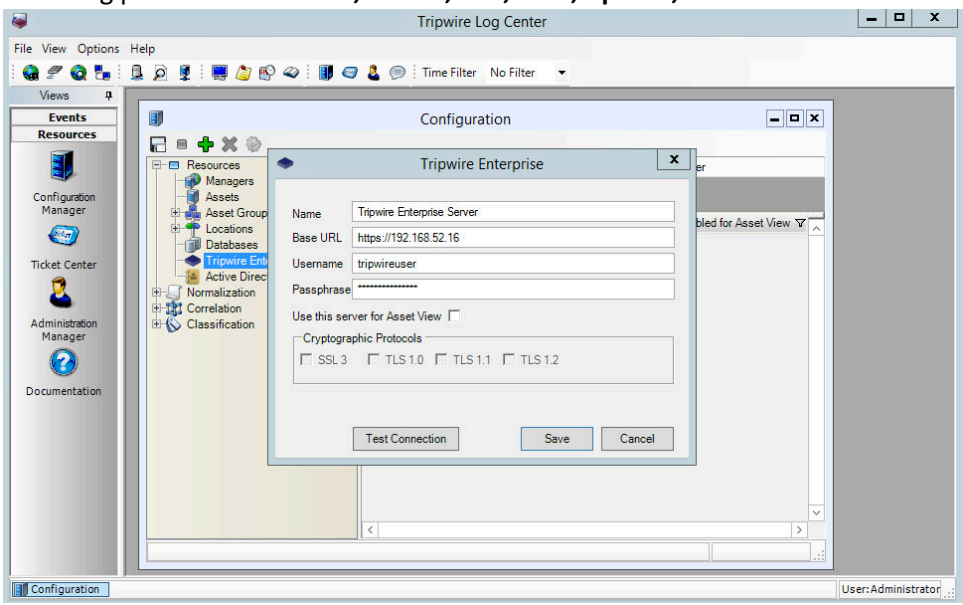
26. Click **Configuration Manager**.



27. Click **Resources > Tripwire Enterprise Servers**.



28. Click **Add**.
29. Enter a **name** for the Tripwire Enterprise server.
30. Enter the **IP address** and **port** for the Tripwire Enterprise server. By default, Tripwire Log Center and Tripwire Enterprise will communicate on port 443. (*https://192.168.50.43*)
31. Enter the name of a user account on the Tripwire Enterprise server. The account must have the following permissions: **create, delete, link, load, update, view.**



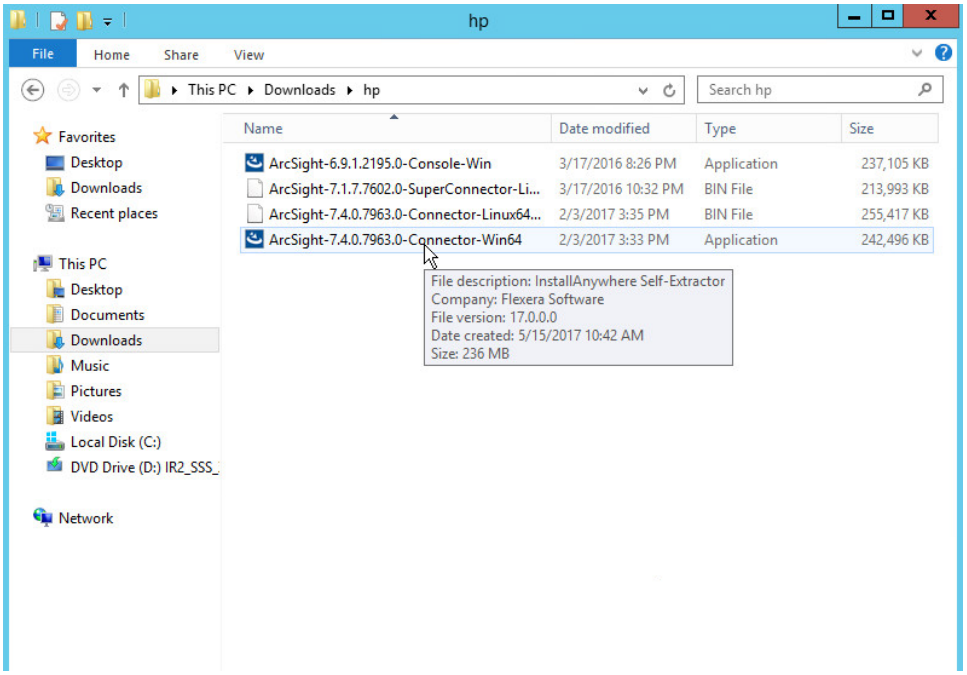
32. Click **Save**.

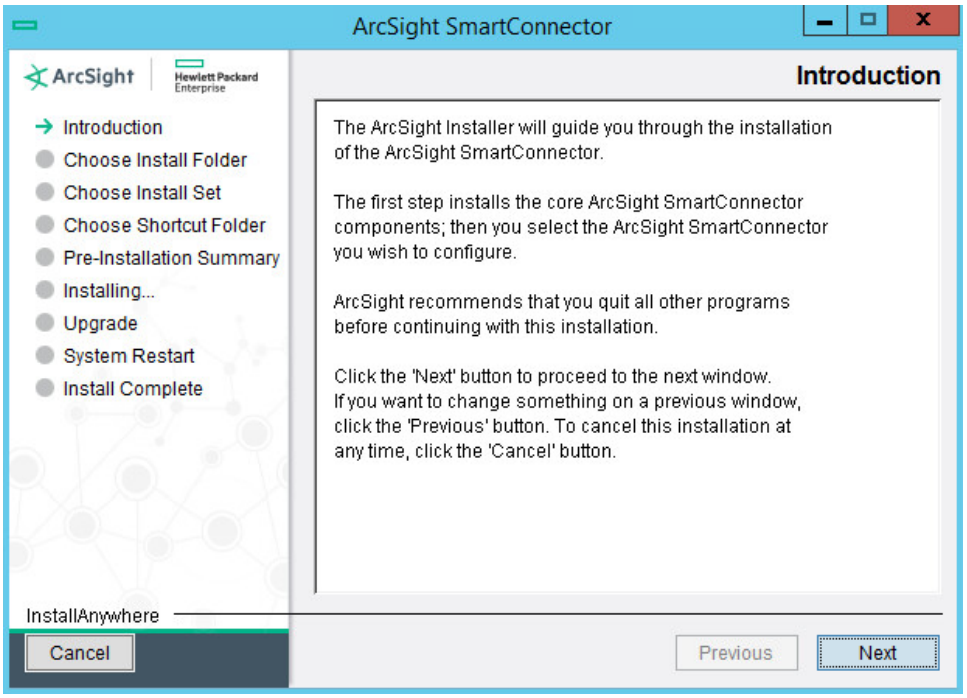
2.11 Integration: Tripwire Log Center (TLC) and HPE ArcSight ESM

In this section is a process for integrating Tripwire Log Center and HPE ArcSight ESM. This integration assumes the correct implementation of Tripwire and ArcSight as described in earlier sections. The result of this integration is the forwarding of logs generated by Tripwire Enterprise to ArcSight ESM as well as a method for filtering specifically for file change events in ArcSight ESM.

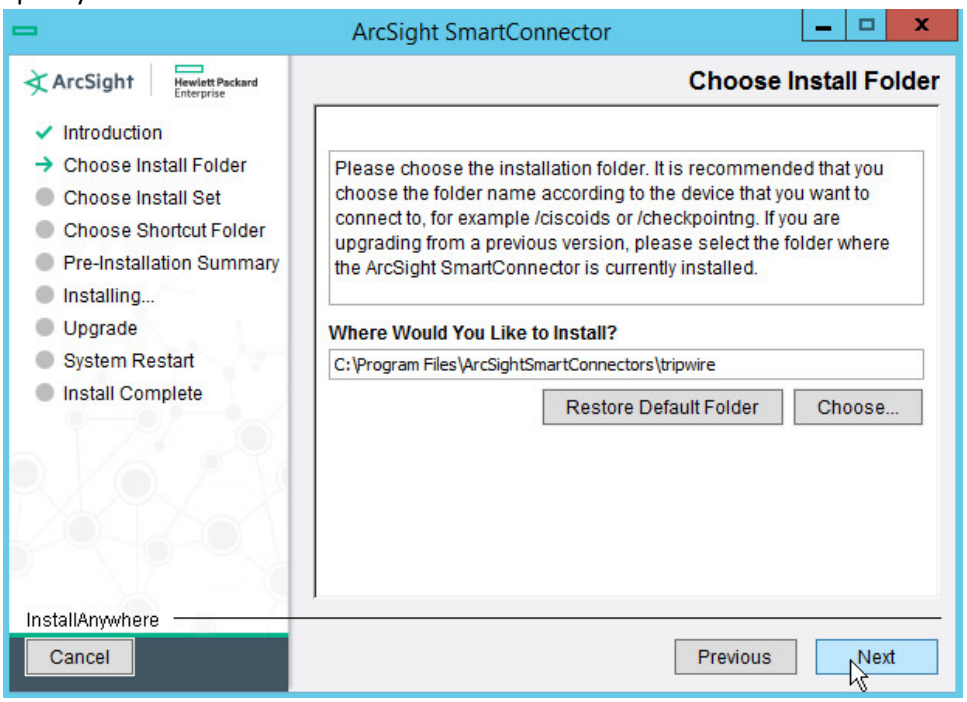
2.11.1 Integrating TLC and ESM

1. Run **ArcSight-7.4.0.7963.0-Connector-Win64** on any Windows server (*except* for the server running the Tripwire Log Center).

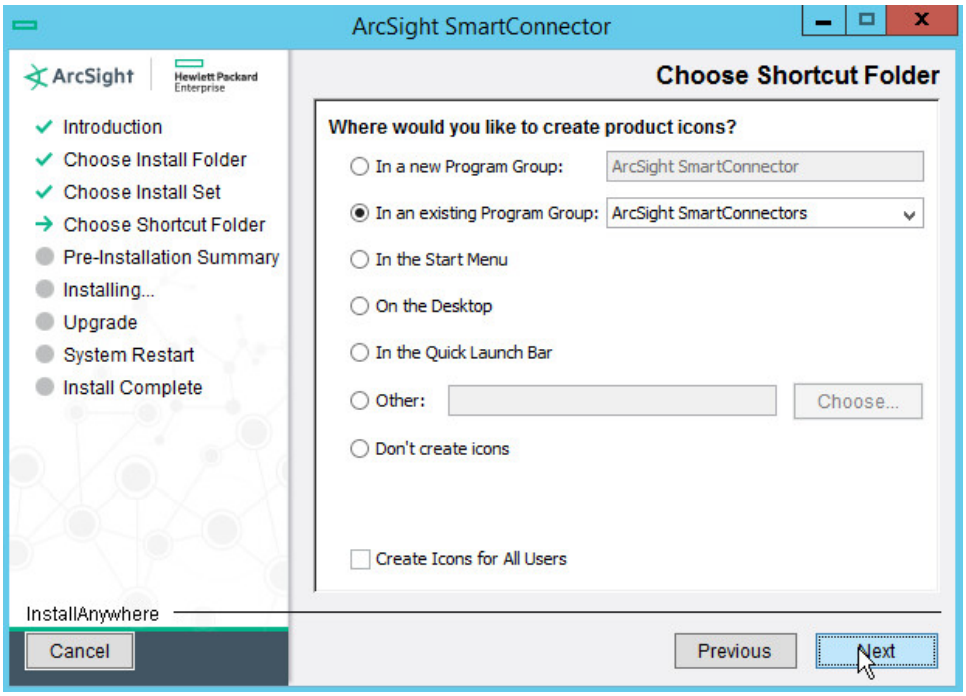




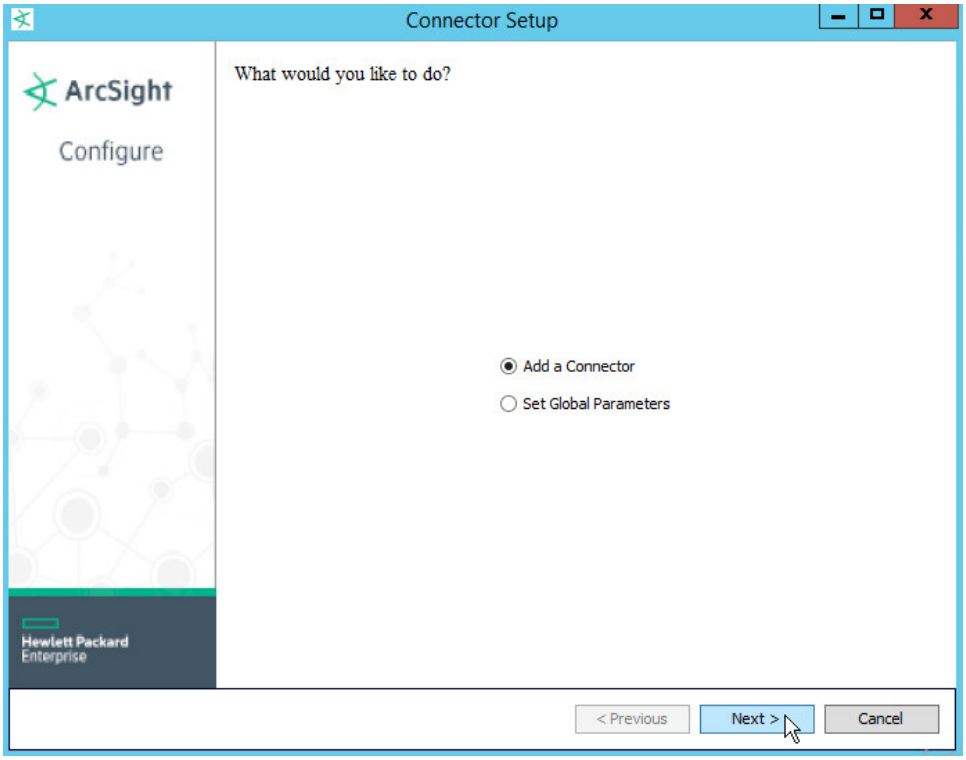
2. Click **Next**.
3. Specify a folder to install the connector.



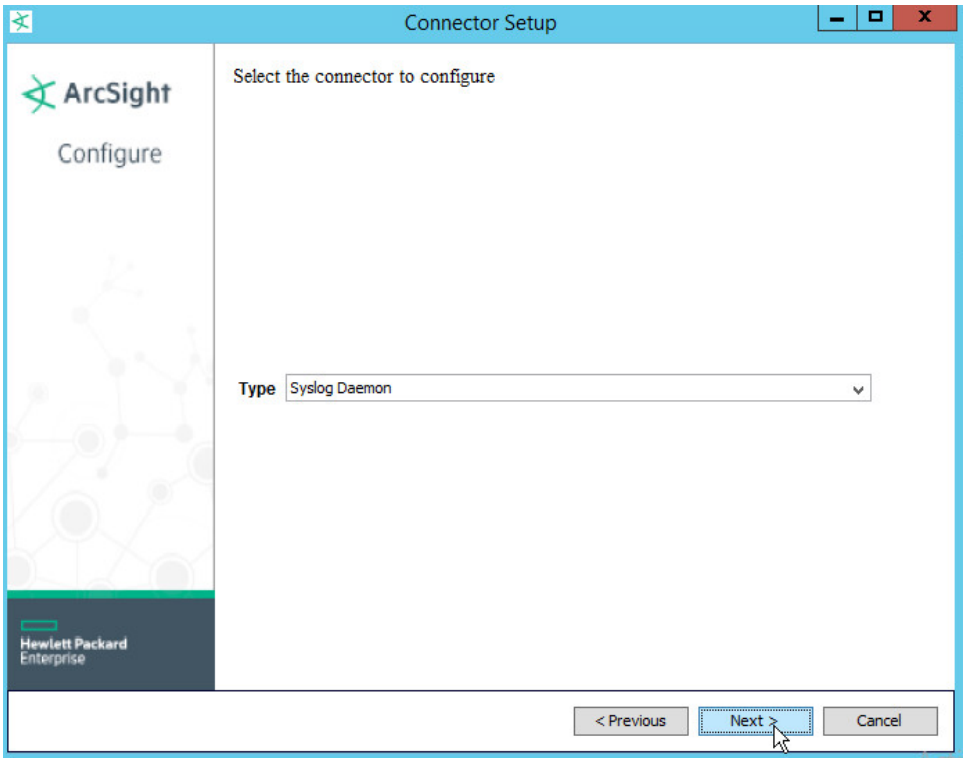
4. Click **Next**.



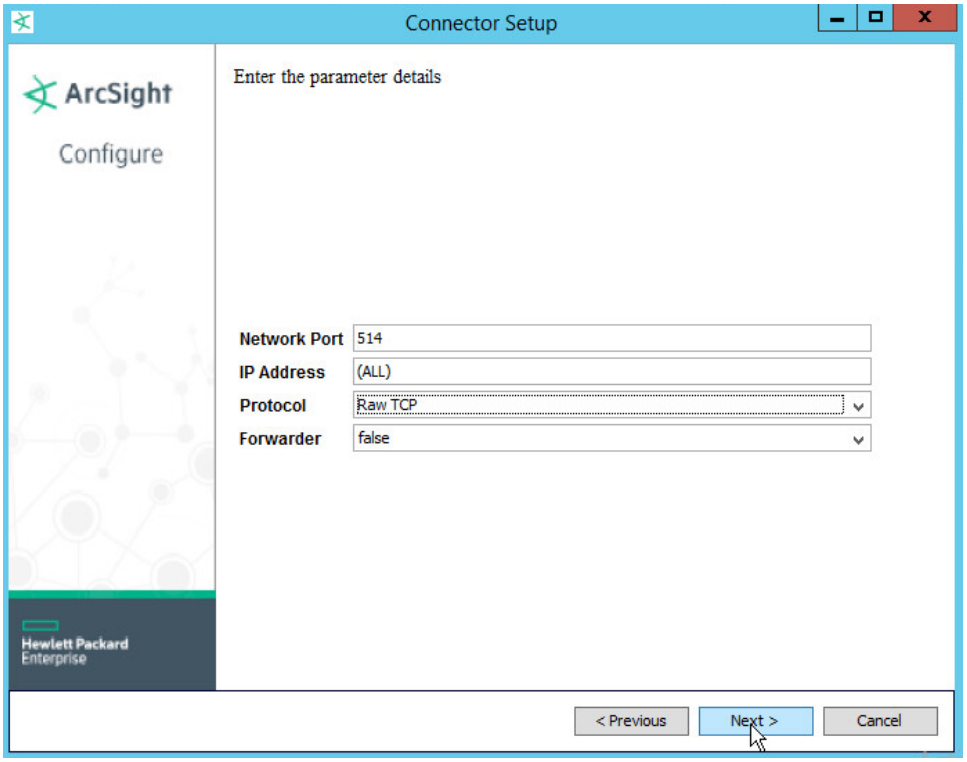
5. Click **Next**.
6. Click **Install**.
7. Select **Add a Connector**.



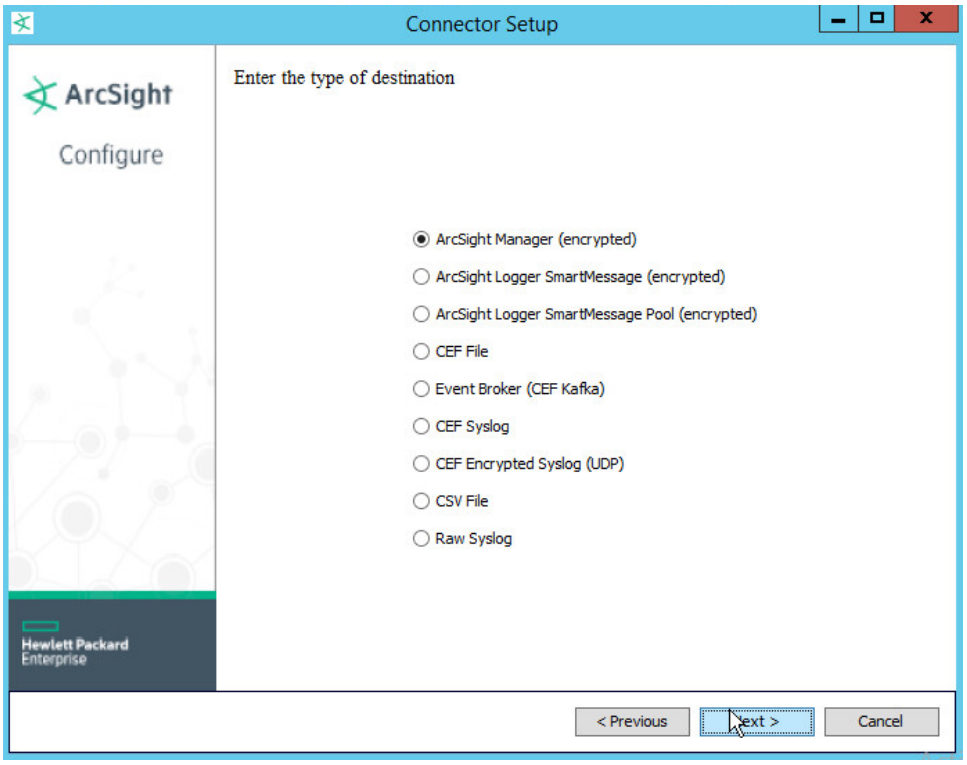
8. Click **Next**.
9. Select **Syslog daemon**.



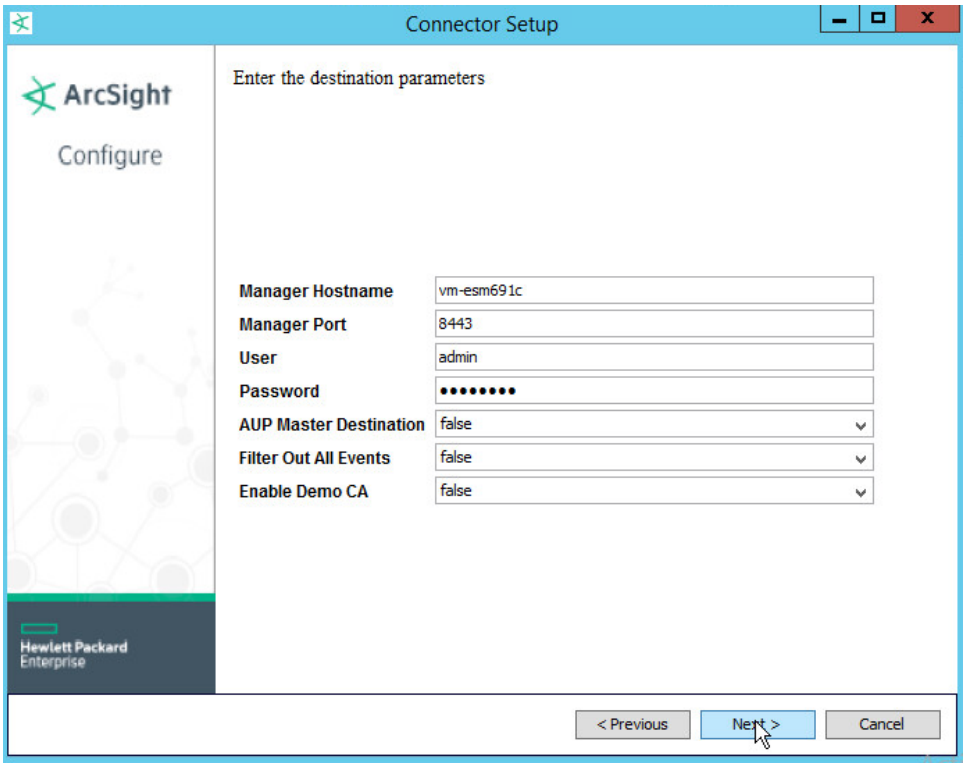
10. Click **Next**.
11. Select a **port** for the daemon to run on.
12. Leave **IP address** as **(ALL)**.
13. Select **Raw TCP** for **Protocol**.
14. Select **False** for **Forwarder**.



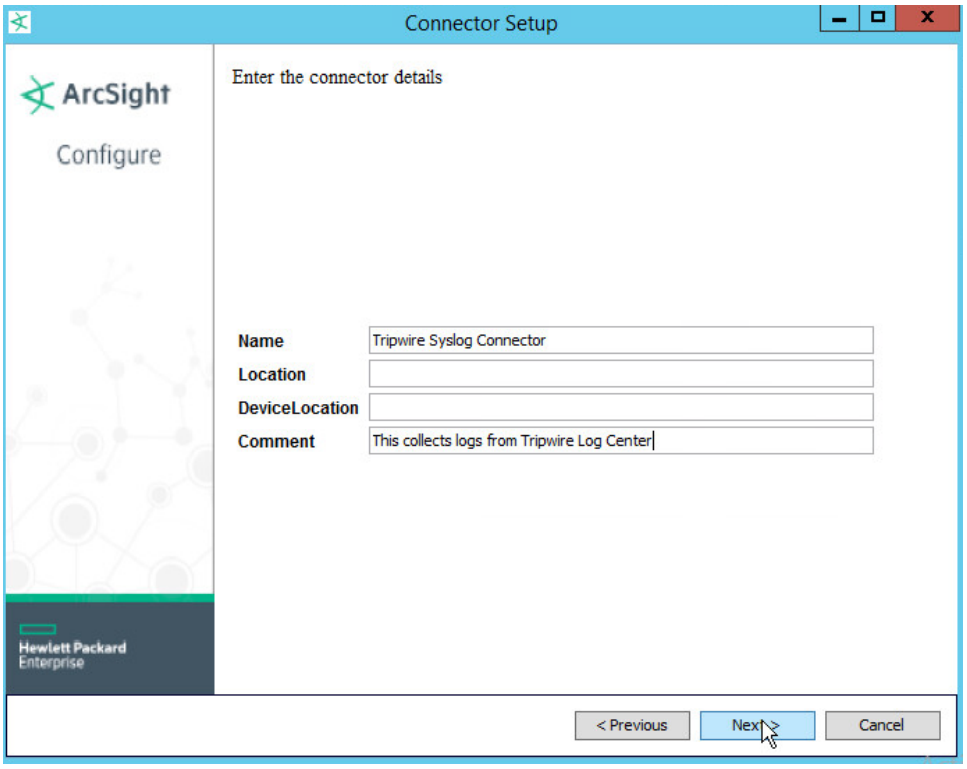
15. Click **Next**.
16. Choose **ArcSight Manager (encrypted)**.



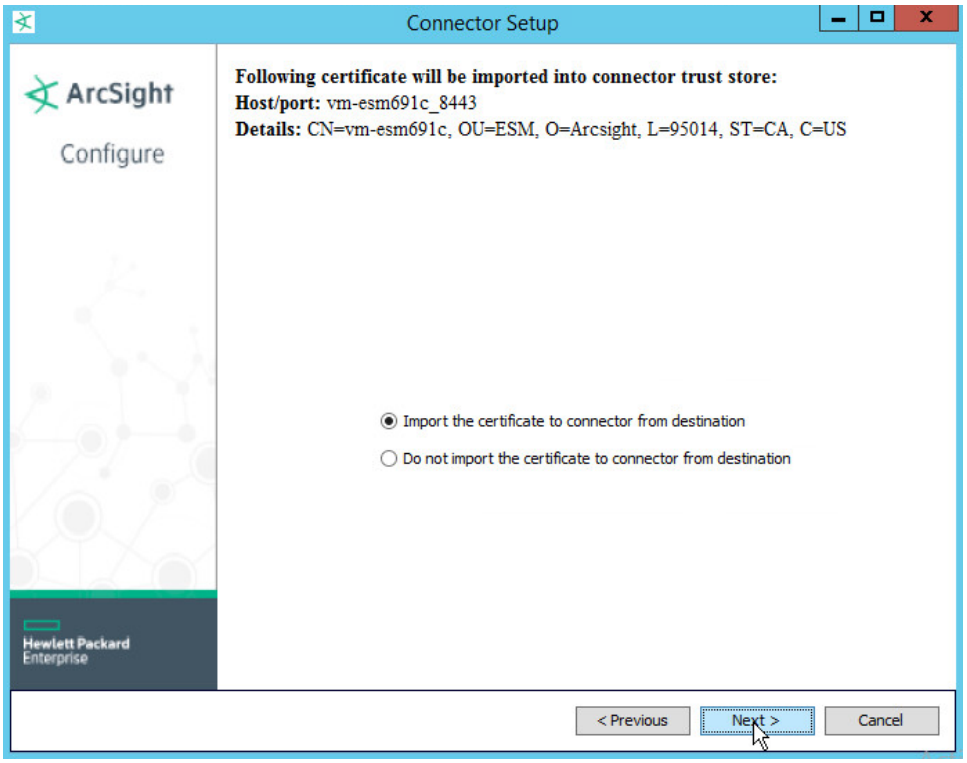
17. Click **Next**.
18. For **Manager Hostname**, put *vm-esm691c* or the hostname of your ESM server.
19. For **Manager Port**, put **8443** (or the port that ESM is running on).
20. Enter the username and password used for logging into **ArcSight Command Center**. Default: (admin/password)



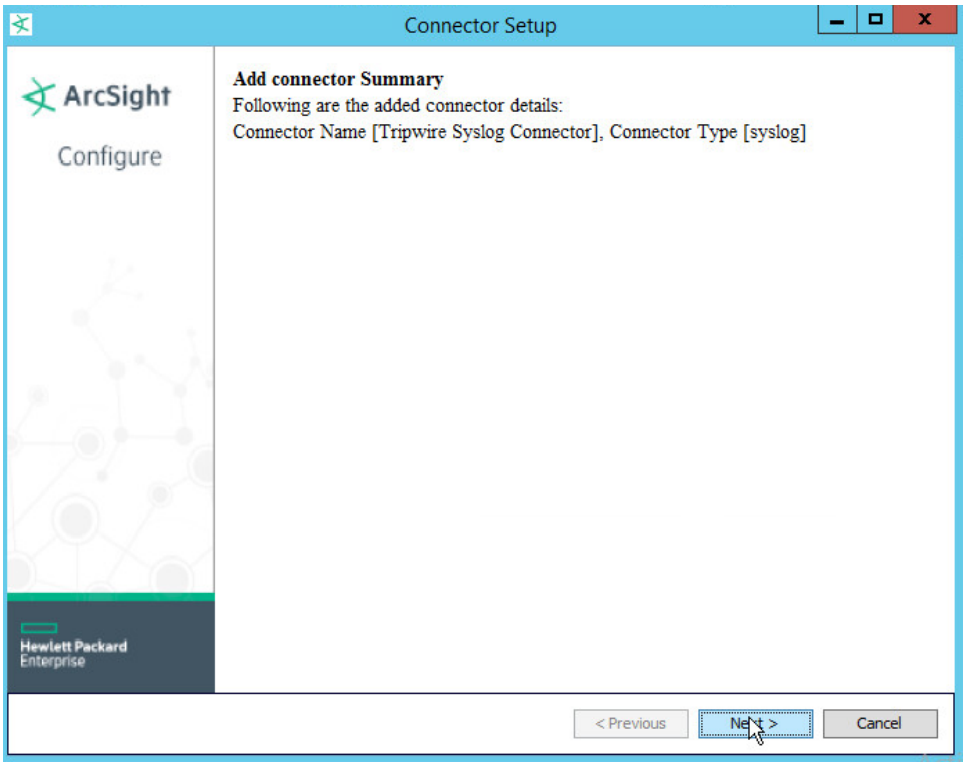
21. Click **Next**.
22. Set identifying details about the system to help identify the connector (include **Name;** the rest is optional).



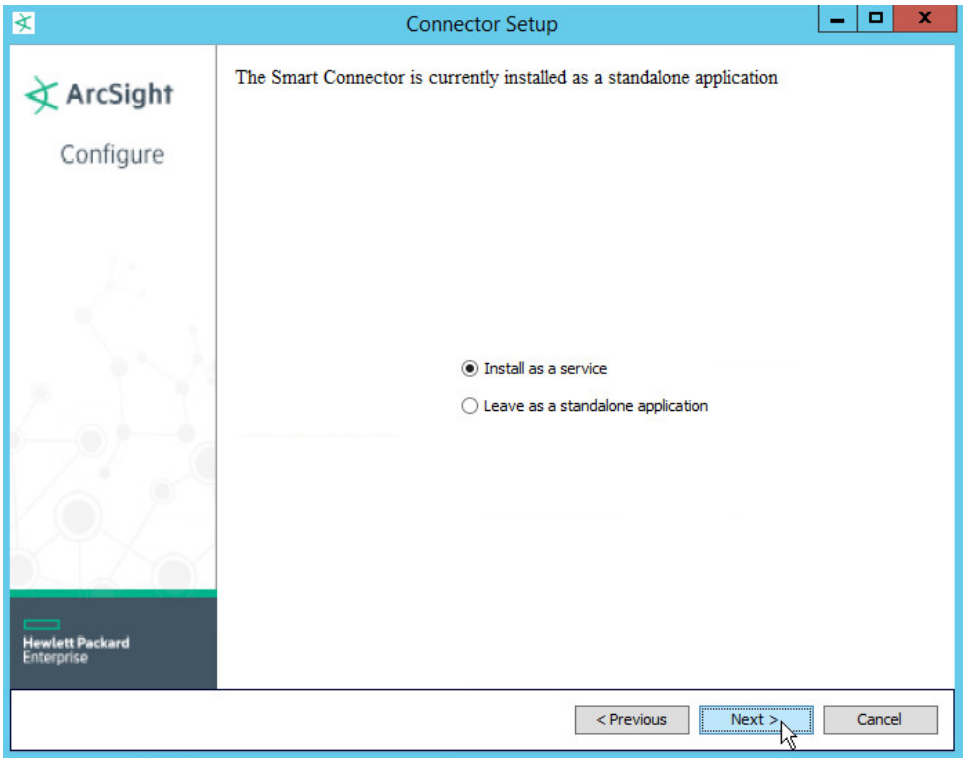
23. Click **Next**.
24. Select **Import the certificate to connector from destination**. This will fail if the **Manager Hostname** does not match the hostname of the VM.



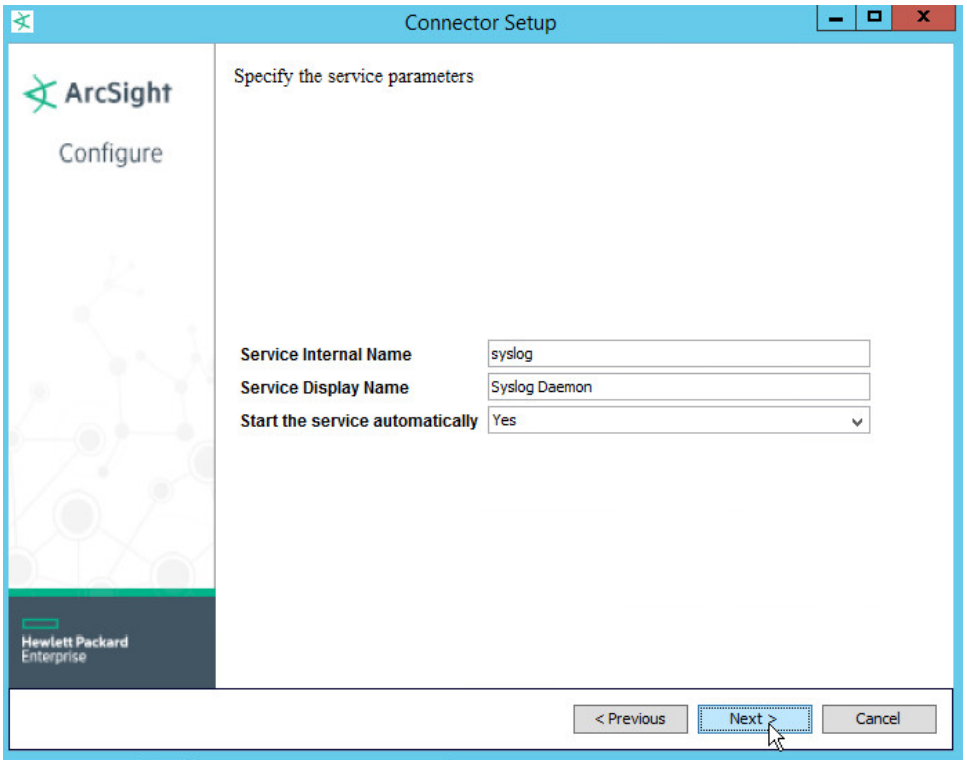
25. Click **Next**.



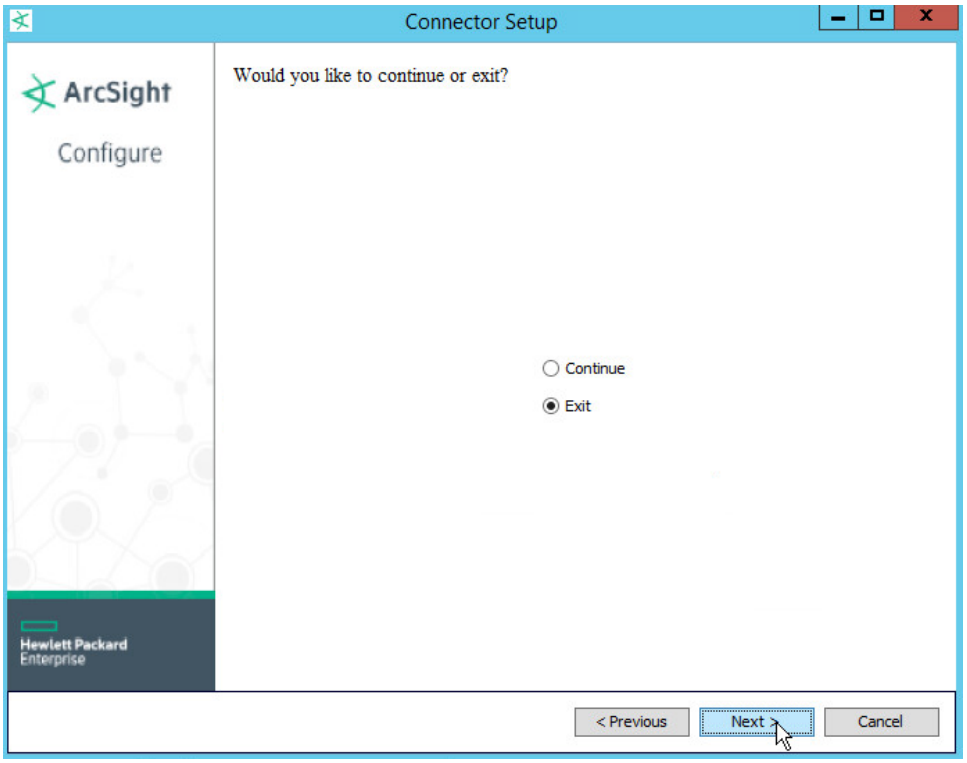
26. Click **Next**.
27. Choose **Install as a service**.



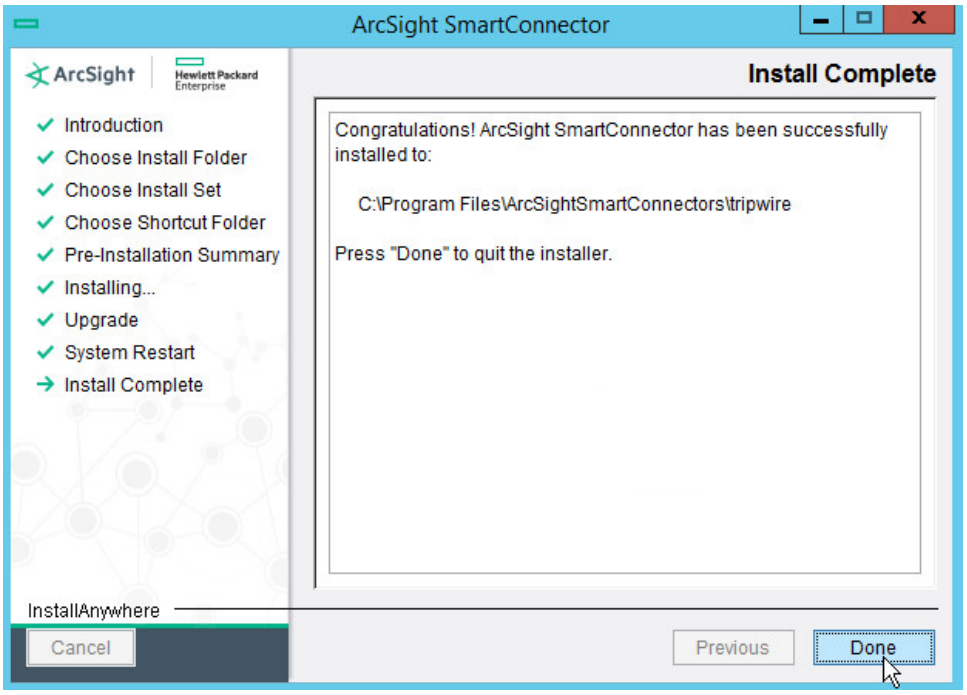
28. Click **Next**.



29. Click **Next**.
30. Choose **Exit**.

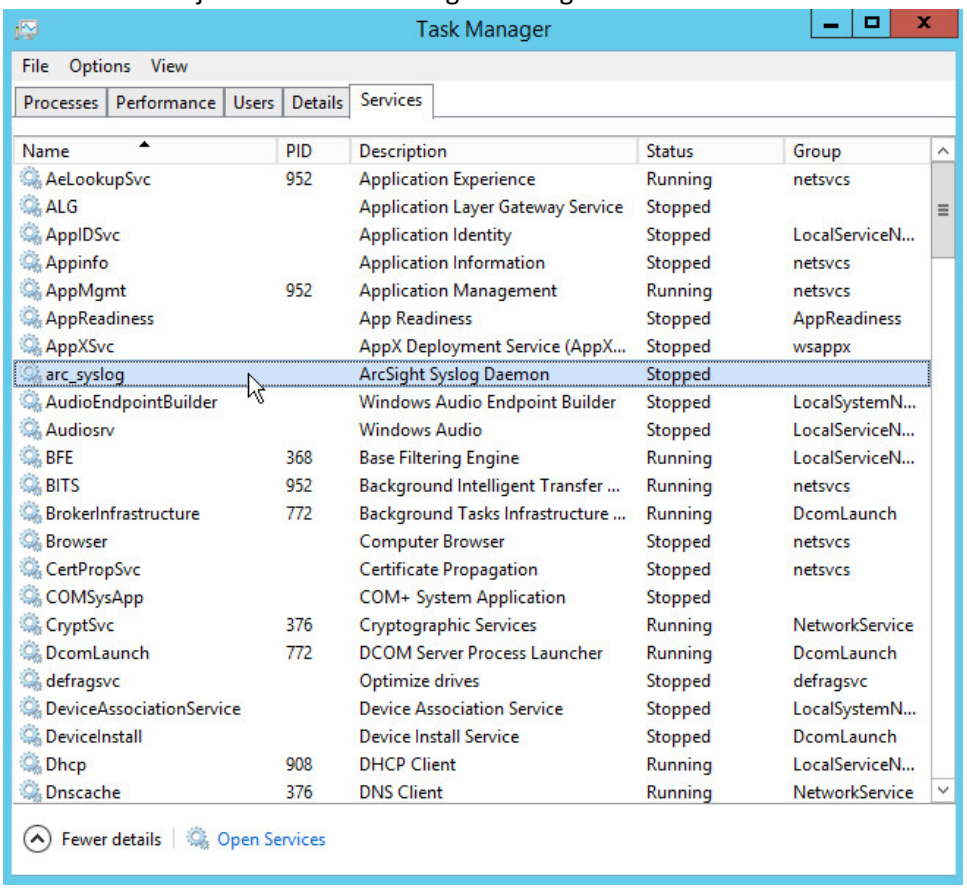


31. Click **Next**.

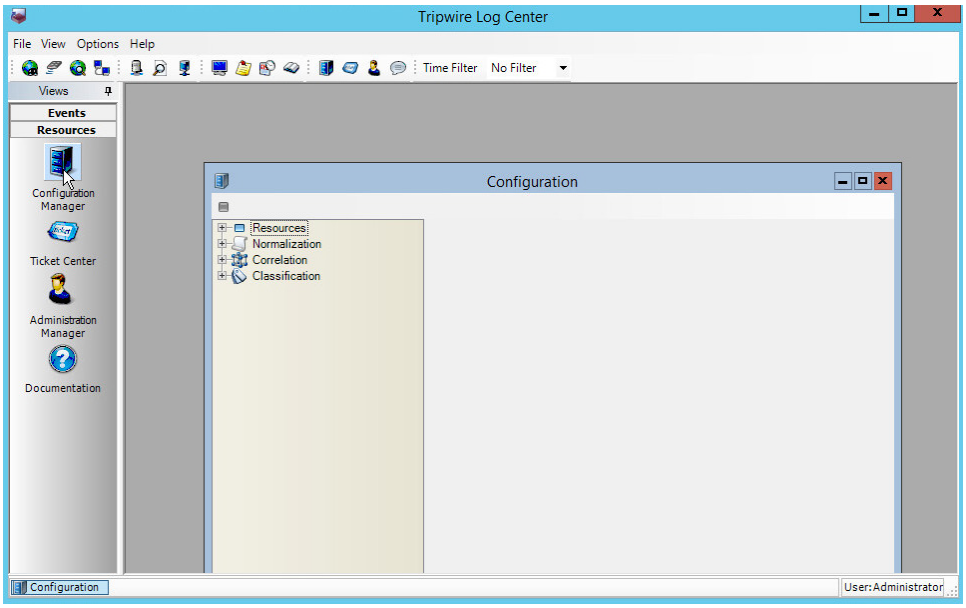


32. Click **Done**.

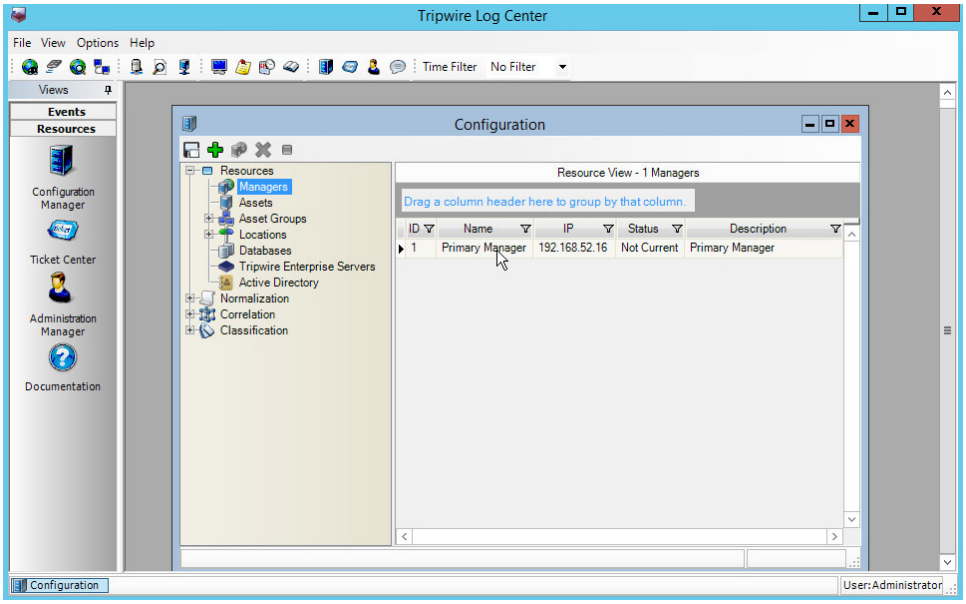
33. Open **Task Manager**.
34. Click **More Details**.
35. Go to the **Services** tab.
36. Find the service just created for ArcSight and right click it.



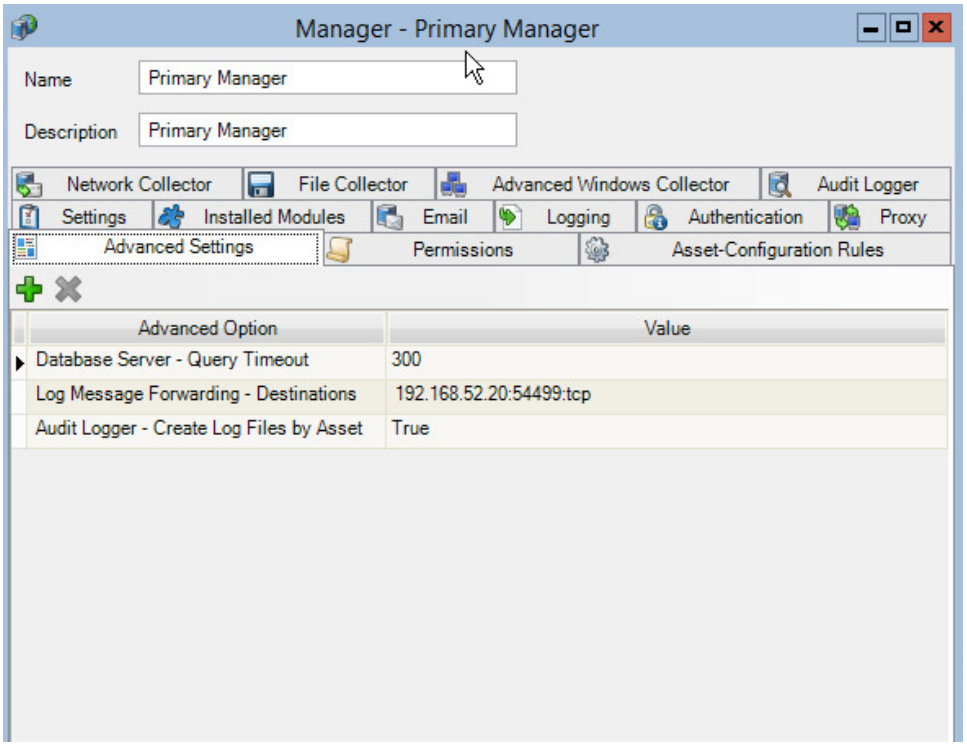
37. Choose **Start**.
38. Open the **Tripwire Log Center Console**.



39. Go to the **Configuration Manager**.
40. Select **Resources > Managers**.



41. Double click the **Primary Manager** listed.

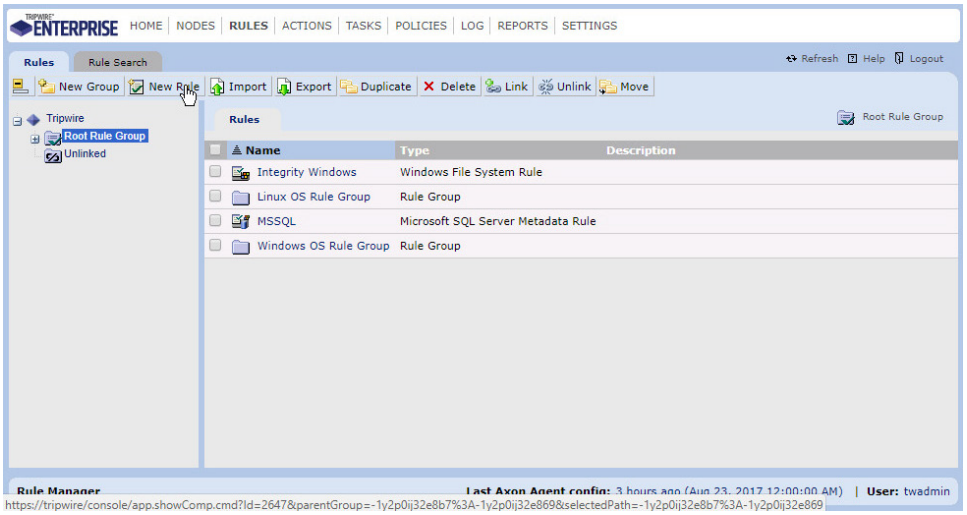


42. Click the **Advanced Settings** tab.
43. Click the **+Add** button. This should add a row to the table.
44. In the **Advanced Option** box, select **Log Message Forwarding - Destinations**.
45. In the **Value** box next to it, type **<ip_address>:<port>:udp**, with the **IP Address** and **port** of the syslog daemon just created.

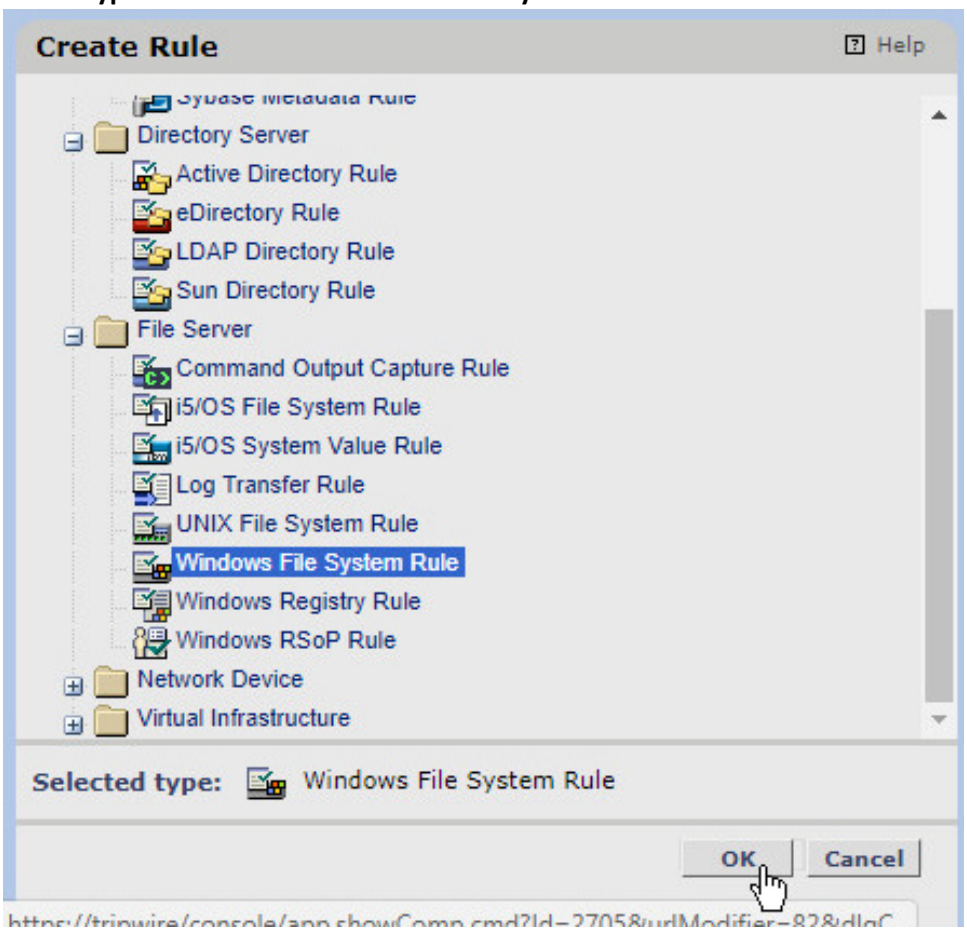
2.11.2 Configuring Tripwire Enterprise and HPE ArcSight ESM to Detect and Report File Integrity Events

2.11.2.1 Creating a Rule for Which Files to Monitor Across Your Enterprise

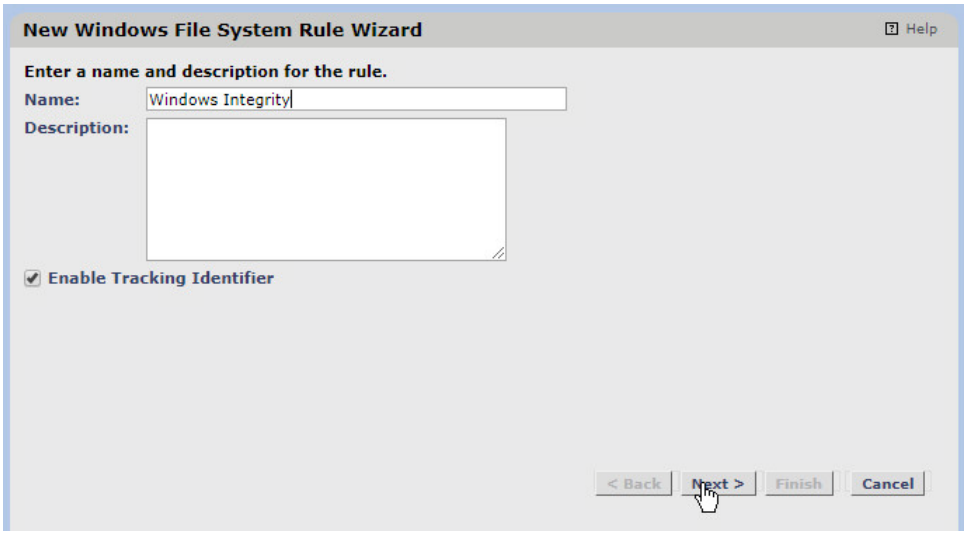
1. Log into **Tripwire Enterprise** by going to *https://tripwire* and entering the user name and password.
2. Click the **Rules** link.



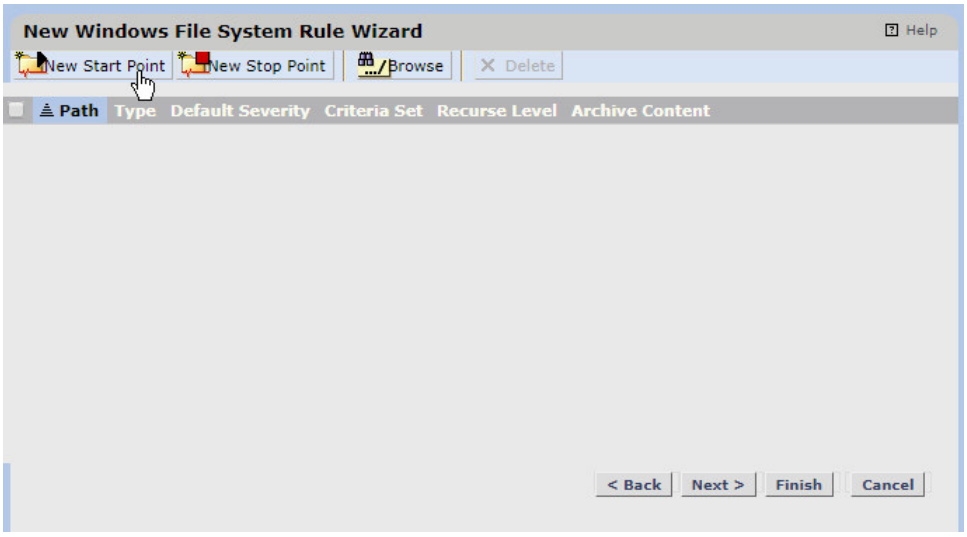
3. Click **New Rule**.
4. Select **Types > File Server > Windows File System Rule**.



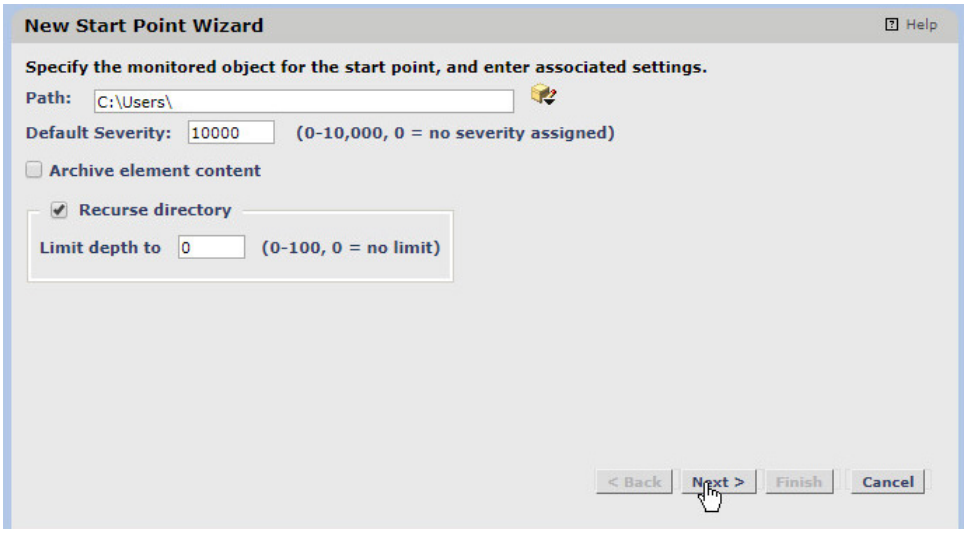
5. Click **OK**.
6. Enter a **name** for the rule.



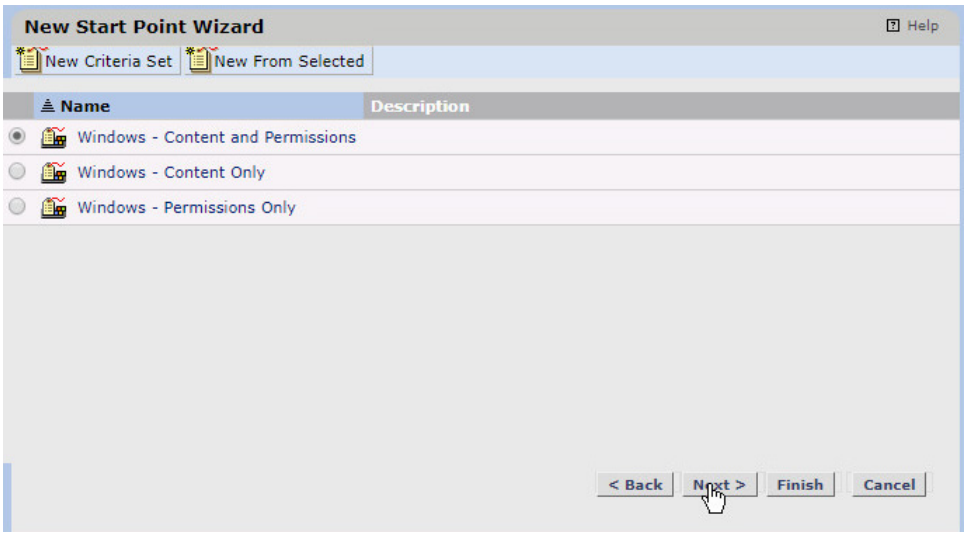
7. Click **Next**.



8. Click **New Start Point**. This will bring up a **New Start Point Wizard**.
9. Enter the **path** to a folder or file that will be monitored across all Windows Systems. For example, we chose to monitor *C:\Users*.
10. If you selected a directory and want the integrity check to recurse in all sub directories, make sure the box next to **Recurse directory** is checked.



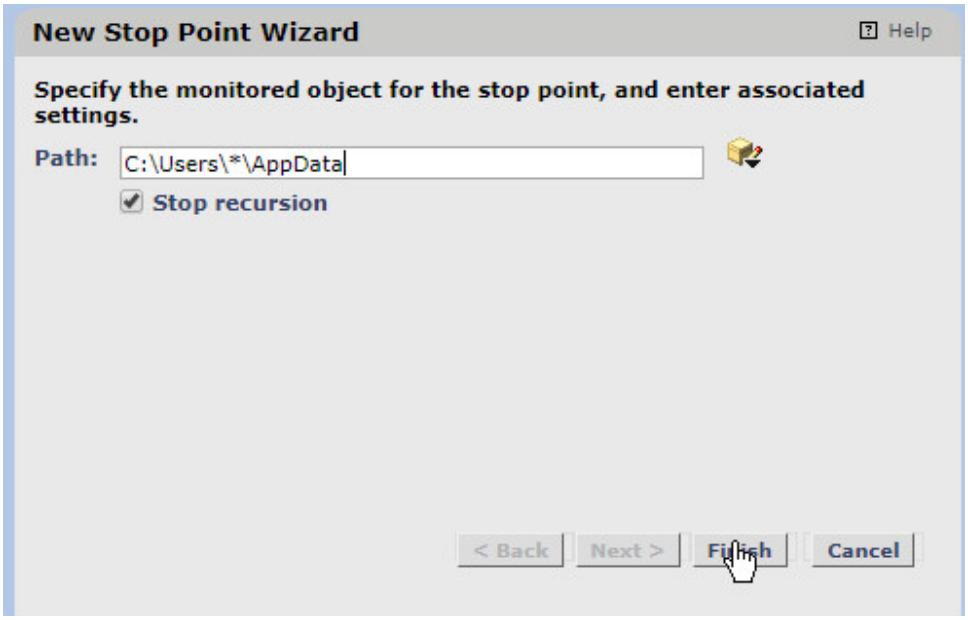
11. Click **Next**.
12. Select **Windows Content and Permissions**.



13. Click **Next**.

14. Click **Finish**.
15. If you wish to exclude directories, click **New Stop Point**.

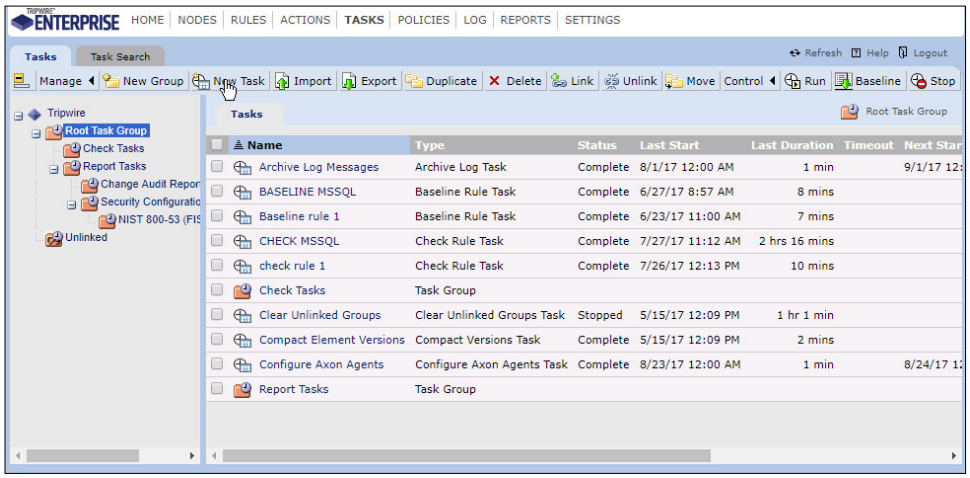
16. Enter the path name of directories you wish to exclude. For example, we chose to exclude *C:\Users*\AppData* because that provided many false flags of routine application data modification.
17. Check the box next to **Stop Recursion**.



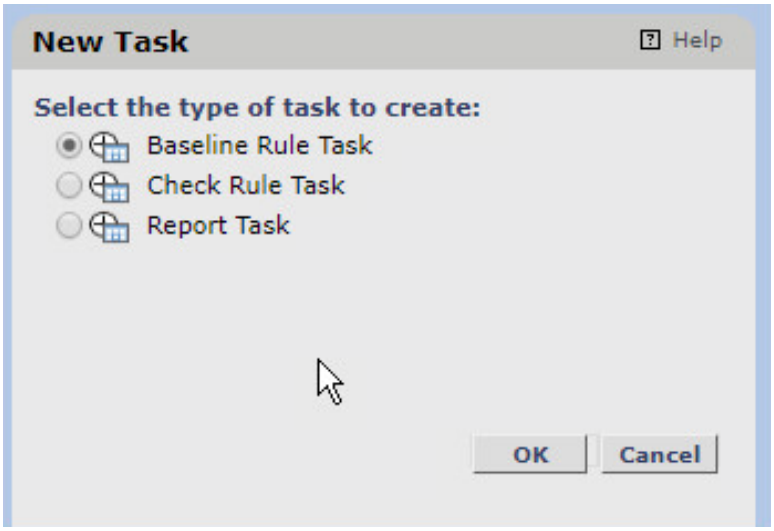
18. Click **Finish**.
19. The rule created defines a space for the tasks we will create to search through.

2.11.2.2 Creating a Baseline Task

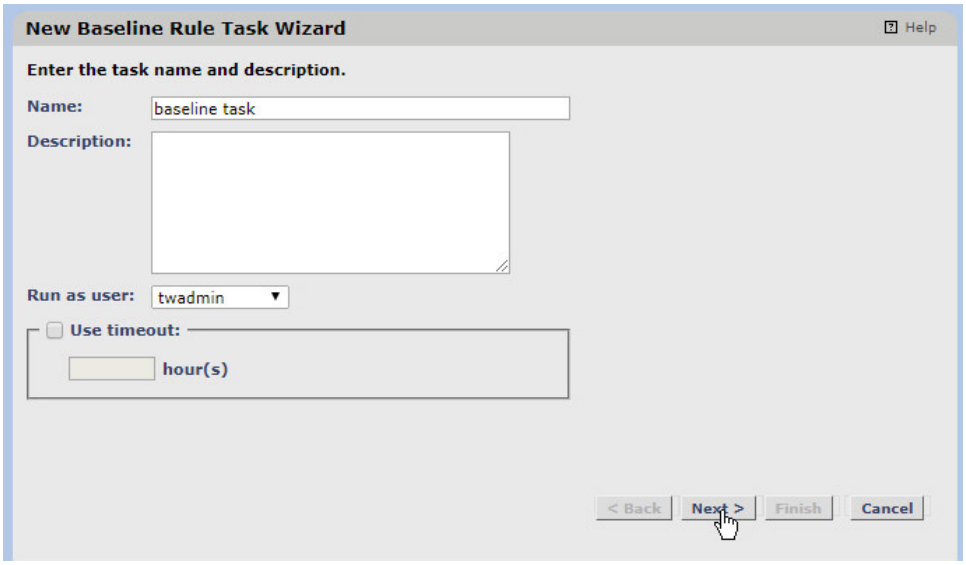
1. Click the **Tasks** link.



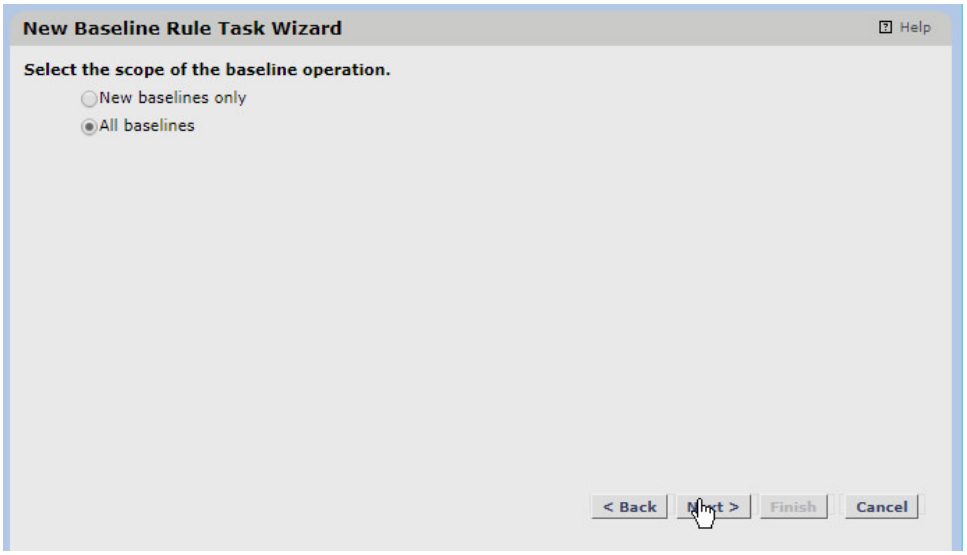
2. Click **New Task**.
3. Select **Baseline Rule Task**.



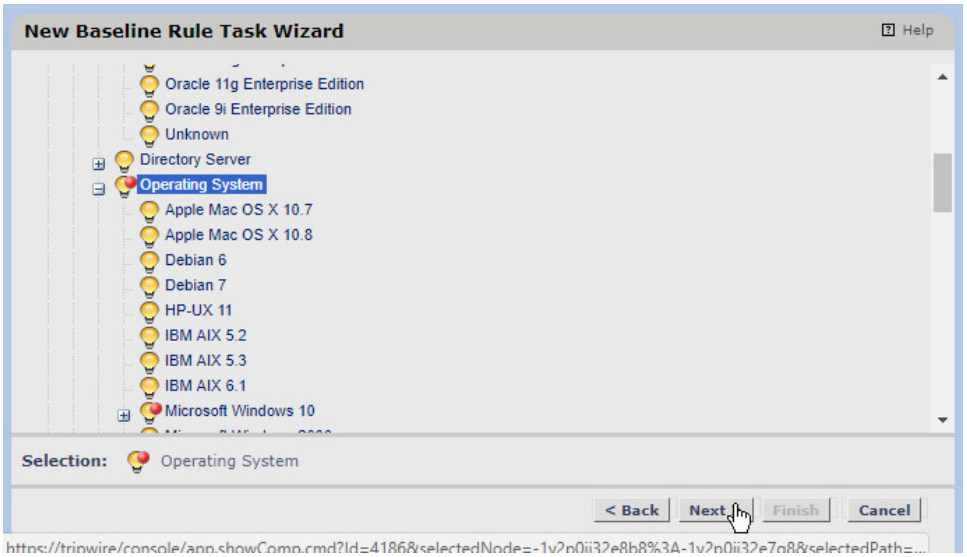
4. Click **OK**.
5. Enter a **name** for the baseline rule task.
6. Select a privileged user in Tripwire Enterprise to run the rule as.



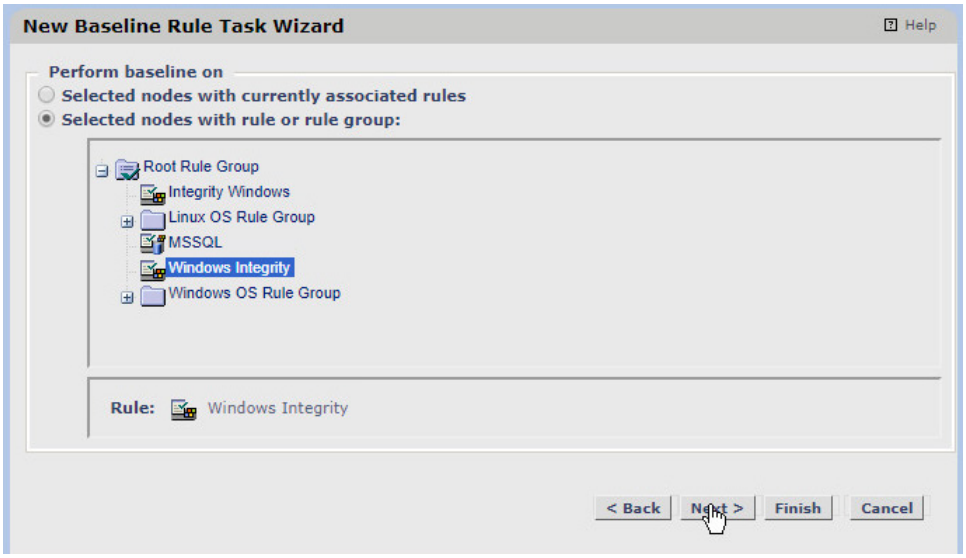
7. Click **Next**.
8. Select **All Baselines**.



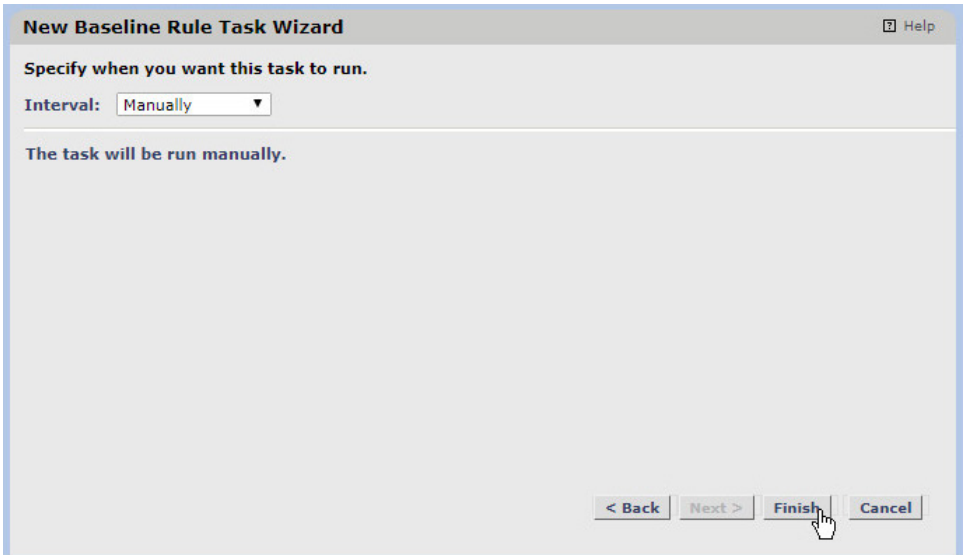
9. Click **Next**.
10. Expand **Root Node Group > Smart Node Groups > System Tag Sets > Operating System**.
11. You can select specific types of operating systems to run the task on or specific machines. We simply selected **Operating System** to have it run on all applicable Windows machines.



12. Once you have made your selection, click **Next**.
13. Select **Selected nodes with rule or rule group**.
14. Click the rule you created earlier.



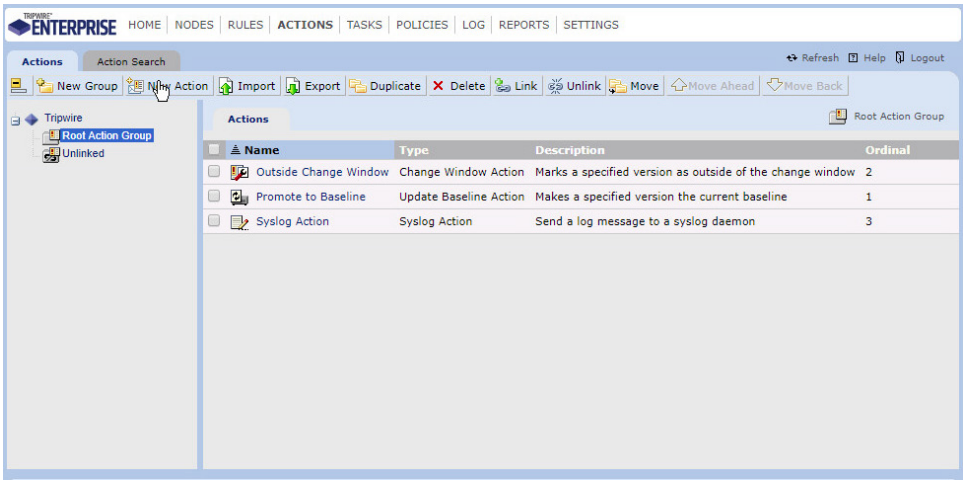
15. Click **Next**.
16. Decide how often the baseline task should be run. We set it to **manually** but you can also set a very specific schedule by choosing **periodic**.



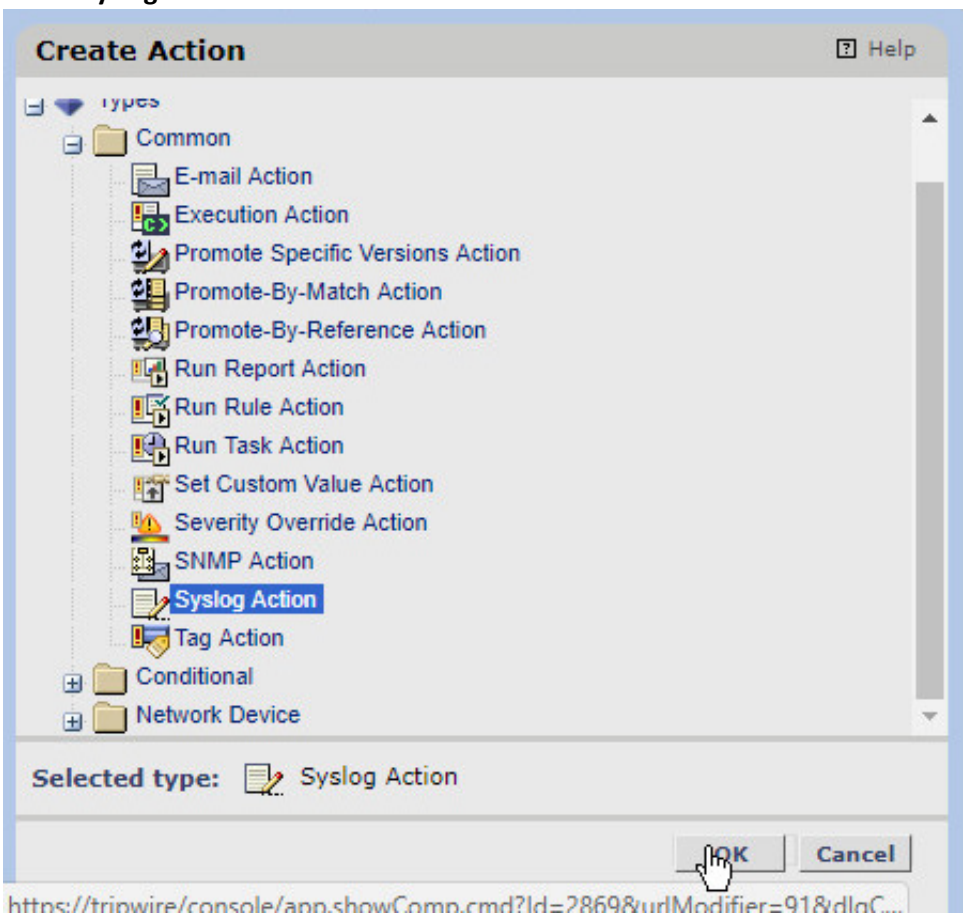
17. Click **Finish**.
18. This rule will create baselines of the specified objects. Baselines are essentially versions of the file that check rules will compare against. Baselines should be primarily taken when the integrity of files are known to be good.

2.11.2.3 Creating a Syslog Action

1. Click the **Actions** link.

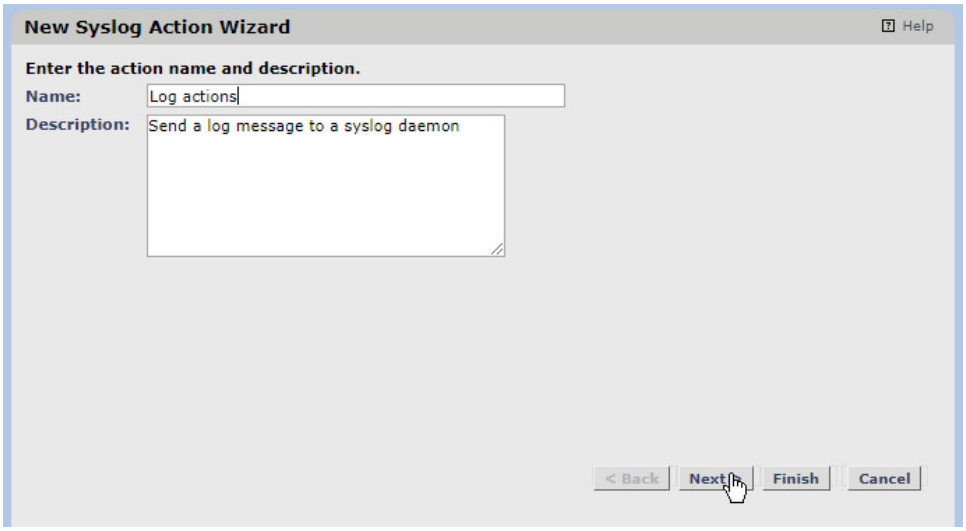


2. Click **New Action**.
3. Select **Syslog Action**.

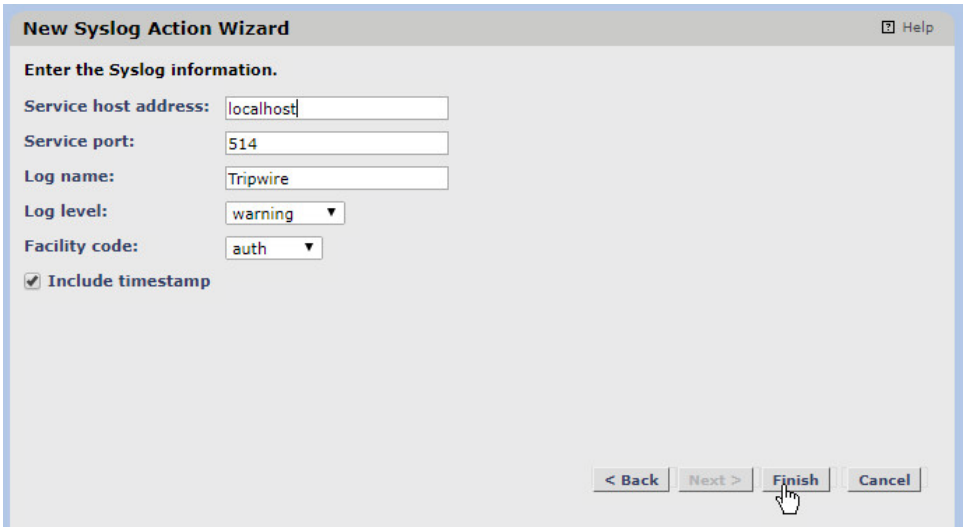


4. Click **OK**.

5. Enter a **name** for the Syslog Action.



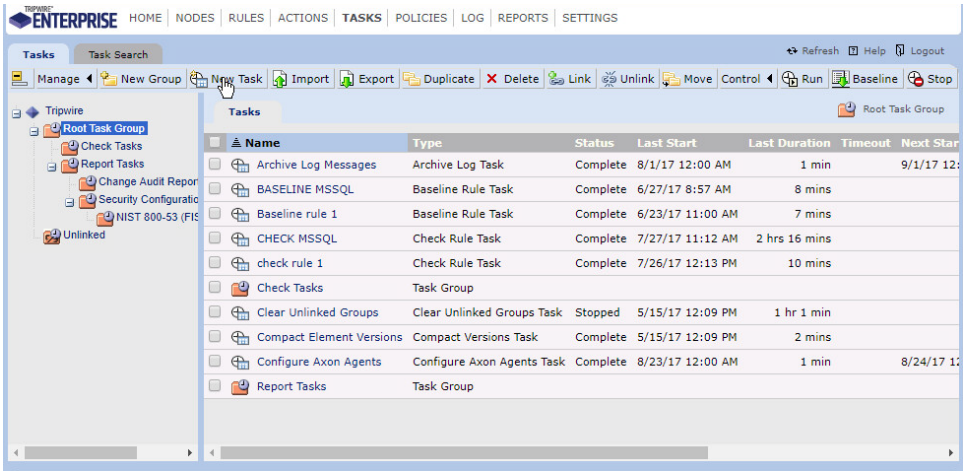
6. Click **Next**.
7. Enter the **IP address** of the Tripwire Log Center server.
8. Enter the **port** that Tripwire Log Center receives TCP syslog messages on.
9. Enter a **log name**, a **level**, and a **facility code** per your needs. These will show up in logs, so you can use these to help separate or identify log sources.



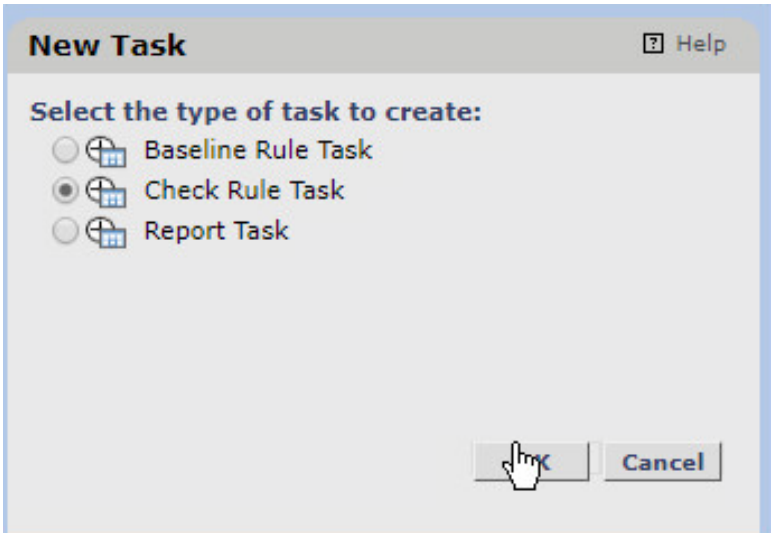
10. Click **Finish**.

2.11.2.4 Creating a Check Task

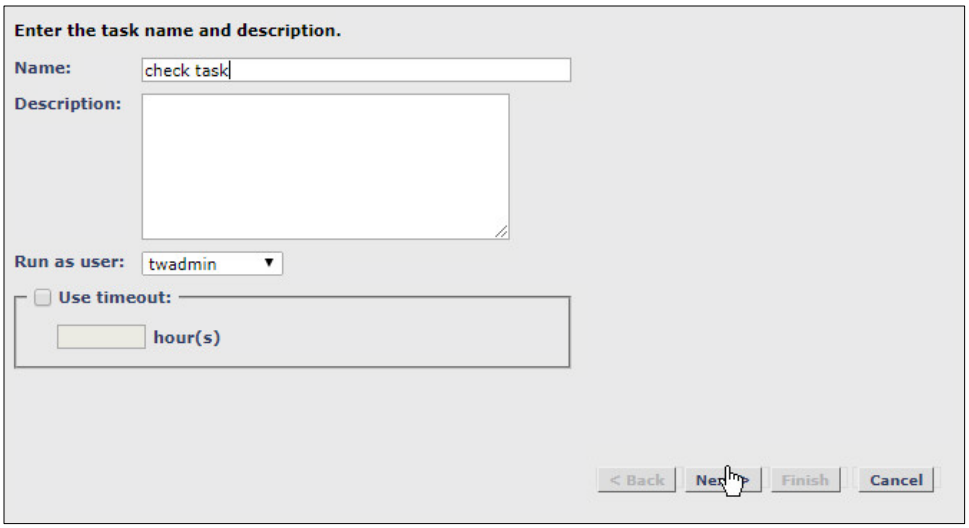
1. Click the **Tasks** link.



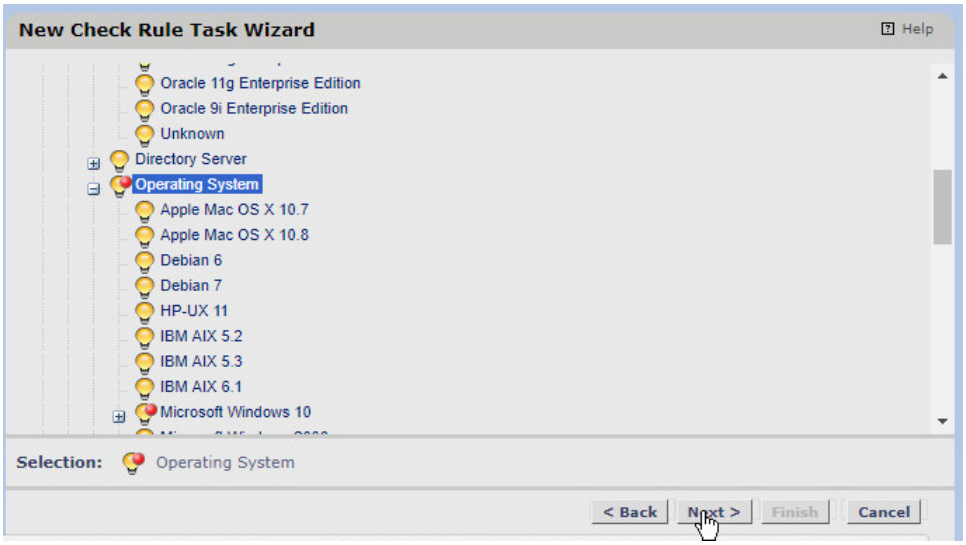
2. Click **New Task**.
3. Select **Check Rule Task**.



4. Click **OK**.
5. Enter a **name** for the baseline rule task.
6. Select a privileged user in Tripwire Enterprise to run the rule as.

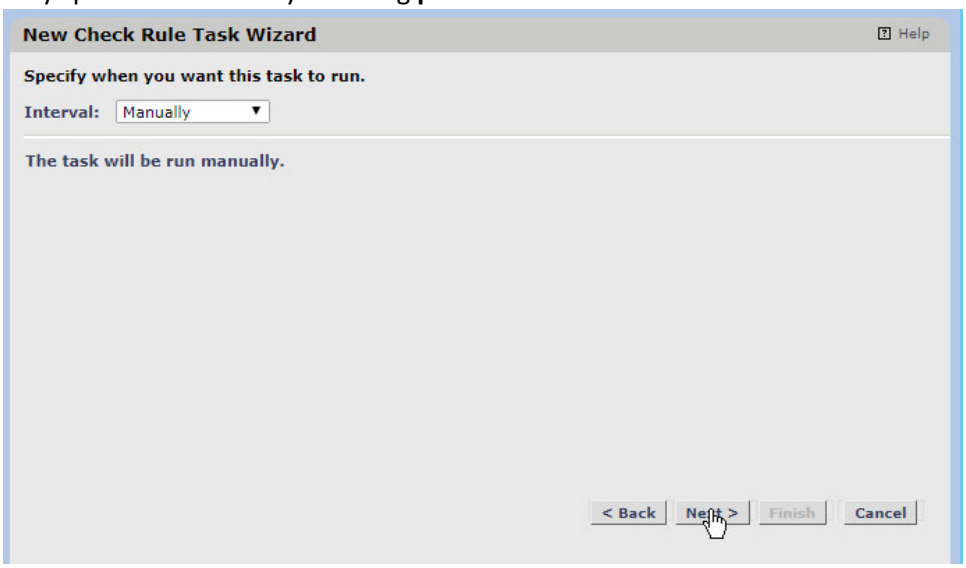


7. Click **Next**.
8. Expand **Root Node Group > Smart Node Groups > System Tag Sets > Operating System**.
9. Here, you can select specific types of operating systems to run the task on or specific machines. We simply selected **Operating System** to have it run on all applicable Windows machines.



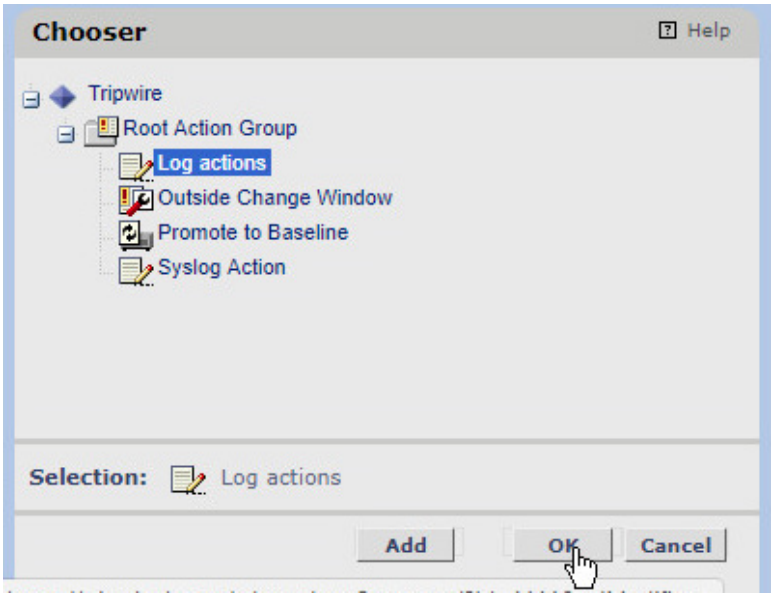
10. Once you have made your selection, click **Next**.
11. Select **Selected nodes with rule or rule group**.
12. Click the rule you created earlier.

13. Click **Next**.
14. Decide how often the check task should be run. We set it to **manually**, but you can also set a very specific schedule by choosing **periodic**.

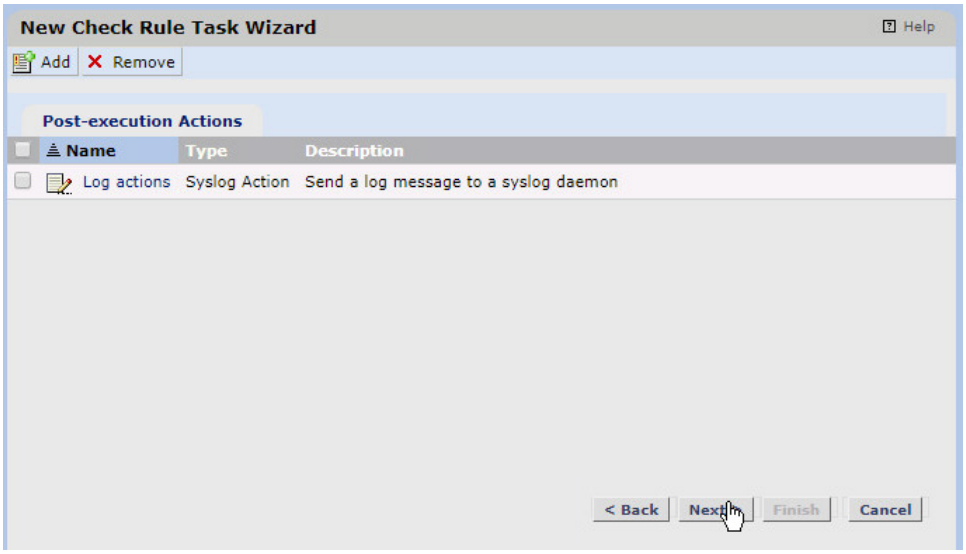


15. Click **Next**.

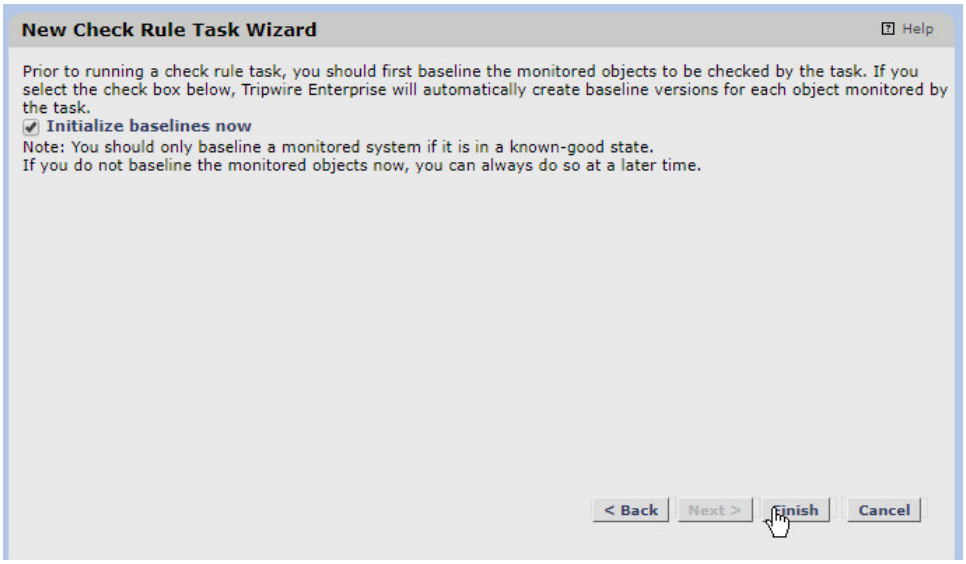
16. Click **Add**.
17. Select the **Syslog Action** created earlier.



18. Click **OK**.



19. Click **Next**.
20. Uncheck the box next to **initialize baselines now** if you do not wish to immediately take a baseline of all systems.



21. Click **Finish**.
22. This rule will check the current versions of the selected files against their baselines and log any changes to Tripwire Log Center.

2.11.2.5 Running the Baseline Task

1. Check the box next to the **baseline** task you created earlier.
2. Click **Control > Run** on the taskbar.

3. Wait for the run to finish. You can click the **Log** link to see the progress.
4. When it finishes, it will log a message such as “Task 'Baseline Rule Windows' was completed in 600 seconds.”

2.11.2.6 Make Changes to Monitored Objects

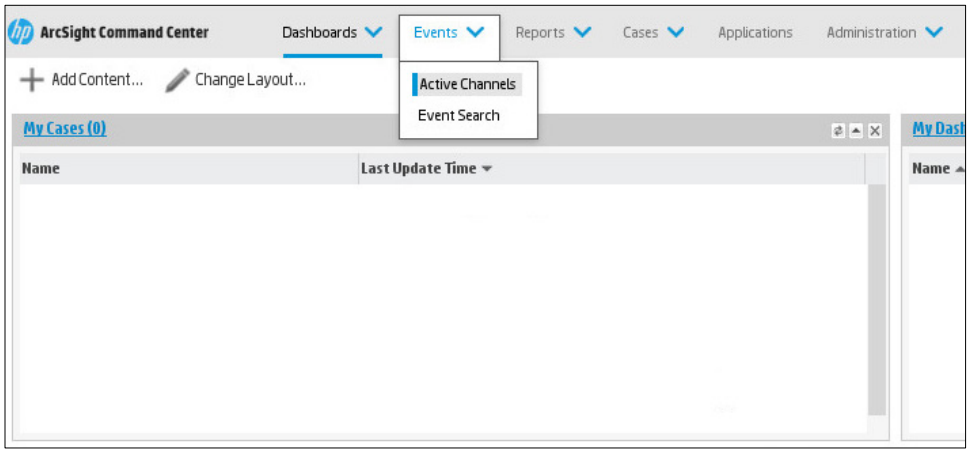
1. Open a machine being monitored by the rule you created.
2. Modify a file or files in the folder that you selected in the rule creation wizard (which are being monitored by Tripwire).

2.11.2.7 Running the Check Task

1. Check the box next to the **check** task you created earlier.
2. Click **Control > Run** on the taskbar.
3. Wait for the run to finish. You can click the **Log** link to see the progress.
4. If you made changes to a monitored object, the log message should appear at the time the changes were made even if the change was made prior to the scan.

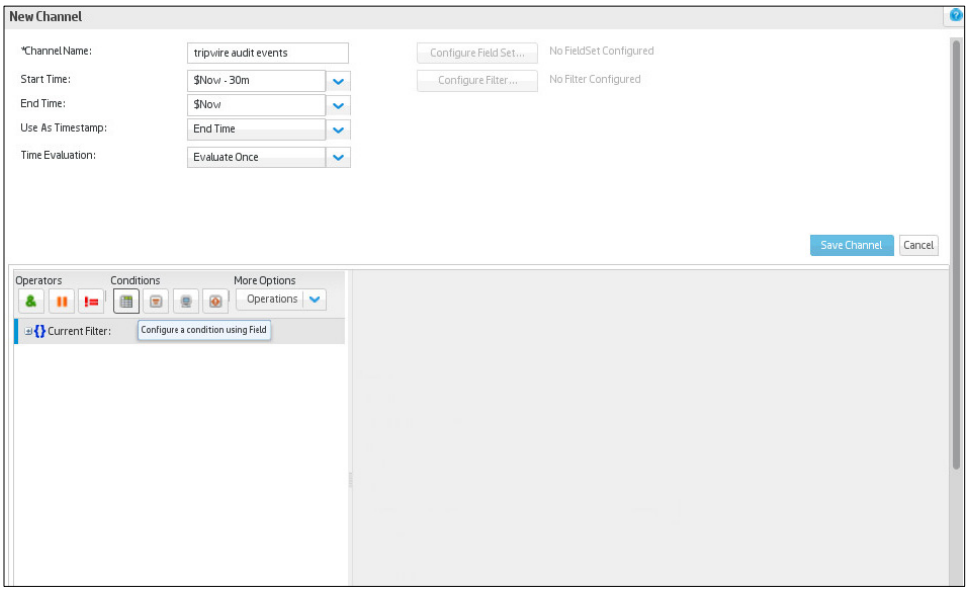
2.11.2.8 Filtering for Tripwire Enterprise Integrity Events in HPE ArcSight ESM

1. Open the **ArcSight ESM** machine.
2. Log in by going to *https://vm-esm691c:8443* and entering your username/password.

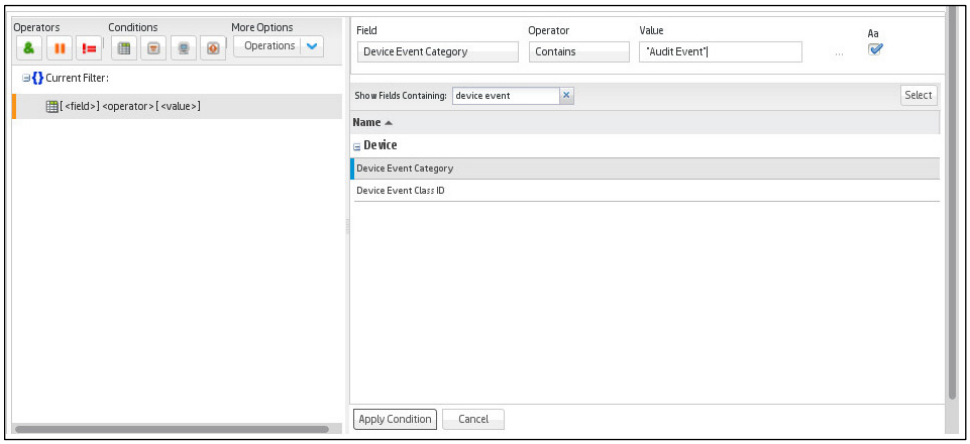


3. Click **Events > Active Channels**.
4. Click **New**.
5. Enter a **name** for the channel. Select a start time to show events, and leave **$NOW** as the end time.

6. Click **Configure Filter**.



7. Click the button that says **Configure a condition using field**.
8. Double click **Device Event Category**.
9. For **Operator**, choose **Contains**.
10. For **Value**, enter **Audit Event**.



11. Click **Apply Condition.**
12. Click **Update Filter Configuration** under the list of fields.

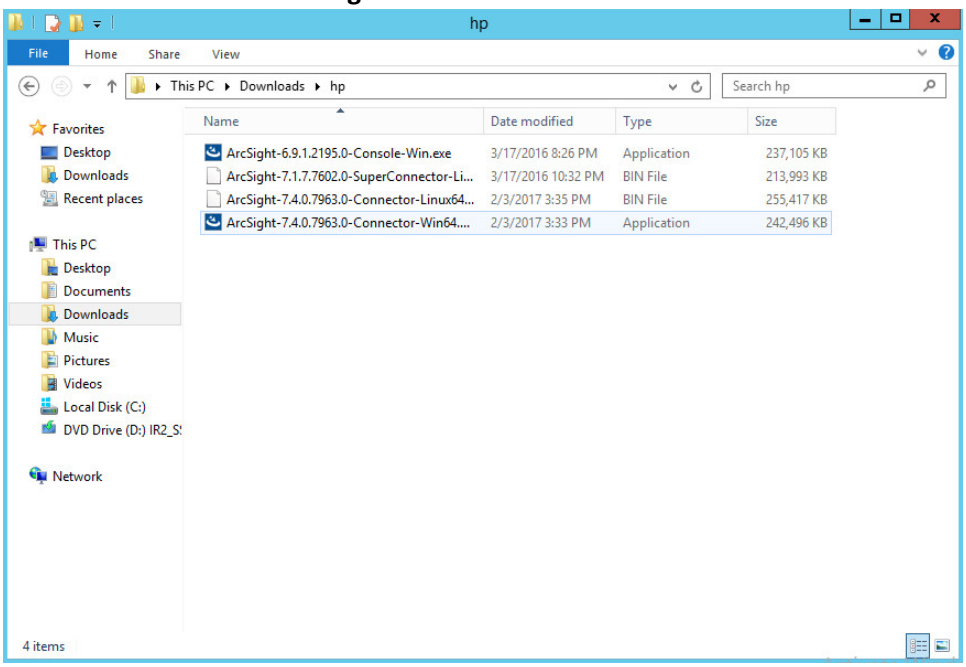
13. Click **Save Channel**.
14. Click the channel you just created. It should show all file changes in the time frame you specified forwarded from Tripwire Enterprise to Tripwire Log Center to ArcSight ESM.

2.12 Integration: HPE ArcSight ESM with Veeam and Hyper-V

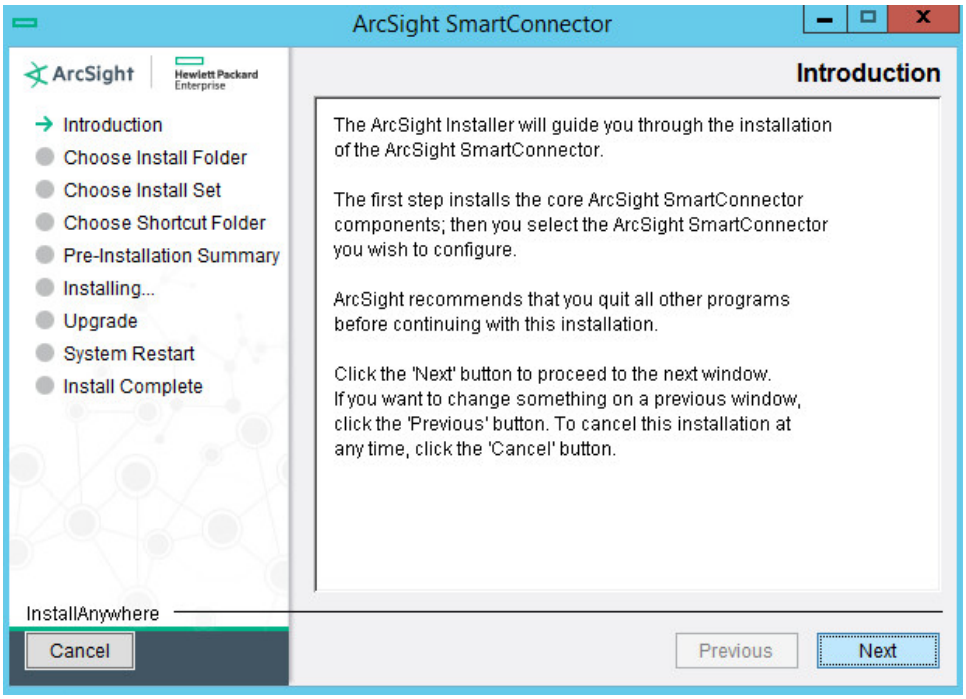
This section covers the process for integrating HPE ArcSight ESM with Veeam and Hyper-V. This integration assumes the correct implementation of Veeam and ArcSight as described in earlier sections. The result is the forwarding of logs generated by Veeam and Hyper-V to ArcSight ESM, as well as custom parsers to supplement the information provided by this forwarding process.

2.12.1 Install ArcSight Connector

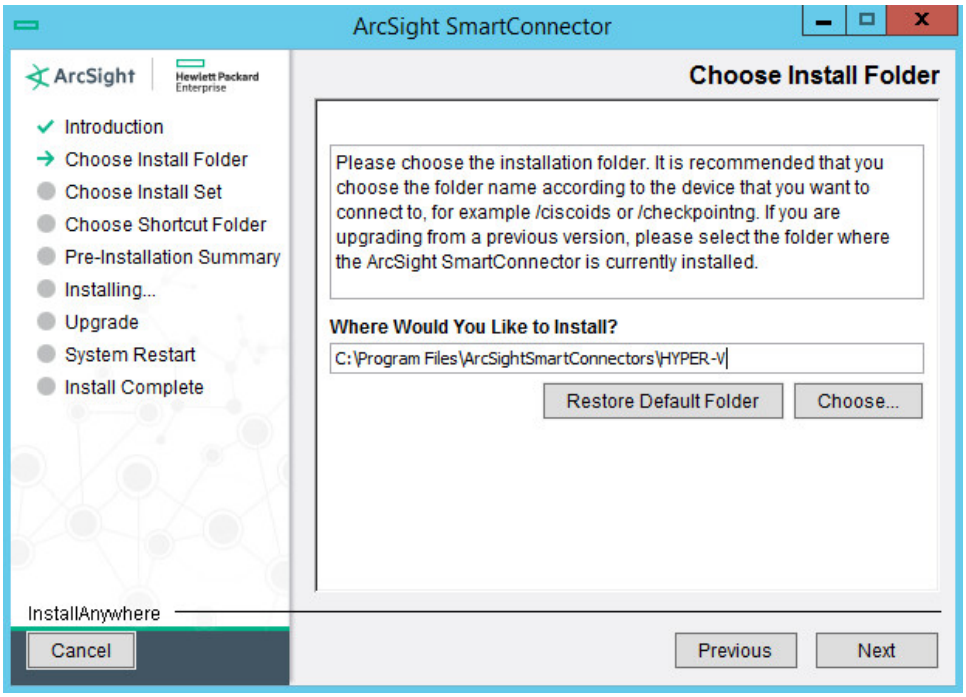
1. Run the installation file **ArcSight-7.4.0.7963.0-Connector-Win64** on the Veeam Server.



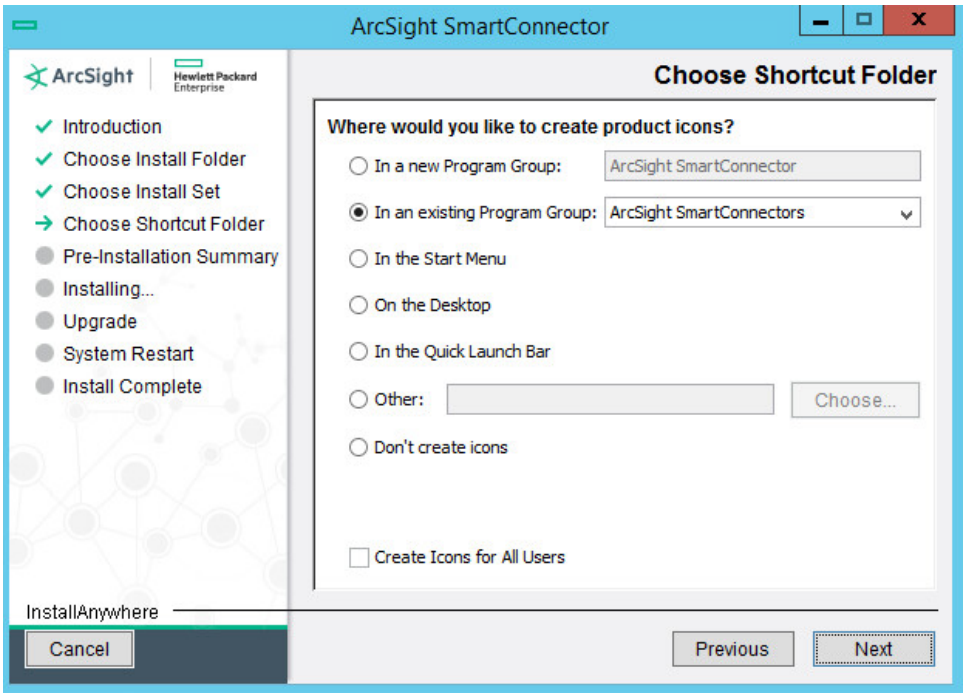
2. Wait for the initial setup to finish.



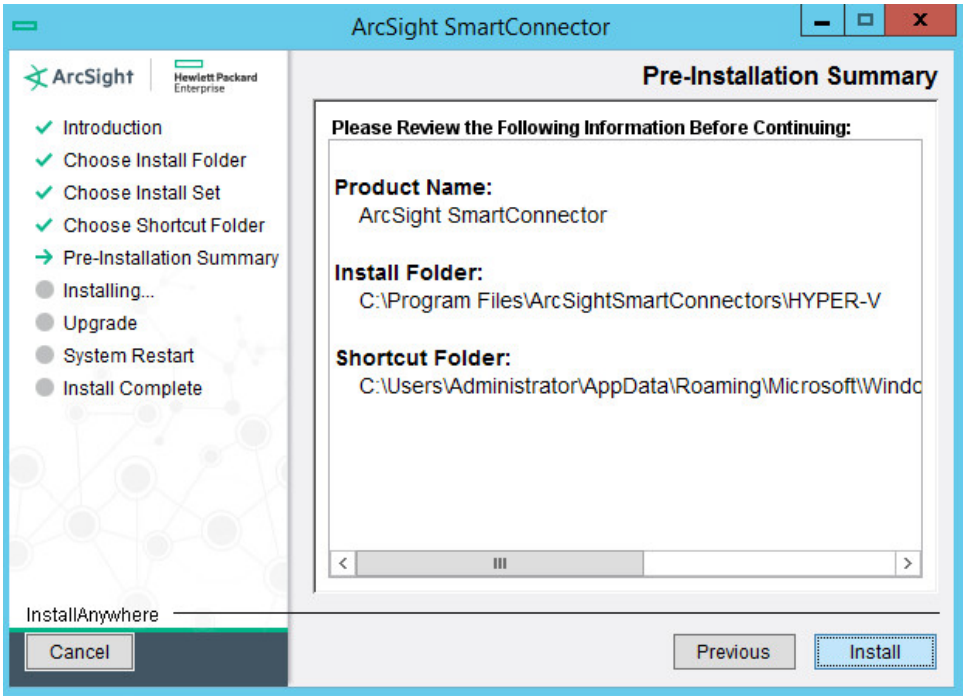
3. Click **Next**.
4. Choose a destination folder. Note: It is recommended to change the default to `<default>\HYPERV` so that other installed connectors do not overwrite this one.



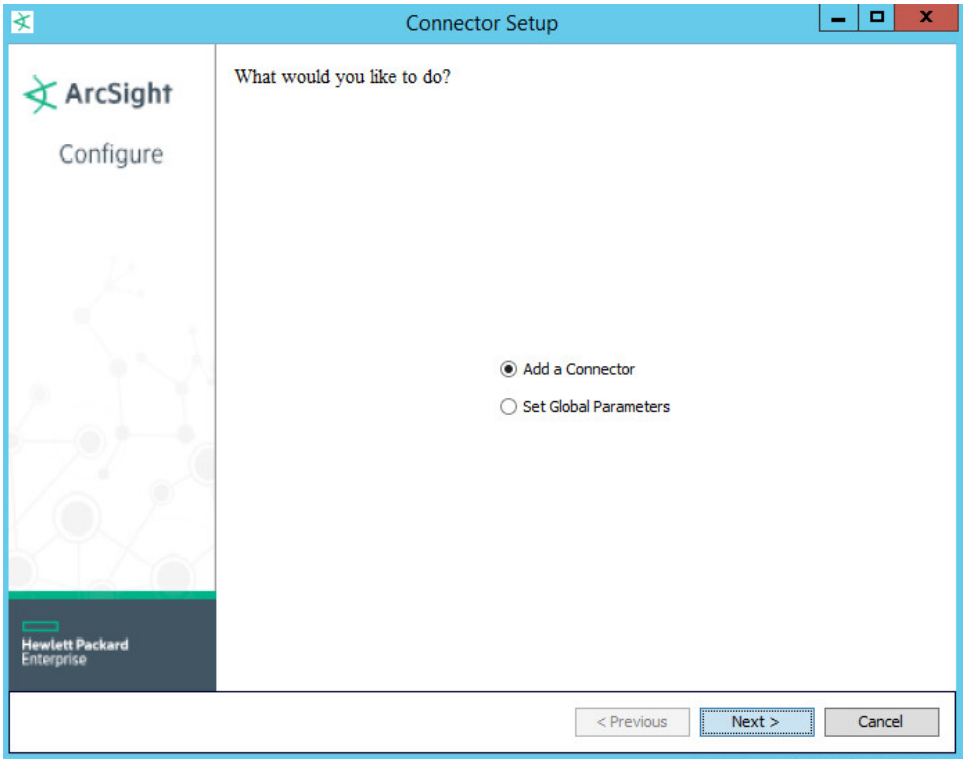
5. Click **Next**.



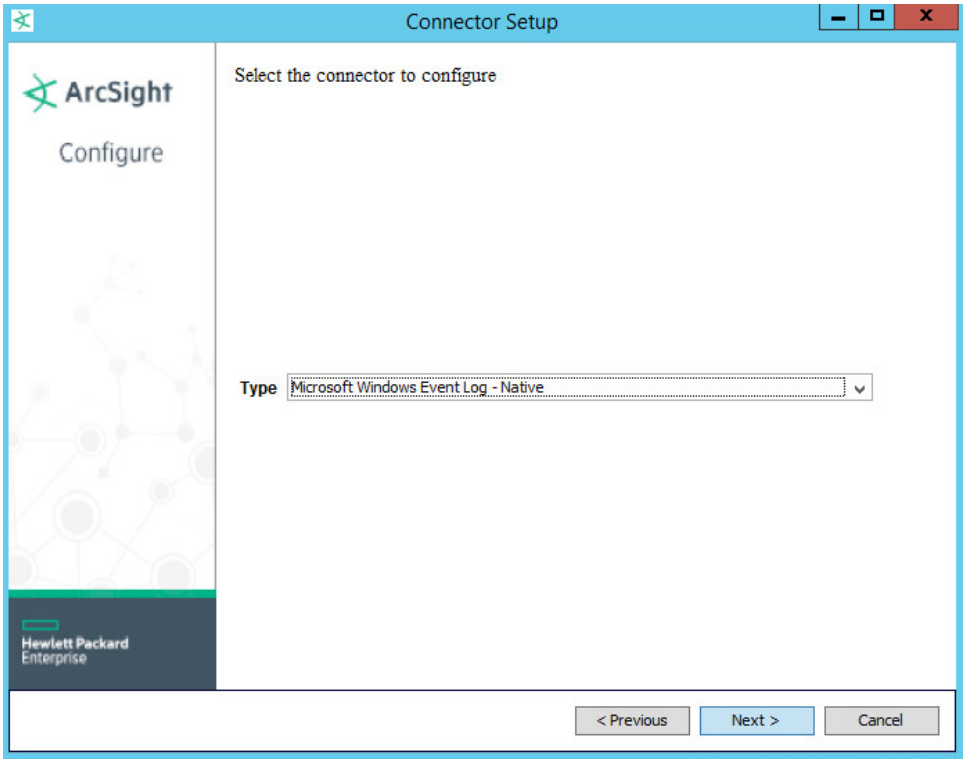
6. Click **Next**.



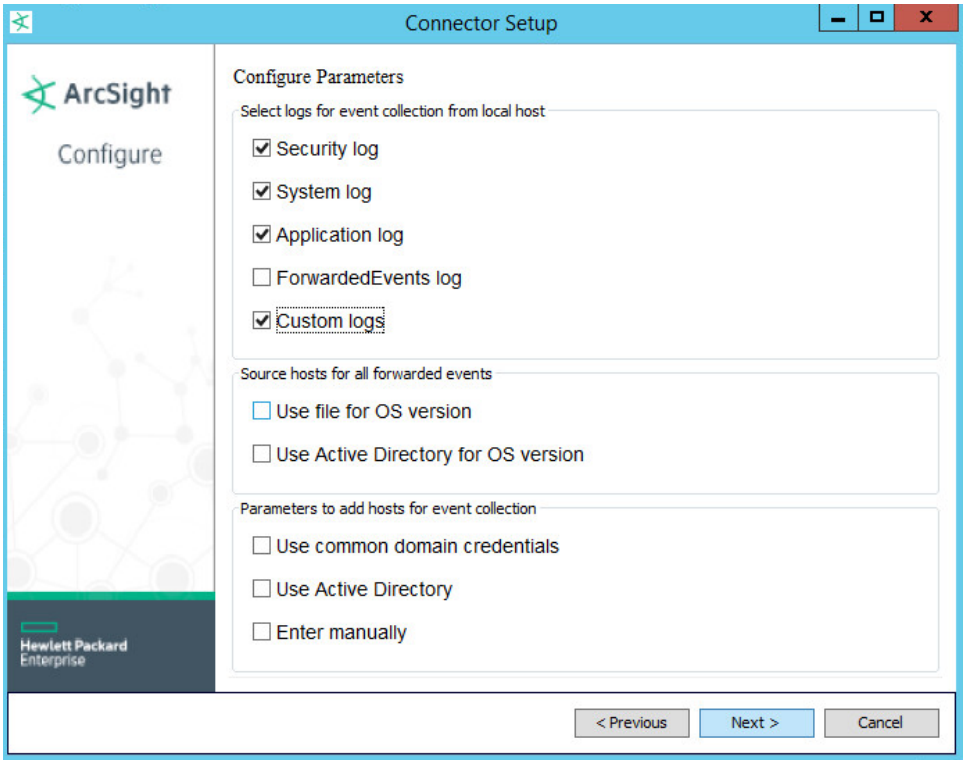
7. Click **Install**.
8. Wait for the installation to finish.
9. Select **Add a Connector**.



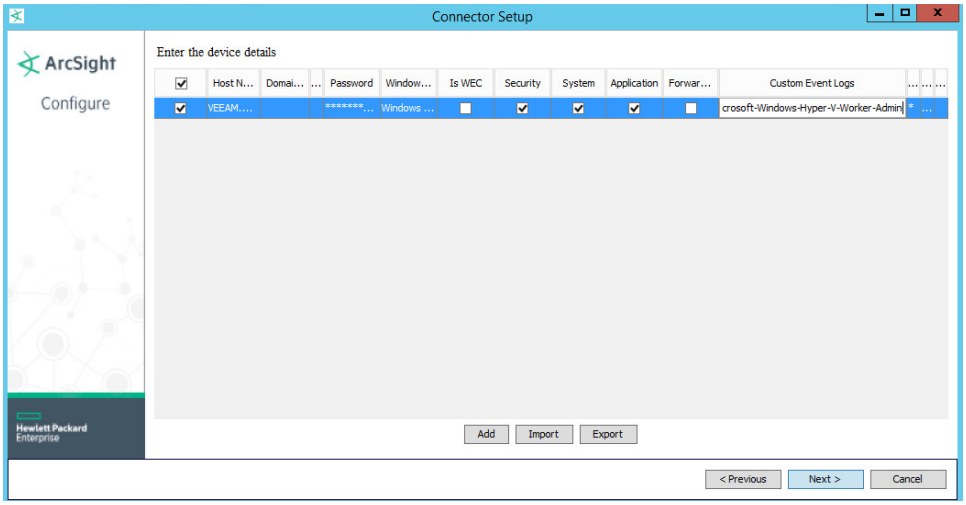
10. Click **Next**.
11. Choose **Microsoft Windows Event Log - Native** from the list.



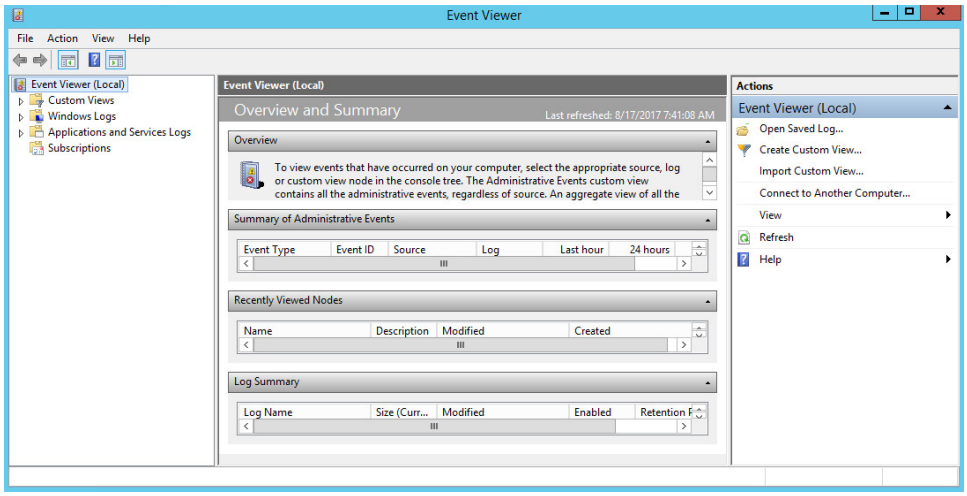
12. Click **Next**.
13. Check **Security log**, **System log**, **Application Log**, and **Custom Log**.



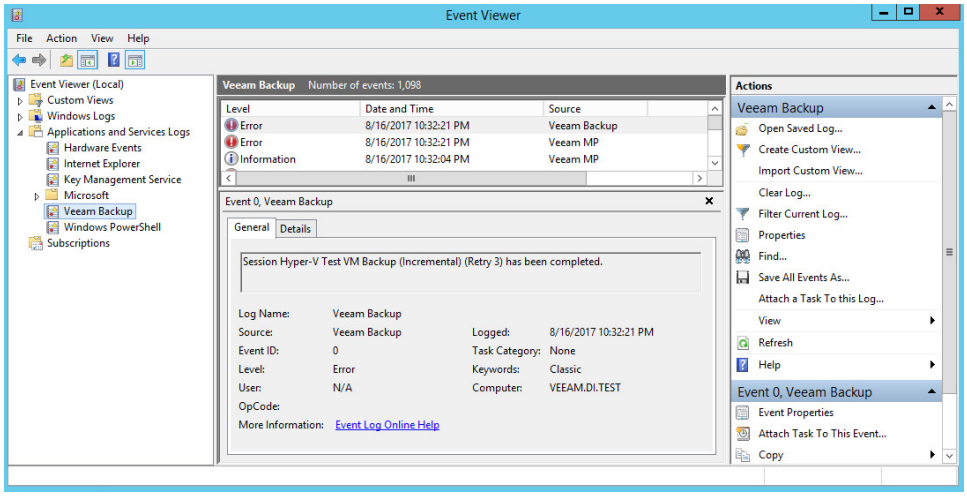
14. Click **Next**.
15. Click on the box underneath **Custom Event Logs**.
16. Enter **Veeam Backup, Microsoft-Windows-Hyper-V-VMMS-Admin, Microsoft-Windows-Hyper-V-Integration-Admin, Microsoft-Windows-Hyper-V-SynthNic-Admin, Microsoft-Windows-Hyper-V-Worker-Admin.**



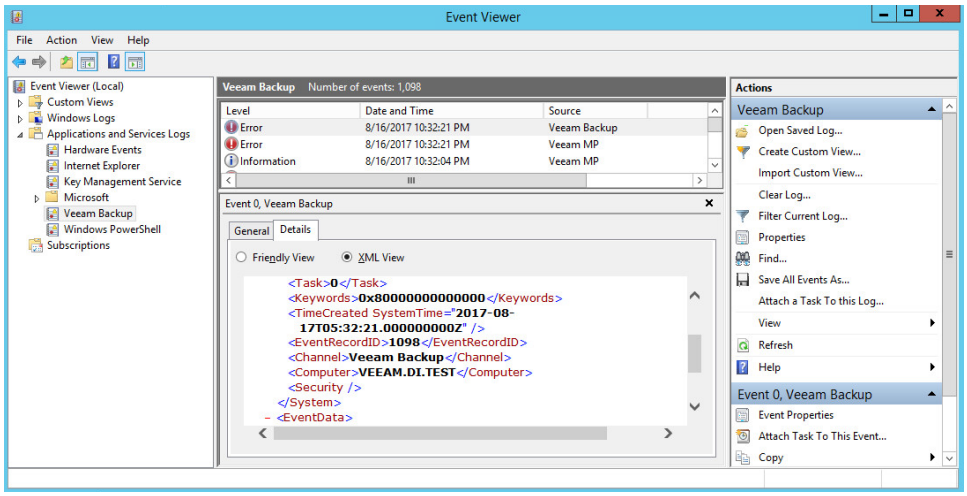
17. You can add more application logs through the following process:
    a. Open **Microsoft Event Viewer**.



b. Find the log you wish to add.



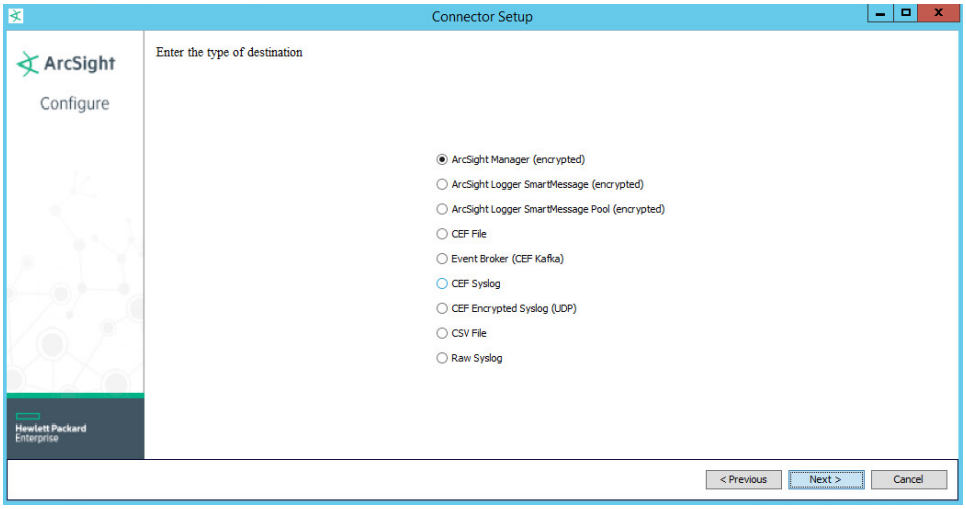
c. Open the **Details** pane of a log and find the field **Channel**.



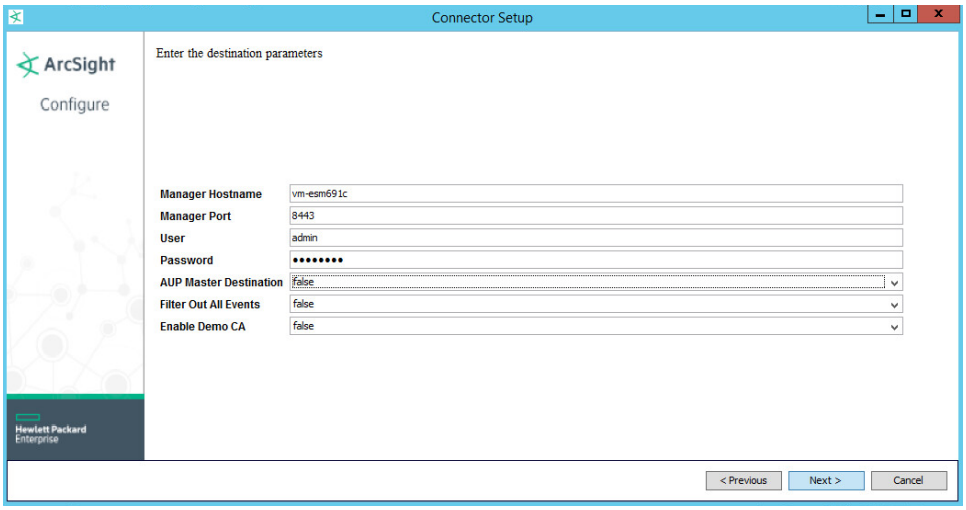
d. Note that this may differ from the **Log Name** in the **General** pane. (For example, one of the Hyper-V log's **Log Name** is **Microsoft-Windows-Hyper-V-VMMS/Admin** but the channel name is **Microsoft-Windows-Hyper-V-VMMS-Admin**.)

e. Enter all these channel names separated by commas in the **Custom Event Logs** field.

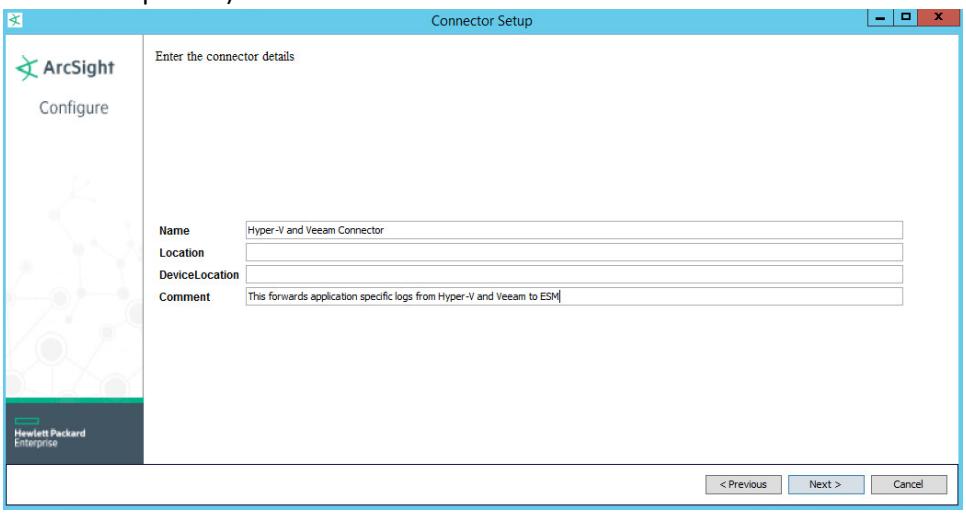
18. Click **Next**.
19. Choose **ArcSight Manager (encrypted)**.



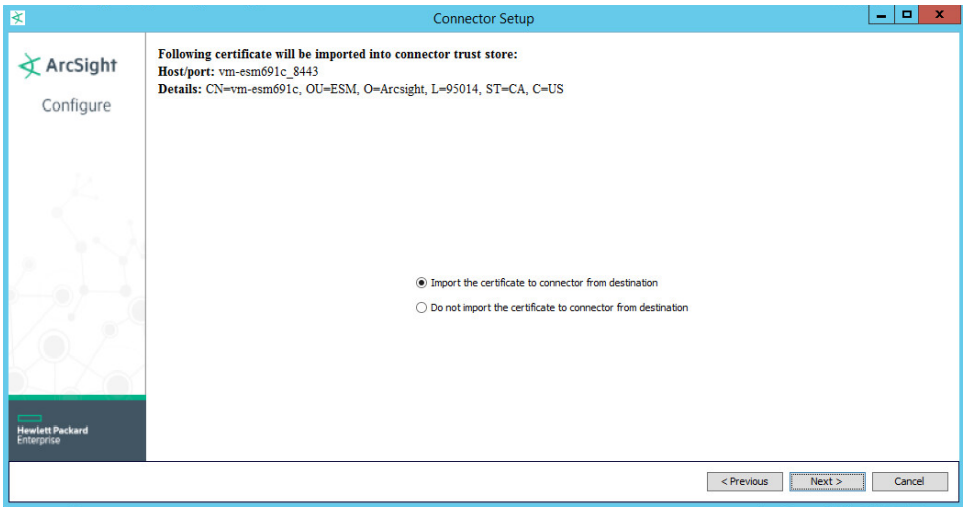
20. Click **Next**.
21. For **Manager Hostname**, put **vm-esm691c**, or the hostname of your ESM server.
22. For **Manager Port**, put **8443**, or the port that ESM is running on, on the ESM server.
23. Enter the **username** and **password** used for logging into ArcSight Command Center (admin/password).



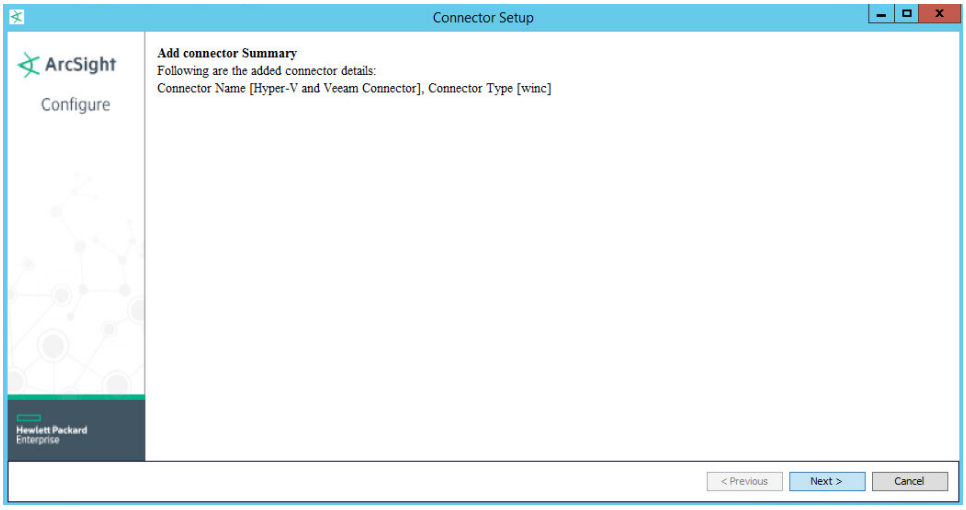
24. Click **Next**.
25. Set identifying details about the system to help identify the connector (include at least **Name;** the rest is optional).



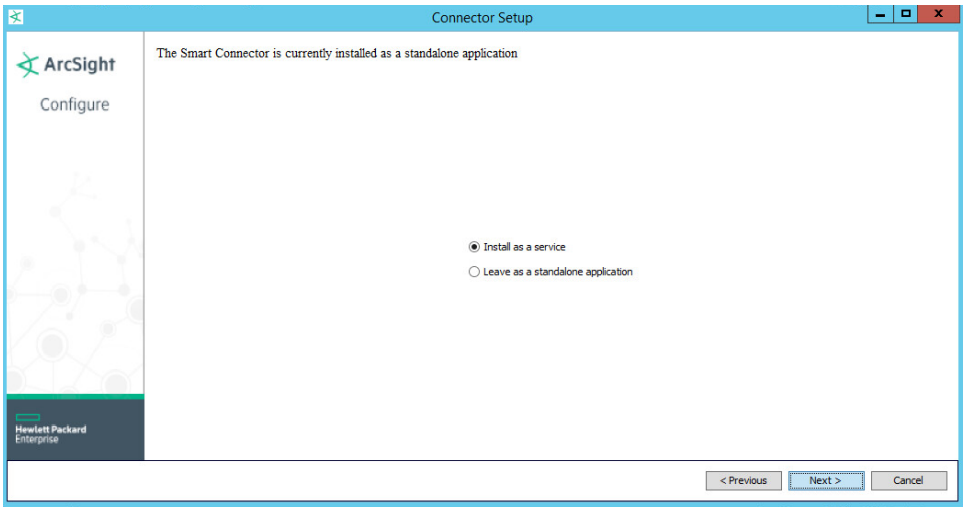
26. Click **Next**.
27. Select **Import the certificate to connector from destination**. This will fail if the **Manager Hostname** does not match the hostname of the VM.



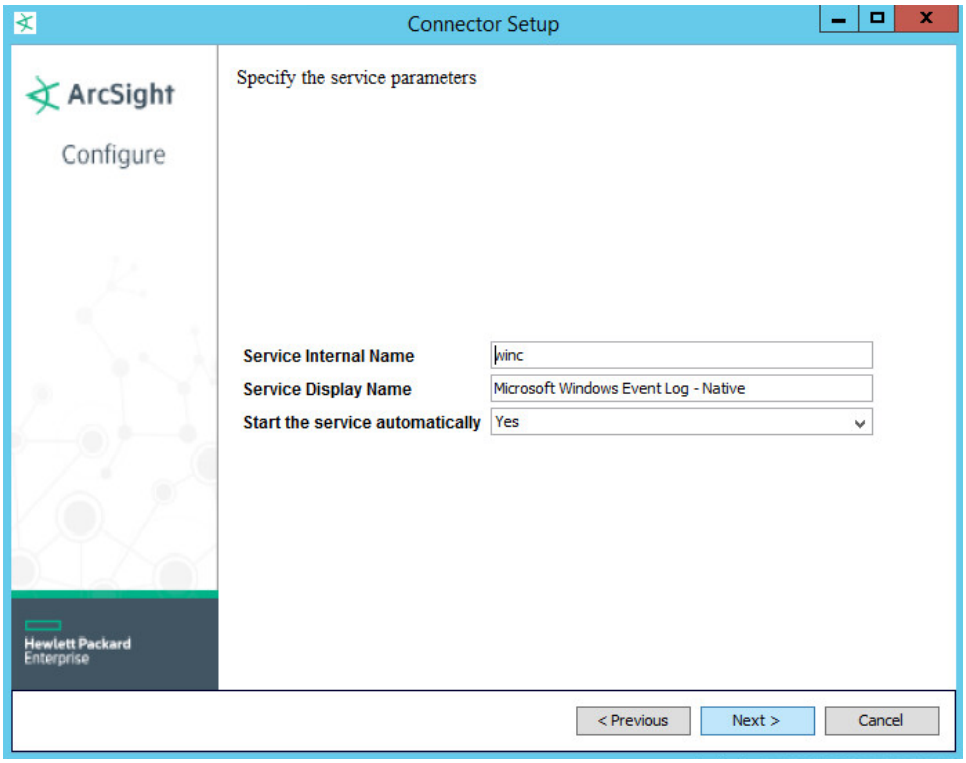
28. Click **Next**.
29. Wait for the process to complete.



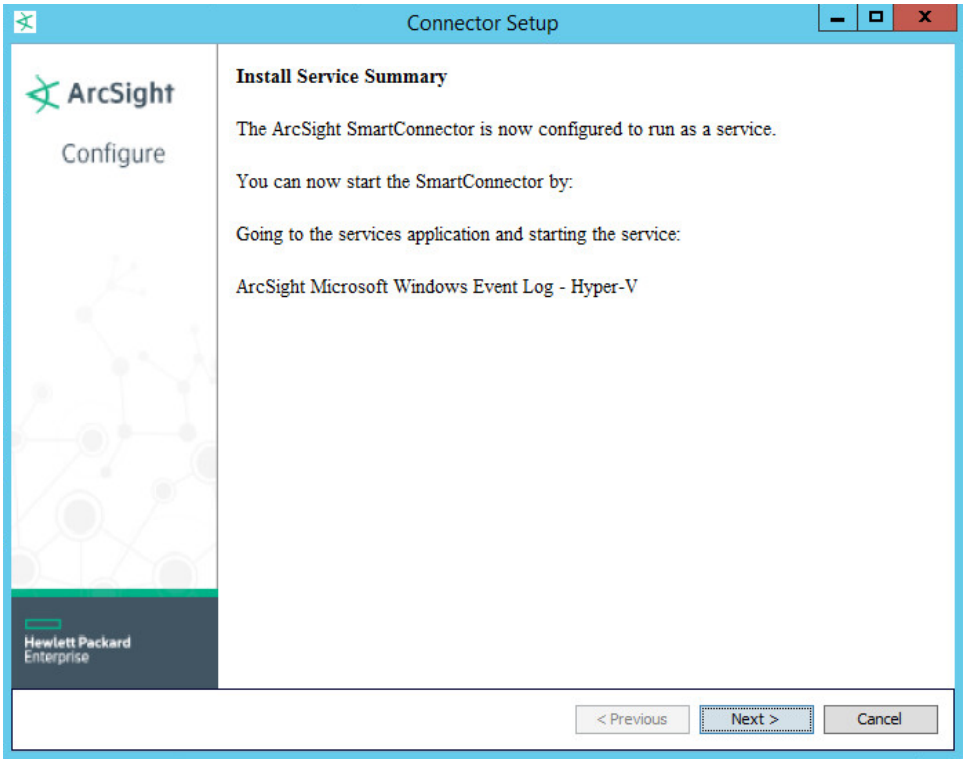
30. Click **Next**.
31. Choose **Install as a service**.



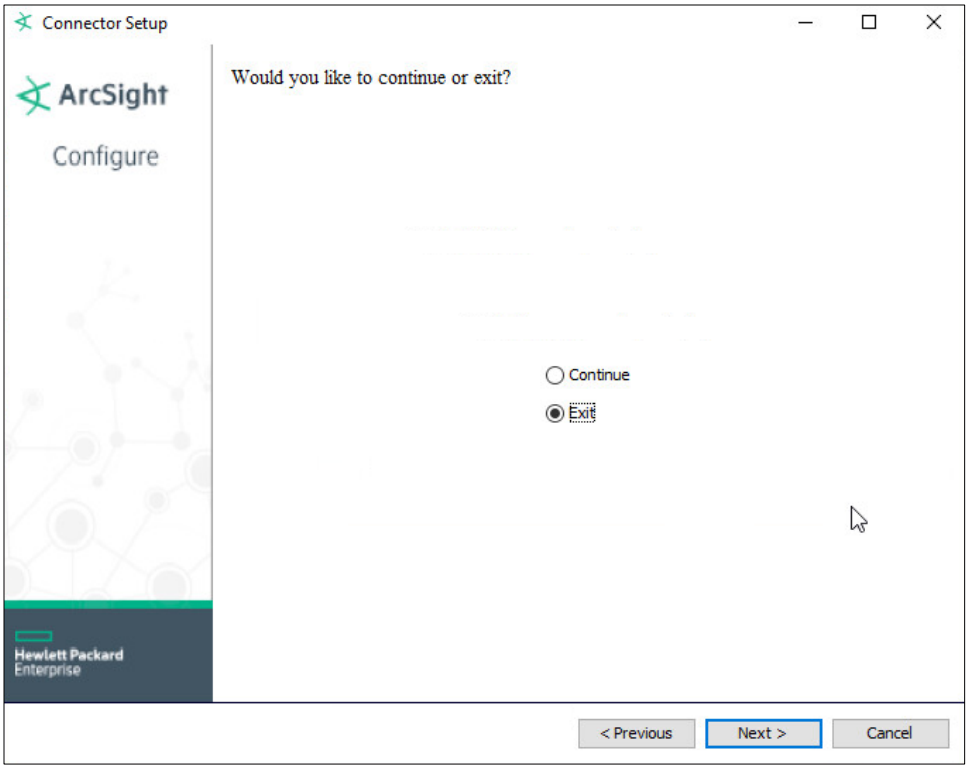
32. Click **Next**.



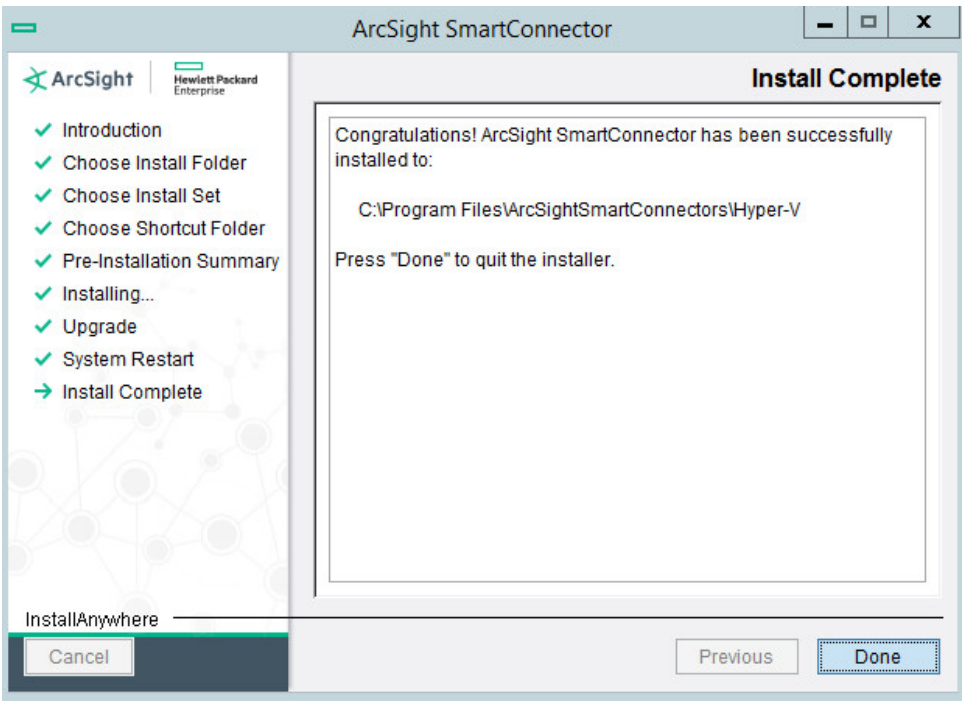
33. Click **Next**.



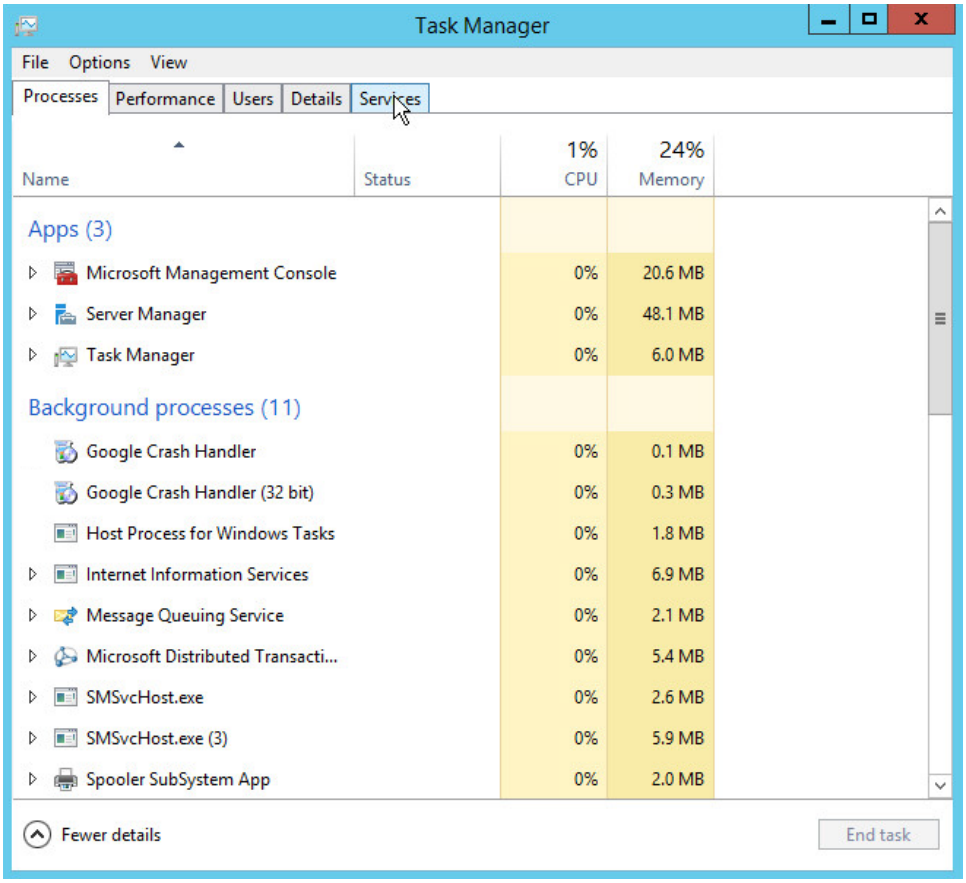
34. Click **Next**.
35. Choose **Exit**.



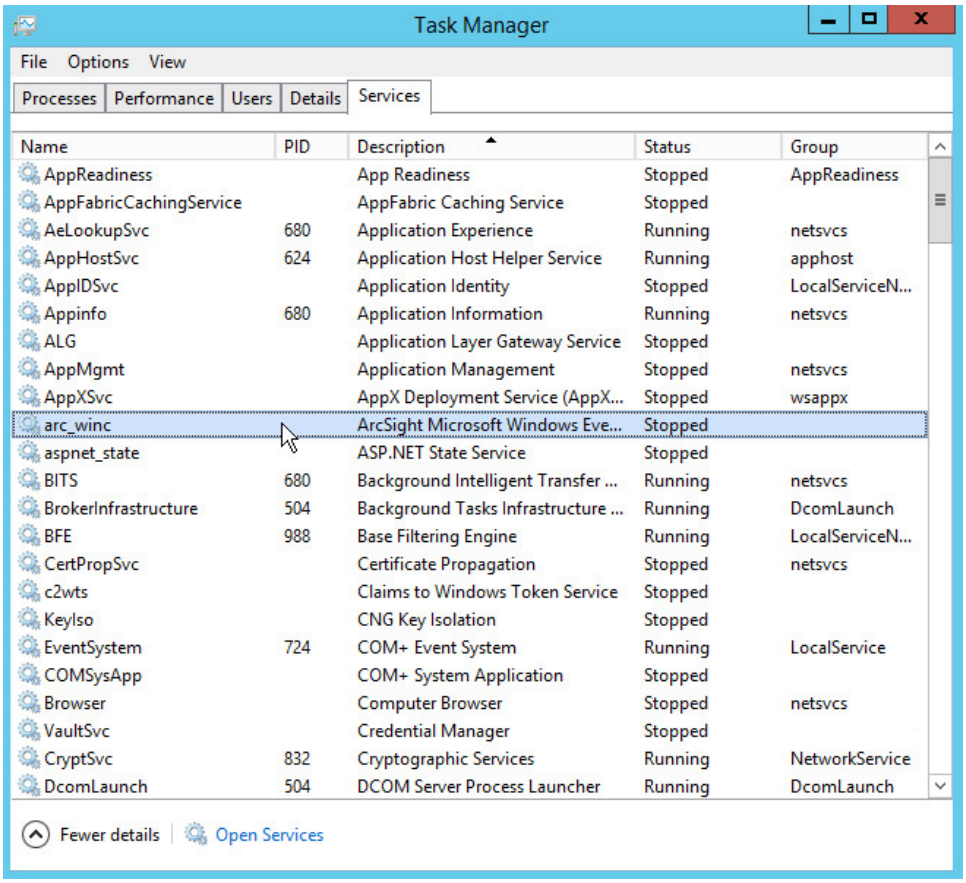
36. Click **Next**.



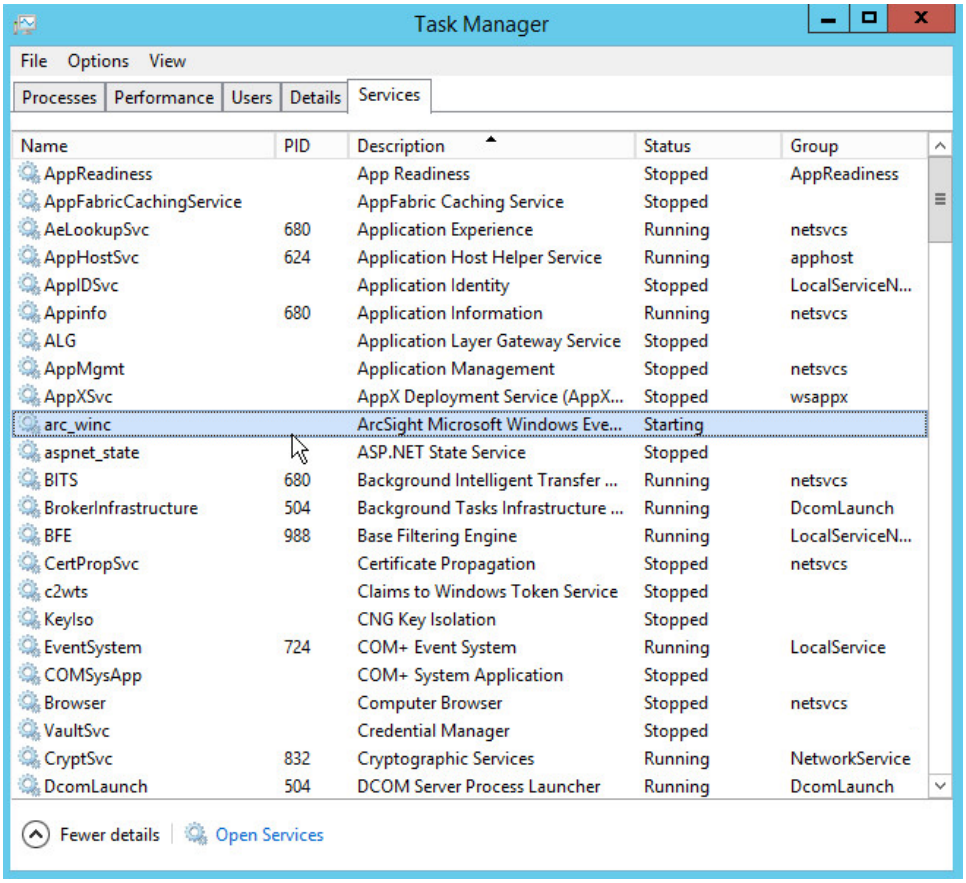
37. Click **Done**.
38. Open **Task Manager**.
39. Click **More Details**.



40. Go to the **Services** tab.
41. Find the service just created **arc_winc** for ArcSight, and right click it.



42. Choose **Start**.



43. The machine will now report its logs to ArcSight ESM.
44. For more fine-grained reporting, such as including more information about the event, you may wish to include custom parsers that are described below.

2.12.2 Create a Parser for Veeam Logs

1. For a Veeam custom parser that handles event numbers **210**, **251**, and **290**, create a configuration file with the following text:

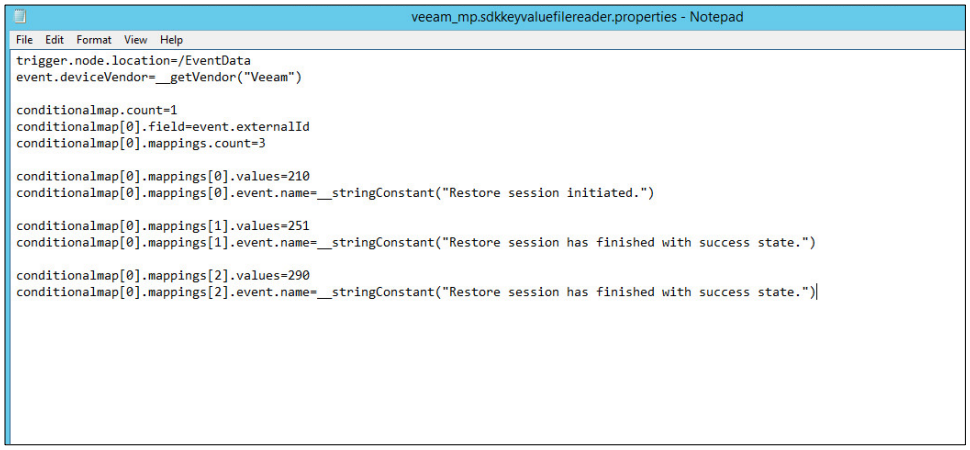
```
trigger.node.location=/EventData
event.deviceVendor=__getVendor("Veeam")
conditionalmap.count=1
conditionalmap[0].field=event.externalId
conditionalmap[0].mappings.count=3
conditionalmap[0].mappings[0].values=210
conditionalmap[0].mappings[0].event.name=__stringConstant("Restore session initiated.")
```

```
conditionalmap[0].mappings[1].values=251

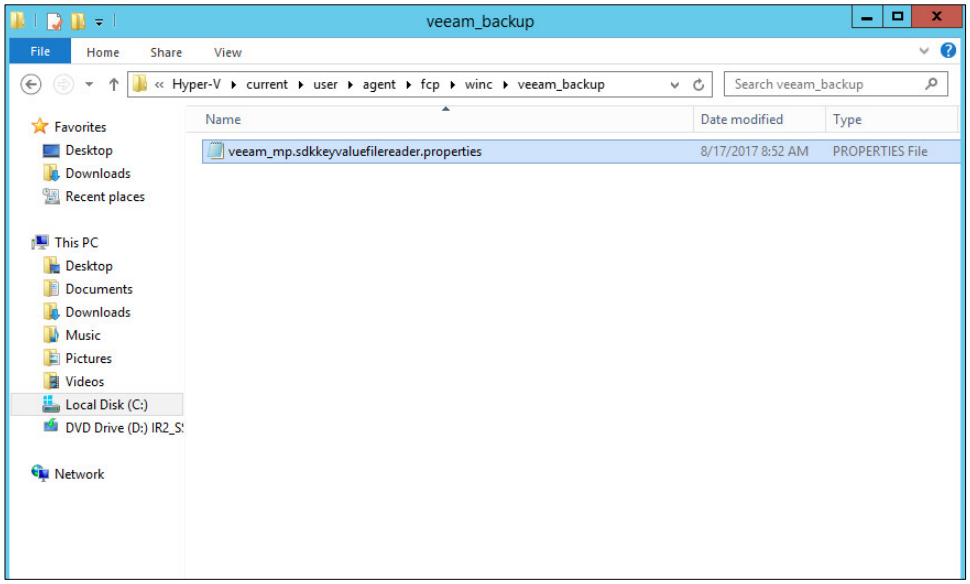
conditionalmap[0].mappings[1].event.name=__stringConstant("Restore session has finished with success state.")

conditionalmap[0].mappings[2].values=290

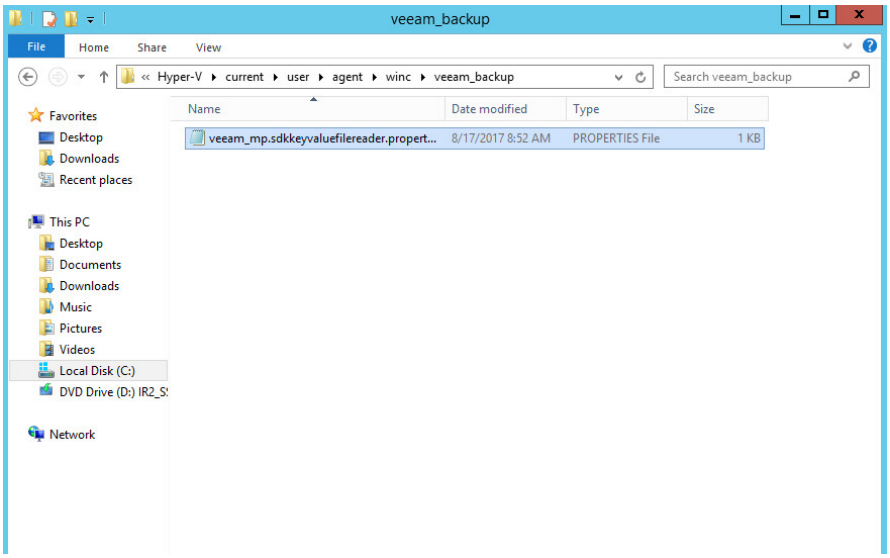
conditionalmap[0].mappings[2].event.name=__stringConstant("Restore session has finished with success state.")
```



2. Save this file as *C:\Program Files\ArcSightSmartConnectors\<name of folder>\current\user\agent\fcp\winc\veeam_backup\veeam_mp.sdkkeyvaluefilereader.properties*



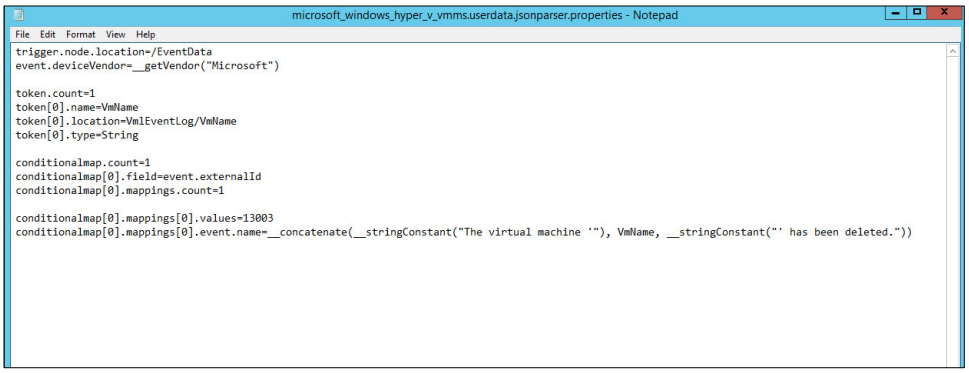
3. Copy this file to *C:\Program Files\ArcSightSmartConnectors\<name of folder>\current\user\agent\winc\veeam_backup\veeam_mp.sdkkeyvaluefilereader.properties*



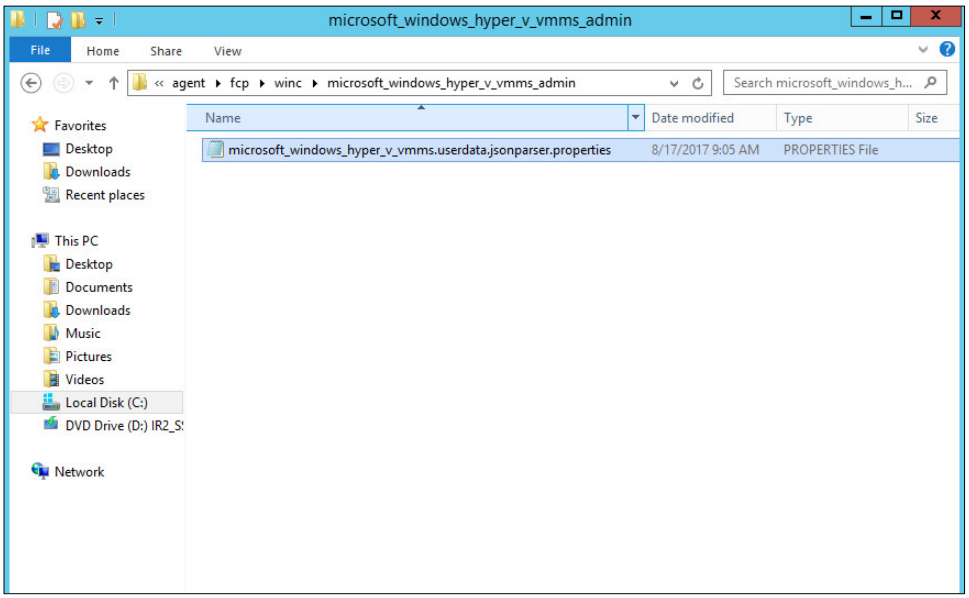
2.12.3 Create a Parser for Hyper-V Logs

1. For a Hyper-V VMMS custom parser, create a configuration file with the following text:

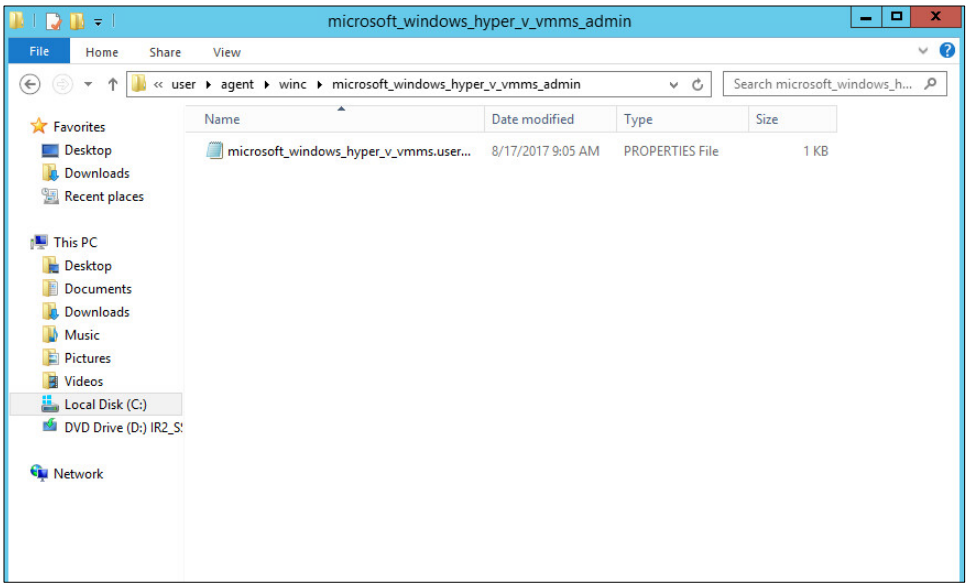
```
trigger.node.location=/EventData
event.deviceVendor=__getVendor("Microsoft")
token.count=1
token[0].name=VmName
token[0].location=VmlEventLog/VmName
token[0].type=String
conditionalmap.count=1
conditionalmap[0].field=event.externalId
conditionalmap[0].mappings.count=1
conditionalmap[0].mappings[0].values=13003
conditionalmap[0].mappings[0].event.name=__concatenate(__stringConstant("The
virtual machine '"), VmName, __stringConstant("' has been deleted."))
```



2. Save this file as *C:\Program Files\ArcSightSmartConnectors\<name of folder>\current\user\agent\fcp\winc\microsoft_windows_hyper_v_vmms_admin\microsoft_windows_hyper_v_vmms.userdata.jsonparser.properties*



3. Copy this file to *C:\Program Files\ArcSightSmartConnectors\<name of folder>\current\user\agent\winc\microsoft_windows_hyper_v_vmms_admin\microsoft_windows_hyper_v_vmms.userdata.jsonparser.properties*



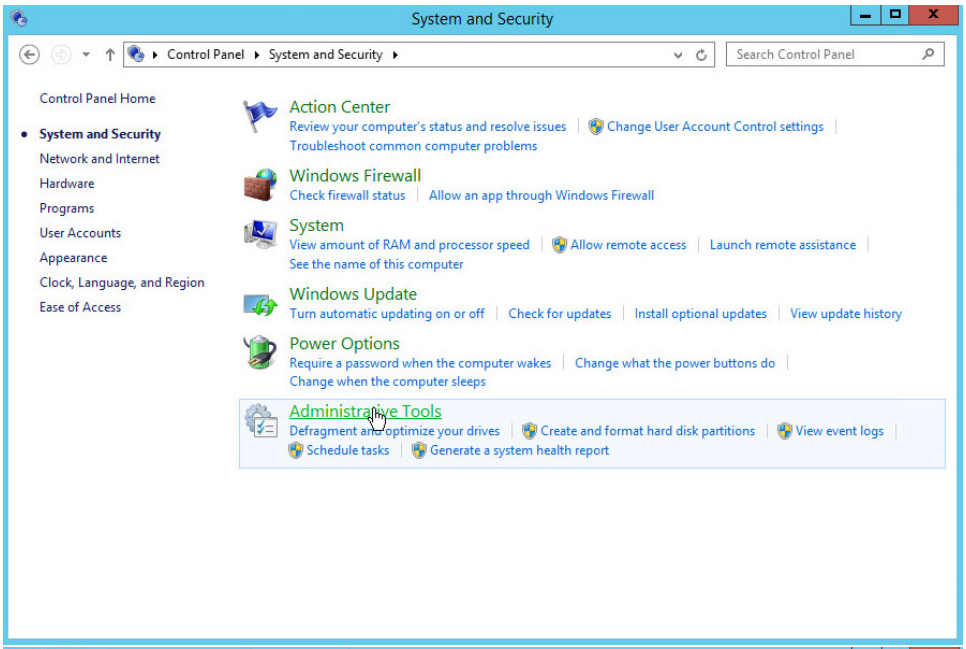
These two parsers will allow for details of VM deletions and VM restores to be shown in ArcSight. Custom parsers are a functionality of ArcSight. For more information on the creation of custom parsers, please see the *ArcSight FlexConnector Developer's Guide*, as well as the *SmartConnector for Microsoft Windows Event Log - Native, Configuration Guide* (for information specific to Windows event logs).

2.13 Integration: GreenTec WORMdisks and IBM Spectrum Protect

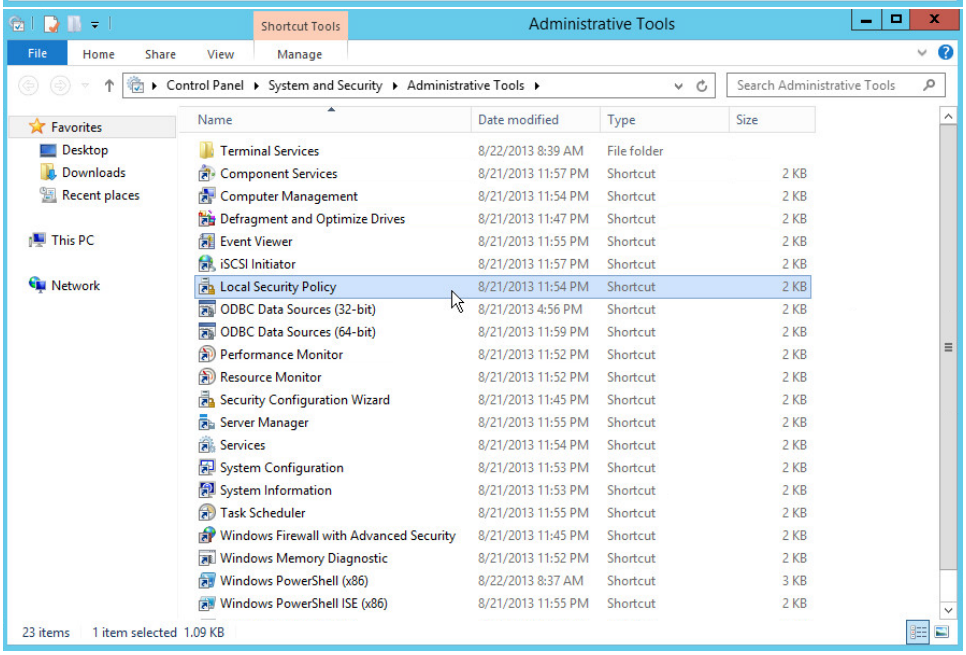
This section covers the process for integrating IBM Spectrum Protect and GreenTec WORMdisks. The result is the capability to backup clients directly to WORMdisks in order to preserve data more securely. This integration process does not include instructions related to locking the WORMdisks – that process is found in the *GT_WinStatus User Guide,* that should accompany the installation disk. Scheduling the locking of these disks is left up to the discretion of the adapting organization.

2.13.1 Install IBM Spectrum Protect Server on the GreenTec Server

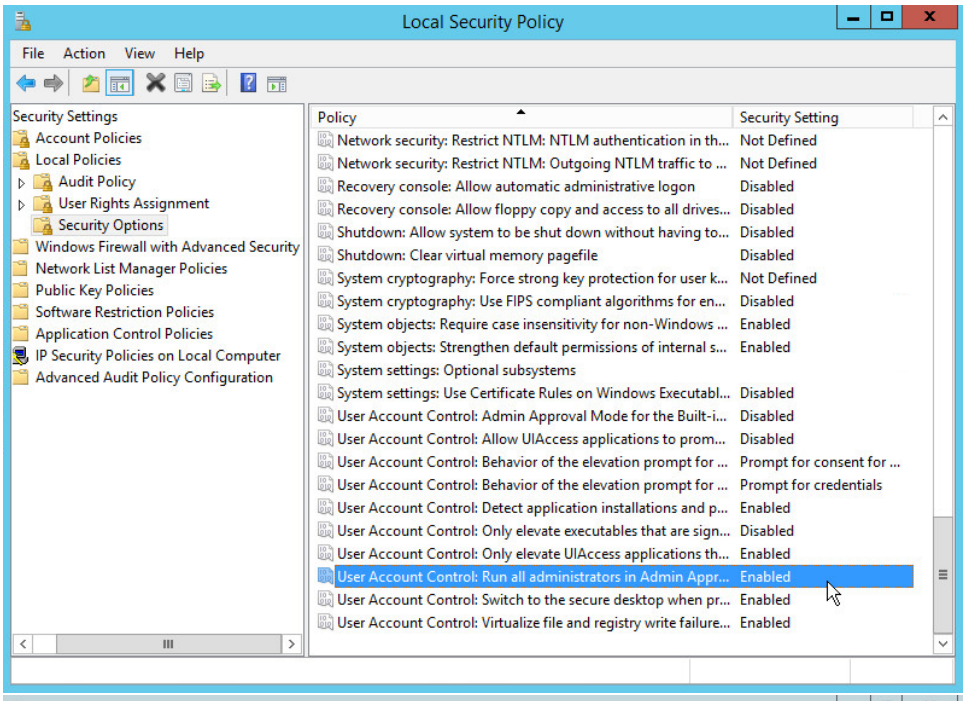
1. You may need to disable **Run all administrators in Admin Approval Mode**. To do this go to **Control Panel > Administrative Tools > Local Security Policy > Local Policies > Security Options**. Double click the **User Account Control: Run all administrators in Admin Approval Mode** section. Select **Disable** and click **OK**. Restart the computer.

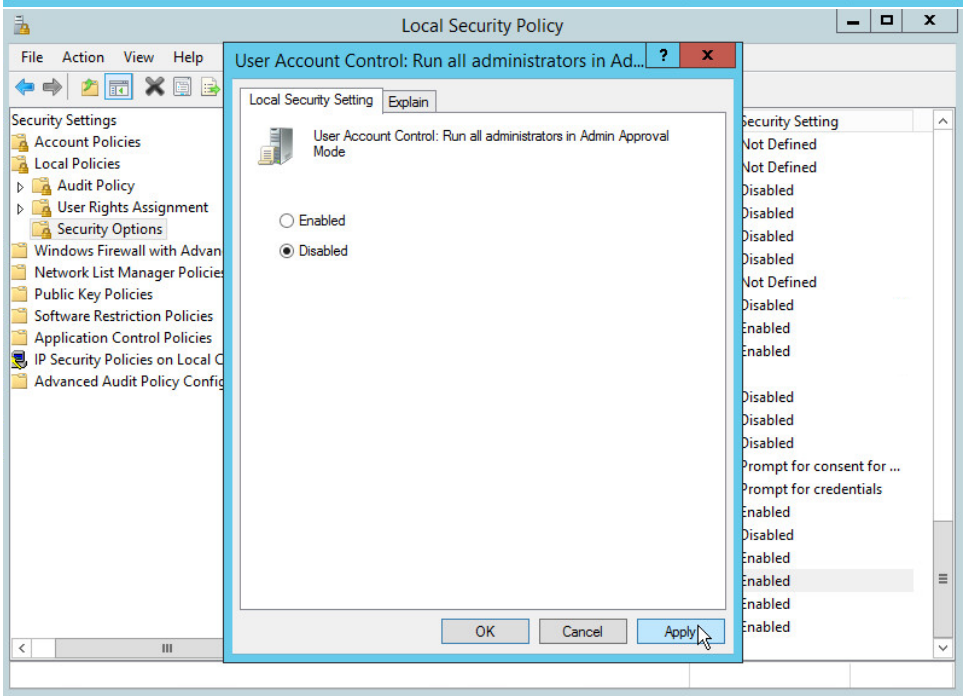

System and Security
Control Panel ▸ System and Security ▸
Search Control Panel
Control Panel Home
System and Security
Network and Internet
Hardware
Programs
User Accounts
Appearance
Clock, Language, and Region
Ease of Access
Action Center
Review your computer's status and resolve issues
Change User Account Control settings
Troubleshoot common computer problems
Windows Firewall
Check firewall status
Allow an app through Windows Firewall
System
View amount of RAM and processor speed
Allow remote access
Launch remote assistance
See the name of this computer
Windows Update
Turn automatic updating on or off
Check for updates
Install optional updates
View update history
Power Options
Require a password when the computer wakes
Change what the power buttons do
Change when the computer sleeps
Administrative Tools
Defragment and optimize your drives
Create and format hard disk partitions
View event logs
Schedule tasks
Generate a system health report

1791

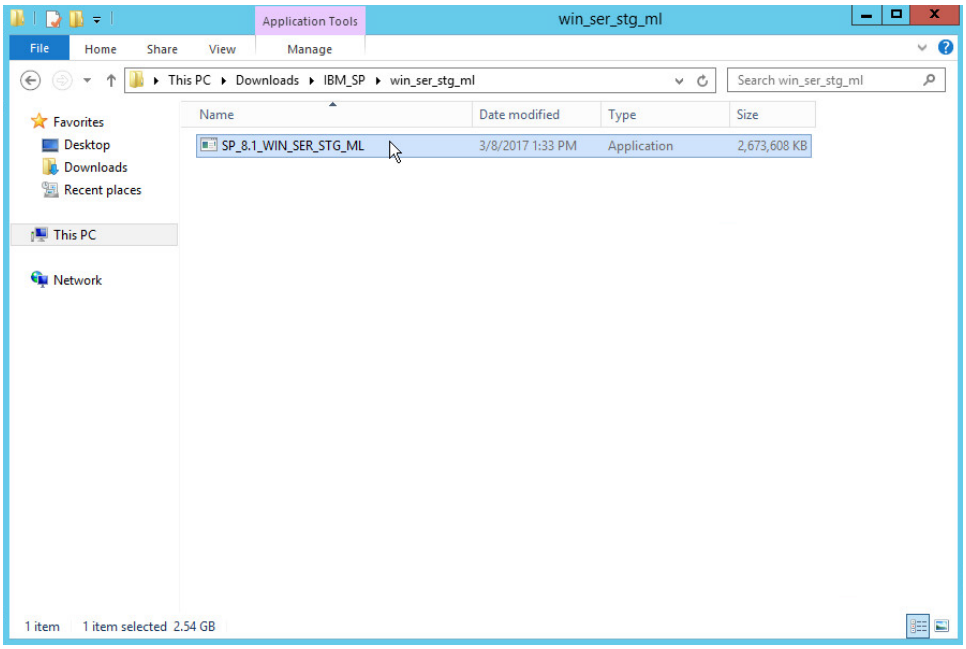

Shortcut Tools
Administrative Tools
File
Home
Share
View
Manage
Control Panel ▸ System and Security ▸ Administrative Tools ▸
Search Administrative Tools
Favorites
Desktop
Downloads
Recent places
This PC
Network
Name
Date modified
Type
Size
Terminal Services 8/22/2013 8:39 AM File folder
Component Services 8/21/2013 11:57 PM Shortcut 2 KB
Computer Management 8/21/2013 11:54 PM Shortcut 2 KB
Defragment and Optimize Drives 8/21/2013 11:47 PM Shortcut 2 KB
Event Viewer 8/21/2013 11:55 PM Shortcut 2 KB
iSCSI Initiator 8/21/2013 11:57 PM Shortcut 2 KB
Local Security Policy 8/21/2013 11:54 PM Shortcut 2 KB
ODBC Data Sources (32-bit) 8/21/2013 4:56 PM Shortcut 2 KB
ODBC Data Sources (64-bit) 8/21/2013 11:59 PM Shortcut 2 KB
Performance Monitor 8/21/2013 11:52 PM Shortcut 2 KB
Resource Monitor 8/21/2013 11:52 PM Shortcut 2 KB
Security Configuration Wizard 8/21/2013 11:45 PM Shortcut 2 KB
Server Manager 8/21/2013 11:55 PM Shortcut 2 KB
Services 8/21/2013 11:54 PM Shortcut 2 KB
System Configuration 8/21/2013 11:53 PM Shortcut 2 KB
System Information 8/21/2013 11:53 PM Shortcut 2 KB
Task Scheduler 8/21/2013 11:55 PM Shortcut 2 KB
Windows Firewall with Advanced Security 8/21/2013 11:45 PM Shortcut 2 KB
Windows Memory Diagnostic 8/21/2013 11:52 PM Shortcut 2 KB
Windows PowerShell (x86) 8/22/2013 8:37 AM Shortcut 3 KB
Windows PowerShell ISE (x86) 8/21/2013 11:55 PM Shortcut 2 KB
23 items
1 item selected 1.09 KB

1792

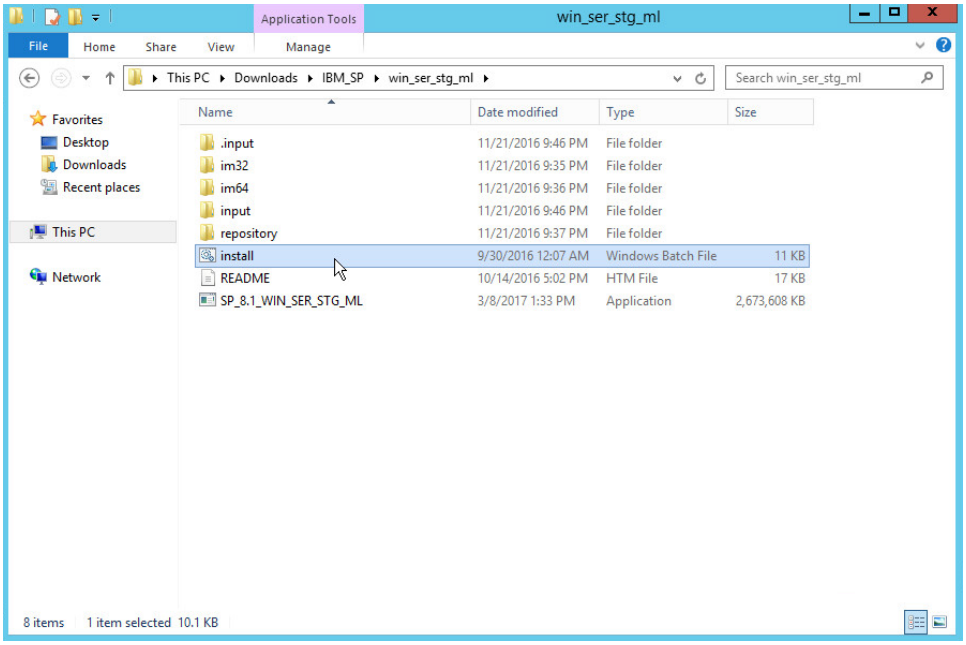




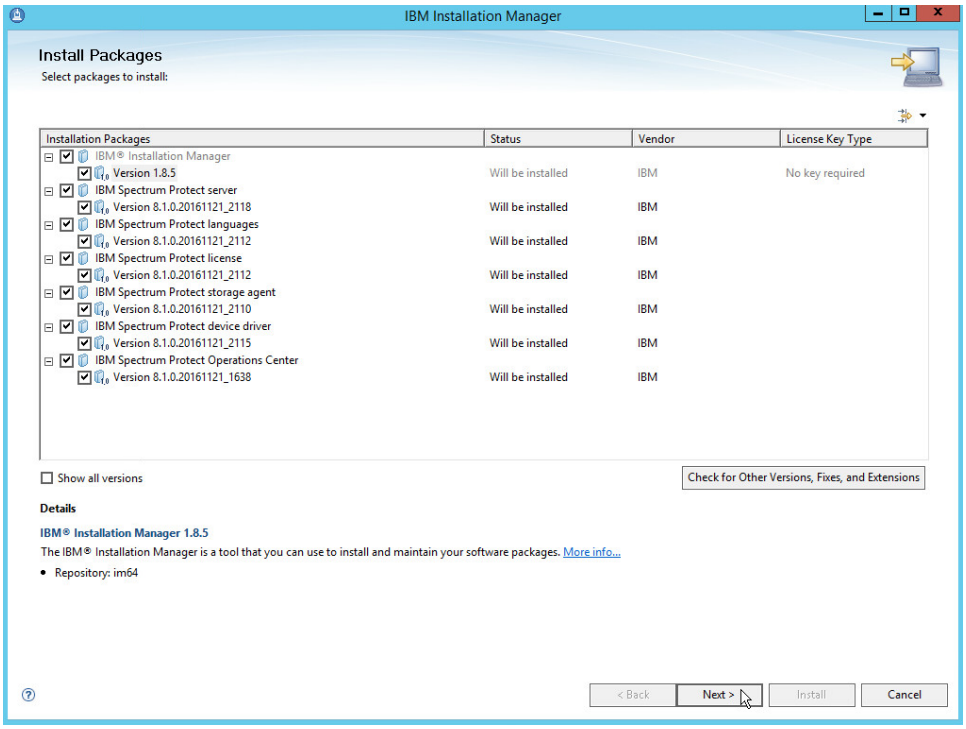
2. Run **WIN_SER_STG_ML** in its own folder to extract the contents.



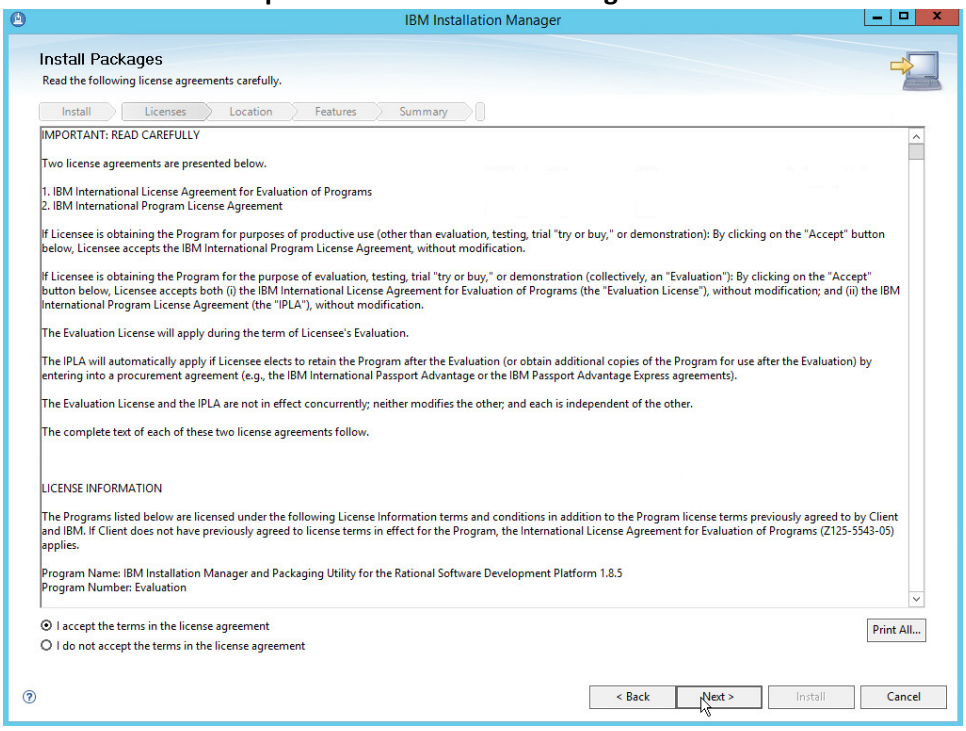
3. Run the **install** script.



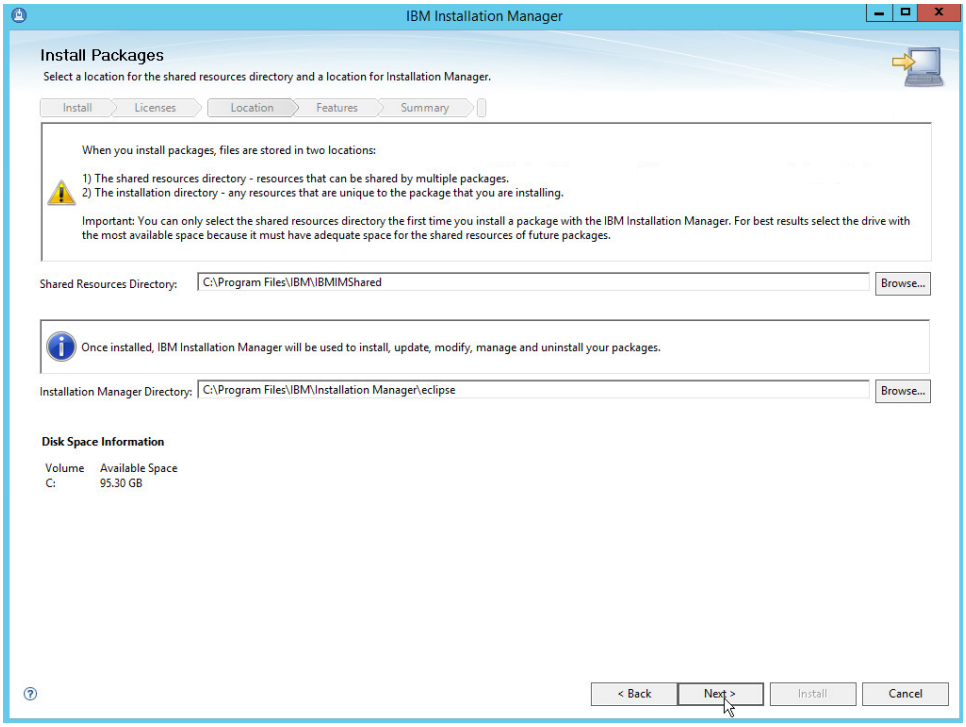
4. Make sure all the boxes are checked.



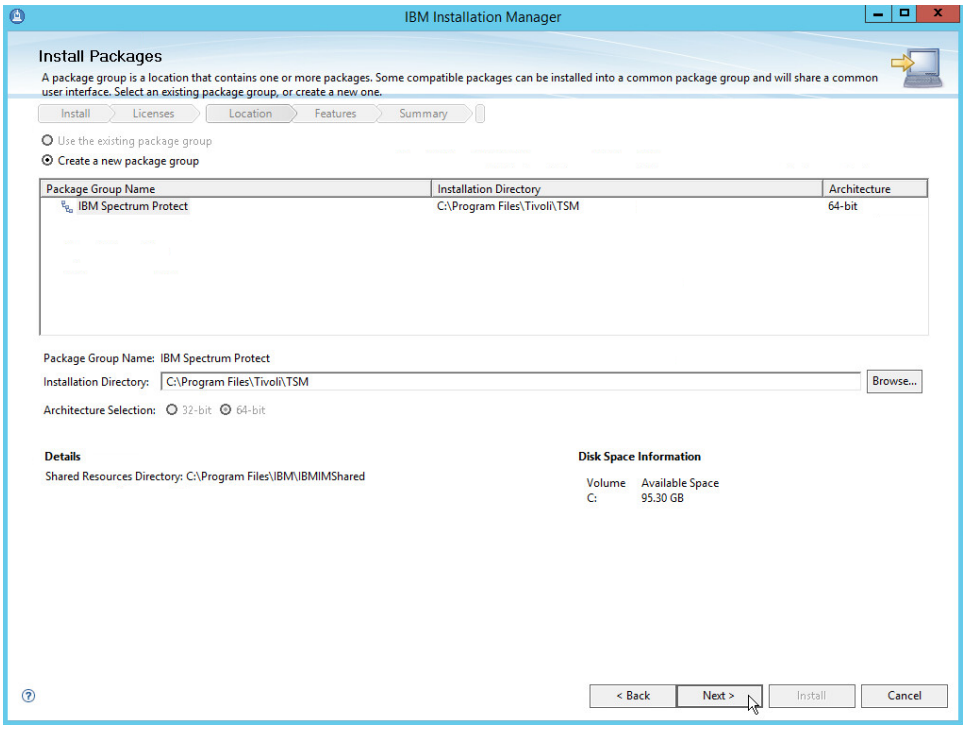
5. Click **Next**.
6. Read and select **I accept the terms in the license agreement**.



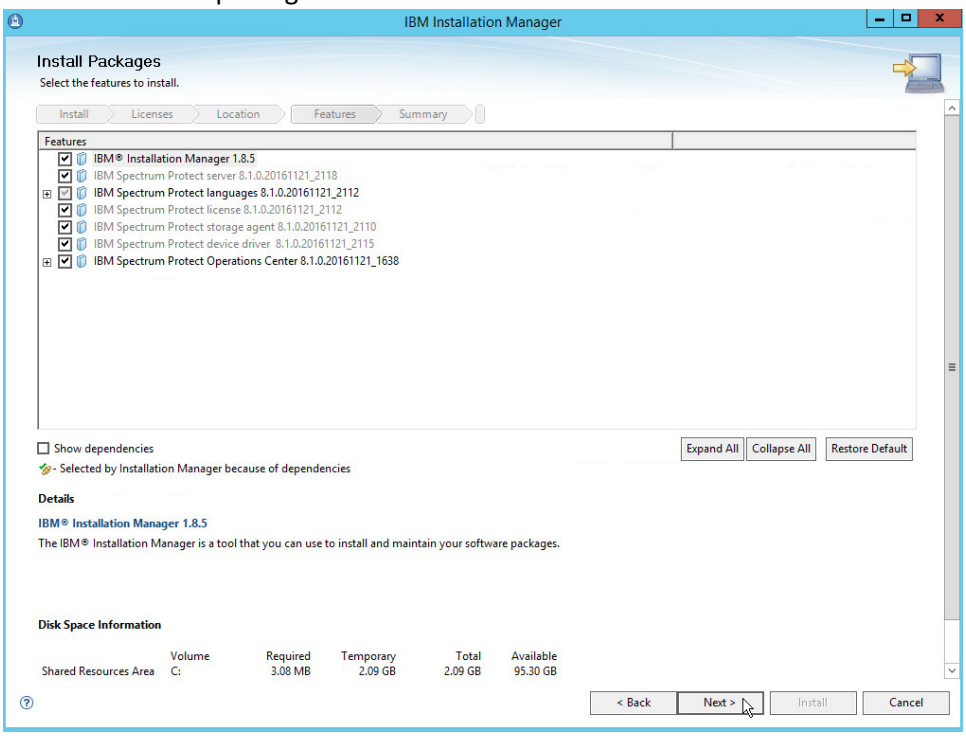
7. Click **Next**.
8. Select the installation location for files.



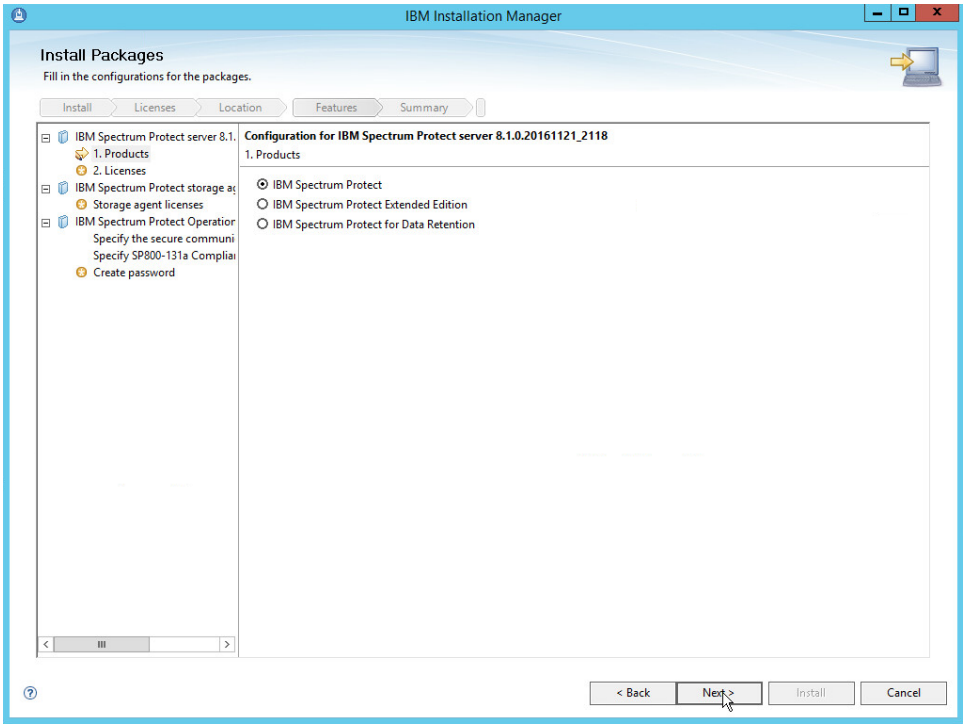
9. Click **Next**.



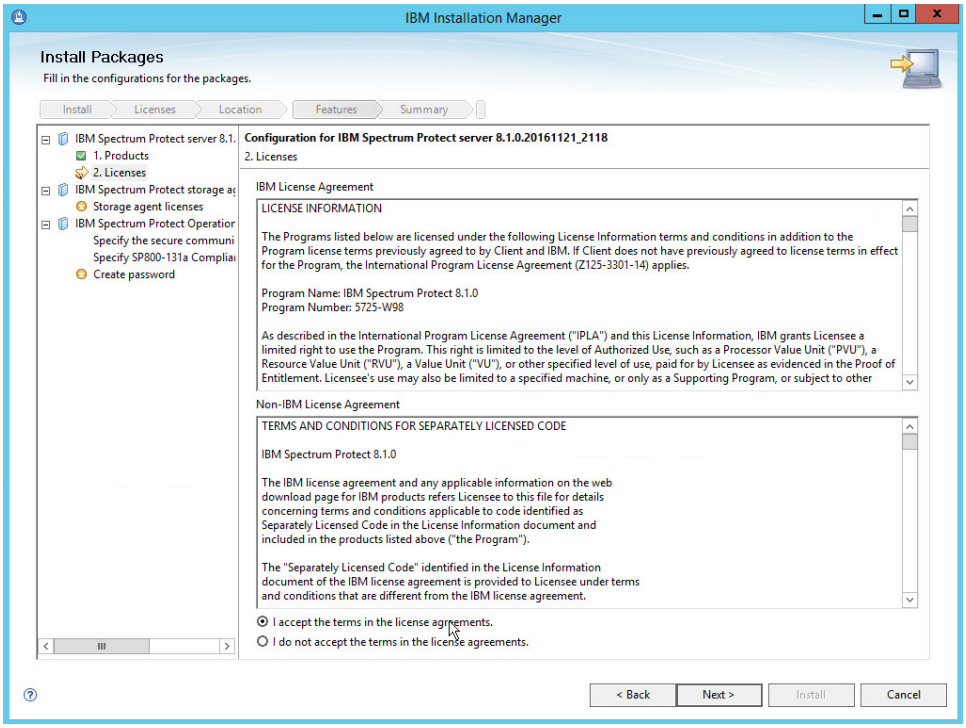
10. Click **Next**.
11. Make sure all the packages are checked.



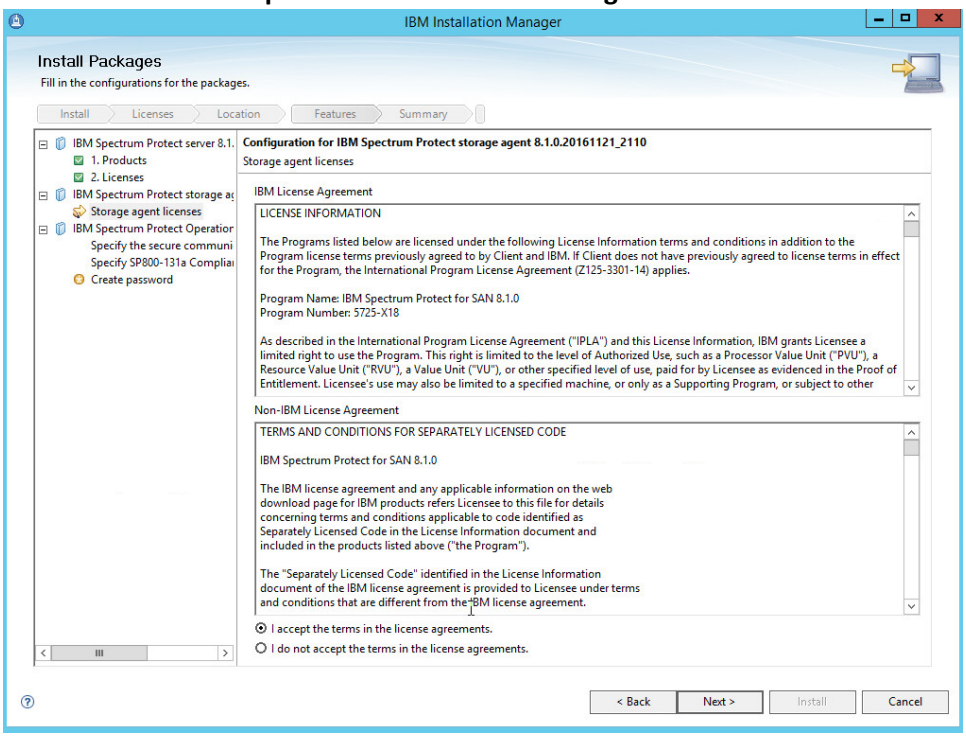
12. Click **Next**.
13. Select **IBM Spectrum Protect**.



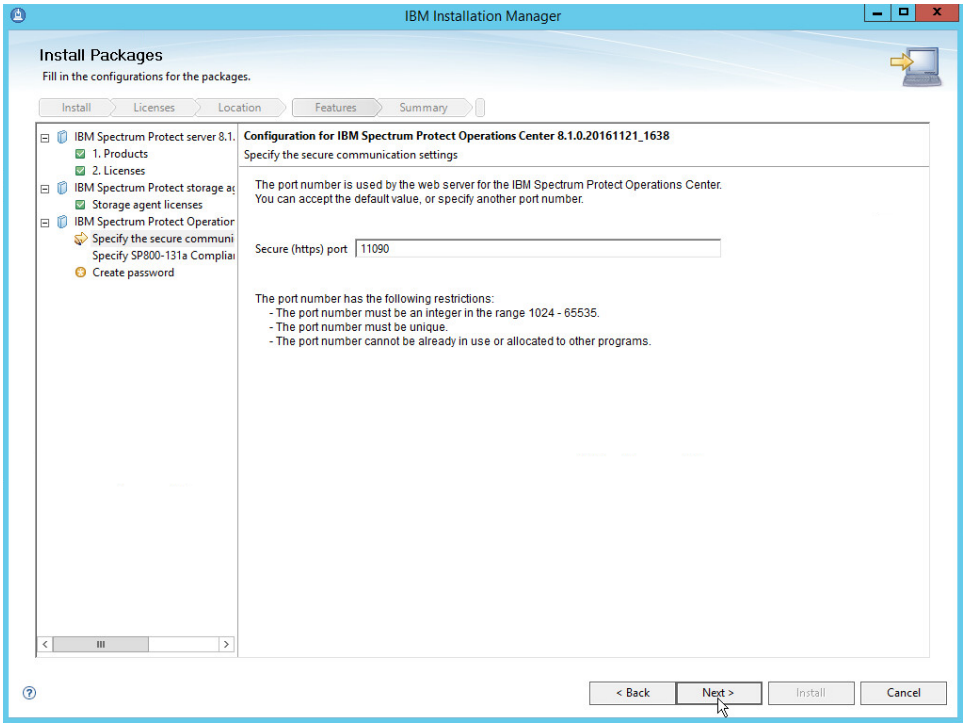
14. Click **Next**.
15. Read and select **I accept the terms in the license agreement**.



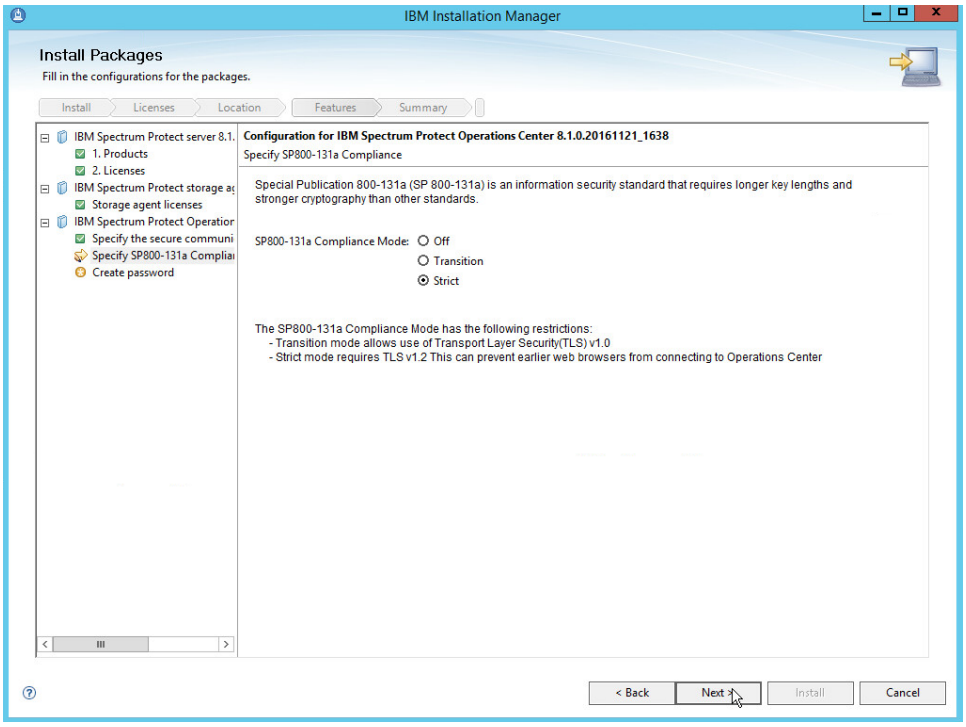
16. Click **Next**.
17. Read and select **I accept the terms in the license agreement**.



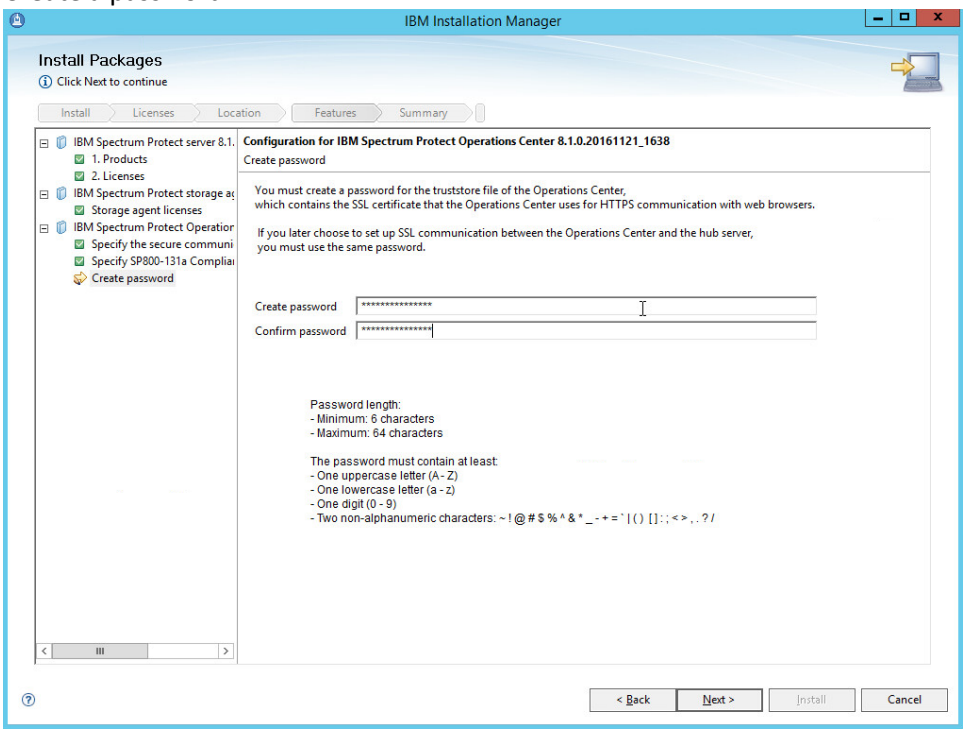
18. Click **Next**.
19. Specify **11090** for the port.



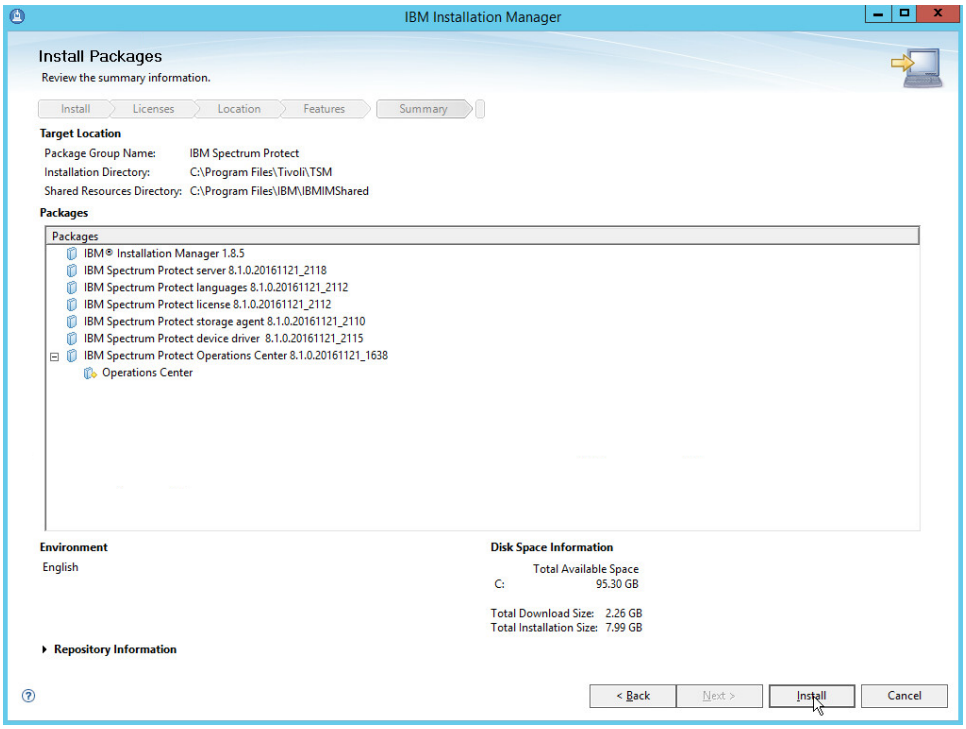
20. Click **Next**.
21. Select **Strict** for the **SP800-131a Compliance**.



22. Click **Next**.
23. Create a password.



24. Click **Next**.

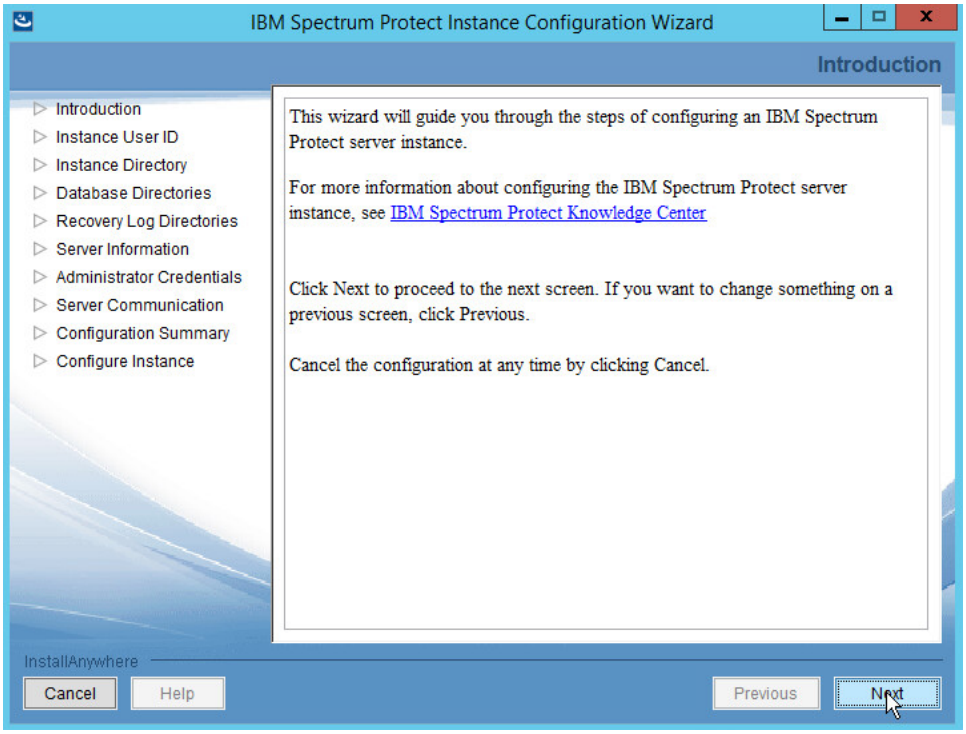


25. Click **Install**.
26. After the successful installation, click **Finish**.

2.13.2 Configure IBM Spectrum Protect

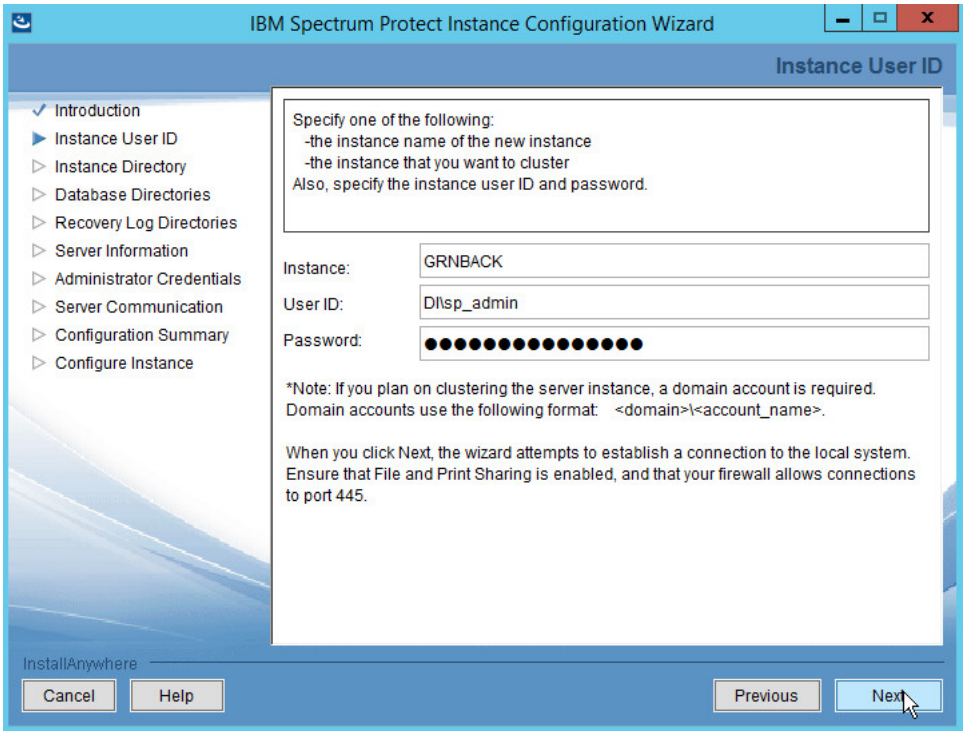
1. Go to **Start > IBM Spectrum Protect Configuration Wizard**.

2. Click **OK**.

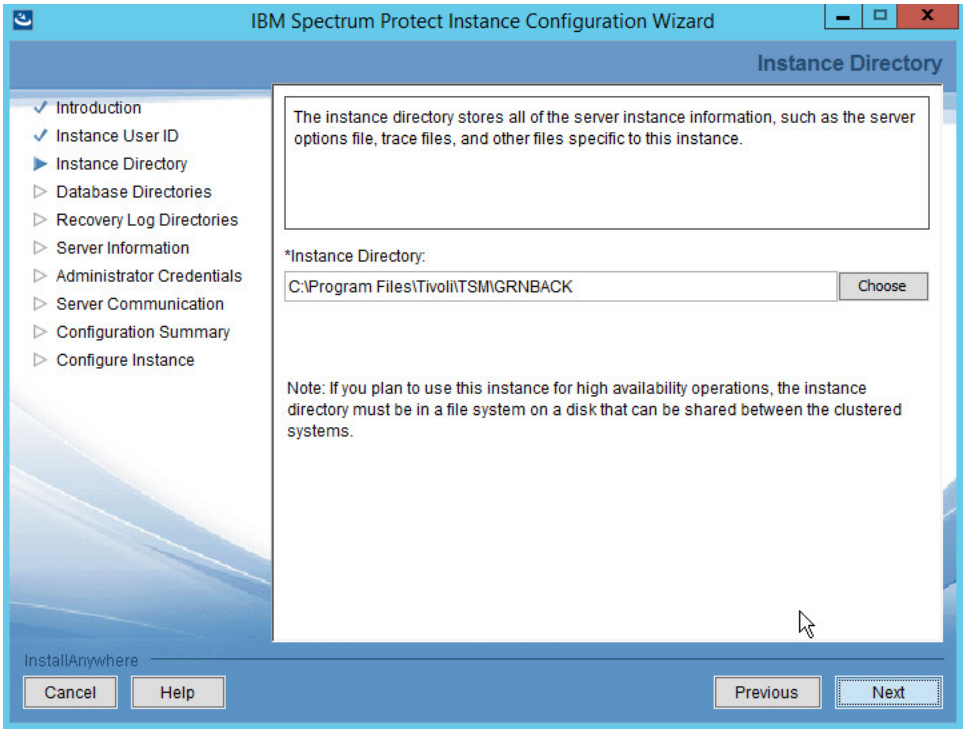


3. Click **Next**.

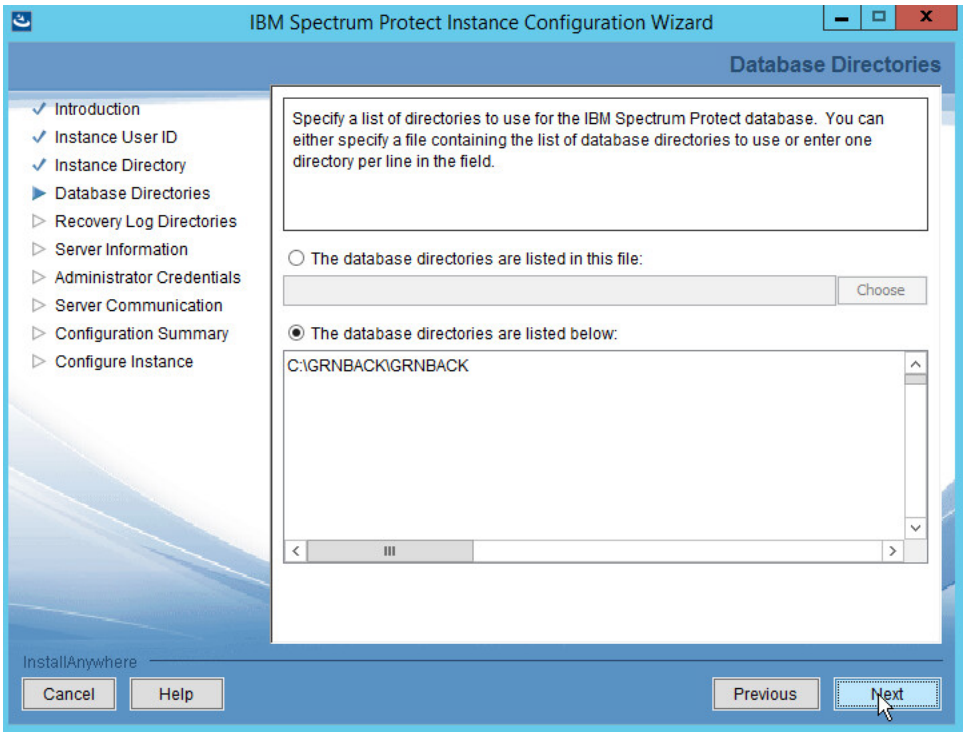
4. Specify a name and an account for the IBM server to use. Example: (name: GRNBACK, User ID: DI\sp_admin)



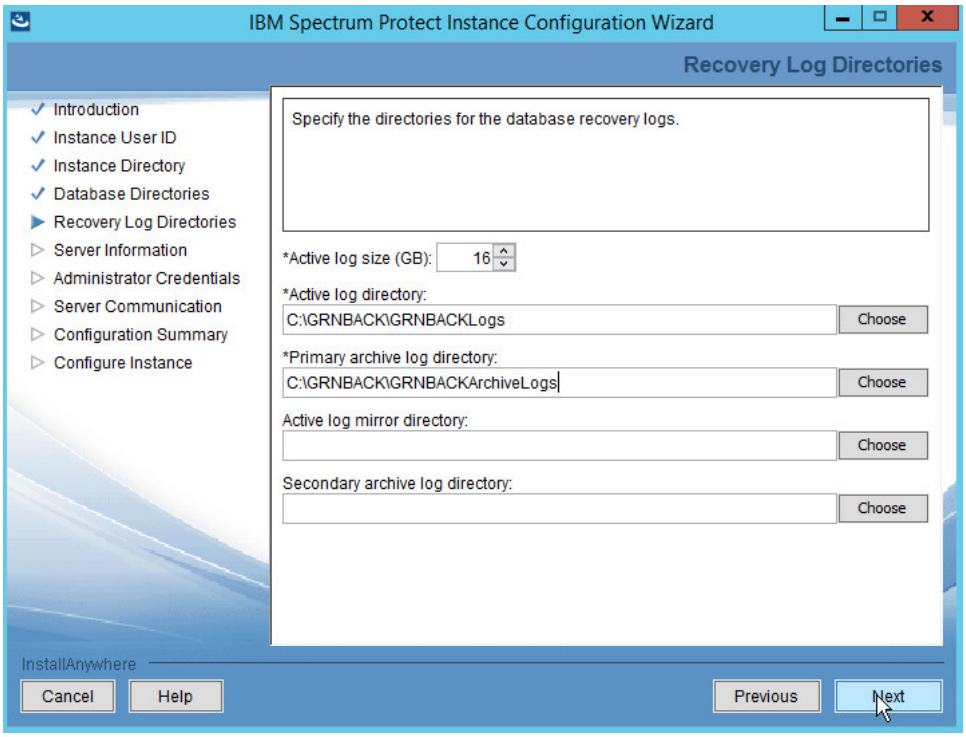
5. Click **Next**.
6. Choose a directory.



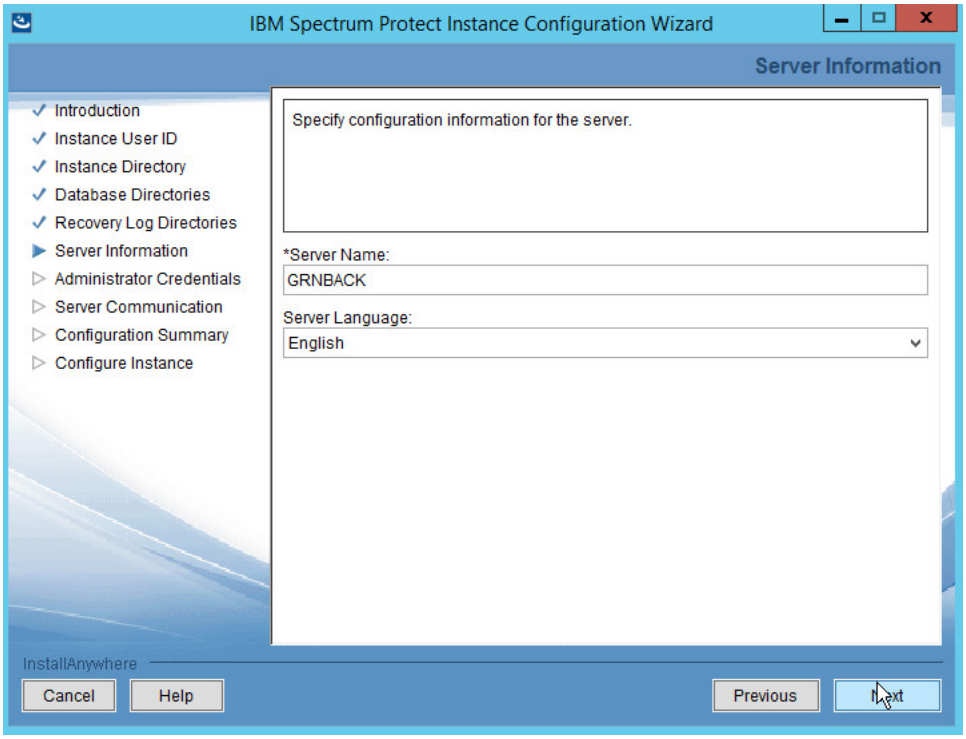
7. Click **Next**.
8. Click **Yes** if prompted to create the directory.
9. Choose **The database directories are listed below**.
10. Create a directory to contain the database. Example: *C:\BACKSERV\IBMBackupServer*.
11. Enter the directory in the space provided.



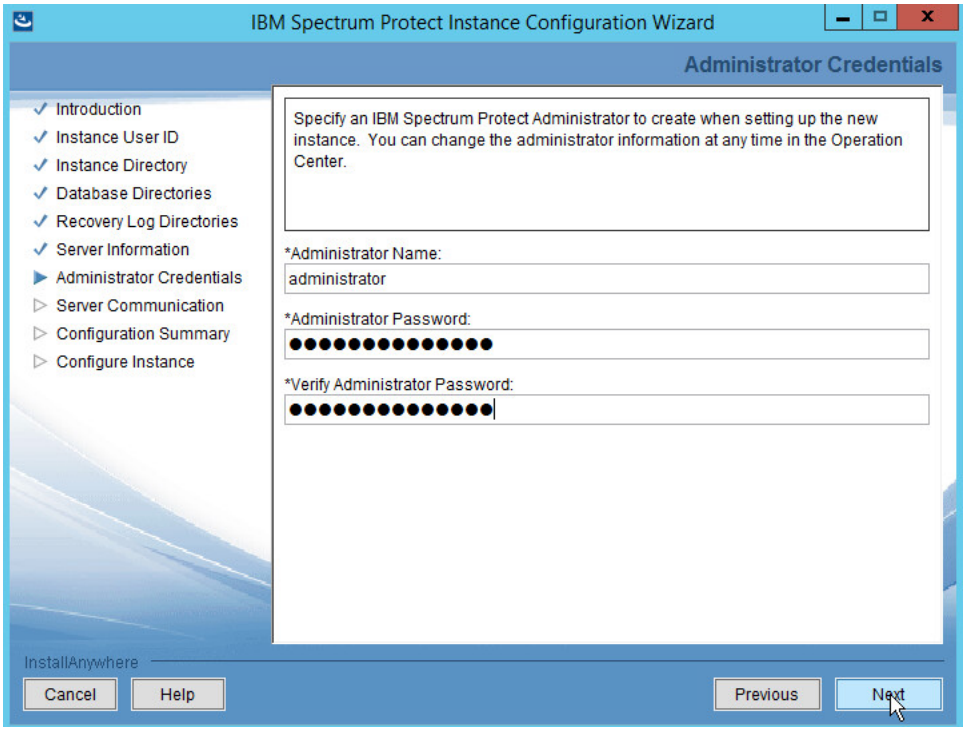
12. Click **Next**.
13. Create directories for **logs** and **archive logs**. Example: *C:\BACKSERV\IBMBackupServerLogs*, *C:\BACKSERV\IBMBackupServerArchiveLogs*.
14. Enter the directories in their respective fields.



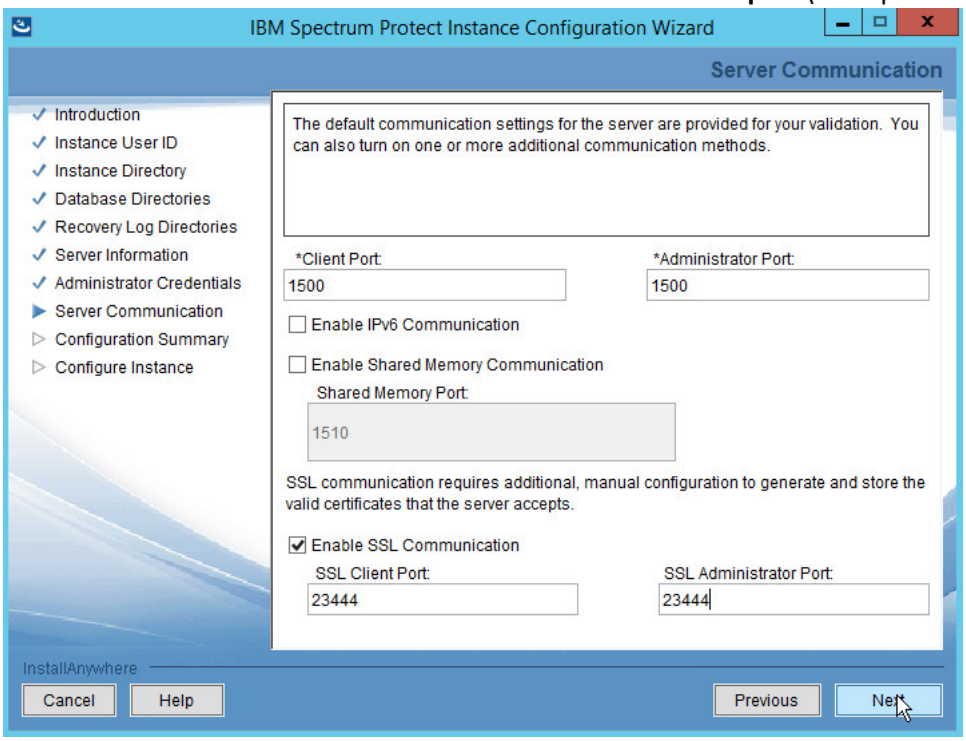
15. Click **Next**.
16. Specify the **server name**.



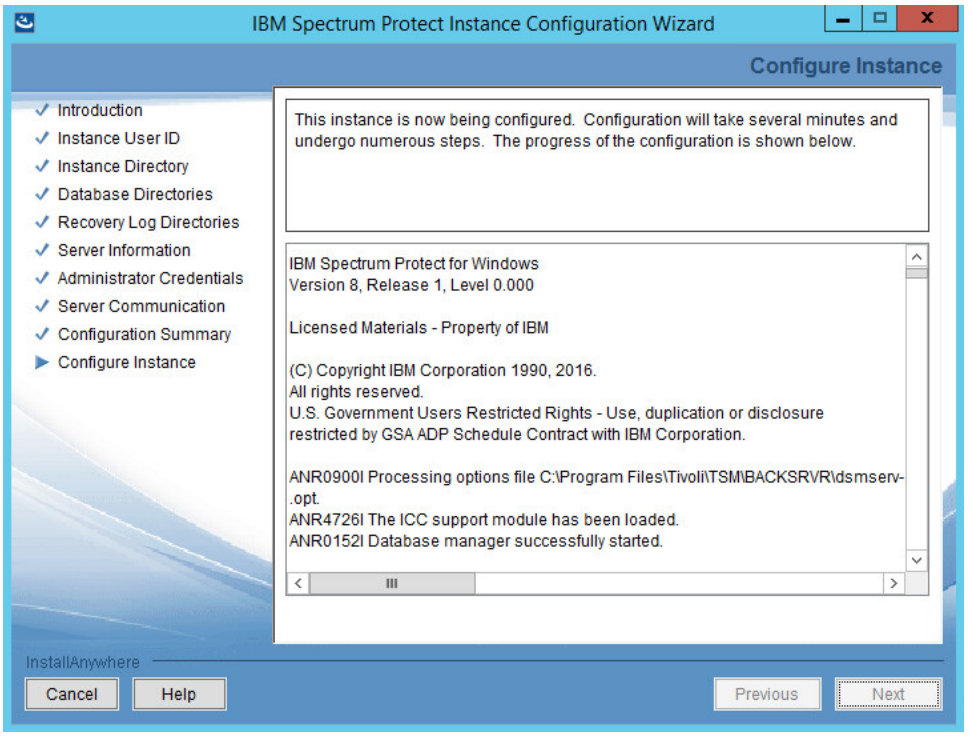
17. Click **Next**.
18. Specify an **Administrator account**.



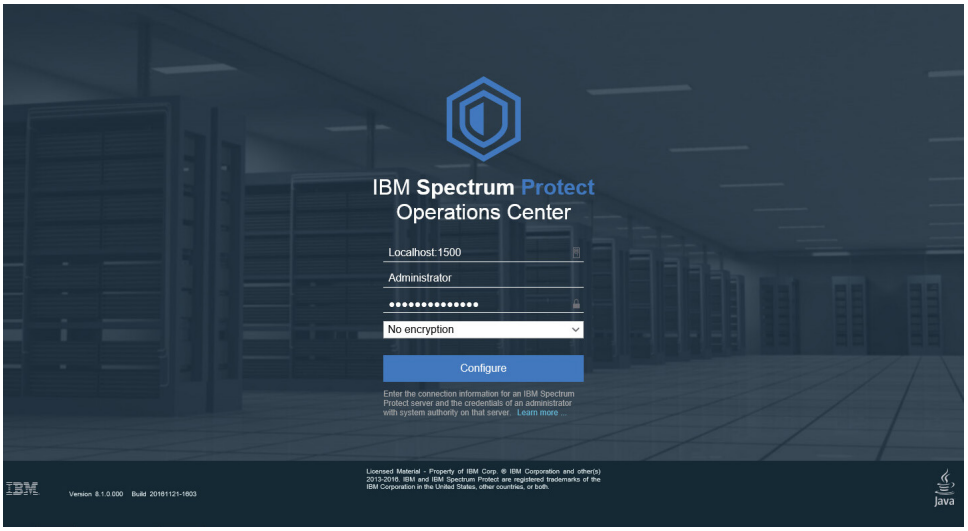
19. Click **Next**.
20. Select a **port** (example: 1500).
21. Check the box next to **Enable SSL Communication** and enter a **port** (example: 23444).



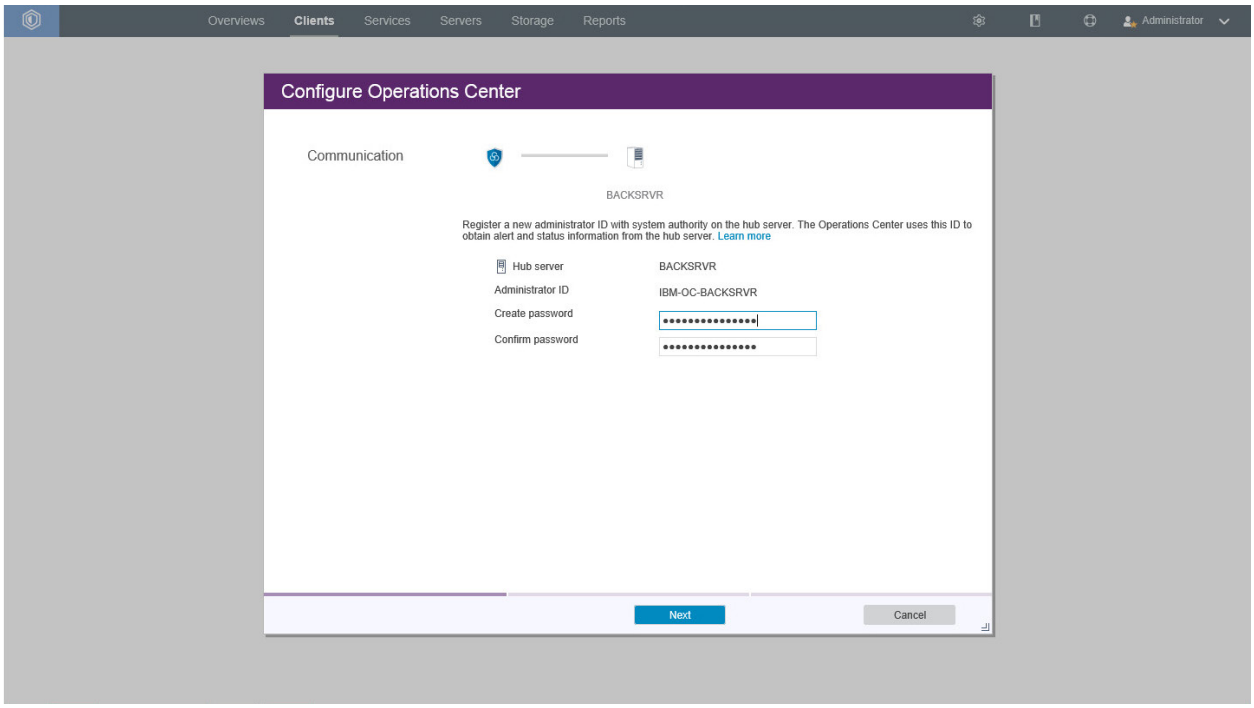
22. Click **Next**.
23. Click **Next**.
24. Wait for the installation to finish.



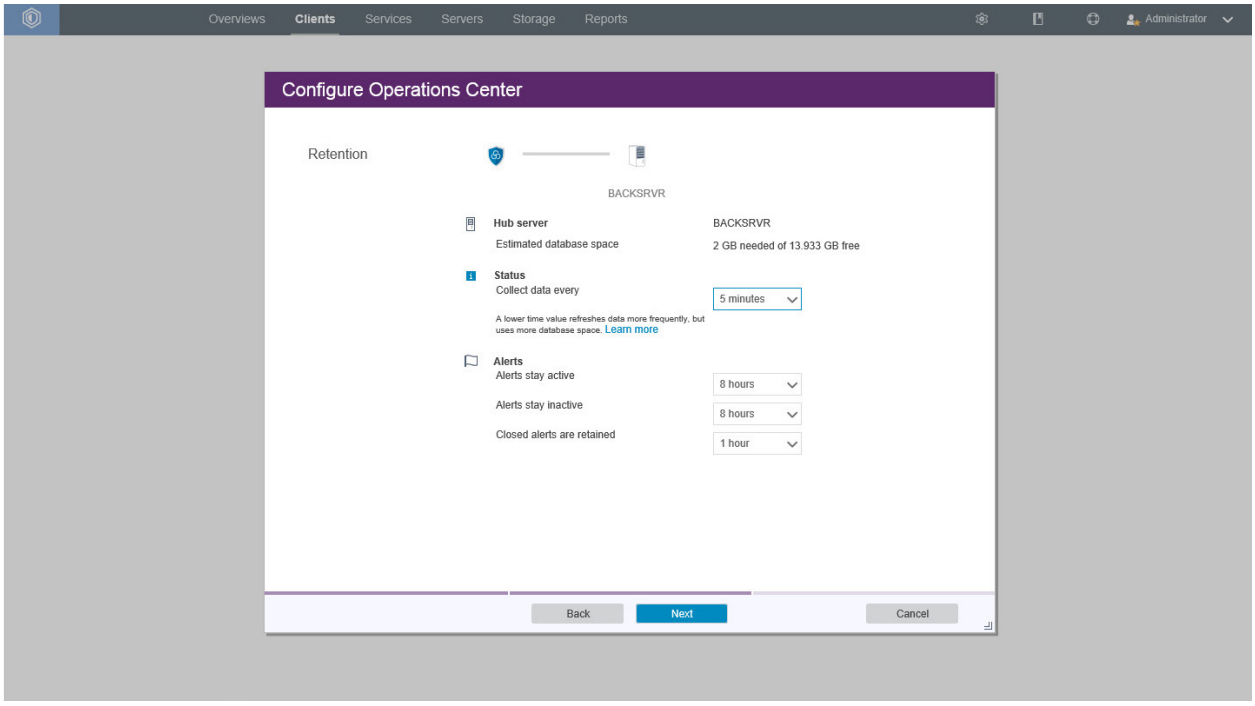
25. Click **Next**.
26. Click **Done**.
27. Log in to **Operations Center** by going to *localhost:11090/oc/.*
28. Log in using the credentials provided in the **Configuration Wizard**.



29. Enter the password for a new account to be created on the system.

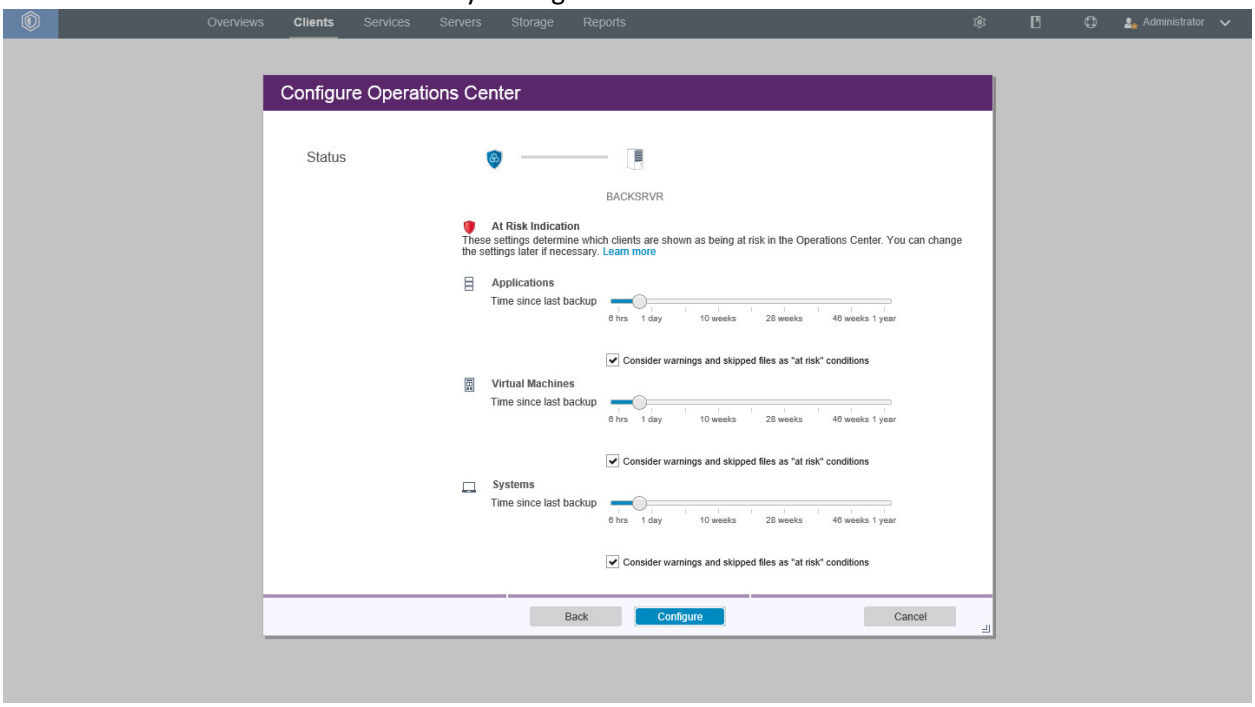


30. Click **Next**.
31. Select the time interval for data collection.

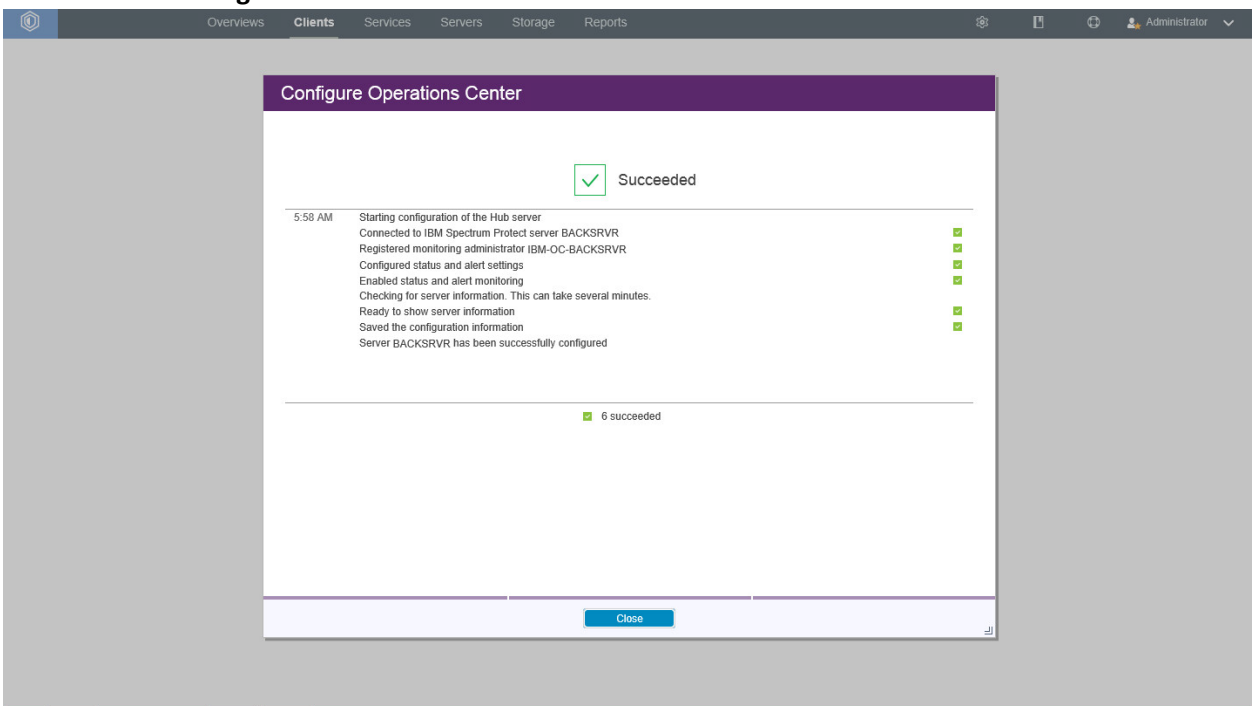


32. Click **Next**.

33. Select time intervals that suit your organization's needs.

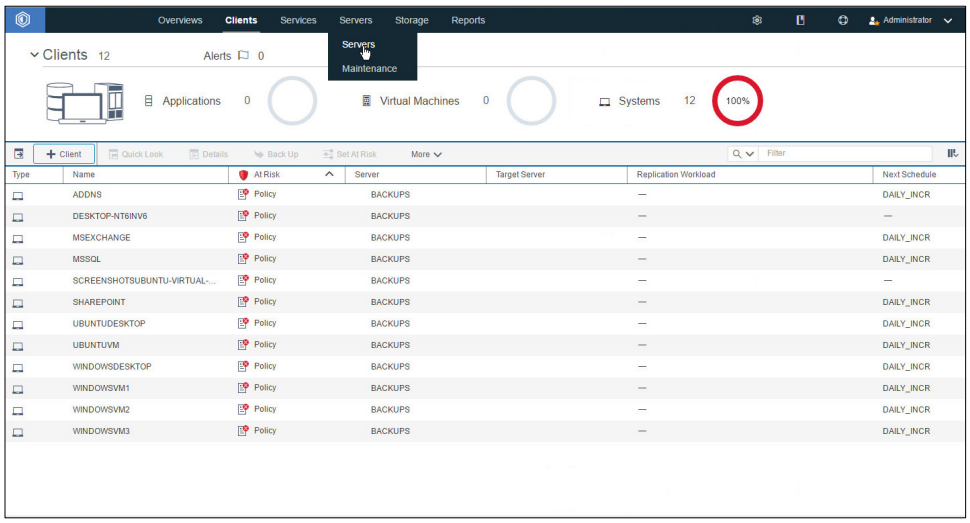


34. Click **Configure**.

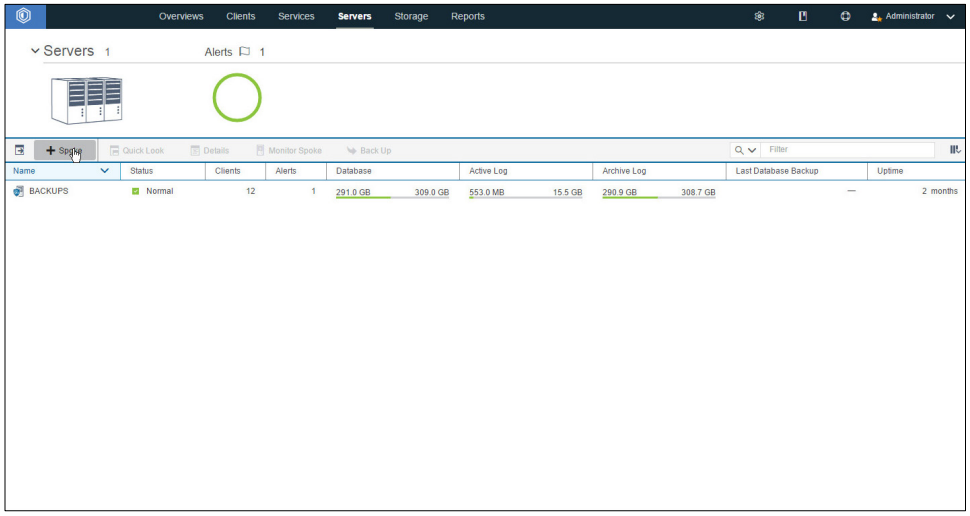


2.13.3 Connect the GreenTec Server to the IBM Spectrum Protect Server

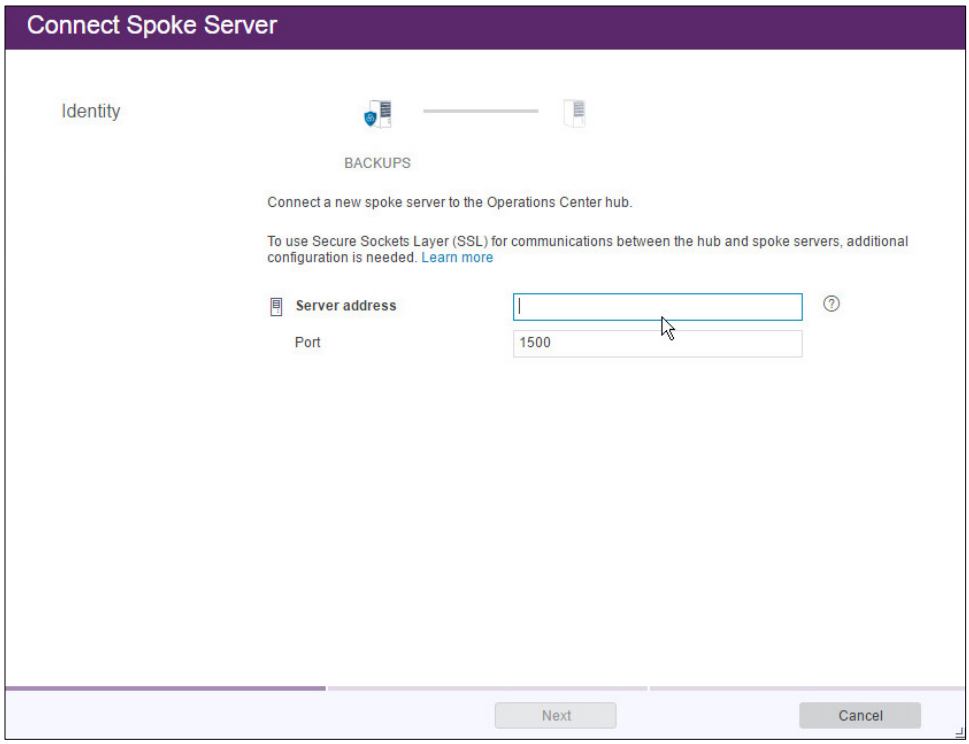
1. Go back to the primary IBM server.



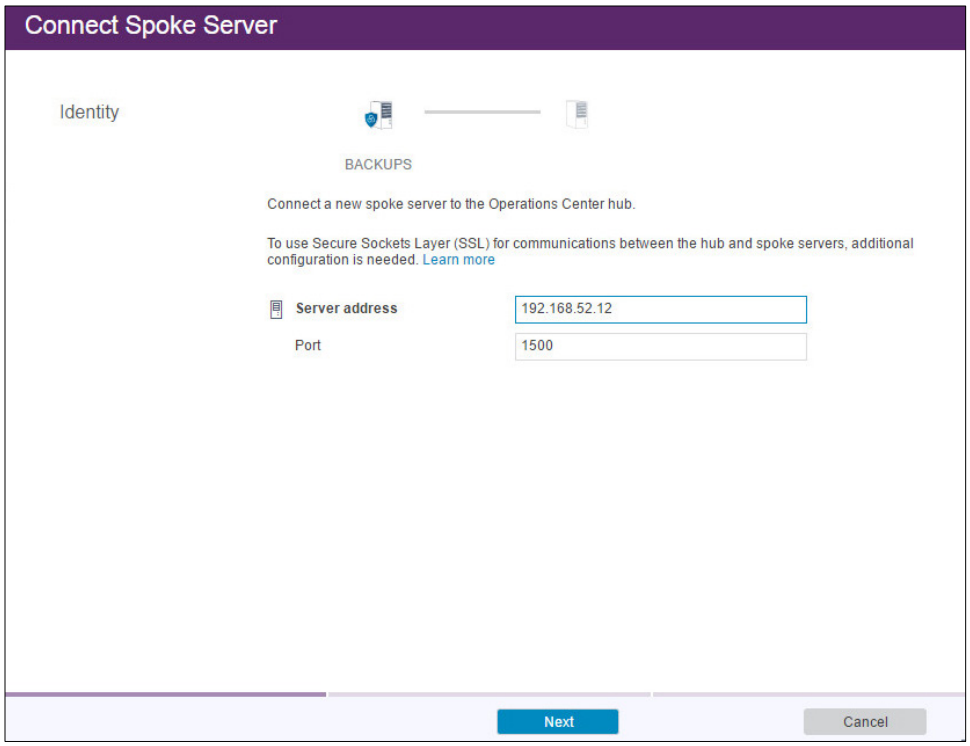
2. Click **Servers**.



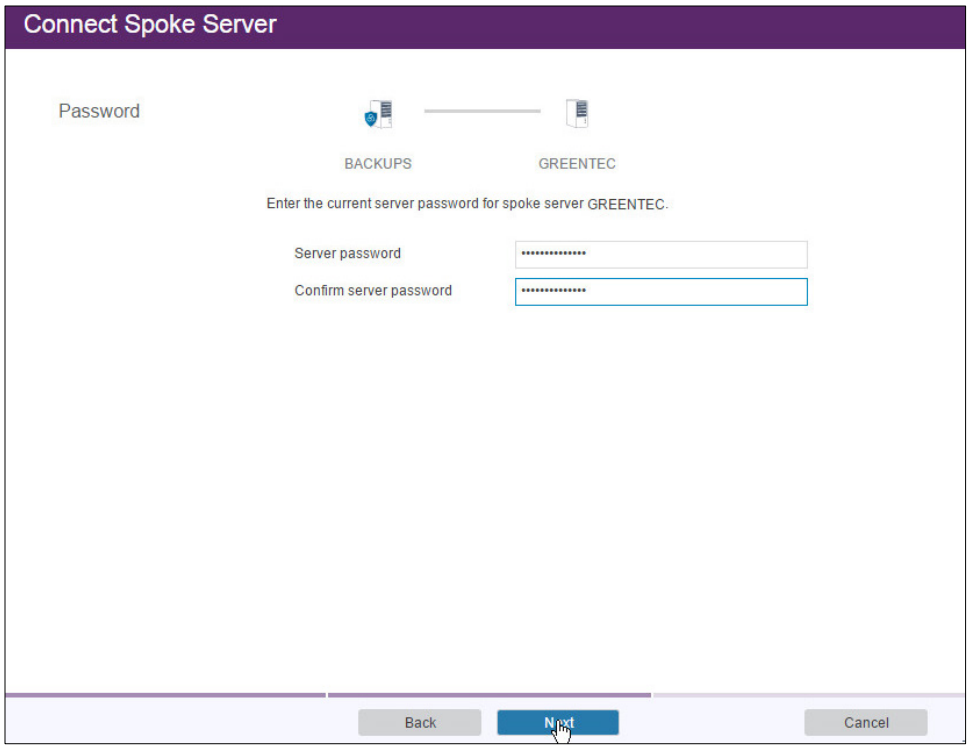
3. Click **+Spoke**.



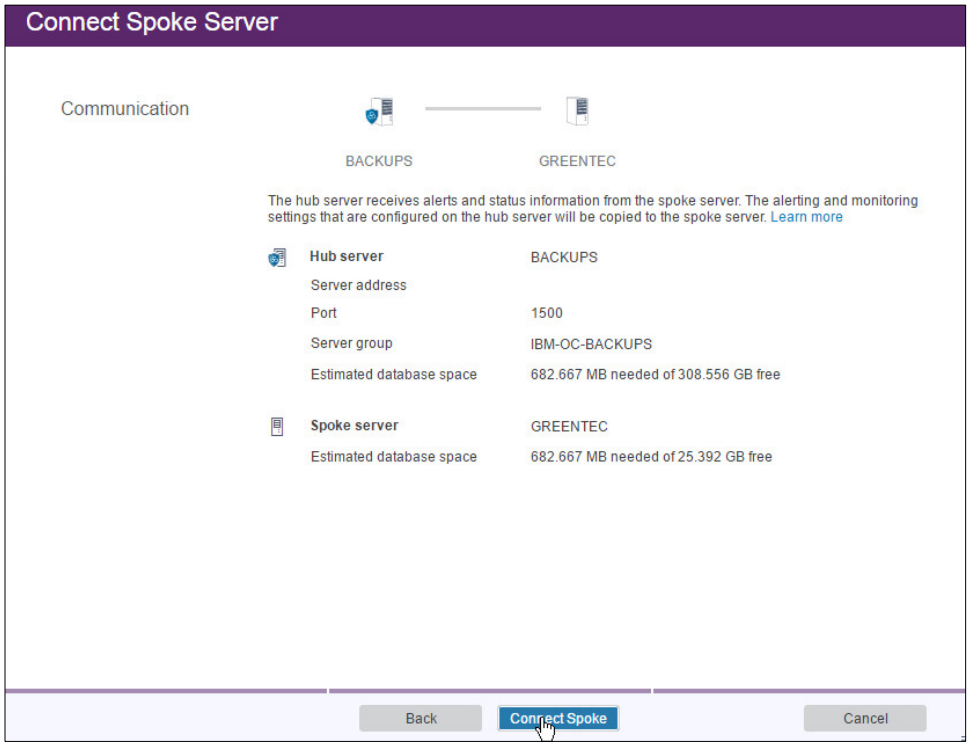
4. Enter the **IP address** of the server with GreenTec disks attached.
5. Enter the **port** that the server is configured to listen for connections on (Example: 1500).



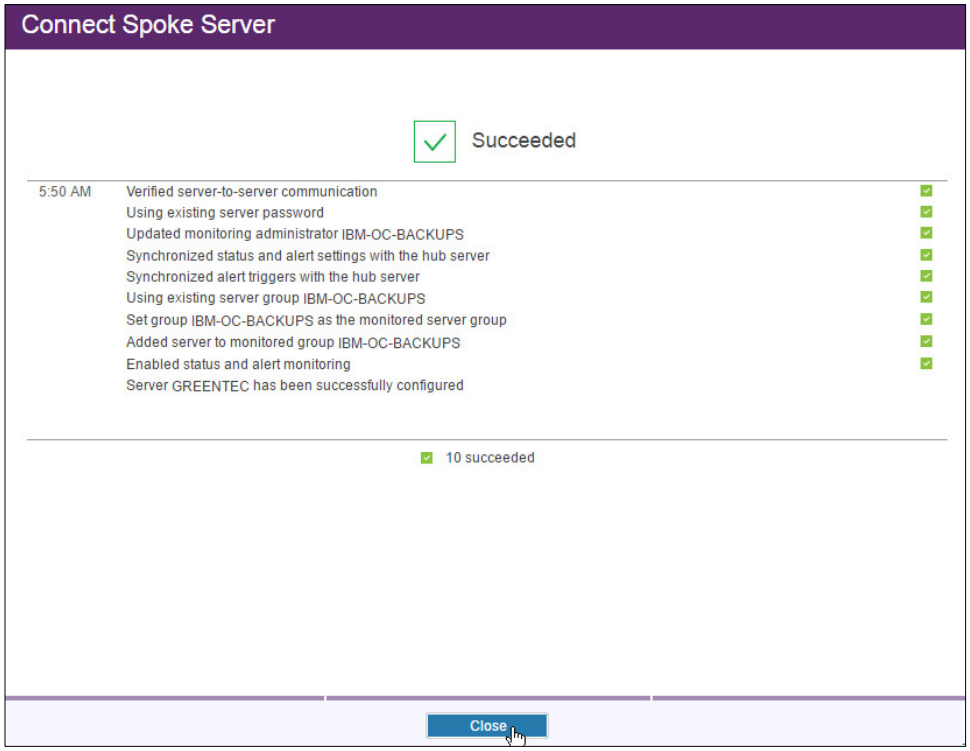
6. Click **Next**.
7. Enter the password for the new server twice.


Connect Spoke Server
Password
BACKUPS
GREENTEC
Enter the current server password for spoke server GREENTEC.
Server password
Confirm server password
Back
Next
Cancel

8. Click **Next**.


Connect Spoke Server
Communication
BACKUPS
GREENTEC
The hub server receives alerts and status information from the spoke server. The alerting and monitoring settings that are configured on the hub server will be copied to the spoke server. Learn more
Hub server
BACKUPS
Server address
Port
1500
Server group
IBM-OC-BACKUPS
Estimated database space
682.667 MB needed of 308.556 GB free
Spoke server
GREENTEC
Estimated database space
682.667 MB needed of 25.392 GB free
Back
Connect Spoke
Cancel

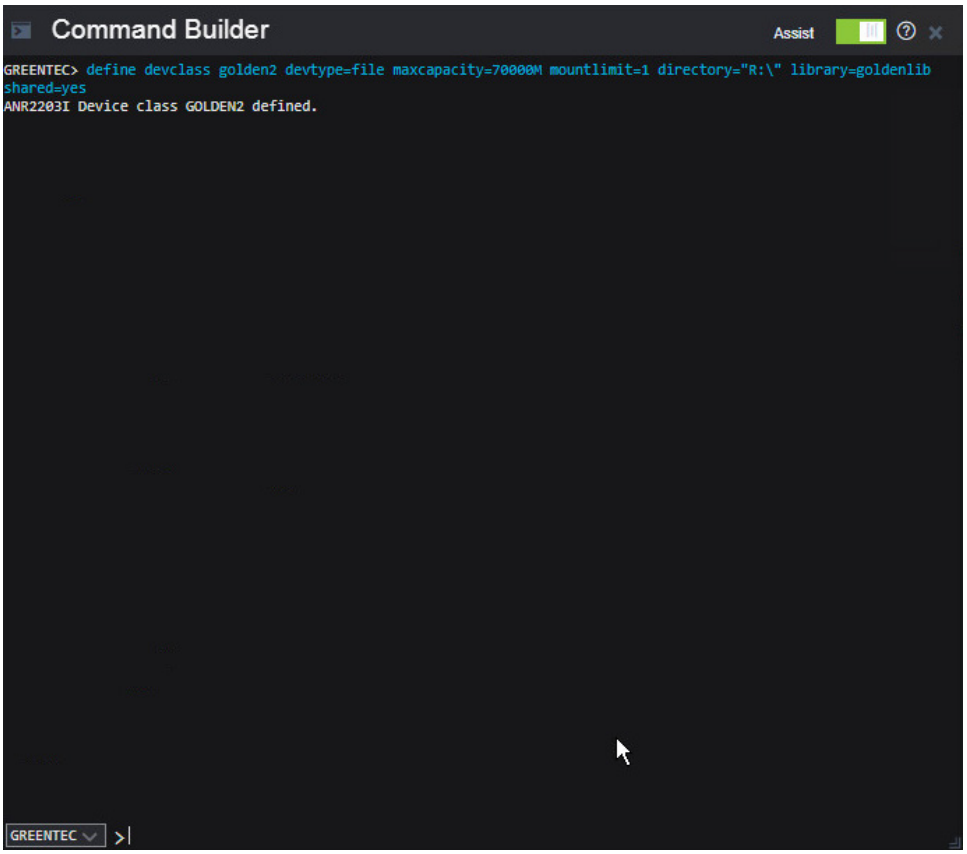
9. Click **Connect Spoke**.



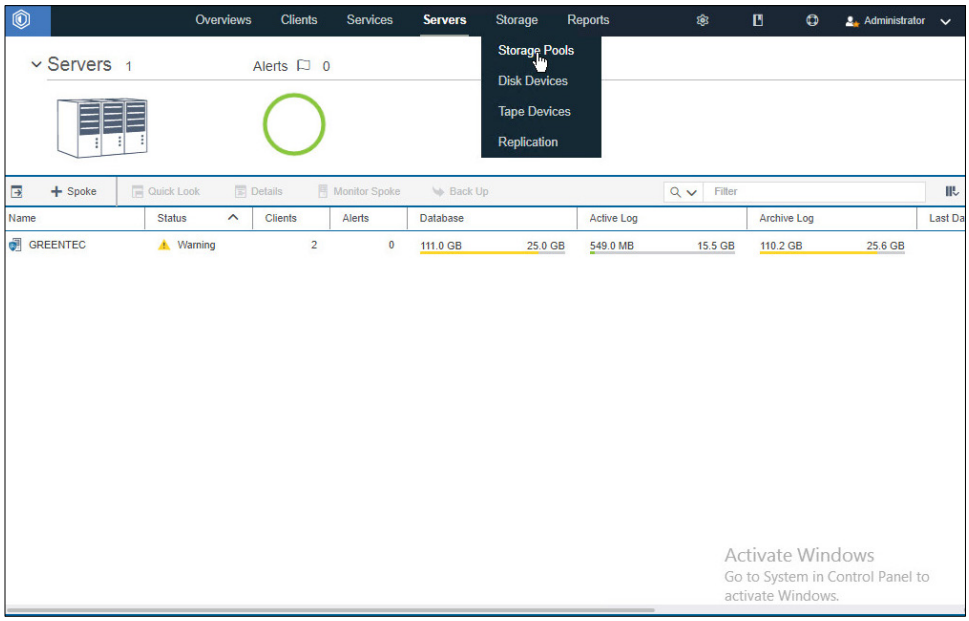
10. Click **Close**.

2.13.4 Define a Volume on the GreenTec Server

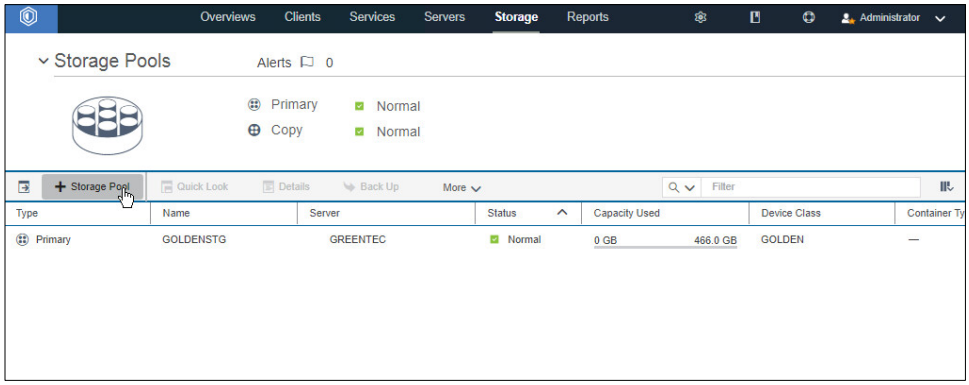
1. Issue the following command in the Operations Center (on the GreenTec server) command builder to create a device class for the backup disk (replace the name **golden**, max capacity value, and directory value as you see fit).



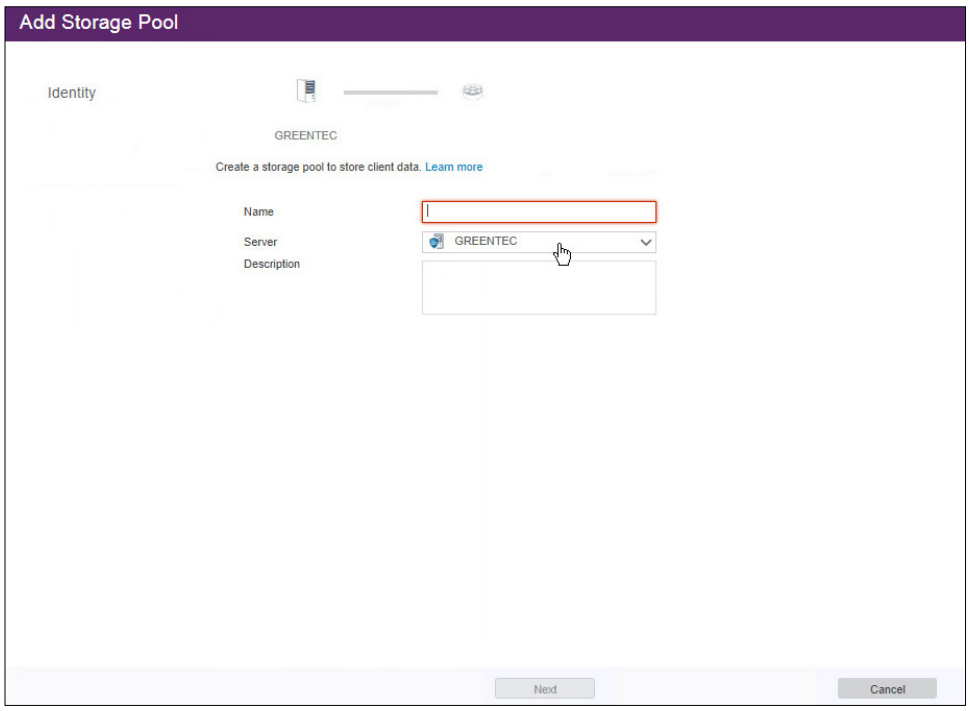

```
> define devclass golden devtype=file maxcapacity=350000M shared=yes
mountlimit=1 directory="E:\" library=backuplib
```



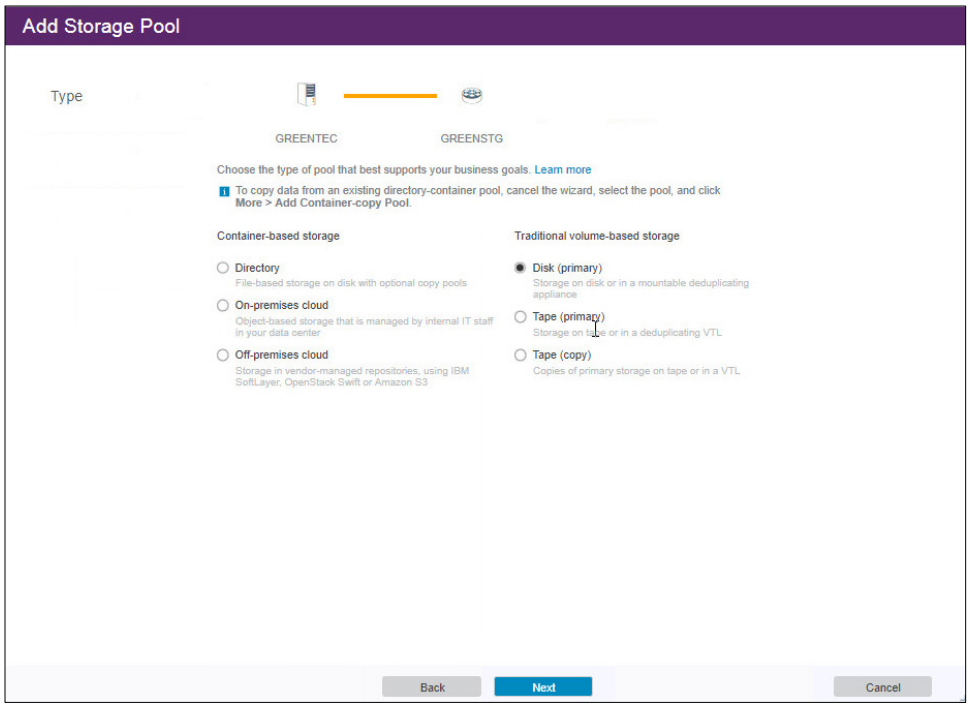
2. Go to **Storage > Storage Pools**.



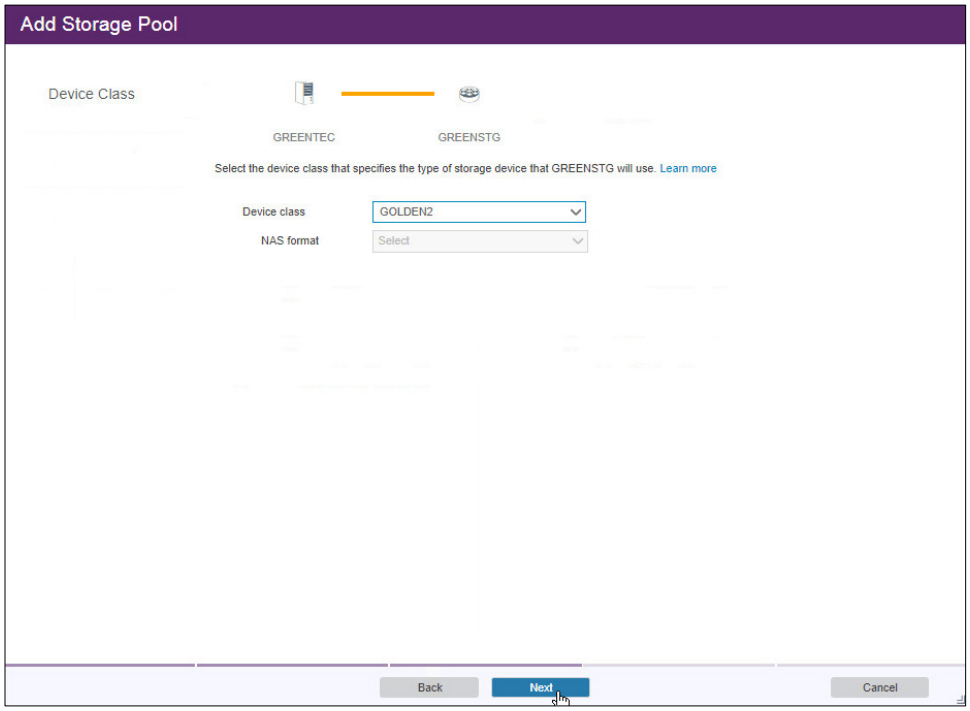
3. Click **+Storage Pool**.
4. Enter a name.



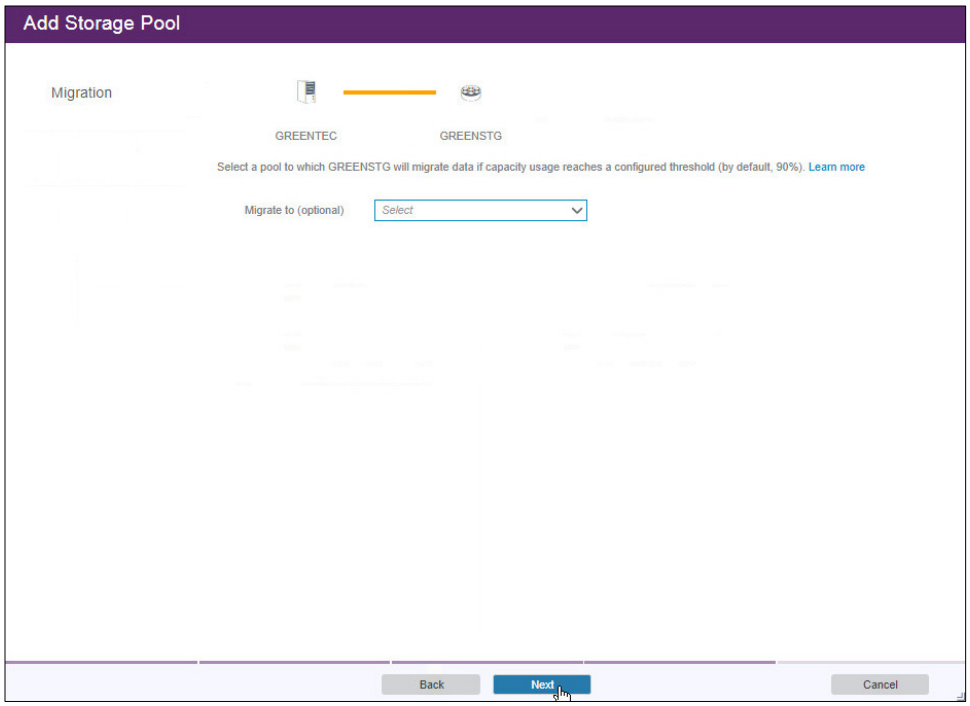
5. Click **Next**.
6. Select **Disk (primary).**



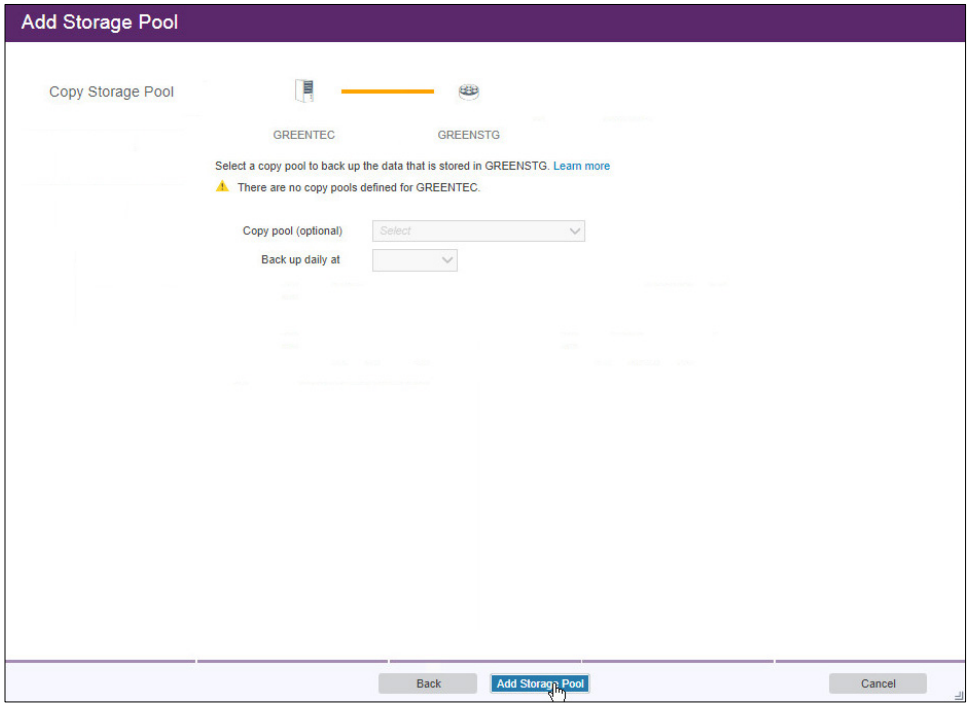
7. Click **Next**.
8. Select the device class you just created.



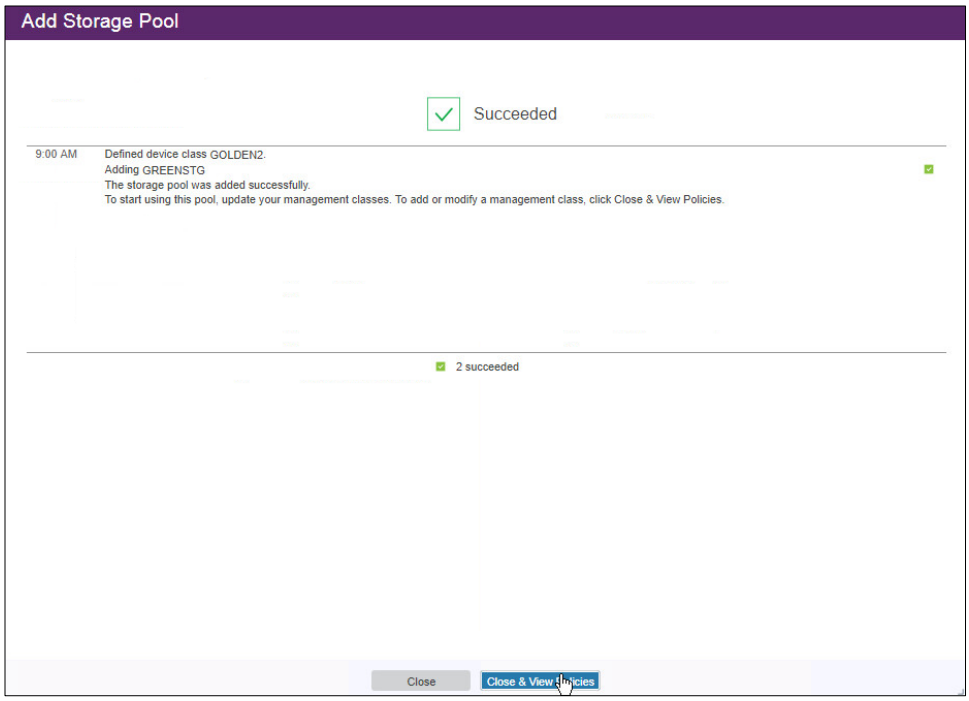
9. Click **Next**.



10. Click **Next**.

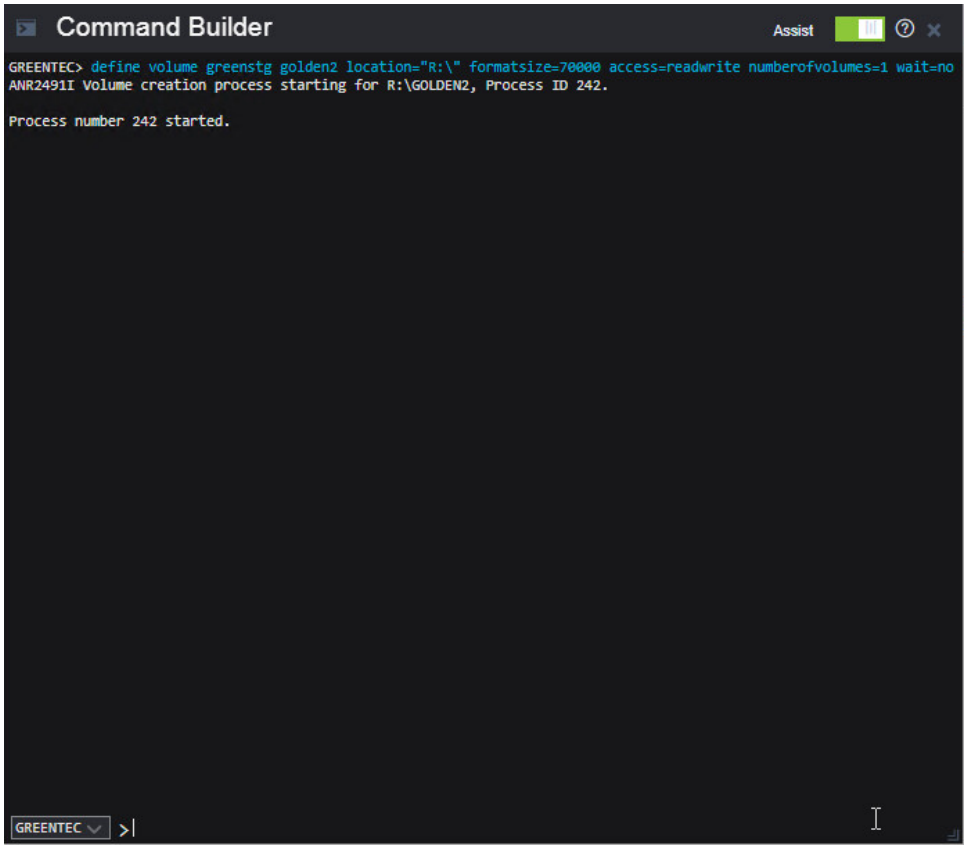


11. Click **Add Storage Pool**.



12. Click **Close & View Policies**.
13. Issue the following command in the Operations Center command builder to create a volume on the backup disk.

```
define volume goldenstg golden1 location="E:\" formatsize=350000
access=readwrite numberofvolumes=1 wait=no
```



14. The storage pool may indicate that there is no capacity, but once you backup something it should correctly show the capacity.

2.13.5 Create a Policy to Backup to GreenTec disks

1. Issue the following command in the Operations Center (on the GreenTec server) command builder to delete the standard policy domain:

   `delete domain standard`

2. Issue the following command to create a new domain.

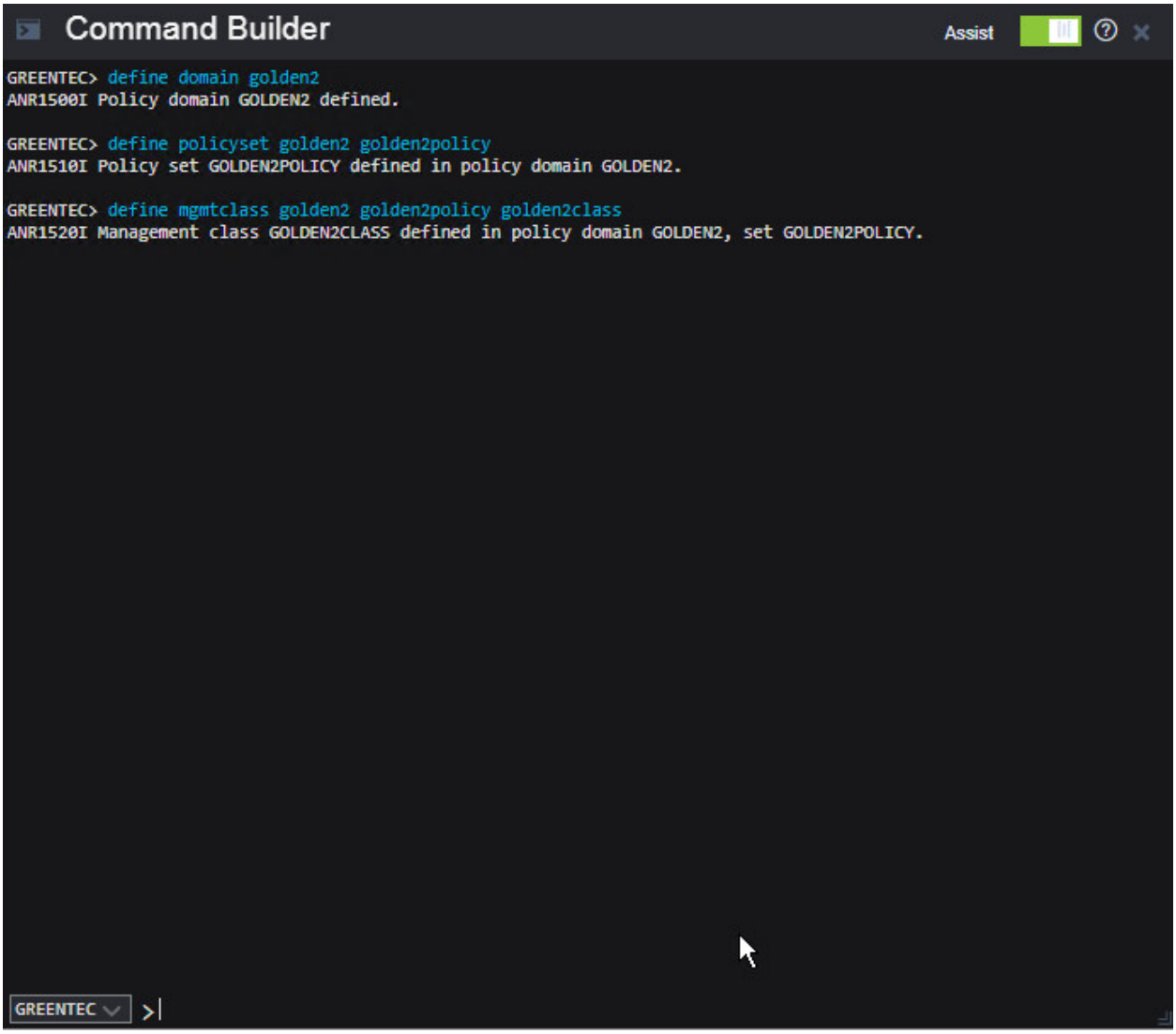
   `define domain golden`

3. Issue the following command to create a new policy set in this domain.

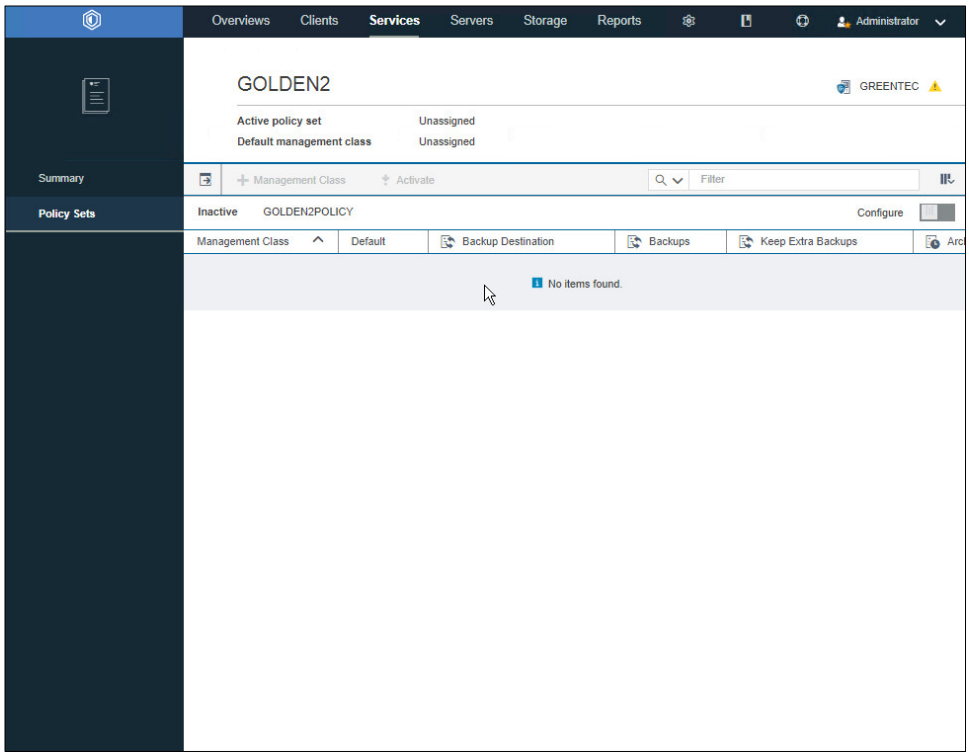
   `define policyset goldenpolicy`

4. Issue the following command to create a management class in this domain.

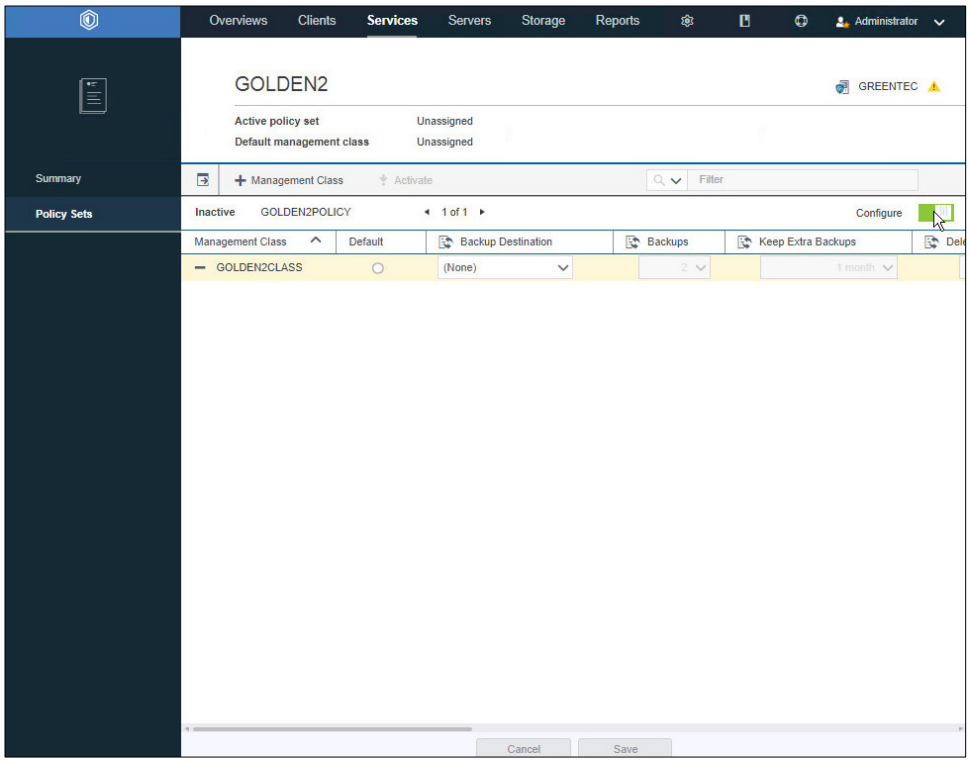
   `define mgmtclass golden goldenpolicy goldenclass`



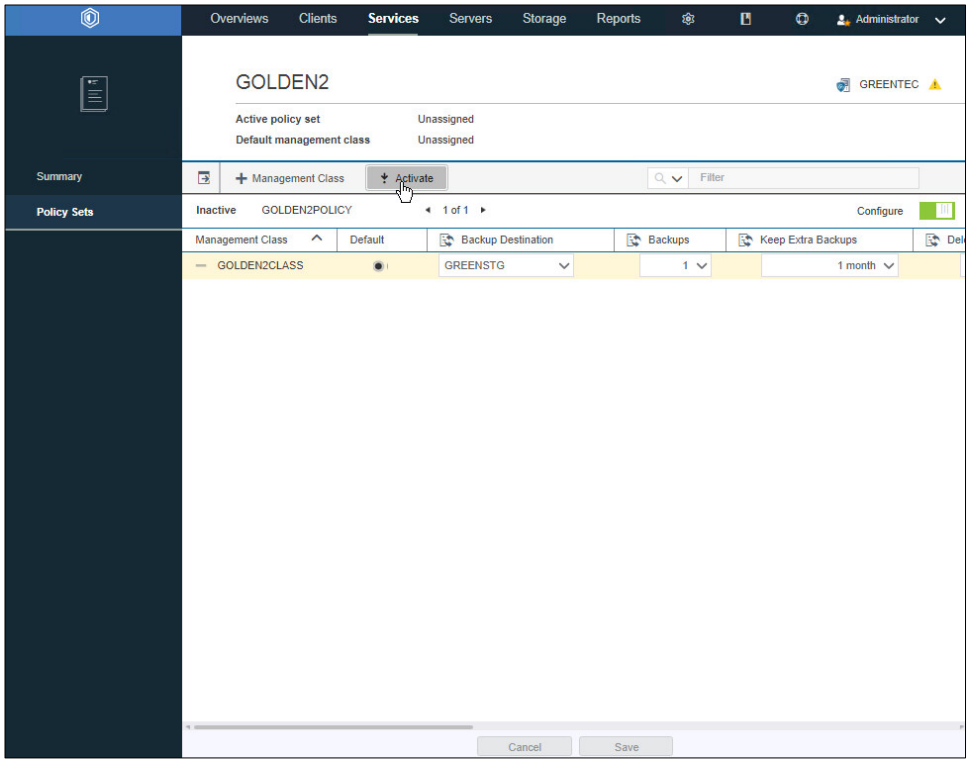
5. Click **Services > Policy Sets**.



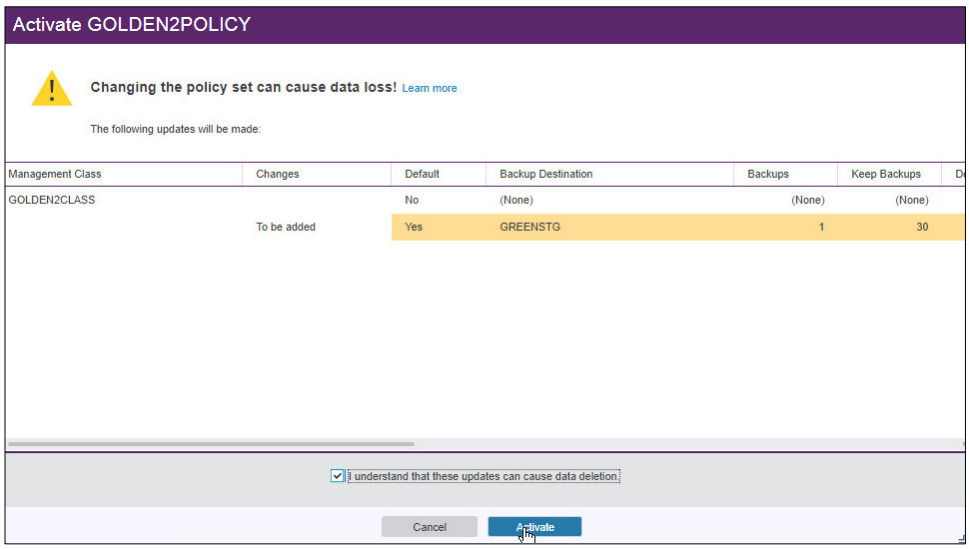
6. Toggle the **Configure** button. This should allow you to edit the settings of the newly created management class.



7. Select **Default**.
8. For **Backup Destination**, select the storage pool you just created.
9. For **Backups**, select **1**.
10. Select the rest of the settings per your organization's needs.



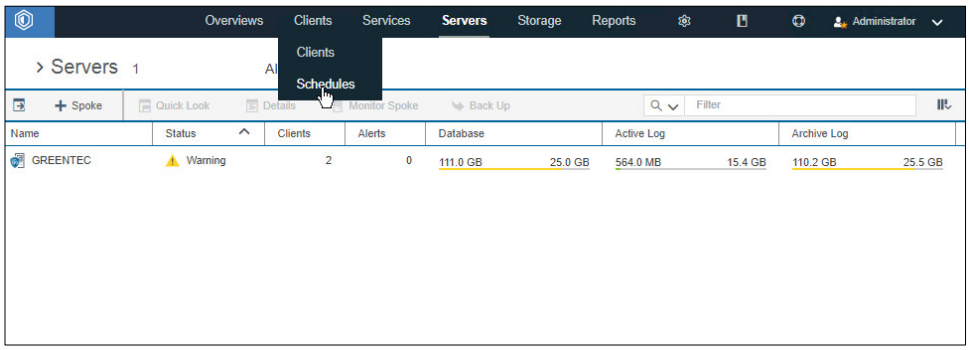
11. Click the **Activate** button.
12. Check the box next to **I understand that these updates can cause data deletion**.



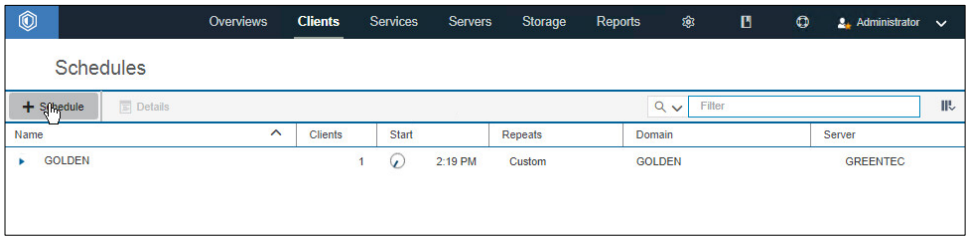
13. Click **Activate**.

2.13.6 Create a Schedule That Uses the New Policy

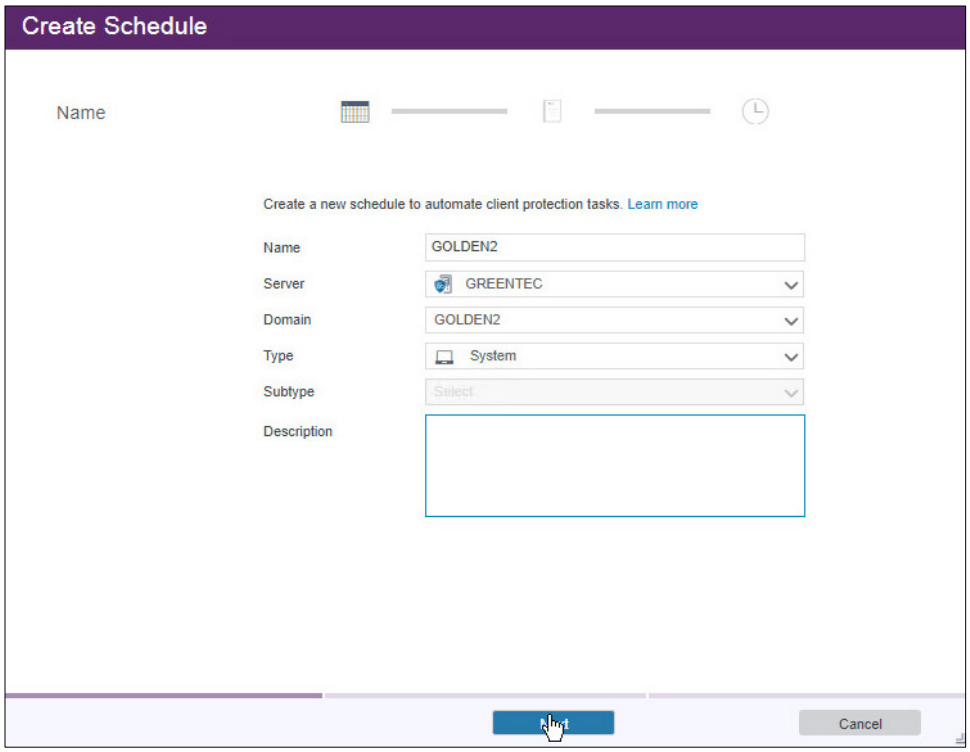
1. On the primary IBM Spectrum Protect Server log in to the Operations Center.



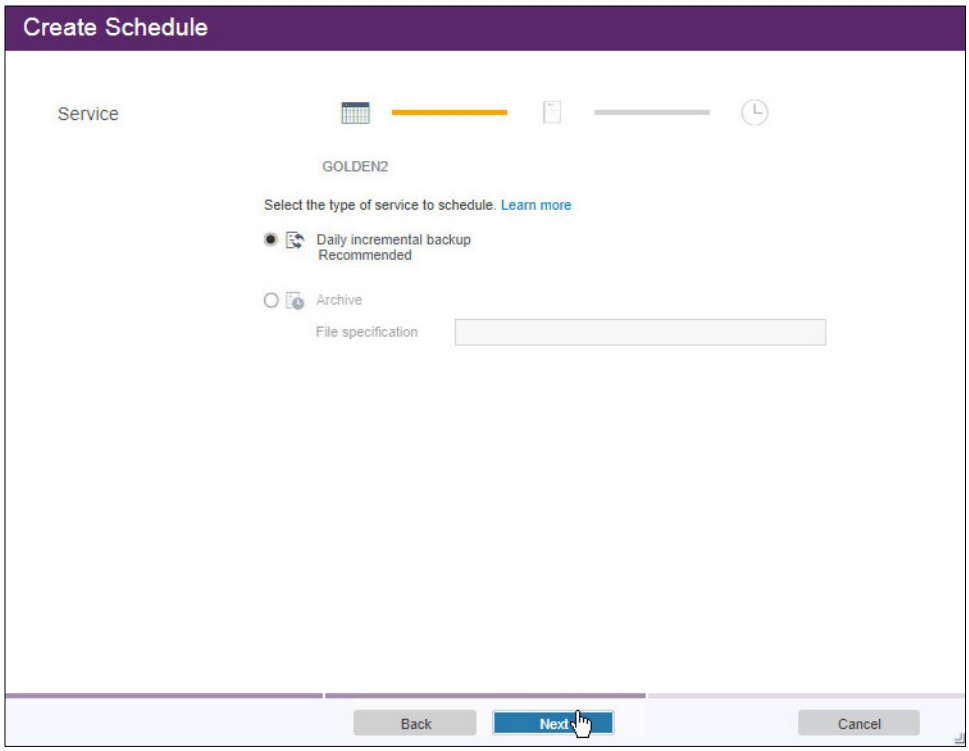
2. Go to **Clients > Schedules**.



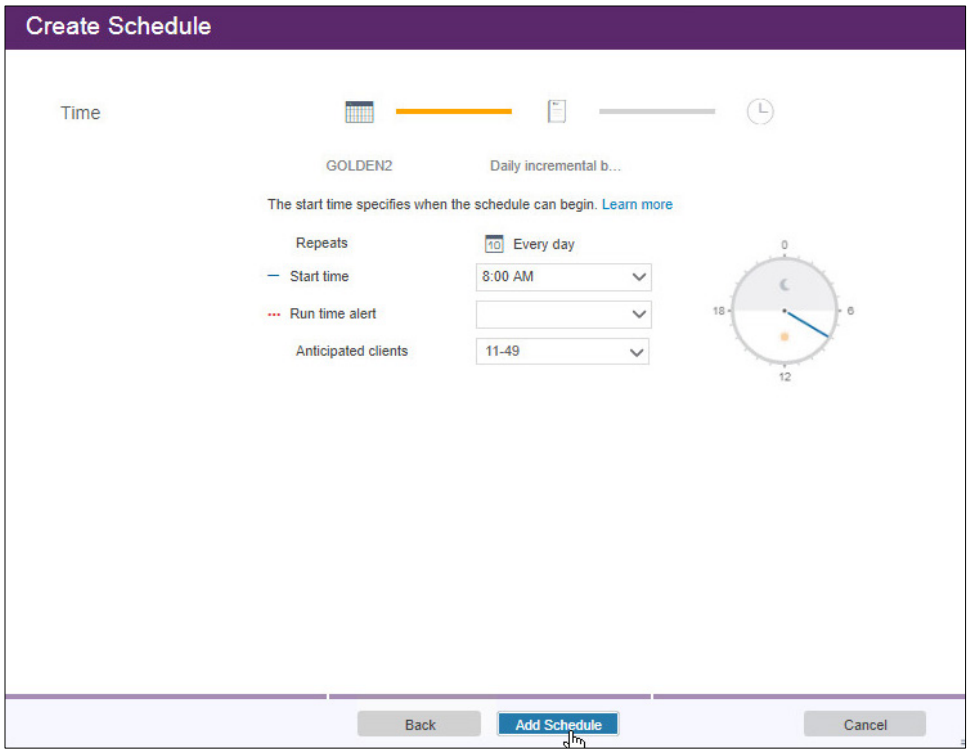
3. Click **+Schedule**.
4. Enter a **name** for the schedule.
5. For **Server**, select the GreenTec server.
6. For **Domain**, select the policy domain you just created.
7. For **Type**, select **System**.



8. Click **Next**.
9. Select **Daily incremental backup**.



10. Click **Next**.
11. Configure the schedule settings for your organization's needs. This can be changed later.

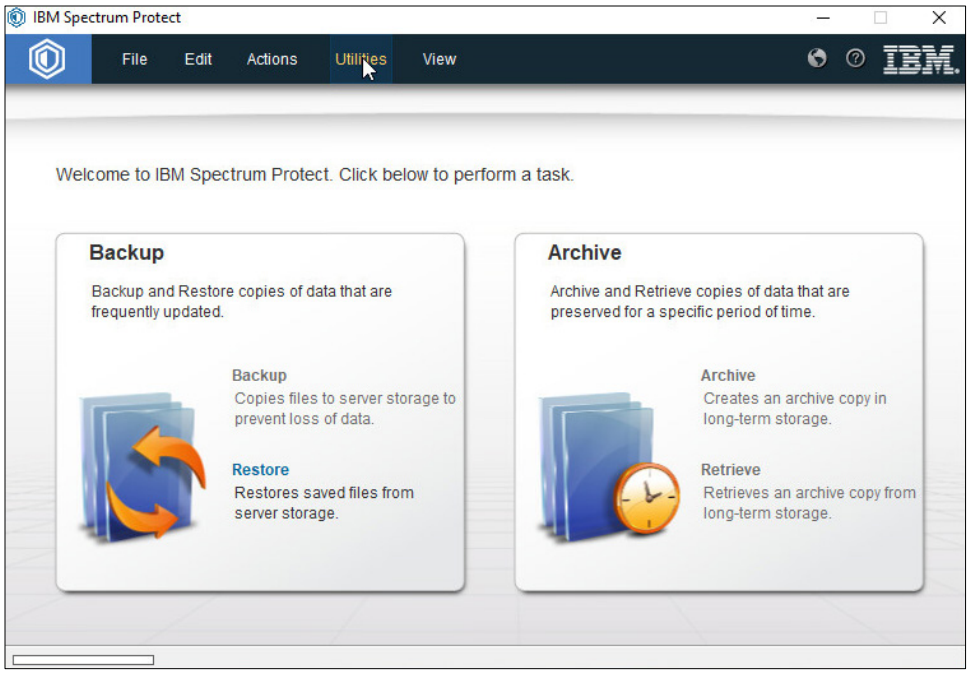


12. Click **Add Schedule**.
13. From the command builder, run the following command to update the schedule:

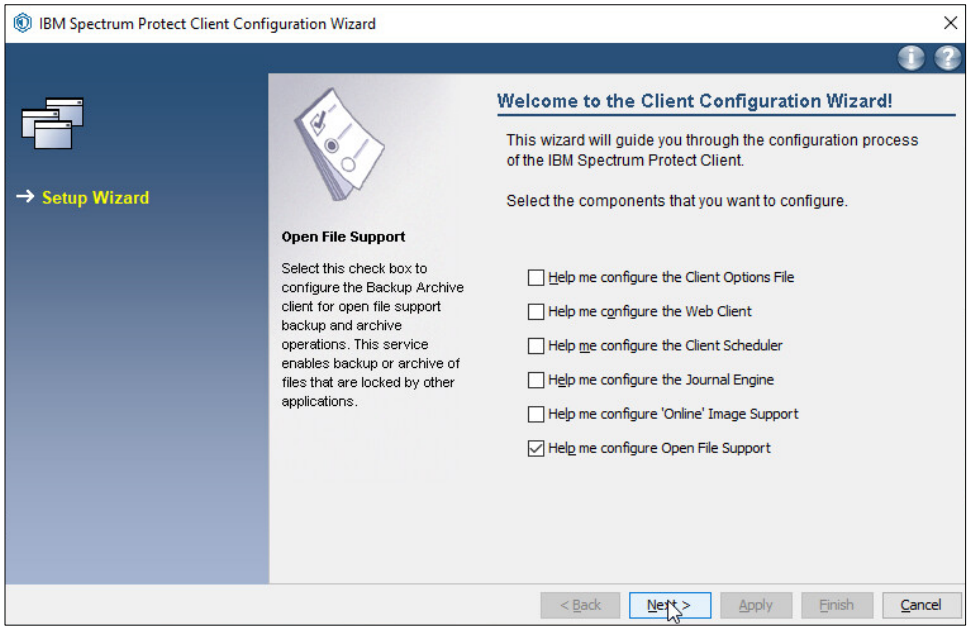
```
update schedule golden golden starttime=now action=backup type=client
objects="c:\*" startdate=06/10/2017 perunits=onetime
```

2.13.7 Installing Open File Support on the Client

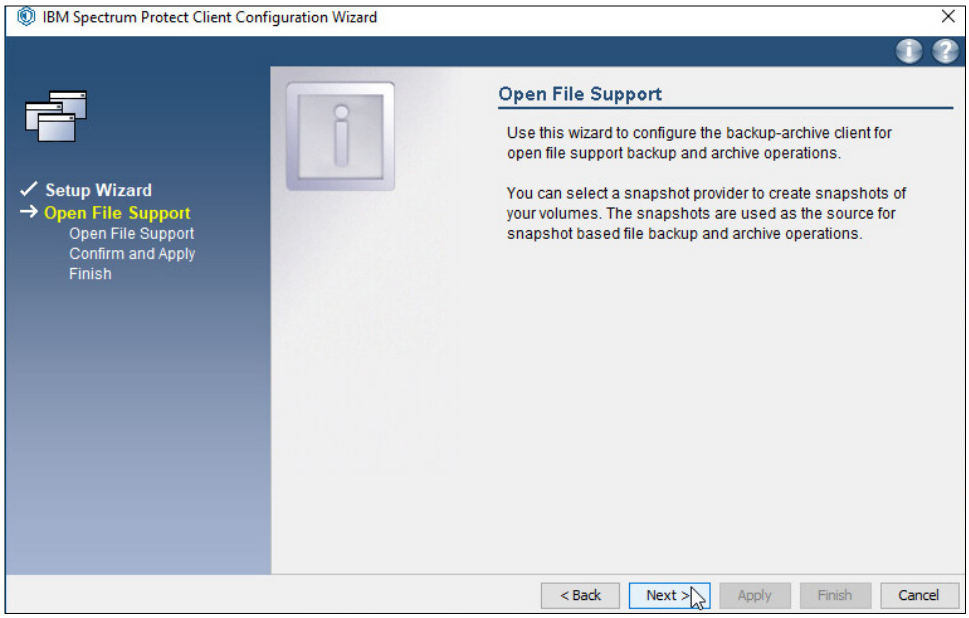
1. Open the client machine (with the IBM Backup Archive Client installed) to make a golden disk.



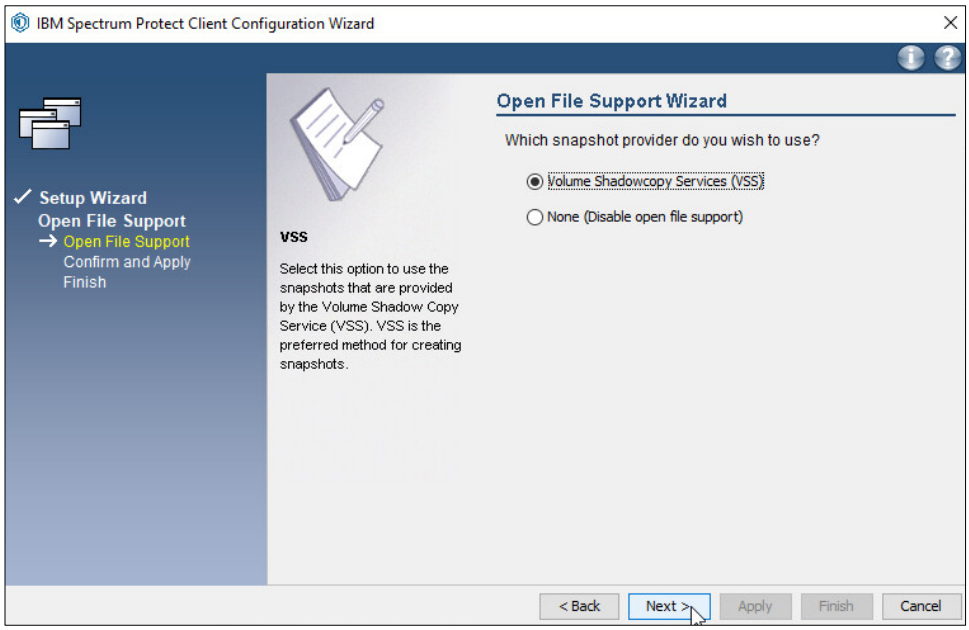
2. Open the **IBM BA Client**.
3. Click **Utilities > Setup Wizard**.
4. Check the box next to **Help me configure Open File Support**.



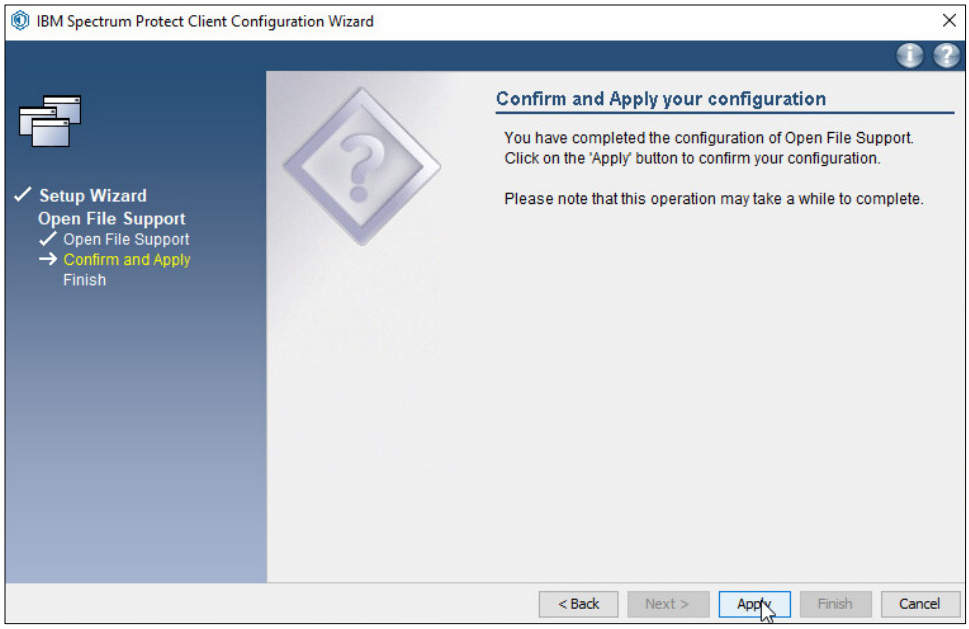
5. Click **Next**.



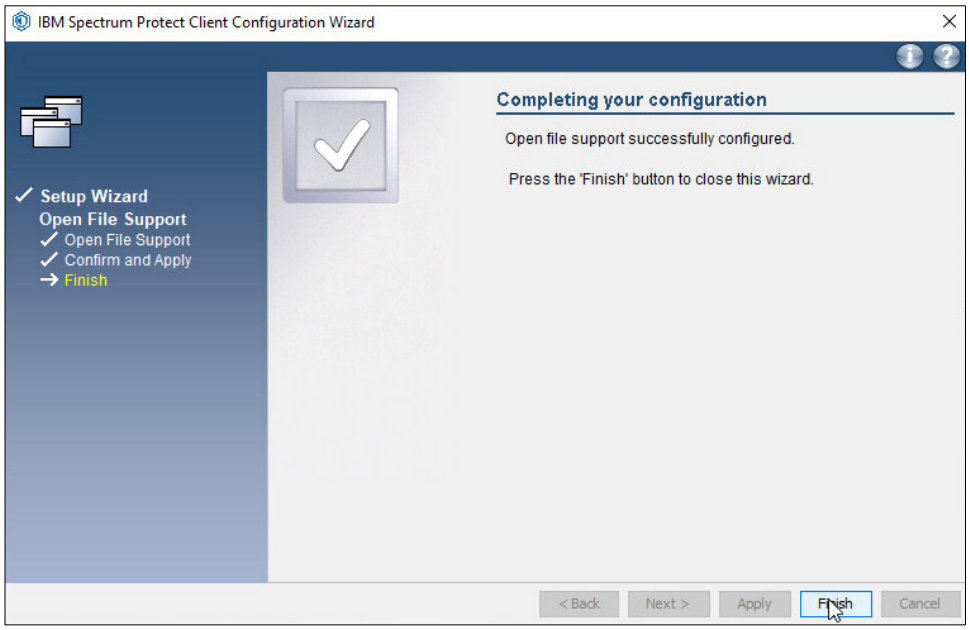
6. Click **Next**.
7. Select **Volume Shadowcopy Services (VSS)**.



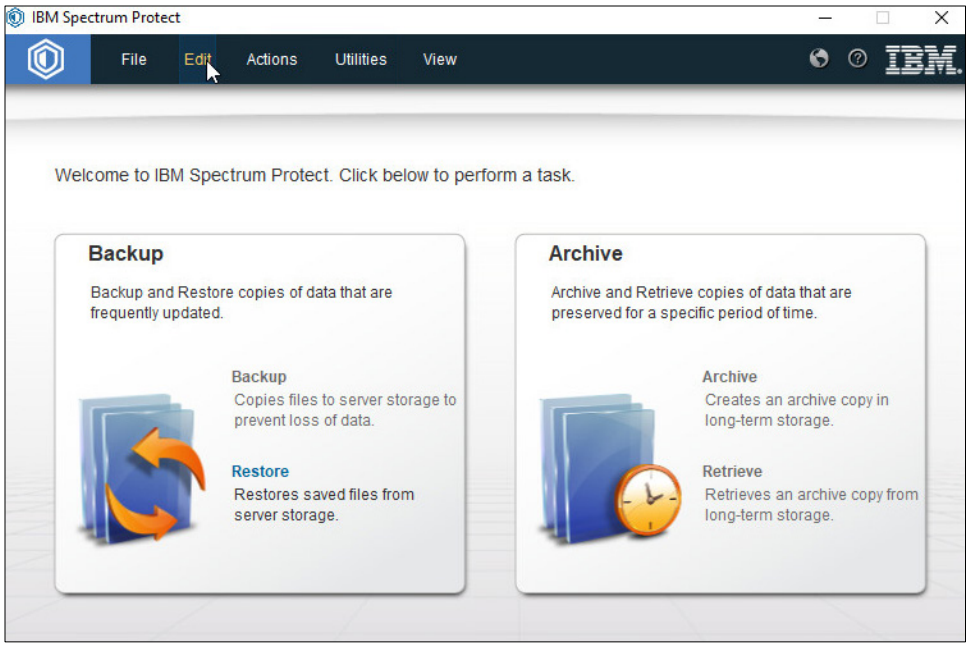
8. Click **Next**.



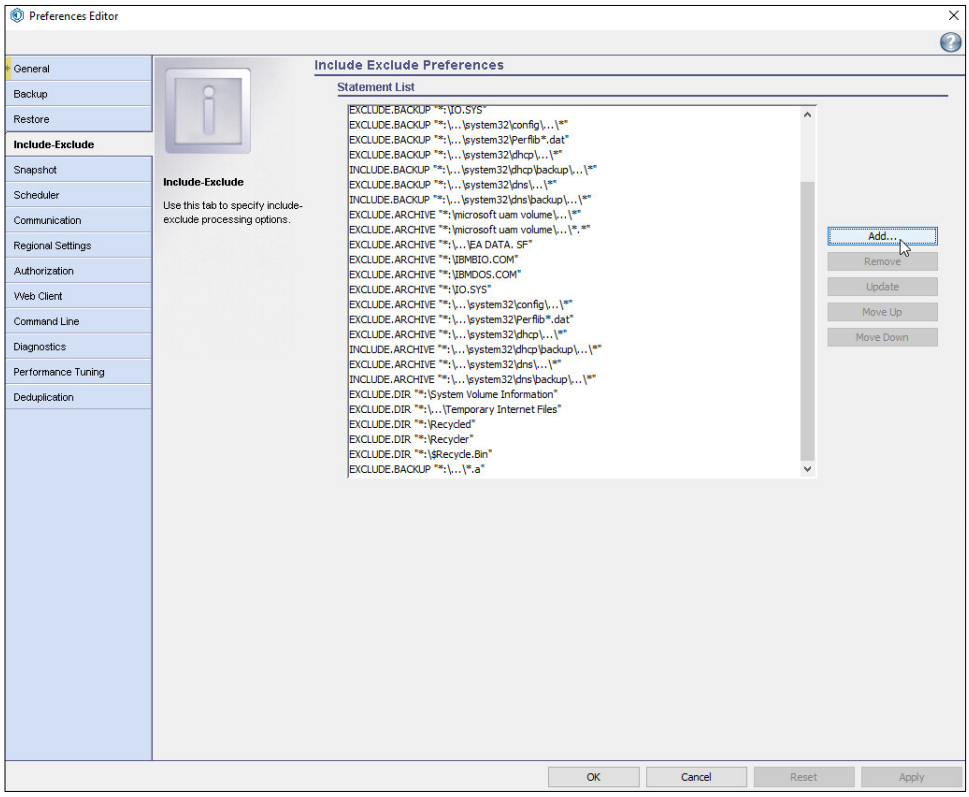
9. Click **Apply**.



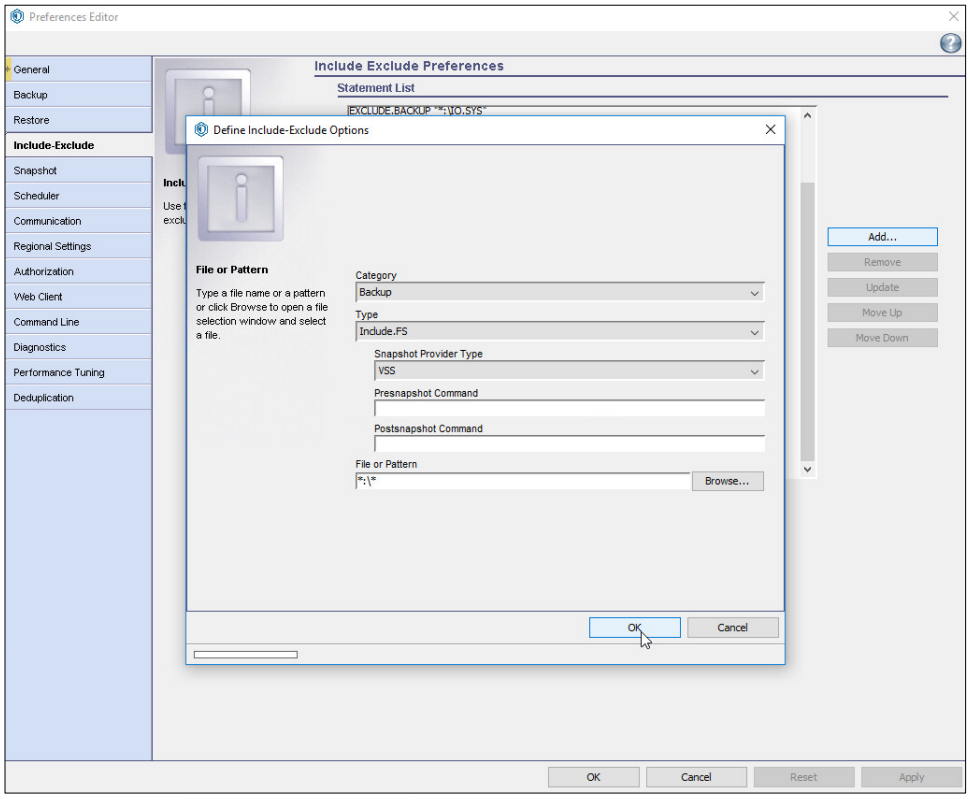
10. Click **Finish**.
11. **Restart** the BA Client.



12. Click **Edit > Client Preferences**.
13. Click the **Include-Exclude tab**.



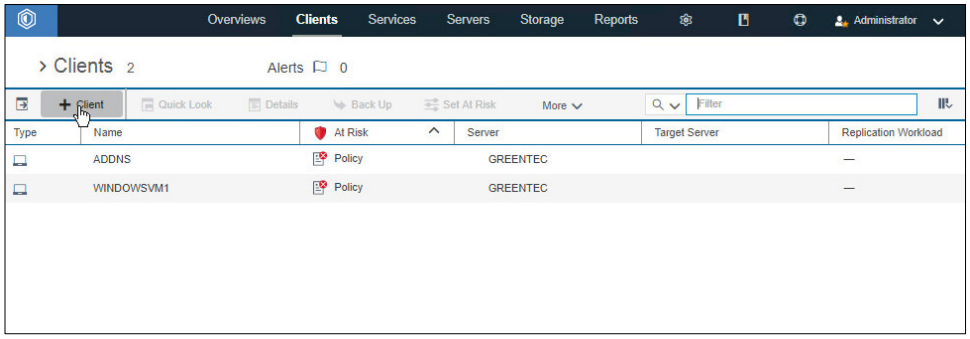
14. Click **Add**.
15. For **Category**, select **Backup**.
16. For **Type**, select **Include.FS**.
17. For **Snapshot Provider Type**, choose **VSS**.
18. For **File or Pattern**, enter ***:****.



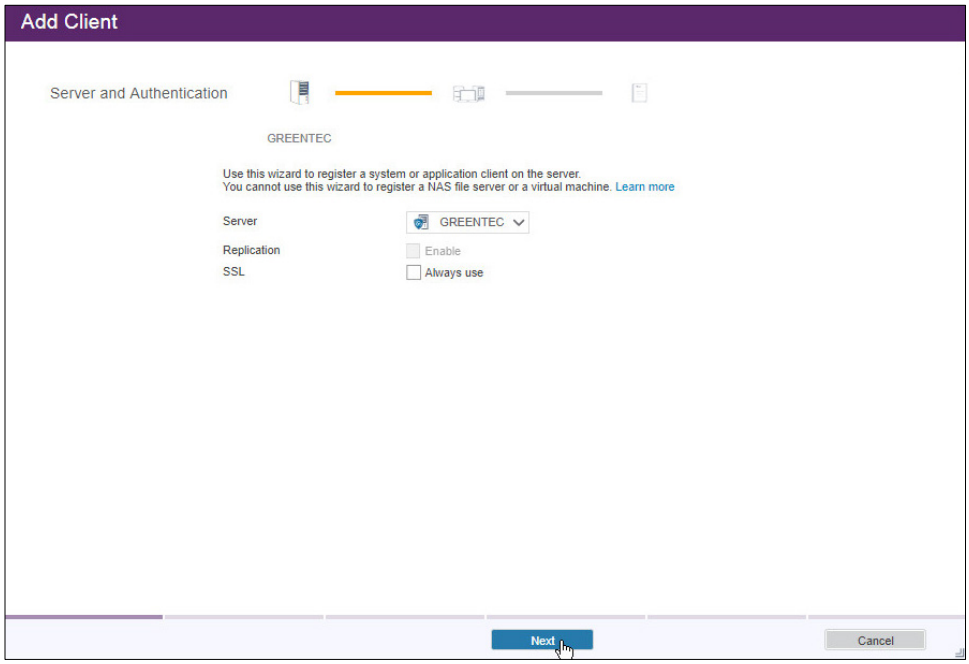
19. Click **OK**.

2.13.8 Temporarily Add Client to GreenTec IBM Server

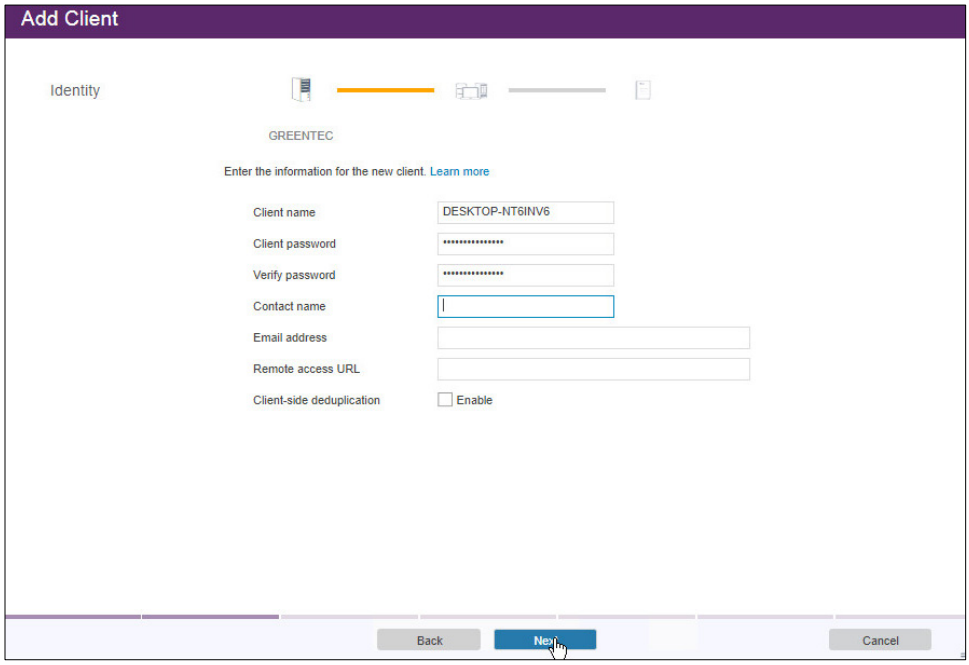
1. Assuming your GreenTec disks are on a separate IBM server, you will need to connect the client you wish to migrate in order to use the created schedule. On the GreenTec server, click **Clients**.



2. Click **+Client**.
3. Select the GreenTec server.

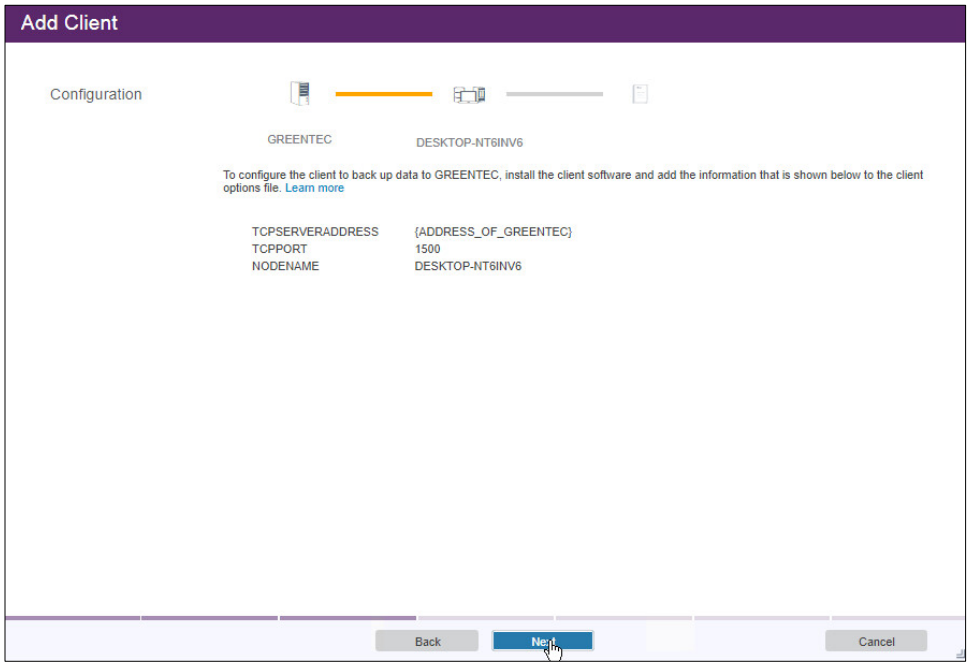


4. Click **Next**.
5. Enter the information for the client you are migrating to this server.

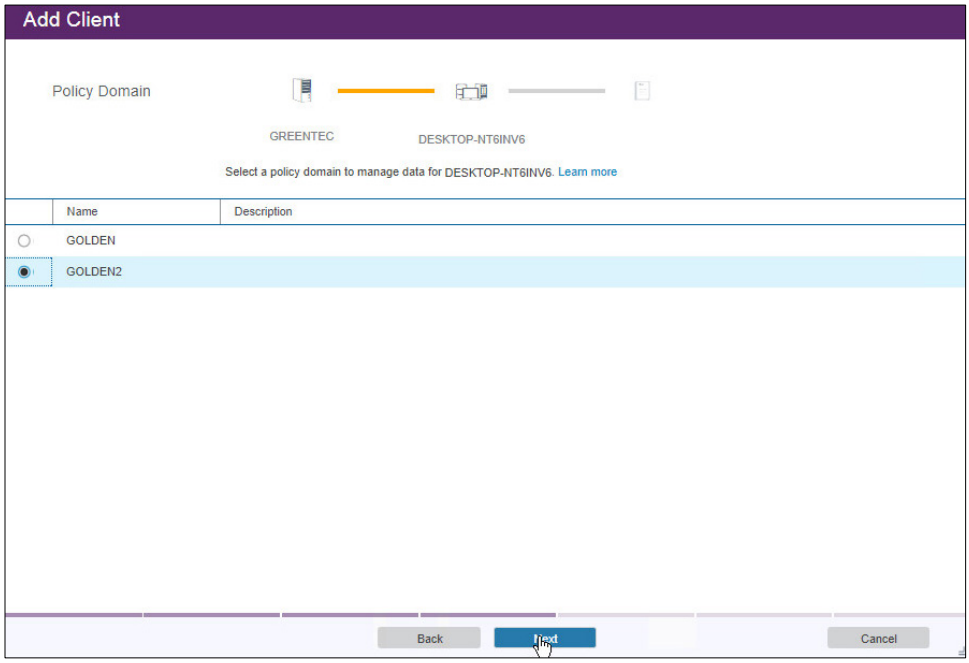


6. Click **Next**.

7. Take note of the information presented here, namely the **IP** and **port** provided, as you will need it on the client machine to connect to the server.

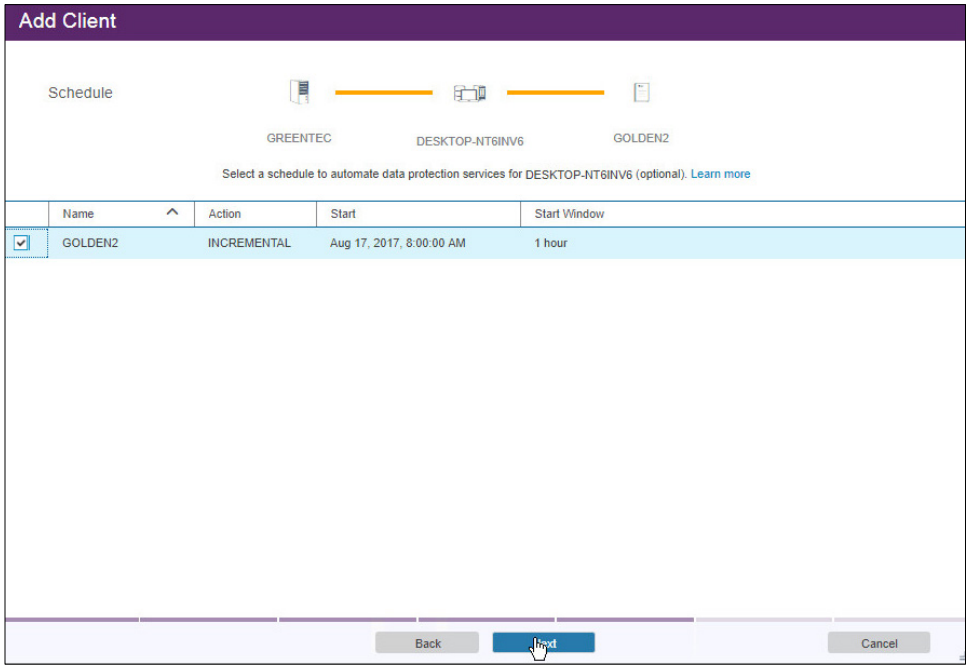


8. Click **Next**.
9. Select the policy domain you created.

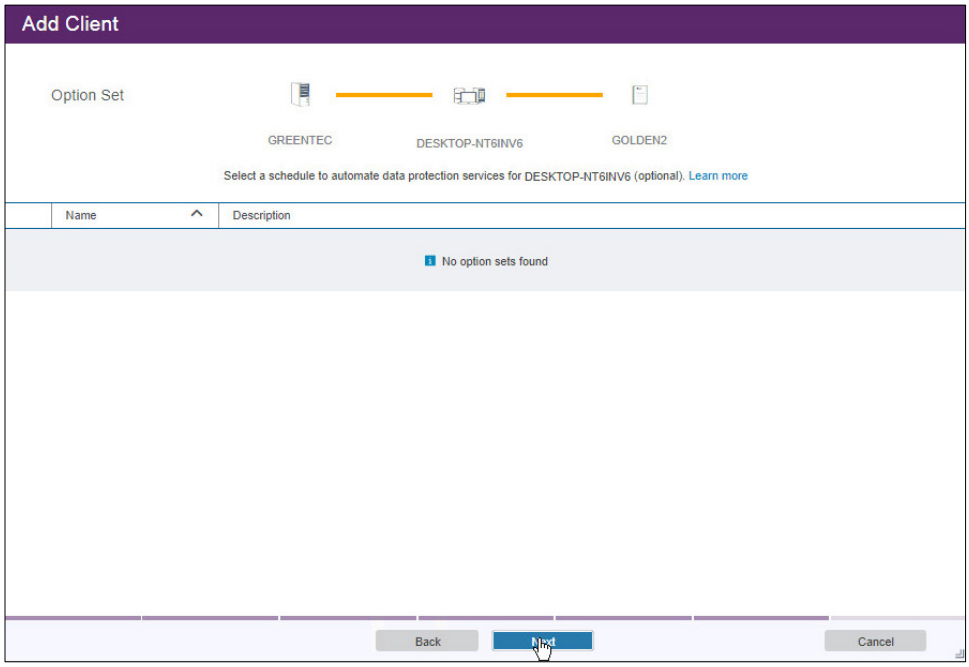


10. Click **Next**.

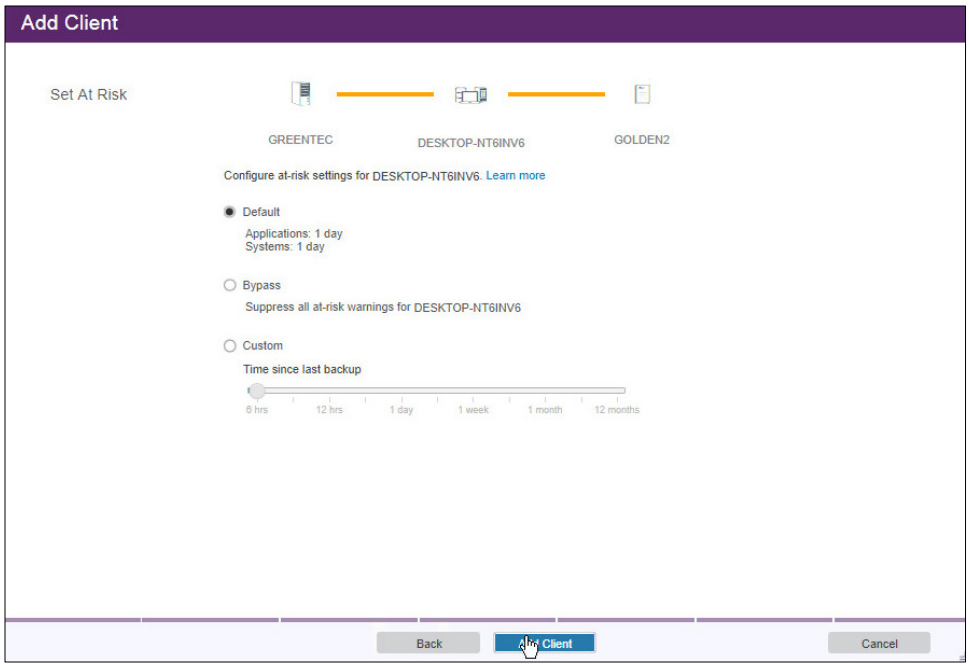
11. Select the schedule created earlier.



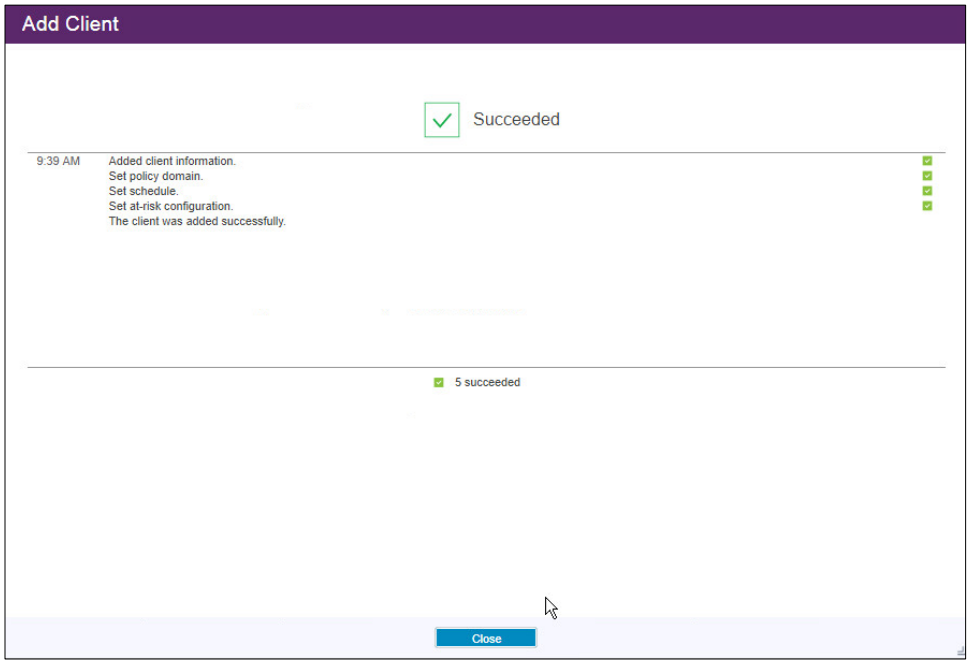
12. Click **Next**.



13. Click **Next**.
14. Select the at-risk options per your organization's needs.

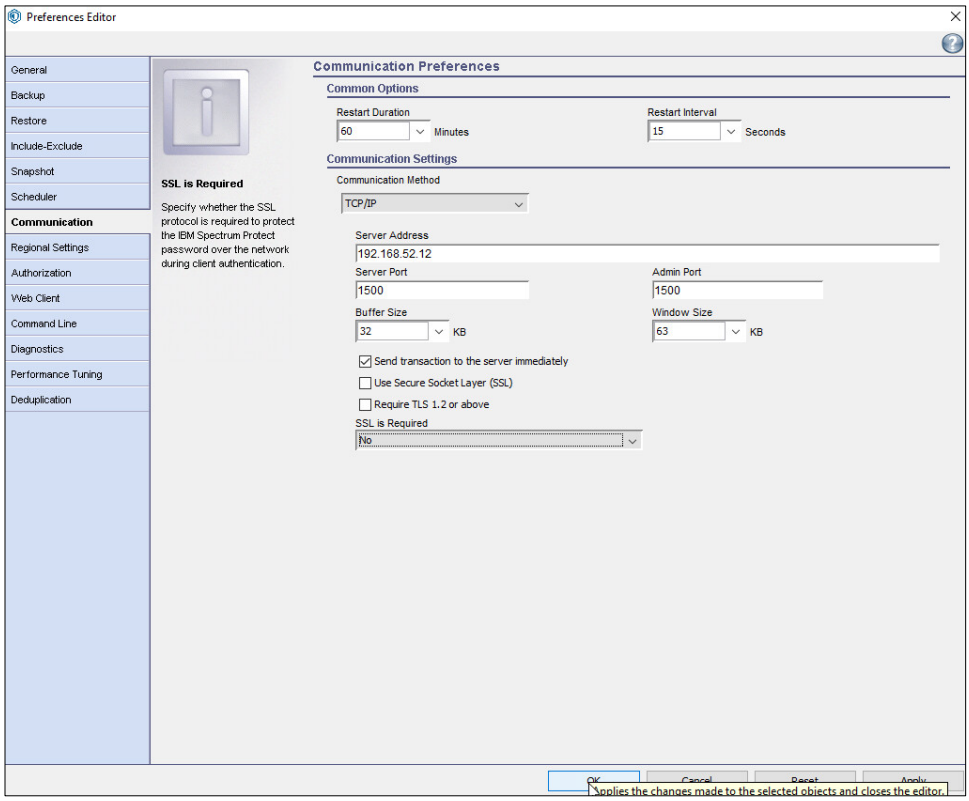


15. Click **Add Client**.



16. Click **Close**.
17. On the client machine, open the BA client.
18. Click **Edit > Client Preferences**.

19. Click the **Communication** tab, and enter the new **server address** and **port**. Only leave **Use SSL** checked if you have set it up for this new server. Similarly, unselect **SSL is required** if you did not setup SSL on this second server.



20. **Restart** the BA client. The client should now connect to the new server.
21. You may be prompted for a password. Enter the password and press **Enter**.
22. To start the schedule, issue the following command in the Operations Center command builder:

```
update schedule golden golden startdate=today starttime=now
```

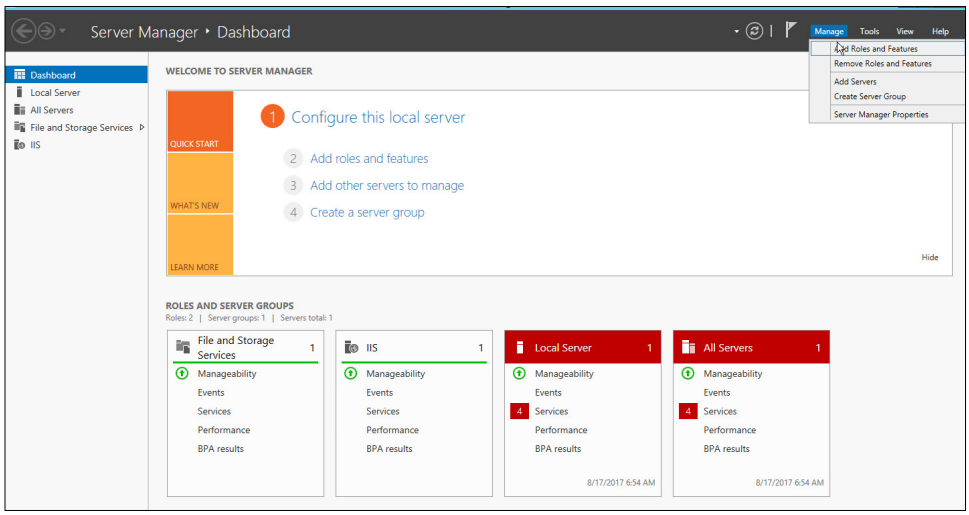
2.14 Integration: Backing Up and Restoring System State with GreenTec

This section covers the process for backing up (and restoring) the Windows System State on a Windows Server with GreenTec as a backup medium. The backup of user information as well as other system state information to a networked GreenTec WORMdisk is intended for the recovery of damage to the Windows system state, such as account permission modification, account creation, account deletion, and various other applicable scenarios.

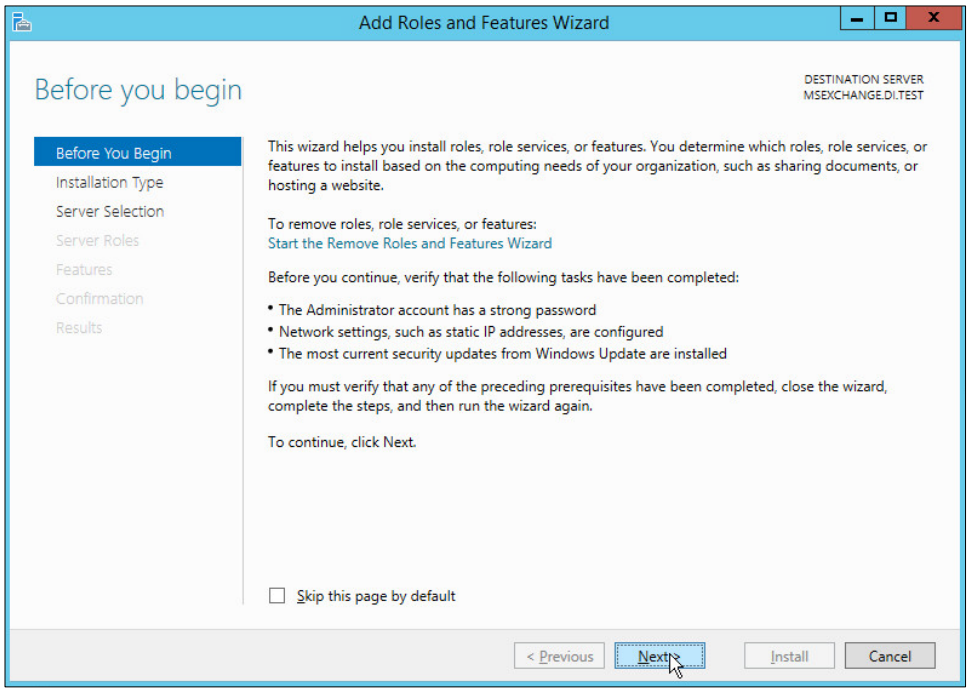
2.14.1 Installing Windows Server Essentials for System State Backup Capability

(NOTE: For older machines, IBM Spectrum Protect's option to backup **SystemState** may be sufficient. However, for newer, more complex versions of Windows, such as Windows Server 2012 and Windows 8+, you should use the following procedure.)

1. Open **Server Manager**.

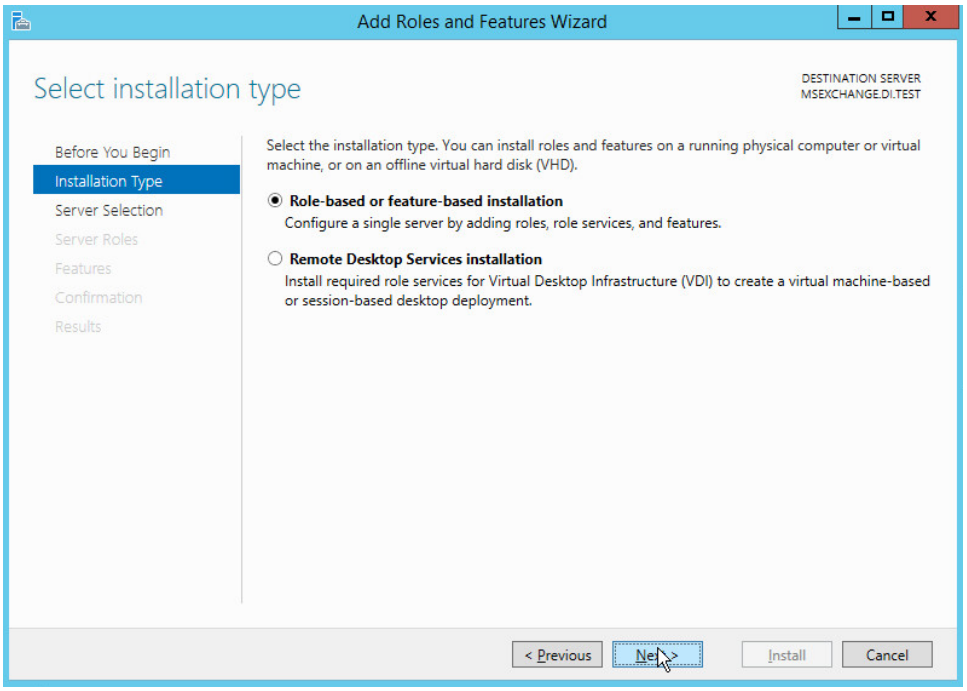


2. Select **Manage > Add Roles and Features**.

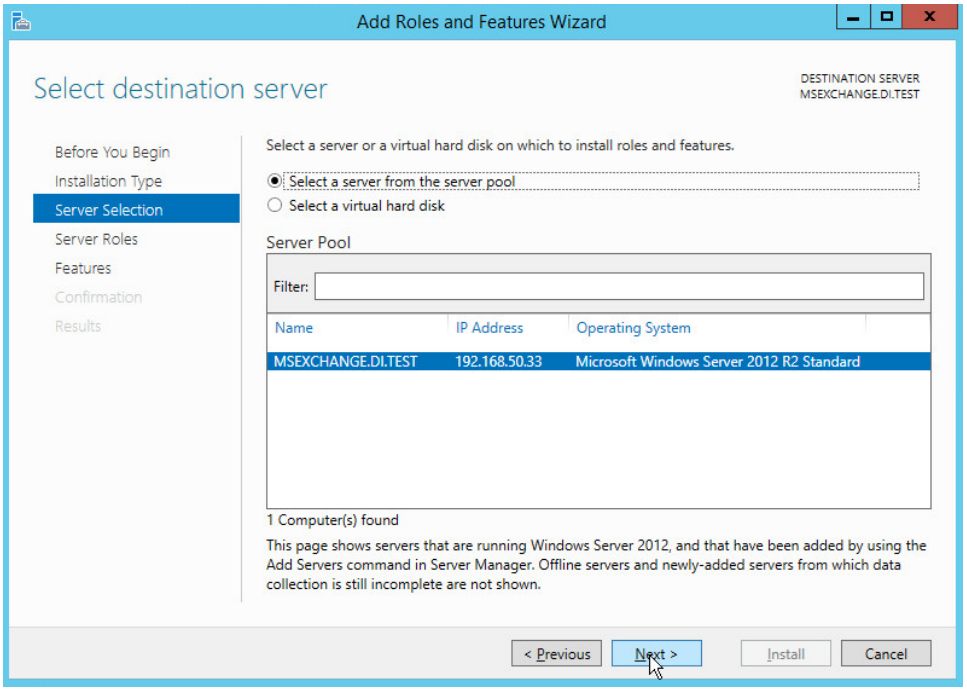


3. Click **Next**.

4. Select **Role-based or feature-based installation**.

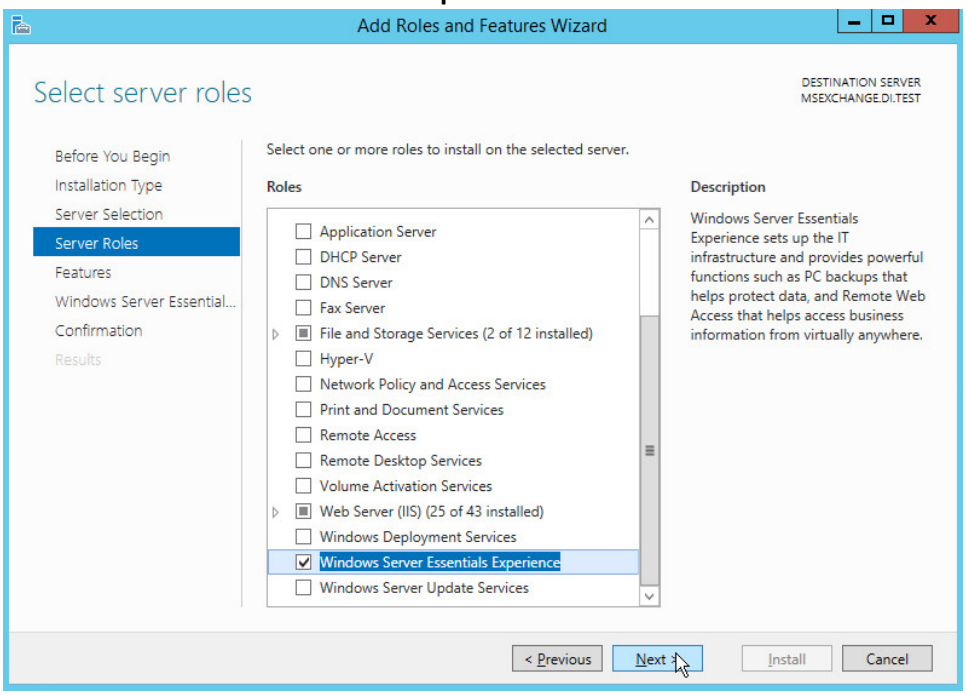


5. Click **Next**.
6. Select the server.

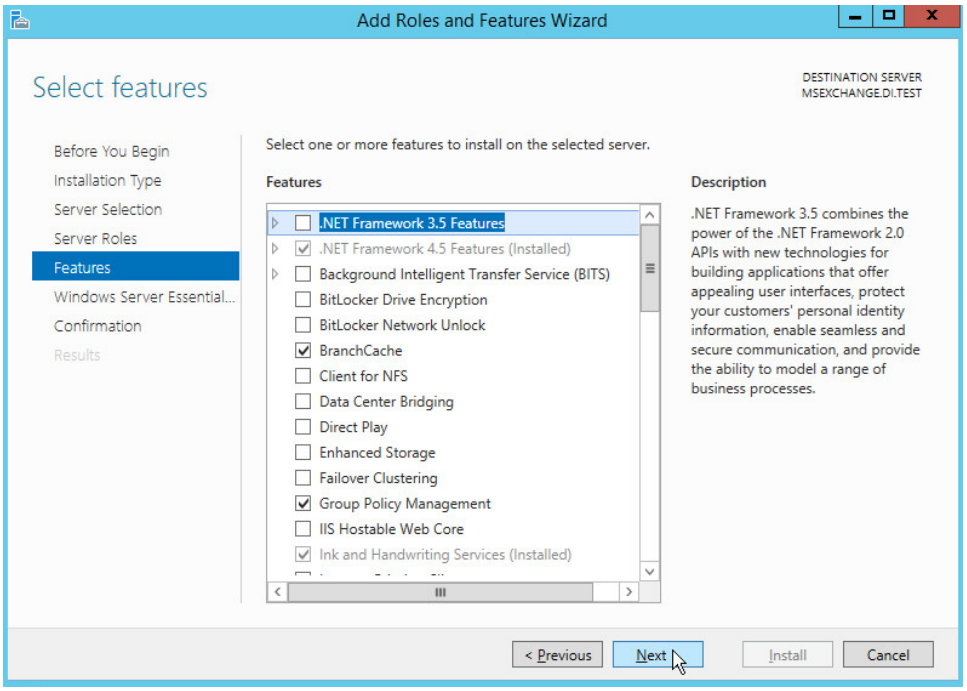


7. Click **Next**.

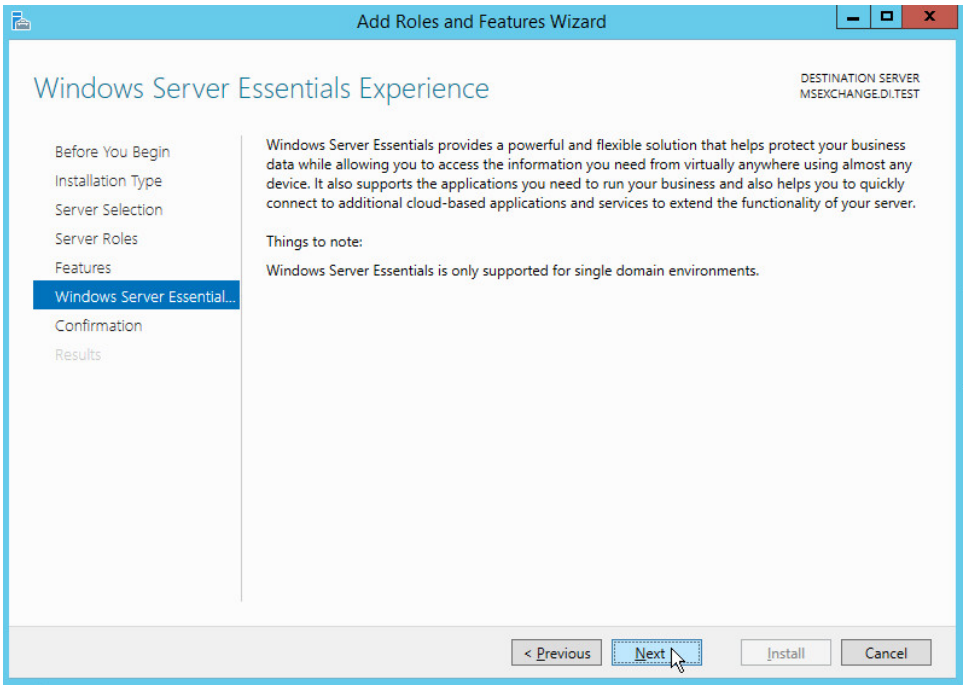
8. Select **Windows Server Essentials Experience**.



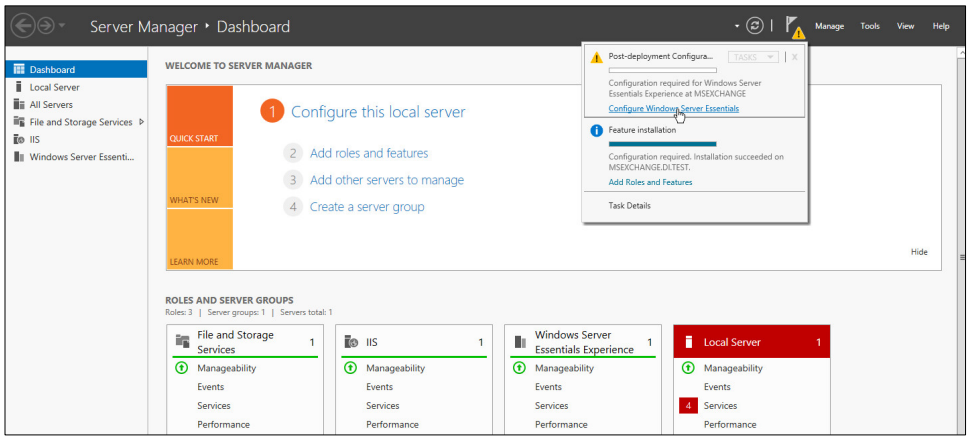
9. Click **Next**.



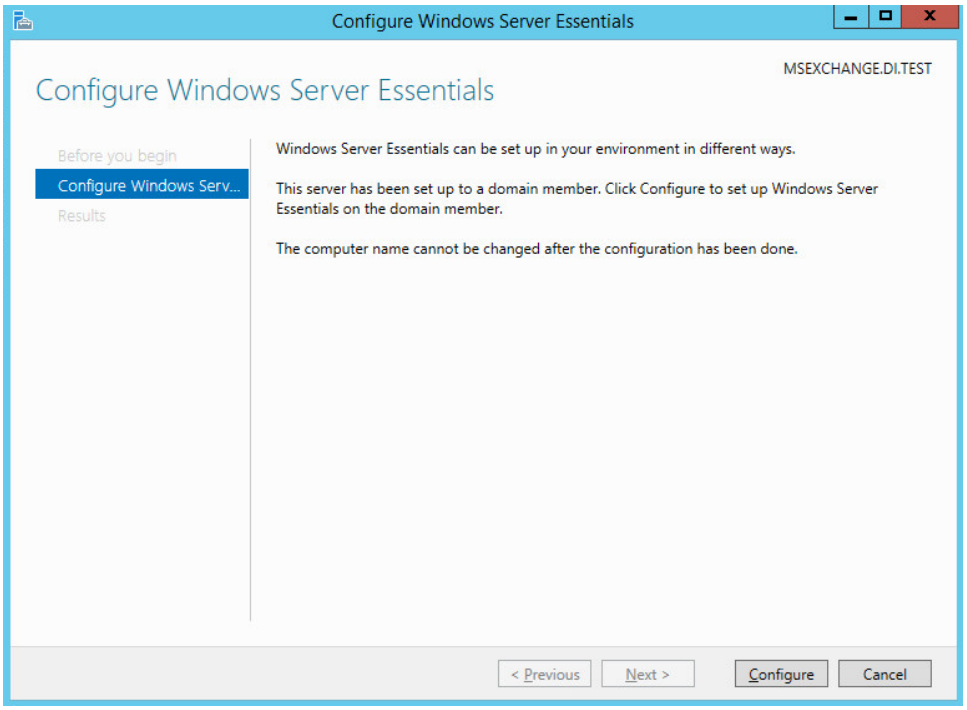
10. Click **Next**.



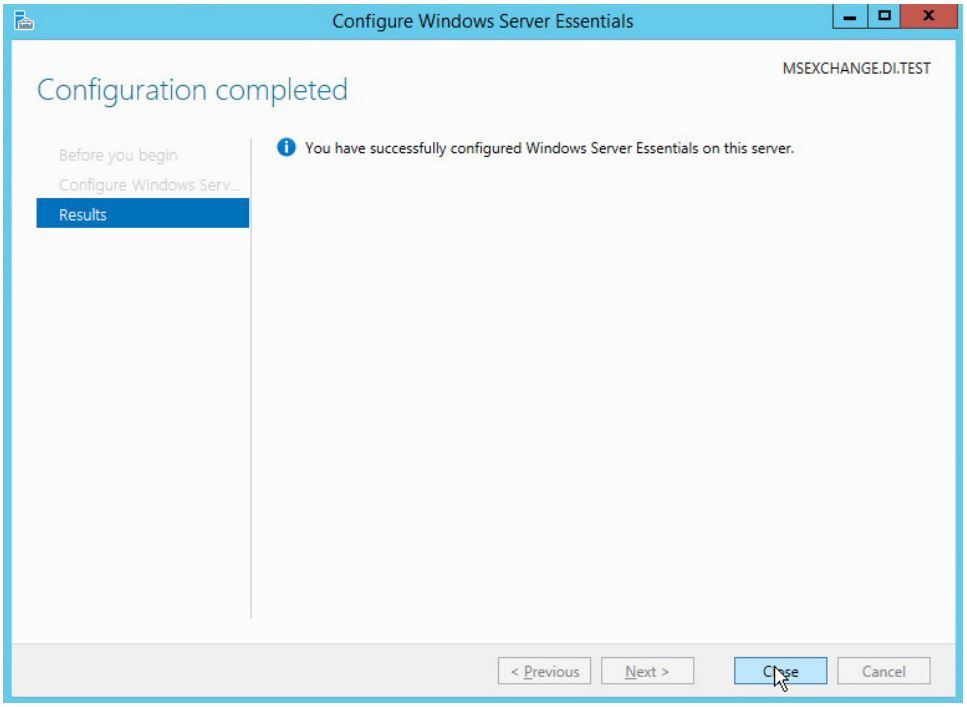
11. Click **Next**.
12. Click **Install**.



13. Click **Configure Windows Server Essentials Experience**.



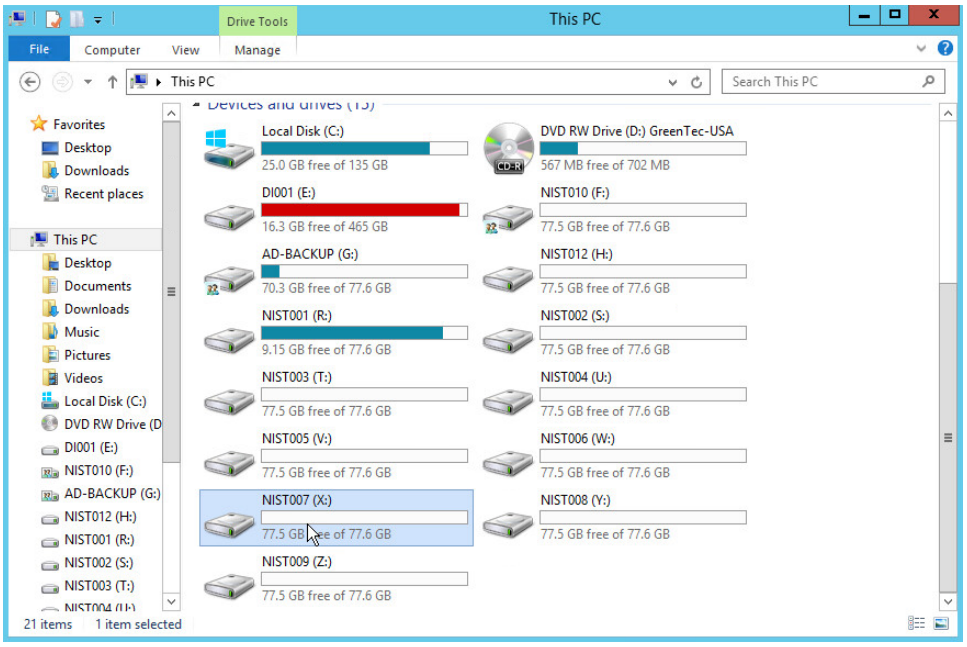
14. Click **Configure**.



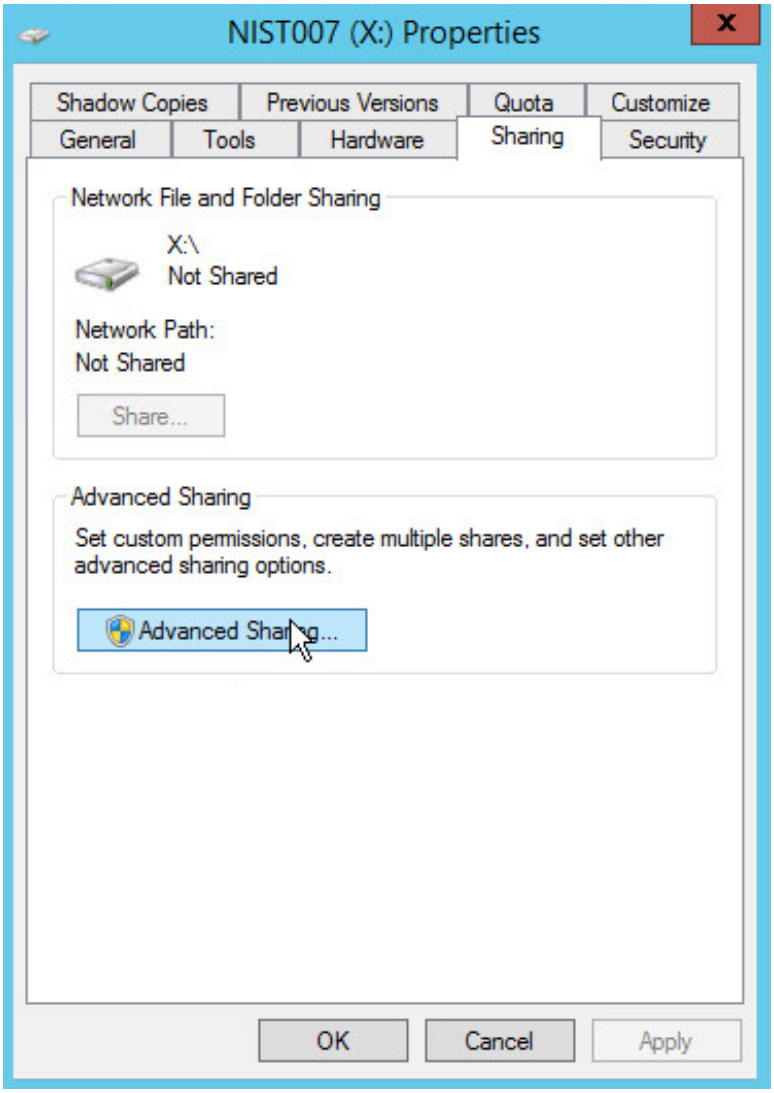
15. Click **Close**.

2.14.2 Configure Network Accessible GreenTec Disk

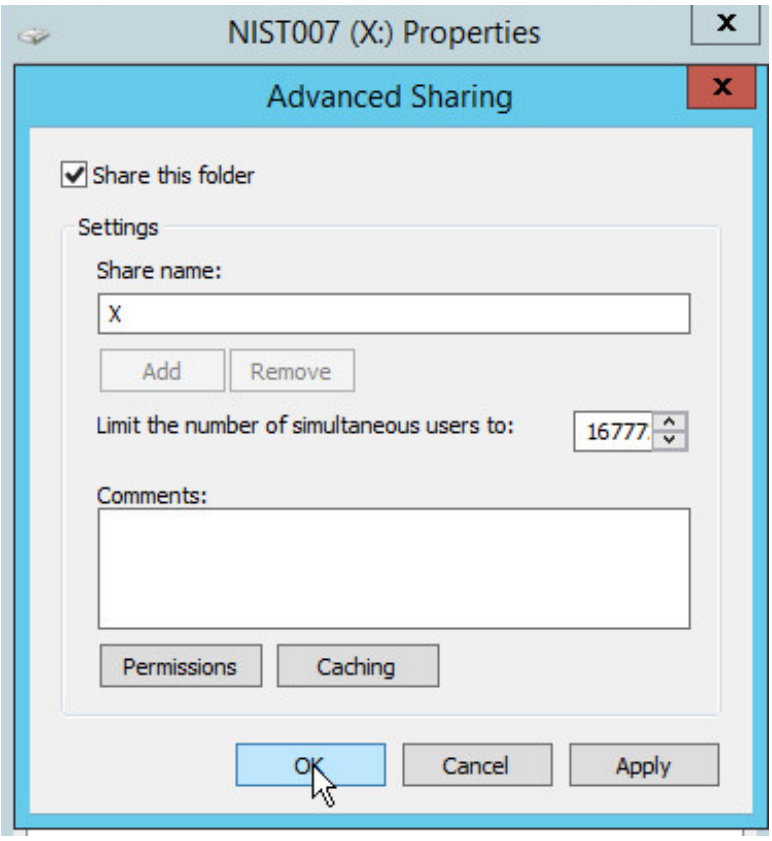
1. To configure a GreenTec disk to be network accessible, right click the disk on the GreenTec server.



2. Click **Share With > Advanced Sharing**.



3. Click **Advanced Sharing**.
4. Check the box next to **Share this folder**.

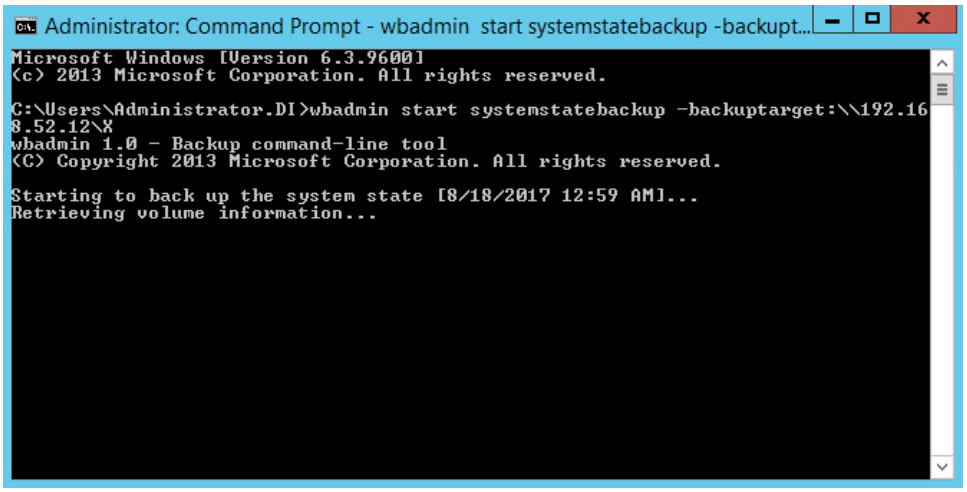


5. Click **OK**.
6. Click **Close**.

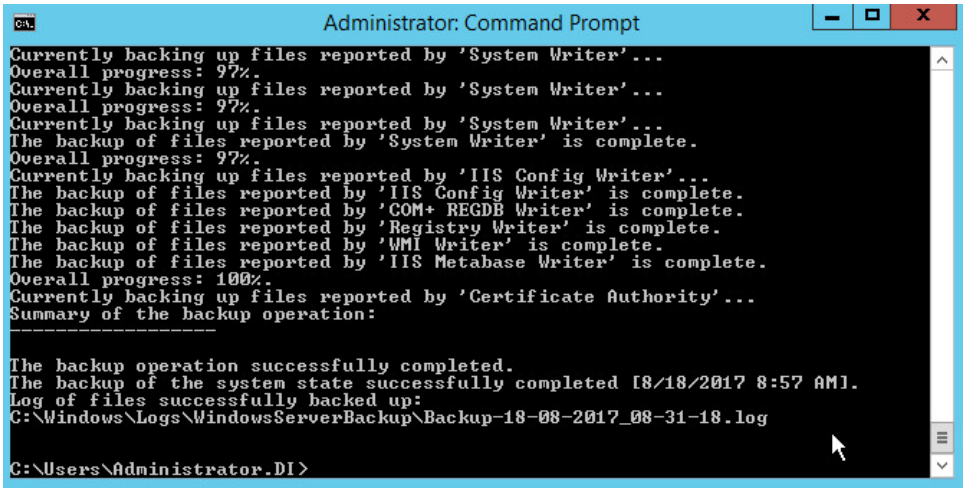
2.14.3 Backup the System State

1. Go to command prompt on the Active Directory server and enter the following command:

```
wbadmin start systemstatebackup -backuptarget:z:
```



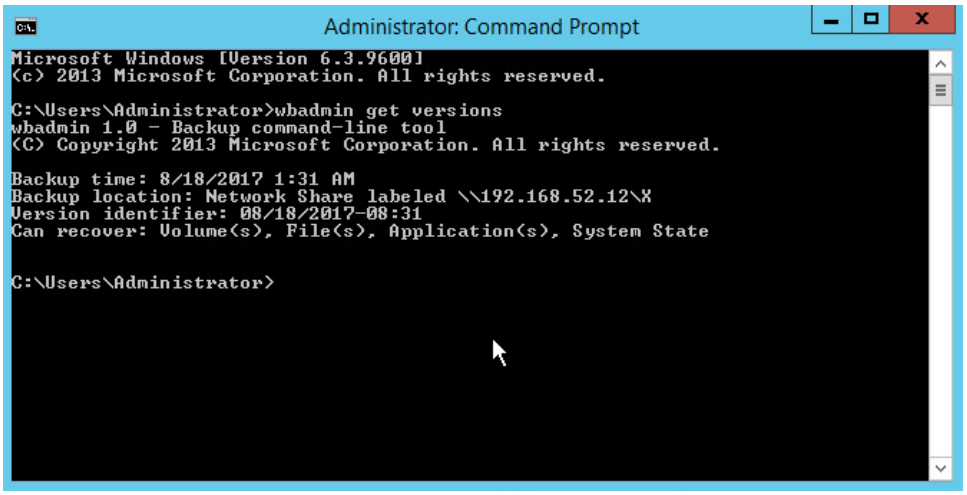
(Instead of **z:**, put the location of a disk for the system state backup. You will get an error if you attempt to use the same location as the disc you are trying to backup. Examples of acceptable targets: **C:**, **Z:**, **\\backup-storage\g**)



2.14.4 Restoring the System State

1. After determining the point in time of a malicious event, restart the Active Directory Server and press **F2 > F8** to start the **Advanced Boot menu**.
2. Select **Directory Services Repair Mode**.
3. Log in as the machine administrator.
4. Open a command prompt.
5. Enter the following command to see the backup versions available:

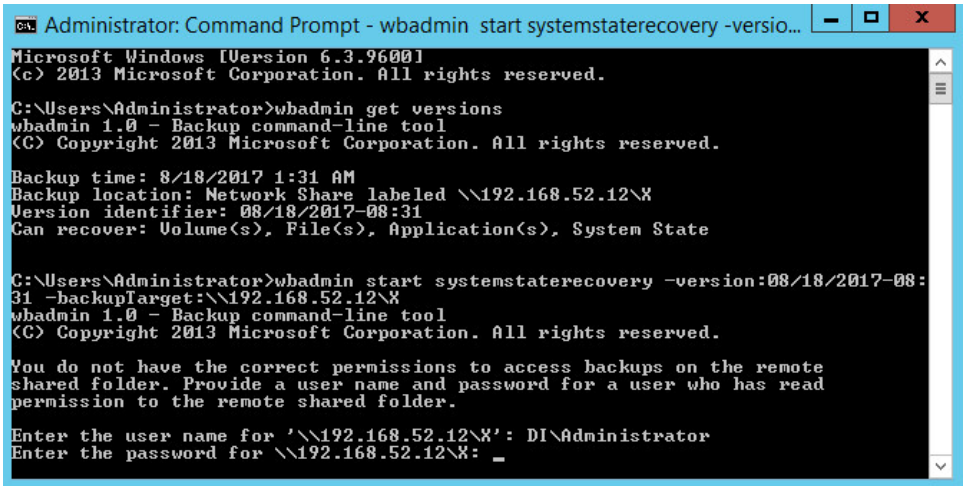
```
wbadmin get versions
```



6. Enter the following command to restore to a specific version (preferably before the malicious event occurred):

```
wbadmin start systemstaterecovery -version:06/21/2017-15:33 -
backupTarget:\\192.168.52.12\g
```

(Replace the **backupTarget** with the location of the backup, and the **version** with the version to restore to.)



7. The computer will restart when you finish the restore process.

2.15 Integration: Copying IBM Backup Data to GreenTec WORMdisks

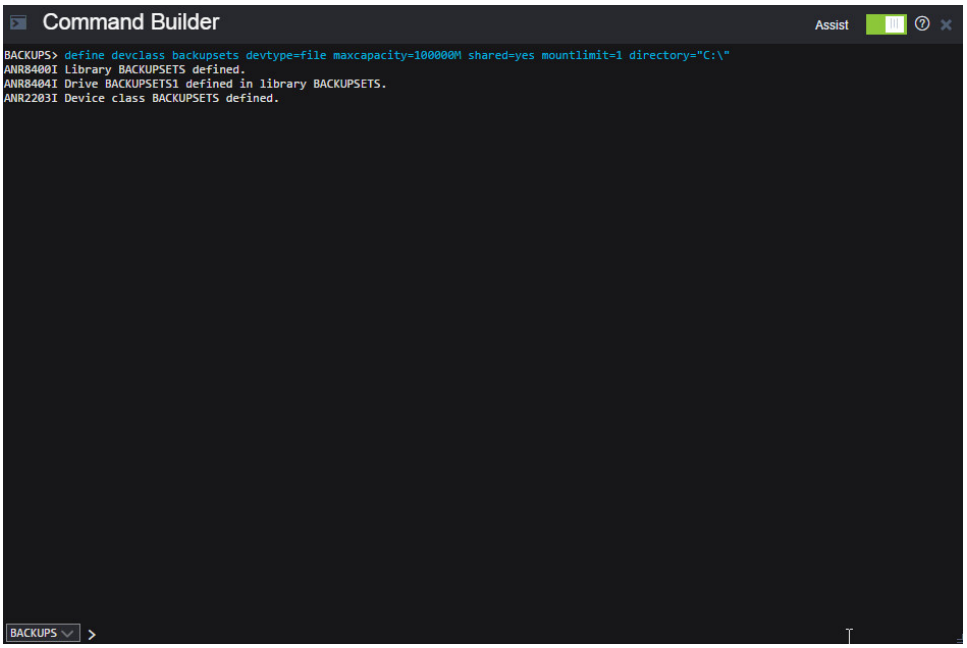
This section covers the process for integrating IBM Spectrum Protect with GreenTec WORMDisks. This integration assumes the correct implementation of IBM Spectrum Protect, as well as the existence of

GreenTec WORMdisks as described in earlier sections. The result of this integration is the capability to store all backup data created by IBM Spectrum Protect for a single client on a secure WORMDisk.

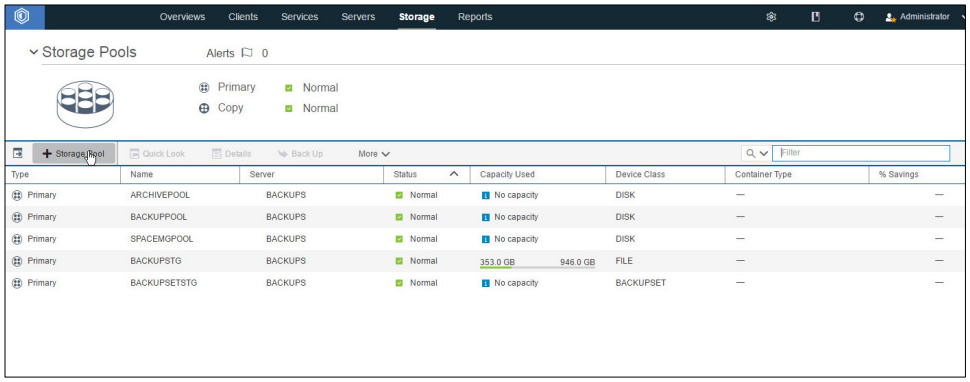
2.15.1 Copying Backups for a Single Machine to a GreenTec WORMDisk

1. On the **IBM Spectrum Protect** server, log on to **IBM Spectrum Protect Operations Center**.
2. Create a new **device class** by running the following command in the Command Builder:

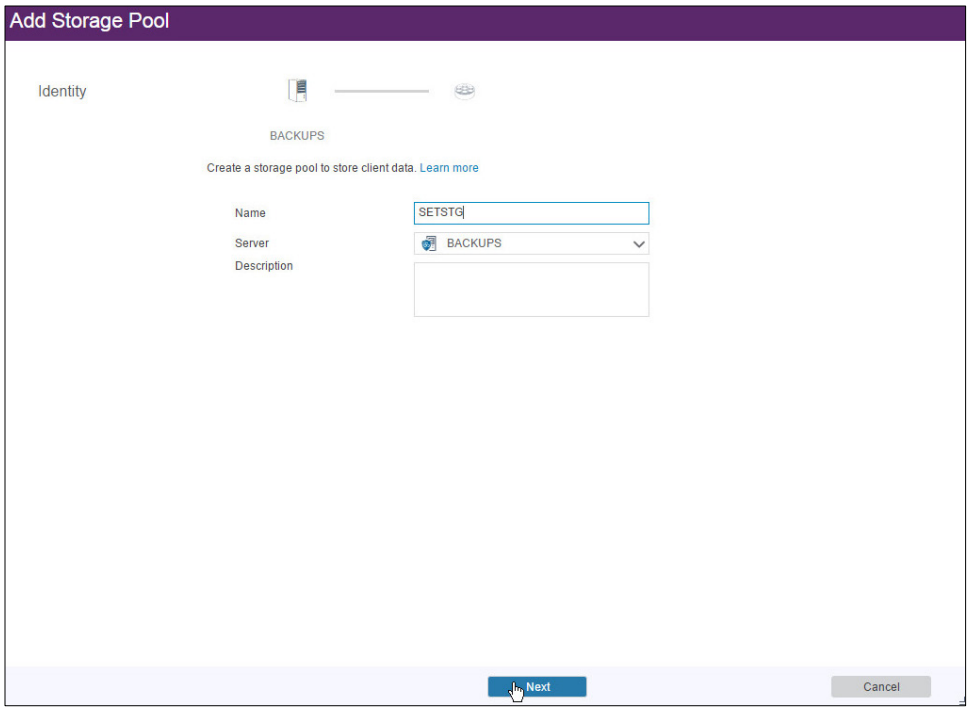
```
define devclass backupset devtype=file maxcapacity=100000M shared=yes
mountlimit=1 directory="C:\"
```



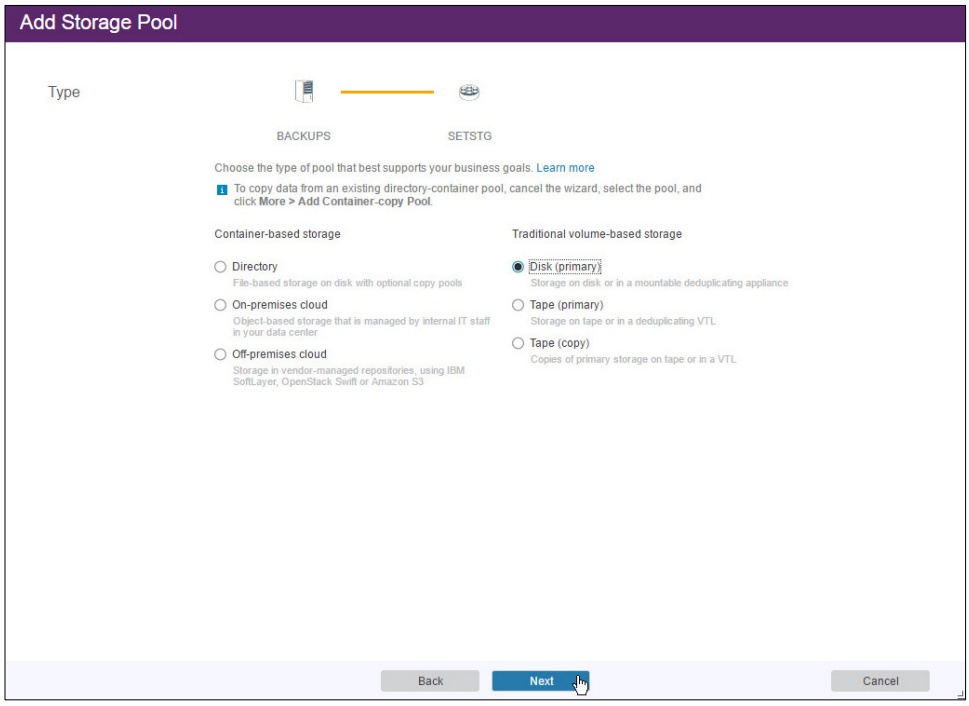
3. Go to **Storage** > **Storage Pools**.



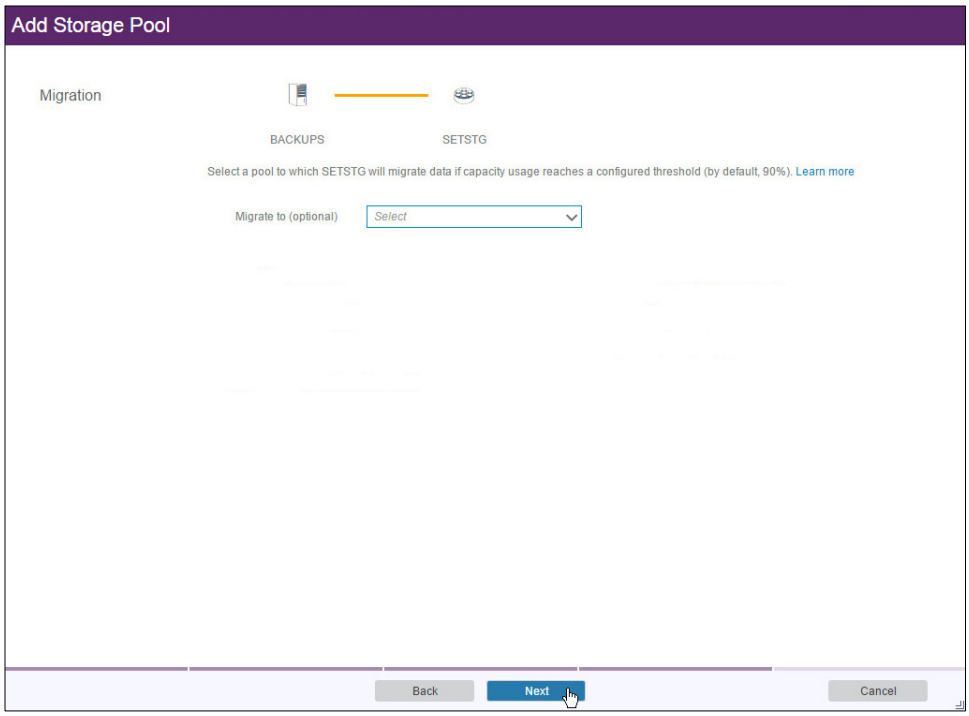
4. Click **+Storage Pool**.
5. Enter a **name**.



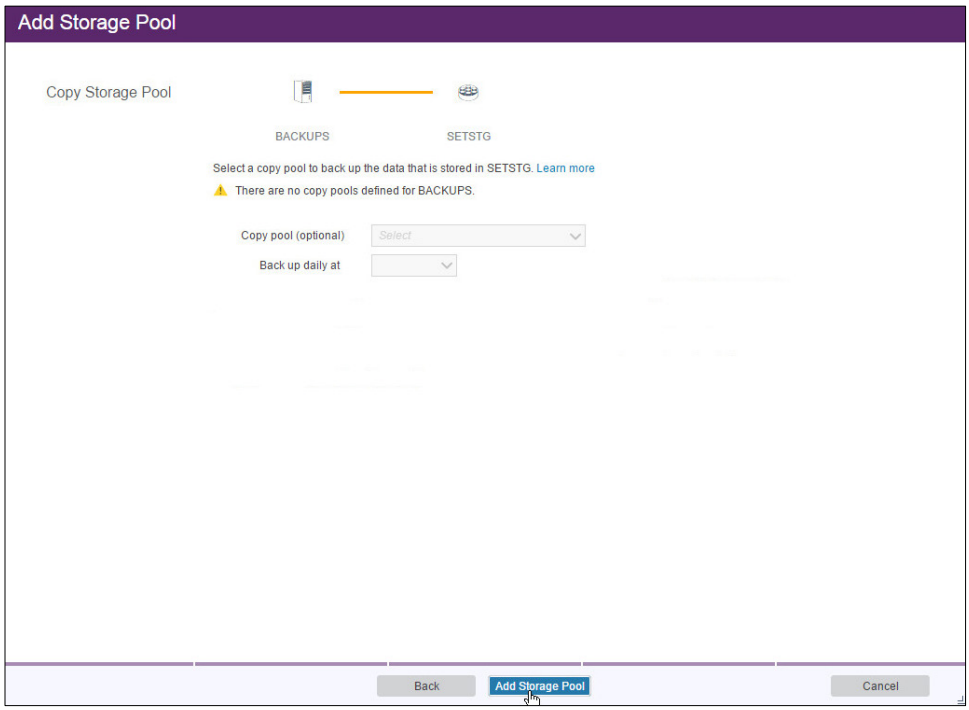
6. Click **Next**.
7. Select **Disk (primary)**.



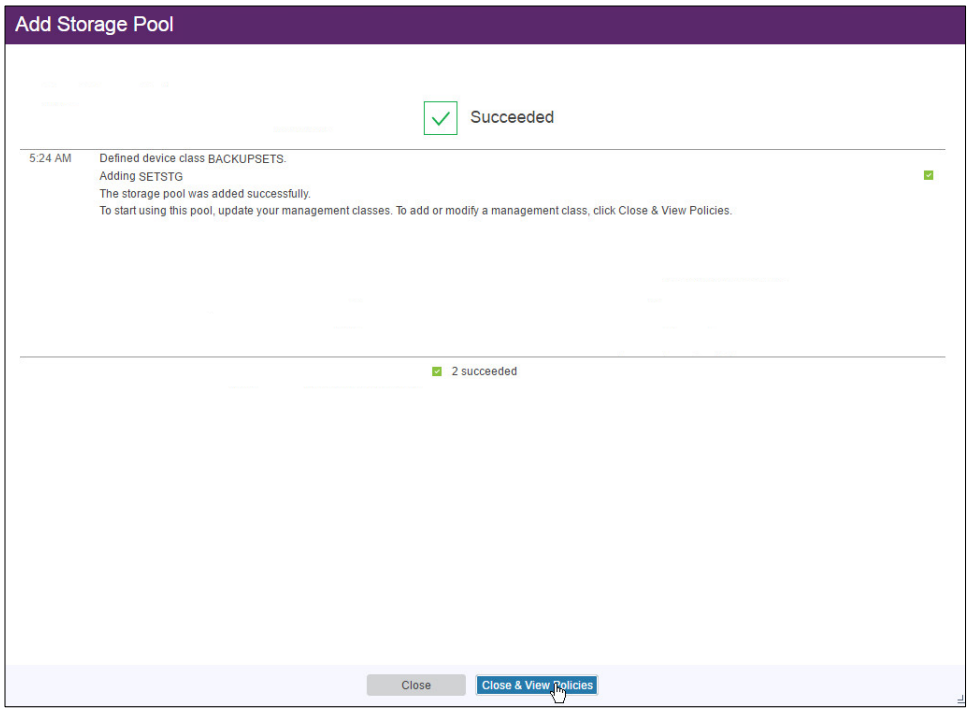
8. Click **Next**.



9. Click **Next**.



10. Click **Add Storage Pool**.

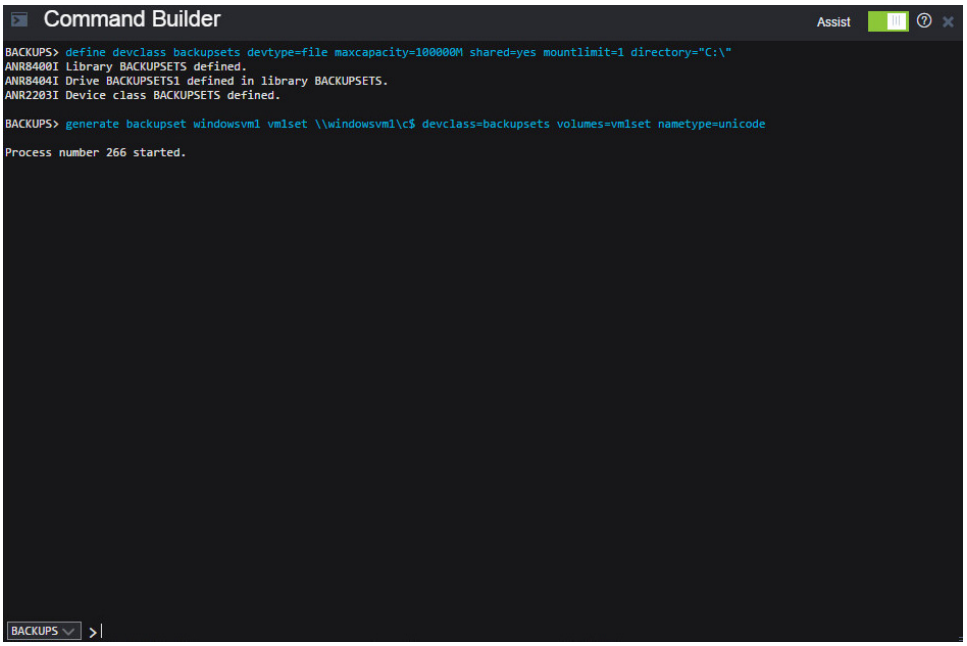


11. Create a backup set for the client whose data you wish to store securely. Run the following command on Command Builder:

```
generate backupset <name of client> <identifier> \\<name of client>\c$
devclass=file volumes=backupset1 nametype=unicode
```

For example:

```
generate backupset windowsvm1 windowsvm1_backupset \\windowsvm1\c$
devclass=file volumes=backupset1 nametype=Unicode
```



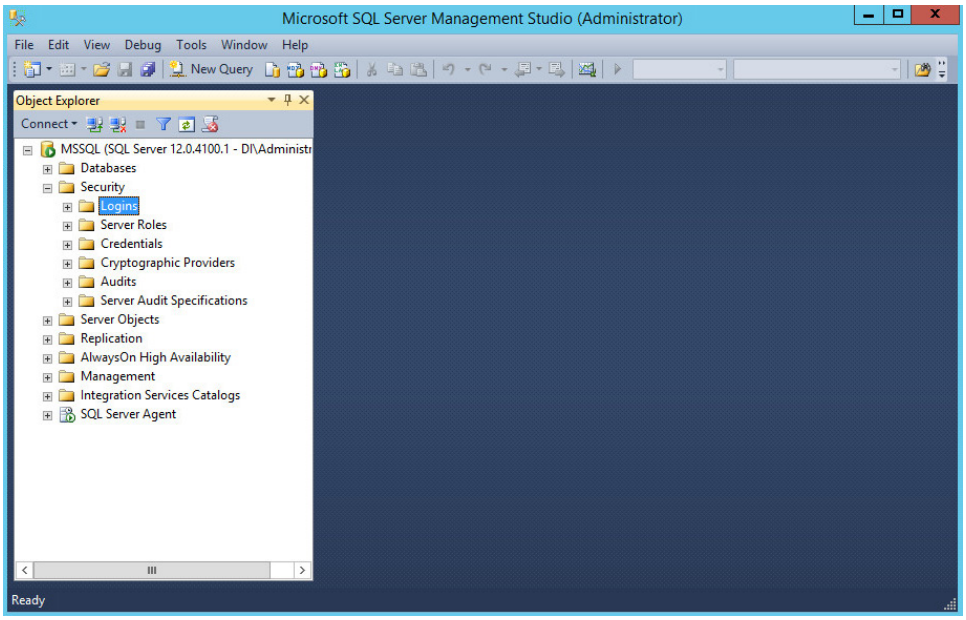
12. This will store all backup data for the client **WINDOWSVM1** in a file called **backupset1**. You can copy this file to a GreenTec disk and store for later use.

2.16 Integration: Tripwire and MS SQL Server

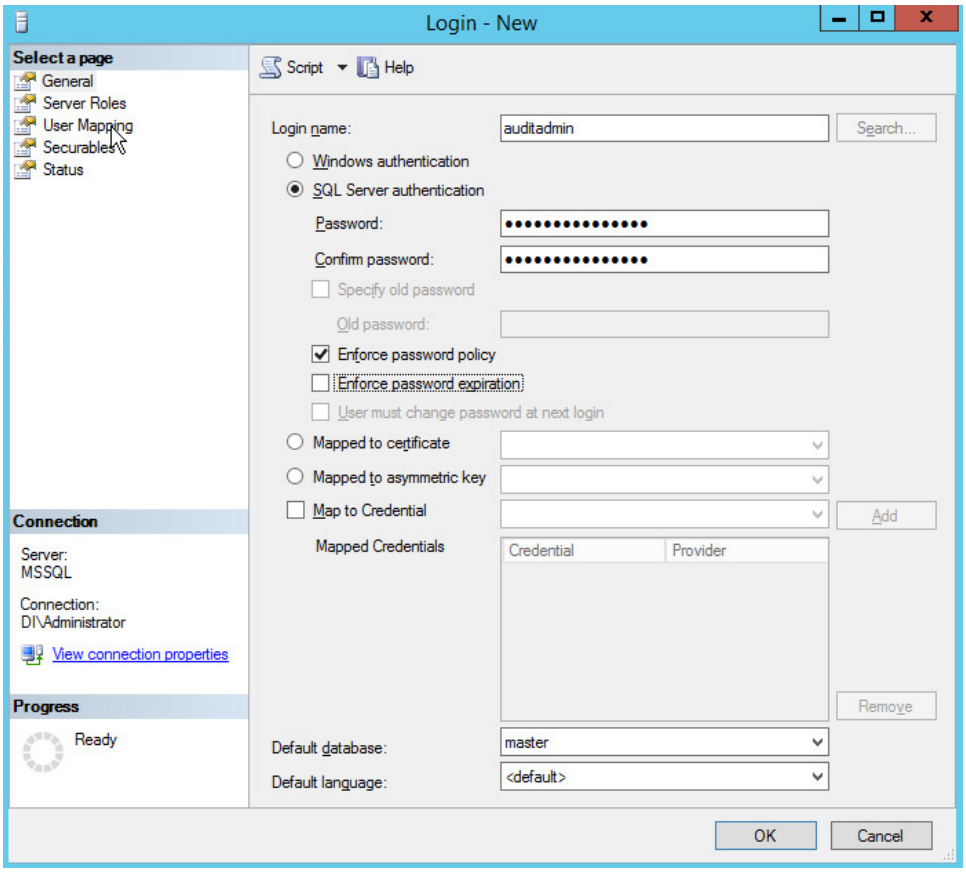
This section covers the process for integrating Tripwire Log Center and Microsoft SQL Server. This integration assumes the correct implementation of Tripwire as described in earlier sections. The result of this integration is the collection of database audit logs in Tripwire, allowing for detection and reporting of events such as specific types of queries, schema modification, and database modification.

2.16.1 Create a New Account on MS SQL Server

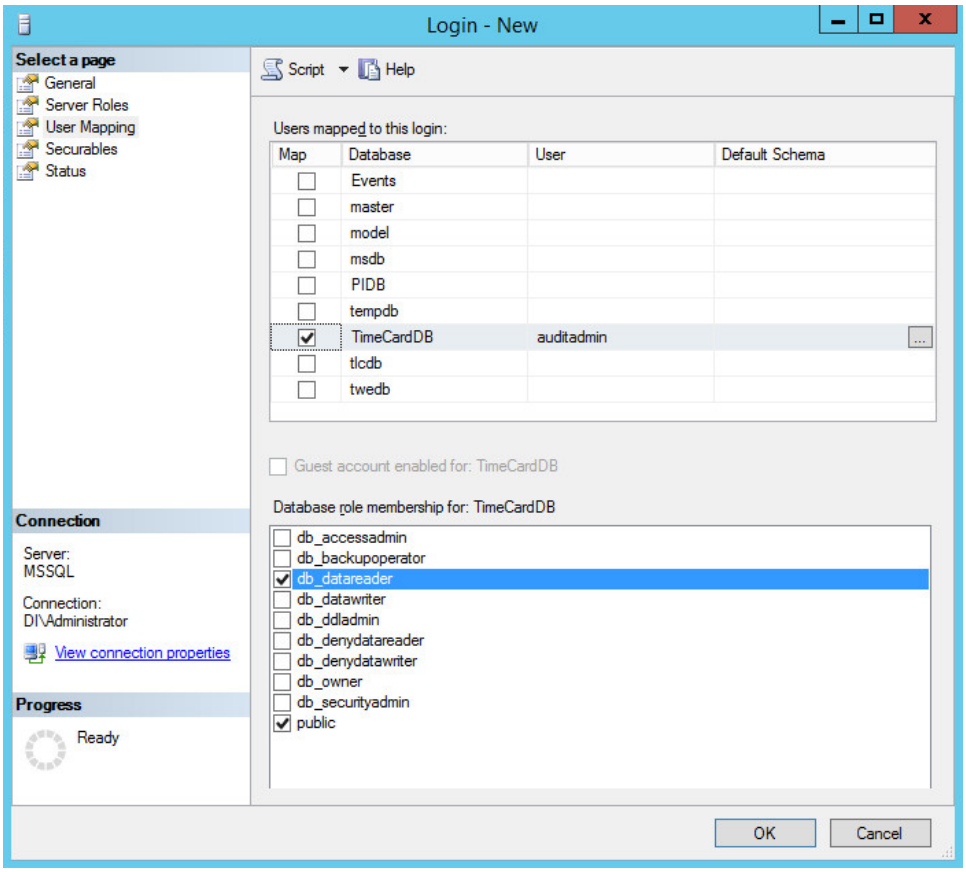
1. Open **SQL Server Management Studio.**
2. Hit **Connect** to connect to the database.
3. In the **Object Explorer** window, expand the **Security** folder.



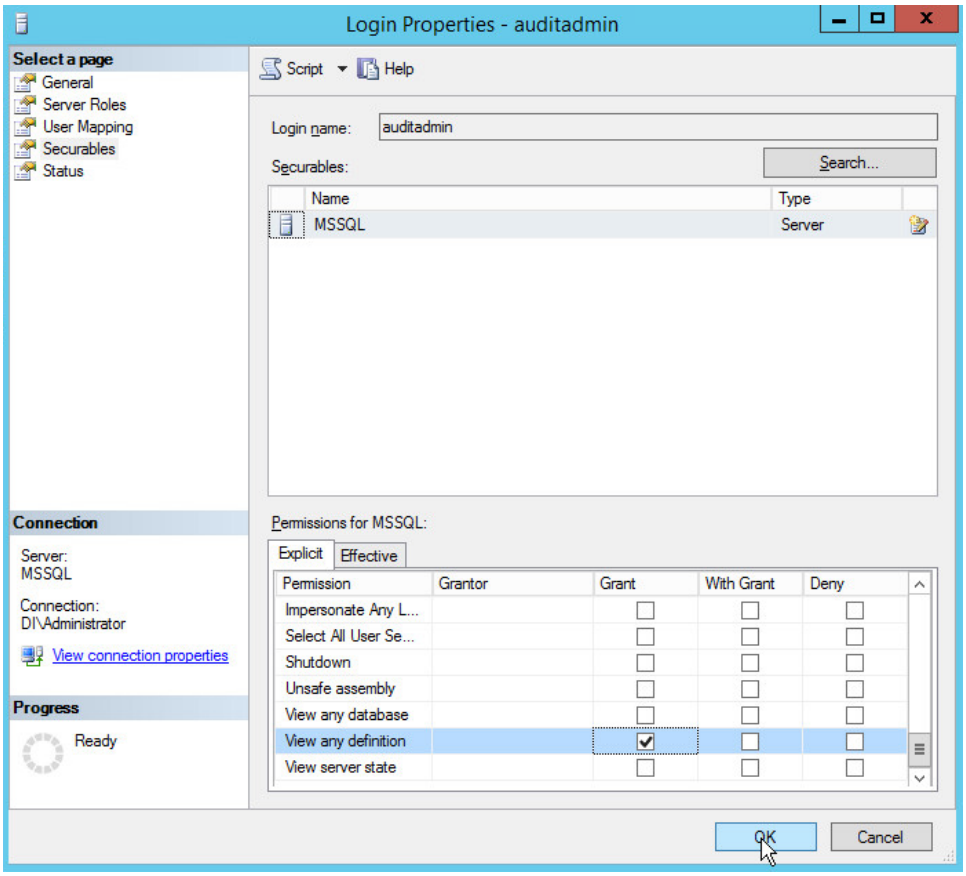
4. Right click on the **Logins** folder and click **New Login…**.
5. Input the desired user.



6. Click **User Mapping.**
7. For each database that Tripwire should monitor, click the database and assign the role **db_datareader**.



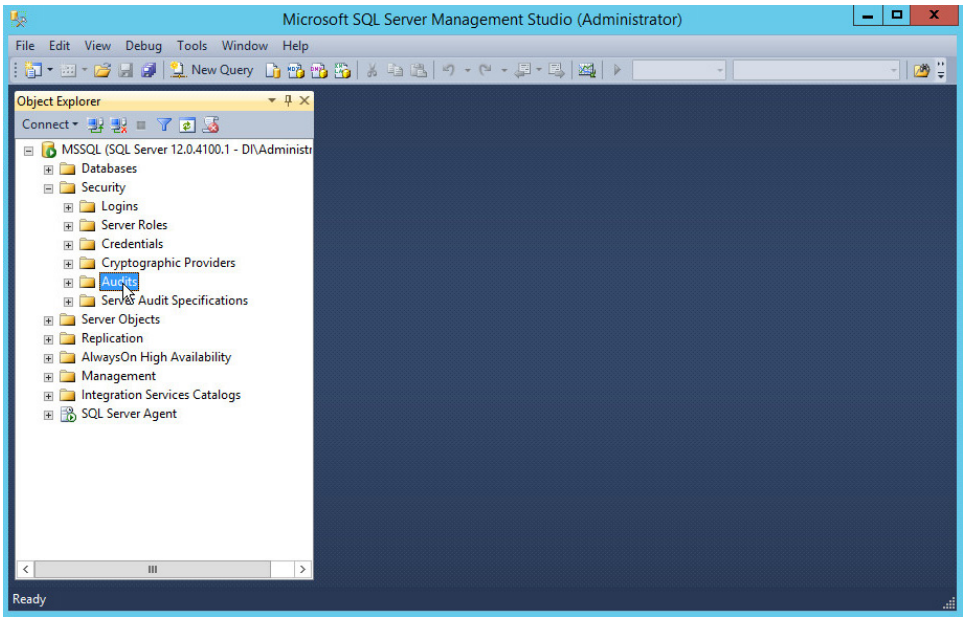
8. Click **Securables**.
9. Under the **Grant** column, check the boxes next to **Alter trace** and **View any definition** (if this is not available, create the user, then edit properties for that user).



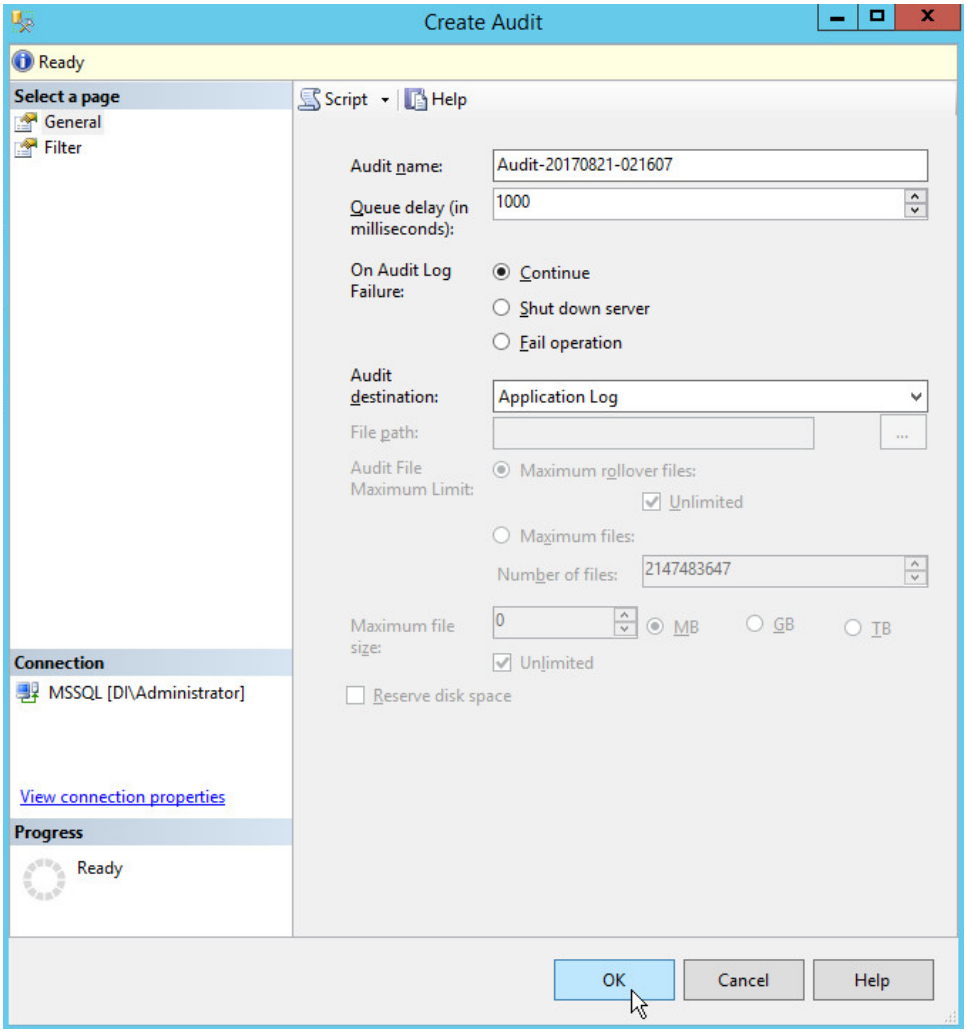
10. Click **OK**.

2.16.2 Create a New Audit on MS SQL Server

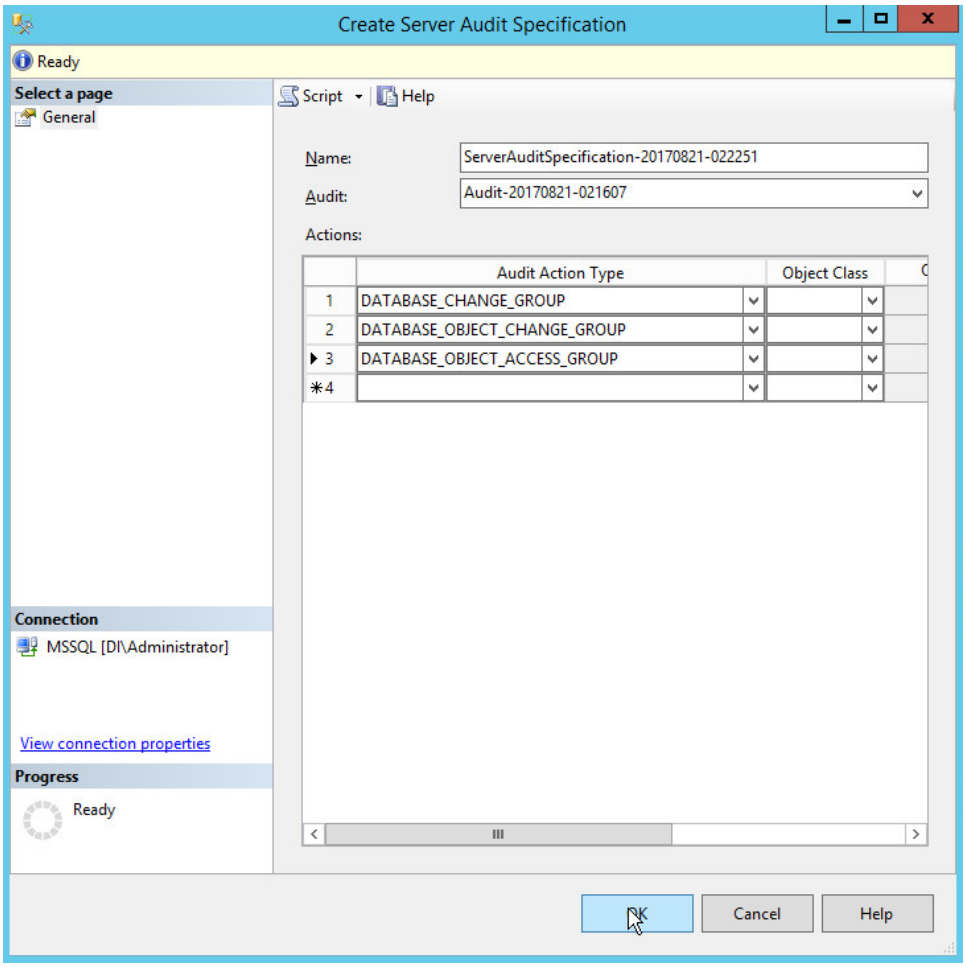
1. In the **Object Explorer** window, expand the **Security** folder.



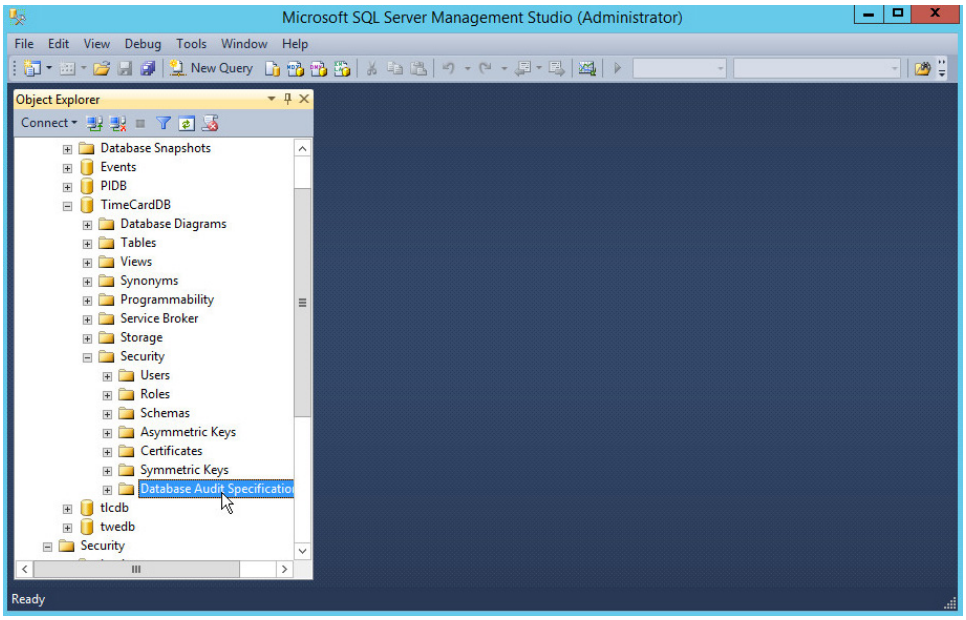
2. Right click on the **Audits** folder.
3. Click **New Audit…**.
4. Specify a **filename** or any other settings per your organization's needs. Note: If you specify a filename, you will be able to view any queries you wish to monitor in this **Audit log**, but not in **Tripwire**. However, if you set the **Audit Destination** to **Application Log**, the messages will be forwarded to the **Microsoft Application Log**. This will result in less structured (but still detailed) messages and allows the capability to collect them easily using **HPE ArcSight ESM.** If your **ArcSight Connector** is configured to collect **Application Logs** from the **MS SQL** server, no further configuration of the connector is required.



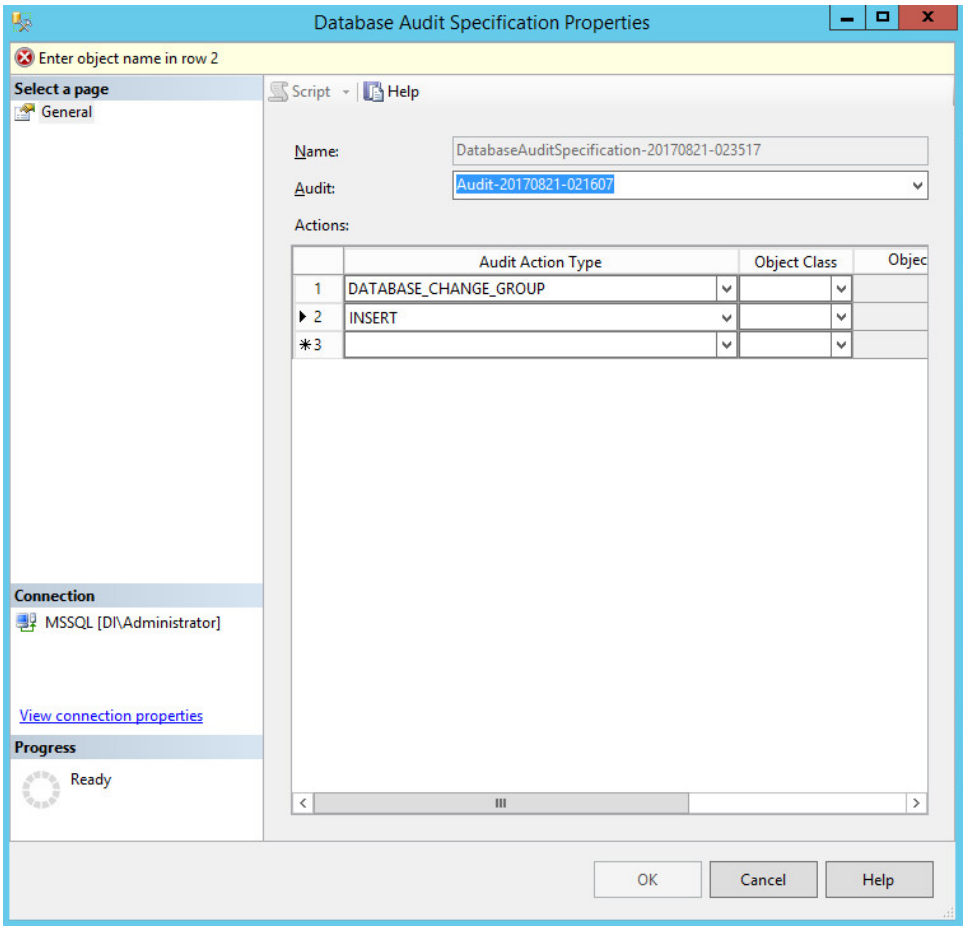
5. Click **OK**.
6. Right click **Security** > **Server Audit Specifications**.
7. Click **New Server Audit Specification…**.
8. For **Audit:** select the audit you just created.
9. Specify any **Audit Action Types** that Tripwire should be able to log.



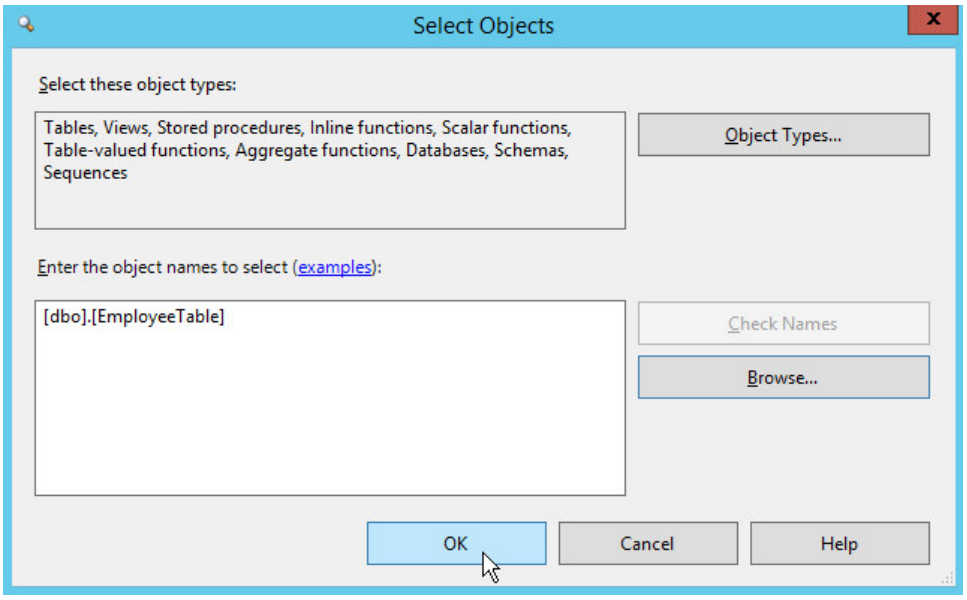
10. Click **OK.**
11. Open a database that you wish to monitor specific objects in.
12. Right click **Databases** > **<Database name>** > **Security** > **Database Audit Specifications**.



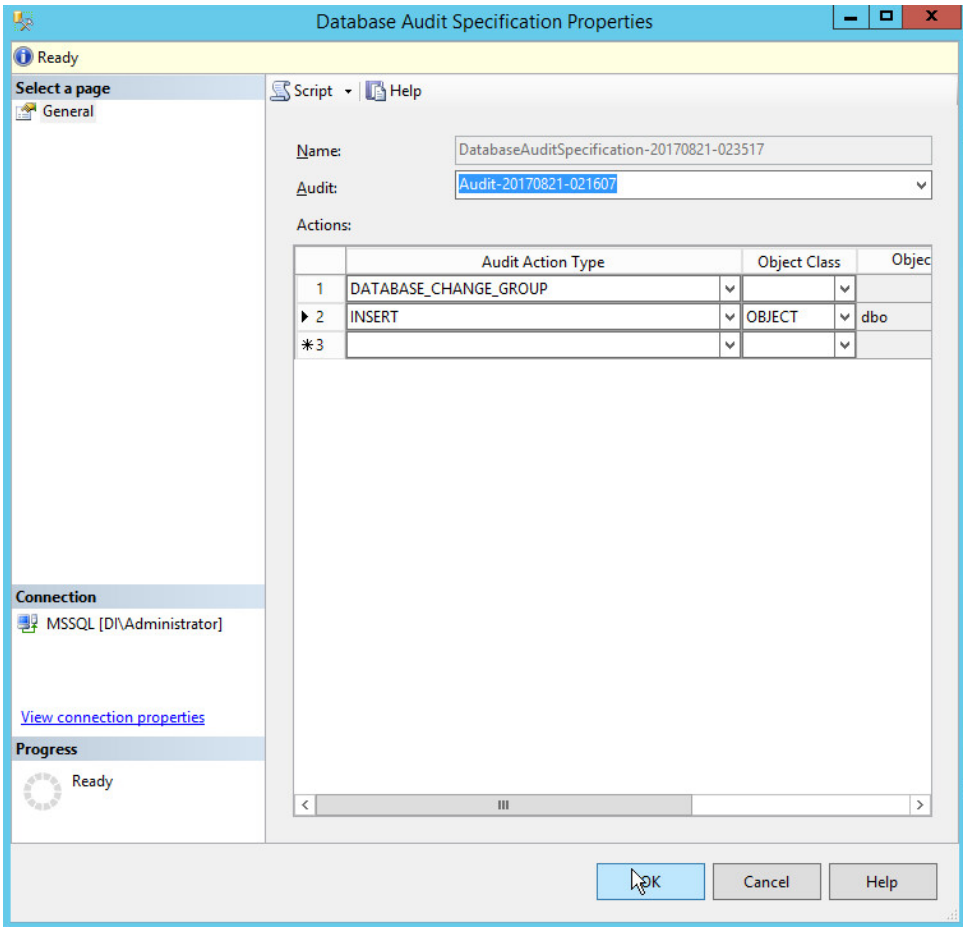
13. Click **New Database Audit Specification…**.
14. Select an **Audit Action Type** to monitor.



15. Select **Object** for the **Object Class**.
16. In the **Object Name** field, use the **Browse** button to find objects that you wish to monitor for the specified **Audit Action Type**.



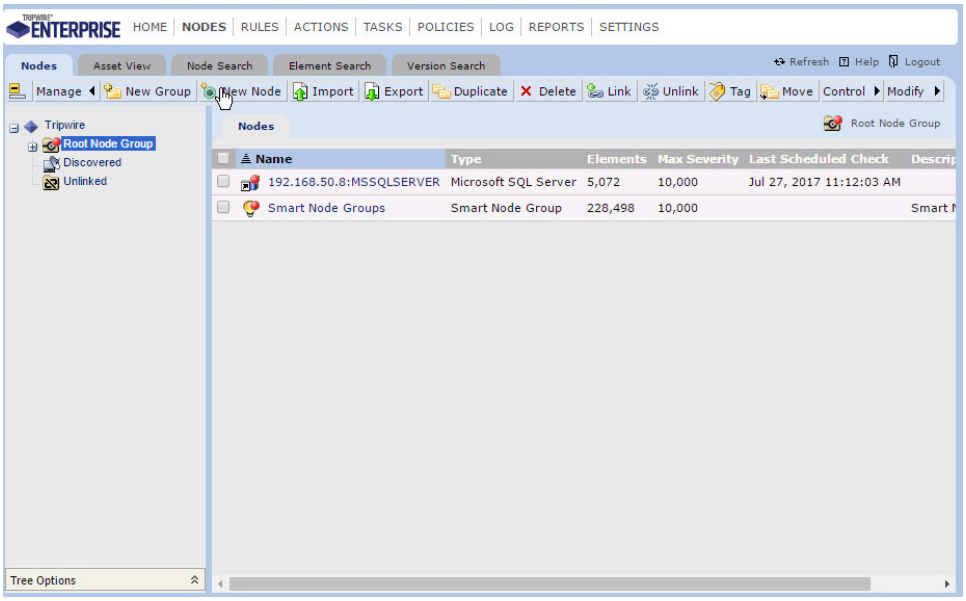
17. Create as many types as you wish Tripwire to monitor.



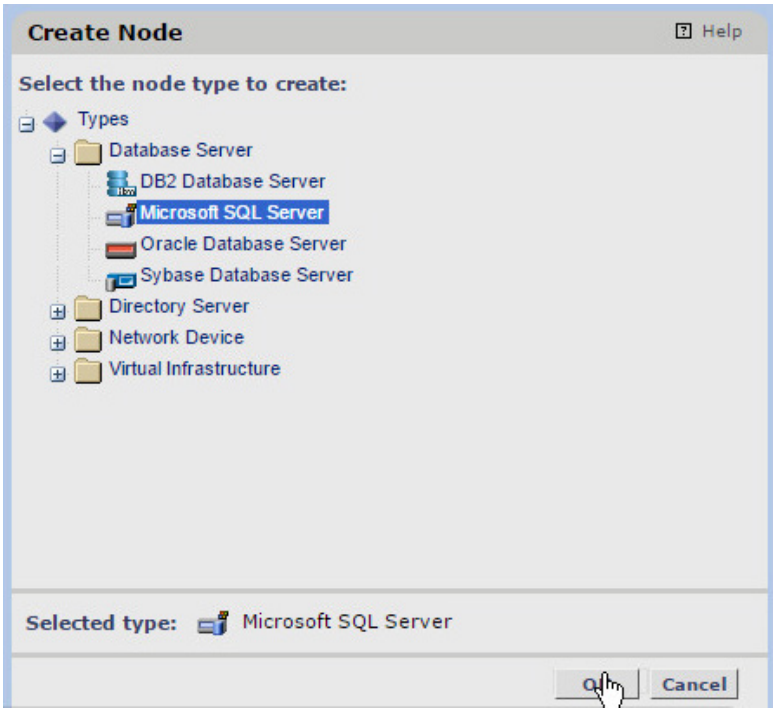
18. Click **OK**.
19. Find the audits you just created in the **Object Explorer** and right click.
20. Select **Enable ___ Audit Specification** for each one.

2.16.3 Create a New Node for the MS SQL Server on Tripwire Enterprise

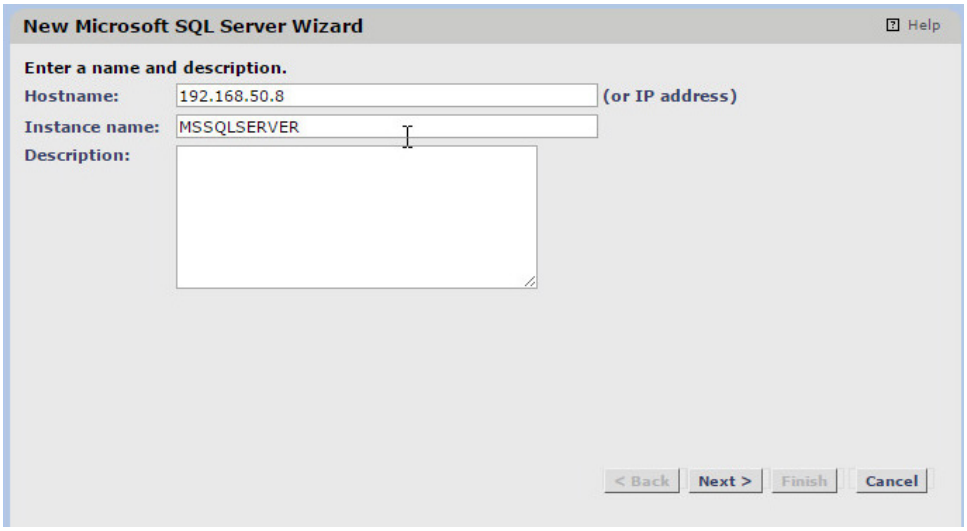
1. Open the Tripwire Enterprise console.
2. Click **Nodes**.



3. Click **Manage** > **New Node**.

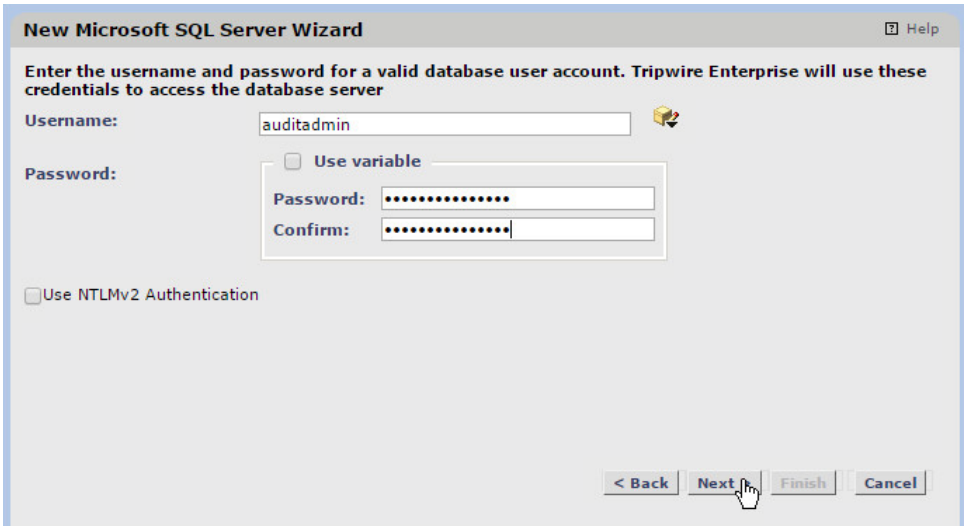


4. Click **Types** > **Database Server** > **Microsoft SQL Server**.
5. Click **Ok**.
6. Enter the **hostname** or **IP** of the MS SQL Server.
7. Enter the **instance name** of the database.

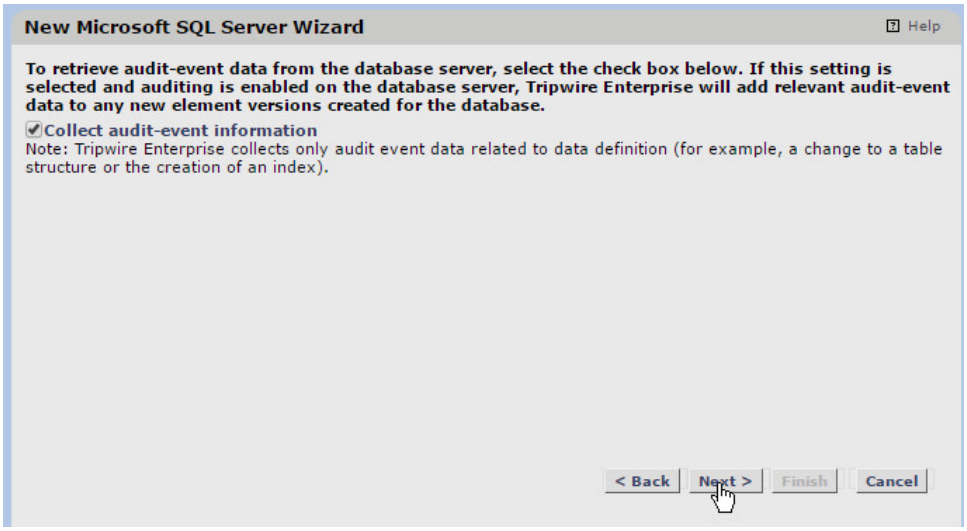


8. Click **Next**.
9. Enter the **port** the database listens on.

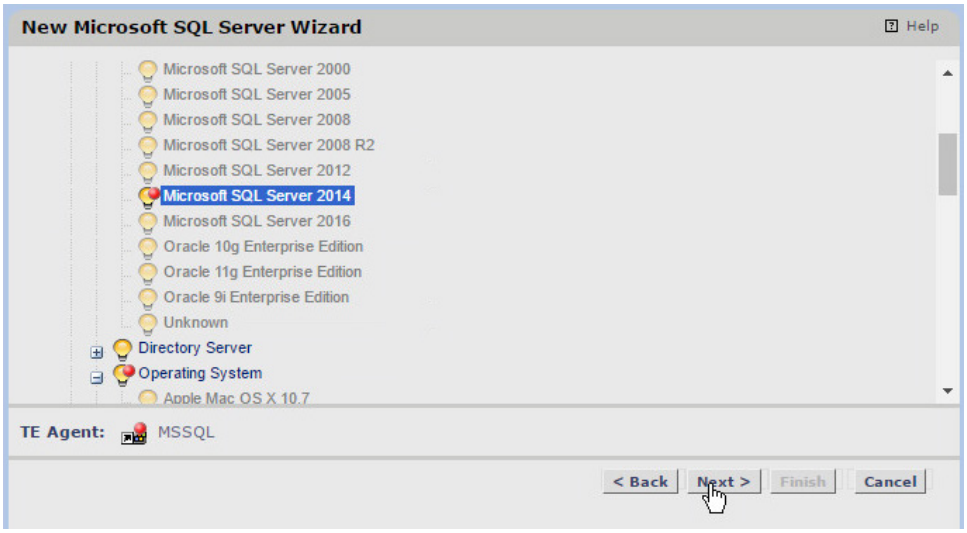
10. Click **Next**.
11. Enter the newly created **username** and **password** for the database.



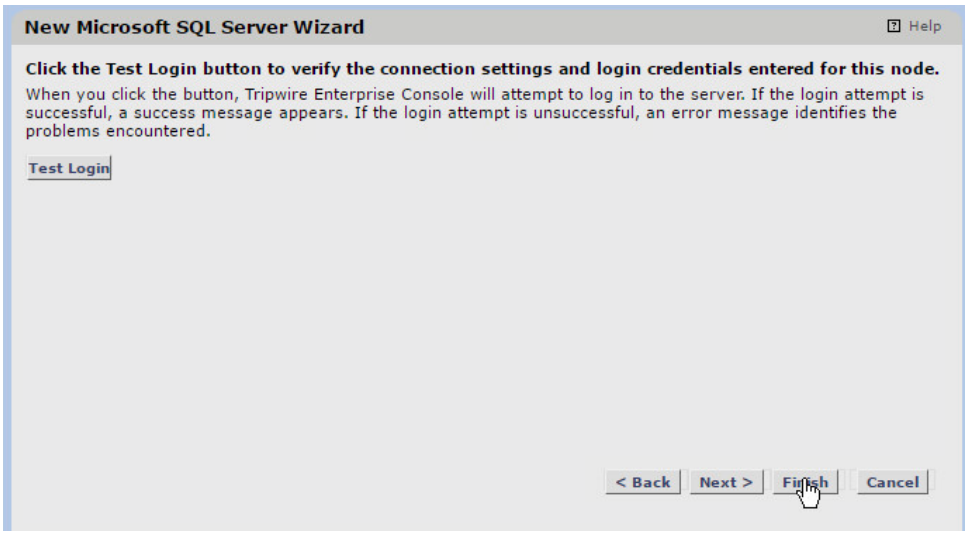
12. Click **Next**.
13. Check the box next to **Collect audit-event information**.



14. Click **Next**.
15. Find the MSSQL Server on the list.



16. Click **Next**.
17. **Test Login** to ensure the information you entered was correct.



18. Click **Finish.**

Appendix A List of Acronyms

AD	Active Directory
BA	Client Backup-Archive Client
DB	Database
DI	Data Integrity
DNS	Domain Name System
EOF	End of File
ESM	Enterprise Security Manager
HPE	Hewlett Packard Enterprise
IP	Internet Protocol
IT	Information Technology
LDAP	Lightweight Directory Access Protocol
MS SQL	Microsoft Structured Query Language
NCCoE	National Cybersecurity Center of Excellence
NIST	National Institute of Standards and Technology
MS	Microsoft
CA	Certificate Authority
DSRM	Directory Services Restore Mode
IIS	Internet Information Services
IP	Internet Protocol
SQL	Structured Query Language
SDK	Software Development Kit
TCP	Transmission Control Protocol
SSL	Secure Sockets Layer
TLS	Transport Layer Security
VSS	Volume Shadowcopy Services

VM	Virtual Machines
VnE	Vulnerability and Exposure
WORM	Write Once Read Many