BUILDING BLOCK WHITE PAPER

PRIVACY-ENHANCED IDENTITY BROKERS

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NCCoE building blocks address technology gaps that affect multiple industry sectors. They represent core capabilities that can and should be applied across industry cybersecurity and business use cases.

ABSTRACT

A *relying party (RP)* that accepts credentials from an *identity provider (IdP)* to login to their website achieves a number of benefits for their users and for themselves. An RP does not need to directly manage credentials when utilized a trusted third-party credentials, allowing them to focus their efforts and assets (both financial and human) on their core business and lower costs associated with conducting identity proofing and authentication on their own. Users can utilize a credential of their choice at many sites, reducing the friction associated with unique logins for every website they interact with. However, as an RP decides to accept credentials from a new IdP, a separate integration effort is required to establish the connection. As a result, the market has responded and a new entrant has emerged to facilitate the reuse of credentials between IdPs and RPs. Commonly referred to as an "identity broker," these entities resolve the repetitive cost an RP repeatedly endures when adding new credential choices to their customers.

An *identity broker* can provide business value to both RPs and IdPs since each RP and IdP only needs to integrate with the identity broker once. The value to the RP is quite simple – connect once (to the identity broker) and accept many types of credentials. Yet the identity broker may raise risks to individual privacy; the broker, if deployed incorrectly, is in a significant position of power, as it creates the potential to track or profile an individual's transactions. In addition, it could gain insight into user data it does not need in order to perform the operations desired by IdPs and RPs.

Privacy-enhancing technologies (PETs) are tools, applications, or automated mechanisms which—when built into software or hardware—reduces or eliminates adverse effects on individuals when their personal information is being collected and/or processed. PETs implemented by identity brokers can reduce the risk of superfluous exposure of individuals' information to participant organizations that have no operational need for the information, as well as shrink the attack surface for unauthorized access.

This document describes the technical challenges unique to integrating *PETs* with identity brokers. It suggests scenarios suited for exploring the tradeoffs of mitigating or accepting specific privacy risks. Ultimately, this project will result in a publicly available NIST Cybersecurity Practice Guide—a description of the practical steps needed to implement a reference architecture that addresses existing challenges in the current identity broker marketplace.

KEYWORDS

Brokered identity management; privacy-enhancing technology; digital identity; identity federation; identity management

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1. Executive Summary

A *Relying Party (RP),* that accepts credentials from an *identity provider (IdP)* to login to their website, achieves a number of benefits for their users and themselves. An RP does not need to directly manage credentials when utilized a trusted third-party credentials, allowing them to focus on their core business and lower costs associated with conducting identity proofing and authentication on their own. The RPs customers can utilize the credential of their choice, reducing the inconvenience associated with unique logins for every website they interact with. However, as an RP decides to accept credentials from a new IdP, a separate integration effort is required to establish the connection.

Identity Brokers in Action

Connect.Gov is a federal government solution that allows citizens to use the third party credential of their choice to interact with agency services. This approach simplifies agency and IdP integration and improves user privacy by eliminating the ability of IdPs to track user behavior. Any solution identified by this white paper could be applied to Connect.Gov.

The market has responded and a new entrant has emerged to facilitate the reuse of credentials between IdPs and RPs. Commonly referred to an "identity broker," these entities resolve the repetitive cost an RP has to endure when adding new credential choices and offerings for their customers. An identity broker can provide business value to both RPs and IdPs since each RP and IdP only needs to integrate with the identity broker once. The value to the RP is quite simple – connect once (to the identity broker) and accept many types of credentials. Yet the identity broker may raise risks to individual privacy; the broker, if deployed incorrectly, is in a significant position of power, as it creates the potential to track or profile an individual's transactions. In addition, it could gain insight into user data it does not need to perform the operations desired by IdPs and RPs.

Privacy-enhancing technologies (PETs) is a general term for a set of tools, applications or automated mechanisms which—when built into hardware or software — reduces or eliminates adverse effects on individuals when their personal information is being collected and/or processed. PETs implemented by identity brokers can reduce the risk of superfluous exposure of individuals' information to participant organizations that have no operational need for the information, as well as reduce vulnerabilities that could lead to unauthorized access.

This document describes the technical challenges unique to integrating *PETs* with *identity brokers.* It suggests a variety of scenarios well suited for exploring the benefits, and possible tradeoffs, of mitigating or accepting specific privacy risks. This project will result in the development of *NIST Cybersecurity Practice Guide*, a description of the practical steps needed to implement a reference design that addresses this challenge. NCCoE specifically seeks information technology and cybersecurity product vendors, and open standards developers, as collaborators on the efforts to create a privacy-enhanced identity broker reference design and practice guide.

2. BUSINESS VALUE

As the National Strategy for Trusted Identities in Cyberspace (NSTIC), also referred to as Strategy stated,

> A secure cyberspace is critical to our prosperity. We use the Internet and other online environments to increase our productivity, as a platform for innovation, and as a venue in which to create new businesses 'Our digital infrastructure, therefore, is a strategic national asset, and protecting it—while safeguarding privacy and civil liberties—is a national security priority' and an economic necessity. By addressing threats in this environment, we will help individuals protect themselves in cyberspace and enable both the private sector and government to offer more services online. [1]

The NSTIC envisioned an identity ecosystem of federated identity solutions playing a key role in achieving a more secure cyberspace. Federated identity solutions, in which RPs accept third-party credentials from an IdP to login to their website, can provide a number of benefits. They minimize the number of digital credentials individuals need to access RP services, which can make it more convenient for individuals to use fewer, stronger credential options, such as multi-factor authentication. An RP that uses third-party credentials does not need to directly manage them, allowing them to focus on their core business and lower costs because IdPs will manage the identity proofing and authentication (and spread those costs across multiple RPs). IdPs can focus on offering secure and efficient identity proofing processes to strengthen trust in identities for higher assurance transactions across the Internet.

However, each pairing of a RP with an IdP requires a separate integration effort. An *identity broker* can provide business value to both RPs and IdPs since each RP and IdP only needs to integrate with the identity broker once. The identity broker also can provide mechanisms to apply technical and policy interoperability among RPs and IdPs.

Nevertheless, federated identity solutions raise new risks for the privacy of individuals and confidentiality of business information. The interoperability that provides the benefits described above can also create the potential for more tracking and profiling of individuals' transactions. The same interoperability can expose businesses as the relationships between RPs and IdPs reveal who their customers are to each other; such exposure may be particularly problematic if the federation occurs within the same industry sector. In addition, the identity broker can become an appealing target to gain access to identity attributes being transmitted through the broker or to RP accounts. Thus, participants in federated identity solutions—whether individuals or organizations—must be able to trust that the solutions are not going to reveal sensitive information or they will not participated in identity federations.

[1] https://www.whitehouse.gov/sites/default/files/rss_viewer/NSTICstrategy_041511.pdf

PETs implemented in federated identity solutions can reduce the risk of superfluous exposure of individuals' information to participant organizations that have no operational need for the information, as well as shrink the attack surface for unauthorized access. Implementing such PETs will enable market differentiation for the adopters and increase trust in federation. Additionally, organizations may be subject to various privacy and security requirements under law or through trust frameworks. PETs can assist in demonstrating compliance with relevant privacy and security requirements.

Market demand within the private sector is not the only domain where business value can be attained. Governments also use federated identity services—but need to minimize the risk of privacy and civil liberties violations (or the international equivalent). A number of current solutions manage these risks via avoidance; they intentionally stay away from the transmission of attributes due to the privacy risks of unintentional disclosure. PETs can enable governments to derive the benefits of federated identity while minimizing violations of privacy and civil liberties that harm individuals and contribute to an overall breakdown in public trust.

3. Description

Purpose of the document

This document describes the specific privacy and cybersecurity goals unique to identity brokers. The privacy and security challenges described herein may require a technical solution that does not yet exist in existing standards or commercial off-the-shelf (COTS) products. However, it is believed that by profiling or extending existing standards, and applying these standards to existing commercially available solutions, the challenges identified in this white paper can be overcome. NIST hopes this document will lead to the development of both "how-to" documentation as well as commercially available products and standards that allow PETs to be ubiquitous in the marketplace.

Audience

The intended audience of this document includes anyone with experience in identity management, privacy-enhancing technologies, cryptography, and their integration to solve real-world problems.

The NCCoE specifically seeks information technology and cybersecurity product vendors, and open standards developers, as collaborators on the efforts to create a privacy-enhanced identity broker reference design and practice guide.

The NCCoE will publish a Federal Register (FR) notice inviting vendors interested in collaborating on this effort.

Goals

The primary goal of this building block is to show how identity brokers, leveraging market dominant standards, can include privacy enhancements directly in the solution.

Specifically, this building block seeks innovative ways to encrypt the attributes of a logged in user such that the identity broker, honest or malicious, can never decrypt the attributes and gain access to personal information—while retaining an architecture in which RPs and IdPs do not know each other's organizational identities—i.e., *double-blind*. In addition, it is required that any approach utilized to achieve this goal can mitigate a broker-based man-in-the-middle attack. Specific goals are as follows:

Goal 1. **Untraceability and unlinkability**. The identity broker prevents RPs and IdPs from learning each other's identities. Neither entity can track or link user activities beyond what is known from their direct relationship with the user.

Goal 2. **The identity broker cannot access user attributes.** RPs obtain validated attributes (and sometimes self-asserted attributes) from authoritative IdPs. Users first consent to sharing the attribute from the IdP to the RP. Once the RP has the actual attribute value, they can use the information to fulfill their service requirements. Often, the RPs use the attributes to link the user to a pre-existing account maintained by the RP, initiate a new account, or to offer them an entitlement or benefit based on their validated attributes. A solution is required to allow the IdP to encrypt attributes so that only the RP may decrypt them. In doing so, the double-blind must be retained; so utilizing an identifiable public key of the RP is not sufficient. In addition, any approach utilized must resist the threat of the broker compromising the attribute encryption (e.g., man-in-the-middle attack).

Goal 3. A compromised or malicious broker cannot impersonate a user. A compromised broker (one that has been hacked or that becomes malicious on its own volition) might be able to satisfy the desired privacy enhancements, yet still be able to impersonate an end user. Controls must be established to reduce this threat.

Goal 4. User attributes are only provided when requested by the RP. Attributes are only provided when a RP requires them, not every time a user logs in to access an RP. While this reduces the potential of exposing personal information, it alone does not alleviate the need to accomplish the first three privacy goals, above.

Background

The economic and security benefits of strong authentication, increased demand in reusable credentials, and the complexity of managing identities and accounts have resulted in an increase in online RPs that are willing to outsource authentication to trusted IdPs. The cost to manage credentials, comply with regulations associated with the collection and storage of identity data, the risk of users bailing out of the registration process, and the interoperability complexities associated with supporting multiple identity protocols are examples of business drivers to adopt identity federation.

In a *brokered identity management* architecture, organizations that participate in the federation interoperate within a formal technical and policy trust framework. RPs realize

savings and reduce complexity by shifting architectures, as illustrated in Figure 1. On the left, the RP establishes business, technological, and interoperability trust relationships with each IdP. On the right, the relationship is simplified with a single "broker," and the RP realizes cost savings by reusing the integration and trust relationships established already by that broker.

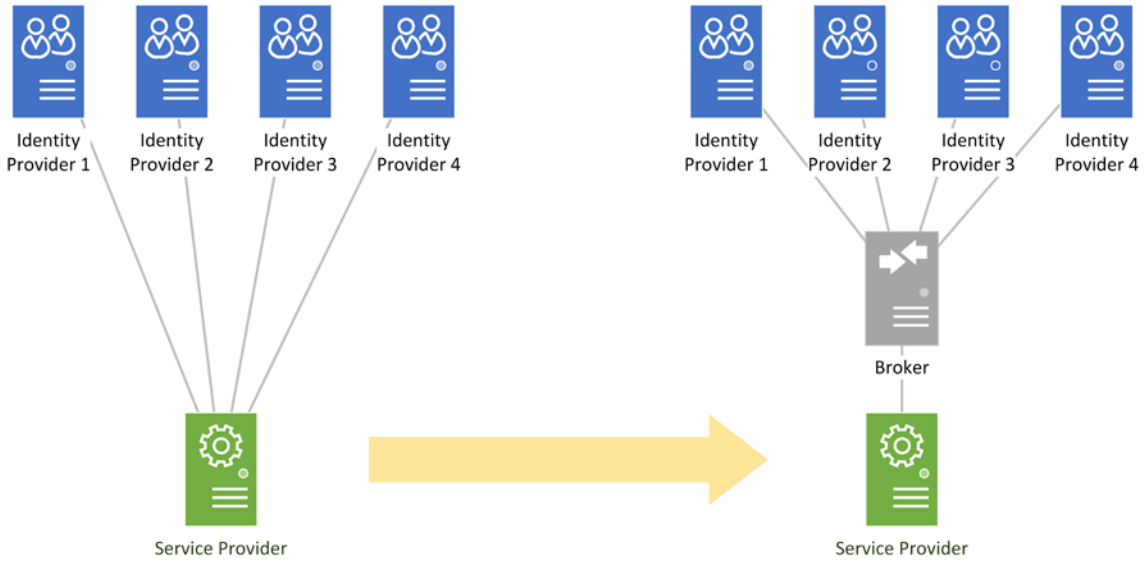

Figure 1. A RP migrates to a brokered identity management model. Instead of integrating with each IdP individually, it interfaces with a single broker.

In the context of this building block, brokered identity management serves the following essential functions:

1. Alleviates the number of integrations required between RPs and IdPs
2. Allows for protocol translation, reducing the number of protocols RPs and IdPs need to support.
3. Enables the privacy principles of untraceability and unlinkability by "blinding" the IdPs and RPs from each other.

Unfortunately, despite the aforementioned benefits afforded by employing a broker, many protocols require explicit trust relationships with each other. For example, Security Assertion Markup Language (SAML) metadata needs to be exchanged at design time, which typically includes public cryptographic keys to sign and encrypt messages (or portions of the message) as users authenticate to an IdP and access a RPs website.

Consequently, an identity broker will need to employ additional security and privacy controls, in collaboration with RPs and IdPs, to ensure that as federated identity transactions are executed, the privacy principles expected by users are met. In doing so in compliance with existing protocols, there is a risk that the broker will be in a position of power that erodes the security and privacy practices that are crucial to long-term market adoption.

Therefore, identity brokers have unique privacy and cybersecurity challenges that must be overcome. In many identity management protocols, it is assumed that there is an explicit relationship, and direct connection, between the RP and the IdP. Many commonly used identity management protocols, such as SAML version 2.0 or OpenID Connect, were *not* specifically designed with unlinkability in mind. That is, as illustrated in Figure 2, a direct "trust" relationship is commonly established, a priori, to allow RPs and IdPs to directly communicate.

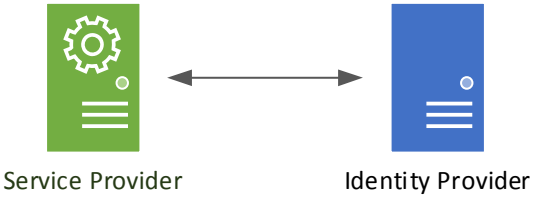

Figure 2. In many identity management protocols, there is a direct trust and communications relationship between a RP and an IdP.

With the constraints of modern identity protocols, for a plurality of identity brokers, the protection of user credentials and attributes must be maintained through:

- **Implicit trust relationships**: The RP mutually trusts the broker and the broker mutually trusts the IdPs; IdPs and RPs can then indirectly trust one another through the transitive established by the broker.
- **Transport layer and message security**: Without a broker, the RP and IdP would use transport layer and message security to assure the integrity and confidentiality of credentials, user attributes, and/or security assertions (the specifics of what is communicated depends on the protocol employed). Those same security measures would be employed with an identity broker, but instead of a direct communication, the identity broker would serve as an intermediate "hop."
- **Operational policies**: An identity broker would implement a host of security policies and procedures to help ensure the secure exchange of messages.

Despite these protections, since identity management protocols do not explicitly recognize the role of an identity broker that blinds RPs, it may have access to unencrypted security assertions and user attributes and has the ability to link user transactions across RPs and IdPs.

As illustrated in Figure 3, if an identity protocol does not explicitly recognize the role (or entity) of the identity broker, then the broker must act like an IdP to the actual RP, and an RP to the actual IdP. Any privacy enhancing technologies must be implemented in such a manner that they are compatible with this model.

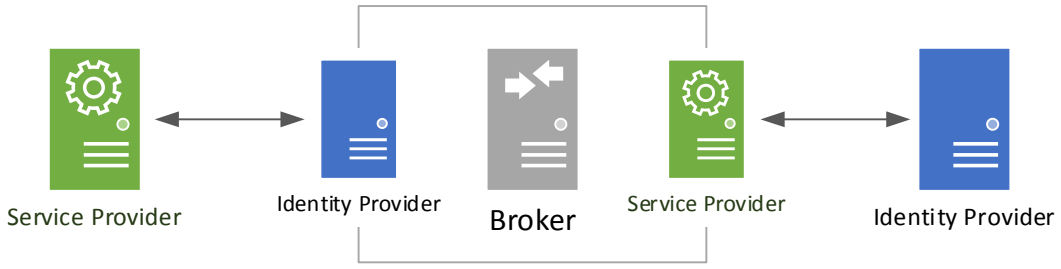

Figure 3. Identity Broker-Based Relationship Model.

Scope

This building block will demonstrate how an identity broker can use profiles and/or extensions of market dominant protocols, such as SAML and OpenID Connect, to implement the privacy enhancements discussed in the Goals Section above. Identification of the challenges to implementing these privacy enhancements is an inherent part of the building block's scope; those enumerated in this document are only a starting point for a larger collaboration effort with the private sector. This effort will include the deployment of the infrastructure required to simulate the identity broker architecture, the use of multiple authenticators, as well as the inclusion of appropriate, publicly available and proven cryptographic algorithms.

With respect to cybersecurity, this particular building block focuses only on the challenges unique to identity broker architectures. How the attributes are protected at rest, and used by RPs and IdPs, is out of scope. Authorization, and any use of fine-grained access control, to include attribute-based access control (ABAC), is also not in scope at this time.

Assumptions

The following foundational assumptions have been made to achieve the goals stated in this white paper:

1. The technologies, algorithms, standards, and processes already exist in today's market, and are available to fully satisfy the goals of this building block; the objective is to utilize state of the market capabilities.
2. Components identified in this building block are relatively high-level. For simplicity, the white paper treats each RP, IdP, or identity broker as a standalone, single entity. In reality, however, each actor in a production system may itself be a system of systems—comprising other components. For example, behind the

abstraction of an IdP could be security token services, identity stores, and/or multifactor authentication technologies. Entities are scoped so that the building block can concentrate specifically on those challenges unique to enhancing privacy.

3. The goal of this building block is to consider how to augment existing, market dominant protocols; it is *not* to develop or research new protocols. However, we recognize that changes to existing protocols and profiles may be necessary to fulfill the building block's privacy enhancement requirements.

4. SCENARIOS

Federated Logon Overview and Example

In a federated logon, a RP trusts the identity assertions issued by an IdP to allow users to access their system. Federated sign-on is not a new concept; in fact, many popular websites allow users to access their services using third party credentials, such as e-mail or social networking accounts.

Consider the following example of a real-world implementation of federated logon:

1. Alice wishes to access the National Institutes of Health publication database, *PubMed.* Alice browses to the PubMed website and is presented with the screen shown in Figure 4.

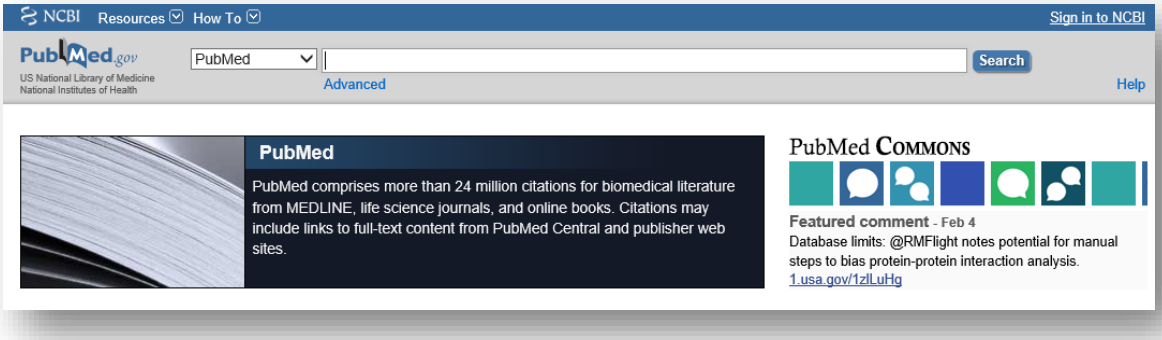

Figure 4. PubMed landing page. Note the "Sign in to NCBI" link in the upper right corner.

2. She clicks *Sign in to NCBI* and sees the web page shown in Figure 5.

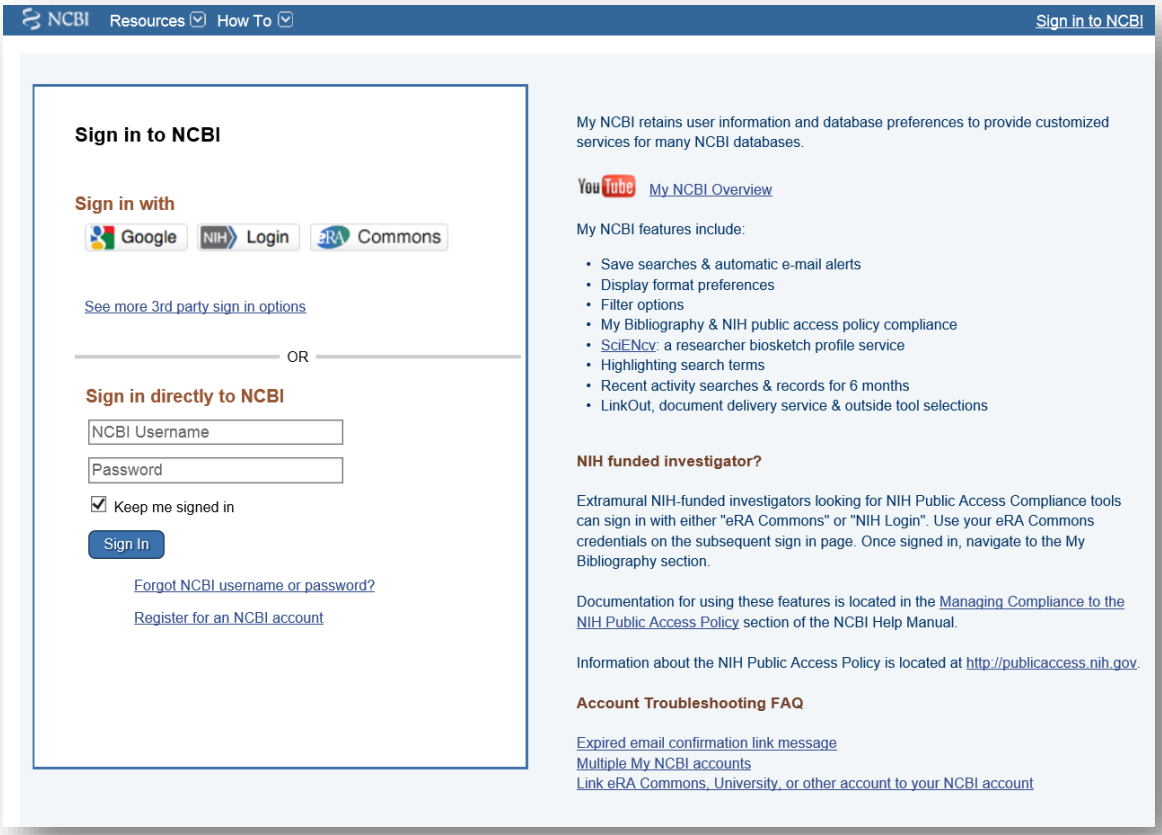

Figure 5. PubMed sign-on page. Users can logon with a direct username and password or use a "third-party option."

3. Alice has the ability to choose a PubMed username and password to logon. She has the option to sign in with a PubMed account **and** a variety of third-party credentials. At the time of writing this document, PubMed allowed for logon with over 90 third-party IdPs.

The following scenarios establish incremental capabilities to achieve the goals of this white paper:

Scenario 1. Baseline: Authentication and Attribute Delivery Given an Identity Broker

In the first scenario, the building block will demonstrate user authentication and attribute delivery, as illustrated in PubMed walkthrough, inclusive of an identity broker. It achieves the previously specified Goal 1 (untraceability and unlinkability).

In the example, the RP, PubMed, was responsible for implementing and maintaining the technology and policy relationships with their third-party IdPs (the left side of Figure 1). In the baseline scenario, we replace these relationships with a single integration with the

broker (the right-hand side of Figure 1). This baseline scenario is intended to capture the essence of the migration from dedicated, multiple IdP connections, to a concept of operations based on an "outsourced," brokered IdP integration concept of operations.

The baseline scenario does not accomplish any of the privacy goals desired herein, however it is a required step to simulate an identity broker along with a set of RPs and IdPs. The goal of this scenario would be to mimic, as much as possible, a system that closely matches the technical control typically in place today—that is, no additional attribute, or credential protection other than what is afforded by the native protocols and policies.

In summary, the first scenario is establishing what currently exists in the market—*RP acceptance of an IdPs credentials via an identity broker*.

Scenario 2. Authentication and Attribute Delivery Given an Honest-But-Curious Broker

In Scenario 2, Goal 1 and Goal 4 are achieved. The identity broker is assumed to be an *honest but curious (HBC)* adversary. The *"honest but curious"* adversary model means that the target protocol is implemented correctly (the entity is *honest*), but might look at the information passing through it in an attempt to learn information (it is *curious*). This is analogous to a situation in which an attacker has gained access to a system, can read information passing through it, but cannot change that information.

To achieve these characteristics, building block participants will need to identify threats unique to this scenario, as well as design specialized mitigations to eliminate or reduce the potential risk of these threats. Threat identification, mitigation, and technological cost/benefit analyses will be among the core building block collaboration activities.

Scenario 3. Authentication and Attribute Delivery Given a Malicious Identity Broker

In Scenario 3, additional controls are applied to Scenario 2 to achieve Goal 3. In this scenario, however, we assume that the identity broker might be compromised. A malicious broker is one that could actively seek to exploit architectural or security vulnerabilities in order to disrupt the overall system's ability to maintain confidentiality, information integrity or system availability. This is analogous to a situation in which an attacker has gained access to the broker and can covertly inject their own behaviors. Protection in the face of a malicious broker, particularly one that exfiltrates sensitive information silently, is a significant cybersecurity challenge.

Scenario 3 will focus on preventing a malicious broker that:

1. Initiates its own authorization or attribute query request without permission from a user or RP.
2. "Phishes" an end user's credentials by pretending to be an IdP.
3. Impersonates the end user by replaying identity assertions.

Like Scenario 2, an activity core to the building block will be to identify additional threats, mitigations, and their technological cost/benefit.

Summary

Table 1 provides a summary of the scenarios. A checkmark indicates that the scenario includes the corresponding requirement.

Requirement	Scenario		
	1	2	3
Federated authentication and attribute delivery via an identity broker	✓	✓	✓
Scenario implements the desired security characteristics		✓	✓
Identity Broker is an "honest but curious" adversary		✓	
Identity Broker is an "malicious" adversary			✓
Identity unique threats, mitigations, and cost/benefit tradeoffs		✓	✓

Table 1. Summary of Scenarios. A checkmark indicates that the scenario fulfills the corresponding requirement.

In all three scenarios, an identity broker is used to intermediate federated identities to a RP, with credentials from an IdP. Scenarios 2 and 3 add the security characteristics enumerated in Section 6 as well as the identification of threats and mitigations unique to brokered identity management.

5. Current Building Block Challenges

RPs wish to accept third-party credentials so that (a) they themselves do not have to manage user credentials, and (b) they reduce the abandonment rate due to requiring users to create another account they may not want (unfortunately, often a username and password). An identity broker can provide business value to a RP (and IdPs alike) by specializing in integration, policy harmonization, and service and IdP "matchmaking."

The NSTIC envisions an Identity Ecosystem that "will provide multi-faceted privacy protections" that are built into the technologies that provide authentication and federation services. The strategy specifically advocates the use of "privacy-enhancing technical standards" that "minimize the transmission of unnecessary information and eliminate the superfluous 'leakage' of information that can be invisibly collected by third parties. Such standards will also minimize the ability to link credential use among multiple RPs, thereby preventing them from developing a complete picture of an individual's activities online."

Identity brokers have conflicting requirements under this viewpoint. On one hand, the broker needs information about all of the entities involved in a particular transaction so that it can help guarantee the integrity and confidentiality of the transaction, as well as the information that is contained within the transaction. Yet, the Strategy also advocates

unlinkability—individual behavior should not be observable among the participants of a trust framework or federation.

As discussed above, the current standards and product market do not have non-proprietary mechanisms to employ a privacy-enhancing solution in identity brokers. Research exists that identify cryptographic solutions to meet the goals outlined in this document. However, these solutions are not yet commercially viable and/or do not have APIs that are readily available, tested, secure, or scalable. The goal of this building block is to enable wider adoption of identity brokers in the marketplace by illustrating how to *simultaneously* satisfy integrity, confidentiality, accountability, unlinkability, and untraceability.

6. Desired Solution Objectives

Below is a list of target characteristics for the building block aligned to the expected results outline in the Goals section. The omission of any security or privacy engineering objective from the complete set is not an indication that the identity broker architecture may not have characteristics of the omitted objective. Any information system needs to maintain all of the objectives to some degree, but this building block is designed to demonstrate capabilities for the specific objectives listed below.

Functional Objectives

Table 2 - Function Objectives

Functional Objective	Example Capability(ies)
Identity federation	• Users can chose from a pre-set number of credential service providers • Dynamically discover identity providers
Protocol translation	• Identity broker can transform an input protocol to a different output protocol, and vice versa • Encrypted and signed data in one protocol can be migrated, transformed, or converted to another protocol without access to plaintext and without breaking the chain of trust of originator of message
Triple blinding	• IdP does not have knowledge of RP identity • RP does not have knowledge of IdP identity • Identity Broker does not know identity of user conducting transaction

Security Objectives

Table 3 - Security Objectives

Security Objective	Example Capability(ies)
confidentiality	• Identity broker does not have plaintext access to user credentials or attributes either at rest, or in motion • The hub will never have access to decryption keys • A malicious man-in-the-middle attack will not result in a breach of personal data of the authenticated user • Unauthorized access to transactional data, even encrypted, is not possible
integrity	• RP is assured that the data has not been modified by the hub or a malicious 3rd party • RP is assured that the data is provided by a valid IdP • RP is assured that a malicious 3rd party can not impersonate a valid user and/or reuse prior, valid assertions

Privacy Engineering Objectives

NIST has developed three draft privacy engineering objectives for the purpose of facilitating the development and operation of privacy-preserving information systems: predictability, manageability, and disassociability. These objectives are designed to enable system designers and engineers to build information systems that are capable of achieving their functional purpose while implementing an organization's privacy goals and supporting the management of privacy risk. As with the above security objectives, these privacy objectives are core characteristics of information systems.

- ***Predictability*** is the enabling of reliable assumptions by individuals, owners, and operators about personal information and its processing by an information system.
- ***Manageability*** is providing the capability for granular administration of personal information including alteration, deletion, and selective disclosure.
- ***Disassociability*** is enabling the processing of personal information or events without association to individuals or devices beyond the operational requirements of the system

Table 4 - Privacy Objectives

Privacy Engineering Objective	Example Capability(ies)
predictability	• Enables user, RP, IdP and identity broker assumptions that identity broker does not have access to user identity attributes. • Enables user, RP, IdP and identity broker assumptions that IdP cannot process information about user's relationship with the RP. • Enables user, RP, IdP and identity broker assumptions that RP cannot process information about user's relationship with the IdP.
disassociability	• The identity broker can transmit identity attributes from an IdP to an RP without being able to access them. • The RP can accept an authentication assertion and identity attributes without associating a user to an IdP. • The IdP can transmit an authentication assertion and identity attributes without associating a user to an RP.

This is not an exhaustive list; it highlights those features that are particularly salient to the unique challenges to this domain. In addition, these characteristics will need to be balanced with the risk level. For example, it might be acceptable (e.g. for specific security or operational reasons) to allow a RP to know the identity of the IdP while still blocking broker access to plaintext user attributes. As stated previously, a goal of this building block is to understand the nature of these tradeoffs among the configuration space of various protections.

7. Relevant Standards, Specifications, and Guidance

- NIST Special Publication 800-63 Revision 2: Electronic Authentication Guideline
- Organization for the Advancement of Structured Information Standards (OASIS) Security Assertion Markup Language (SAML) v2.0 Standard
- OpenID Connect Core
- Draft NISTIR 8062 - Privacy Risk Management for Federal Information Systems
- OAuth 2.0 Specification
- Federal Information Processing Standards 140-2, Special Requirements for Cryptographic Modules

- Javascript Object Signing and Encryption (JOSE)
- XML Encryption
- XML Signature

8. Security Control Mapping

This table maps the necessary objectives of the commercial products that the NCCoE will apply to this cybersecurity challenge to the applicable standards and best practices described in the Framework for Improving Critical Infrastructure Cybersecurity (CSF), and other NIST activities. This exercise is meant to demonstrate the real-world applicability of standards and best practices, but does not imply that products with that meet these objectives will achieve a given industry's requirements for regulatory approval or accreditation.

Objectives Objective	Cybersecurity Standards and Best Practices						
	CSF Function	**CSF Category**	**CSF Subcategory**	**NIST 800-53-4**	**IEC/ISO27001**	**SANS/CSC**	**CSF CCMv3.0.1**
Identity federation	Protect	Access	PR.AC-1 PR.AC-5	IA-4 SC-23	A.9.4.2 A.13.1.1 A.13.2.3	16-2 16-15 17-7	IAM-09 AIS-01 AIS-02 EKM-03 STA-0
		Data Security	PR.DS-2				
		Protective Technologies	PR.PT-4				
Protocol translation	Protect	Access	PR.AC-5	AC-4 SC-8 SC-23 SI-10	A.13.1.1 A.13.2.3	6-2	AIS-01 AIS-02 AIS-03 AIS-04 DSI-01 DSI-03 EKM-03 EKM-04 STA-03
		Data Security	PR.DS-2				
		Protective Technologies	PR.PT-4				
confidentiality	Protect	Access	PR.AC-1	AC-3	A.9.2	12-1	AIS-01

Objectives Objective	Cybersecurity Standards and Best Practices						
	CSF Function	**CSF Category**	**CSF Subcategory**	**NIST 800-53-4**	**IEC/ISO27001**	**SANS/CSC**	**CSF CCMv3.0.1**
			PR.AC-4	AC-5 AC-6 SC-8 SC-13	A.9.4.1 A.10 A.13.1.2 A.13.2.3 A.14.1.2 A.14.1.3	15-1 15-4 17-2 17-3 17-7 17-9 17-10 17-12 17-13 17-15	DSI-03 EKM-02 EKM-03 EKM-04 IAM-05 IAM-09 IAM-12 IAM-13
		Data Security	PR.DS-2 PR.DS-5				
		Protective Technologies	PR.PT-4				
Disassociability **Triple Blinding**	Protect	Data Security	PR.DS-2 PR.DS-5 PR.DS-6	AC-4 AC-8 AC-14 AC-23 CM-5 IA-4 SC-4 SC-8 SC-12 SC-13 SC-17 SC-26 SC-30 SI-16	A.10 A.12.2 A.12.6.1 A.13.1.2 A.13.2.3 A.14.1.2 A.14.1.3	5-6 15-1 15-4 17-2 17-3 17-7 17-9 17-10 17-12 17-13 17-15	AIS-01 AIS-04 DSI-01 DSI-02 DSI-03 EKM-02 EKM-03 EKM-04 IAM-06 IAM-09
Predictability **Integrity**	Protect	Data Security	PR.DS-2	AC-8 AC-14	A.10 A.13.1.2	17-2 17-3	AIS-01 AIS-03

Objectives Objective	Cybersecurity Standards and Best Practices						
	CSF Function	**CSF Category**	**CSF Subcategory**	**NIST 800-53-4**	**IEC/ISO27001**	**SANS/CSC**	**CSF CCMv3.0.1**
		Information Protection Processes and Procedures	PR.IP-6	AC-23 IA-4 SA-13 SA-18 SC-7 SC-11 SC-13 SC-17 SI-4 SI-7 SI-12	A.13.2.3 A.14.1.2 A.14.1.3	17-7 17-9 17-10 17-12 17-13 17-15	DSI-02 DSI-03 DSI-04 IAM-05 IAM-09 EKM-02 EKM-03 EKM-04 IVS-01 IVS-06 IVS-09 IVS-12 TVM-01

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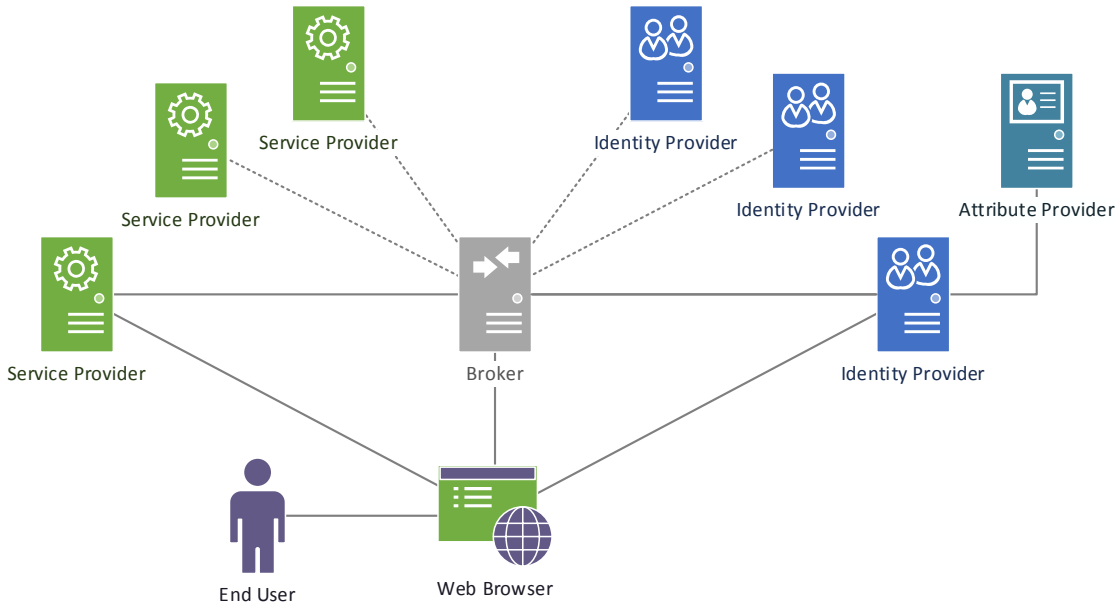
9. High-Level Architecture

The following is a high-level diagram of a potential building block architecture. This architecture captures the various actors at a *system of systems* level; each RP and IdP could comprise a variety of additional components.



It is important to note that a single solution may not exist, and that innovation and collaboration within the private sector may identify solutions that require additional components and/or standards than those already identified.

10. Component List

The following list is an example of the components that might comprise a final building block solution. *This list is only a starting point*; specific components will be identified through future vendor collaborations.

- RP hosts (physical or virtual) and instances
- IdP hosts (physical or virtual) and instances
- Identity Broker host(s) (physical or virtual) and instance
- Attribute provider hosts (physical or virtual) and instance(s) (optional)
- User agent / host with web browser
- Multi-factor credentials
- Network, compute, and storage infrastructure to support the above

APPENDIX A – ACRONYMS AND ABBREVIATIONS

The following are acronyms commonly used in the context of identity management and may be helpful for readers of this and related National Cybersecurity Center of Excellence materials.

ABAC	Attribute-Based Access Control
BB	Building Block
FICAM	Federal Identity, Credential, and Access Management
FR	Federal Register
HBC	Honest But Curious
Id *or* ID	Identity
IdP	Identity Provider
IETF	Internet Engineering Task Force
IT	Information Technology
LOA	Level of Assurance
MFA	Multi-factor Authentication
NCCoE	National Cybersecurity Center of Excellence
NIST	National Institute of Standards and Technology
NSTIC	National Strategy for Trusted Identities in Cyberspace
OASIS	Organization for the Advancement of Structured Information Standards
OMB	Office of Management and Budget
PET	Privacy-Enhancing Technologies
PKI	Public Key Infrastructure
RFC	Request for Comment
RP	Relying Party
SAML	Security Assertion Markup Language

APPENDIX B – GLOSSARY

This building block, where possible, leverages external authoritative sources of terms for identity, credential and access management. The table below outlines terms as they are used within the context of this building block.

Term	Definition	Source
access control	a process by which use of system resources is regulated according to a security policy and is permitted only by authorized entities (users, programs, processes or other systems) according to that policy	Internet Engineering Task Force (IETF) Request for Comments (RFC) 4949
assertion	a statement from a verifier to a relying party that contains identity information about a subscriber. Assertions may also contain verified attributes. Assertions may be digitally signed objects or they may be obtained from a trusted source by a secure protocol	NIST Special Publication 800-63-2
assurance	the grounds for confidence that the set of intended security controls in an information system are effective in their application	NIST Special Publication 800-37-1
assurance level	a measure of trust or confidence in an authentication mechanism in terms of four levels: Level 1 - little or no confidence; Level 2 - some confidence; Level 3 - high confidence; Level 4 - very high confidence	Office of Management and Budget (OMB) Memorandum M-04-04
attribute	a claim of a named quality or characteristic inherent in or ascribed to someone or something	NIST Special Publication 800-63-2
attribute based access control (ABAC)	a policy-based access control solution that uses attributes assigned to subjects, resources or the environment to enable access to resources and controlled information sharing	Authorization and Attribute Services Committee Glossary
authentication	the process of establishing confidence in the identity of users or information systems	NIST Special Publication 800-63-2
credential	an object or data structure that authoritatively binds an identity (and optionally, additional attributes) to a token possessed and controlled by a subscriber	NIST Special Publication 800-63-2
federation	a trust relationship between discrete digital identity providers (IdPs) that enables a relying party to accept credentials from an external identity provider in order to make access control decisions; provides path discovery and secure access to the credentials needed for authentication; federated services	Federal Identity, Credential, and Access Management (FICAM)

	typically perform security operations at run-time using valid NPE credentials	
identity	a set of attributes that uniquely describe an entity within a given context	Modified from NIST Special Publication 800-63-2
Multi-factor authentication	Combining two or more authentication factors to logon to an authentication system. Allowable factors include “something you know”, “something you have”, and “something you know”.	
identity provider (IdP)	a trusted entity that issues or registers subscriber tokens and generates subscriber credentials	Modified from NIST Special Publication 800-63-2
password	a secret that a claimant memorizes and uses to authenticate his or her identity	NIST Special Publication 800-63-2
privacy-enhancing technologies	a set of tools, applications or mechanisms which—when integrated in information systems—enables the mitigation of risks of adverse effects on individuals from the processing of their personal information within the information systems.	NIST
public key infrastructure	a set of policies, processes, server platforms, software and workstations used for the purpose of administering certificates and public-private key pairs, including the ability to issue, maintain, and revoke public key certificates	NIST Special Publication 800-63-2
Relying Party (RP)	an entity that relies upon the subscriber’s token and credentials or a verifier’s assertion of a claimant’s identity, typically to process a transaction or grant access to information	NIST Special Publication 800-63-2

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