Practical Implications of Public Key Infrastructure for Identity Professionals

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Abstract

Public Key Infrastructure, or "PKI," is a technology that enables authentication via asymmetric cryptography. It is widely deployed for some vital security use cases on the Internet, especially for authentication of servers via Transport Layer Security (TLS).

Despite its wide use for some scenarios, there are significant challenges in deploying PKI for more widespread use among smaller organizations or consumers.

Identity Professionals who need to deploy a PKI or have inherited a deployed PKI from someone else have several important considerations, including lifecycle management of keys and certificates, choosing the appropriate way to encode user identifiers and understanding cross-PKI trust.

Introduction

In high-risk environments, where all participants must always know the identity of an authentication subject to a high degree of assurance, PKI is one of the oldest and most widely deployed authentication technologies in use. There are significant challenges in the deployment of PKI, which we discuss below, but for many years PKI was the only high assurance credential[i] available in the broader market. It is still considered the gold standard of credential assurance by many experts. Military and government environments have used PKI to provide secure authentication since the late 90s.

In commercial environments, PKI has not seen the same degree of success. This article discusses some reasons for the lack of widespread adoption. Despite the lack of broad deployment, PKI can be a feasible alternative to passwords for some enterprises, thanks to Microsoft's implementation of Smartcard Login. Enterprises have taken a renewed interest in smartcard login to eliminate passwords for specific environments and scenarios.

This article includes analysis and guidance for the deployment of PKI for both human users and machines.

Terminology

- Asymmetric Cryptography: Any cryptographic algorithm which depends on pairs of keys for encryption and decryption. They are referred to as asymmetric because one key encrypts, and the other decrypts. And the keys are not shared between parties.
- Automatic Certificate Management Environment (ACME): A communication protocol for automating interactions between Private Key Holders and Certificate Authorities. Based on JSON and HTTP, it is widely deployed to support the issuance of TLS certificates for web servers.

- Certificate Authority Trust List (CTL): A list of Trusted Certificate Authorities maintained by a client.
- Certificate Management System (CMS): A system that provides a management and reporting layer around certificate issuance and revocation. They can integrate with CA products from multiple vendors, as well as IGA and Service Desk systems.
- Certificate Policy (CP): A document that defines the high-level policy requirement for a PKI. The outline for a CP is described RFC 3647, which identifies the policy framework for PKI. A certificate policy is typically published to external parties so that they can determine whether to trust certificates issued by the CA publishing the CP.
- Certification Practices Statement (CPS): A document using the RFC 3647 format which identifies the Practices which implement the requirements documented in the CP. Unlike the CP, the CPS is rarely published in unredacted form.
- Certificate Revocation List (CRL): A list of revoked certificates published by a Certificate Authority
- Certificate Signing Request (CSR): When requesting a certificate, the requesting entity provides a copy of the public key along with their name and other information in a specially formatted binary object called a CSR.
- Classical Computer: A computer that uses binary encoding and Boolean logic to make calculations in a deterministic way. Classical Computers are usually contrasted with Quantum Computers.
- Cryptographic Module Validation Program (CMVP): A program allowing cryptographic module developers to test their modules against the requirements defined in FIPS-140. Compliant modules are listed on a US government-run website.
- Electronic Identification, Authentication and Trust Services (eIDAS): European legislation that gives legal standing to electronic signatures. This legislation also documents how to provide legally binding digital signatures with X.509 certificates to comply with Qualified Signature.
- Elliptic Curve Cryptography (ECC): An asymmetric cryptosystem based on calculations of points along elliptic curves.
- Encryption: Processing data using a cryptographic algorithm to provide confidentiality assurance.
- Federal Agency Smart Credential Number (FASC-N): A unique identifier associated with a smart card. Used in the US Federal Government PIV standard to support Physical Access.
- Federal Information Processing Standard **(**FIPS) 140: A NIST standard defining “Security Requirements for Cryptographic Modules.
- Groups: A set of identities with defined permissions. In this specific context, a group contains many individuals, but the group identity is opaque, and no information is available regarding which group member took an individual action.
- Hardware Security Modules (HSMs): A hardware device that generates and protects cryptographic keys.

- Identifier: The way a system refers to a digital identity. PKI Certificates support both internal and external identifiers. See Ian Glazer's article, "Identifiers and Usernames," for a generic overview of identifiers.[ii]
- Internet Key Exchange (IKE): A subordinate standard under IPsec which specifies how to use X.509 certificates to establish symmetric keys for an IPsec tunnel.
- Internet Protocol Security (IPsec): A standard for communication between two machines providing confidentiality and integrity over the Internet Protocol.
- Key: In a cryptosystem, a Key is a piece of information used to encrypt or decrypt data in a cryptographic algorithm.
- National Institute of Standards and Technology (NIST): A US Government agency that defines and publishes standards. One department within NIST, the Computer Security Resource Center (CSRC), publishes the Federal Information Processing Standards (FIPS) series. While these standards are only mandatory for US Government Agencies, they are widely recognized as de-facto standards globally.
- Non-person entities: Any unique combination of hardware, software firmware (e.g., device) that utilizes the capabilities of other programs, devices, or services to perform a function. Non-person entities may either act independently or on behalf of an authenticated individual or NPE.[iii]
- Online Certificate Status Protocol (OCSP): A protocol that allows a client to query the Certificate Authority or a Validation Authority for the status of an individual certificate rather than downloading a CRL.
- Path Discovery and Validation (PDVal): The process to determine whether a certificate is valid and trusted by the validator.
- Personal Identification Number (PIN): A numeric secret commonly used to unlock a private key container in software or hardware.
- Personal Identity Verification (PIV): A US Government program designed to enable strong authentication for all government employees and contractors, based on Public Key Infrastructure.
- Private key: A key that is exclusively and privately controlled by a single entity. It corresponds to a public key that the entity may share for data encryption or signature verification.
- Public key: A key that is publicly distributed by an entity that is used with the corresponding private key.
- Public Key Certificate: A certificate containing a public key, one or more identifiers for the private key holder, an identifier for the Certificate Authority, and additional metadata to support security requirements.
- Public Key Infrastructure: A set of tools, standards, and related policies designed to manage trust based on public/private key pairs and certificates.
- Registration Authority (RA): An individual, system, or business function which provides registration and identity proofing for entities receiving certificates and manages the certificate issuance and renewal process. The most important responsibilities of an RA include identity proofing and binding of the private key to the identity.

- Roles: An entity that defines a set of permissions. A role must be associated with an individual user, and the user gains the associated authorization during the time that they are associated with the role.
- RSA: An asymmetric cryptosystem based on large prime numbers. The acronym RSA stands for the three principal inventors, Ron Rivest, Adi Shamir, and Len Adleman.
- S/MIME: A standard for constructing and sending digitally signed or encrypted messages using asymmetric cryptography.
- Secure Socket Layer (SSL): A deprecated standard for encrypting data in transit; it has been superseded by TLS.
- Server-based Certificate Validation Protocol (SCVP): A protocol that allows a client to query a server to determine whether a certificate is valid and trusted. The server does not need to be associated with the issuing CA SCVP does two things; (1) it determines the path between the end-entity and the trusted root whereby the client doesn't need to trust any intermediate CAs. (2) it also performs delegated path validation according to policy.
- Signature: Processing data using a cryptographic algorithm to provide integrity assurance.
- Subject Alternative Name: One or more identifiers for a certificate subject that can be used to carry application-specific identifiers such as email address or User Principle Name (UPN).
- Subject Distinguished Name (Subject DN): A unique identifier for the Subject, within the scope of the Certificate Authority. Subject DN is structured like an LDAP entry name.
- Transport Layer Security (TLS): A cryptographic protocol designed to provide confidentiality and integrity of communications between two endpoints.
- X.509: An ISO standard from the X.500 series that defines the basic rules for encoding public key certificates.
- Validator: An entity that verifies a certificate and confirms that the other party controls the private key in the transaction.

Basics of PKI for Identity Practitioners

What is PKI

PKI stands for "*Public Key Infrastructure*." a set of interlocking standards and technologies supporting the secure exchange of public keys for *asymmetric cryptography* use cases.

Originally developed as part of the X.500 series of specifications for electronic directory services, the *X.509* standard proposed a way to link a public key into a universal, hierarchical directory designed to support OSI networks.

OSI is, for all intents and purposes, dead. However, the X.500 specification lives on in simplified form as LDAP, and X.509 certificates are widely deployed for some critical use cases.

PKI lives on and is woven deeply into the fabric of the Internet. PKI supports the following critical internet capabilities:

- *TLS* as a general encryption layer for application protocols
- *S/MIME* is a standard for Secure Email
- *IPsec* is a for Virtual Private Networking, which supports PKI through the Internet Key Exchange (IKE) extension
- Some commercial software or services, such as Adobe Acrobat, Microsoft Word, or Docusign, support electronic signatures for non-repudiation or integrity protection. In Europe, Qualified Signatures and Time Stamps have official legal standing, recognized in the Electronic Identification, Authentication and Trust Services (eIDAS) framework

This article is not a general primer on PKI. Interested readers are referred to the References section at the end for more detail. This article provides a minimal overview of PKI related to Identity Management and identifies critical issues relevant to Identity Practitioners.

Here are some excellent resources to learn more about PKI in general:

Books:

- Applied Cryptography, by Bruce Schneier, is a classic guide to the cryptographic technology underlying PKI and its applications. For those who want to know everything about this subject, this is the place to start.

Online Resources

- The US Federal government has deployed PKI widely for both logical and physical access. IDManagement.gov maintains information about the Federal PKI here: https://playbooks.idmanagement.gov/fpki/
- Bruce Schneier, the author of Applied Cryptography, maintains a fascinating and helpful blog here: https://www.schneier.com/

Standards:

- X.509: The original specification for PKI certificates. This document must be purchased.
- RFC 5280: The Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile standard specifies a subset of the X.509 standard for use on the Internet.

How do a ‘Private Key’ and a ‘Public Key Certificate’ Provide Authentication Assurance

Public and Private Keys

Private and *public keys* are random numbers, but not just any random number.

- In the *RSA* specification, keys are derived from a large prime number.
- In *ECC*, keys are related to points along a particular elliptical curve.

By taking some data such as text or an image and plugging these inputs into a specific equation with one of the numbers (keys), you create a scrambled version of the data that only the other number (key) can unscramble. This concept is the basis of asymmetric cryptography.

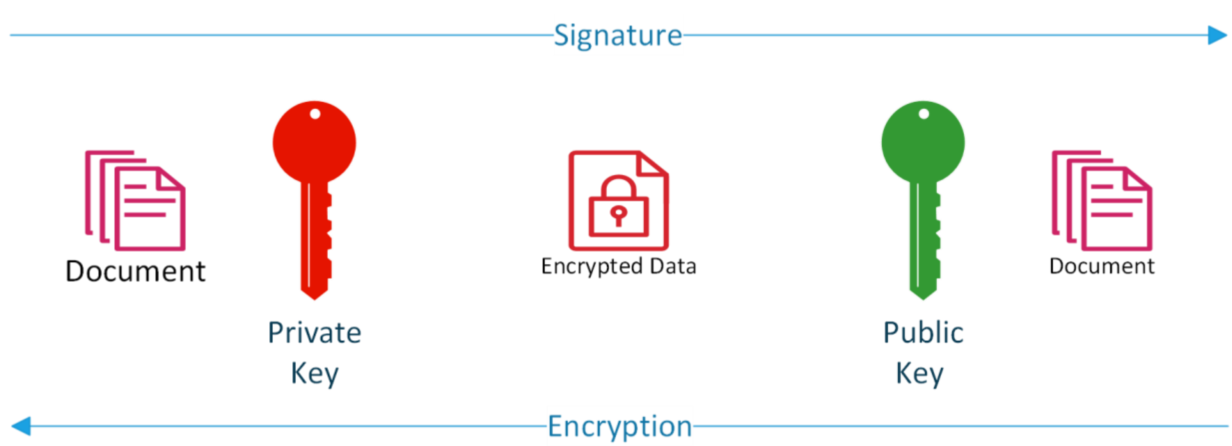
The *private key’s* owner must retain and closely guard it, but the public key can be shared with anyone.

The sender of a message can scramble it using another user’s public key to ensure that only the other user, with their private key, can unscramble and read the message.[iv]

The sender of a message can scramble it using their private key, and a recipient, who can unscramble the message with the public key, can be sure that the message was sent by the owner of the private key and has not been modified in transit[v].

In asymmetric cryptography, “*encryption*” refers to scrambling a message with the public key, and “*signature*” refers to scrambling a message with the private key.

In practice, signature and encryption are much more complicated, involving cryptographic hashes or intermediate symmetric keys. For our purposes, it is sufficient to understand that private keys sign, and public keys encrypt.



In public-key cryptography, the user is whoever has control of the private key. To authenticate someone in asymmetric cryptography is to require them to use their private key.

The user can provide a signed message for the *validator* to decrypt. Alternatively, the validator can choose and encrypt data that the user must decrypt with the private key. In both scenarios, possession, and control of the private key, demonstrated by the ability to use the private key to encrypt or decrypt data, is sufficient to prove the user's identity.

Public Key Certificates

Exchanges of "naked" public keys will not scale beyond the simplest of closed systems in the context of business process support. They are used in some contexts, notably in the SSH protocol, or "Web of Trust" based systems like PGP. In an enterprise or government context, where a central trusted authority vouches for identities according to a documented process, public keys are typically exchanged in public key certificates.

Business processes occur between named entities, such as companies, employees, or systems. Supporting business applications with asymmetric cryptography requires the named entity's public key to be connected or "bound" to the named entity's *identifier*. Public key certificates are the artifacts that provably connect a key and a named entity's identifier.

A *public key certificate* contains at least three critical pieces of information:

- A public key
- One or more identifiers associated with a user
- Information about the authority that vouches for the association between the key and the identifier.

The public key certificate is a file structured in a particular way, defined by the X.509.3 standard, which contains the user's public key and their identifiers and some critical metadata.[vi] The package is signed using the private key of a trusted third party, called a "Certificate Authority."

Who Can Get a Certificate

Any business process participant that can generate and store a private key and associated public key may receive a certificate. The most common recipients of certificates are listed here:

- Humans: A human being can receive a public key certificate that names them individually.

- *Non-person entities*: Examples of non-person entities include devices like routers, software services like web or email servers, IoT devices, or other non-human entities like software providers who digitally sign software packages.
- *Roles*: Sometimes, a person may be acting in a role, such as “Software Release Manager” or “Doctor on call.” A certificate can be issued to someone acting in a role, which allows them to authenticate in the persona of their role. Role certificates are issued to individuals and contain a personal identifier for the person holding the private key to maintain individual accountability. Everyone with a role certificate has a unique private key.
- *Groups*: In some cases, a private key must be shared by several people. In this case, a certificate can be issued to a group. The certificate will identify the group, and additional security precautions will be taken to ensure that only authorized group members use the private key.

How Are PKI Certificates Like Other Credentials, and How Are They Different?

Like other credentials, a user can use a private key and PKI certificate to authenticate in an electronic transaction.

As with all electronic credentials, the overall assurance of the credential depends on the security of the identity proofing and issuance process. If the proofing and issuance processes are insecure, authentication is insecure, regardless of how secure the credential itself can be.

However, there are several differences between PKI and other authentication credentials.

A public key certificate file contains all the information necessary to authenticate the Subject: For most other credential types, each authentication challenge requires the involvement of the credential issuer. By contrast, a PKI authentication can occur without any direct interaction with the issuing Certificate Authority. The user generally provides a secret to activate the private key, such as a PIN or password. This secret is input directly to the software or device containing the private key; it is not provided to the Certificate Authority.

Public key certificates are long-life credentials: Certificates may be valid for a much longer-term than is typical for other credential types. It is not unusual for a Public Key certificate to be issued to a user with a three-year lifetime. This extended lifetime is acceptable because the private key credential is not user-selected and is too long to be easily memorized or copied by humans. This characteristic is discussed in more detail in a later section.

Key protection affects the overall security of the PKI credential: Like any other authentication secret, a private key must be protected from third parties in order to prevent them from using the secret to impersonate a user. Recall that in public-key cryptography, the user is whoever controls the private key. For this reason, it is essential to ensure that private keys cannot be copied or taken without a user's awareness and permission. Because private keys are usually very long and appear random, they cannot be memorized and must be stored.

There are several technologies designed to protect private keys, including *Hardware Security Modules (HSMs)* or personal tokens such as the YubiKey Security Key or SafeNet eToken Smart Card. The United States *National Institute of Standards and Technology (NIST)* has published a standard, *Federal Information Processing Standard (FIPS) 140*, and has implemented the *Cryptographic Module Validation Program (CMVP)* to ensure that HSMs implement proper cryptographic algorithms and key protections for private keys.
The security properties of PKI credentials mean that they can provide a higher level of identity assurance than other kinds of credentials. The highest levels of assurance defined by governments are usually reserved for PKI certificates stored on smart cards. This security comes at a cost, both in terms of direct costs and additional complexity.

PKI credentials can support additional use cases beyond authentication: While passwords, OTP, and others are limited to interactive authentication, PKI credentials can be used for additional use cases where identity is important, but the transaction is not immediate and interactive. One example is a digital signature, where the identity of the signer must be established, but the entity verifying the identity may be completely unknown to the signer. Encryption is another case where the sender of the sensitive data must ensure that the intended recipient is the only one who will have access, but the data may be exchanged out-of-band and asynchronously.

Factors and Problems Limiting PKI Adoption

The roots of PKI extend back into the 1970s, and its use as the basis for secure communication was cemented in the earliest versions of SSL published in the mid-1990s. However, despite its maturity and widespread use for some specific use cases, it has not seen broad adoption for authentication of individuals, either for business to consumer or business to employee use cases. There are many reasons why PKI has not seen widespread adoption outside these narrow use cases, though the technology and vendor support has improved. The following are some of the most important areas of concern:

Enterprise key management is challenging: In order for PKI to be a trustworthy and secure authentication approach, the private key must be controlled by the authentication subject. As we said earlier, the user is whoever controls the private key. There are two ways to ensure that the intended user is the only one with access to the private key: The authentication subject must generate their own private key within a protected software environment, or the private key must be generated on behalf of the Subject and then passed to the Subject using a secure transfer mechanism. Both of these are complex processes that are difficult to automate without extensive tooling.

Internet software providers have focused on providing automation for key technical use cases, such as TLS for Web Servers. Protocols like *Automatic Certificate Management Environment (ACME)* and services like Let's Encrypt are designed to provide zero-touch key management and certificate rotation for web servers. These services are not designed for the management of certificates issued to humans.

Vendors, meanwhile, have implemented sophisticated, proprietary solutions for the automation of key management. Microsoft Active Directory Certificate Services can provide key management and certificate services for machines and human users in an Active Directory environment. The Entrust Certificate Authority provides a client-side tool that will manage key and certificate lifecycle for the clients with the tool installed. These tools are designed to support a closed system.

Other providers, like KeyFactor or Venafi, can provide certificate lifecycle services. However, the tools are proprietary, and significant integration efforts may be required to implement these products.

PKI has poor usability: As discussed above, key management is a complex organizational and technical issue with its share of challenges. Unfortunately, many PKI implementations require end-users to manage a lot of that complexity. Particularly, users must initiate the key generation and request process. Once a private key is generated and a certificate issued, each tool the user uses to authenticate with (web browser, mail client, desktop environment, etc.) must be configured to use the private key generated by the user and manage the list of trusted issuers. Sophisticated enterprises with dedicated engineering teams should be able to manage this complexity on behalf of the user community, but this complexity is difficult to manage even in highly controlled environments. For the vast majority of small business and home users, this complexity is completely unmanageable.

One way to address this user challenge is to have a designated administrator or security officer who assists users in generating their private keys and initializing their tokens. This approach is very common in large enterprises but can be feasible for smaller companies as well. Individual assistance for users

In high-security environments, private keys are generated on a hardware security module. This hardware requirement adds device driver installation and management issues on top of all of the other issues that confront users attempting to use PKI for authentication. Some platform vendors have implemented platform-level API (e.g., Microsoft CAPI), but support for this API is not universal, with some applications implementing proprietary or platform-neutral key storage systems that do not integrate with the host OS.

As is the case with many IDM technologies, the 80/20 rule should be observed. IDM professionals should ensure that critical or widespread user applications support your PKI implementation and accept alternative credentials for critical legacy applications.

Public key enablement of applications is hard: So far, we have discussed the difficulty of using PKI for authentication from the perspective of Authentication Subjects. Enabling applications to consume PKI credentials is even more challenging in some ways. First, the list of trusted CA issuers must be maintained and synchronized across all applications where the user may need to authenticate. Secondly, certificates must be validated by the authenticating application, which requires the application to access a public HTTP site or LDAP directory to obtain Certificate Revocation information. Finally, a local user profile must be created in the application based on an identifier present in the certificate or obtained from the user via manual registration. There is no concept of provisioning or deprovisioning built into PKI by default, and so any such capability must be implemented via a separate integration with the Registration Authority (RA). Since it is common for users to authenticate with a site directly, such a capability may not even be offered by the CA. Identity professionals should investigate existing directory technologies such as AD that can support user profiles for multiple applications.

For enterprise applications, an internal IGA system may manage these aspects, but across enterprise boundaries or in a B2C context, this additional complexity makes PKI credentials difficult and expensive compared to other authentication options.

Certificate trust path discovery and validation are hard, and existing implementations have inconsistent behavior: In the previous section, we discussed the need for applications to validate the certificates. This validation is complicated, even when certificates are issued from a static Trust List of known good issuers[vii]. However, PKI supports a form of federation through cross-certification, discussed below in more detail. In this section, we will simply note that the process of determining whether a certificate is issued by a trusted partner in a federated, or cross-certified, environment is very challenging.

Path Discovery and Validation (PDVal) is complex. Different vendors implement it inconsistently. A certificate may be trusted by one service but not another depending on the underlying certificate validation library. Third-party solutions exist which support consistent PDVal across products, but they must be implemented and integrated with each endpoint. This burden has made enterprises leery of implementing PKI on the server-side.

Unique Considerations for Identity Practitioners

Ensure that PKI is the Right Fit for Your Requirements

Deployment of PKI involves several complexities and difficulties that I have outlined in this document. However, PKI is a powerful tool that can offer strong authentication and support other use cases, such as email signing/encryption, that are not possible with other strong authentication credentials. When considering the deployment of PKI, ensure that the use cases you can support justify the added complexity for your environment and for your users.

For TLS and link encryption, PKI may be the best or only choice, but that does not necessarily mean that you should implement your own local PKI. Use of a third-party PKI service provider is a great alternative for many organizations.

The Importance of Planning

If you determine that an internal PKI is the right option for your organization, planning is critical for a successful PKI deployment. While the need for planning is not unique to PKI, the complexity of a PKI environment can make retroactive cleanup much more difficult than careful up-front planning and deployment. As with any Identity Management technology, planning is critical to success.

IGA and PKI

Enterprises that leverage Identity Governance and Administration tools may need to expand their toolkit to accommodate PKI credentials. Existing IGA tools can manage accounts and privileges but may not manage PKI credentials associated with the managed accounts. It is important to recall that a PKI certificate and private key represent a self-contained credential that may be used even if the underlying account is deactivated or deleted. Unless the certificate is revoked or has expired, external applications may still accept a PKI credential as valid.

In addition, certificates issued to NPEs may have a lifecycle that is not managed in any existing tool. Yet these credentialed entities will have access rights within the enterprise that must be managed.

Many CAs include management capabilities to address these challenges. There are third-party CMS products that interact with multiple CA products to provide a single pane of glass for certificate management in a multi-vendor multi-CA environment. These products are discussed in more detail in the next section but be aware that IGA and CMS products may need to be integrated.

Lifecycle Management of PKI Certificates Compared to Other Credentials

Cryptographic algorithms are designed to ensure that private keys cannot be easily guessed. For example, a *classical (non-quantum) computer* would need about 300 trillion years to break a 2048-bit RSA key, while the same computer would require an average of five sextillion seven hundred eighty-three quintillion + years to break a 128-bit ECC key. However, the security of an overall system rarely depends exclusively on math.

The overall security of a PKI system includes several variables, including unreliable humans. Certificates are generally issued for a relatively short time, such as 90 days for public SSL certs or three years for human subscriber certificates. CA certificates may be valid for as long as 20 years. This lifetime is much longer than a typical password or other authenticator because the private key is never directly presented during authentication. The CA certificates need to be stored in a Hardware Security Module to ensure they are not stolen.

Because certificates are programmed to expire, key management can become a significant challenge. A Certificate Management System (CMS) can be used to monitor certificates and automate the renewal process or provide notification when a renewal is required. Most CA products include a rudimentary management console, but dedicated products are available that provide a single pane of glass to manage multiple CA events from different vendors. CMS systems can also provide Service Desk support tools for assisting in smartcard registration and forgotten/locked PIN issues.

As with any credential, it is possible that a credential may no longer be trusted for security reasons or due to other circumstances. PKI provides for revocation of public key certificates in this case. The list for "no longer trusted" certificates is called the *Certificate Revocation List (CRL)* and is published to a location that is identified in the certificate. Alternative protocols such as the *Online Certificate Status Protocol (OCSP)* offer other means of checking whether a certificate is revoked.

In addition, most browsers have implemented proprietary revocation checking techniques.

A third technology, called *Server-based Certificate Validation Protocol (SCVP),* has been developed and documented in a standard but has not been widely implemented. It is mentioned here for completeness but can be disregarded.

Because a certificate can be passed between the Subject and a third party without the original issuer of the certificate being involved, it is imperative that applications correctly validate certificates and check the revocation information.

Options for Identifiers in Public Key Certificates

The purpose of the certificate, as described above, is to link a public key with a user identifier. Of course, a user may have several identifiers for different use cases. Rather than issuing separate certificates for users with different embedded identifiers, the PKI specification supports including multiple identifiers in a single certificate.

The primary user identifier in a certificate is the *Subject Distinguished Name (Subject DN)*. The Subject DN must be structured like a directory Distinguished Name. Typically, there will be a “Base DN” shared by all certificates issued from a Certificate Authority and one or more “Relative DNs” which identify distinct certificate subjects. Common relative DNs include “Organization” and “Organizational Unit”. Finally, a common specific Identifier for the user is known as the “Common Name”. This identifier is usually the user’s Legal Name. In large PKI deployments, users with frequently seen names may have other identifiers embedded or appended to their names to distinguish between users with the same legal name.

Common Name is not the only possible identifier for a user. UID can also be used to identify a certificate subject in the Subject DN

Because the Subject DN mimics an LDAP Distinguished Name, it is fairly limiting. For this reason, an additional field is often used instead. The “*Subject Alternative Name*” field is a much more flexible option to encode additional user identifiers. It allows multiple names to be encoded and does not impose any structure. Common uses for Subject Alternative Name include:

- Email address to support S/MIME digital signature and encryption
- UPN to support smart card login on the Windows platform
- Hostname to support TLS connections

The Subject Alternative Name does not impose any constraints on the type of identifiers that can be encoded, and so in addition to all of the previously listed identifiers, private communities of interest will insert identifiers that have strictly local meaning into this field. An example is the *Federal Agency Smart Credential Number (FASC-N),* which is part of the US Federal Government’s *Personal Identity Verification (PIV)* standard.

Generally, Subject Alternative Names should be used for user identifiers. The Subject DN must be unique but should not contain multiple identifiers or non-standard ID types.

Machine Identities and Certificate Management Systems

While PKI has not seen widespread adoption as a credential for people, it is completely dominant as a credential for machines, thanks to its use in TLS. TLS is not only used to provide secure access to web servers in end-user browsers; it is also widely used as a tunneling technology in machine-to-machine or site-to-site communication.

With the spread of virtualization and containerization technologies and the increased use of cloud architectures, the number of PKI-based machine identities is exploding in most enterprises. Managing and tracking the keys and associated certificates is becoming more difficult.

A Certificate Management System is an increasingly critical tool for enterprises to deploy in order to avoid service outages due to expired certificates, especially for enterprises with hybrid-cloud-based infrastructure or multi-vendor server environments.

Cross-certification for PKI

The key difference between cross-certification for PKI credentials vs. other types of credentials is that the user may authenticate to an external application without the issuer performing any runtime validation. This action can potentially simplify authentication flows but places a larger burden on end applications since they are expected to validate the trust themselves.

Typically, trusted issues are explicitly added to a static *Certificate Authority Trust List (CTL)*. The location of the trust list may vary from product to product. Java maintains its own trust store, as does the Windows Operating System and most web servers. Managing and maintaining a trust list for an Enterprise using an internal PKI can be complicated, whereas the complexity is greatly diminished if one obtains certificates from commercial CAs whose CA certificates are trusted by browsers and web servers.

Alternatively, it is possible to use cross-certificates between independent Certificate Authorities to create a more complicated trust fabric. In this case, enterprises manage a minimal set of certificates in their trust list and allow the authenticating applications to dynamically discover trust relationships between CAs using PDVal. Vendor support for PDVal varies widely, and real-world deployments are not straightforward and are prone to unexpected and difficult technical issues due to differences in implementations between vendors. If your application must do PDVal, then some third-party tools implement the protocol and can be plugged into authenticating applications.

Finally, Identity Federation technologies can simplify the implementation of cross-domain trust by providing assertions across enterprise boundaries rather than relying directly on PDVal. The certificate can be validated within enterprise boundaries, using relatively simple processes, and a federated assertion can be provided to external applications. It should be noted that this can address the interactive authentication use case but will not solve the challenges associated with other use cases that PKI can support, such as secure email encryption and signature or digital signatures for documents.

Conclusion

PKI is a powerful but complex tool for highly-secure authentication. It is likely already in use within your environment for NPE or machine identities, and Identity professionals should investigate the tools and processes used by individual programs to minimize redundancy of effort and cost.

Carefully weigh the benefits of the use cases within your own environment before committing to deploying the technology to end-users. If you choose to deploy PKI, avoid the temptation to introduce local or proprietary extensions, and stick to widely supported standards.

If an enterprise identity management environment is needlessly complex, it will complicate PKI deployment significantly. Before deploying PKI, or any other complex authentication technology, ensure that identity management tools and practices are rationalized and streamlined within the enterprise environment.

If you do introduce PKI for end-users, consider deploying a Certificate Management System to track the lifecycle of keys and certificates across your entire domain.

Author Bio

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[i] Note that credential assurance is distinct from identity assurance. Identity assurance measures how well you verified the identity of the account holder and how securely you connected the identity to the credential at the time of issuance. Credential assurance measures how confident you can be that the credential subject has maintained control over the credential, and that the credential has not been compromised.

[ii] Glazer, Ian, "Identifiers and Usernames," IDPro Body of Knowledge, 31 March 2020, https://bok.idpro.org/article/id/16/.

[iii] Williamson, Graham, and André Koot, "Non-human Account Management," IDPro Body of Knowledge, 30 October 2020, https://bok.idpro.org/article/id/52/.

[iv] Technically, the sender generates a symmetric key, encrypts the message with the symmetric key, and then encrypts the symmetric key with the intended recipient's public key.

[v] Technically, digital signing appends a 'hash' to the document that can be deciphered by the sender's public key - ensuring the sender's identity.

[vi] International Telecommunications Union – Technology (ITU-T), *X.509 : Information technology - Open Systems Interconnection - The Directory: Public-key and attribute certificate frameworks*, October 2019, https://www.itu.int/rec/T-REC-X.509.

[vii] For example, see this article on how browsers handle revocation checks: https://www.ssl.com/blogs/how-do-browsers-handle-revoked-ssl-tls-certificates/.