Network Security Essentials

Sixth Edition

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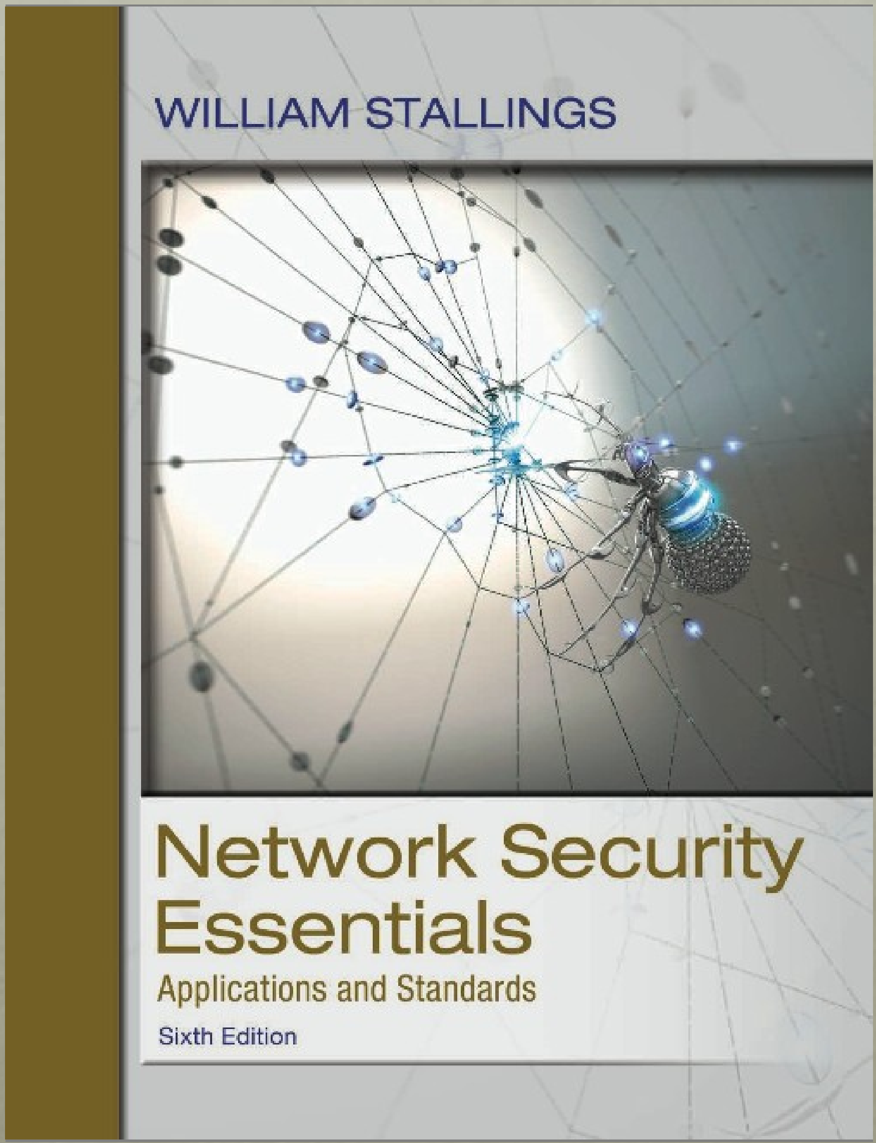


Chapter 4

Key Distribution and User Authentication

Remote user authentication principles

- In most computer security contexts, user authentication is the fundamental building block and the primary line of defense
- User authentication is the basis for most types of access control and for user accountability
- RFC 4949 (Internet Security Glossary) defines user authentication as the process of verifying an identity claimed by or for a system entity
  - Identification step
    - Presenting an identifier to the security system
  - Verification step
    - Presenting or generating authentication information that corroborates the binding between the entity and the identifier

NIST Model for Electronic User Authentication

- NIST SP 800-63-2 (*Electronic Authentication Guideline,* August 2013 defines electronic user authentication as the process of establishing confidence in user identities that are presented electronically to an information system
- Systems can use the authenticated identity to determine if the authenticated individual is authorized to perform particular functions
- In many cases, the authentication and transaction or other authorized function take place across an open network such as the Internet
- Equally, authentication and subsequent authorization can take place locally, such as across a local area network

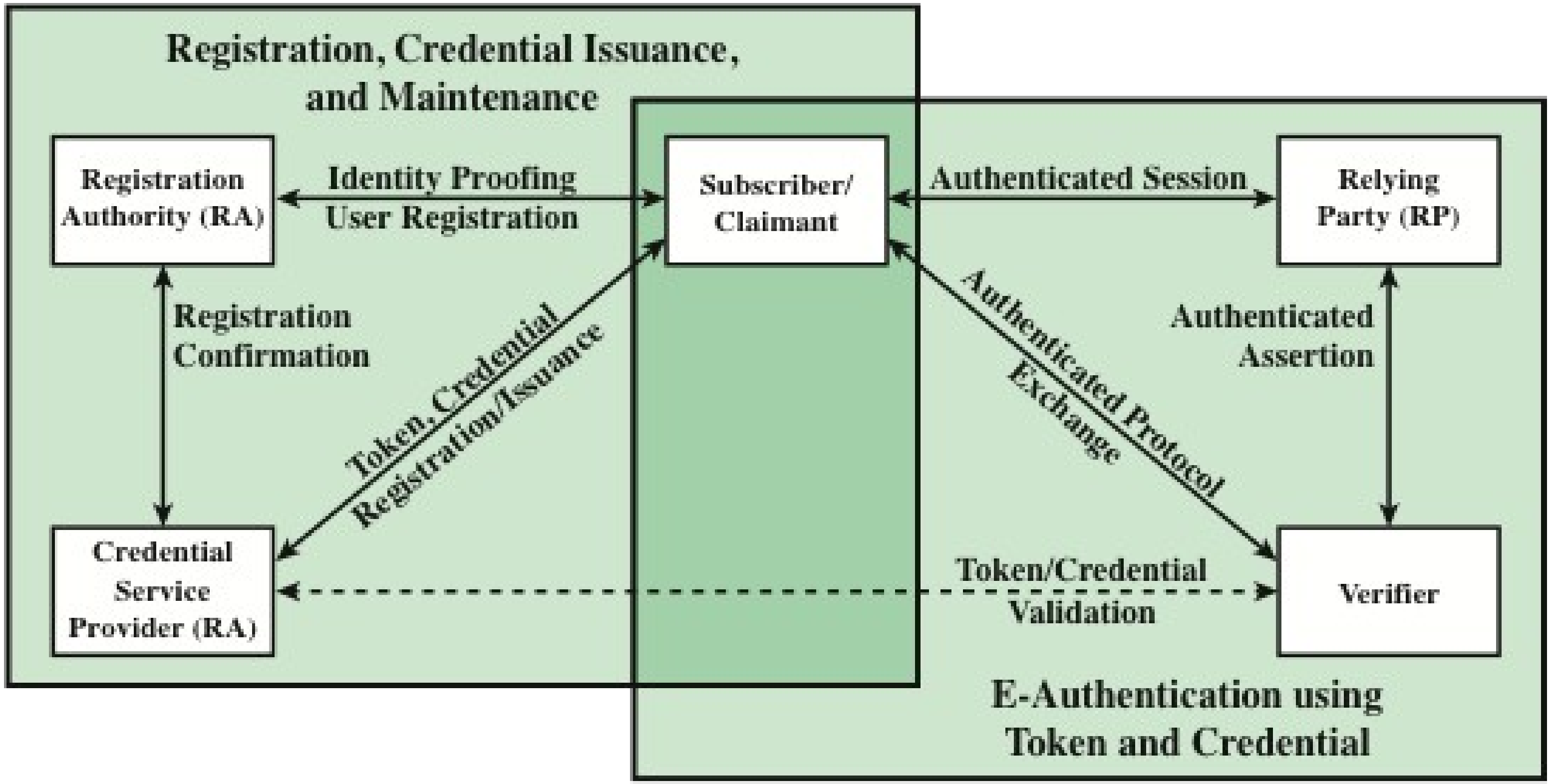


Figure 4.1 The NIST SP 800-63-2 E-Authentication Architectural Model

Means of authentication

- There are four general means of authenticating a user's identity, which can be used alone or in combination
  - Something the individual knows
    - Examples include a password, a personal identification number (PIN), or answers to a prearranged set of questions
  - Something the individual possesses
    - Examples include cryptographic keys, electronic keycards, smart cards, and physical keys
    - This type of authenticator is referred to as a *token*
  - Something the individual is (static biometrics)
    - Examples include recognition by fingerprint, retina, and face
  - Something the individual does (dynamic biometrics)
    - Examples include recognition by voice pattern, handwriting characteristics, and typing rhythm

Symmetric Key Distribution using symmetric encryption

- For symmetric encryption to work, the two parties to an exchange must share the same key, and that key must be protected from access by others
- Frequent key changes are usually desirable to limit the amount of data compromised if an attacker learns the key
- Key distribution technique
  - The means of delivering a key to two parties that wish to exchange data, without allowing others to see the key

Key Distribution

For two parties A and B, there are the following options:

1. A key could be selected by A and physically delivered to B.
2. A third party could select the key and physically deliver it to A and B.
3. If A and B have previously and recently used a key, one party could transmit the new key to the other, using the old key to encrypt the new key.
4. If A and B each have an encrypted connection to a third party C, C could deliver a key on the encrypted links to A and B.

Kerberos

- Key distribution and user authentication service developed at MIT
- Provides a centralized authentication server whose function is to authenticate users to servers and servers to users
- Relies exclusively on symmetric encryption, making no use of public-key encryption

Kerberos version 4

- A basic third-party authentication scheme
- Authentication Server (AS)
  - Users initially negotiate with AS to identify self
  - AS provides a non-corruptible authentication credential (ticket granting ticket TGT)
- Ticket Granting Server (TGS)
  - Users subsequently request access to other services from TGS on basis of users TGT
- Complex protocol using DES

Table 4.1
Summary of Kerberos Version 4 Message Exchanges

(1) **C → AS** $ID_c \| ID_{tgs} \| TS_1$

(2) **AS → C** $E(K_c, [K_{c,tgs} \| ID_{tgs} \| TS_2 \| Lifetime_2 \| Ticket_{tgs}])$

$$Ticket_{tgs} = E(K_{tgs}, [K_{c,tgs} \| ID_C \| AD_C \| ID_{tgs} \| TS_2 \| Lifetime_2])$$

(a) Authentication Service Exchange to obtain ticket-granting ticket

(3) **C → TGS** $ID_v \| Ticket_{tgs} \| Authenticator_c$

(4) **TGS → C** $E(K_{c,tgs}, [K_{c,v} \| ID_v \| TS_4 \| Ticket_v])$

$$Ticket_{tgs} = E(K_{tgs}, [K_{c,tgs} \| ID_C \| AD_C \| ID_{tgs} \| TS_2 \| Lifetime_2])$$

$$Ticket_v = E(K_v, [K_{c,v} \| ID_C \| AD_C \| ID_v \| TS_4 \| Lifetime_4])$$

$$Authenticator_c = E(K_{c,tgs}, [ID_C \| AD_C \| TS_3])$$

(b) Ticket-Granting Service Exchange to obtain service-granting ticket

(5) **C → V** $Ticket_v \| Authenticator_c$

(6) **V → C** $E(K_{c,v}, [TS_5 + 1])$ (for mutual authentication)

$$Ticket_v = E(K_v, [K_{c,v} \| ID_C \| AD_C \| ID_v \| TS_4 \| Lifetime_4])$$

$$Authenticator_c = E(K_{c,v}, [ID_C \| AD_C \| TS_5])$$

(c) Client/Server Authentication Exchange to obtain service

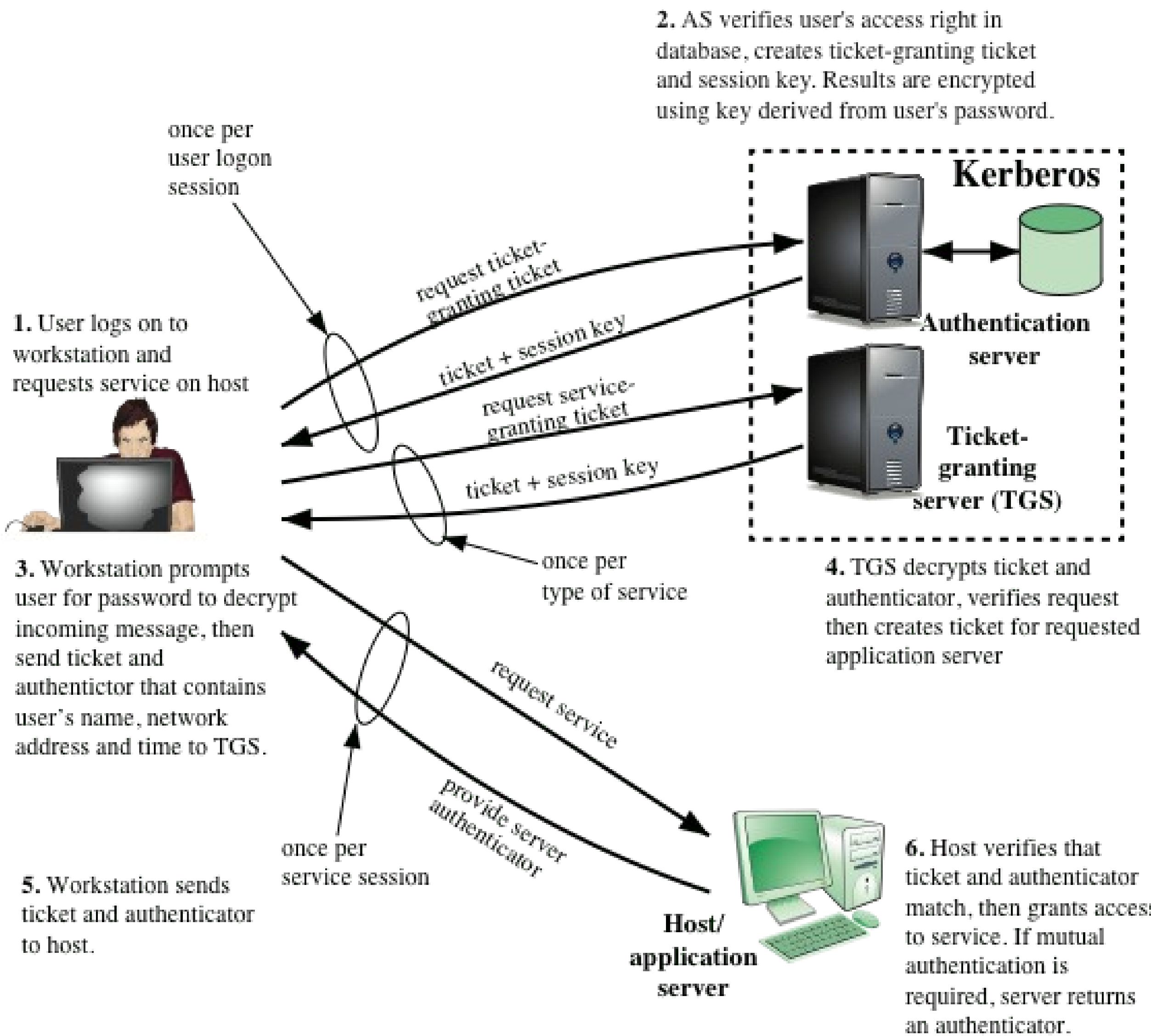


Figure 4.2 Overview of Kerberos

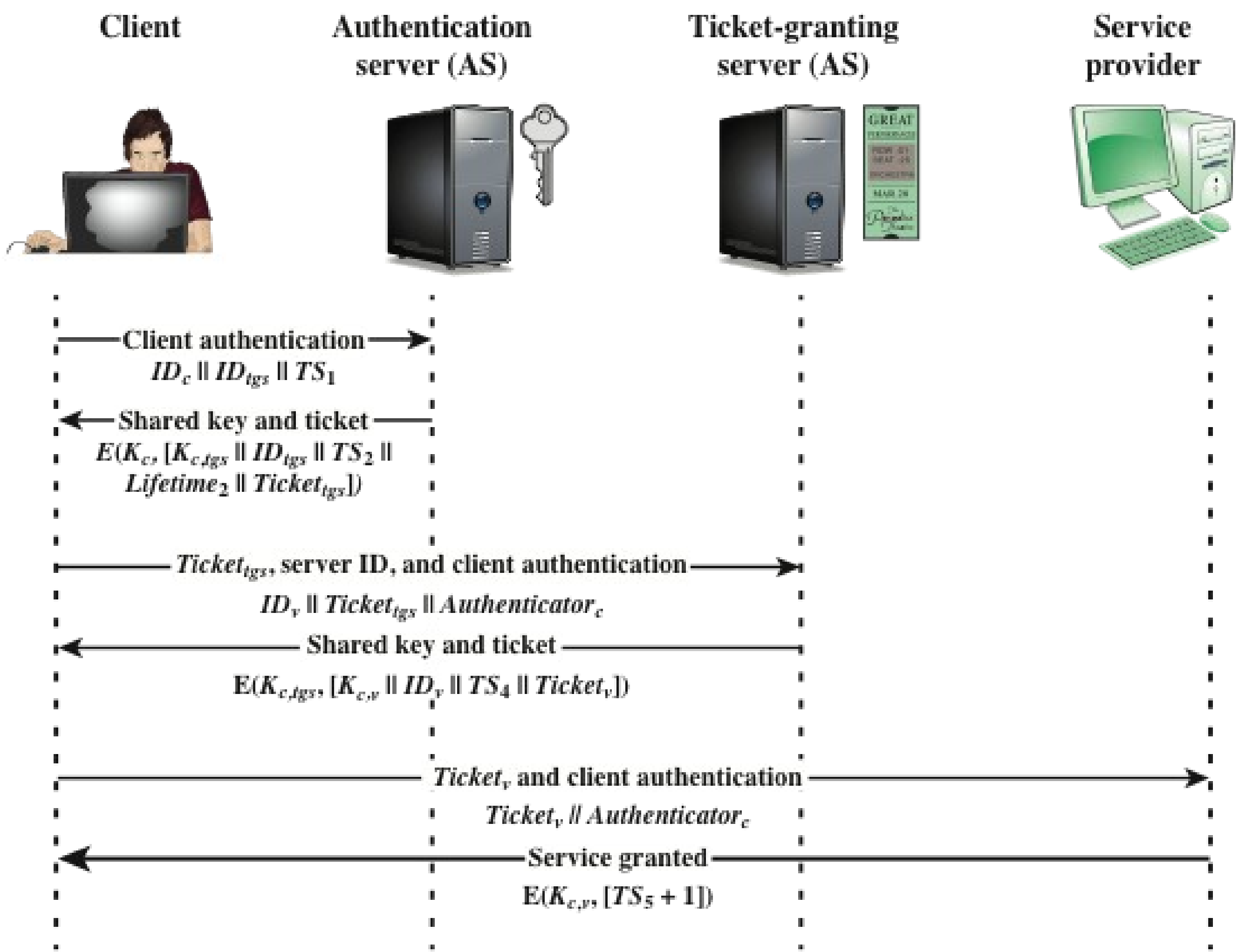


Figure 4.3 Kerberos Exchanges

Table 4.2 Rationale for the Elements of the Kerberos Version 4 Protocol (page 1 of 3)

Message (1)	Client requests ticket-granting ticket.
ID_C	Tells AS identity of user from this client.
ID_{tgs}	Tells AS that user requests access to TGS.
TS_1	Allows AS to verify that client's clock is synchronized with that of AS.
Message (2)	AS returns ticket-granting ticket.
K_c	Encryption is based on user's password, enabling AS and client to verify password, and protecting contents of message (2).
$K_{c,tgs}$	Copy of session key accessible to client created by AS to permit secure exchange between client and TGS without requiring them to share a permanent key.
ID_{tgs}	Confirms that this ticket is for the TGS.
TS_2	Informs client of time this ticket was issued.
$Lifetime_2$	Informs client of the lifetime of this ticket.
$Ticket_{tgs}$	Ticket to be used by client to access TGS.

(a) Authentication Service Exchange

Table 4.2 Rationale for the Elements of the Kerberos Version 4 Protocol (page 2 of 3)

Message (3)	Client requests service-granting ticket.
ID_V	Tells TGS that user requests access to server V.
$Ticket_{tgs}$	Assures TGS that this user has been authenticated by AS.
$Authenticator_c$	Generated by client to validate ticket .
Message (4)	TGS returns service-granting ticket.
$K_{c,tgs}$	Key shared only by C and TGS protects contents of message (4).
$K_{c,v}$	Copy of session key accessible to client created by TGS to permit secure exchange between client and server without requiring them to share a permanent key.
ID_V	Confirms that this ticket is for server V.
TS_4	Informs client of time this ticket was issued.
$Ticket_V$	Ticket to be used by client to access server V.
$Ticket_{tgs}$	Reusable so that user does not have to reenter password.
K_{tgs}	Ticket is encrypted with key known only to AS and TGS, to prevent Tampering.
$K_{c,tgs}$	Copy of session key accessible to TGS used to decrypt authenticator, thereby authenticating ticket.
ID_C	Indicates the rightful owner of this ticket.
AD_C	Prevents use of ticket from workstation other than one that initially requested the ticket.
ID_{tgs}	Assures server that it has decrypted ticket properly.
TS_2	Informs TGS of time this ticket was issued.
$Lifetime_2$	Prevents replay after ticket has expired.
$Authenticator_c$	Assures TGS that the ticket presenter is the same as the client for whom the ticket was issued has very short lifetime to prevent replay.
$K_{c,tgs}$	Authenticator is encrypted with key known only to client and TGS, to prevent tampering.
ID_C	Must match ID in ticket to authenticate ticket.
AD_C	Must match address in ticket to authenticate ticket.
TS_3	Informs TGS of time this authenticator was generated.

(b) Ticket-Granting Service Exchange

Table 4.2 Rationale for the Elements of the Kerberos Version 4 Protocol
(page 3 of 3)

Message (5)	Client requests service.
$Ticket_V$	Assures server that this user has been authenticated by AS.
$Authenticator_c$	Generated by client to validate ticket.
Message (6)	Optional authentication of server to client.
$K_{c,v}$	Assures C that this message is from V.
$TS_5 + 1$	Assures C that this is not a replay of an old reply.
$Ticket_v$	Reusable so that client does not need to request a new ticket from TGS for each access to the same server.
K_v	Ticket is encrypted with key known only to TGS and server, to prevent Tampering.
$K_{c,v}$	Copy of session key accessible to client; used to decrypt authenticator, thereby authenticating ticket.
ID_C	Indicates the rightful owner of this ticket.
AD_C	Prevents use of ticket from workstation other than one that initially requested the ticket.
ID_V	Assures server that it has decrypted ticket properly.
TS_4	Informs server of time this ticket was issued.
$Lifetime_4$	Prevents replay after ticket has expired.
$Authenticator_c$	Assures server that the ticket presenter is the same as the client for whom the ticket was issued; has very short lifetime to prevent replay.
$K_{c,v}$	Authenticator is encrypted with key known only to client and server, to prevent tampering.
ID_C	Must match ID in ticket to authenticate ticket.
AD_c	Must match address in ticket to authenticate ticket.
TS_5	Informs server of time this authenticator was generated.

(c) Client/Server Authentication Exchange

Kerberos Realms

- Kerberos realm
  - A set of managed nodes that share the same Kerberos database
  - The Kerberos database resides on the Kerberos master computer system, which should be kept in a physically secure room
  - A read-only copy of the Kerberos database might also reside on other Kerberos computer systems
  - All changes to the database must be made on the master computer system
  - Changing or accessing the contents of a Kerberos database requires the Kerberos master password

Kerberos principal

- A service or user that is known to the Kerberos system
- Each Kerberos principal is identified by its principal name

Principal names consist of three parts:

- service or user name
- an instance name
- a realm name.

Table 4.3 Summary of Kerberos Version 5 Message Exchanges

(1) C → AS *Options* ‖ *IDc* ‖ *Realmc* ‖ *IDtgs* ‖ *Times* ‖ *Nonce1*

(2) AS → C *Realmc* ‖ *IDC* ‖ *Tickettgs* ‖ E(*Kc*, [*Kc,tgs* ‖ *Times* ‖ *Nonce1* ‖ *Realmtgs* ‖ *IDtgs*])

Tickettgs = E(*Ktgs*, [*Flags* ‖ *Kc,tgs* ‖ *Realmc* ‖ *IDC* ‖ *ADC* ‖ *Times*])

(a) Authentication Service Exchange to obtain ticket-granting ticket

(3) C → TGS *Options* ‖ *IDv* ‖ *Times* ‖ ‖ *Nonce2* ‖ *Tickettgs* ‖ *Authenticatorc*

(4) TGS → C *Realmc* ‖ *IDC* ‖ *Ticketv* ‖ E(*Kc,tgs*, [*Kc,v* ‖ *Times* ‖ *Nonce2* ‖ *Realmv* ‖ *IDv*])

Tickettgs = E(*Ktgs*, [*Flags* ‖ *Kc,tgs* ‖ *Realmc* ‖ *IDC* ‖ *ADC* ‖ *Times*])

Ticketv = E(*Kv*, [*Flags* ‖ *Kc,v* ‖ *Realmc* ‖ *IDC* ‖ ADC ‖ *Times*])

Authenticatorc = E(*Kc,tgs*, [*IDC* ‖ *Realmc* ‖ *TS*1])

(b) Ticket-Granting Service Exchange to obtain service-granting ticket

(5) C → V *Options* ‖ $Ticket_v$ ‖ $Authenticator_c$

(6) V → C $E_{K_{c,v}}$ [TS_2 ‖ *Subkey* ‖ *Seq#*]

Ticketv = E(*Kv*, [Flags ‖ *Kc,v* ‖ *Realmc* ‖ *IDC* ‖ *ADC* ‖ *Times*])

Authenticatorc = E(*Kc,v*, [*IDC* ‖ *Realmc* ‖ *TS*2 ‖ *Subkey* ‖ *Seq#*])

(c) Client/Server Authentication Exchange to obtain service

Key distribution using asymmetric encryption

- One of the major roles of public-key encryption is to address the problem of key distribution
- There are two distinct aspects to the use of public-key encryption in this regard:
  - The distribution of public keys
  - The use of public-key encryption to distribute secret keys
- Public-key certificate
  - Consists of a public key plus a user ID of the key owner, with the whole block signed by a trusted third party
  - Typically, the third party is a certificate authority (CA) that is trusted by the user community, such as a government agency or a financial institution
  - A user can present his or her public key to the authority in a secure manner and obtain a certificate
  - The user can then publish the certificate
  - Anyone needing this user's public key can obtain the certificate and verify that it is valid by way of the attached trusted signature

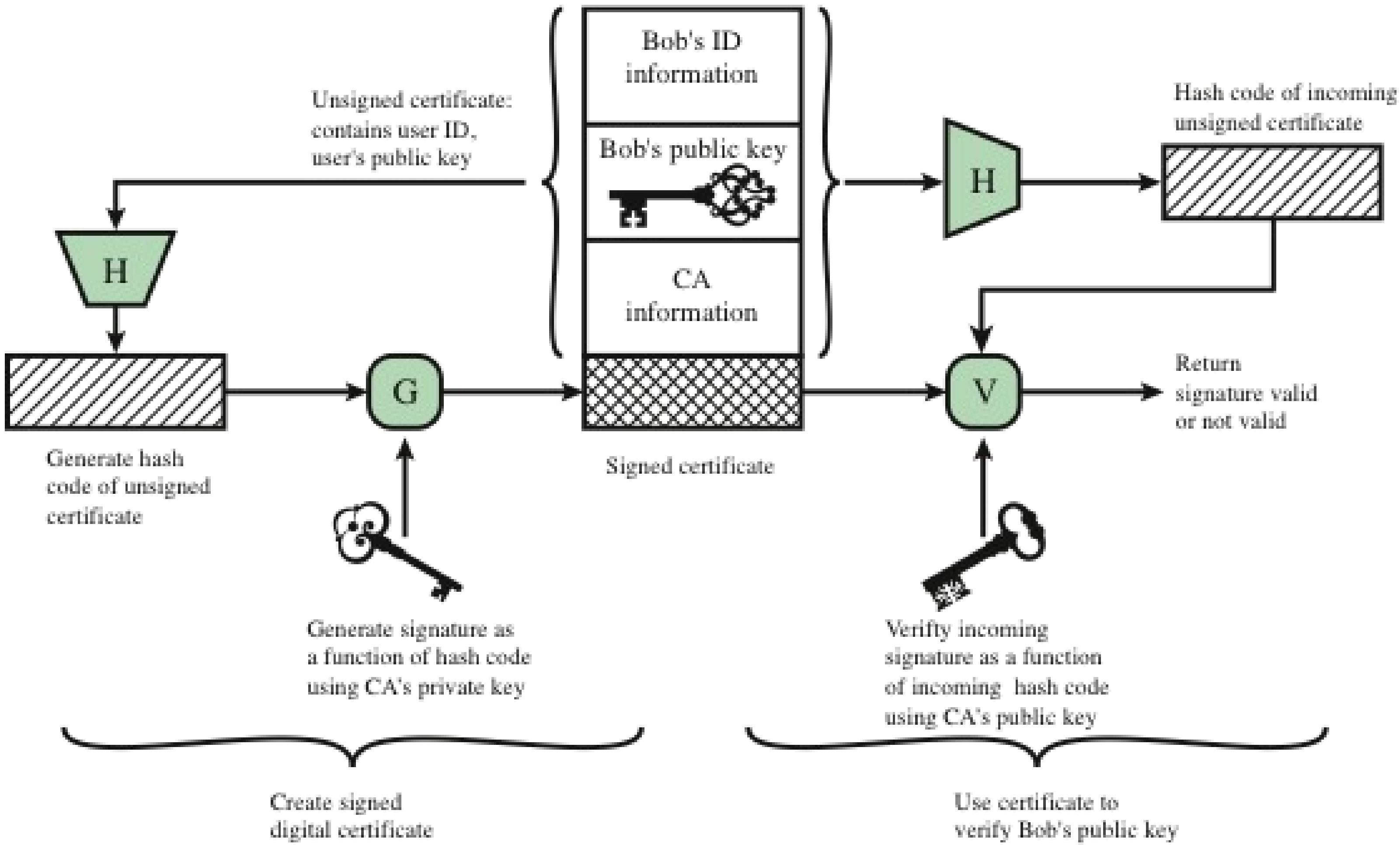


Figure 4.4 Public-Key Certificate Use

X.509 Certificates

- ITU-T recommendation X.509 is part of the X.500 series of recommendations that define a directory service
- Defines a framework for the provision of authentication services by the X.500 directory to its users
- The directory may serve as a repository of public-key certificates
- Defines alternative authentication protocols based on the use of public-key certificates
  - Was initially issued in 1988
  - Based on the use of public-key cryptography and digital signatures
- The standard does not dictate the use of a specific algorithm but recommends RSA

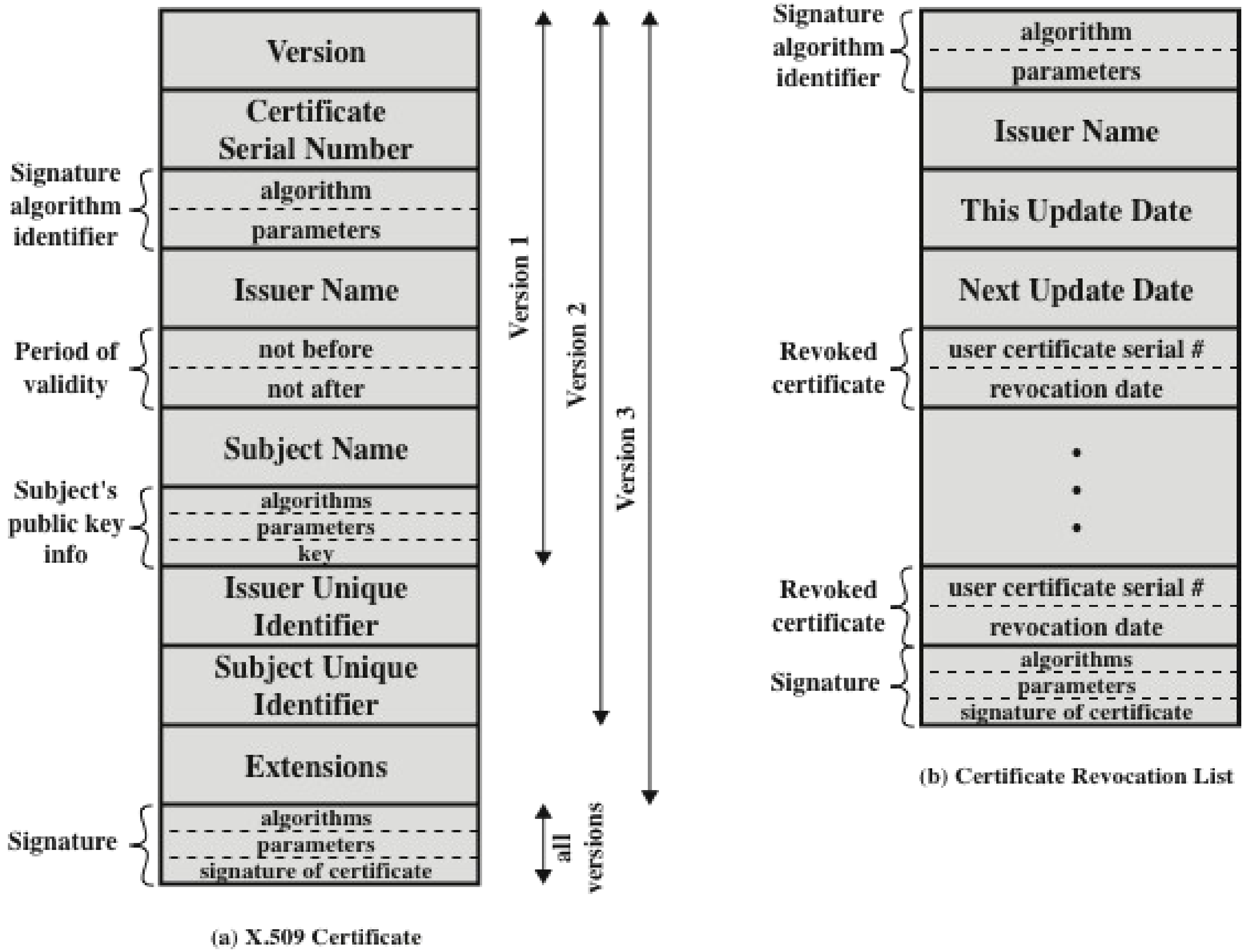


Figure 4.5 X.509 Formats

Obtaining a user’s certificate

- User certificates generated by a CA have the following characteristics:
  - Any user with access to the public key of the CA can verify the user public key that was certified
  - No party other than the certification authority can modify the certificate without this being detected

- Because certificates are unforgeable, they can be placed in a directory without the ne for the directory to make special efforts protect them

Revocation of certificates

- Each certificate includes a period of validity
- Typically a new certificate is issued just before the expiration of the old one
- It may be desirable on occasion to revoke a certificate before it expires for one of the following reasons:
  - The user's private key is assumed to be compromised
  - The user is no longer certified by this CA; reasons for this include subject's name has changed, the certificate is superseded, or the certificate was not issued in conformance with the CA's policies
  - The CA's certificate is assumed to be compromised

Key and policy information

- These extensions convey additional information about the subject and issuer keys, plus indicators of certificate policy
- A certificate policy is a named set of rules that indicates the applicability of a certificate to a particular community and/or class of application with common security requirements

PKIX Management functions

- Functions that potentially need to be supported by management protocols:
  - Registration
  - Initialization
  - Certification
  - Key pair recovery
  - Key pair update
  - Revocation request
  - Cross certification
- Alternative management protocols:
  - Certificate management protocols (CMP)
    - Designed to be a flexible protocol able to accommodate a variety of technical, operational, and business models
  - Certificate management messages over CMS (CMC)
    - Is built on earlier work and is intended to leverage existing implementations

Identity Management

- A centralized, automated approach to provide enterprise wide access to resources by employees and other authorized individuals
  - Focus is defining an identity for each user (human or process), associating attributes with the identity, and enforcing a means by which a user can verify identity
  - Central concept is the use of single sign-on (SSO) which enables a user to access all network resources after a single authentication
- Principal elements of an identity management system:
  - Authentication
  - Authorization
  - Accounting
  - Provisioning
  - Workflow automation
  - Delegated administration
  - Password synchronization
  - Self-service password reset
  - Federation

Summary

- Remote user authentication principles
  - The NIST model for electronic user authentication
  - Means of authentication
- Symmetric key distribution using symmetric encryption
- Kerberos
  - Version 4
  - Version 5
- Key distribution using asymmetric encryption
  - Public-key certificates
  - Public-key distribution of secret keys
- X.509 certificates
  - Certificates
  - X.509 Version 3
- Public-key infrastructure
  - PKIX management functions
  - PKIX management protocols
- Federated identity management
  - Identity management
  - Identity federation

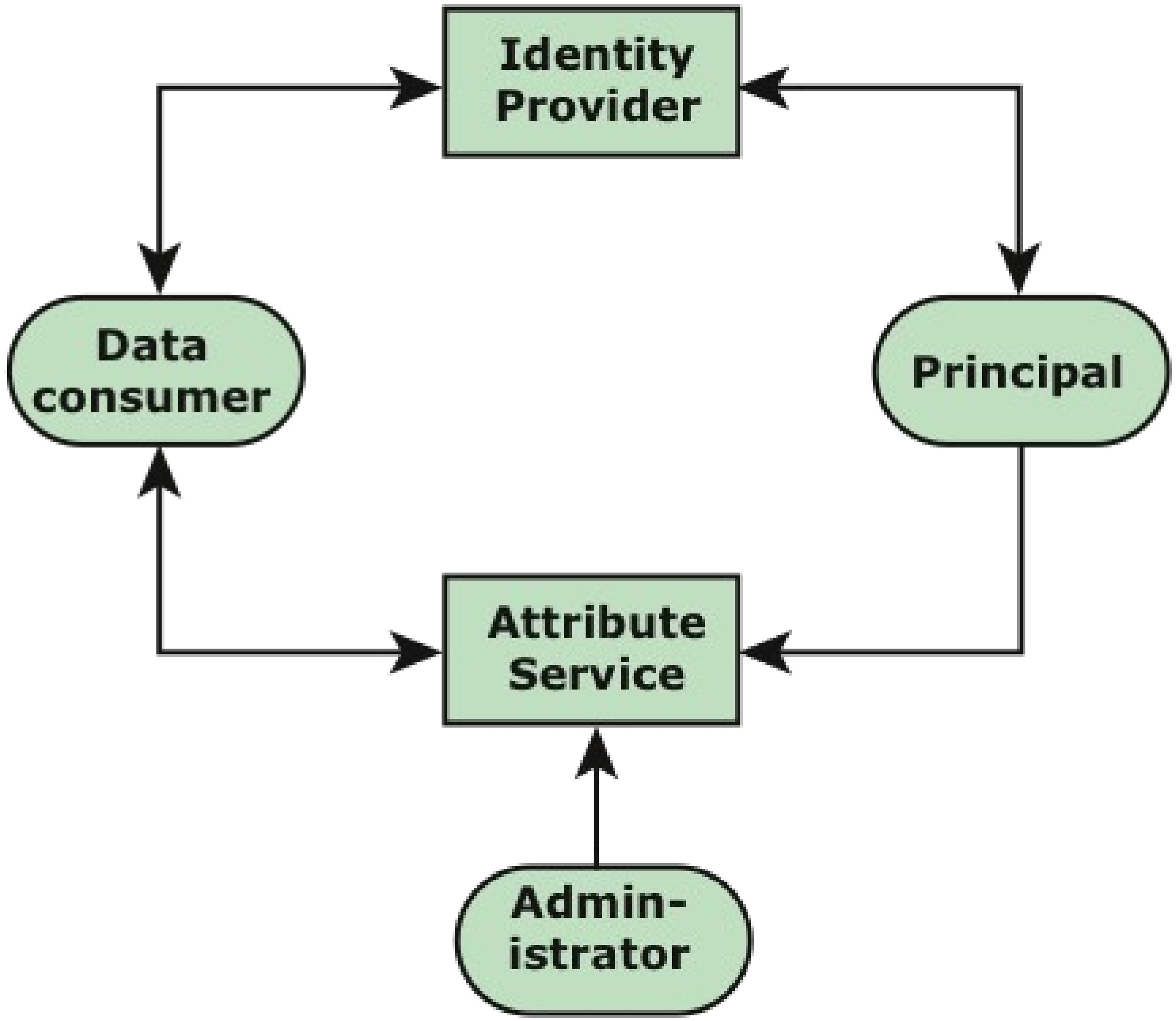
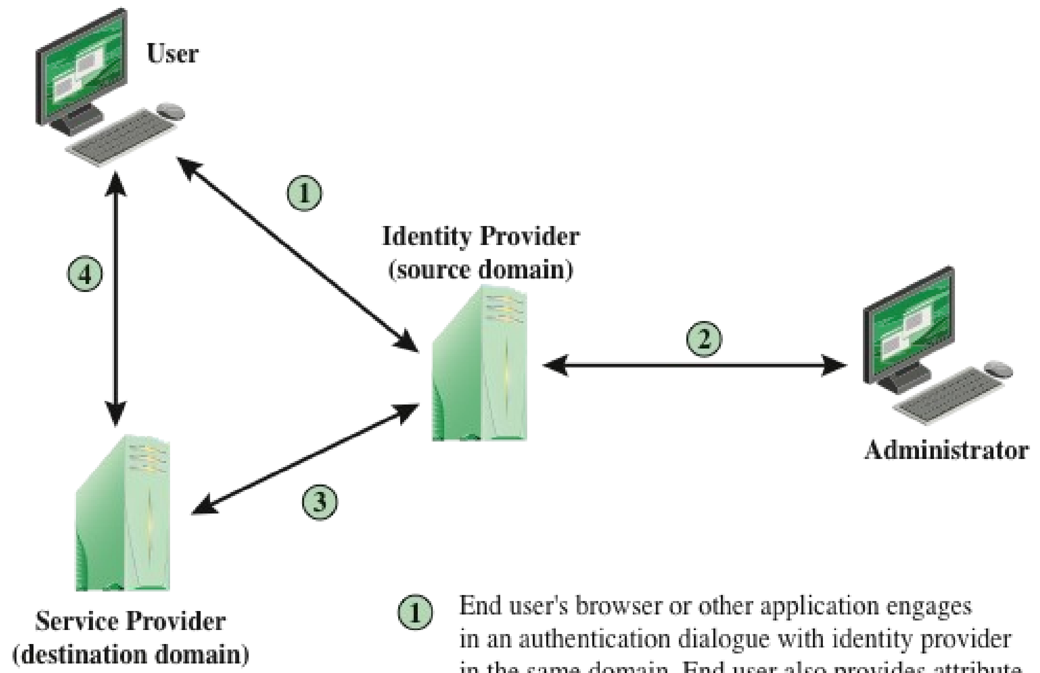


Figure 4.8 Generic Identity Management System

Identity federation

- Identity federation is, in essence, an extension of identity management to multiple security domains
- Federated identity management refers to the agreements, standards, and technologies that enable the portability of identities, identity attributes, and entitlements across multiple enterprises and numerous applications and supports many thousands, even millions, of users
- Another key function of federated identity management is identity mapping
  - The federated identity management protocols map identities and attributes of a user in one domain to the requirements of another domain



1. End user's browser or other application engages in an authentication dialogue with identity provider in the same domain. End user also provides attribute values associated with user's identity.

2. Some attributes associated with an identity, such as allowable roles, may be provided by an administrator in the same domain.

3. A service provider in a remote domain, which the user wishes to access, obtains identity information, authentication information, and associated attributes from the identity provider in the source domain.

4. Service provider opens session with remote user and enforces access control restrictions based on user's identity and attributes.

Figure 4.9 Federated Identity Operation

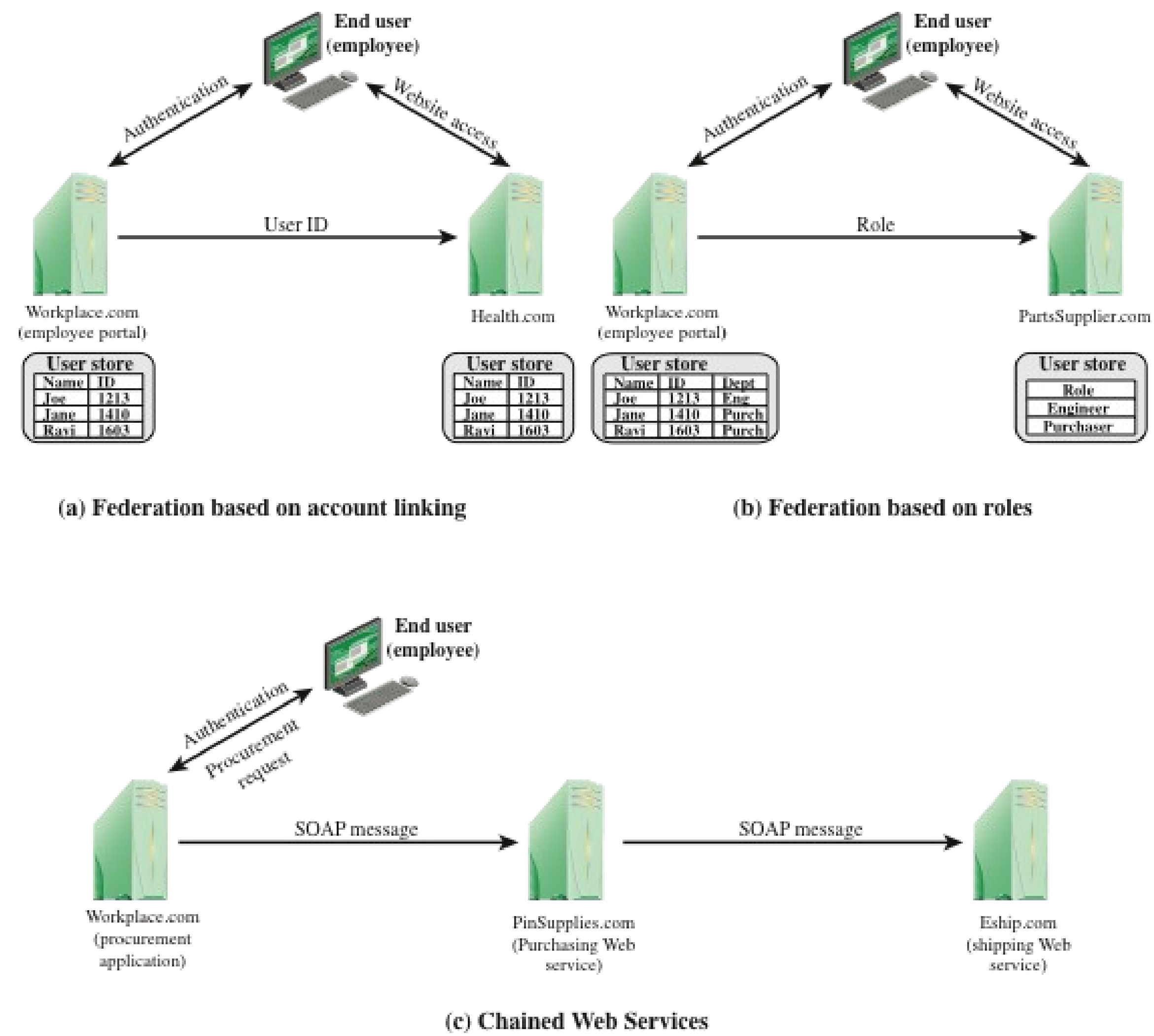


Figure 4.10 Federated Identity Scenarios

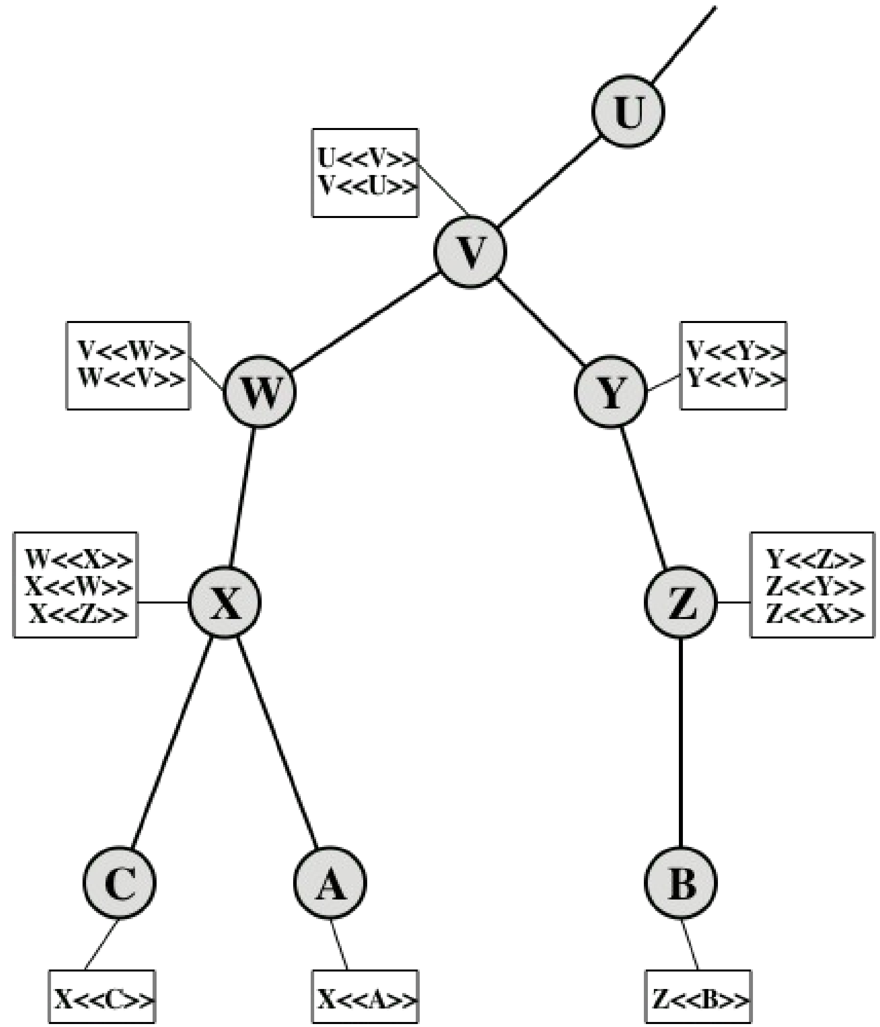


Figure 4.6 X.509 CA Hierarchy: a Hypothetical Example