NISSC '99 Statement for Tutorial

Tutorial Title: Usage of Certificate Policies in a PKI to Model Real-World Trust Relationships

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Summary of Topics to be addressed in session:

X.509 v3 certificates and certificate policy processing
Trust relationships in the business world
Modeling trust relationships using X.509 policy constructs
Policy Support Features in PKI Entities
Anomalies in X.509 policy handling and a proposed fix

Short Bio of Speaker:

Dr. Sarbari Gupta has been active in the security field for over 12 years. As the Director of Information Security, she has oversight of the security consulting, development and integration teams at CygnaCom Solutions. She participates in a number of standards organizations. Her interests include PKI technology, key recovery, and secure applications.

Usage of Certificate Policies in a PKI to Model Real-World Trust Relationships

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Outline

- X.509 Version 3 certificates and certificate policy processing
- Trust relationships in the business world
- Modeling trust relationships using X.509 policy constructs
- Policy support Features in PKI entities
- Anomalies in X.509 policy handling and a proposed fix

Public Key Certificate

A digital document that binds an entity (name, id) to a specific public key. A trusted third party (certification authority) establishes the binding using a digital signature.

Public Key Infrastructure (PKI)

A digital infrastructure that provides the needed levels of confidence to users of a public key that the associated private key is owned by the correct subject (person or system).

A PKI also provides a means of distributing public keys over an untrusted medium

PKI Architectural Entities

Certification Authority

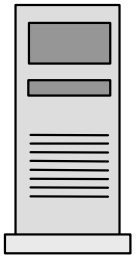
A trusted entity that:

- Verifies and vouches for the identity of subscribers
- Generates and signs Public Key Certificates
- Revokes Public Key Certificates
- Publishes Public Key Certificates and Certificate Revocation Lists in Directory Servers
- Operated under control of Security Officer(s)

Subscriber

A entity that:

- Generates asymmetric key pairs
- Requests public key certificates from CAs
- Receives issued certificates
- Uses private key in crypto operations



Repository

Contains valid Public Key Certificates and Certificate Revocation Lists

Relying Party

A entity that:

- Looks up peer certificates in Repository
- Validates peer certificates and certificate paths in order to establish trust in peer public key
- Uses peer public key in crypto operations

X.509 Version 3

Version 1:

- published in 1988 as part of the X.500 Directory recommendations,
- defines a standard, basic, certificate format.

Version 2:

- released when X.500 was revised in 1993,
- adds two more fields to support directory access control.

Version 3:

- adds extensions for performance, security, and limiting trust,
- adds support for cross-certification of CAs,
- adds X.500 naming constraints,
- adds support for management of policies

X.509 v3 Certificate Profile

version (v3)	Version Number
serial number	Unique Integer assigned by Certificate Issuer
signature algorithm id	Algorithm ID used to sign certificate
issuer name	X.500 DN of the certificate signing authority
validity period	Time period within which certificate is valid
subject name	X.500 DN of the subject entity
subject public key info	Algorithm ID and public key of the subject
issuer unique identifier	Additional identifying info to disambiguate issuer name
subject unique identifier	Additional identifying info to disambiguate subject name
extensions	Zero or more extension fields for the certificate
signature	Digital signature by the CA over the other certificate fields

X.509 v3 Certificate Standard Extensions

Authority Key Identifier

Subject Key Identifier

Key Usage

Extended Key Usage

Private Key Usage Period

Certificate Policies

Policy Mappings

Subject alternative name

Issuer alternative name

Subject directory attributes

Basic constraints

Name constraints

Policy constraints

CRL Distribution Points

X.509v3 Policy Extensions

- Certificate Policies
- Policy Mappings
- Policy Constraints

Certificate Policy

A certificate policy is defined as “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.” [1]

1 “Information Technology - Open Systems Interconnection:The Directory: Authentication Framework,” 1997 edition.

Certificate Policy

A CP addresses requirements for:

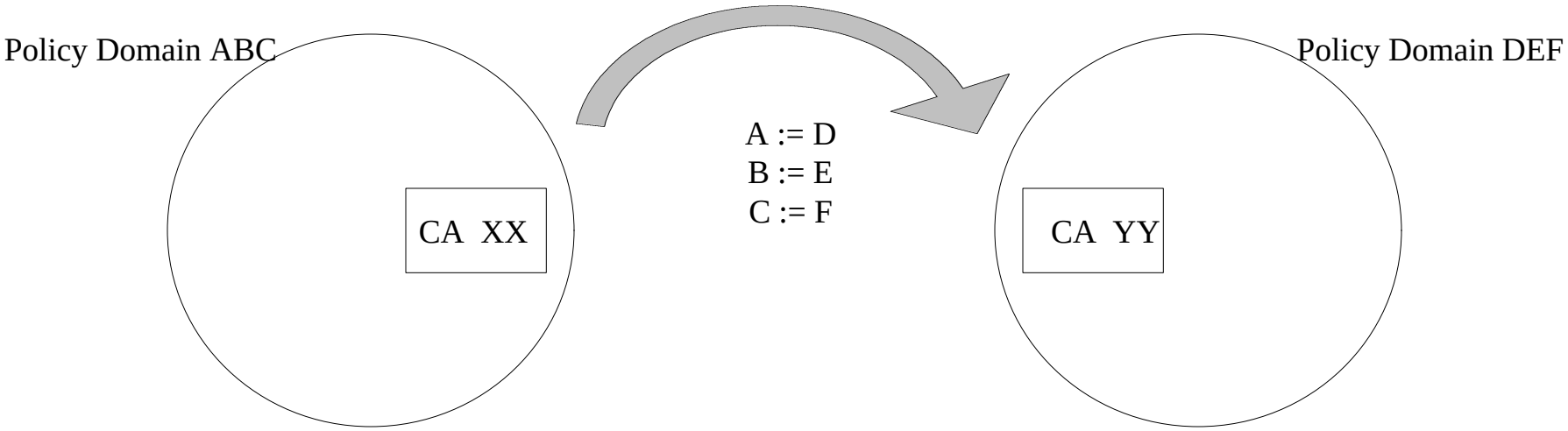
- Key generation
- Identity proofing
- Certificate and CRL generation and distribution
- Certificate Update, Renewal, and Re-key
- Certificate token initialization, programming, and management
- Privilege and Authorization Management
- System Management Functions (e.g. audit, certificate tracking, archiving)
- responsibilities and liabilities of the relevant parties
- security controls (technical, personnel, physical, and procedural)

Certificate Policy Extension

- Assertion of the policies under which the certificate was issued, indicating the purposes for which it may be used
- Multiple policies may be asserted
- ***Policy qualifiers*** allow further qualification of each policy asserted. IETF PKIX defines two qualifiers:
  - CPS Pointer
  - User Notice

Policy Mapping Extension

- Used in CA Certificates only
- Asserts equivalency relations between policies across disparate policy domains



Policy Constraints Extension

- Used in CA certificate only
- Asserts two types of policy related constraints
  - ***Inhibit Policy Mapping*** **-** indicates policy mapping is to be inhibited while processing subsequent certificates
  - ***Require Explicit Policy*** **-** indicates that subsequent certificates need to include an acceptable policy identifier

Policy Authority and Policy Domain

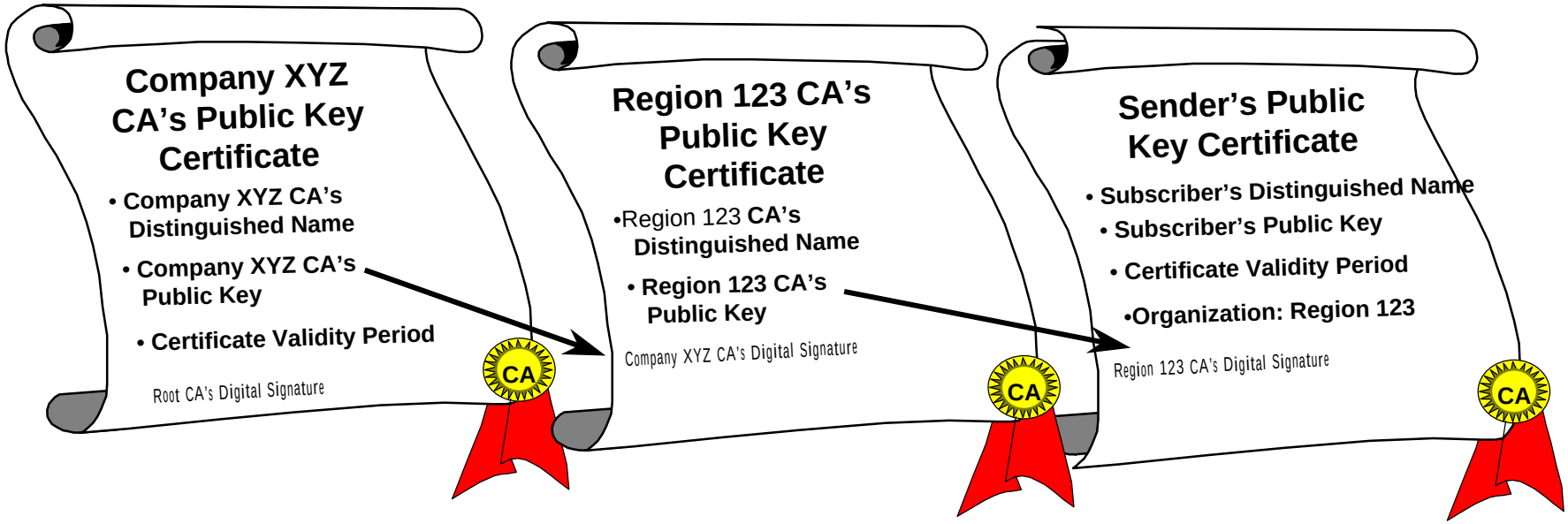
Policy Authority

An entity that defines (one or more) certificate policies, and assigns certificate policy identifiers.

Policy Domain

The set of policies administered by a single Policy Authority comprise a policy domain.

Certificate Path Processing



- Relying Party knows and trusts a CA's Public Key; called trust anchor
- Relying Party has the Subscriber's Public Key certificate
- Relying Party develops a chain of certificates beginning with a certificate signed by the trust anchor and ending with the Subscriber's certificate

X.509 v3 Path Processing(I)

- **Inputs**:
  - *initial-policy-set*
  - *initial-explicit-policy* indicator
  - *initial-policy-mapping-inhibit* indicator
- **Outputs**:
  - success/failure of path validation
  - set of constrained policies and their qualifiers

X.509 v3 Path Processing(II)

- **State Variables**:
  - *user-constrained-policy-set* -- initialized to *initial-policy-set*
  - *authority-constrained-policy-set* -- initialized to *any-policy*
  - *explicit-policy-indicator* -- initialized to *initial-explicit-policy* indicator
  - *policy-mapping-inhibit-indicator* -- initialized to *initial-policy-mapping-inhibit* indicator

X.509 v3 Path Processing(III)

- **Return Failure if any of these checks fail**:
  - non-policy checks (e.g., signature verifies, dates are valid, certificate chains correctly, subject name in permitted namespace, etc.)
  - *if explicit-policy-indicator* is set
    - certificate policies extension contains at least one policy from the *user-constrained-policy-set*
  - if certificate policies extension is critical
    - update *authority-constrained-policy-set* by intersecting it with the certificate policies extension. Check that *authority-constrained-policy-set* is non-empty
- **Return success if this is the end certificate**

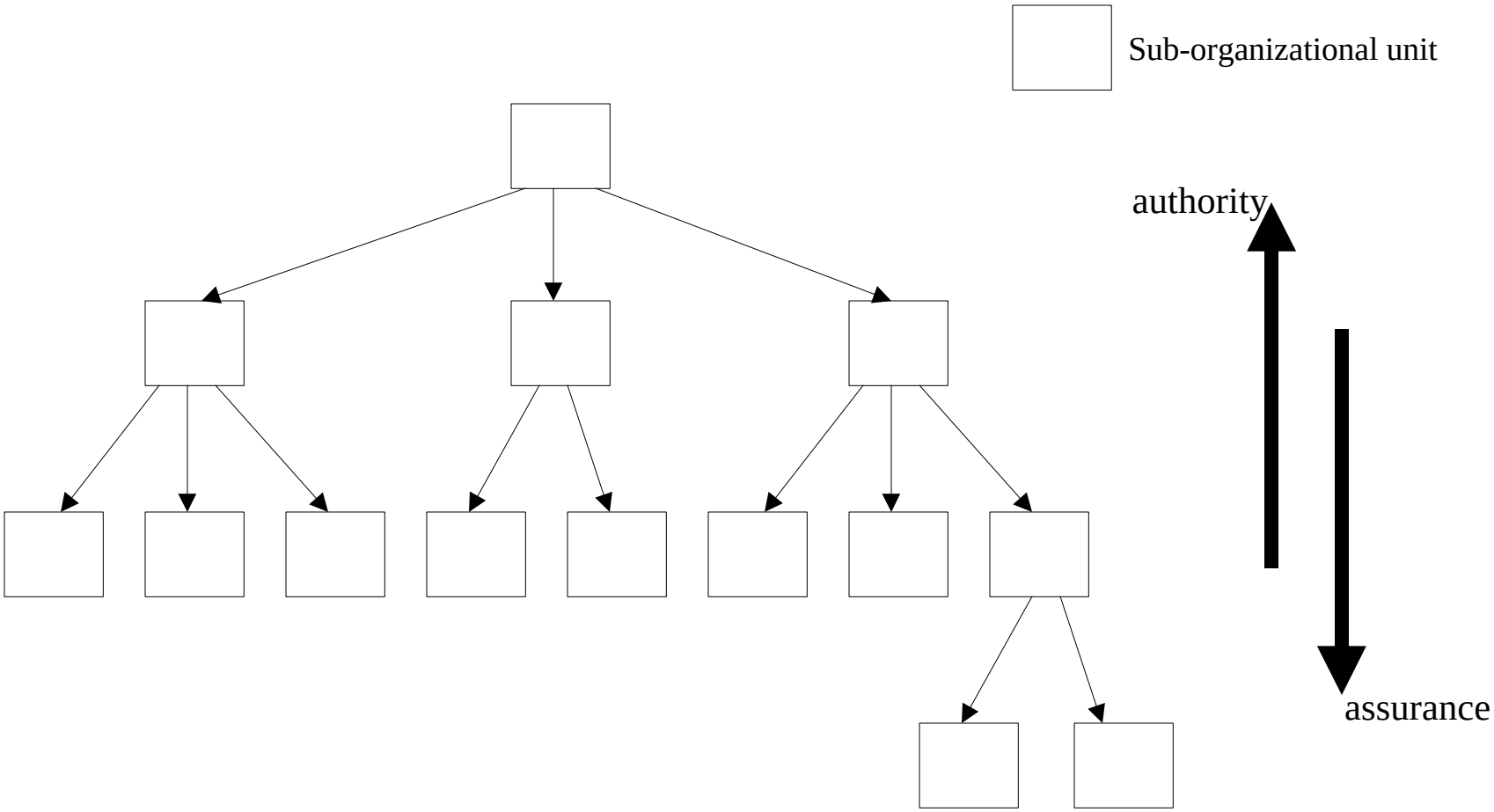
X.509 v3 Path Processing(IV)

- **Update the state variables**:
  - update non-policy state variables
  - if *explicit-policy-indicator* is not set
    - update *explicit-policy-indicator* based on the presence of the **requireExplicitPolicy** constraint in the certificate
  - if *policy-mapping-inhibit-indicator* is not set
    - if policy mapping extension is present
      - update *user-constrained-policy-set* based on mappings
      - update *authority-constrained-policy-set* based on mappings
    - update *policy-mapping-inhibit-indicator* based on the presence of the **inhibitPolicyMapping** constraint in the certificate

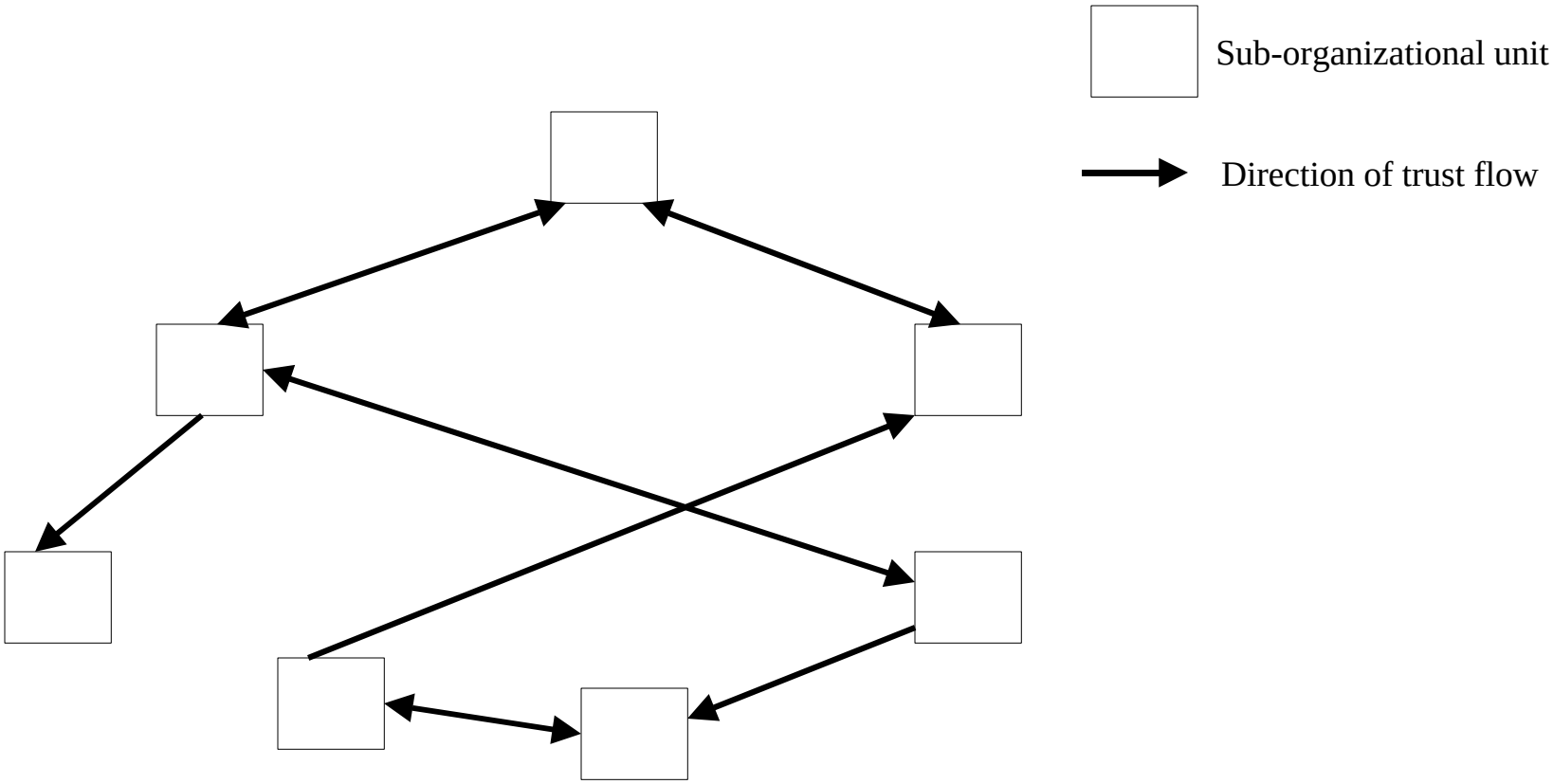
Trust/Authority Relationships in the Business World

- Intra-Organizational:
  - hierarchical (one or more levels)
  - networked
  - combination
- Inter-Organizational:
  - networked with no trust propagation
  - networked with trust propagation

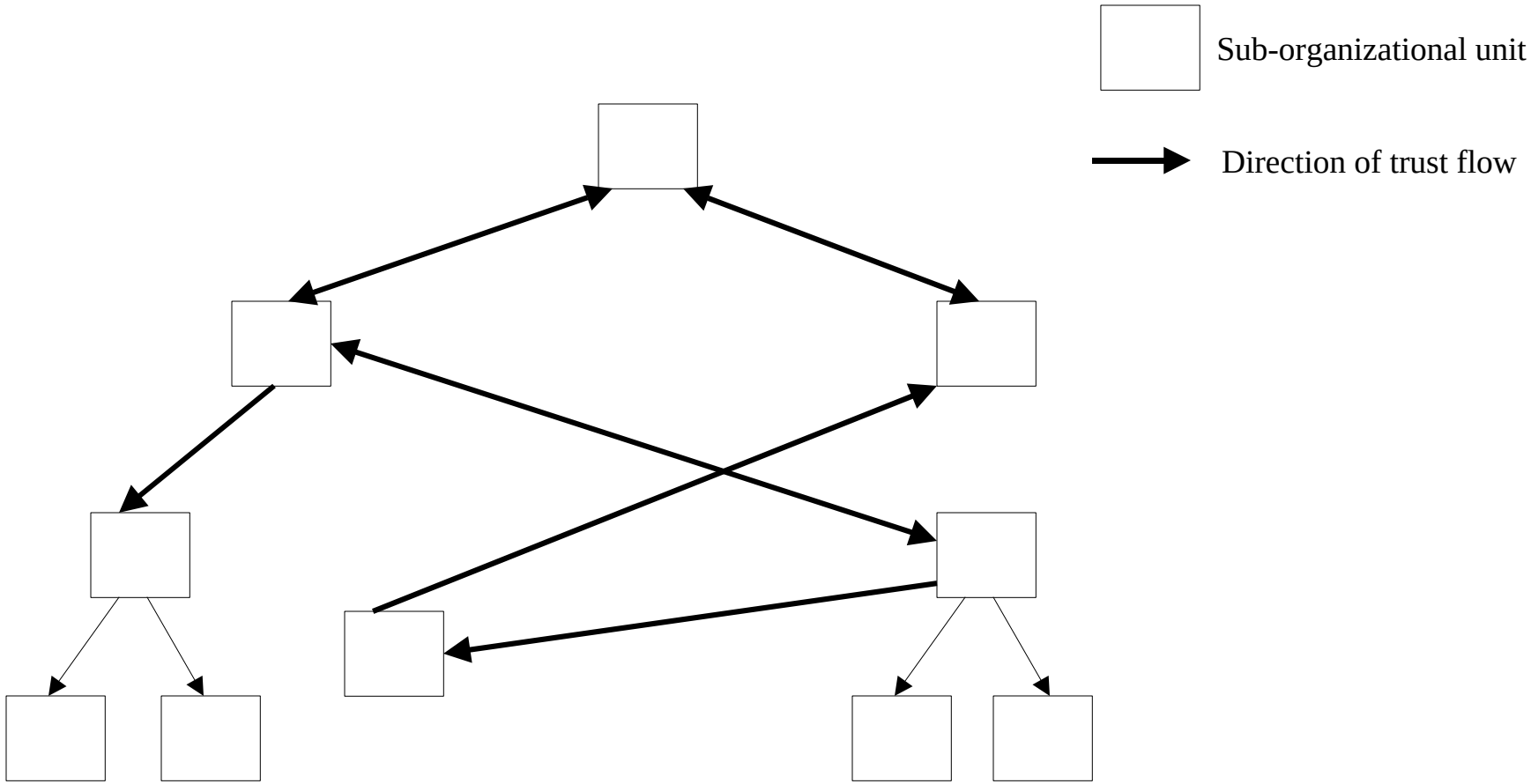
Hierarchical Trust Relationships



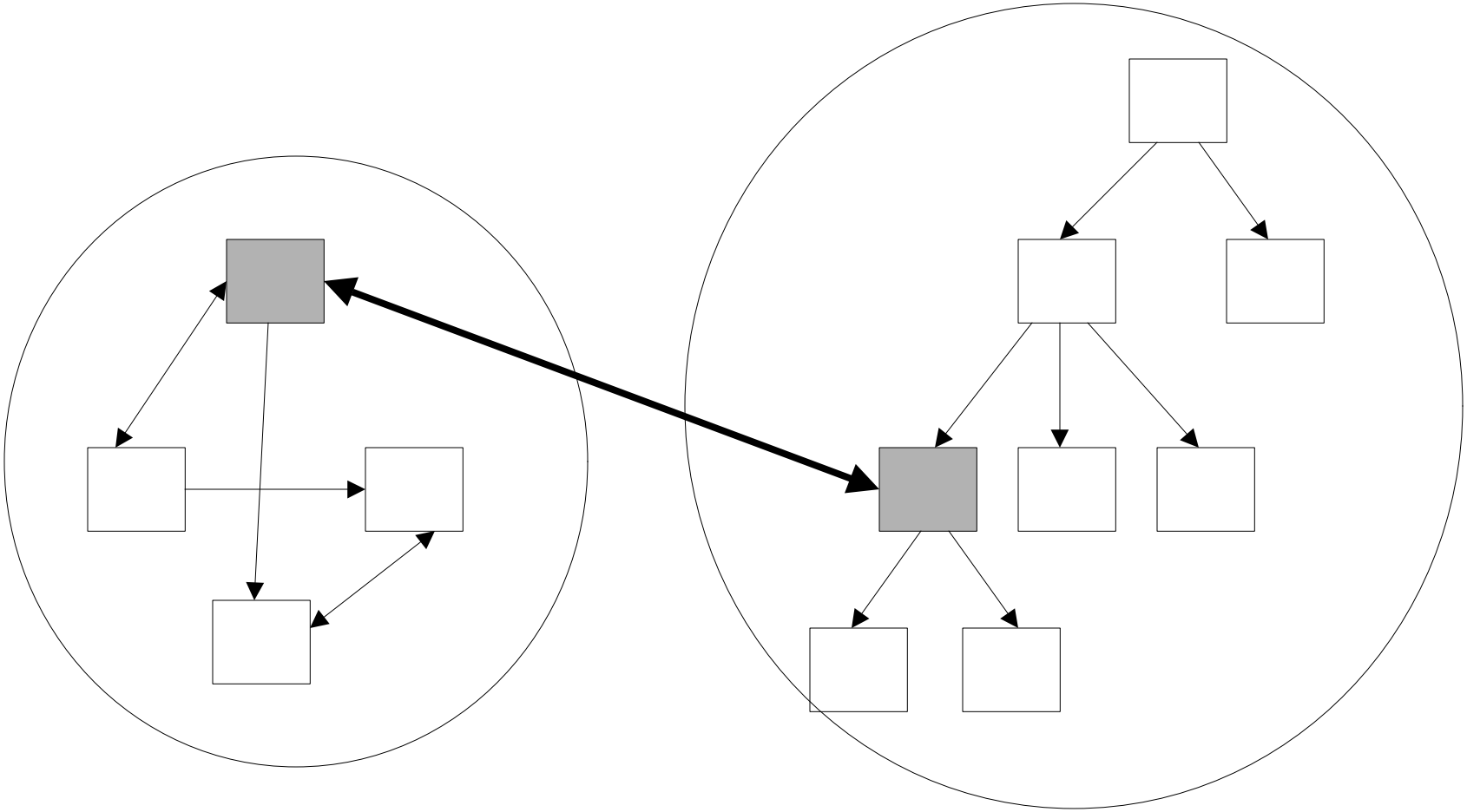
Networked Trust Relationships



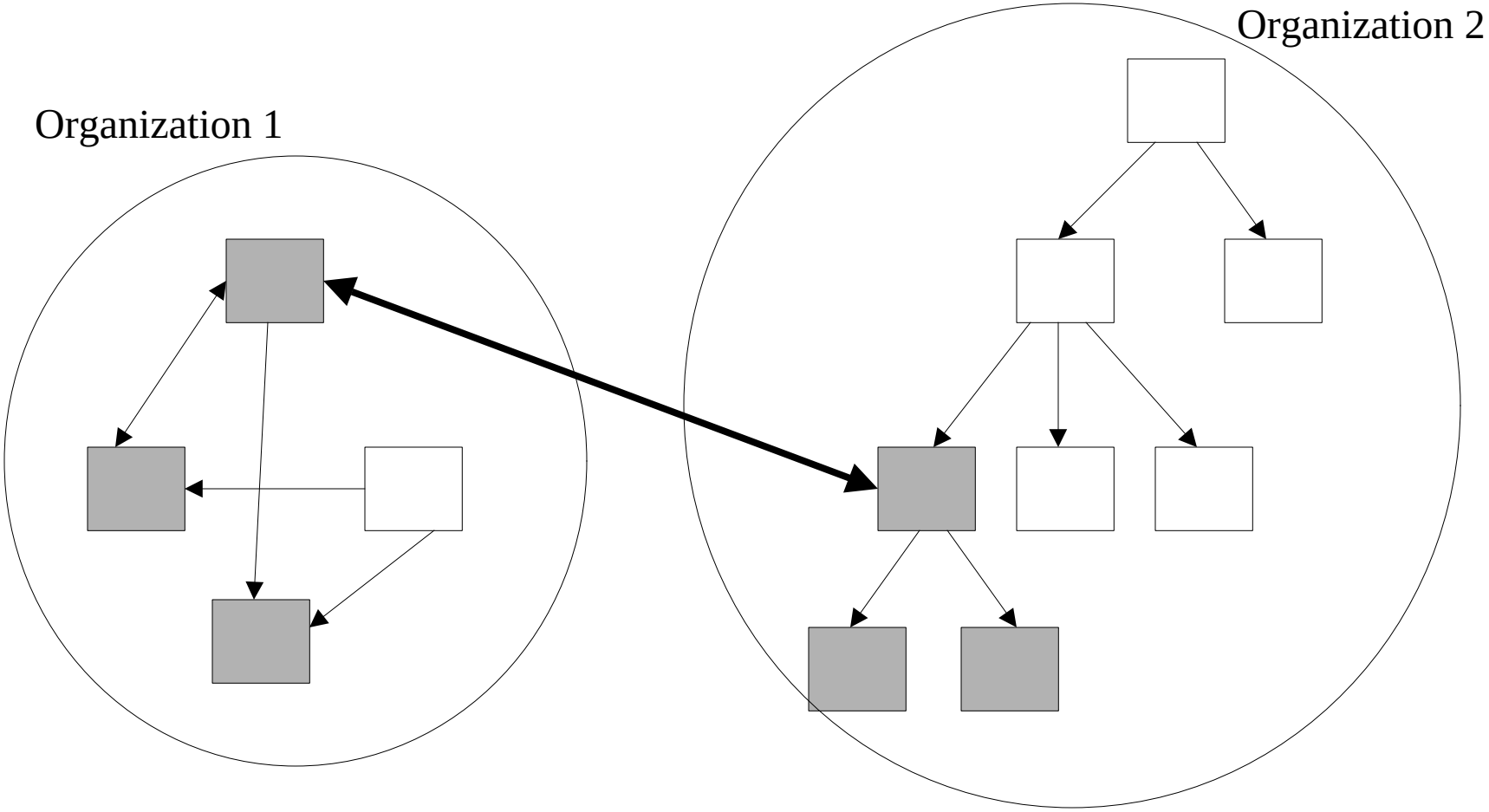
Combination Trust Relationships



Networked with no Trust Propagation



Networked with Trust Propagation



Modeling Trust Relationships using X.509 constructs

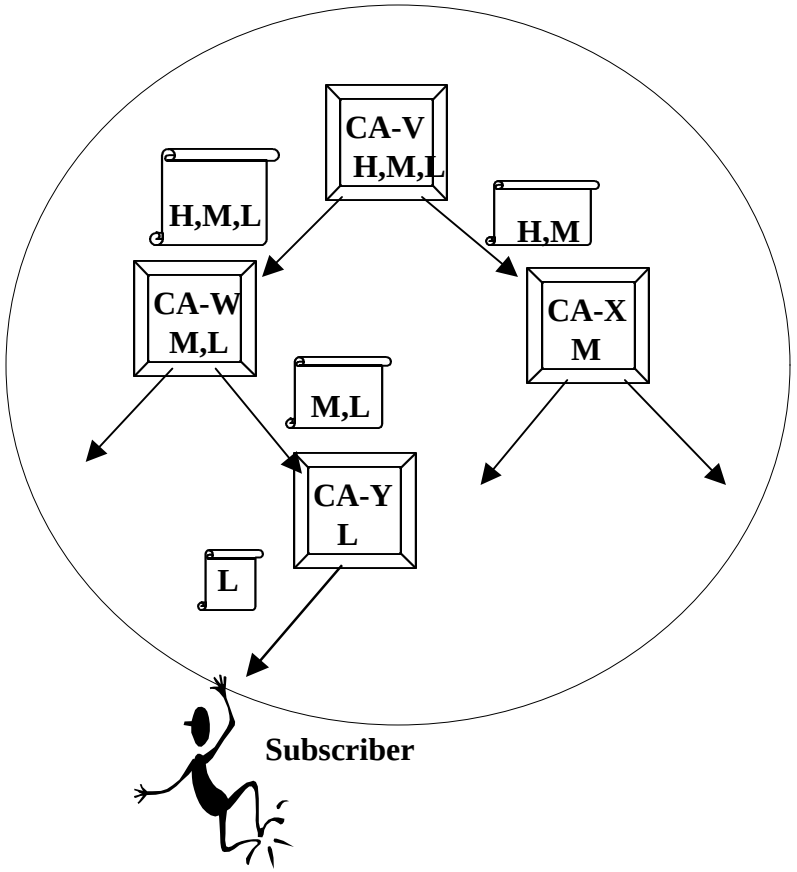
- Assumptions
  - an organization has a single policy authority
  - an organization comprises a single policy domain
  - a sub-organizational unit may operate its own Certification Authority

Business Goals for Trust/Authority Modeling

- superior CAs can apply different policies than subordinate CAs
- superior CAs can restrict the policies asserted by subordinate CAs
- new policies can be added dynamically to a existing policy domain without need to reissue superior certificates

Hierarchical Policy Domain (I)

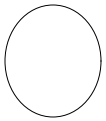
•Single rooted hierarchy
•CAs closer to root apply higher assurance policies than CAs farther from the root
• superior CAs assert a superset of the policies asserted by subordinate CAs



H = High Assurance
M = Medium Assurance
L = Low Assurance

CA X using policy M

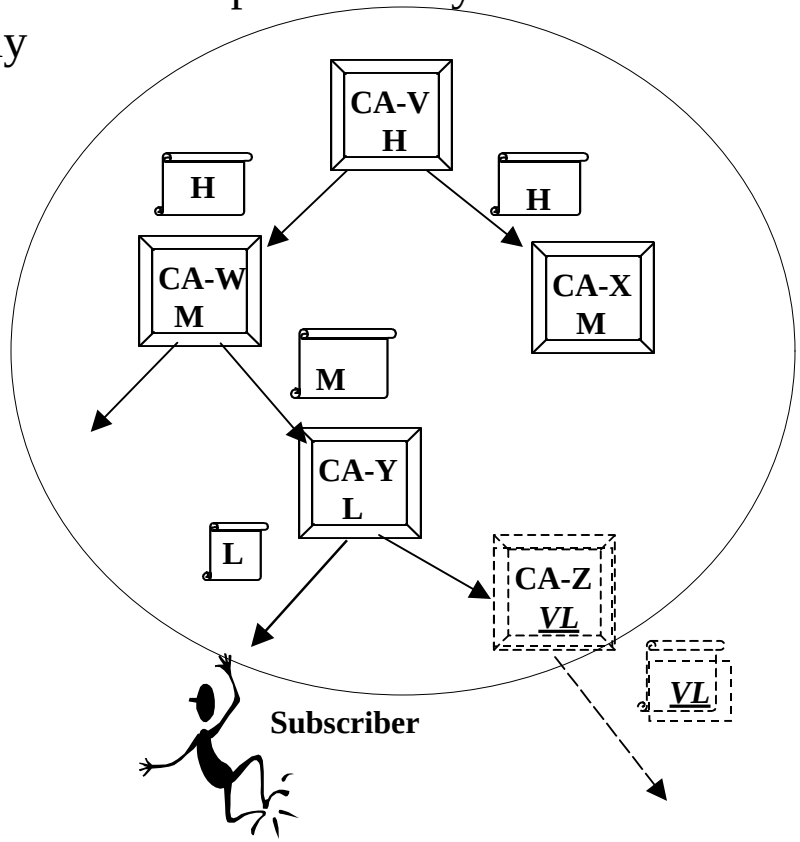
Certificate asserting policy H



Policy Domain

Hierarchical Policy Domain (II)

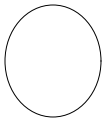
- Single rooted hierarchy
- CAs closer to root apply higher assurance policies than CAs farther from the root
- superior CAs assert their local policy independent of the policies asserted by subordinate CAs
- new lower assurance policies may be added to the PKI dynamically



H = High Assurance
M = Medium Assurance
L = Low Assurance
VL = Very Low Assurance

CA X using policy M

Certificate asserting policy H

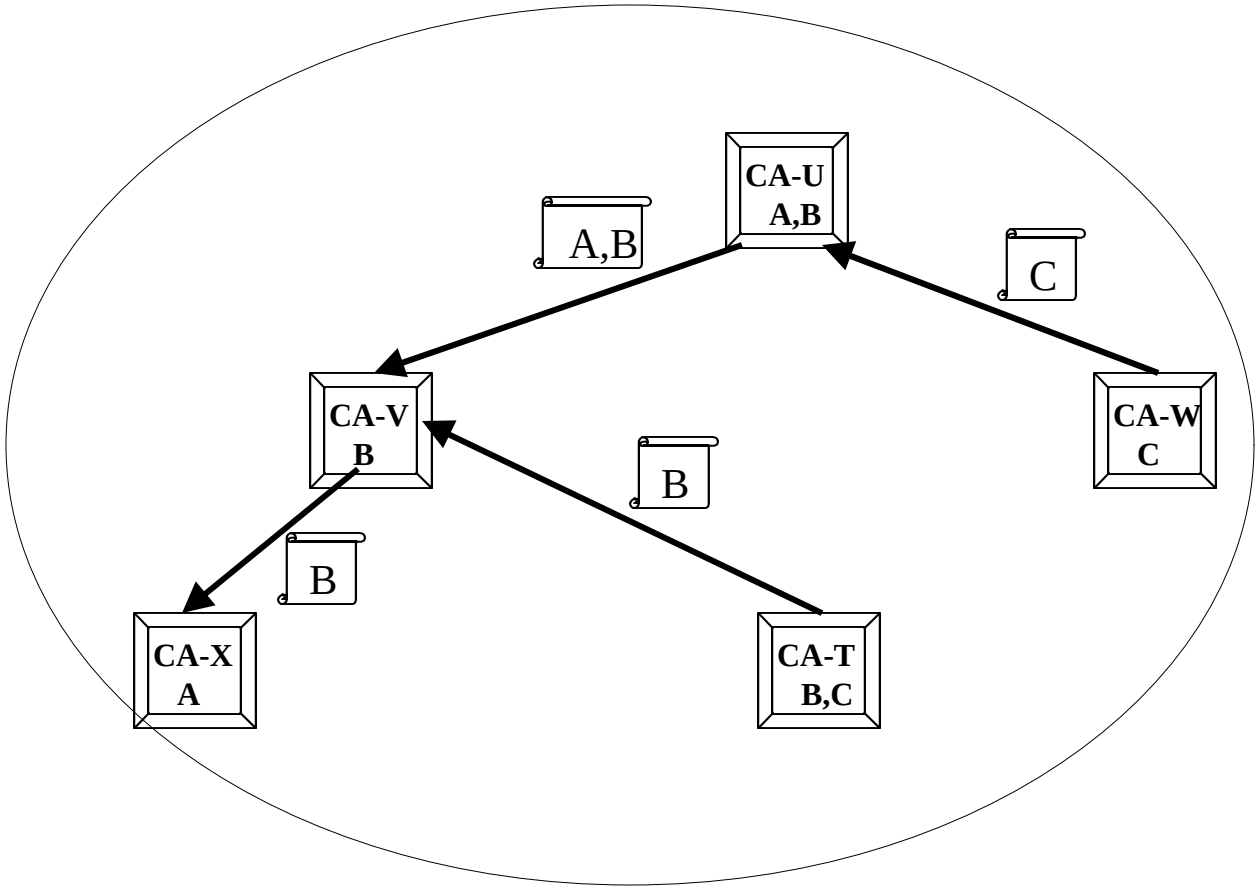


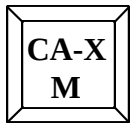
Policy Domain

Networked Policy Domain

- no common root
- relying party trusts local CA
- CAs may establish pair-wise trust relations

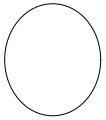
A = secure mail
B = secure web connections
C = secure network logon





CA X using policy M

Certificate asserting policy H

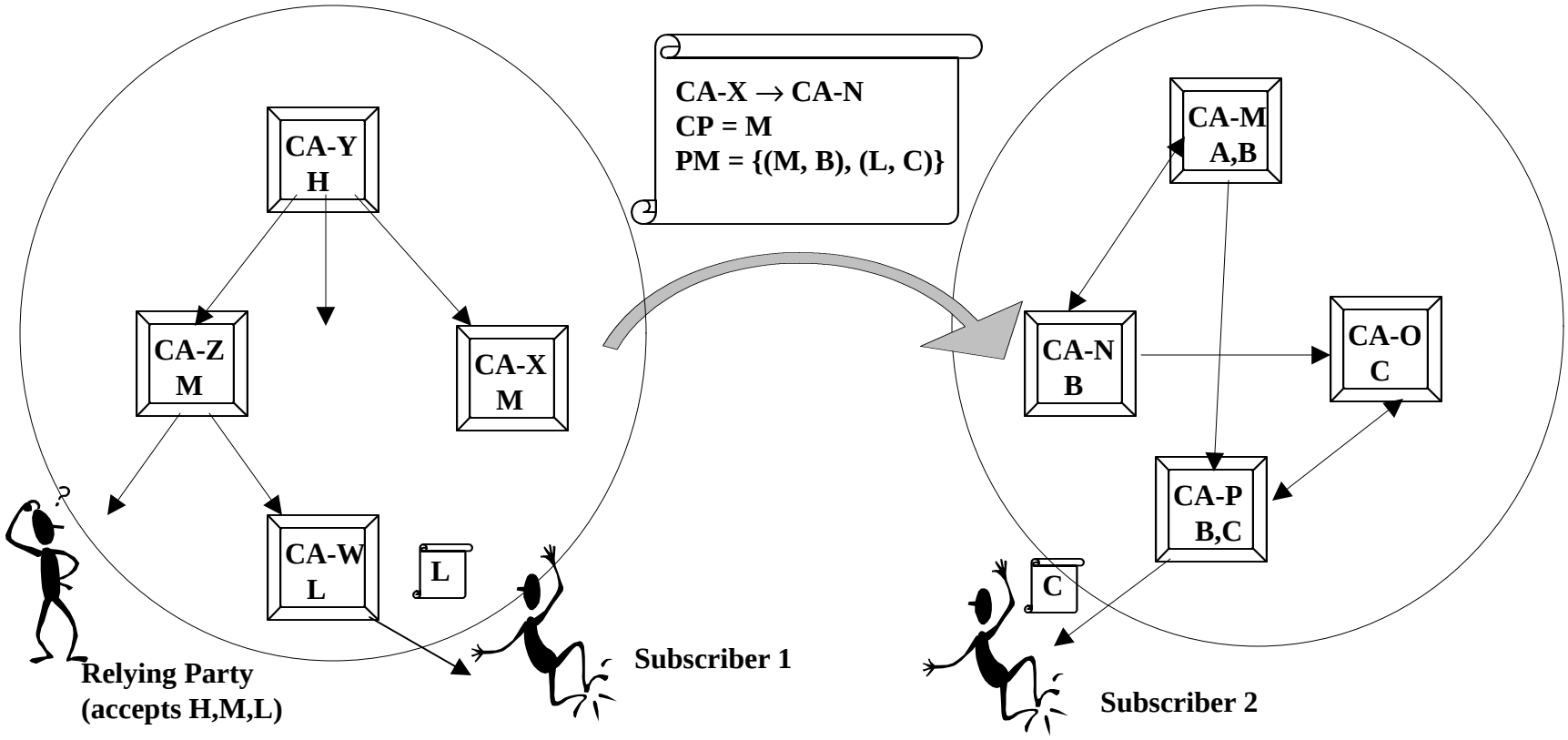


Policy Domain

Trust Propagation Across Policy Domains

• Cross-certifying CAs assert all possible policy equivalencies between their respective domains
• Relying party can authenticate Subscriber 2 as well as Subscriber 1 using certificate path via cross-certificate

A = secure mail
B = secure web connections
C = secure network logon



Features for Maximal Support of Policy Processing

Affected Entities in the Public Key Infrastructure:

- Certification Authority
- Subscriber
- Relying Party

Certification Authority Features

Support for:

- multiple certificate policies in issued certificates
- selectable set of certificate policies for each certificate
- multiple policy mappings in cross-certificates
- inclusion of policy mappings independent of policies asserted
- self-signed certificates for use as trust anchors

Subscriber Features

Support for:

- multiple certificate policies in certificate requests
- self-signed certificates for use as trust anchors

Relying Party Features

Support for:

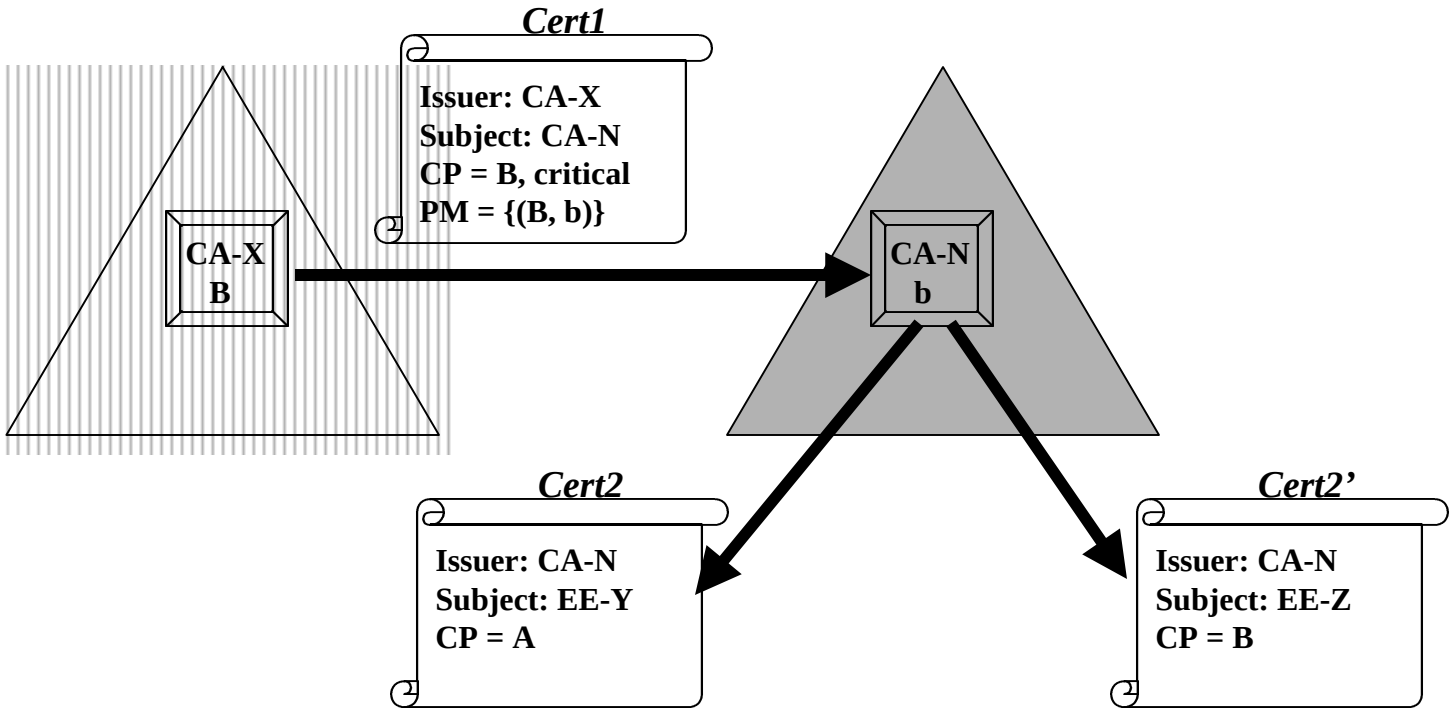
- full X.509 path processing algorithm
- use of a set of policies as *initial-policy-set*
- configurable contents of *initial-policy-set*
- processing of policy qualifiers
- use of self-signed certificates as trust anchors

Anomalies in X.509 Policy Processing

- Three anomaly scenarios
- Identification of underlying flaws in X.509 policy handling
- Proposed Fix to policy anomalies

Scenario 1

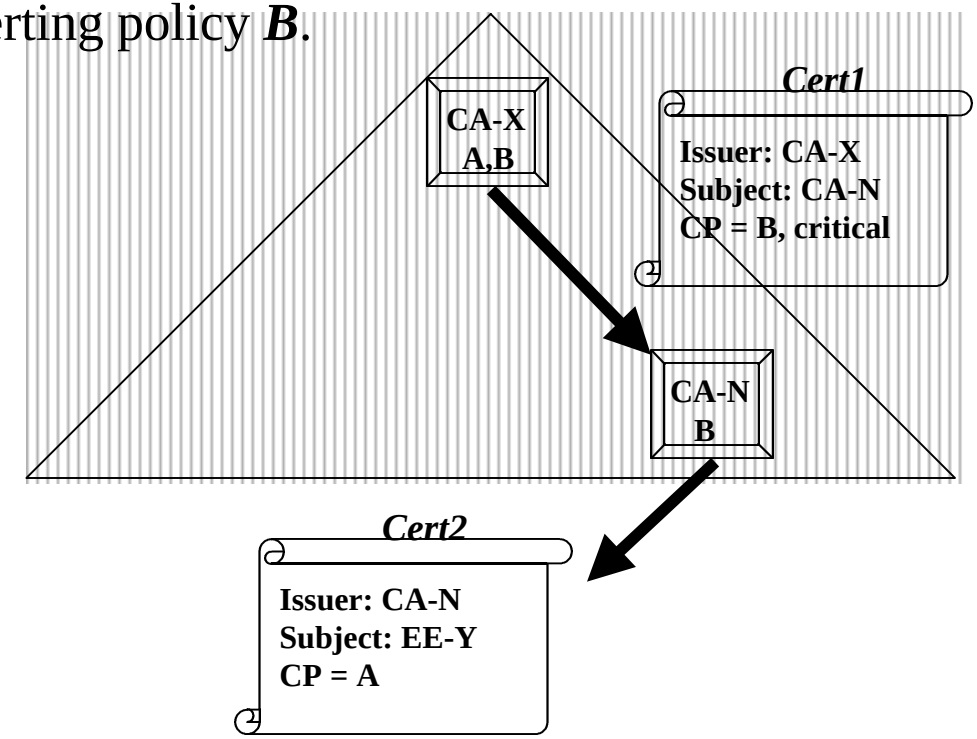
It appears to be difficult for a CA issuing a cross-certificate to a subject CA to restrict the policies that may be asserted by the subject CA.



If *initial-policy-set* is {A, B}, then the above chains will be valid. It is difficult for ***CA-X*** to restrict ***CA-N*** to only asserting policy ***b*** in ***Cert2*** and ***Cert2'***

Scenario 2

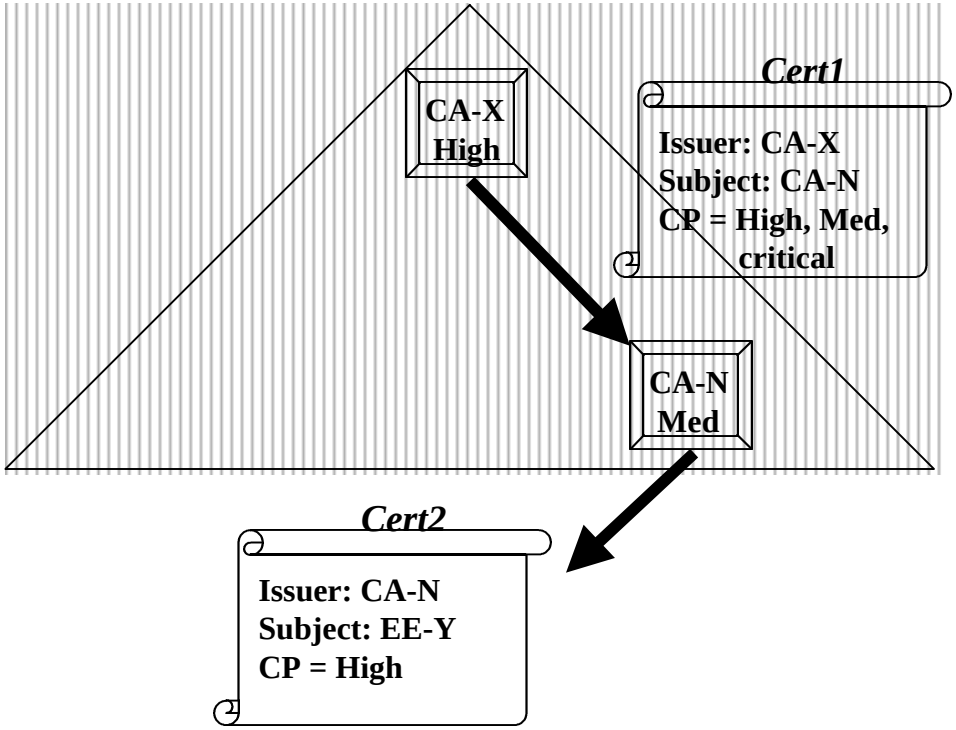
There appears to be no way for a superior CA to restrict the policies that may be asserted by a subordinate CA. Assume ***CA-X*** would like to restrict ***CA-N*** to only asserting policy ***B***.



If *initial-policy-set* is {A, B}, then the above chain will be valid. It is difficult for ***CA-X*** to restrict ***CA-N*** to only asserting policy ***B*** in ***Cert2***

Scenario 3

It appears to be difficult for a superior CA (***CA-X)*** to restrict a subordinate CA (***CA-N)*** from asserting policy ***High***.



If *initial-policy-set* is {High, Med}, then the above chain will be valid.

Underlying Policy Flaws in X.509

All 3 anomaly scenarios are symptomatic of two underlying flaws:

1) The *certificatePolicies* extension is overloaded to signify:
   – policies under which certificate was issued, indicating the purposes for which it may be used
   – polices that may be asserted by subordinate CAs, through use of the “critical” flag

2) The path processing logic does not check policies asserted in a certificate against *authority-constrained-policy-set*

Fix to Policy Flaws in X.509 (I)

• Restrict the usage of the *certificatePolicies* extension to signify:
  – policies under which certificate was issued
  – criticality flag has no effect on path processing

•Add a new extension, *permittedPolicies* to signify:
  – polices that may be asserted by subordinate CAs

Fix to Policy Flaws in X.509 (II)

• Update path processing logic such that the *explicit-policy-indicator* state variable is not used

• Update path processing logic such that the policies asserted in a certificate are always checked against the constraints placed by the user as well as the authorities.

New X.509v3 Extensions

• ***permittedPolicies***: populated in a CA certificate to restrict the set of policies that may be asserted by subordinate CAs

Updates to Path Processing (I)

Inputs : Delete an input

– *initial-explicit-policy-indicator*

- **Outputs** :
  – if validation was successful, the set of acceptable policies and the corresponding qualifiers contained in the end certificate.
- **State variables** : Delete a variable
  - *explicit-policy-indicator*
- **Initialization Step**: No change
- **Local Variables**: Add a local variable
  – *acceptable-policies* - policy identifiers asserted in the current certificate that are considered acceptable to the certificate user, as well as the preceding authorities

Updates to Path Processing (II)

- Processing of all certificates :

  c) If *user-constrained-policy-set* is not *any-policy*, compute the intersection of the *user-constrained-policy-set*, the *authority-constrained-policy-set*, and the identifiers within the certificate policies field and put the result as the *acceptable-policies* set.

  Check that the *acceptable-policies* set is not the NULL set. [UPDATE TO EXISTING STEP]

  If all checks pass, and this is the end certificate, return the policies in the *acceptable-policies* set and the corresponding policy qualifiers that appear in the current certificate.

Updates to Path Processing (III)

- Processing of intermediate certificates :

  d) Delete update of *explicit-policy-indicator* state variable

  e) If *policy-mapping-inhibit-indicator* is not set: [NO CHANGE]

  – process any policy mapping extension with respect to … *user-constrained-policy-set* and add appropriate policy identifiers ...

  – process any policy mapping extension with respect to … *authority-constrained-policy-set* and add appropriate policy identifiers …

  f) If the ***permittedPolicies*** extension is present, compute the intersection of the policies in that extension and the *authority-constrained-policy-set* and put the result as the new value of the *authority-constrained-policy-set* [NEW STEP ADDED]

Advantages of Proposed Fix

- Semantics of all existing extensions remain unchanged
- No restrictions on the way policies may be deployed within policy domains, when new extension is not used
- Minimal changes (through augmentation rather than replacement) in path processing algorithm
- Full backward compatibility with existing CAs and issued certificates
- Ability of superior CAs to restrict policies that may be asserted by subordinate CAs

Usage of certificatePolicies Extension

- This extension should include policy identifiers only for the policies that were used in issuing the subject certificate. For example, in Scenario 1, CA V should assert only {H}, instead of {H,M,L}
- The semantic description of this extension should be changed to "… policy information terms indicate the policy under which the certificate has been issued indicating the suitability of the certificate for specific purposes and applications"

Usage of permittedPolicies Extension

- When dynamic addition of lower assurance policies is desirable within a policy domain, the permittedPolicies extension should not be used within CA certificates within the domain.
- When the assertion of policies by subordinate CAs within a domain is to be restricted, the permittedPolicies extension should be populated with ALL policies that may be asserted be subordinate CAs.

Usage of PolicyMappings Extension

- This extension should be used to convey policy equivalence relations between two policy domains. Thus, when cross-certifying between policy domains, the policyMappings extension may include all possible equivalency statements between policies in the subject domain and issuer domain. This extension is not required to be limited to equivalency relations corresponding to the policies asserted within the cross-certificate.