Sensitive Information in a Wired World

CPSC 457/557, Fall 2013

Lecture 10, October 1, 2013

1:00-2:15 pm; AKW 400

http://zoo.cs.yale.edu/classes/cs457/fall13/

What is a certificate?

- A certificate is a digitally signed statement that binds a public key to some identifying information.
  - The signer of the certificate is called its issuer.
  - The entity talked about in the certificate is the subject of the certificate.
- That's all a certificate is, at the 30,000-foot level.

Certs in the "real world"

- A driver's license is *like* a certificate
  - It is a "signed" document (sealed, tamper-resistant)
  - It is created and signed by an "issuing authority" (the state DMV)
  - It binds together various pieces of identifying information
    - Name
    - License number
    - Driving restrictions (must wear glasses, etc.)

More certs in the real world

- Many physical objects are like certificates:
  - Any type of license (vehicle tabs, restaurant liquor license, amateur radio license, etc.)
  - Government-issued IDs (passports, green cards)
  - Membership cards (Costco, discount cards, etc.)
- All of these examples bind an identity and certain rights, privileges, or other identifiers
  - "BAL ==N1TJT" signed FCC

Why do we believe what certs say?

- In the physical world, why do we trust the statements contained on a physical cert?
  - We believe it's hard to forge the cert
  - We trust the entity that "signed" the cert
- In the digital world, we need analogous properties
  - We need to believe it's hard to forge the digital signature on a signed document
  - We need to trust the issuer/signer not to lie to us

Getting a certificate

- How does Bob get a certificate for his key?
- He goes to a Certificate Authority (CA) that issues certificates and asks for one...
- The CA *issues* Bob a certificate for his public key.
  - CA is the *issuer*
  - Bob is the *subject*

Using Certificates

- Now that Bob has a certificate, is it useful?
- Alice will believe Bob's key belongs to Bob if Alice believes the certificate Bob gives her for his key.
- Alice will believe Bob's key belongs to Bob if Alice trusts the issuer of Bob's certificate to make key-name binding statements
- Have we made the situation any better?

Does Alice Trust Bob's CA?

How can we convince Alice to trust Bob's CA?

- Alice and Bob's CA could have met previously and exchanged keys directly.
  - *Bob's CA isn't going to shake hands with everyone he has certified, let alone everyone whom Bob wants to talk to.*

Does Alice Trust Bob's CA?

How can we convince Alice to trust Bob's CA?

- Alice and Bob's CA could have met previously & exchanged keys directly.
  - *Bob's CA isn't going to shake hands with everyone he's certified, let alone everyone whom Bob wants to talk to.*
- Someone Alice trusts could vouch to her for Bob's CA and Bob's CA's key
  - *Infinite Loop: See Loop, Infinite.*
  - Actually, it's just a bounded recursion...

What is Alice's Trust Model?

- Alice has to implicitly trust *some* set of keys
  - Once she does that, those keys can introduce others to her.
- In the model used by SSL/TLS, CAs are arranged in a hierarchy
  - Alice, like everyone else, trusts one or more "root CA" that live at the top of the hierarchy
- Other models work differently

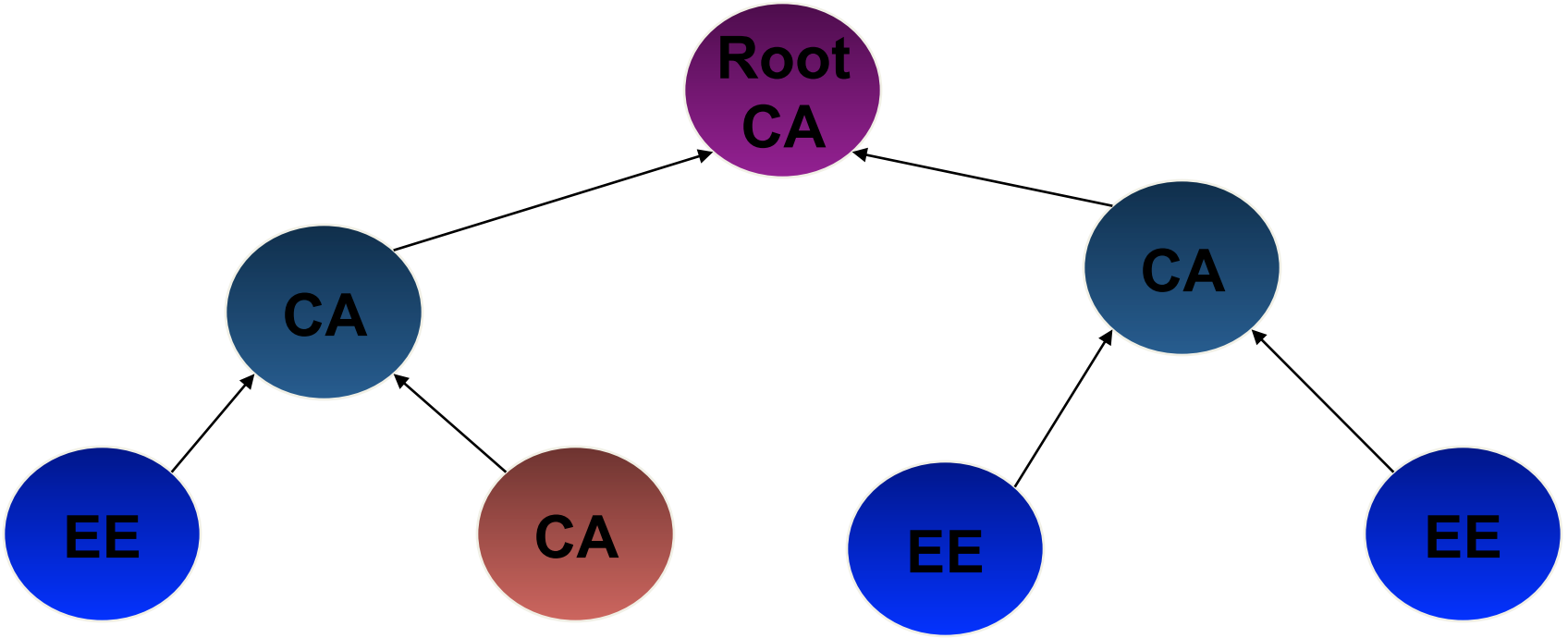
Public Key Infrastructure

Certificate Authorities

- A certificate authority (CA) guarantees the connection between a key and another CA or an "end entity."
- An end entity is:
  - A person
  - A role ("VP of sales")
  - An organization
  - A pseudonym
  - A piece of hardware or software
  - An account
- Some CAs only allow a subset of these types.

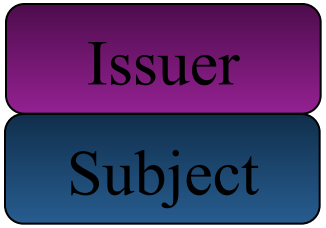
CA Hierarchies

- CAs can certify other CAs or "end entities"
- Certificates are links in a tree of EEs & CAs



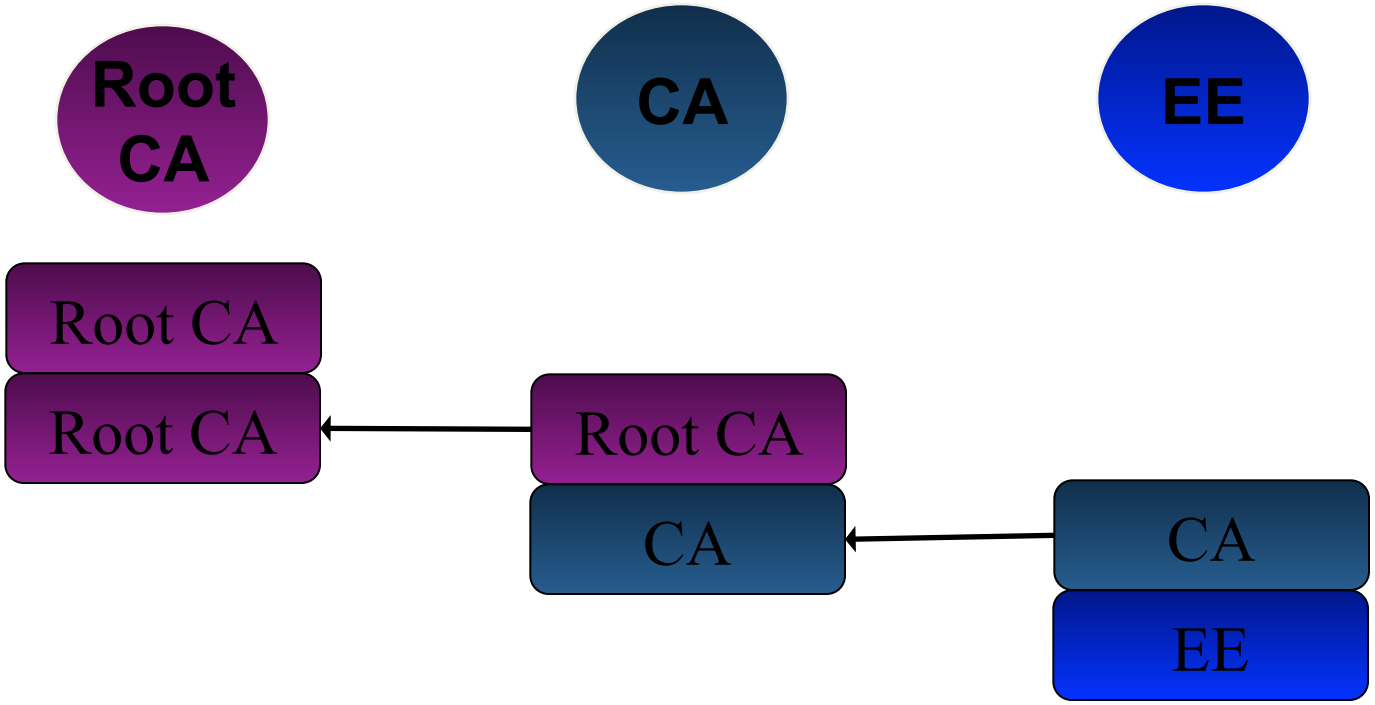
No-Frills Certs

- Certificates can contain all sorts of information inside them
  - We'll talk about the details in a little bit
- In the abstract, though, they're just statements by an issuer about a subject:



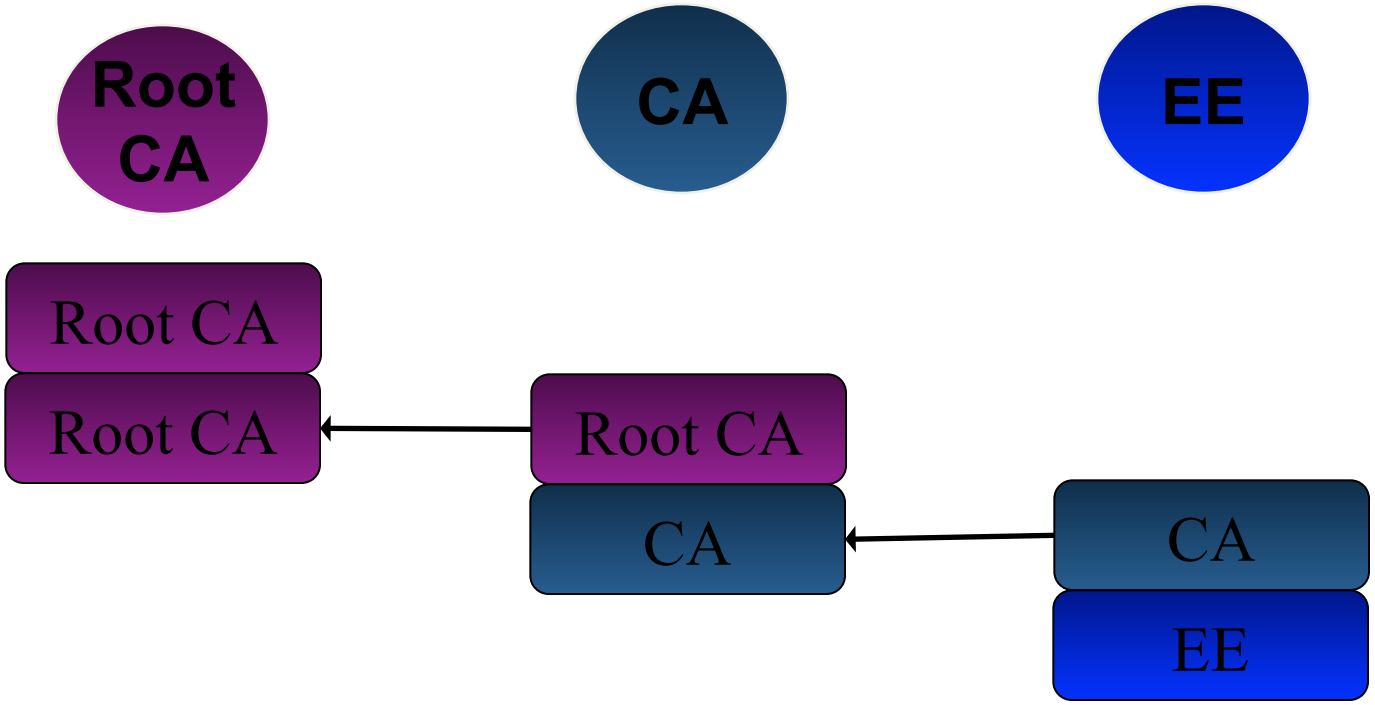
Does Alice trust Bob's Key?

- Alice trusts Bob's key if there is a chain of certificates from Bob's key to a root CA that Alice implicitly trusts

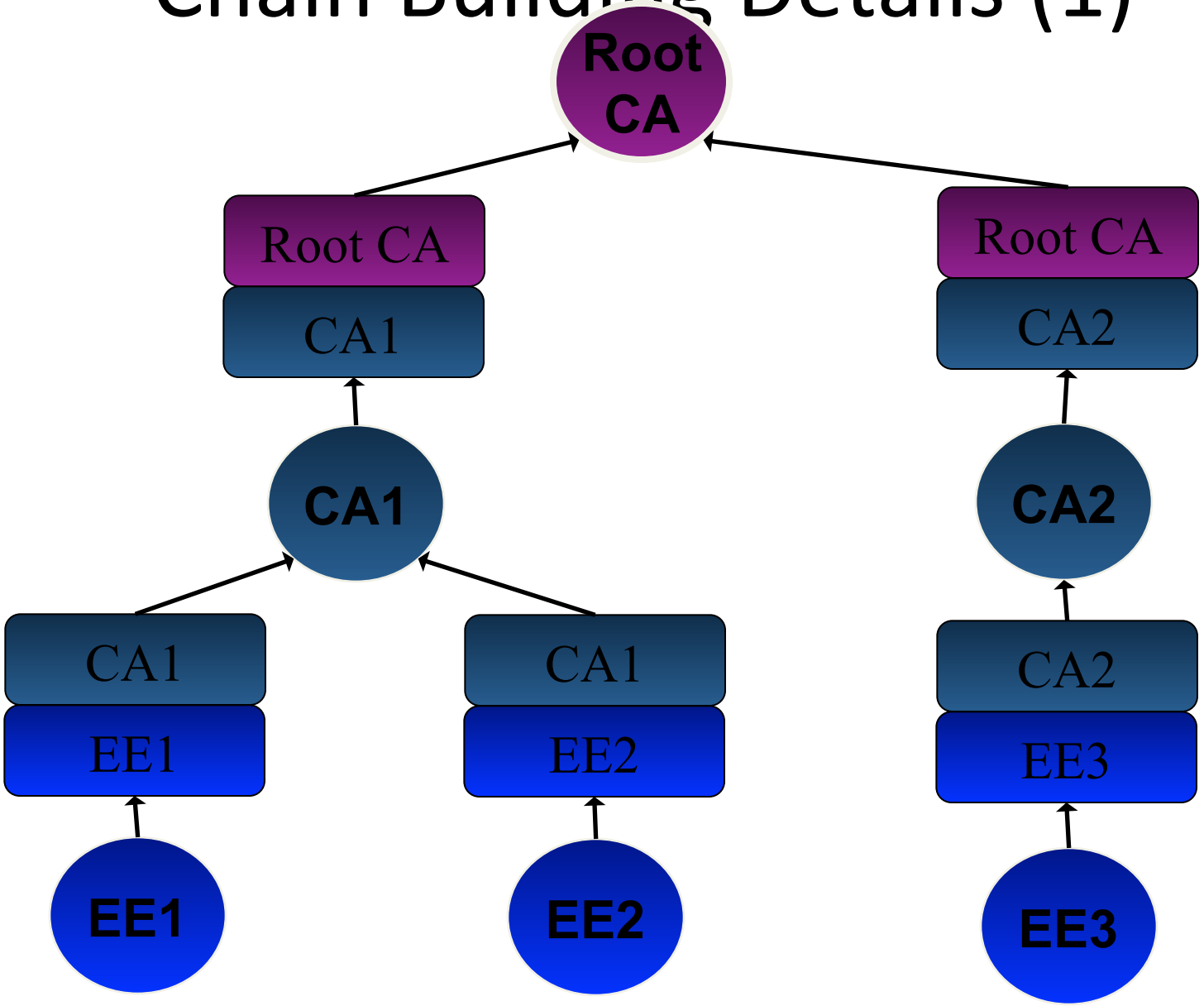


Chain Building & Validation

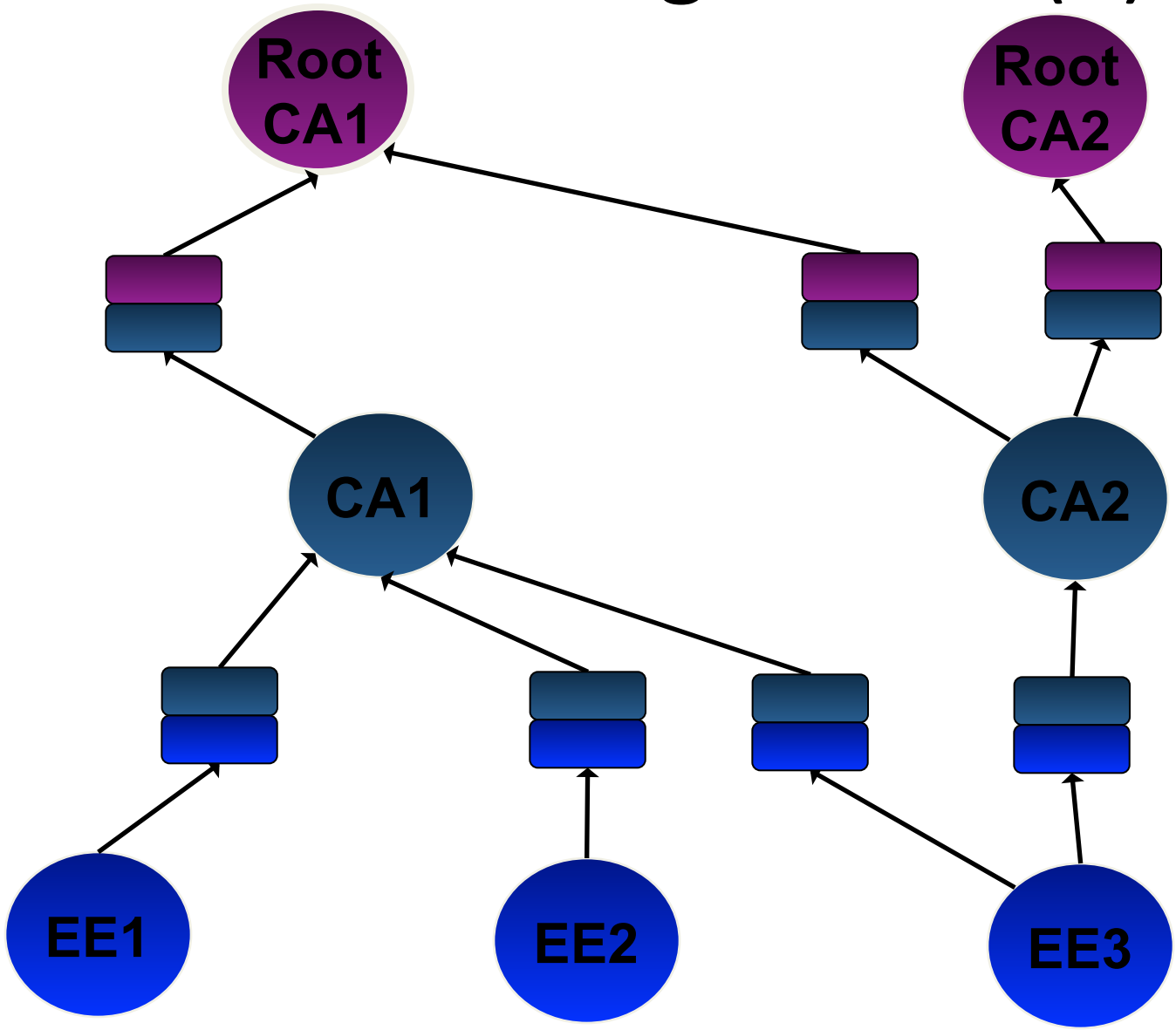
- "Given an end-entity certificate, does there exist a cryptographically valid chain of certificates linking it to a trusted root certificate?"



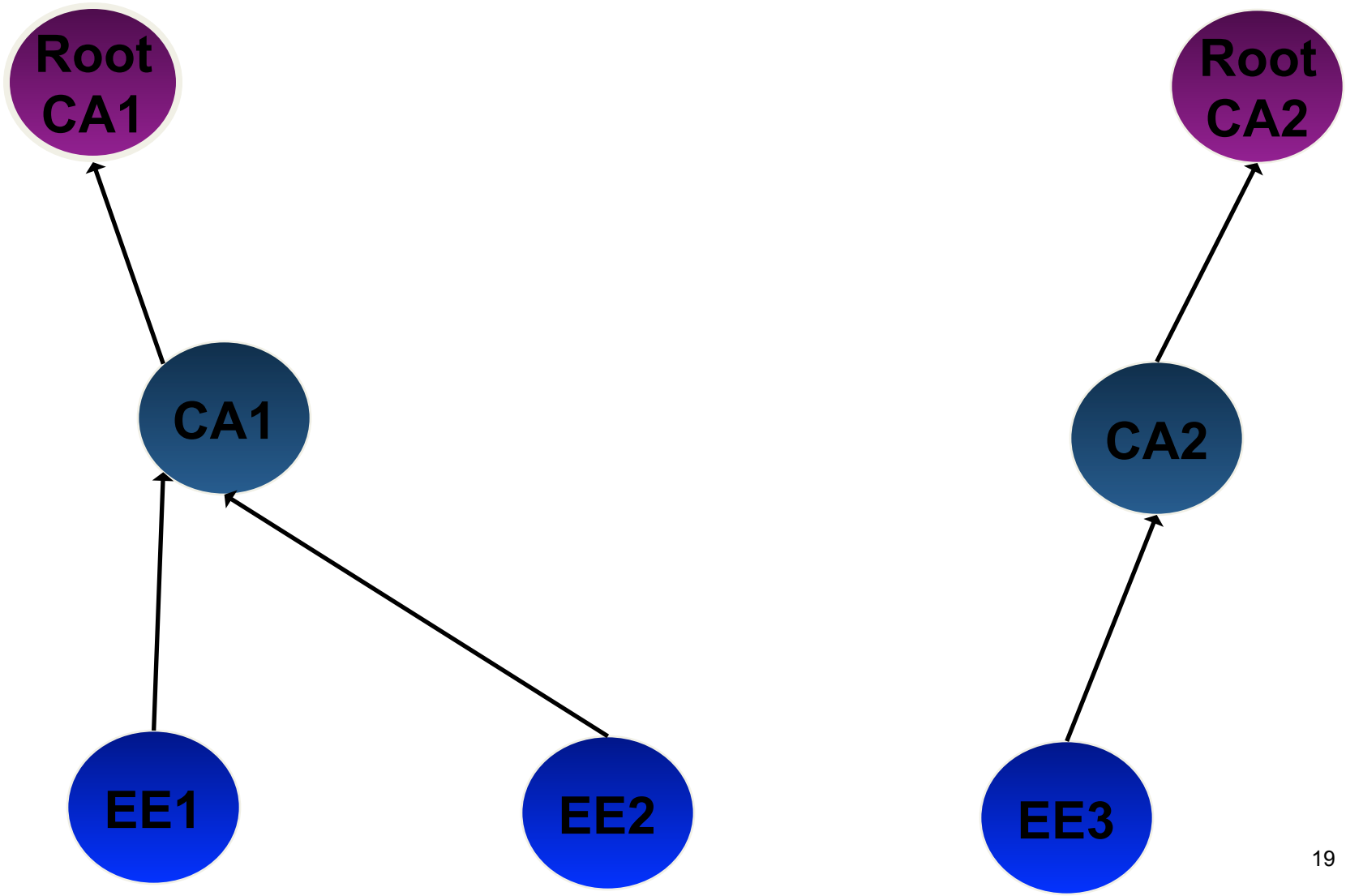
Chain Building Details (1)



Chain Building Details (2)



Chain Building Details (3)



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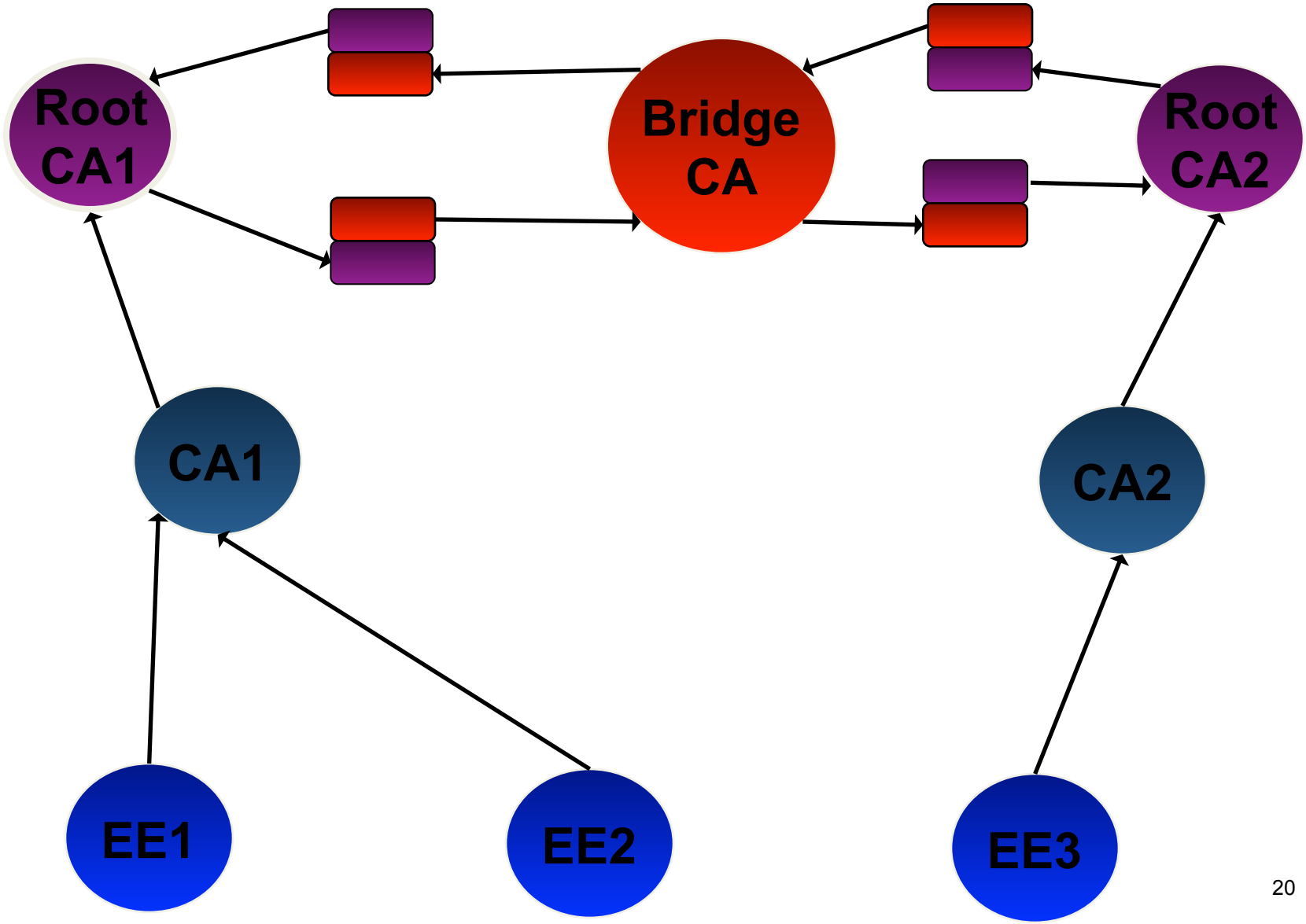

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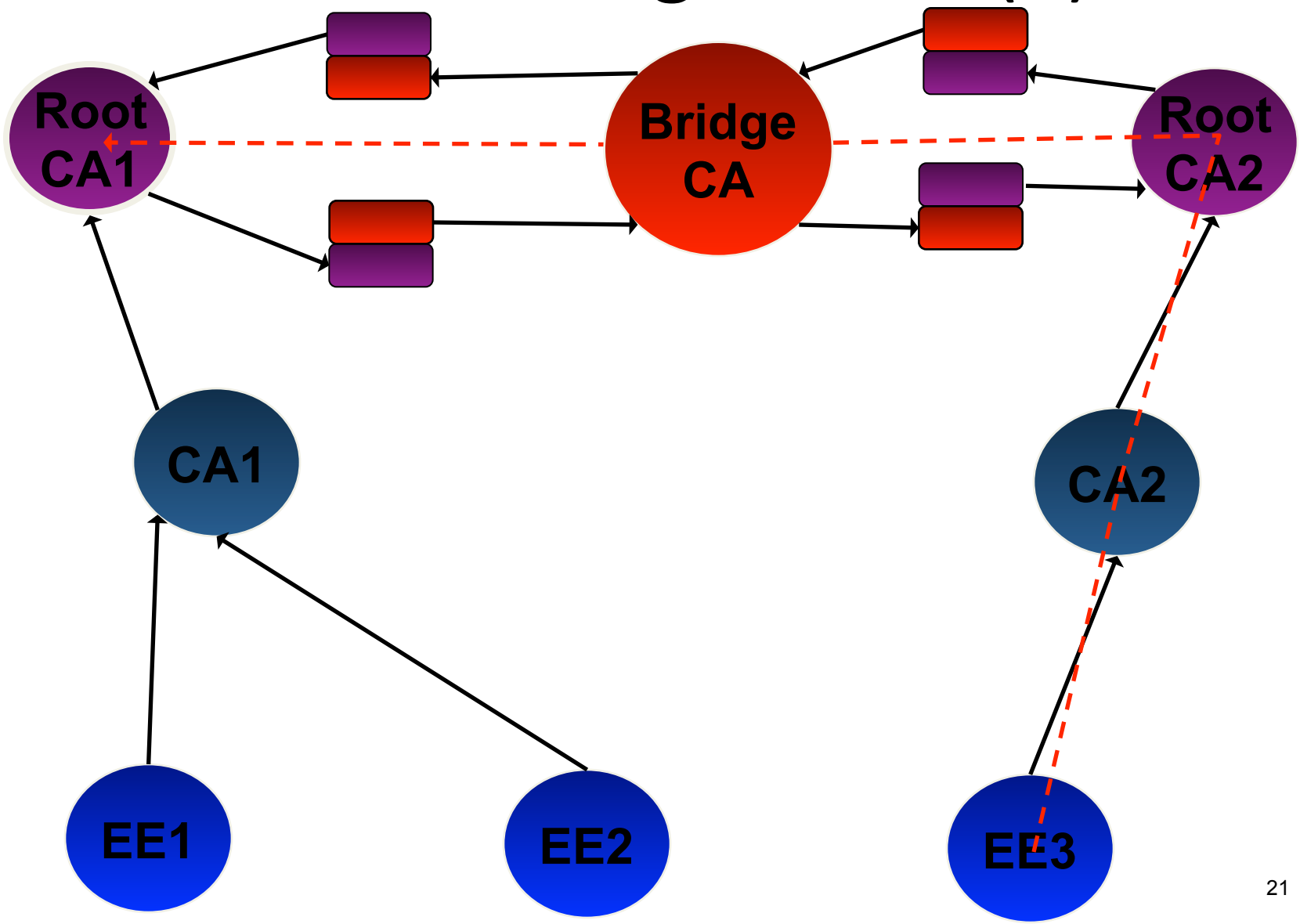

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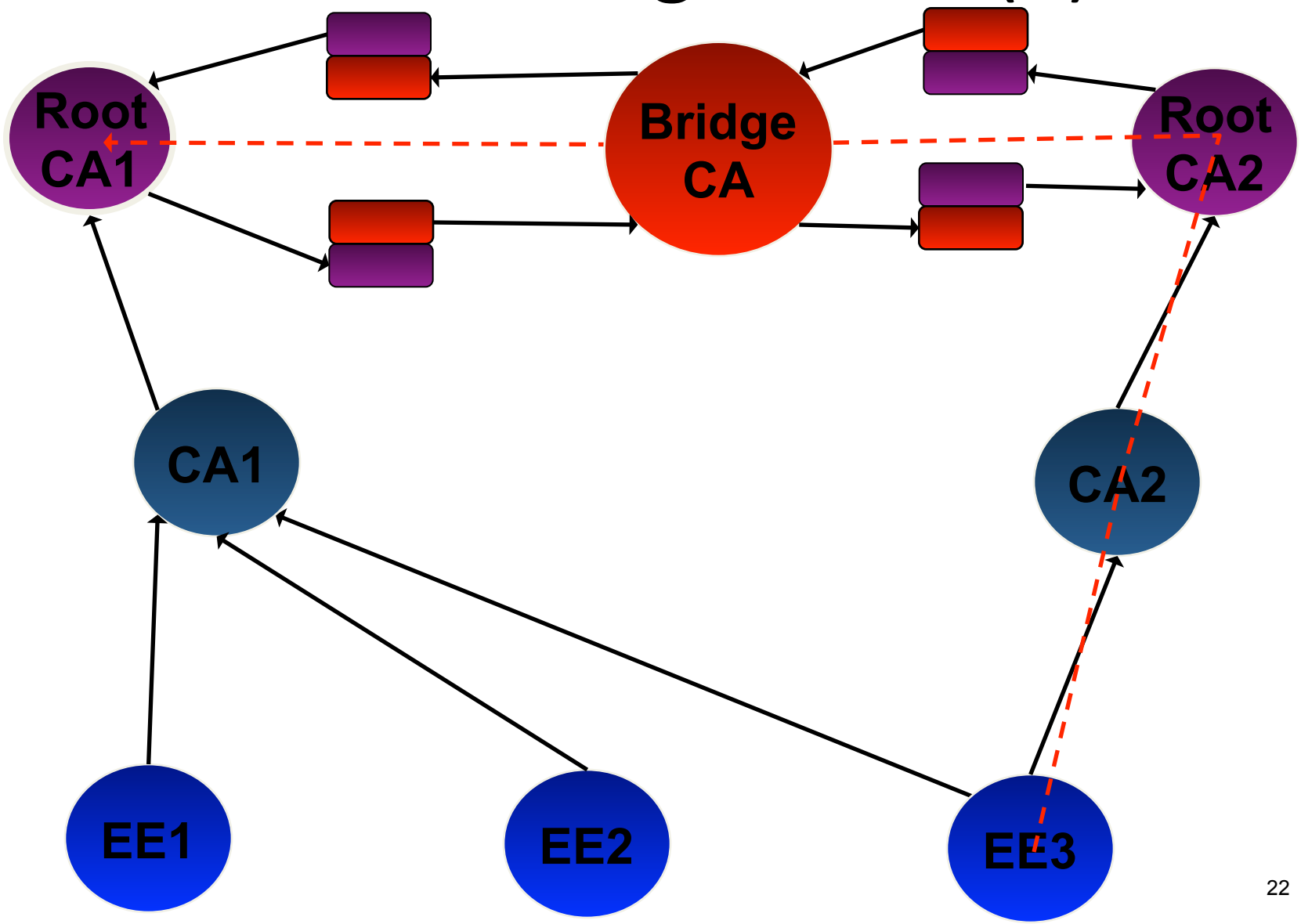

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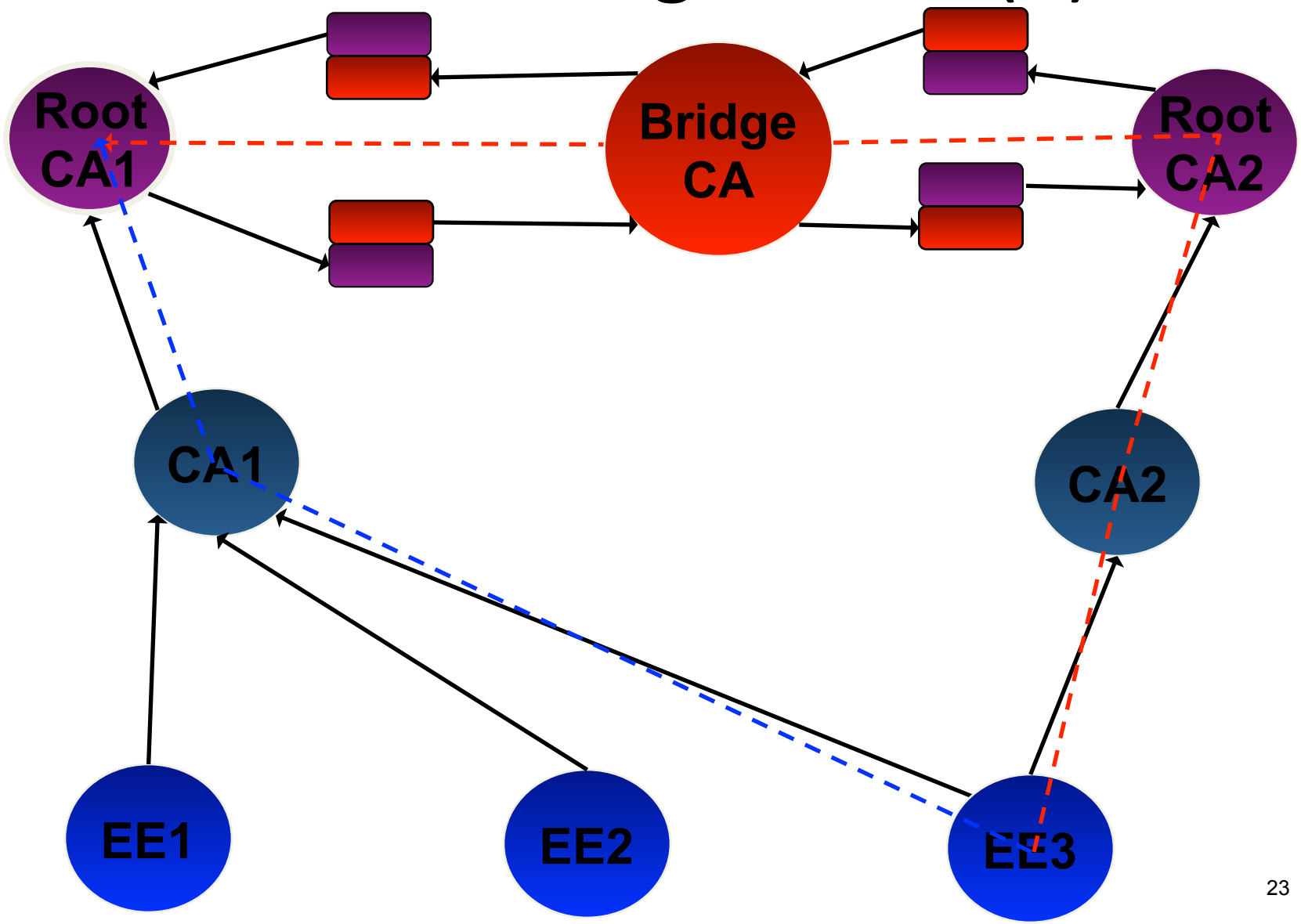


Chaining Certificates

- How do we determine whether two certificates chain together?
  - *You'd think this was an easy problem...*
  - *But it's actually a question with religious significance in the security community*
  - *"Are you a believer in names, or in keys?"*
- In order to understand the schism, we need to digress for a bit and talk about names and some history

PKI Alphabet Soup

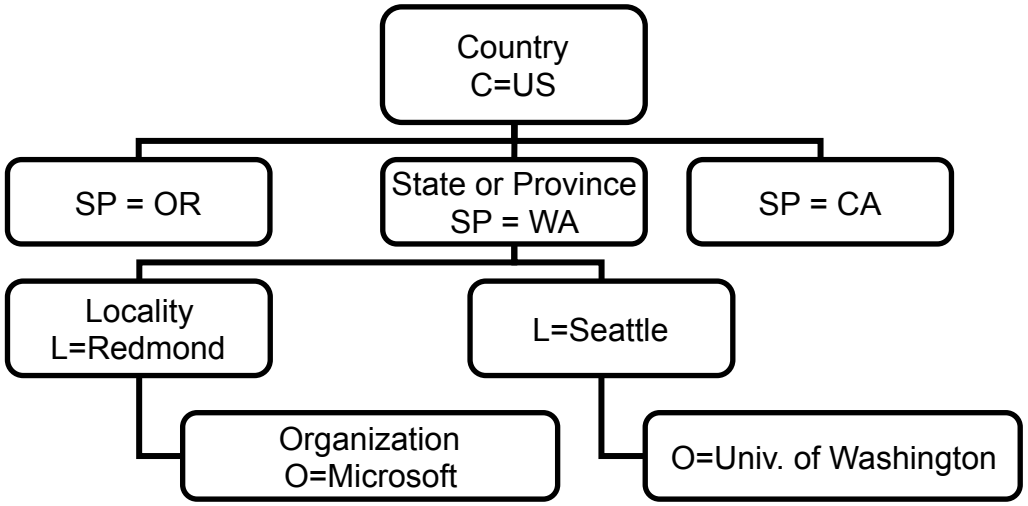
- X.509v3 - standard content of a certificate
- PKIX – IETF Working Group on PKI interoperability
  - PKIX == Public Key Infrastructure using X.509v3 certificates
- ASN.1 - Abstract Syntax Notation, exact description of a certificate format
- DER - Distinguished Encoding Rules, how to physically package a certificate

The X.500 Directory Model

- The model SSL/TLS uses, the X.509 certificate model, is based on names
  - *Names as principles*
- Specifically, X.509 is based on the X.500 directory model
- X.500 defined a global, all-encompassing directory, to be run by the telcos
  - *One directory to rule them all, one directory to define them...*

X.500 Distinguished Names

- In the X.500 model, everything has a single, unique, global, assigned name
  - There is a worldwide hierarchy, and you're in it!



DNs in Practice

- Name is unique within the scope of the CA's name
- Public CAs (e.g., Verisign) typically set
  - C = CA Country
  - O = CA Name
  - OU = Certificate type/class
  - CN = User name
  - E= email address

Private-label DNs

- If you own the CA, you get to decide what fields go in the DN
  - Really varies on what the software supports
- Can get really strange as people try to guess values for fields that are required by software
  - Software requires an OU, we don't have OUs, so I better make something up!

DNs in X.509 Certificates

- The X.509 certificate standard began as a way to associate a certificate with a node in the directory.
- How is the subject of a cert identified?
  - By its DN.
- How is the issuer of a cert identified?
  - By its DN.
- How are certificates linked together?
  - By DNs.

Key fields in a certificate

- The core fields of an X.509 certificate are
  - The subject public key
  - The subject Distinguished Name
  - The issuer Distinguished Name
- What's missing here?

Key fields in a certificate

- The core fields of an X.509 certificate are
  - The subject public key
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  - The issuer Distinguished Name
- What's missing here?
  - The issuer's public key is not present in the certificate.
  - You can't verify the signature on the cert without finding a parent cert!

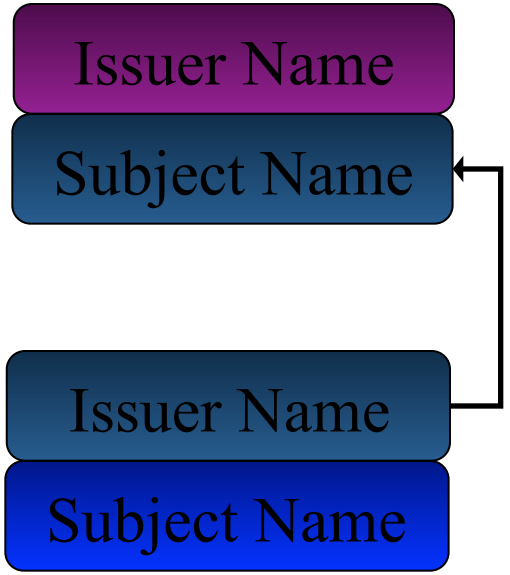
Back to Chain Building

- OK, assume we're a "relying party application" -- something that received an end-entity certificate and wants to verify it.
  - Our task is to build a cert chain from that end-entity cert to one of our trusted roots
- How do we do that?
  - We start with our EE cert, and using the information contained within we look for possible parent certificates.

Parent certs

- What's a valid parent certificate?
  - In the raw X.509 model, parent-child relationships are determined solely by matching Issuer DN in the child to Subject DN in the parent
  - Recall that there's an assumption that you have a big directory handy to find certs.
- If you don't have a directory handy, you need to do the matching yourself
  - This is not as easy as you might think…

Name matching



Matching Names

- How do we determine if two DNs match?
  - "Use directory name matching rules!"
  - Try to be mildly smart about it
    - Remove spaces, case-fold, etc.
    - Disaster…
  - Try to be really dumb about it
    - Exact binary match
    - Less of a disaster, but there are still problems we can't work around…

Unicode Names

- Are these two character equal?

  é é

- They look equal…

Unicode Names

- Are these two character equal?

  é é

- They look equal…
- …but may not be
- In Unicode, you can compose characters, so:
  - “é” as one character
  - “é” as two characters – “e” followed by non-spacing accent
  - “é” as two characters – non-spacing accent followed by “e”
- Ick!

Even More Chain Building

- Name matching is just the beginning of the chain-building process
  - It is necessary that subject and issuer DNs exactly match for two certs to chain, but not always sufficient
- The chain building process is also influenced dynamically by other information contained within the certs themselves
  - *What other information is there in certs?*

Trusted Root Certificates

- Who do I trust to be roots at the top of the cert chain?
- In theory, "anyone you want"
- In practice, trusted roots come from two sources
  - They're baked into your web browser or operating system
  - They're pushed onto your "enterprise managed desktop"

More Aspects of PKI

- X.509 Cert "extensions"
  - Usage extensions
  - Constraint extensions
- Cert life-cycle management
  - Validity / expiration
  - Revocation!
  - Online status checking

❖ Certs not based on names

- "Trust management" need not be cert management