Computer Science 425
Distributed Systems

CS 425 / ECE 428

Fall 2013

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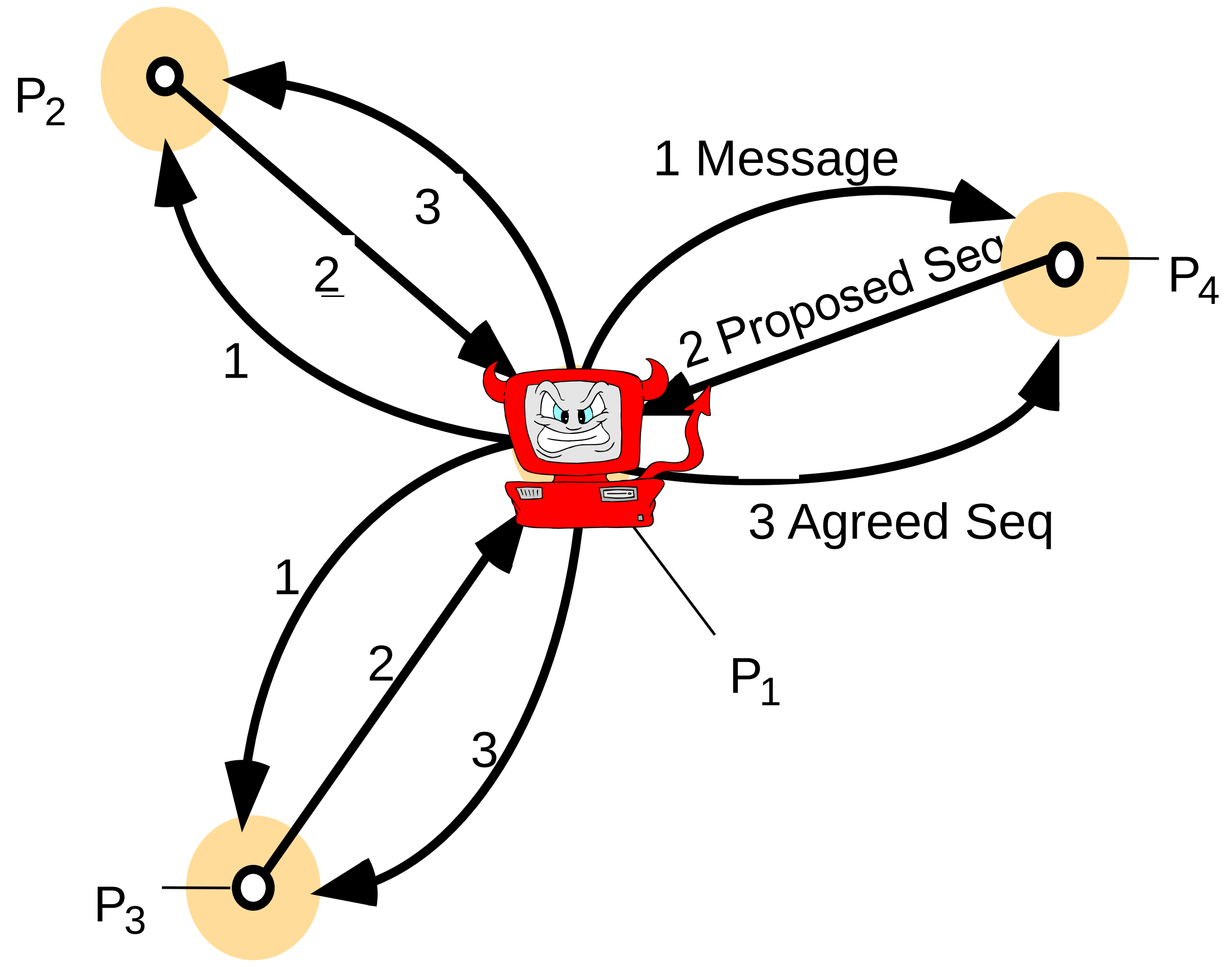
Lecture 25

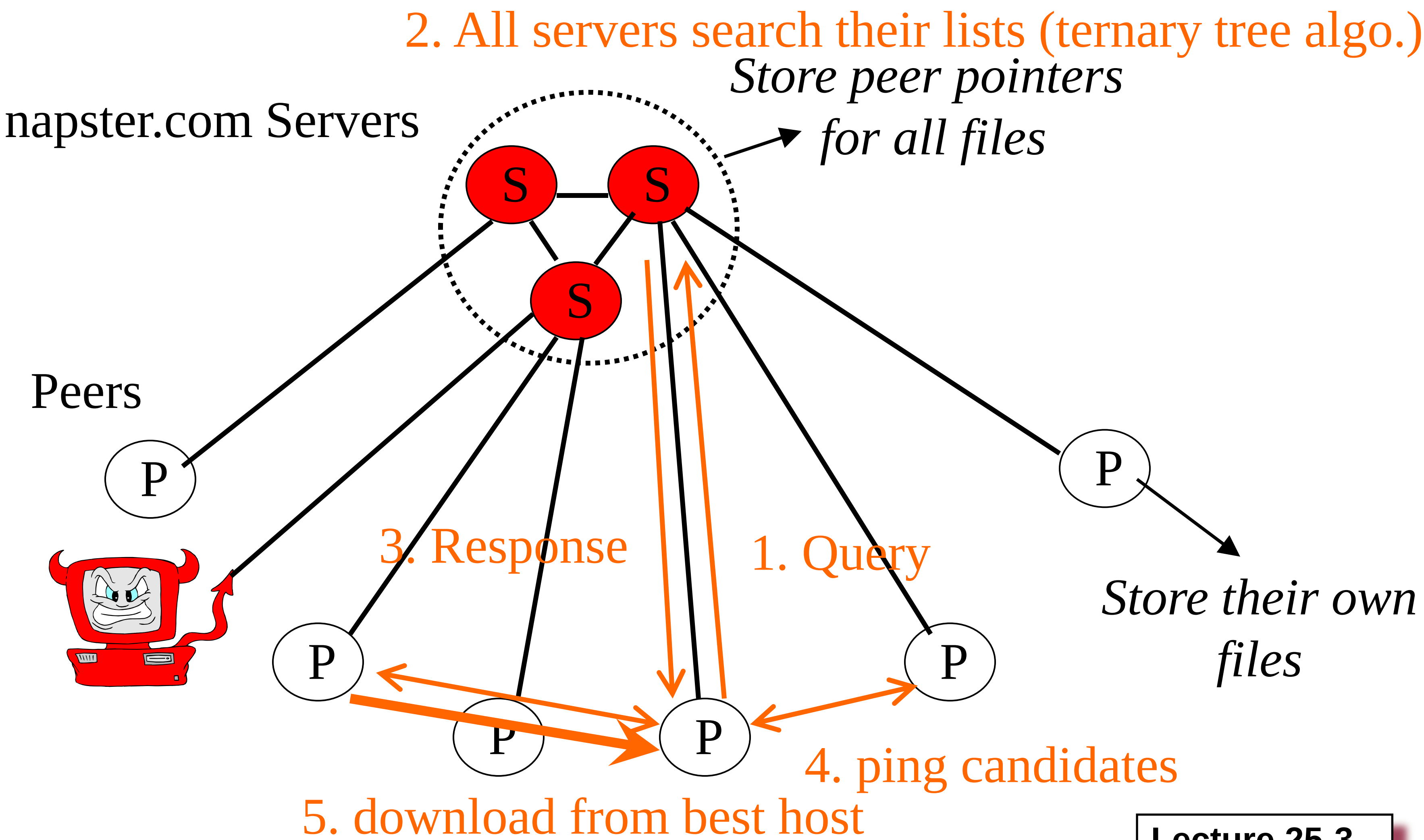
Security

Reading: Chapter 11 (relevant parts)

ISIS algorithm for total ordering



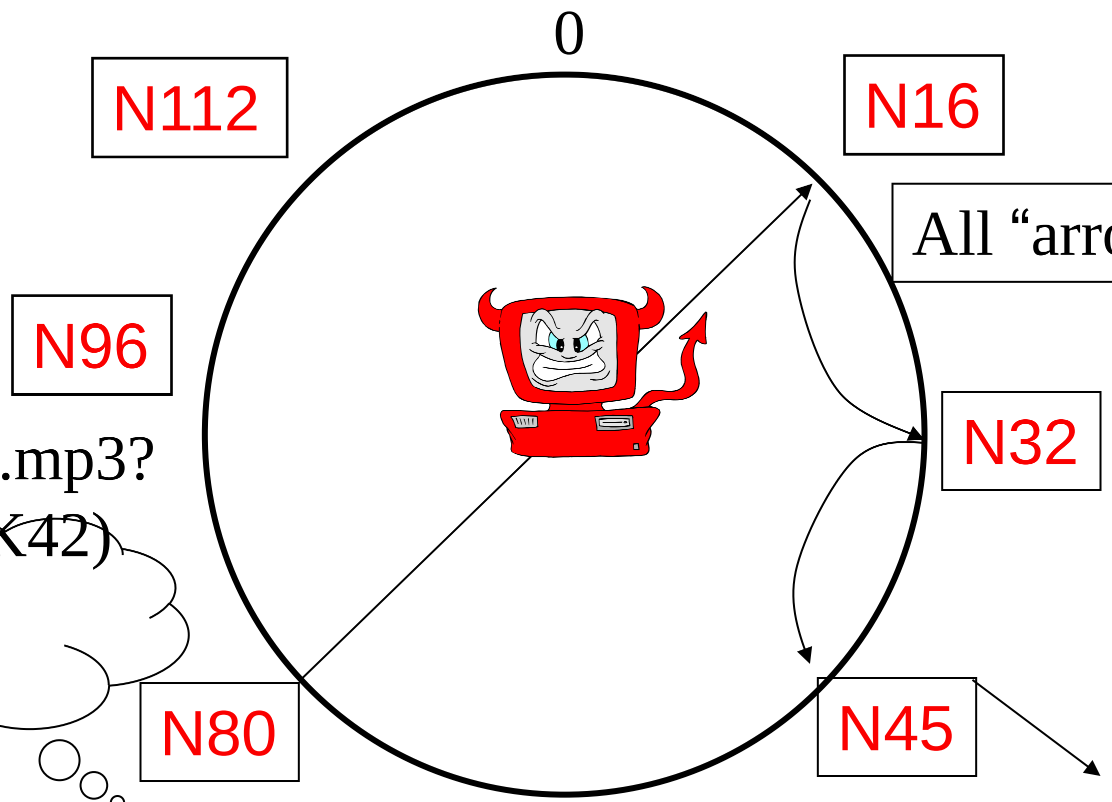
Napster


2. All servers search their lists (ternary tree algo.)
Store peer pointers for all files
napster.com Servers
S
S
S
Peers
P
P
P
P
P
P
P
3. Response
1. Query
Store their own files
4. ping candidates
5. download from best host

Chord: client to client

At node *n*, send query for key *k* to largest successor/finger entry < *k*
if none exist, return *successor(n)* to requestor

Say $m=7$

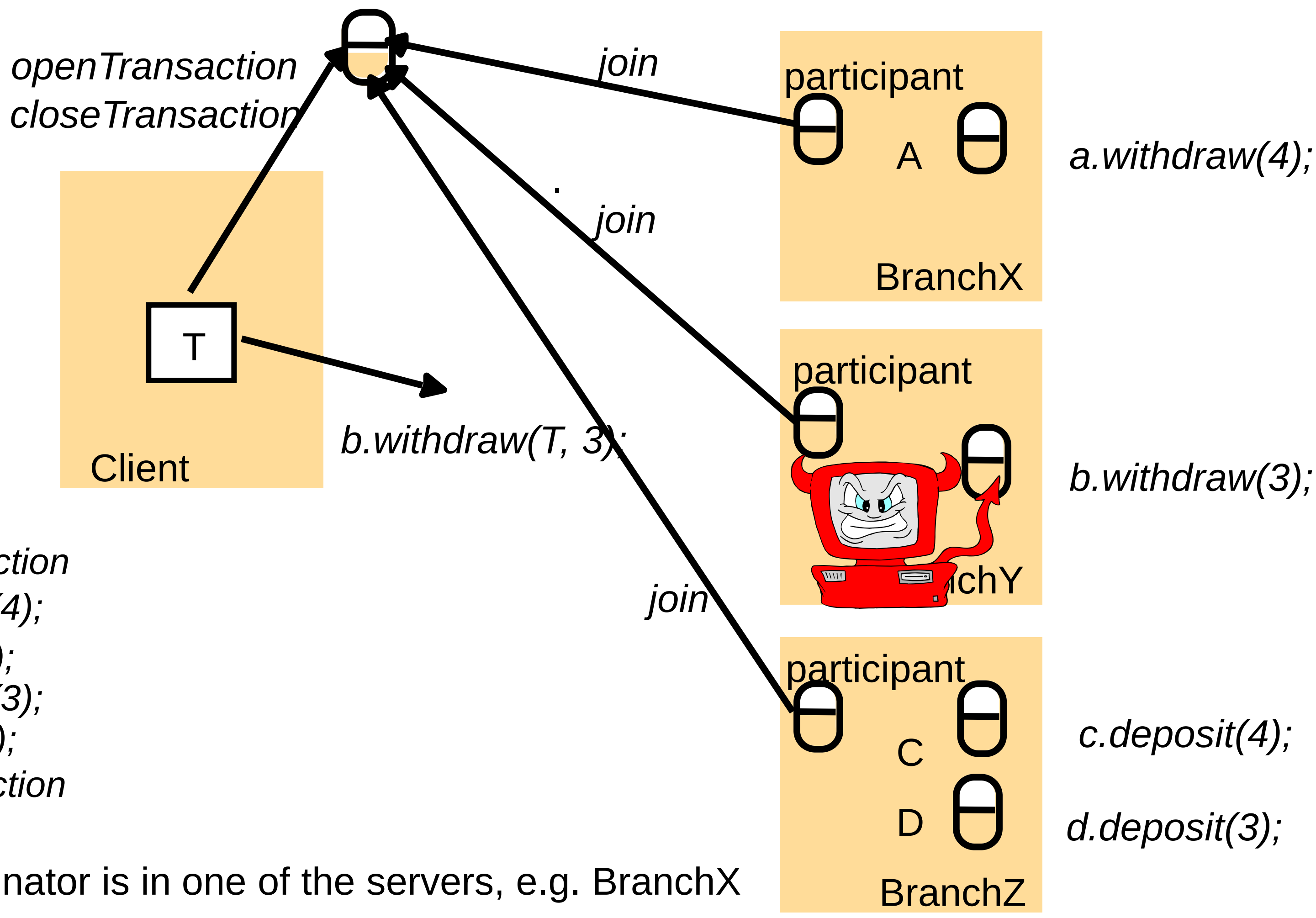


All "arrows" are RPCs

Who has bad.mp3?
(hashes to K42)

File bad.mp3 with
key K42 stored here

Distributed banking transaction



T = openTransaction
a.withdraw(4);
c.deposit(4);
b.withdraw(3);
d.deposit(3);
closeTransaction

Note: the coordinator is in one of the servers, e.g. BranchX

Security Threats

- **Leakage:** An unauthorized party gains access to a service or data.
  - Attacker obtains knowledge of a withdrawal or account balance, e.g., via eavesdropping
- **Tampering:** Unauthorized change of data, tampering with a service
  - Attacker changes the variable holding your personal checking $$ total
- **Vandalism:** Interference with proper operation, without gain to the attacker
  - Attacker does not allow any transactions to your account
  - E.g., DOS=denial of service

How Attacks are Carried Out

Attacks on Communication Channel / Network

- **Eavesdropping –** Obtaining copies of messages without authority.
- **Masquerading –** Sending or receiving messages with the identity of another principal (user or corporation). Identity theft.
- **Message tampering –** Intercepting messages and altering their contents before passing them onto the intended recipient.
- **Replaying –** Intercepting messages and sending them at a later time.
- **Denial of Service Attack –** flooding a channel or other resources (e.g., port) with messages.

Addressing the Challenges: Security's CIA

- **Leakage: An unauthorized party gains access to a service or data.**
  - **Confidentiality : protection against disclosure to unauthorized individuals.**
- **Tampering: Unauthorized change of data, tampering with a service**
  - **Integrity : protection against alteration or corruption.**
- **Vandalism: Interference with proper operation, without gain to the attacker**
  - **Availability : protection against interference with the means to access the resources.**

Security Policies & Mechanisms

- A Security ***Policy*** **indicates which actions each entity (user, data, service) is allowed or prohibited to take.**
  - **E.g., Only an owner is allowed to make transactions to his account. CIA properties.**
- A Security ***Mechanism*** **implements and enforces the policy**
  - ***Encryption and decryption:*** **transform data to a form only understandable by authorized users, and vice-versa.**
  - ***Authentication:*** **verify the claimed identity of a principal, i.e., user, client, service, process, etc.**
  - ***Authorization:*** **verify access rights of principal for resource.**
  - ***Auditing*****: make record of and check access to data and resources. Mainly an offline analysis tool, often ex-post.**

Designing Secure Systems

- **Need to make worst-case assumptions about attackers:**
  - **exposed interfaces, insecure networks, algorithms and program code available to attackers, attackers may be computationally very powerful**
  - **Typically design system to withstand a known set of attacks (<u>Attack Model or Attacker Model</u>)**
  - **Tradeoff between security and performance impact**
- **Designing Secure Systems**
  - **Traditionally done as a layer on top of existing protocols.**

  Three phases:
  - **Design security protocol**
  - **Analyze Protocol Behavior when under attacks**
  - **Measure effect on overall performance if there were no attacks (the *common-case*)**

Familiar Names for Principals in Security Protocols

Alice	First participant
Bob	Second participant
Carol	Participant in three- and four-party protocols
Dave	Participant in four-party protocols
Eve	Eavesdropper
Mallory	Malicious attacker
Sara	A server

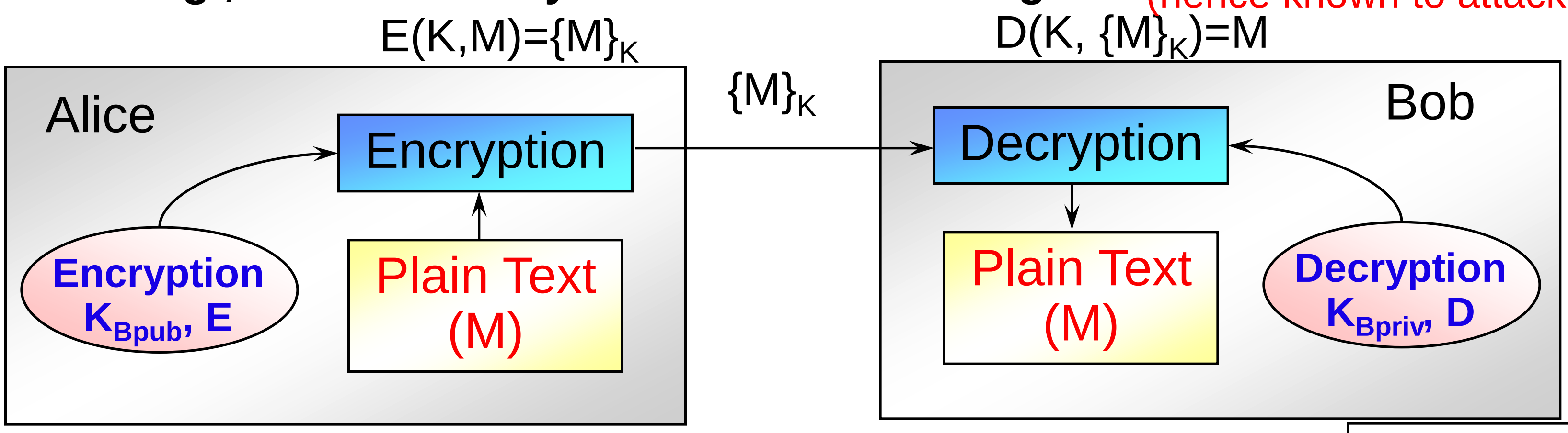
Cryptography Notations

K_A	Alice's secret key
K_B	Bob's secret key
K_{AB}	Secret key shared between Alice and Bob
K_{Apriv}	Alice's private key (known only to Alice)
K_{Apub}	Alice's public key (published by Alice for all to read)
$\{M\}_K$	(Typical) Message *M* encrypted with key
$[M]_K$	(Typical) Message *M* signed with key *K*

Cryptography

- Encoding (encryption) of a message that can only be read (decryption) by a key.
- In shared key cryptography (symmetric cryptography) the sender and the recipient know the key, but no one else does.
  - E.g., DES (Data Encryption Standard) – 56 b key operates on 64 b blocks of data. Notation: K_{AB} (M).
  - How do Alice and Bob get the shared key K_{AB} to begin with?
- In public/private key pairs messages are encrypted with a published public key, and can only be decrypted by a secret private decryption key.
  - E.g., RSA / PGP keys – at least 512 b long

Code for E & D
is "open-source"
(hence known to attacker)



Cryptography

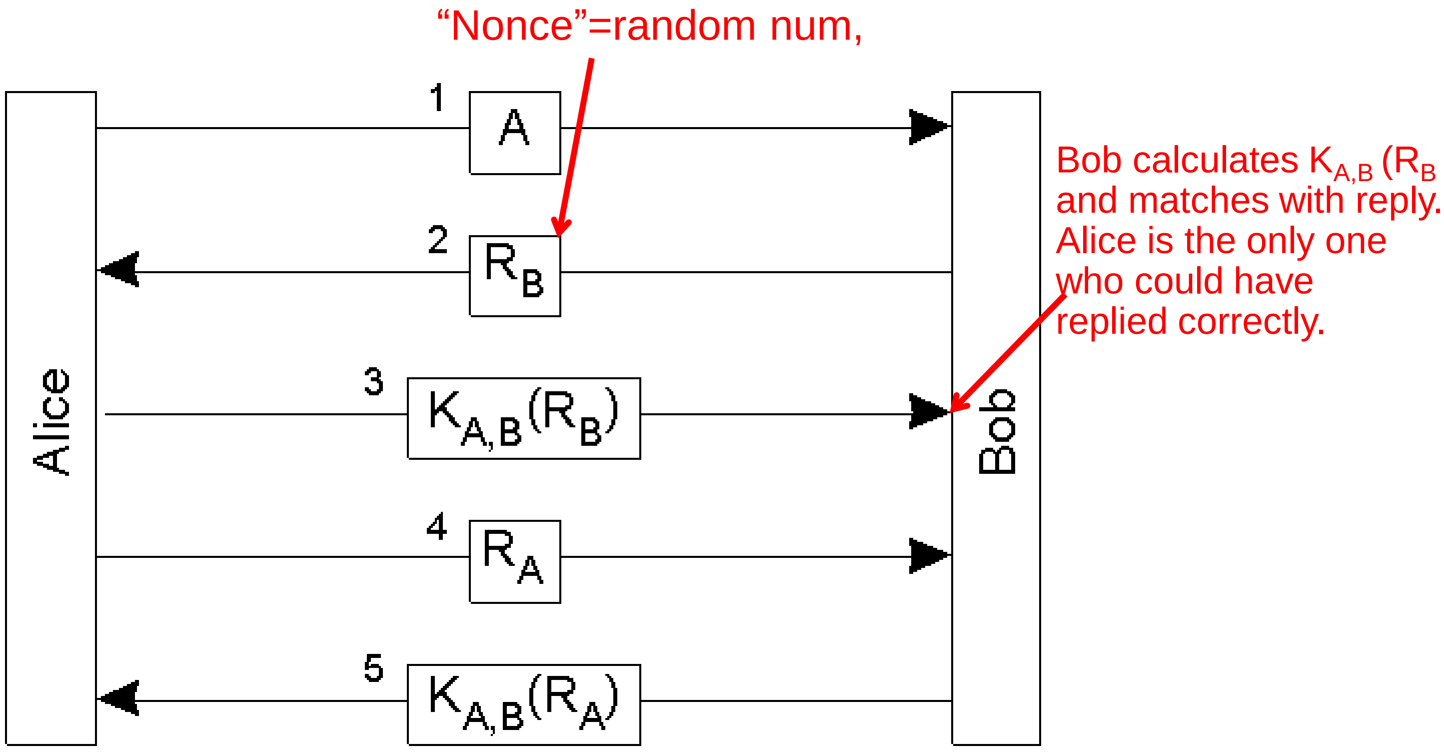
- Shared versus public/private:
  - Shared reveals information to too many principles; may need key distribution and revocation/repudiation mechanisms
  - In electronic commerce or wide area applications, public/private key pairs are preferred to shared keys.
  - Public/private key encrypt/decrypt ops are costly
  - May use hybrid: pub/pri generates a shared key.
- Presentation of many next few protocols independent of which keying scheme, viz., shared or pub/priv

Authentication

- Use of cryptography to have two principals verify each others' identities.
  - Direct authentication: the server uses a shared secret key to authenticate the client.
  - Indirect authentication: a trusted authentication server (third party) authenticates the client.
  - The authentication server knows keys of principals and generates temporary shared key (ticket) to an authenticated client. The ticket is used for messages in this session.
    - E.g., Verisign servers

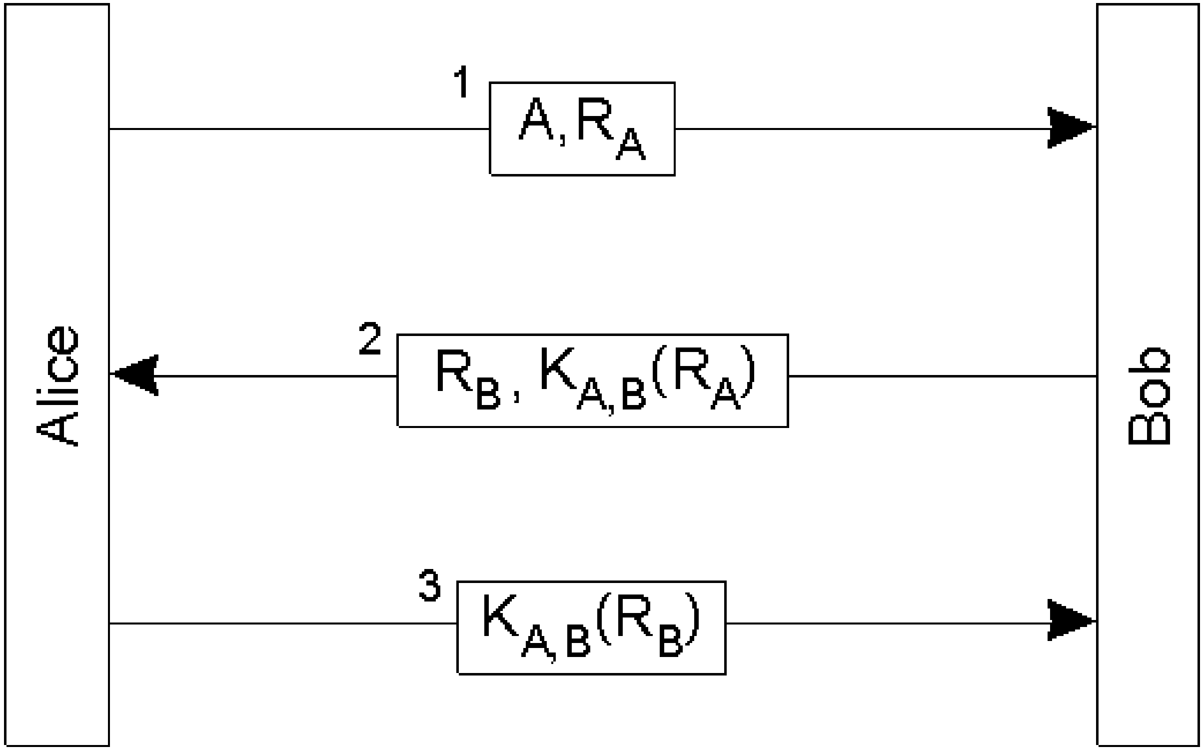
Direct Authentication

- **Authentication based on a shared secret key.**

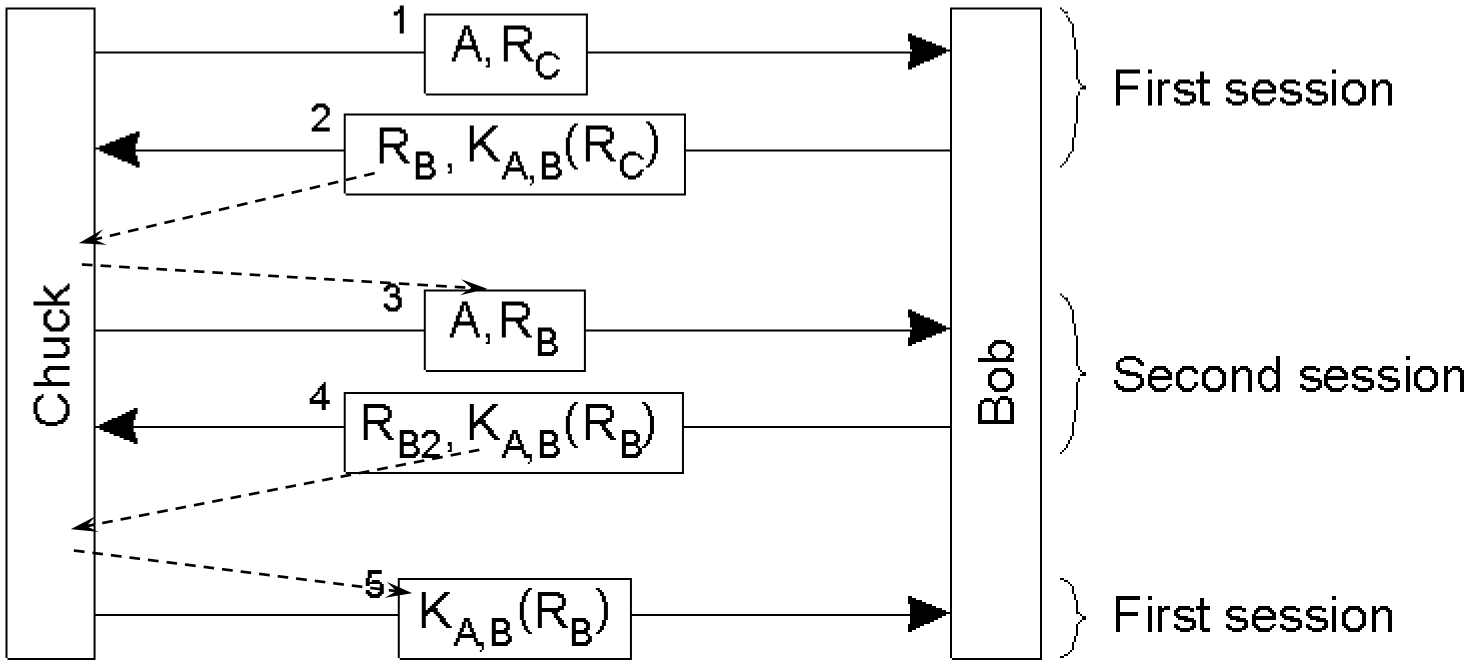


“Optimized” Direct Authentication

- **Authentication based on a shared secret key, but using three instead of five messages.**



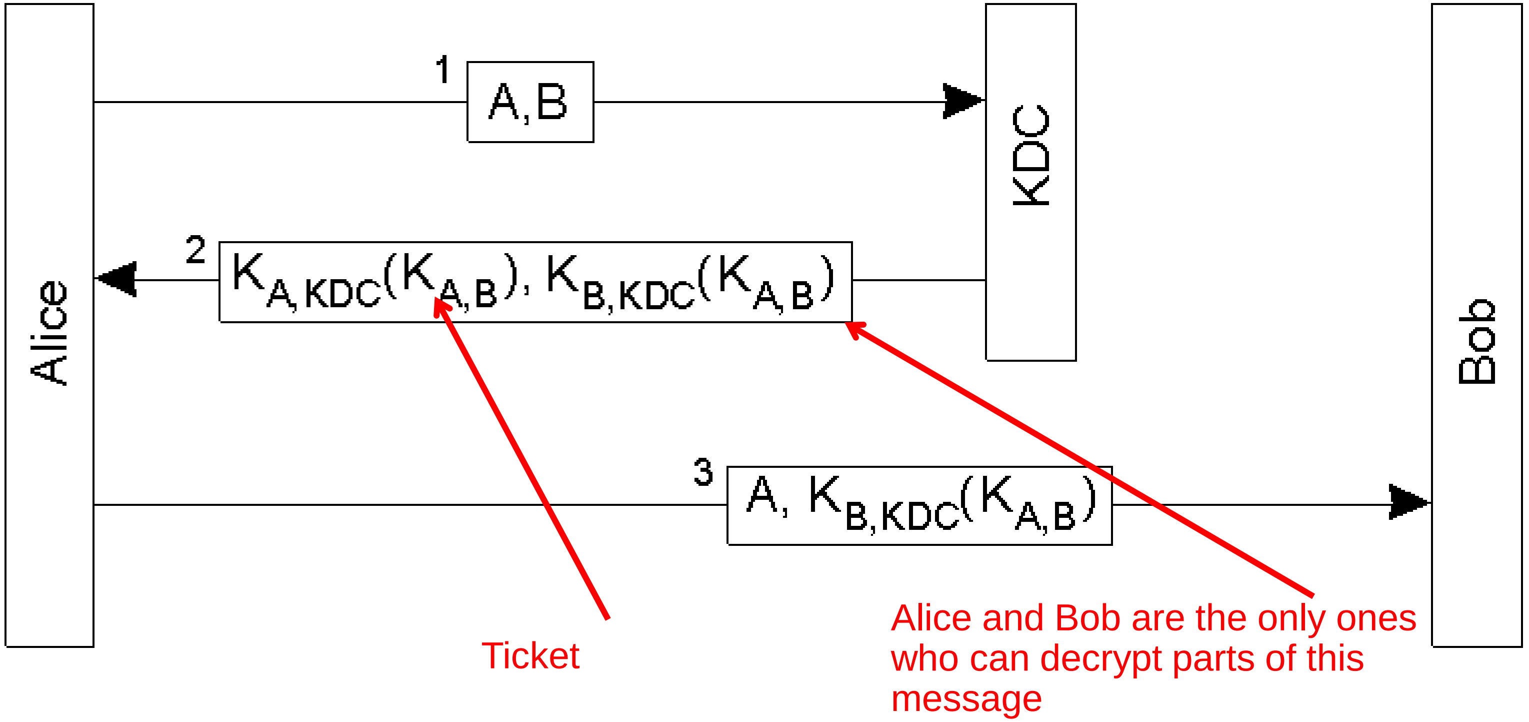
Replay/Reflection Attack (with shared keys)



Steps 1, 2, 5 -> Chuck is authenticated as Alice

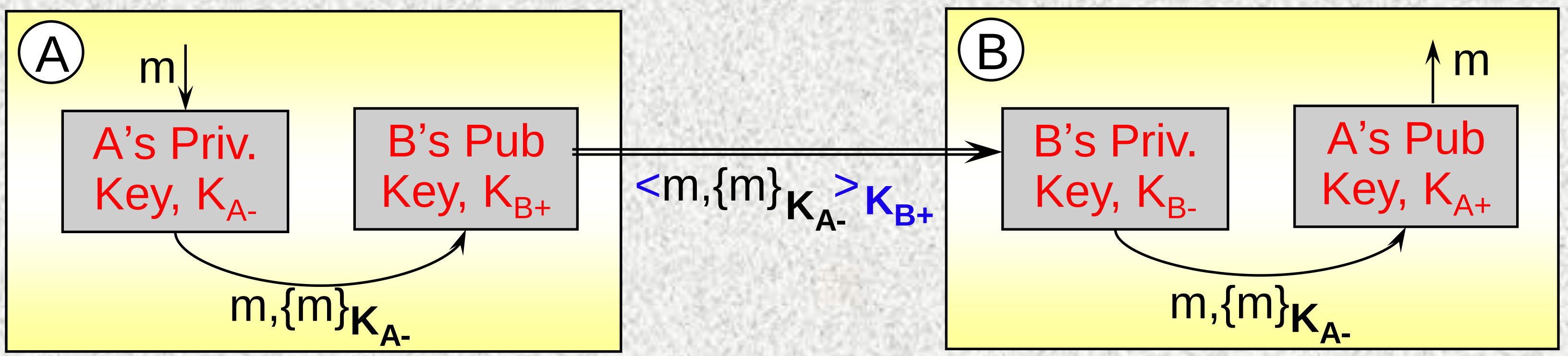
Indirect Authentication Using a Key Distribution Center

- **Using a ticket and letting Alice set up a connection to Bob.**

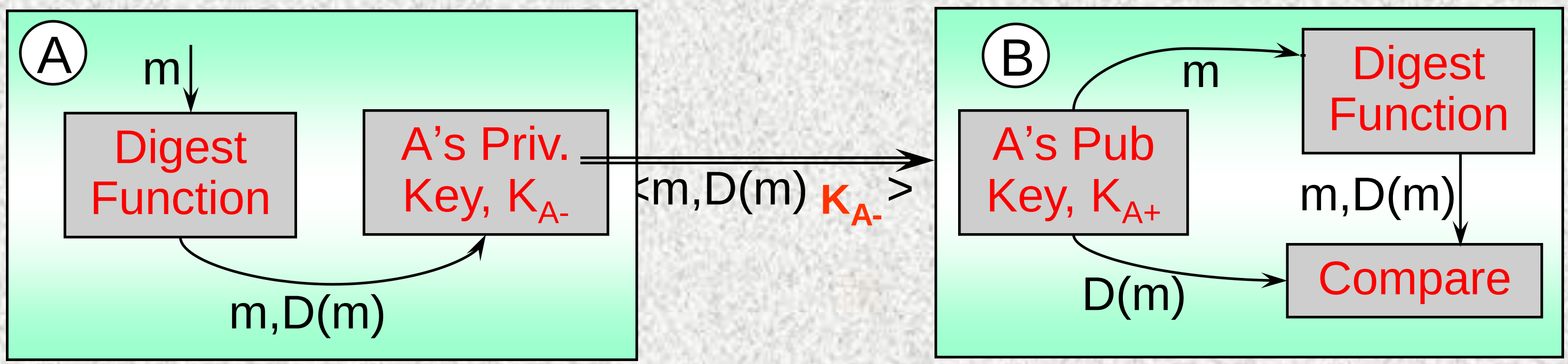


Digital Signatures

- Signatures need to be authentic, unforgeable, and non-repudiable.



Digital Signature Using Public-Private Keys

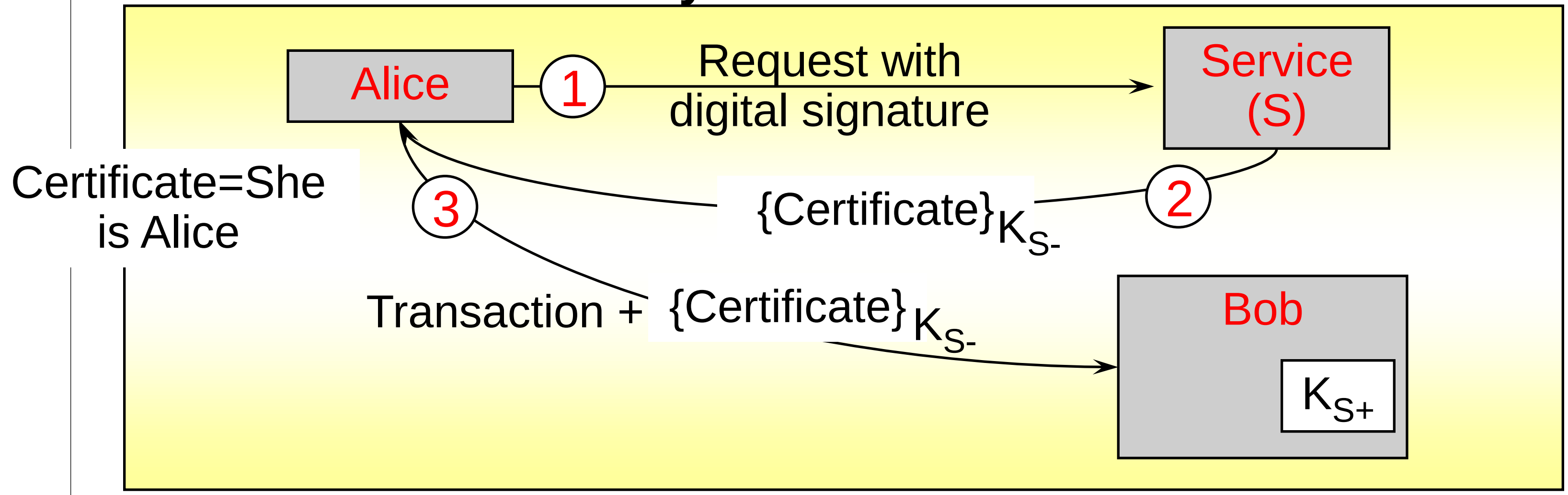


D()=Digital Signature Using One-way hash, e.g., SHA-1 or MD-5

Hashes are fast and have compact output

Digital Certificates

- A **digital certificate** is a statement signed by a third party principal, and can be reused
  - e.g., Verisign Certification Authority (CA)
- To be useful, certificates must have:
  - A standard format, for construction and interpretation
  - A protocol for constructing chains of certificates
  - A trusted authority at the root of the chain



Alice's Bank Account Certificate

1. *Certificate type*	Account number
2. *Name*	Alice
3. *Account*	6262626
4. *Certifying authority*	Bob's Bank
5. *Signature*	$\{Digest(field\ 2 + field\ 3)\}_{K_{Bpriv}}$

Public-Key Certificate for Bob's Bank

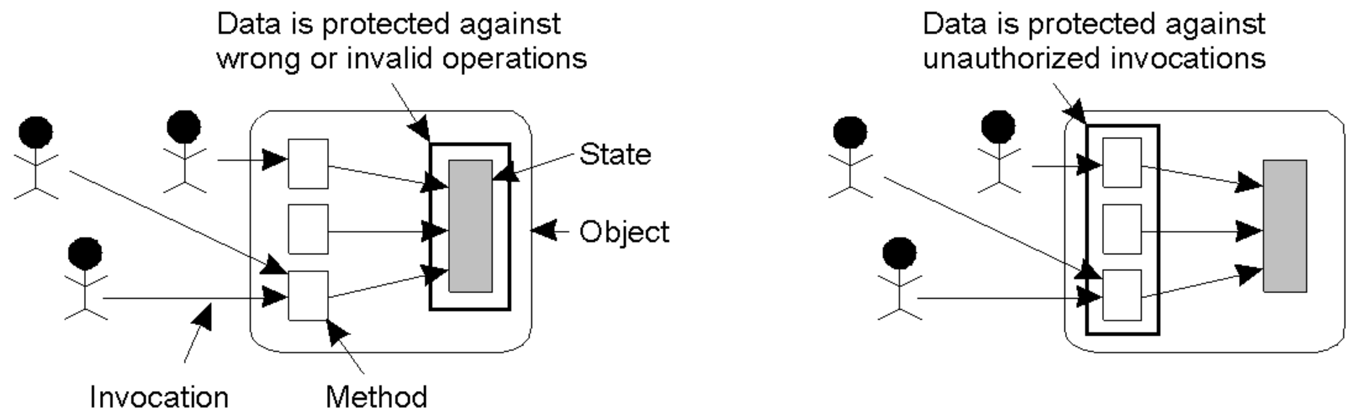
1. *Certificate type*	Public key
2. *Name*	Bob's Bank
3. *Public key*	K_{Bpub}
4. *Certifying authority*	Fred – The Bankers Federation
5. *Signature*	$\{Digest(field\ 2 + field\ 3)\}_{K_{Fpriv}}$

(In turn, Fred has a certificate from Verisign, i.e., the root).

Authorization: Access Control

- Control of access to resources of a server.
- A basic form of access control checks <principal, op, resource> requests for:
  - Authenticates the principal.
  - Authorization check for desired op, resource.
- Access control matrix M (e.g., maintained at server)
  - Each principal is represented by a row, and each resource object is represented by a column.
  - M[s,o] lists precisely what operations principal s can request to be carried out on resource o.
  - Check this before carrying out a requested operation.
  - M may be sparse.
- Access control list (ACL)
  - Each object maintains a list of access rights of principals, i.e., an ACL is some column in M with the empty entries left out.
- Capability List = row in access control matrix, i.e., per-principal list. May be a signed certificate (verifiable by anyone).

Focus of Access Control



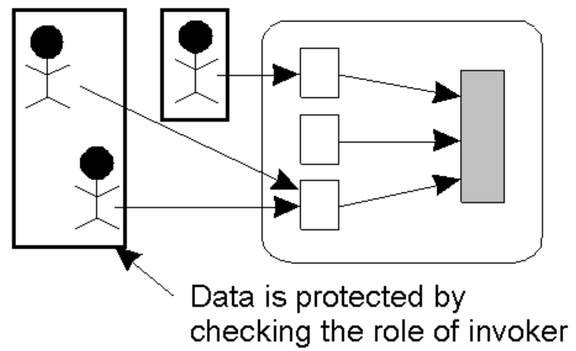
(a) (b)

- Three approaches for protection against security threats

a) Protection against invalid operations

b) Protection against unauthorized invocations

c) Protection against unauthorized users



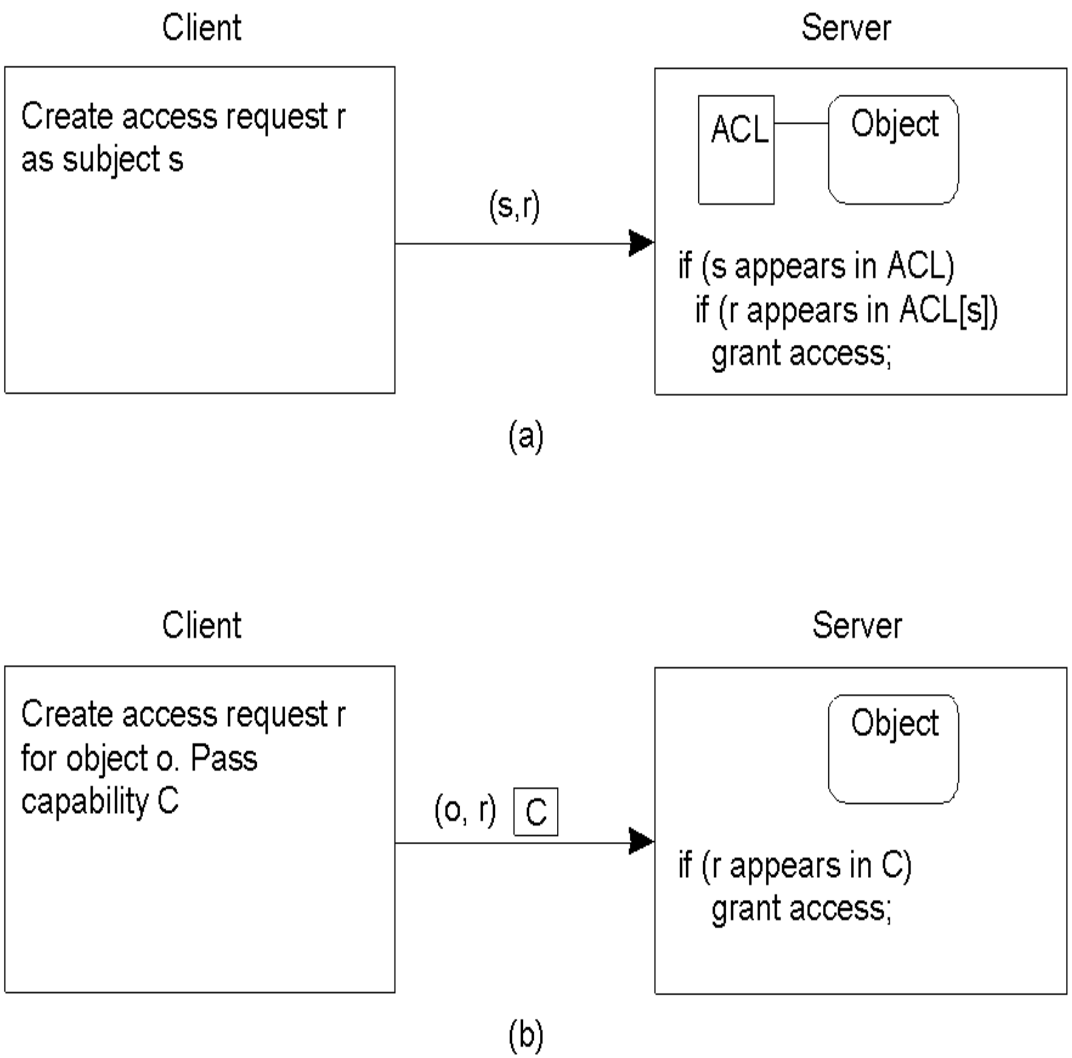
(c)

ACL and Capability Usage

Comparison between ACLs and capabilities for protecting objects.

a) Using an ACL

b) Using capabilities.



Common Web Attacks: XSS

- XSS = Cross-site Scripting (84% vulnerabilities, according to Symantec in 2007)
  - Most common reported vulnerability to websites
  - “Same origin” policy: used by sites to enable code within same website to access each other without restrictions, but not across different websites. Browsers often use HTTP cookies for this.
  - XSS exploits/bypasses same origin policy
  - Two flavors: (while you’re using your favorite bank mybank.com)
    - (More frequent) Non-persistent: You click on a link that takes you to mybank.com (the real one), but the link contains malicious code. This code executes in your browser with same credentials as mybank.com, e.g., code could send your cookie to attacker who then exploits info from inside it.
    - Persistent: Attacker uses info from inside your cookie to pretend to be you. E.g., someone adds a script to their myspace profile, and when you visit it, the script executes with your authentication.
  - Prevention
    - Better cookie handling, e.g., tie cookie to an IP address, or make cookie unavailable to client-side scripts
    - Disable scripts

Confused Web Attacks: Deputy Attacks

- **Exploits user's trust in user's deputy (often the browser)**
- **Clickjacking: "layer" a malicious site over/under another legitimate site. When user clicks on legitimate site, they're actually clicking on malicious site.**
  - **Prevention: Firefox NoScript feature**
- **CSRF (Cross-Site Request Forgery): Different from XSS in many ways: carried out from user's IP address.**
  - **While browsing mybank.com, you open another tab to browse a Google group**
  - **Someone there has posted a link Like this page!**
  - **You like that page by clicking. Boom!**
- **Prevention**
  - **Better cookie handling, e.g., timeout**
  - **Authentication for each operation**
  - **Sandboxing**

Byzantine Failure Model

- **Computer systems fail**
  - **So far: Crash-stop and Crash-recovery failure**
- **<u>Byzantine failure</u>: Process behaves arbitrarily**
- **Example:**
  - **malicious attack**
  - **hardware failure**
  - **software bug**
- **Need highly available service**
  - **Byzantine Fault-tolerant Consensus Protocols**
    - » **PBFT, Aardvark, Zyzzyva, …**
  - **Byzantine Failure detection protocols**
    - » **PeerReview**
    - » **HW4**

Announcements

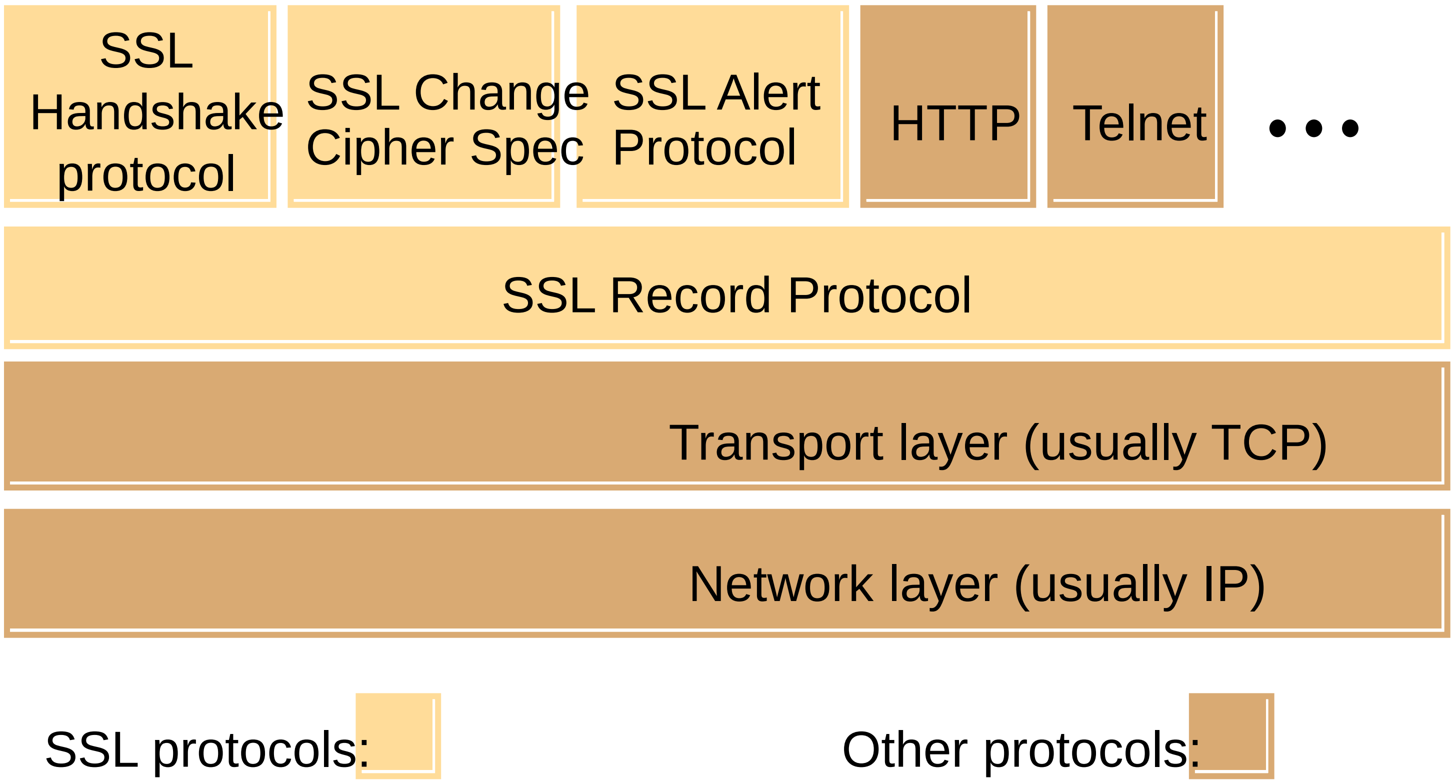
- **HW4 released**
- **This Thursday: Self-stabilization**

Optional Slides (Not Covered)

Secure Socket Layer Protocol

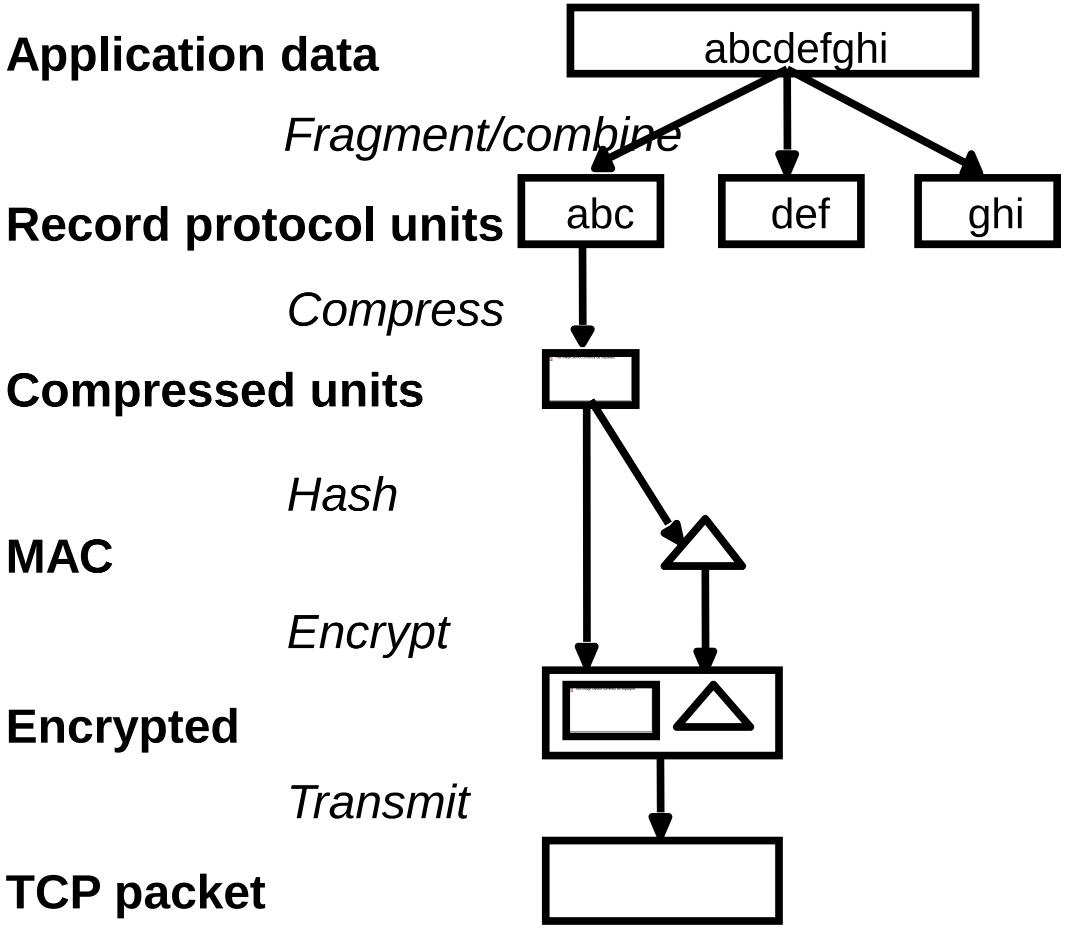
- SSL was developed by Netscape for electronic transaction security.
- A protocol layer is added below the application layer for:
  - Negotiating encryption and authentication methods.
  - Bootstrapping secure communication
- It consists of two layers:
  - The Record Protocol Layer implements a secure channel by encrypting and authenticating messages
  - The Handshake Layer establishes and maintains a secure session between two nodes.

SSL Protocol Stack



SSL Record Protocol

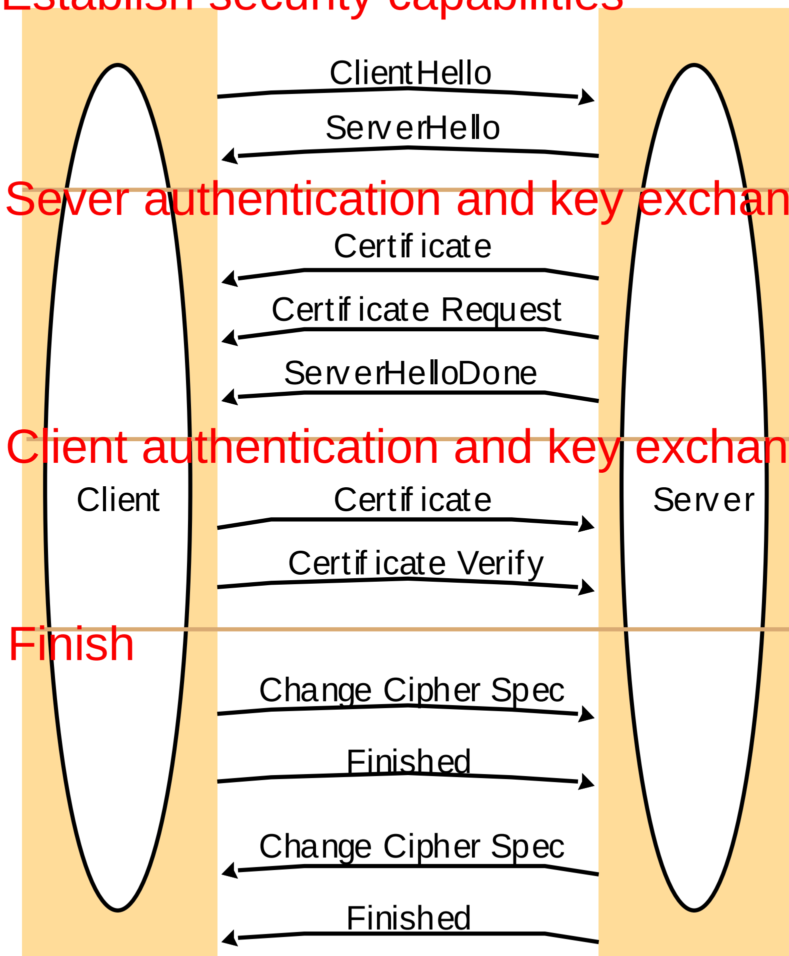
- **The record protocol takes an application message to be transmitted,**
  - **fragments the data into manageable blocks,**
  - **optionally compresses the data,**
  - **computes a message authentication code (MAC),**
  - **encrypts and**
  - **adds a header.**



SSL Handshake Protocol

Cipher suite: a list of cryptographic algorithm supported by the client

Phase 1: Establish security capabilities



Establish protocol version, session ID, cipher suite, compression method, exchange random values

Phase 2: Sever authentication and key exchange

Optionally send server certificate and request client certificate

Phase 3: Client authentication and key exchange

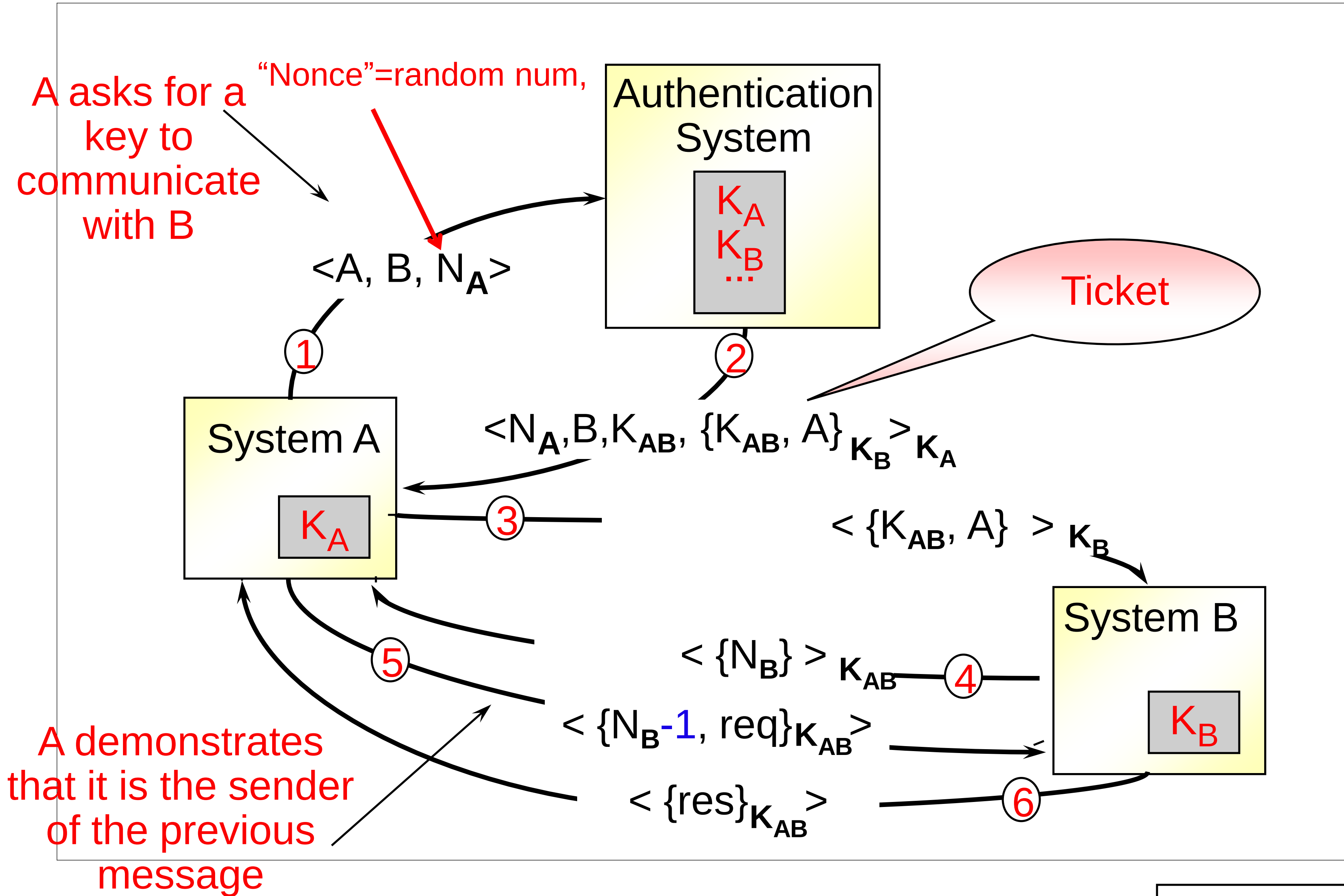
Send client certificate response if requested

Phase 4: Finish

Change cipher suite and finish handshake

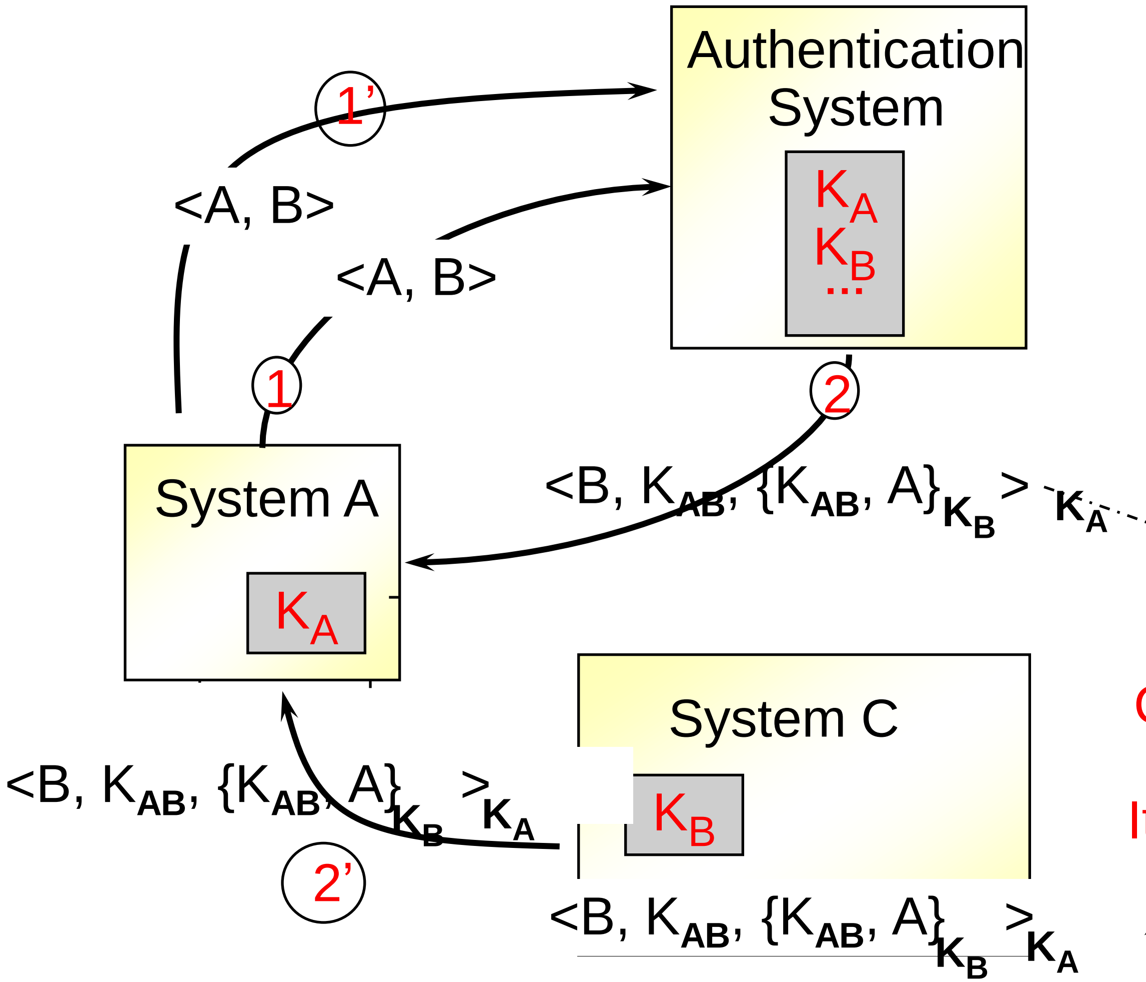
The client sends a change Cipher Spec message and copies the pending CipherSpec into the current CipherSpec.

Needham-Schroeder Authentication



Why Do We Need Nonce N_A in Message 1?

Because we need to relate message 2 to message 1



Chuck has stolen K_B and intercepted message 2. It can masquerade as the authentication system.

Needham–Schroeder Secret-key Authentication Protocol

Variant used for authentication in Windows 2K (slightly modified – nonce added to msg 3)

Header	*Message*	*Notes*
1. A->S:	A, B, N_A	A requests S to supply a key for communication with B.
2. S->A:	$\{N_A, B, K_{AB}, \{K_{AB}, A\}_{K_B}\}_{K_A}$	S returns a message encrypted in A's secret key, containing a newly generated key K_{AB} and a 'ticket' encrypted in B's secret key. The nonce N_A demonstrates that the message was sent in response to the preceding one. A believes that S sent the message because only S knows A's secret key.
3. A->B:	$\{K_{AB}, A\}_{K_B}$	A sends the 'ticket' to B.
4. B->A:	$\{N_B\}_{K_{AB}}$	B decrypts the ticket and uses the new key K_{AB} to encrypt another nonce N_B.
5. A->B:	$\{N_B - 1\}_{K_{AB}}$	A demonstrates to B that it was the sender of the previous message by returning an agreed transformation of N_B.

Kerberos Authentication

Read section 7.6.2 from text

Access Control

- Notion of protection domain for a collection of processes:
  - A protection domain is a set of (object, access rights) pairs kept by a server.
  - A protection domain is created for each principal when it starts
  - Unix: each (uid,gid) pair spans a protection domain, e.g., user parts of two processes with same (uid, gid) pair have identical access rights.
  - Whenever a principal requests an operation to be carried out on an object, the access control monitor checks if the principal belongs to the object's domain, and then if the request is allowed for that object.
- Each principal can carry a certificate listing the groups it belongs to.
  - The certificate should be protected by a digital signature.