Authentication in Distributed Systems

CS60002: Distributed Systems

Bhaskar Pal

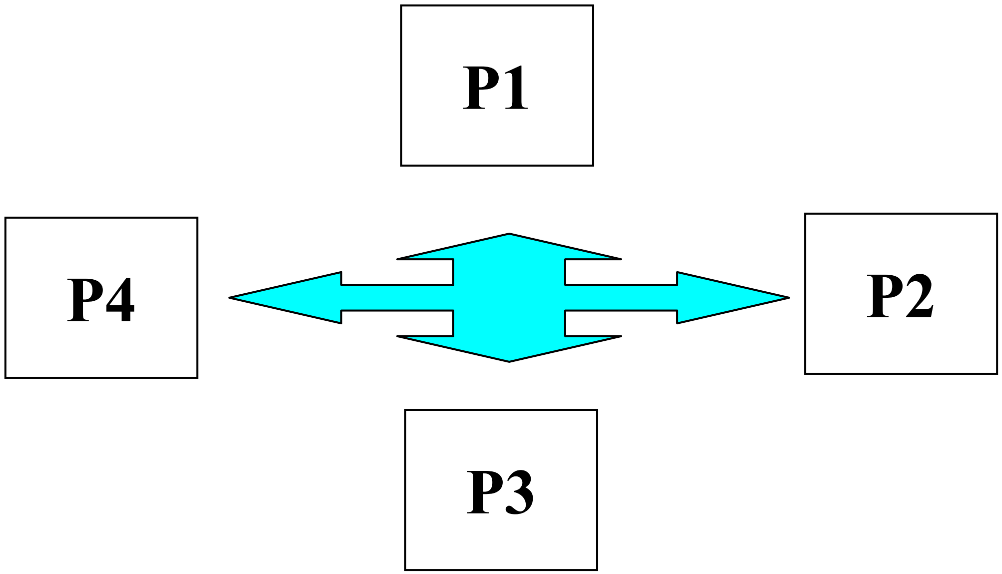
Dept. of Computer Sc. & Engg.,

Indian Institute of Technology Kharagpur

Outline

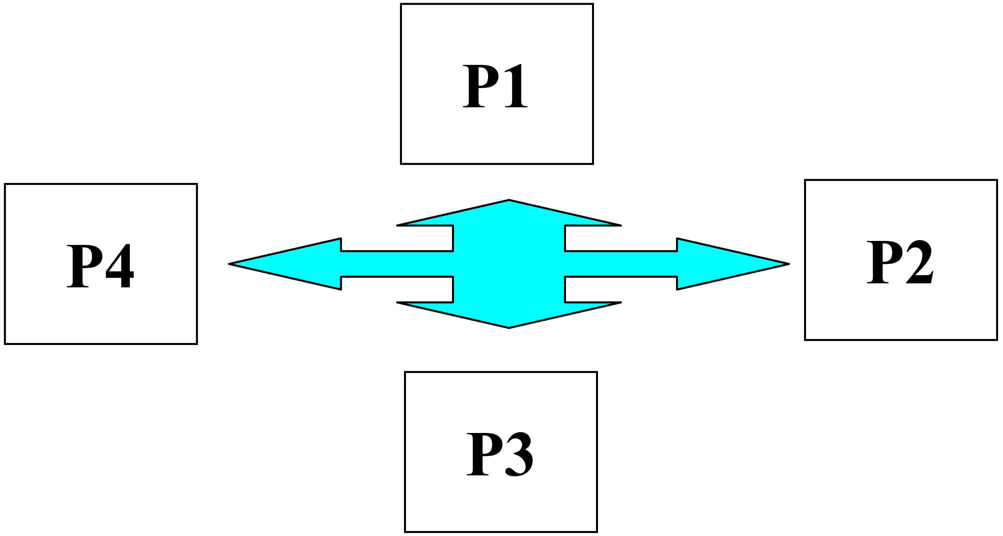
- Background
- Conventional Cryptography
- Modern Cryptography
  - Private Key
  - Public Key
- Authentication Protocols

System Model



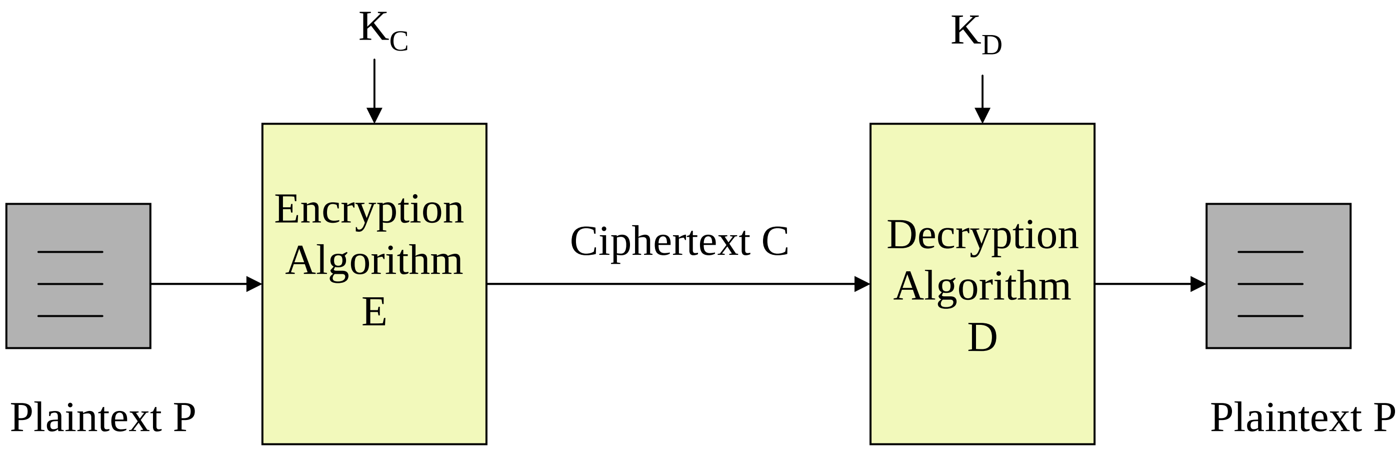
- **An Intruder is an entity which is not authorized to access information**

Role of Cryptography



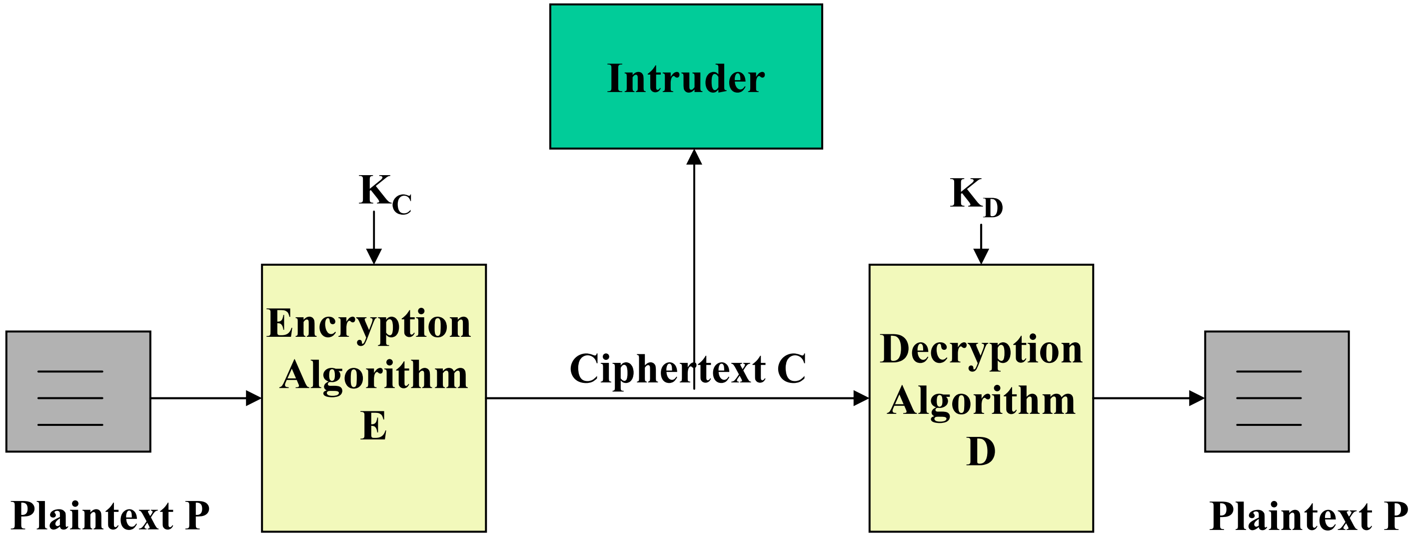
- Study of mathematical techniques to secure information
- Goals
  - Confidentiality of Information
  - Authentication
  - Data integrity

A Simple Model of Cryptographic System



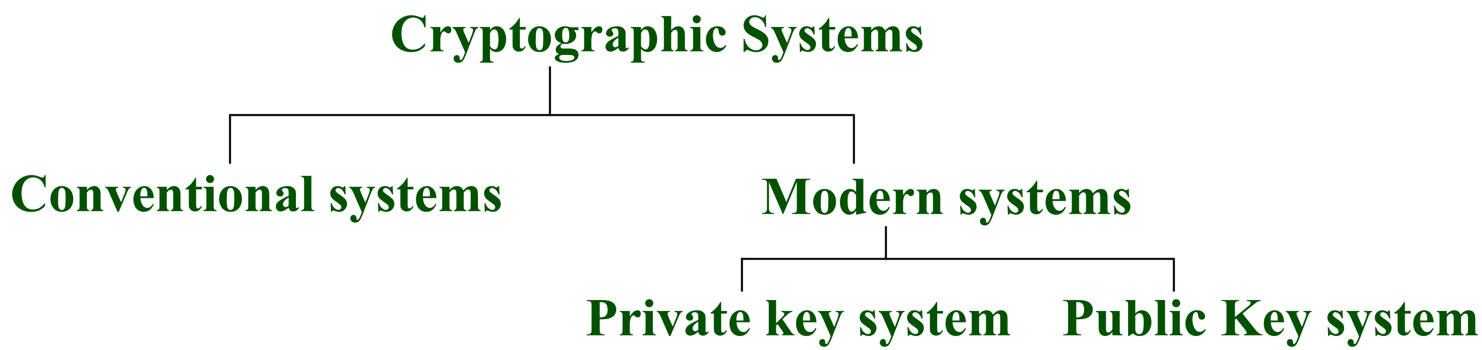
- P is plaintext
- C is ciphertext
- K_C and K_D are encryption and decryption keys
- E and D are encryption and decryption algorithms
- $C= E_{KC}(P)$ $P=D_{KD}(C)= D_{KD}(E_{KC}(P))$

Intruder



- Has knowledge of E,D and other information
- Does not know the Key
- The objective of intruder is to interpret the ciphertext
- Also it can perform some malicious communication

A Classification of Cryptographic System



- Conventional Systems
  - Plain-text a text written in some language. Use a secret mapping procedure to map a letter (or a set of letters) to some other letter (s) in the same alphabet
  - Example: “adr” → “pgk”

Conventional Cryptography

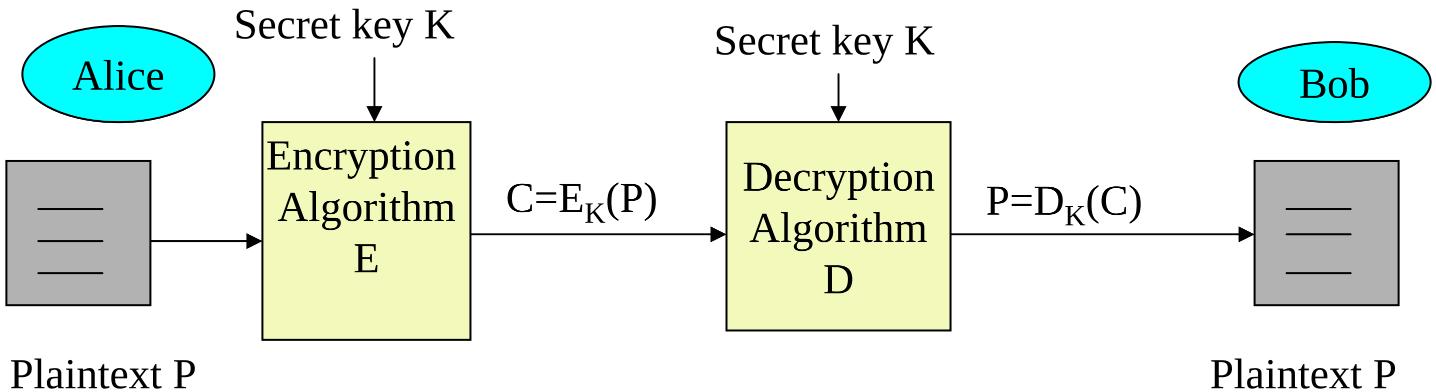
- **The Caeser Cipher**
  - C=E(P)=(P+3)mod 26
  - P=D(C)=(C-3)mod26
  - 3 can be replaced by any k, (0<k<26) k is the key
- **Simple Substitution**
  - Eliminate positional correlation of caeser cipher
  - Cipher line can be any permutation of the alphabets
  - frequency distribution of letters are not changed- !attack
- **Polyalphabetic Ciphers**
  - periodic sequence of n substitution alphabet ciphers
  - 11, 3, 4, 5, 6

Modern Cryptography

- The plain-text is in binary
- Private key Cryptosystem
  - Same key is used for encryption and decryption
  - Keys are kept secret
  - e.g. DES, AES
- Public key Cryptosystem
  - Encryption and decryption keys are different
  - Decryption keys is kept secret i.e. private and the Encryption key is public
  - e.g. RSA

Private Key Cryptography

- **Alice and Bob share a secret key**
- **If Alice wants to send Bob a message M, she encrypts M with the secret key shared between them**
- **Bob decrypts the message with the same key**
- **No other person can decrypt the message as only Alice and Bob know the secret key**

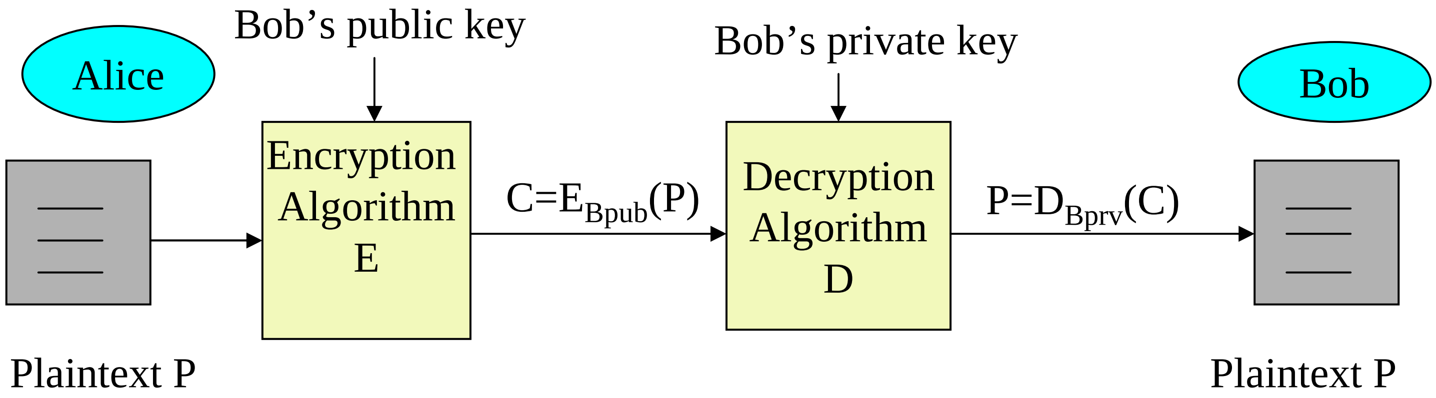


Data Encryption Standard (DES)

- Encrypts 64 bit blocks with 56 bit key to 64 bit blocks of ciphertext
- Major operations used are permutation and substitution
- Three main stages
  - Initial Permutation
  - 16 rounds of substitution are performed
  - Final Permutation
- Each round uses a round-key generated from the initial key
- Decryption uses the same algorithm but the steps and keys are applied in reverse order
- The crux of the system is the length of the key (56 bits), the intruder has to search 2^{56} values

Public Key Cryptography

- **Each user generates a pair of keys**
- **If Alice wants to send Bob a message M, she encrypts M with Bob's public key**
- **Bob decrypts the message with its private key**
- **No other person can decrypt the message as only Bob knows his private key**



The Rivest-Shamir-Adleman Method

- Select 2 large primes p, q and compute $n = p * q$
- $\Phi(n) = (p-1) * (q-1)$
- select e, relatively prime to $\Phi(n)$ i.e. $GCD(e, \Phi(n)) = 1$
- Find $d = e^{-1} \bmod \Phi(n)$
- Encryption key known to sender is a pair (e, n)
- Decryption key known to receiver is a pair (d, n)
- Encryption is performed as follows

$$C = M^e \bmod n$$

- Decryption is performed as

$$M = C^d \bmod n = M^{ed} \bmod n$$

Authentication in Distributed Systems

- **Goal** - The application of cryptographic methods in performing authenticated communication between two entities
- **Authentication in DS** - To verify the identity of the communicating entities to each other
- **System Model**
  - A set of computers connected by a network
  - No shared memory
  - Communication solely by passing messages to each other

Authentication Services

- **Authenticated Interactive Communication**
  - Both the parties should involve in the communication
  - Synchronous in nature
- **Authenticated One Way Communication**
  - Sender and Receiver need not to synchronize
  - Asynchronous in nature
  - Example: Electronic Mailing System
- **Signed Communication**
  - Message is signed by the sender
  - Sender’s identity and content of the message can be authenticated to a third party

Potential Threats

- An intruder
  - Can gain access to any point in the network
  - Can copy or alter parts of the message
  - Can replay back an old message
  - Can transmit erroneous messages
- Intruder can have knowledge about
  - The authentication protocol
  - Message types
  - Message sequences and purposes
- An Intruder
  - May involved in an on-going transaction
  - Can try to prevent a secure authenticated communication

Authentication Servers

- A secret conversation key is required in setting up authenticated communication
- AS is responsible for distributing this secret key
- Each user X registers its secret key KX with AS
- KX is only known to X and AS
- AS uses this KX to securely communicate the secret conversation key to X

Establishing Interactive Connections

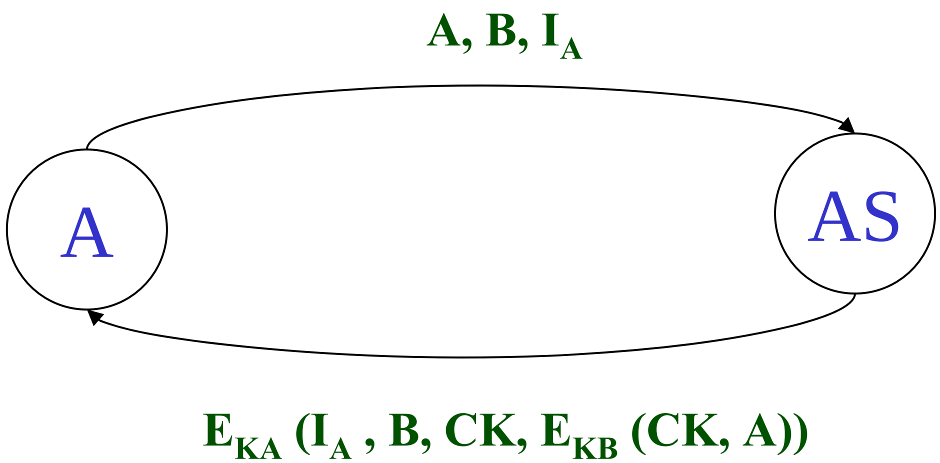
- If A wants to set up a secure authenticated interactive communication with B
  - It has to send a message M to B
  - M must have the following properties
    - Only B should understand M
    - B should to able to verify that M is a legitimate message from A and it is not a replay from an intruder

A Protocol for Private Key Systems

- Symmetric in nature - A single secret key is used for both encryption and decryption
- A & B both share a secret conversation key with AS
- Issues Involved
  - How A can get the conversation key from AS?
  - How A can send the received conversation key to B?

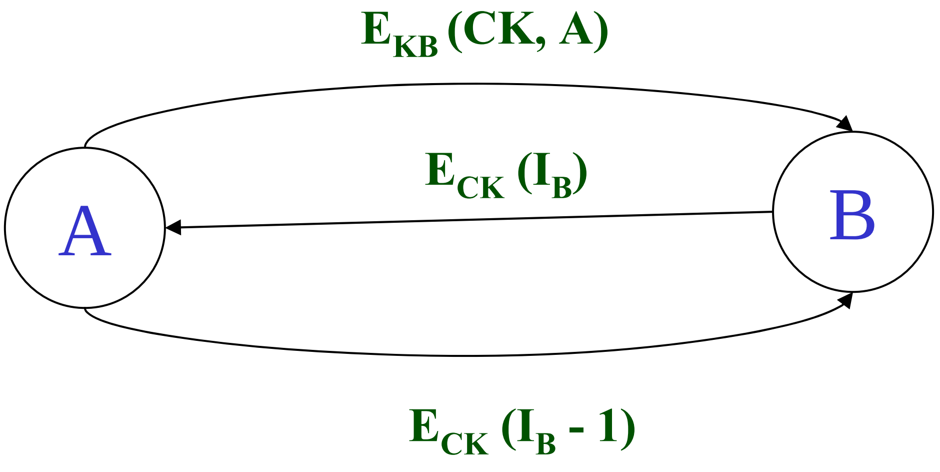
Obtaining a Conversation Key

- $A \rightarrow AS : A, B, I_A$ (1)
- $AS \rightarrow A : E_{KA}(I_A, B, CK, E_{KB}(CK, A))$ (2)



Communicating the Conversation Key

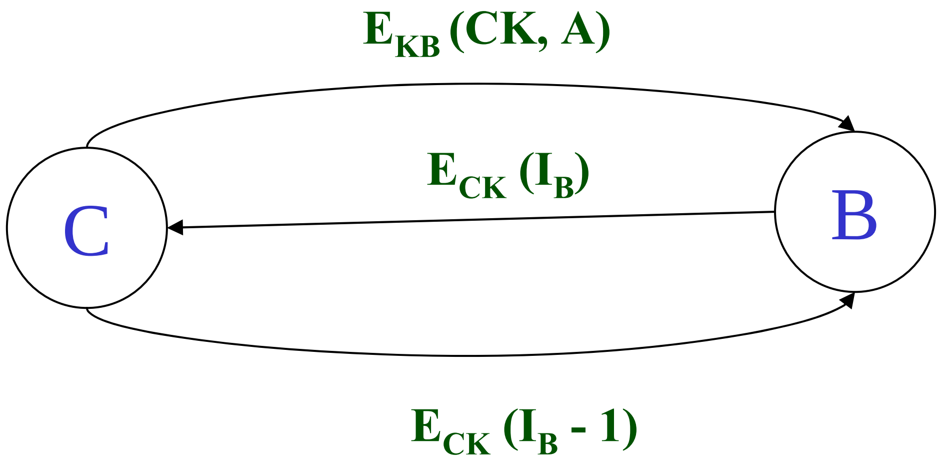
- $A \rightarrow B : E_{KB}(CK, A)$ (3)
- To prevent foul play by the intruder
- $B \rightarrow A : E_{CK}(I_B)$ (4)
- $A \rightarrow B : E_{CK}(I_B - 1)$ (5)



Compromising the Conversation Key

- **Intruder C has recorded all the messages 3 - 5**

- **$C \rightarrow B : E_{KB}$ (CK, A)** (3)
- **$B \rightarrow A : E_{CK} (I_B)$** (4)
- **$A \rightarrow B : E_{CK} (I_B - 1)$** (5)



Compromise of a Conversation Key

- Denning - Sacco's Remedy
  - Incorporate Time-stamp in the messages
  - The new protocol

$A \rightarrow AS : A, B$
$AS \rightarrow A : E_{KA} (B, CK, T, E_{KB} (CK, T, A))$
$A \rightarrow B \quad : E_{KB} (CK, T, A)$

Check at B: $| CLOCK_B - T | < \Delta t1 + \Delta t2$

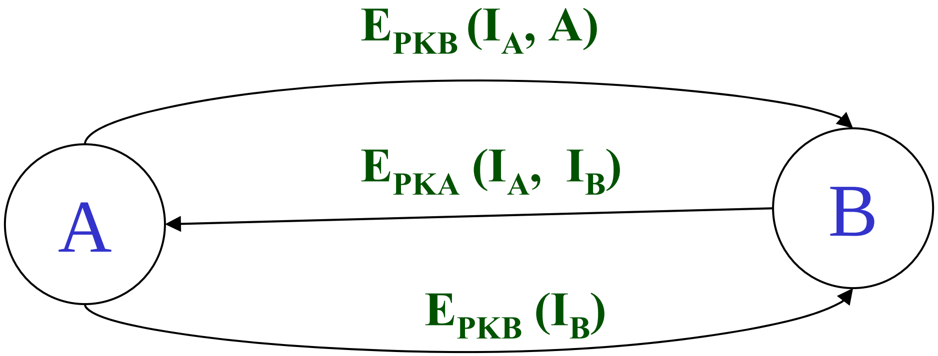
$\Delta t1$: Max discrepancy with the server's clock
$\Delta t1$: Expected Network Delay

A Protocol for Public Key Systems

- For X, The encryption key PKX is known publicly
- The decryption key SKX is secret
- Main Issue:
  - No explicit conversation key is required for communication
  - Public encryption keys are used
  - Handshake protocol
    - A knows the public encryption key of B
    - A doesn’t know the public encryption key of B. However it is known to AS

Handshake Protocol: Public Key is known

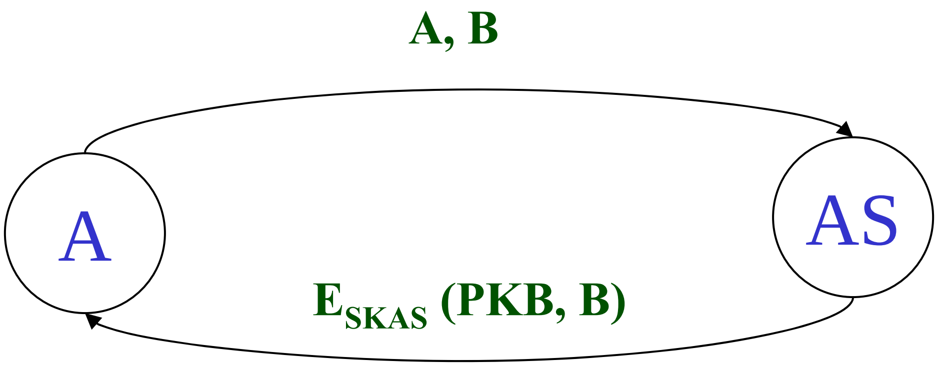
- $A \rightarrow B : E_{PKB}(I_A, A)$
- The intruder can replay such a message
- To verify B sends the following
- $B \rightarrow A : E_{PKA}(I_A, I_B)$
- $A \rightarrow B : E_{PKB}(I_B)$



Handshake Protocol: Public Key is not known

- $A \rightarrow AS : A, B$
- $AS \rightarrow A : E_{SKAS} (PKB, B)$

- The second message is a *signed* message and only AS can create it
- $D_{PKAS} (E_{SKAS} (m)) = m$

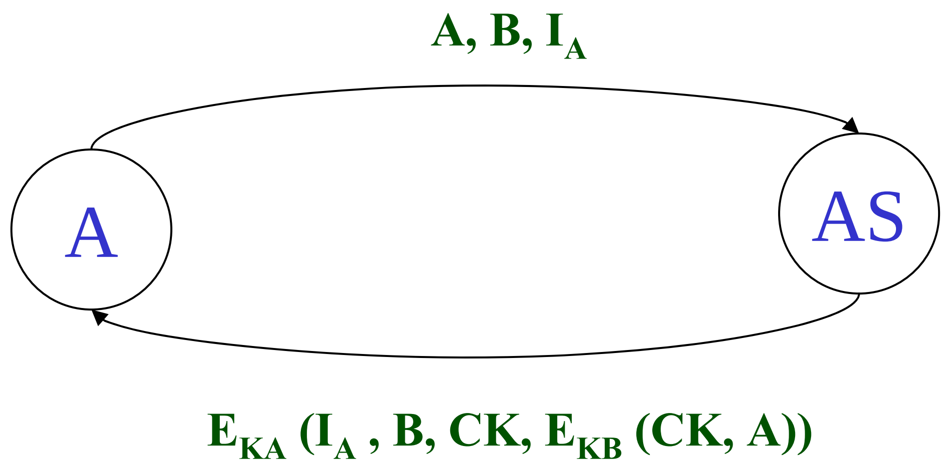


Performing One-Way Communication

- Asynchronous
- Main Issue is to ensure that the receiver is able to verify the authenticity of the sender and the message

A Protocol for Private Key Systems

- $A \rightarrow AS : A, B, I_A$ (1)
- $AS \rightarrow A : E_{KA}(I_A, B, CK, E_{KB}(CK, A))$ (2)



A Protocol for Private Key Systems

- E_{KB}(CK, A) is used to authenticate the identity of the sender
- This template is put at the header of the message (mail)
- The mail has the following format -

$$A \rightarrow B : E_{KB}(CK, A); E_{CK}(M)$$

A Protocol for Public Key Systems

- A and B know their public encryption keys
  - Otherwise A can take it from AS and send to B
- The mail has the following format -

$$A \rightarrow B : E_{PKB}\ (A, I, E_{SKA}\ (B));\ E_{PKB}\ (I, M)$$

- E_{SKA} (B) helps B to authenticate the identity of the sender
- Only A can create E_{SKA} (B)
- Nonce identifier 'I' is used to verify the integrity i.e. to connect the header with that of the mail message