An Introduction to Kerberos

CS60002: Distributed Systems

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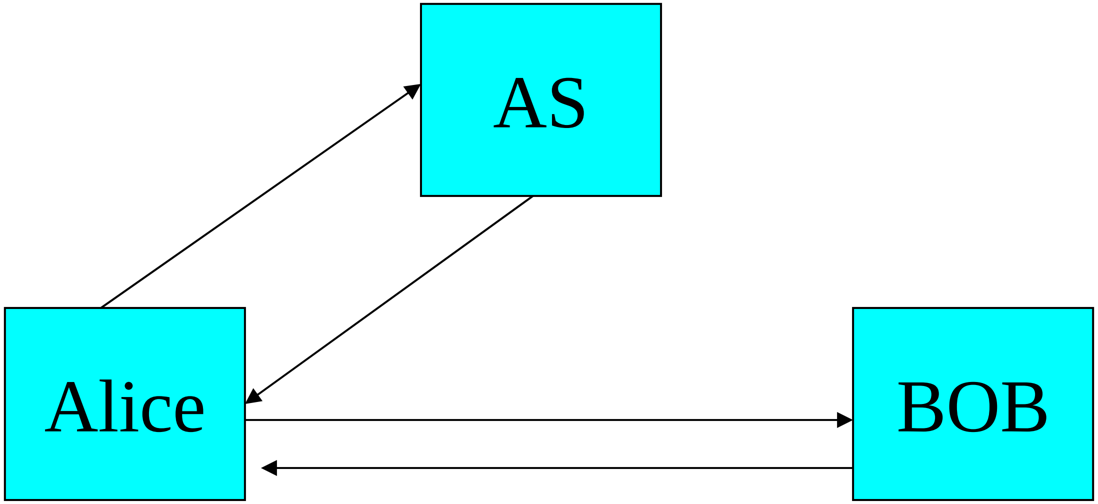
Private Key Cryptography

- Same key is used for encryption and decryption
- There is a trusted authority called the authentication server (AS)
  - Keeps the secrets
- Every user shares its private secret key with AS
  - User X doesn't know the private key of user Y
- Kay Distribution: When X wants to communicate with Y, they need to use a secret key between them
  - AS is responsible for distributing this session key (conversation key) between X and Y
- Everybody has to trust AS

How it works?



- AS knows the private keys of Alice and Bob
- Alice and Bob requires a session key
  - Alice doesn’t know the private key of Bob
- How the session key is transmitted to Alice and Bob

A simple overview

- Alice → AS : Alice, Bob
- AS recovers K_A and K_B and creates a session key $K_{A, B}$
- It makes two copies of $K_{A, B}$
  - One is for Alice and is encrypted using Alice's private key
  - One is for Bob, encrypted using Bob's private key (ticket)
    - Also included the identity of Alice
- The ticket conveys the following to Bob
  - I am AS (only AS knows the private key of Bob)
  - Alice wants to communicate with you
  - Only you and Alice (except me) have the knowledge of $K_{A, B}$
  - If some one proves that she has the knowledge of $K_{A, B}$ -- it is Alice

Overview Contd..

- AS → Alice : $E_{K\ (A)}$ {Bob, $T_{A,\ B}$, $K_{A,\ B}$, *timestamp*, ..}
- $T_{A,\ B}$ = $E_{K(B)}$ { Alice, Bob, $K_{A,\ B}$, …}

- Alice sends the Ticket to the Bob
  - Adding an authenticator to prove its authenticity
    - Ticket can be replayed by some intruder
- Authenticator
  - $E_{K\ (A,\ B)}$ {Alice, *timestamp*}
- The session key recovered from the ticket is used to decrypt the authenticator
- Timestamp checks for replay of Authenticator
- Mutual Authen.. : Bob → Alice : $E_{K(A,\ B)}$ {*timestamp + 1*}

Kerberos Basics

- Kerberos is an authentication protocol implemented on Project Athena at MIT
- Athena provides an open network computing environment
- Each user has complete control of its workstation
- The workstations can not be trusted completely to identify its users to the network services
- Kerberos acted as a third party authenticator
  - Helps the user to prove its identity to the various services and vice versa

Kerberos Basics

- It is based on symmetrical cryptographic algorithms (private key cryptosystems)
  - Same key is used for encryption as well as decryption
  - Uses DES
- Every user U has a private key that can be obtained by
  - K_U = f (*password*)
- Every users private key is also known to Kerberos
  - Kerberos maintains a database of its users and their private keys
- Kerberos uses this private key for communicating any message to the user
  - User is convinced about Kerberos's authenticity
- If an user U gets a message encrypted using its private key
  - The message must be from Kerberos
  - In case of replays?

Kerberos Basics

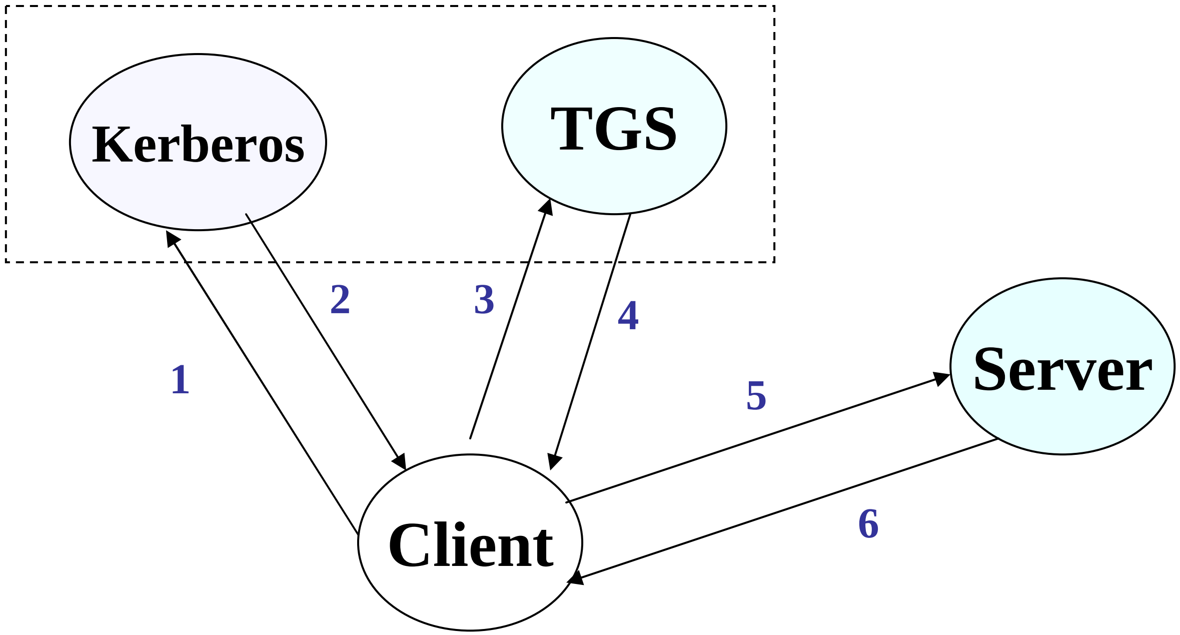
- Kerberos requires the workstations to be synchronized
- A *timestamp* which is the current time of the sender is added in the message to check for any replays
- The receiver checks for the timeliness by comparing its own clock value with that of the *timestamp*
  - Timely if *timestamp* is equal to the local clock value

The Basic notion

- To request a service from a server, the client goes through three phases of authentication
- Phase 1
  - The client requests a ticket from the Kerberos
  - Kerberos grants a ticket and a session key
  - The ticket is used for requesting other tickets for various services
  - Ticket conveys the identity of the client to the server
  - The session key is used for conversation between the client and the server

Basic notions

- Phase - 2
  - The client uses the ticket of the first phase to request a ticket from the ticket granting server (tgs) for a specific service
- Phase 3
  - The client presents the key to the server for the service



Protocols

- The three phases of authentication is achieved via two authentication protocols

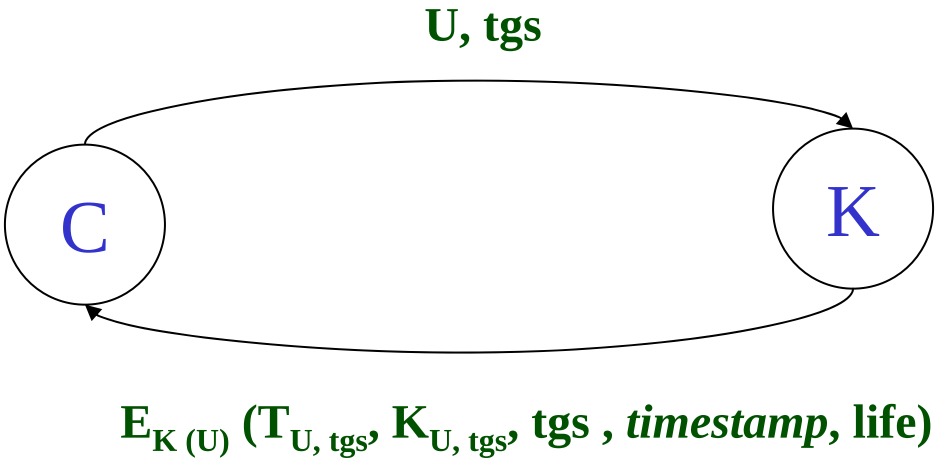
- The user-authentication protocol (1st Phase)
  - Verifies the authenticity of the user and grants the initial ticket and the session key

- Client - Server authentication protocol (2nd & 3rd phases)
  - Mutual authentication of a client and a server

- Hierarchy
  - Medium-term session key (TGT) – get once and use for requesting other sessions
  - Short-term key – used for a particular service

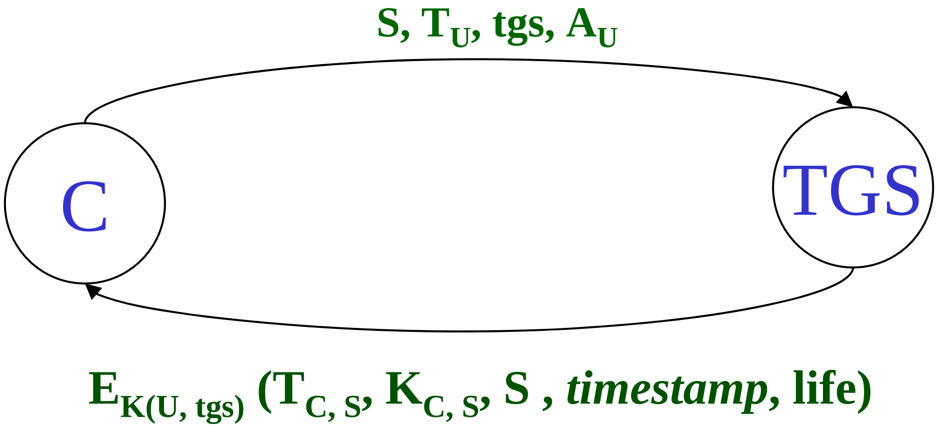
Phase - 1 (Getting the Initial Key)

- $U \rightarrow C : U$
- $C \rightarrow K : U, tgs$ (1)
- Kerberos finds out K_U and K_{tgs}
- It creates the session key $K_{U,\ tgs}$
- It creates the ticket
  - $T_{U,\ tgs} = E_{K\ (tgs)}\ (U, tgs, K_{U,\ tgs}, \textit{timestamp}, life)$
- $K \rightarrow C : E_{K\ (U)}\ \{T_{U,\ tgs}, K_{U,\ tgs}, tgs, \textit{timestamp}, life\}$ (2)


U, tgs
C
K
$E_{K\ (U)}\ (T_{U,\ tgs}, K_{U,\ tgs}, tgs\ , \textit{timestamp}, life)$

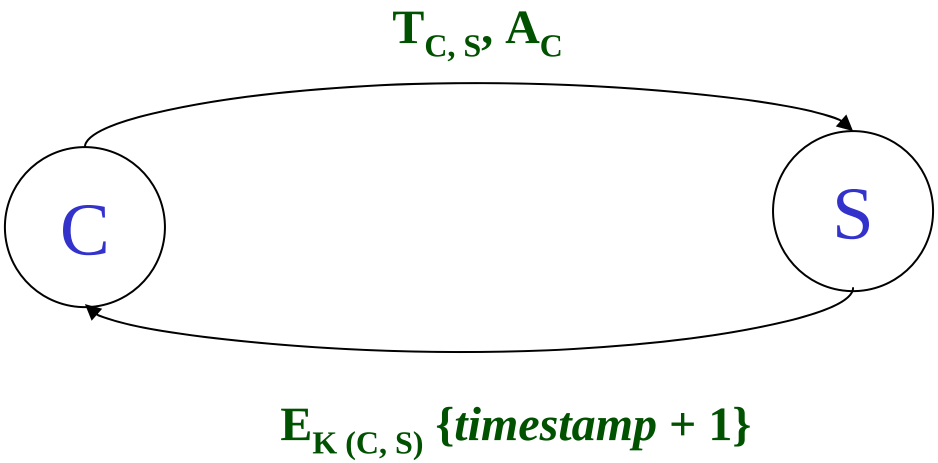
Phase - 2 (Getting Server Tickets)

- $C \rightarrow TGS : S, T_{U,\ tgs}, A_U$ (3)
- A_U is the authenticator : $E_{K\ (U,\ tgs)}$ {C, *timestamp*}
- Intruder can replay $S, T_{U,\ tgs}$
  - Session key is used to verify first level of authenticity
  - Session key may be the same in a session
  - *timestamp* is used for second level of authenticity
- Ticket: $T_{C,\ S} = E_{K(S)}$ (C, S, $K_{C,\ S}$, *timestamp*, life)
- $TGS \rightarrow C : E_{K\ (U,\ tgs)}$ {$T_{C,\ S}$, $K_{C,\ S}$, S, *timestamp*, life} (4)


S, T_U, tgs, A_U
C
TGS
$E_{K(U,\ tgs)}$ ($T_{C,\ S}$, $K_{C,\ S}$, S , *timestamp*, life)

Phase - 3 (Requesting the Service)

- $C \rightarrow S : T_{C, S}, A_C$ (5)
- A_C is sent to prevent foul play by the intruder
  - $E_{K(C, S)}$ (C, *timestamp*)
- $S \rightarrow C : E_{K(C, S)}$ {*timestamp* + 1} (6)



Why two servers?

- Note that
  - First phase is used for user-authentication (using the id and password)
  - Second and third phase may continue several times with the same TGT granted by the first phase
- In absence of this additional phase
  - For each service, the user needs to authenticate itself using its *password*
  - Once the intruder gets the first session key, it can continue doing malicious works throughout the session
  - That's why *life* and *timestamp* are mentioned