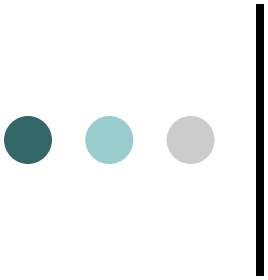
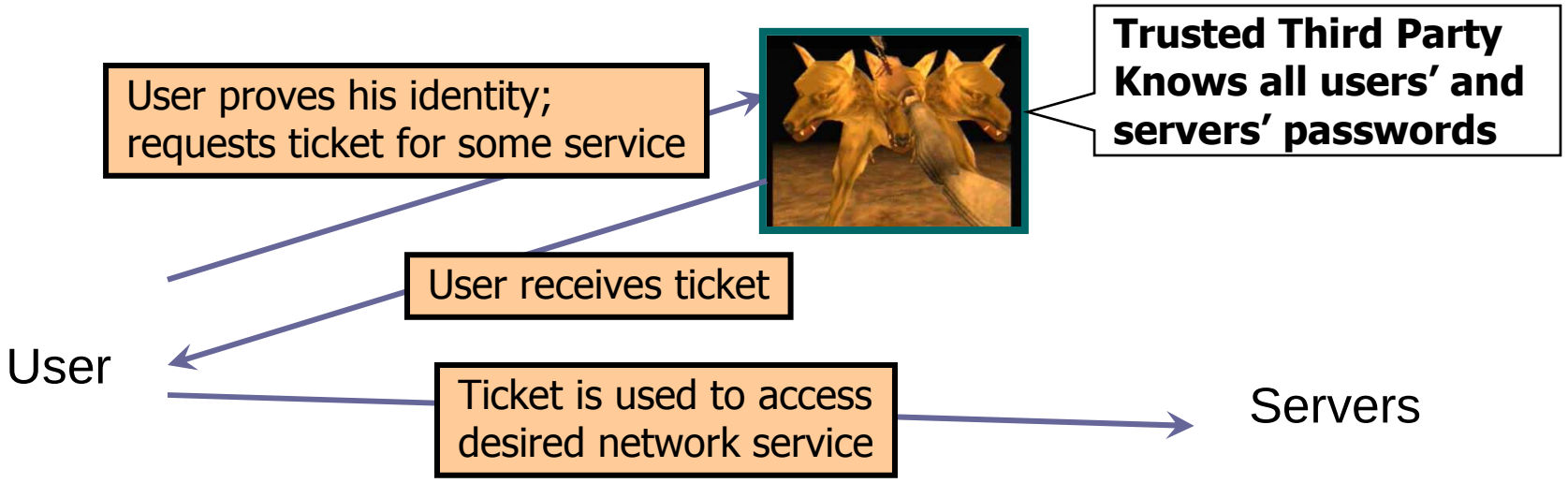


Kerberos

Authenticating to Multiple Servers

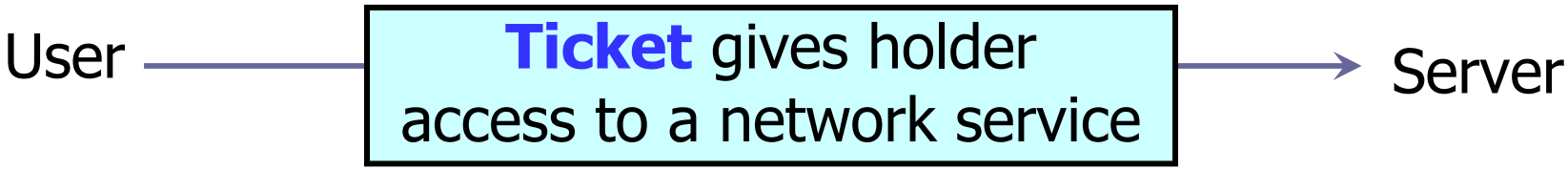
- Consider a set of user that needs to access different services on the net
  - Need to authenticate to each of them
  - Naïve solution: every server knows every user's password
    - Insecure: breaking into one server can compromise all users
    - Inefficient: to change password, a user must contact every server

Trusted Third Party



- Trusted authentication service on the network
  - Knows all passwords, can grant access to any server
  - Convenient, but also the single point of failure
  - Requires high level of physical security

What is a Ticket?

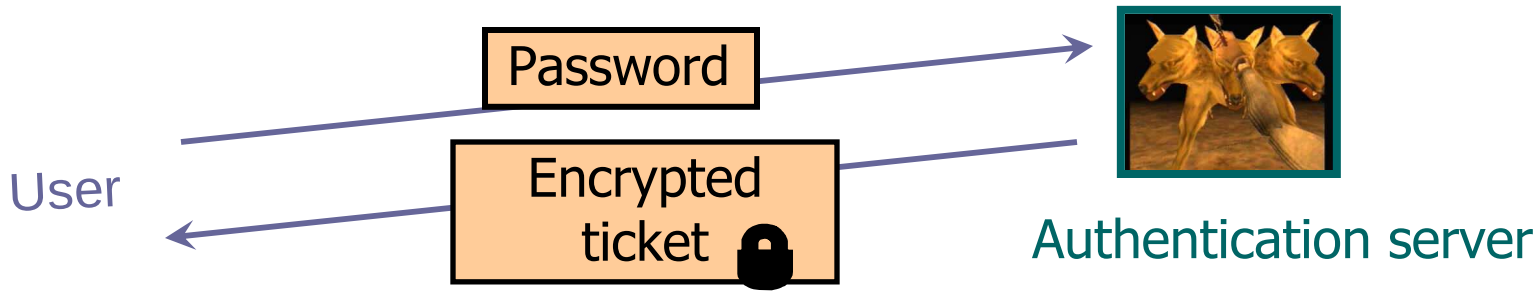


- Ticket cannot include server's plaintext password
  - Otherwise, next time user will access server directly without proving his identity to authentication service
- Solution: encrypt some information with a key known to the server (but not the user!)
  - Server can decrypt ticket and verify information
  - User does not learn server's key

Contents of a Ticket

- User name
- Server name
- Address of user's workstation
  - Otherwise, a user on another workstation can steal the ticket and use it to gain access to the server
- Ticket lifetime (duration for which valid)
- A few other things (e.g., session key)

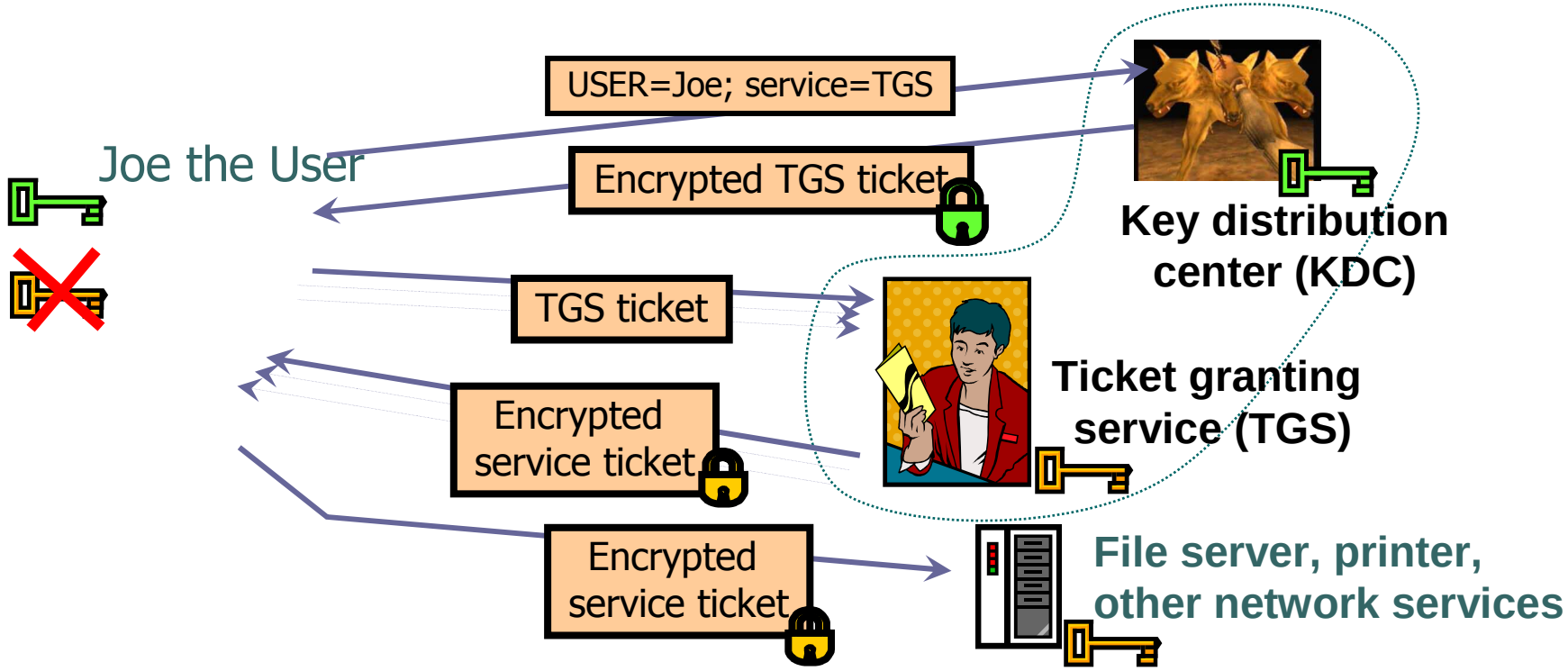
User Authentication to Third Party



- Insecure:
  - Eavesdropper can steal the password and later impersonate the user to the authentication server
- Inconvenient: need to send the password each time to obtain the ticket for any network service
  - Separate authentication for email, printing, etc.

Two-Step Authentication

- Prove identity once to obtain special TGS ticket
- Use TGS to get tickets for any network service



Symmetric Keys in Kerberos

- K_c : private key of client C
  - Derived from user's password
  - Known to client and key distribution center (KDC)
- K_{TGS} : private key of TGS
  - Known to KDC and ticket granting service (TGS)
- K_v : private key of network service V
  - Known to V and TGS; separate key for each service
- $K_{c,TGS}$: session key between C and TGS
  - Created by KDC, known to C and TGS, valid only for one session (some lifetime) between C and TGS
- $K_{c,v}$: session key betwen C and V
  - Created by TGS, known to C and V, valid only for one session (some lifetime) between C and TGS

“Single Logon” Authentication

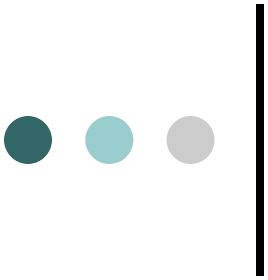
- Client C types in password once
- Converted to client key K_c
- C sends to KDC : $(ID_C, ID_{TGS}, time_C)$
- KDC sends to C : $(K_{c,TGS}, ID_{TGS}, time_{KDC}, lifetime, ticket_{TGS})$ encrypted with K_c
  - $ticket_{TGS} = (K_{c,TGS}, ID_C, Addr_C, ID_{TGS}, time_{KDC}, lifetime)$ encrypted with K_{TGS}
  - Client will use this ticket to get other tickets without re-authenticating

- $K_{C,TGS}$: short term session key
  - used for communication between C and TGS during lifetime
- Typical validity of TGS ticket – 1 day
  - Client only needs to obtain TGS ticket once a day (say, every morning)
  - Password is entered once and then deleted from the client machine after obtaining the TGS ticket
  - Password is never sent over the network
  - Ticket is encrypted; client cannot forge it or tamper with it

Obtaining a Service Ticket

- C sends to TGS: **(ID_V , $ticket_{TGS}$, $auth_C$)**
  - **$auth_C$** = **(ID_C , $Addr_C$, $time_C$)** encrypted with **$K_{C,TGS}$**
  - **authenticator** to ensure it is the same client that got the ticket

- TGS sends to C: **($K_{C,V}$, ID_V , $time_{TGS}$, $ticket_V$)** encrypted with **$K_{C,TGS}$**
  - **$ticket_V$** = **($K_{C,V}$, ID_C, $Addr_C$, ID_V , $time_{TGS}$, lifetime)** encrypted with **K_V**

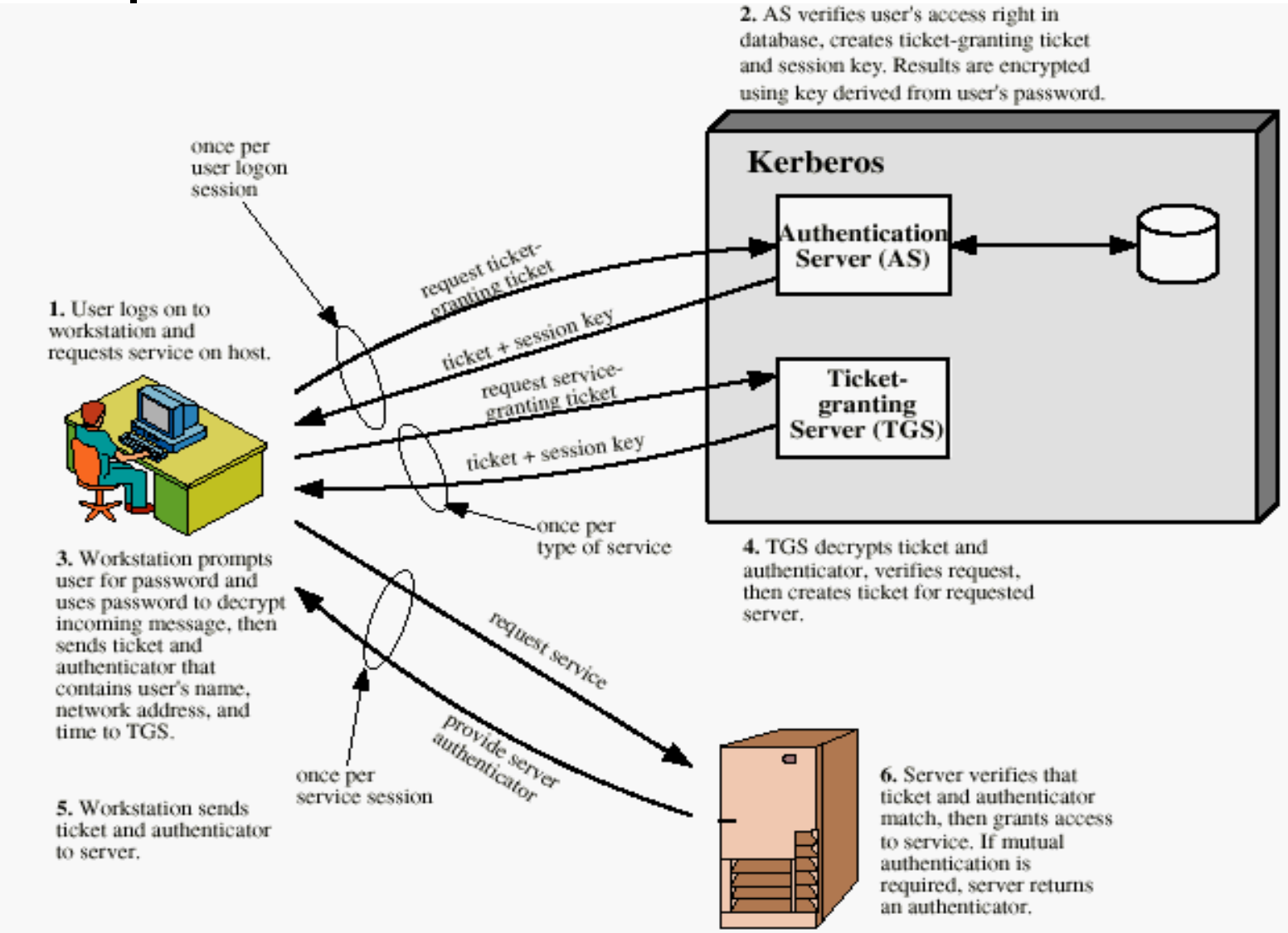


- Client uses TGS ticket to obtain a service ticket and a short-term session key for each network service
  - One encrypted, unforgeable ticket per service (printer, email, etc.)

Obtaining Service

- C sends to V: **($ticket_V$, $auth_C$)**
- **$auth_C$** = **(ID_C , $Addr_C$, $time_C$)** **encrypted with $K_{C,V}$**
- V sends to C: **($time_C$+1)** **encrypted with $K_{C,V}$**
  - Authenticates server to client
- For each service request, client uses the short-term session key for that service and the ticket he received from TGS

Summary of Kerberos



Important Ideas in Kerberos

- Short-term session keys
  - Long-term secrets used only to derive short-term keys
  - Separate session key for each user-server pair
    - … but multiple user-server sessions re-use the same key
- Proofs of identity are based on authenticators
  - Client encrypts his identity, address and current time using a short-term session key
    - Also prevents replays (if clocks are globally synchronized)
  - Server learns this key separately (via encrypted ticket that client can't decrypt) and verifies user's identity

Kerberos in Large Networks

- One KDC isn't enough for large networks (why?)
- Network is divided into realms
  - KDCs in different realms have different key databases
- To access a service in another realm, users must do cross-realm authentication
  - Get ticket for home-realm TGS from home-realm KDC
  - Get ticket for remote-realm TGS from home-realm TGS
    - As if remote-realm TGS were just another network service
  - Get ticket for remote service from that realm's TGS
  - Use remote-realm ticket to access service
  - N(N-1)/2 key exchanges for full N-realm interoperation (NOT SCALABLE)
- Use Hierarchical cross-realm authentication

Hierarchical Cross-realm Authentication

- Organize realms as trees