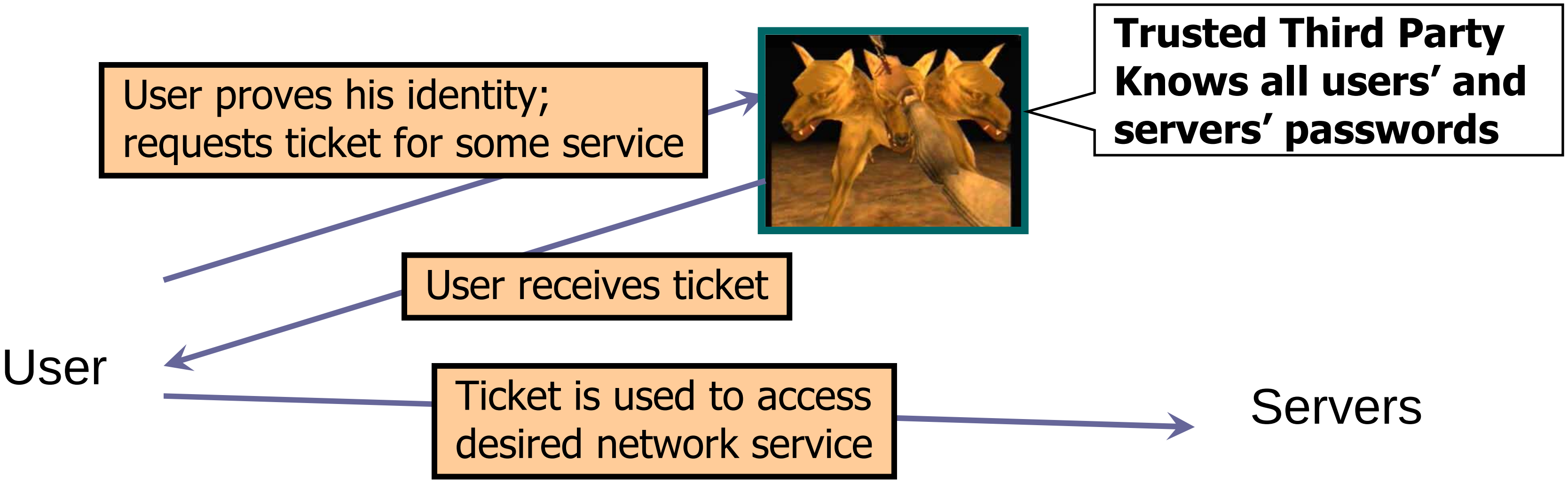
Kerberos

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



User proves his identity;
requests ticket for some service

Trusted Third Party
Knows all users' and
servers' passwords

User receives ticket

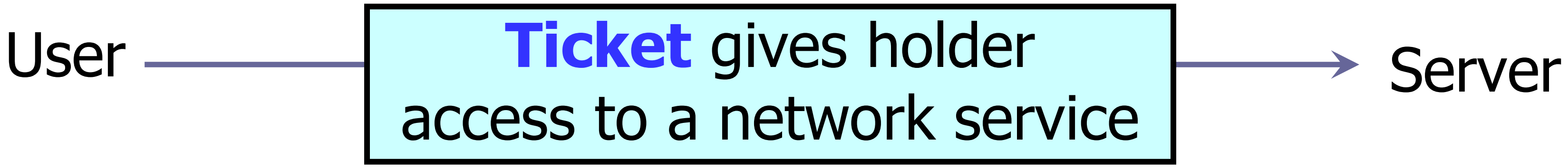
User

Ticket is used to access
desired network service

Servers

- 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?



User

Ticket gives holder access to a network service

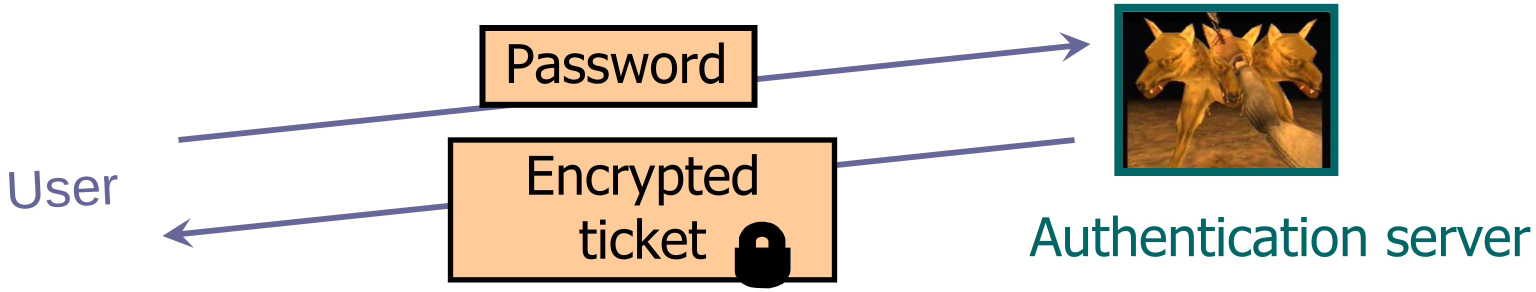
Server

- 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



Password

User

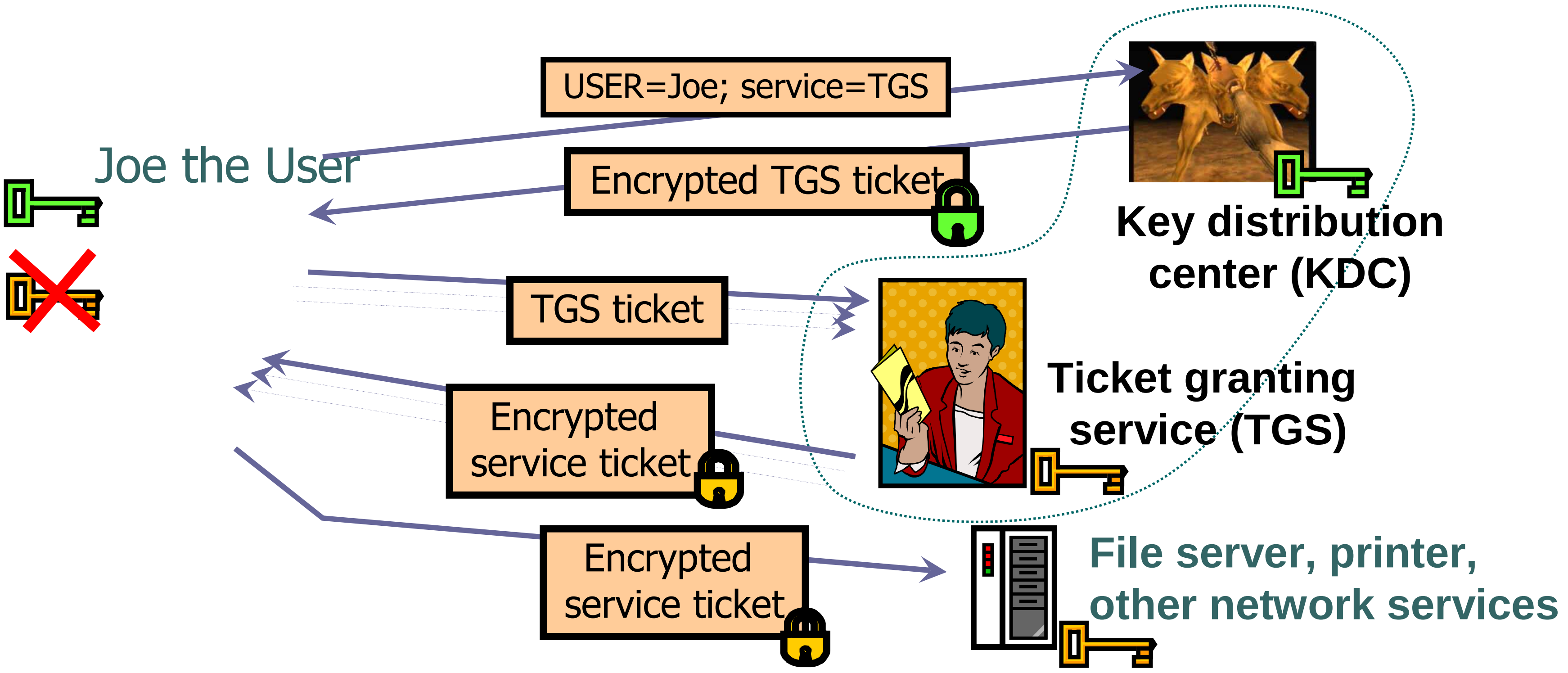
Encrypted ticket

Authentication server

- 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



USER=Joe; service=TGS

Joe the User

Encrypted TGS ticket

TGS ticket

Encrypted service ticket

Encrypted service ticket

Key distribution center (KDC)

Ticket granting service (TGS)

File server, printer, other network services

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

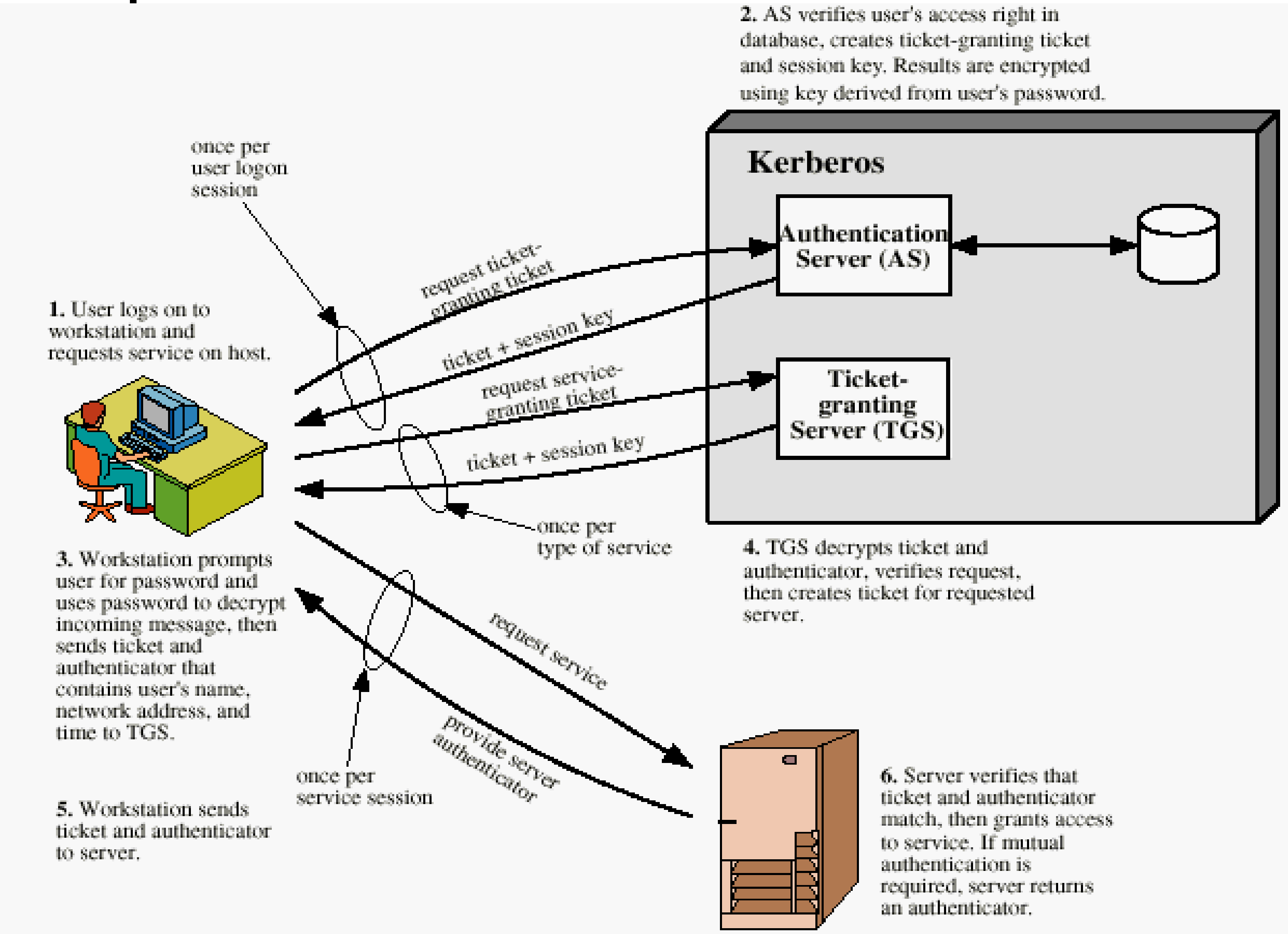
- TGS sends to C: **$(K_{C,V}$, ID_V , $time_{TGS}$, $ticket_V)$** encrypted with **$K_{C,TGS}$**
  - **$ticket_V$** = **$(K_{C,V}$, ID_C, $Addr_C$, ID_V , $time_{TGS}$, lifetime)** encrypted with **K_V**

- 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


Kerberos
Authentication Server (AS)
Ticket-granting Server (TGS)
once per user logon session
request ticket-granting ticket
ticket + session key
request service-granting ticket
ticket + session key
once per type of service
request service
provide server authenticator
once per service session

1. User logs on to workstation and requests service on host.

2. AS verifies user's access right in database, creates ticket-granting ticket and session key. Results are encrypted using key derived from user's password.

3. Workstation prompts user for password and uses password to decrypt incoming message, then sends ticket and authenticator that contains user's name, network address, and time to TGS.

4. TGS decrypts ticket and authenticator, verifies request, then creates ticket for requested server.

5. Workstation sends ticket and authenticator to server.

6. Server verifies that ticket and authenticator match, then grants access to service. If mutual authentication is required, server returns an authenticator.

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