Authentication Service

(Kerberos)

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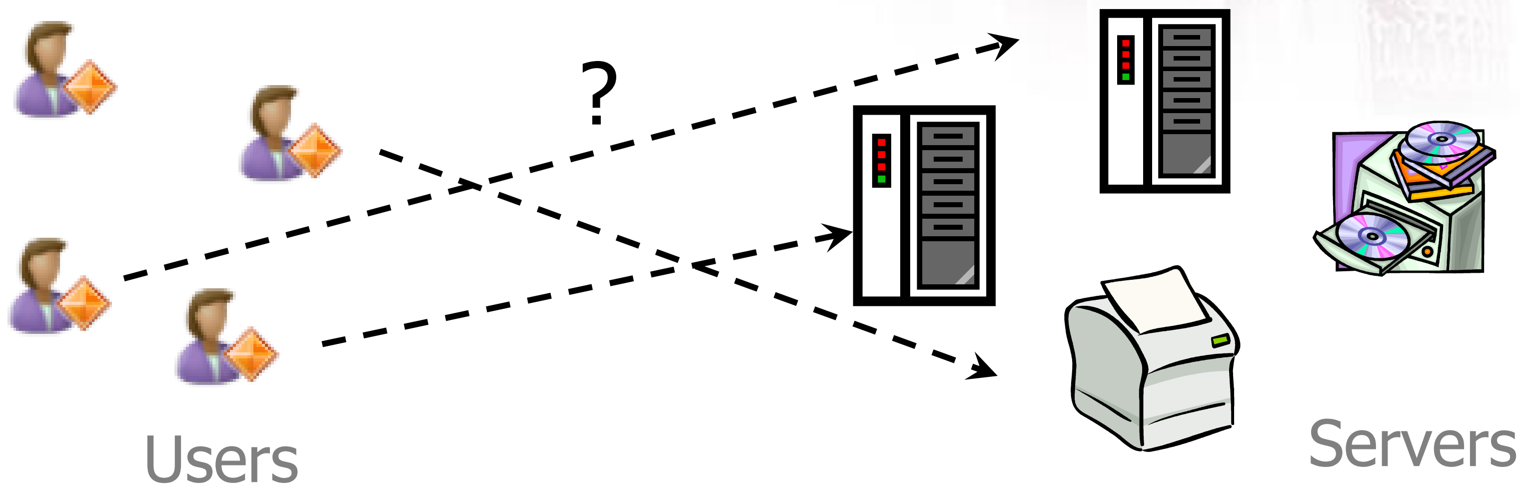
Identity Management System

- ***Identity Management (IdM)***
  - Manage identities for authentication & authorization within or across systems
- ***Authentication (AuthN)***
  - A process of verifying the ***identity*** of a user or system
  - Verifying that "*you are who you say you are*"
- **Authorization (AuthZ)**
  - A process of determine the ***privileges*** the user or system has
  - Verifying that "*you are permitted to do what you are trying to do*"
- ***Directory Service***
  - A software system that stores, organizes and provides access to information in a directory.

Many-to-Many Authentication



How do users prove their identities when requesting services from machines on the network?

Naïve solution: every server knows every user's password

- Insecure: break into one server ⇒ compromise all users
- Inefficient: to change password, user must contact every server

Requirements

- Security
  - … against attacks by passive eavesdroppers and actively malicious users
- Transparency
  - Users shouldn't notice authentication taking place
  - Entering password is Ok, if done rarely
- Scalability
  - Large number of users and servers

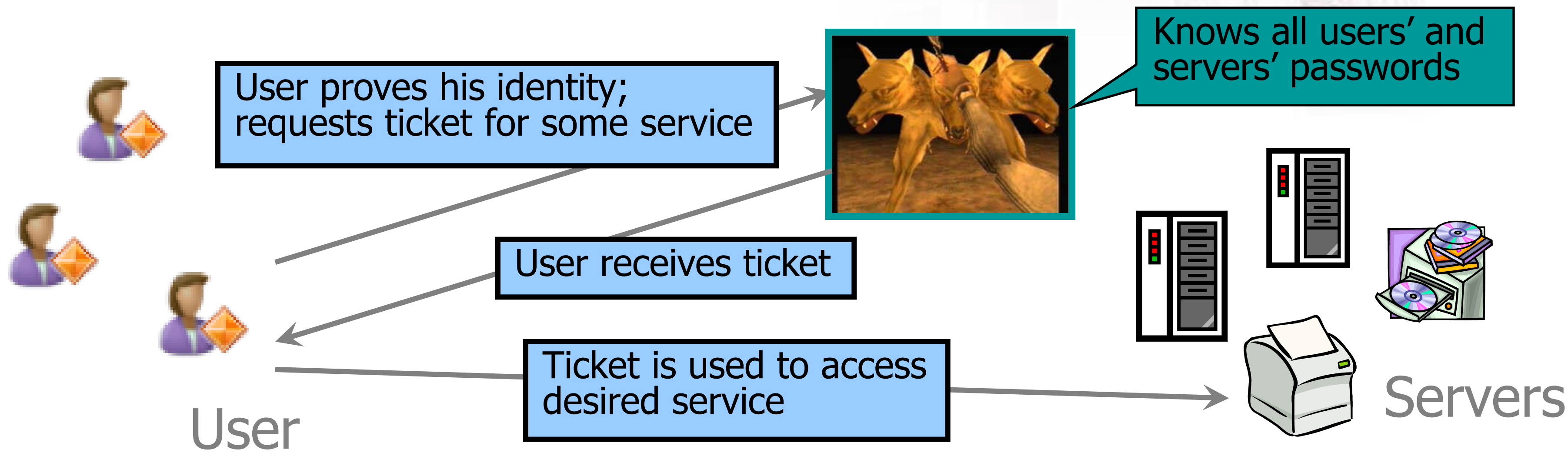
Scalability Issue

- Generalizing the model for *m* users and *n* services, requires a priori distribution of $m \times n$ shared keys.
- Possible improvement:
  - Use trusted 3rd party, with which each user and service shares a secret key: $m+n$ kyes.
  - Also has important security advantages.

Threats

- ***User impersonation***
  - Malicious user with access to a workstation pretends to be another user from the same workstation
- ***Network address impersonation***
  - Malicious user changes network address of his workstation to impersonate another workstation
- ***Eavesdropping, tampering, replay***
  - Malicious user eavesdrops, tampers, or replays other users' conversations to gain unauthorized access

Solution: 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*

Kerberos

- A Network Authentication Protocol.
- Developed at MIT in the mid 1980s.
- A *secret-key based* service for providing strong authentication for client/server applications.
- Authentication mediated by a trusted 3rd party
  - Key Distribution Center (KDC)
- Available as open source or in supported commercial software.

Kerberos Objectives

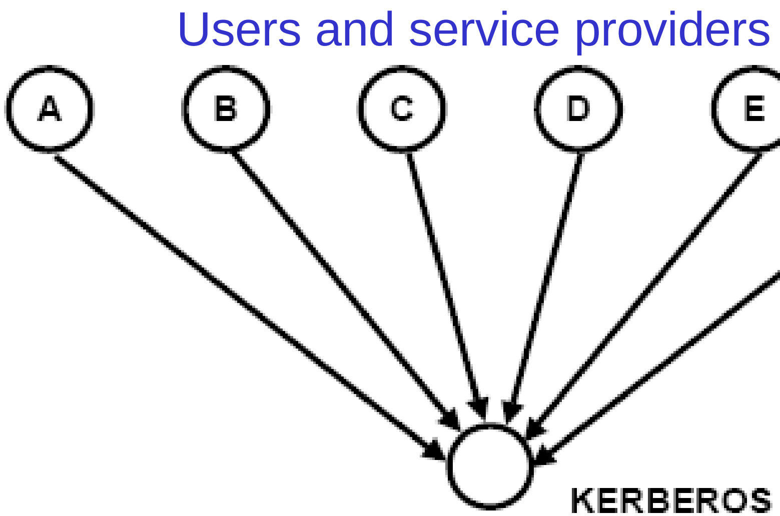
- Standards based *strong authentication system*
- Prevents transmission of passwords over the network
- Servers can build *authorization* and *access control services* on top of Kerberos
- Provides "*single-sign-on*" (SSO) capability
  - Only 1 password to remember
  - Only need to enter it once per day (typically)

Kerberos Design Goals

- Impeccability
  - no cleartext passwords on the *network*
  - no client passwords on *servers* (server must store secret server key)
  - minimum exposure of client key on workstation (smartcard solution would eliminate this need)
- Containment
  - compromise affects only one client (or server)
  - limited authentication lifetime (8 hours, 24 hours, more)
- Transparency
  - password required only at login
  - minimum modification to existing applications

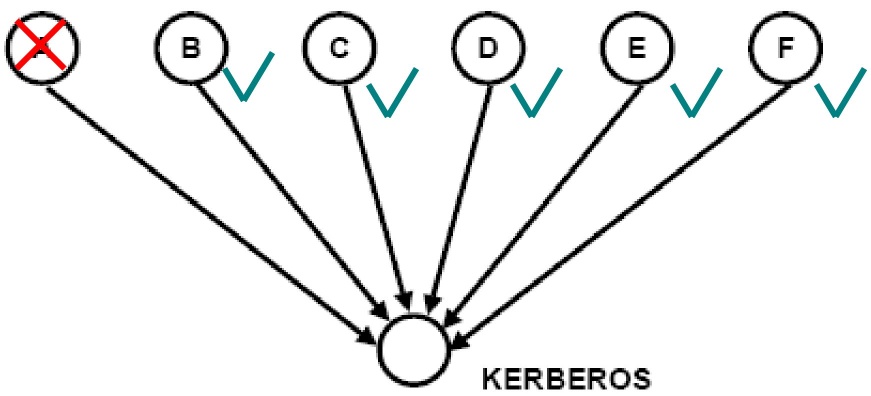
Trust: Consolidated Kerberos Model

- Centralized Trust model (vs. decentralized / hierarchical)



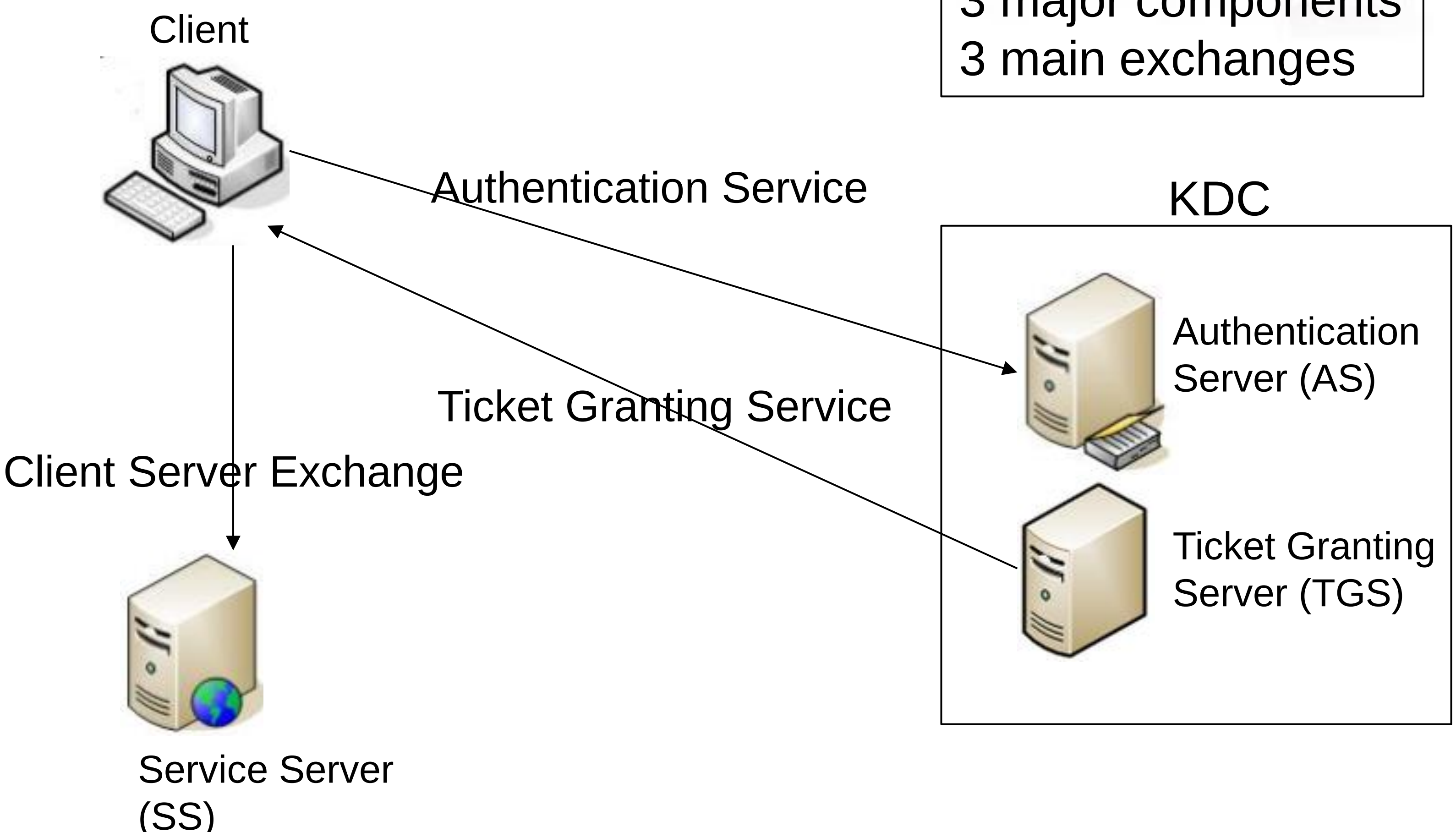
Trust: Consolidated Kerberos Model

- Breaking into one host provides a cracker no advantage in breaking into other hosts
- Authentication systems can be viewed as trust propagation systems
  - the Kerberos model is a centralized star model

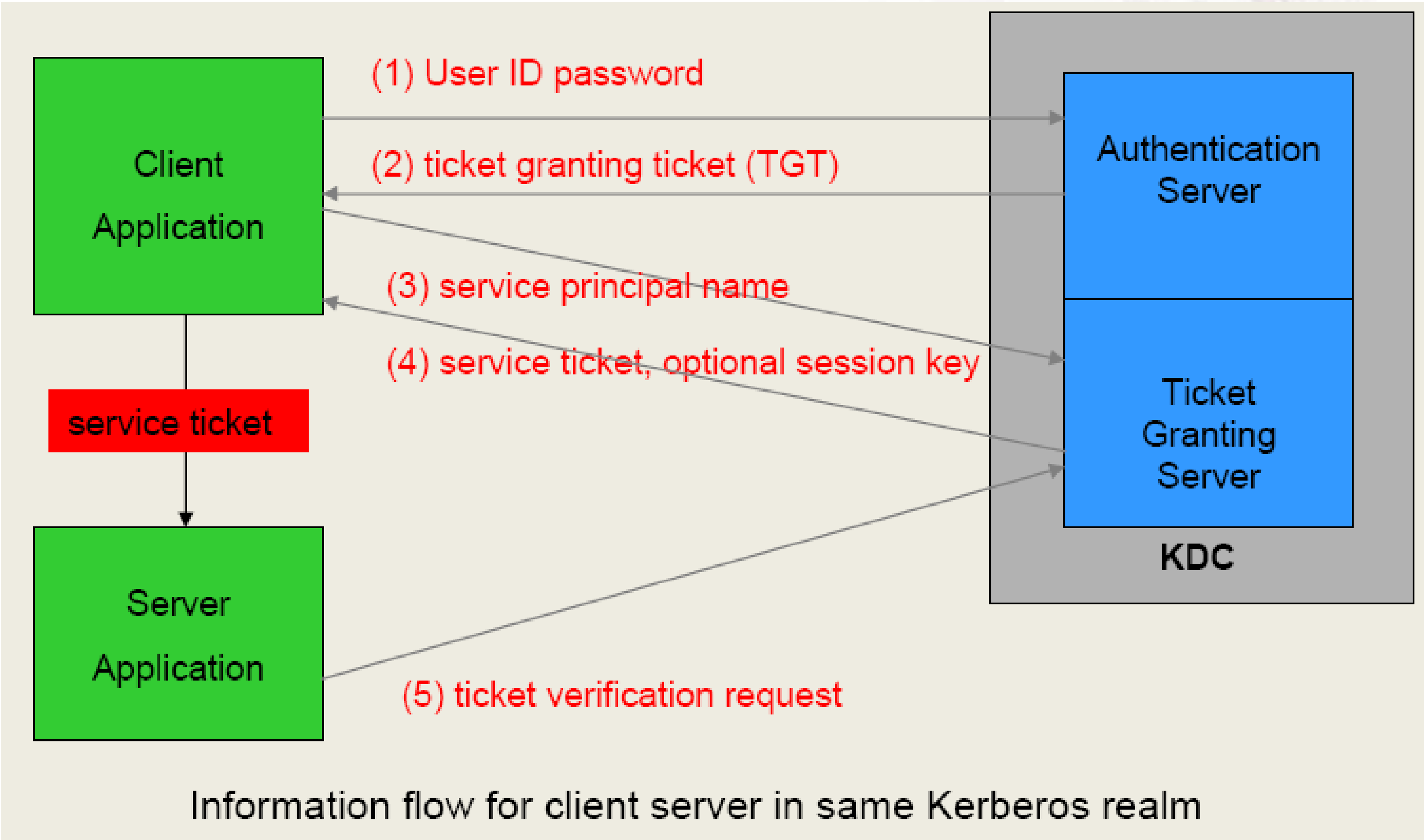


Kerberos Architecture

3 major components
3 main exchanges



Kerberos Protocol Overview



Key Distribution Center

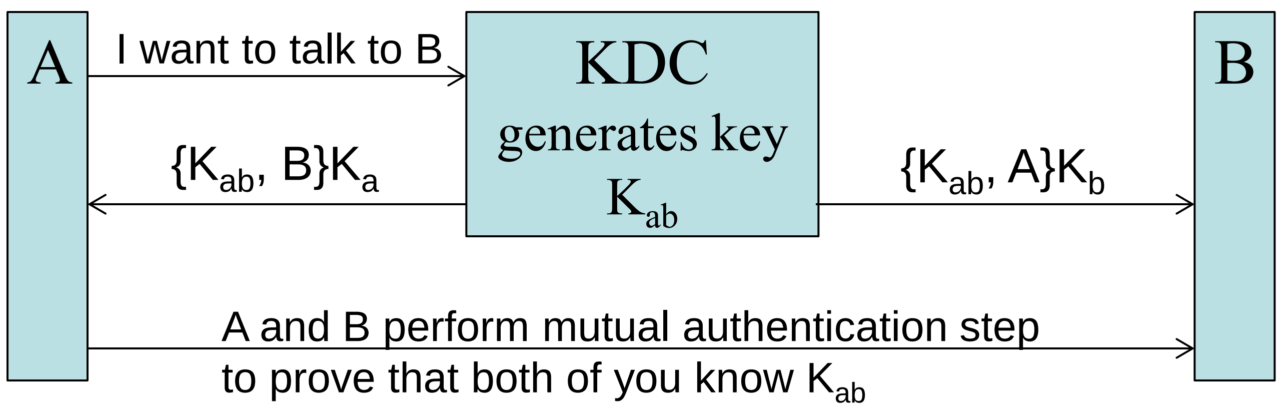
- Responsible for maintaining *master keys* for all *principles* and issuing Kerberos *tickets*
  - Master key: the key shared by user and KDC
- Authentication Service (AS) gives the client a *session key* and a *Ticket Granting Ticket (TGT)*
  - Session key: the key shared by client, server and AS
- Distributes service session keys and ticket for the service via a Ticket Granting Service (TGS)

KDC (cont.)

- Everyone trusts the KDC
- Each user and service registers a secret key with KDC
- KDC holds a database of clients and servers (principals) and their private keys
- *principal*: a client of the AS, a user, or a service
  - Format: name/instance@realm
  - Examples:
    - user : alice@asu.edu
    - service : printing/cise.asu.edu@asu.edu

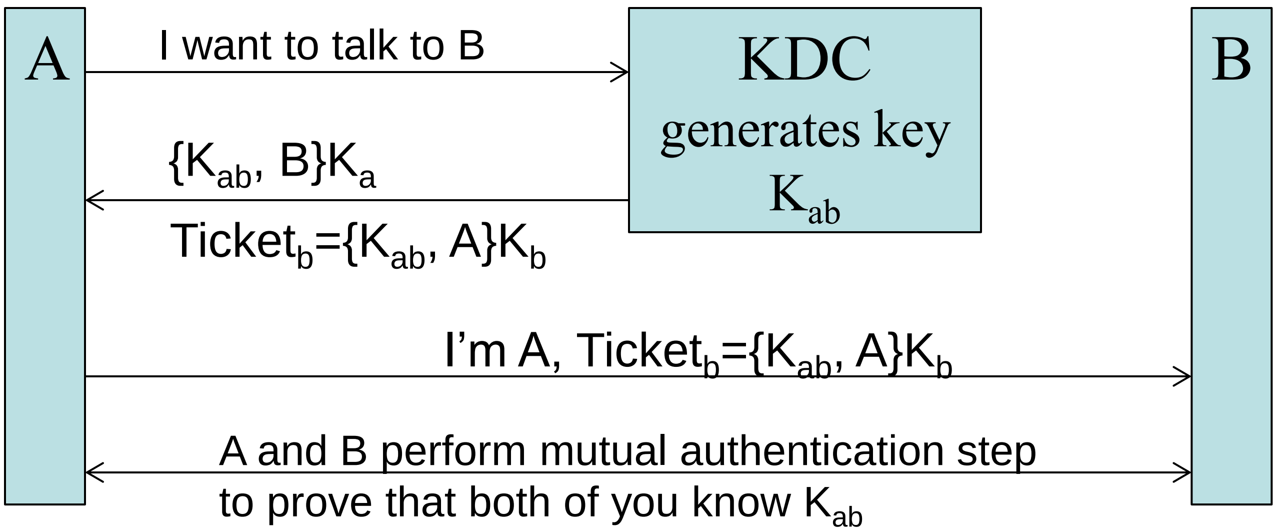
Mediated Authentication

- Between Two parties



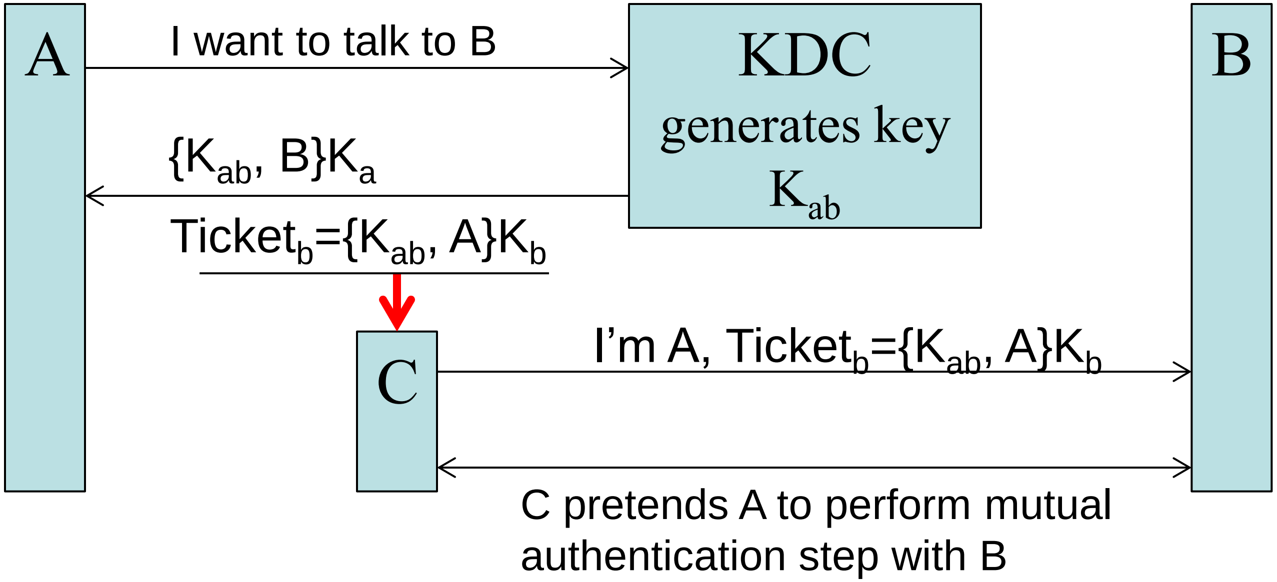
Mediated Authentication

- Involve more parties

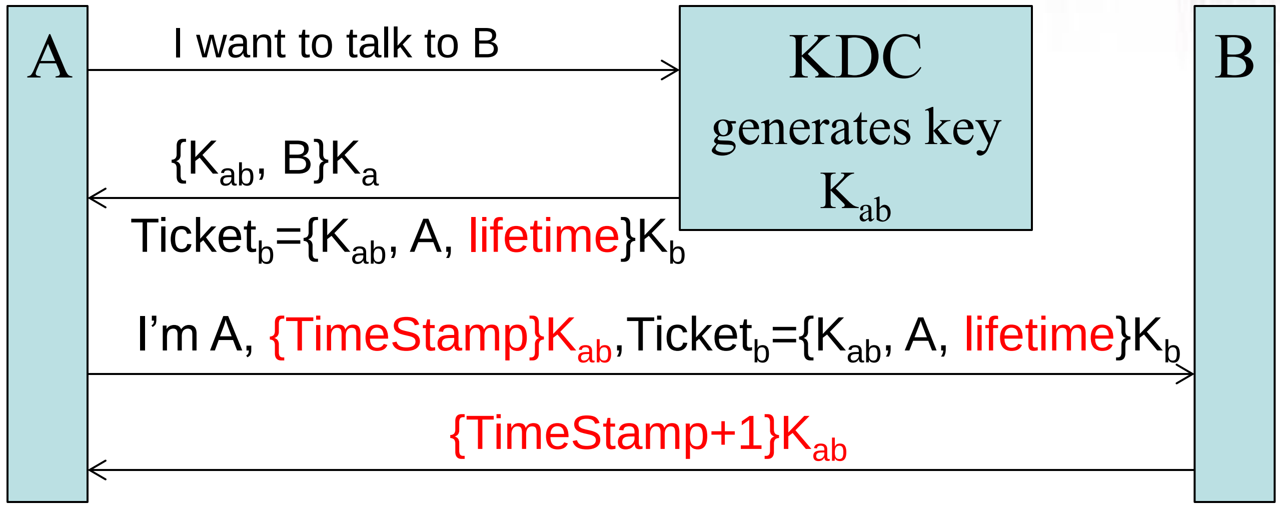


Replay Attack

- A replay attack occurs when an intruder steals the packet and presents it to the service as if the intruder were the user.



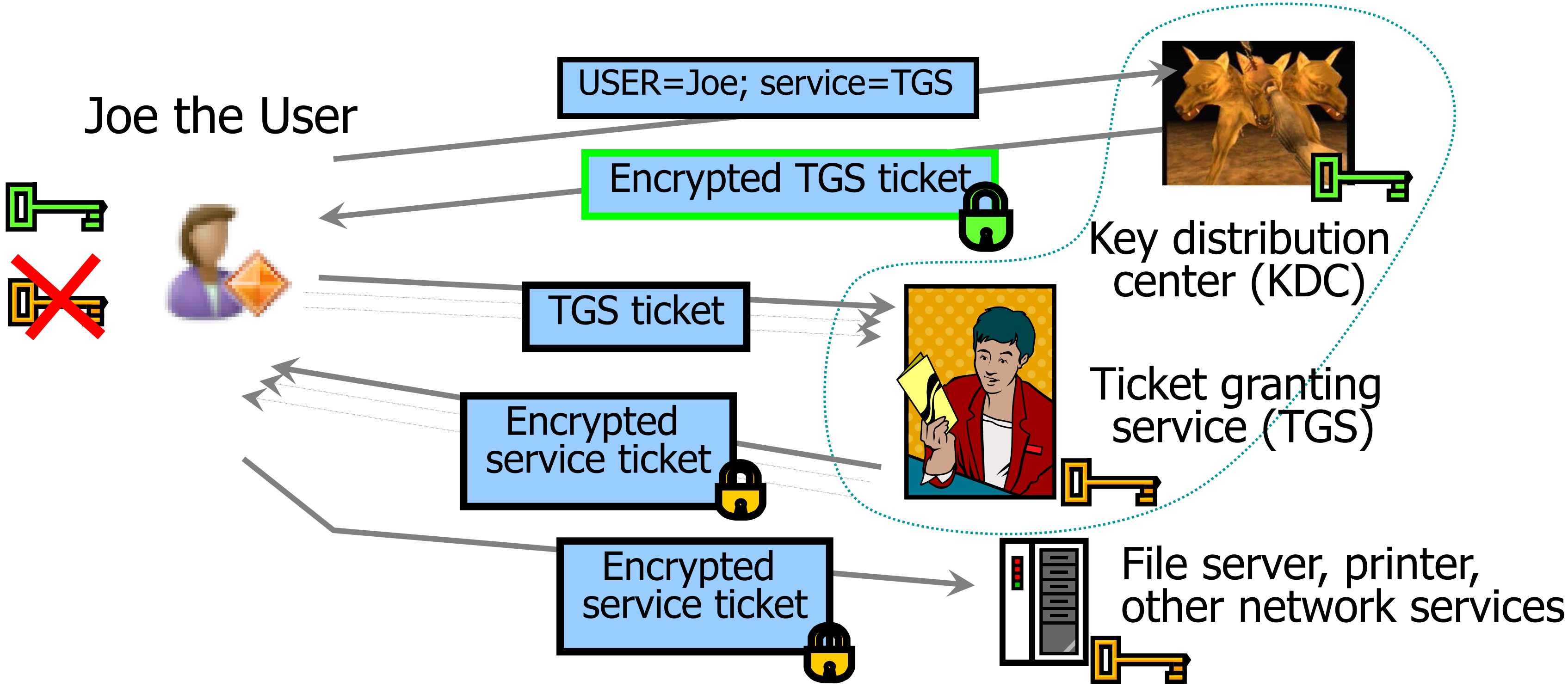
Kerberos (simplified)



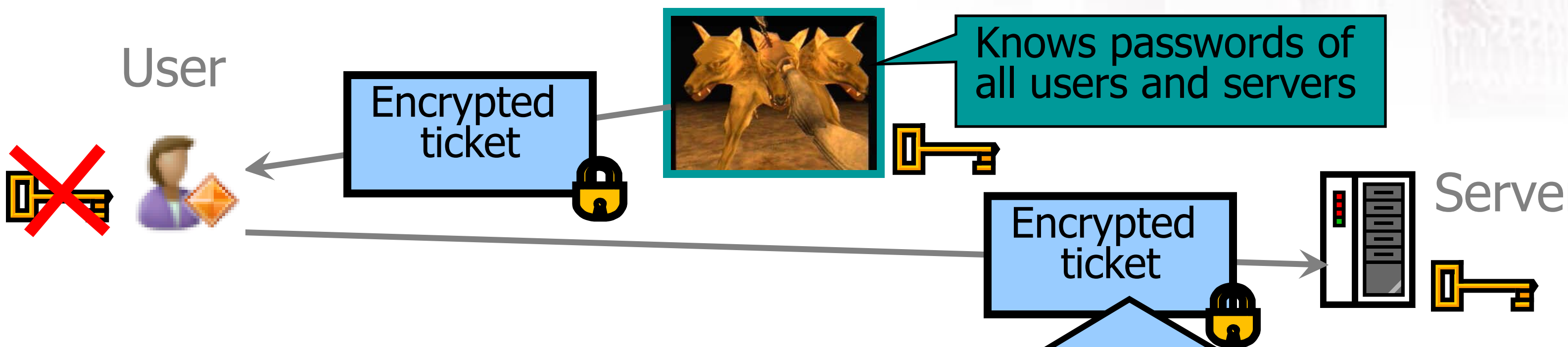
- If a packet is replayed, the timestamp is checked. If the timestamp is earlier or the same as a previous authenticator, the packet is rejected because it's a replay.
- In addition, the time stamp in the authenticator is compared to the server time. It must be within five minutes (by default in Windows).

Two-Step Authentication

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



What Should a Ticket Include?



- 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
- A few other things (session key, etc.)

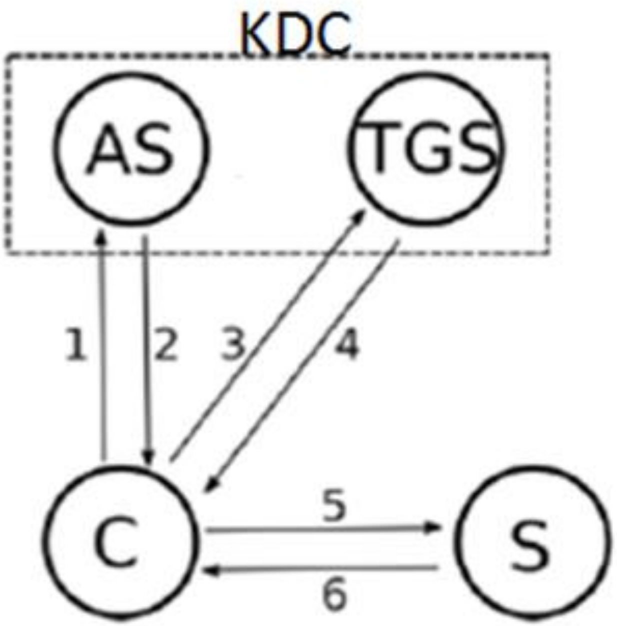
TGS Benefits

- Single Sign-on (SSO) capability
- Limits exposure of user’s password
  - Client’s workstation can forget the password immediately after using it in the early stages of the protocol.
  - Less data encrypted with the user’s secret key travels over the network, limiting attacker’s access to data that could be used in an offline *dictionary attack*.
  - Dictionary attack:
    - tries only those possibilities which are most likely to succeed, typically derived from a list of words for example a dictionary

Ticket Granting Service

- Problem: Transparency
  - user should provide password once upon initial login, and should not be asked for it on every service request
  - workstation should not store the password, except for the brief initial login
- Solution: Ticket-Granting Service (TGS)
  - store session key on workstation in lieu of password
  - TGS runs on same host as Kerberos (needs access to K_c and K_s keys)

Kerberos Protocol



AS – Authentication Service
C – Client
TGS – Ticket-Granting Service
S – Server

Authenticating the identity and obtaining TGT

1. $[ID_C, ID_{TGS}, TS_1]$
2. $\{K_{C,TGS}, ID_{TGS}, TS_2, lifetime_1, Ticket_{TGS}\}K_C$
   $Ticket_{TGS} = \{K_{C,TGS}, ID_C, AD_C, ID_{TGS}, TS_2, lifetime_1\}K_{TGS}$

Obtaining Service-granting-ticket

3. $[ID_S, Ticket_{TGS}, Auth_{C1}]$. $Auth_{C1} = \{ID_C, AD_C, TS_3\}K_{C,TGS}$
4. $\{K_{C,S}, ID_S, TS_4, Ticket_S\}K_{C,TGS}$
   $Ticket_S = \{K_{C,S}, ID_C, AD_C, ID_S, TS_4, lifetime_2\}K_S$

Obtaining service

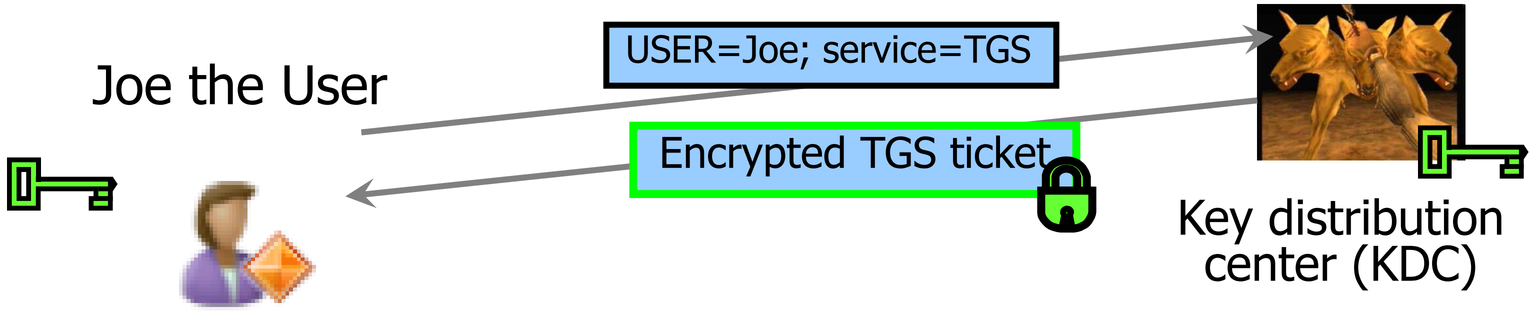
5. $[Ticket_S, Auth_{C2}]$, $Auth_{C2} = \{ID_C, AD_C, ID_S, TS_5, lifetime_2\}K_{C,S}$
6. $\{TS_{5+1}\}K_{C,S}$

Symmetric Keys in Kerberos

- K_c is long-term key of client C
  - Derived from user's password
  - Known to client and key distribution center (KDC)
- K_{TGS} is long-term key of TGS
  - Known to KDC and ticket granting service (TGS)
- K_s is long-term key of network service S
  - Known to V and TGS; each service S has a separate key
- $K_{c,TGS}$ is short-term session key between C and TGS
  - Created by KDC, known to C and TGS
- $K_{c,s}$ is short-term session key between C and S
  - Created by TGS, known to C and V

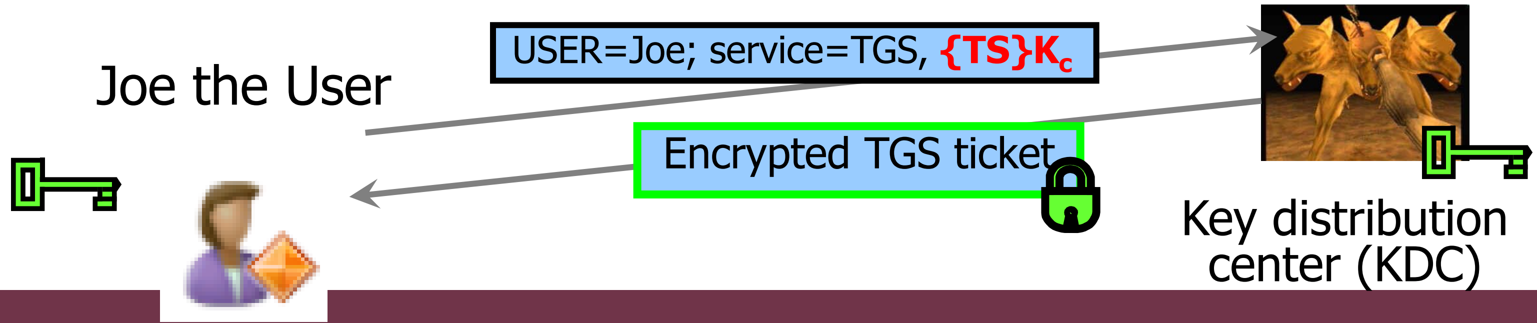
Kerberos Dictionary Attack

- First two messages reveal known plaintext for dictionary attack
- First message can be sent by anyone
- Kerberos v5 has pre-authentication option to prevent this attack



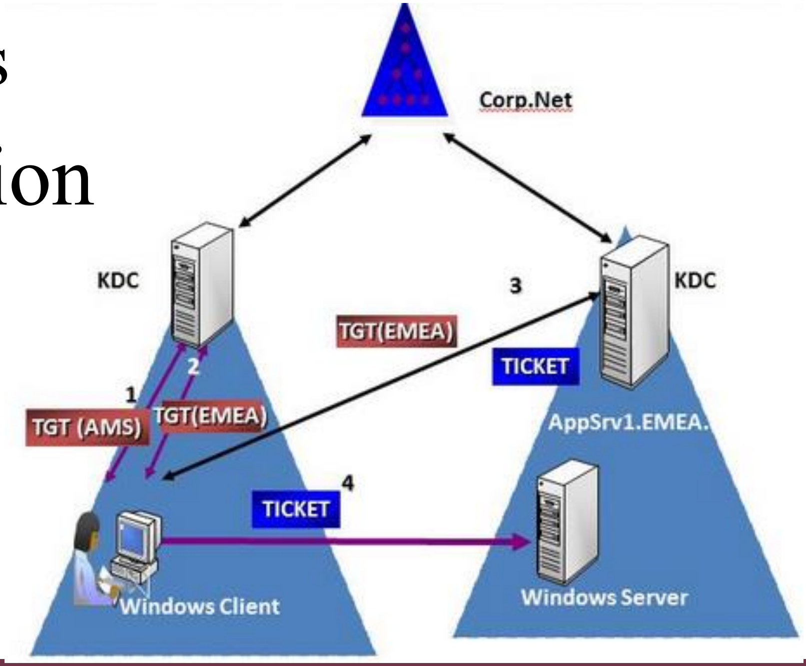
Pre-authentication

- Kerberos 5 added pre-authentication
  - Client is required to prove it's identity to the Kerberos AS in the first step.
  - By supplying an *encrypted timestamp* (encrypted with users secret key)
  - This prevents an active attacker being able to easily obtain data from the KDC encrypted with any user's key, then able to mount an offline dictionary attack.



Realms

- A Realm is an *authentication domain*
  - one Kerberos database and a set of KDCs
- Hierarchical organization (new in v5)
  - Active Directory in Windows
- One or two way authentication
- Cross-realm authentication
  - transitive cross-realm
  - direct between realms



Kerberos Design Features

- Uses timestamps to avoid replay.
  - Requires time synchronized within a small window (5 minutes)
- Uses DES-based symmetric key cryptography for user authentication
  - Converting user’s password to a DES key
- Stateless

Kerberos - Summary

- Authentication method:
  - User's enter password on local machine only
  - Authenticated via central KDC once per day
  - No passwords travel over the network
- Single Sign-on (via TGS)
  - KDC gives you a special "ticket", the TGT, usually good for rest of the day.
  - This ticket can be used to get other service tickets allowing user to access them.

Advantages of Kerberos (1)

- Passwords aren't exposed to eavesdropping
- Password is only typed to the local workstation
  - It never travels over the network
  - It is never transmitted to a remote server
- Password guessing more difficult
- Single Sign-on
  - More convenient. Only one password, entered once
  - Users may be less likely to store passwords

Advantages of Kerberos (2)

- Stolen tickets hard to reuse
  - Need authenticator as well, which can't be reused
- Much easier to effectively secure a small set of limited access machines (the KDC's)
- Easier to recover from host compromises
- Centralized user account administration

Kerberos Caveats

- Kerberos server can impersonate anyone
- KDC is a single point of failure
  - Can have replicated KDC's
- KDC should be a performance bottleneck
  - Everyone needs to communicate with it frequently
  - Not a practical concern these days
  - Having multiple KDC's alleviates the problem
- If local workstation is compromised, user's password could be stolen
  - Only use a desktop machine or laptop that you trust
  - Use hardware token pre-authentication

Kerberos, LDAP, and AD

- Kerberos is for authentication only and provides Single Sign-on (SSO)
- LDAP can be used for authentication, authorization, and name services (no SSO)
- Active Directory is a kerberized directory service with an LDAP interface
- Use Kerberos for authN, LDAP for authZ and name services