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CS355: Cryptography

Lecture 18: Kerberos

What is Kerberos?

- Kerberos is a **network authentication protocol**
- Provides authentication for client-server applications, and data integrity and confidentiality
- Relies entirely on **symmetric cryptography**
- Developed at MIT: two versions, Version 4 and Version 5 (specified as RFC1510)
- http://web.mit.edu/kerberos/www

Kerberos Overview

- Client wants service from a particular server
- An Authentication Server allows access
- How? Based on tickets
- **Ticket**: specifies that a particular client (authenticated by the Authentication Server) has the right to obtain service from a specified server S
- **Realm**: network under the control of an Authentication Server

Basic Authentication Protocol

C → AS: $ID_c \,||\, P_c \,||\, ID_S$

AS → C: Ticket

C → S: $ID_c \,||\, \text{Ticket}$

$\text{Ticket} = E_{K_S}[\, ID_c \,||\, P_c \,||\, ID_S \,]$

- ID represents identifiers
- P_C represents password of client
- E denotes encryption
- K_s is a key shared by Authentication Server AS and server S

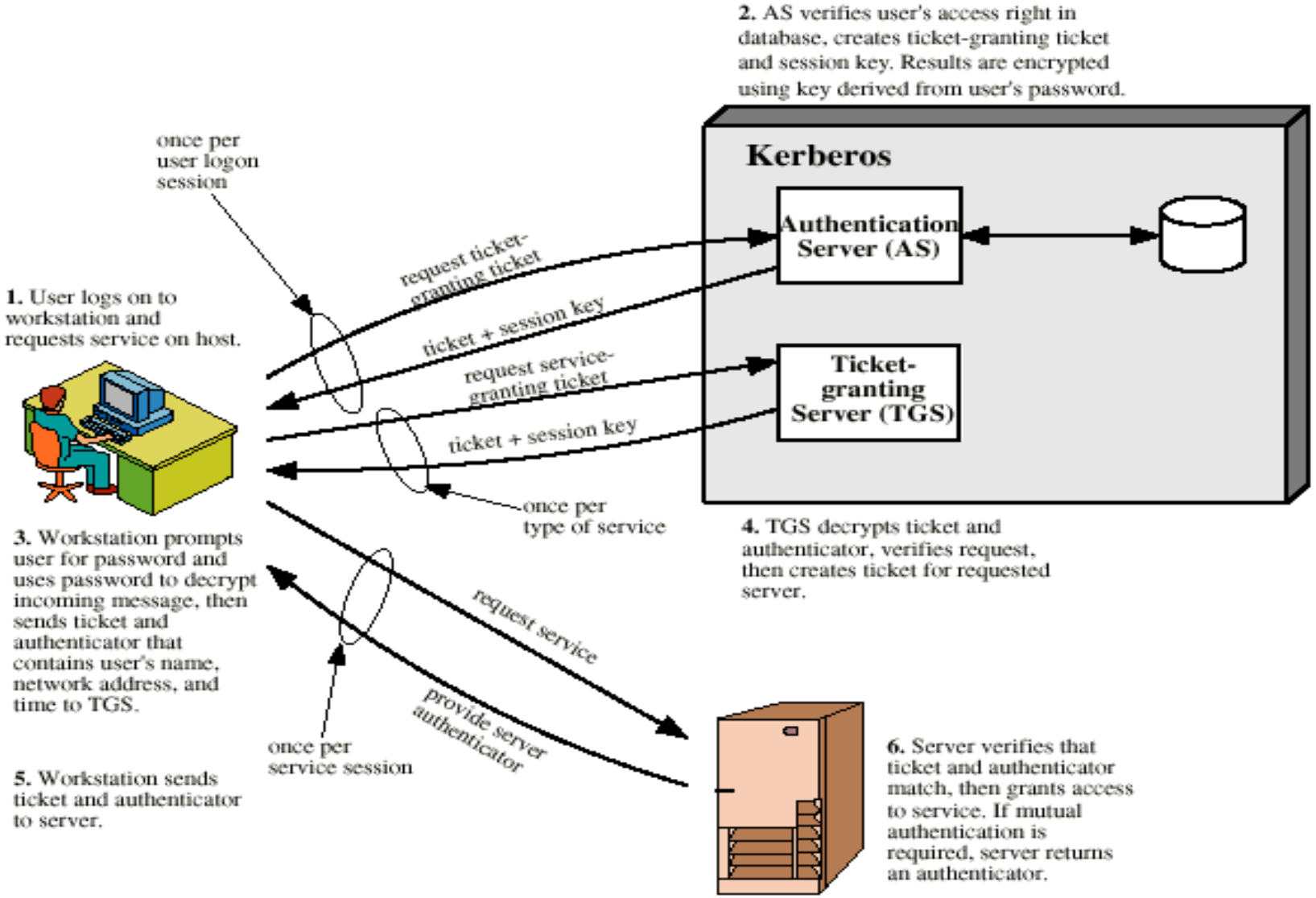
Vulnerabilities

- How long is the ticket valid?
- Ticket valid for a short time: then the client needs to come back and ask for another one
- Ticket valid for a longer time: if the ticket is stolen, somebody can reuse it before expiration
- Replay attack: the first message can be stored and replay later. There is no time indication associated with the ticket and the request.

Improved Authentication Protocol

- Use two type of tickets with two different lifetimes:
  - One ticket grants to right to ask for service; performed once per login session $Ticket_{tgs}$
  - For each type of service, use a ticket that grants the right to use that particular service $Ticket_S$
  - Every time that service is needed, used the ticket $Ticket_S$
- Mark time when tickets are issued and also lifetime of tickets.

Overview of Kerberos



V4: Authentication Service Exchange

Goal: Obtain Ticket-Granting Ticket

C → AS: $ID_c \| ID_{tgs} \| TS_1$

AS → C: $E_{Kc}[K_{c,tgs} \| ID_{tgs} \| TS_2 \| Lifetime_2 \| Ticket_{tgs}]$

$Ticket_{tgs} = E_{K_{tgs}}[K_{c,tgs} \| ID_C \| AD_C \| ID_{tgs} \| TS_2 \| Lifetime_2]$

ID_{tgs} denotes the identifier of the Ticket Granting Server (TGS)

TS1 and TS2 are timestamps

K_C is the key shared by the AS and client C

$K_{C,\ tgs}$ is the key shared by the TGS and client C

K_{tgs} key known by AS and the TGS

$Ticket_{tgs}$ …is the ticket

Lifetime is the validity of the ticket

AD is address identifier

V4: Ticket-Granting Service Exchange

Goal: Obtain Service-Granting Ticket

C → TGS: $ID_S \| Ticket_{tgs} \| Authenticator_C$

TGS → C: $E_{K_{c,tgs}} [K_{C,S} \| ID_S \| TS_4 \| Ticket_S]$

$Ticket_{tgs} = E_{K_{tgs}} [K_{C,tgs} \| ID_C \| AD_C \| ID_{tgs} \| TS_2 \| Lifetime_2]$

$Ticket_S = E_{K_S} [K_{C,S} \| ID_C \| AD_C \| ID_s \| TS_4 \| Lifetime_4]$

$Authenticator_C = E_{K_{C,\ tgs}} [ID_C \| AD_C \| TS_3]$

K_S is the key shared by the TGS and server S

V4: Client-Server Authentication Exchange

Goal: Obtain Service

$C \rightarrow S$: $Ticket_S \,||\, Authenticator_C$

$S \rightarrow C$: $E_{K_{C,S}} [\, TS_5 + 1 \,]$

$Ticket_S = E_{K_S} [\, K_{C,S} \,||\, ID_C \,||\, AD_C \,||\, ID_s \,||\, TS_4 \,||\, Lifetime_4 \,]$

$Authenticator_C = E_{K_{C,\,S}} [\, ID_C \,||\, AD_C \,||\, TS_5 \,]$

Protocol Design Motivations

- AS knows passwords for all clients
- Confidentiality, requires shared keys: include shared keys distribution in the protocols
- AS distributes keys C-TGS
- TGS distributes keys C-S
- Lifetime validity for tickets, include a time validity
- Freshness of messages to prevent replay attacks: use sequence numbers, timestamp or random numbers

Request for Service in Another Realm

- Authenticate to local AS and obtain ticket to local TGS
- Ask local TGS for ticket for remote TGS, obtain ticket for remote TGS
- Ask remote TGS for ticket for remote server S, obtain ticket for remote server S
- Ask for service from remote server S

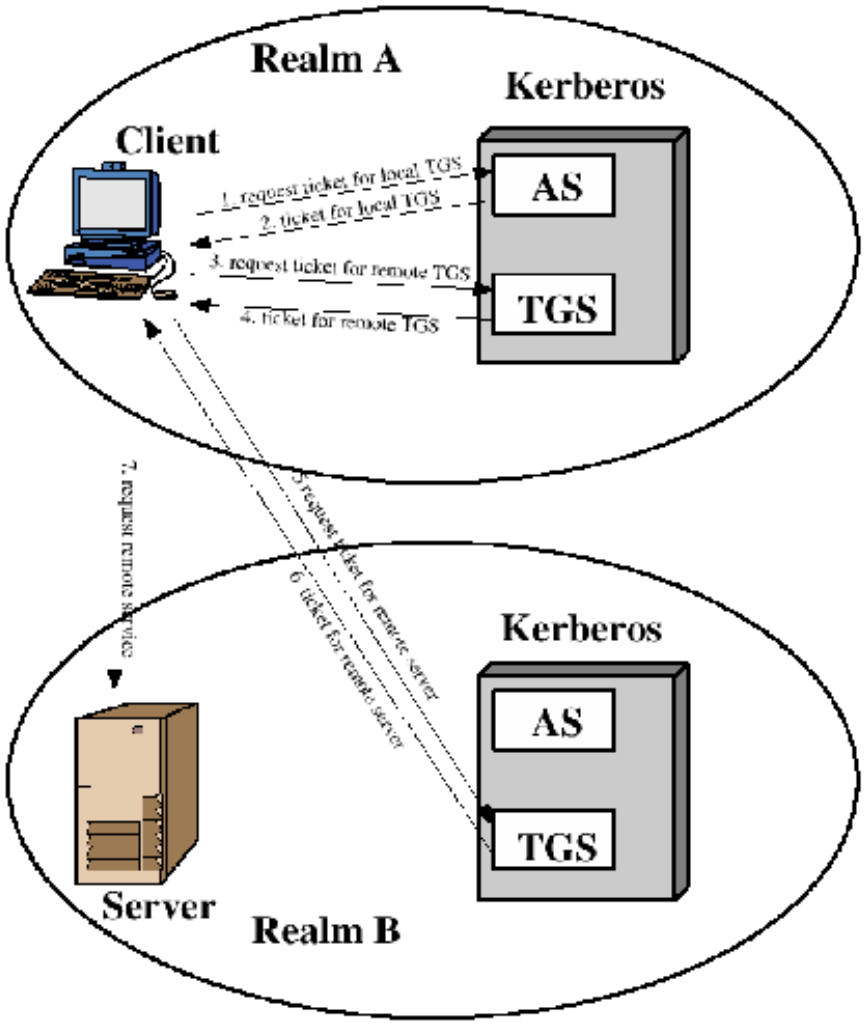


Figure 4.2 Request for Service in Another Realm

Kerberos Version 4 vs. Version 5

- Version 5 overcomes certain deficiencies in Version 4: environment and technical (1994)
- Environment:
  - V4 was using DES as encryption and there were restrictions; not general enough
  - Depending on IP, modify such that any network type address can be used
  - Message byte ordering; move the standards that provide unambiguous byte ordering
  - Ticket lifetime: V5 allows arbitrary lifetimes
  - Inter-realm authentication: V4 requires N^2 keys; V5 is better

Kerberos Version 4 vs. Version 5

- Technical:
  - V5 eliminates one unnecessary encryption
  - V4 was using a non-standard DES encryption mode that was found vulnerable; V5 uses CBC mode.
  - Use sub-session keys
  - Include a pre-authentication protocol that makes password attacks more difficult

V5: Authentication Service Exchange

Goal: Obtain Ticket-Granting Ticket

C → AS: $Options \| ID_c \| Realm_C \| ID_{tgs} \| Times \| Nonce_1$

AS → C: $Realm_C \| ID_C \| Ticket_{tgs} \| E_{Kc}[K_{c,tgs} \| Times \| Nonce_1 \| Realm_{tgs} \| ID_{tgs}]$

$Ticket_{tgs} = E_{K_{tgs}}[Flags \| K_{c,tgs} \| Realm_C \| ID_C \| AD_C \| Times]$

V5: Ticket-Granting Service Exchange

Goal: Obtain Service-Granting Ticket

C → TGS: $Options \| ID_S \| Times \| Nonce_2 \| Ticket_{tgs} \| Authenticator_C$

TGS → C: $Realm_C \| ID_C \| Ticket_S \| E_{K_{c,tgs}} [K_{C,S} \| Times \| Nonce_2 \| Realm_S \| ID_S]$

$Ticket_{tgs} = E_{K_{tgs}} [Flags \| K_{C,tgs} \| Realm_C \| ID_C \| AD_C \| Times]$

$Ticket_S = E_{K_S} [Flags \| K_{C,S} \| Realm_C \| ID_C \| AD_C \| Times]$

$Authenticator_C = E_{K_{C,\ tgs}} [ID_C \| Realm_C \| TS_1]$

V5: Client-Server Authentication Exchange

Goal: Obtain Service

$C \rightarrow S$: $\quad Options \,||\, Ticket_S \,||\, Authenticator_C$

$S \rightarrow C$: $\quad E_{Kc,s}[\, TS_2 \,||\, Subkey \,||\, Seq\# \,]$

$Ticket_S = E_{K_S}[\, Flags \,||\, K_{C,S} \,||\, Realm_C \,||\, ID_C \,||\, AD_C \,||\, Times]$

$Authenticator_C = E_{K_{C,\,S}}[\, ID_C \,||\, Realm_C \,||\, TS_2 \,||\, Subkey \,||\, Seq\#]$