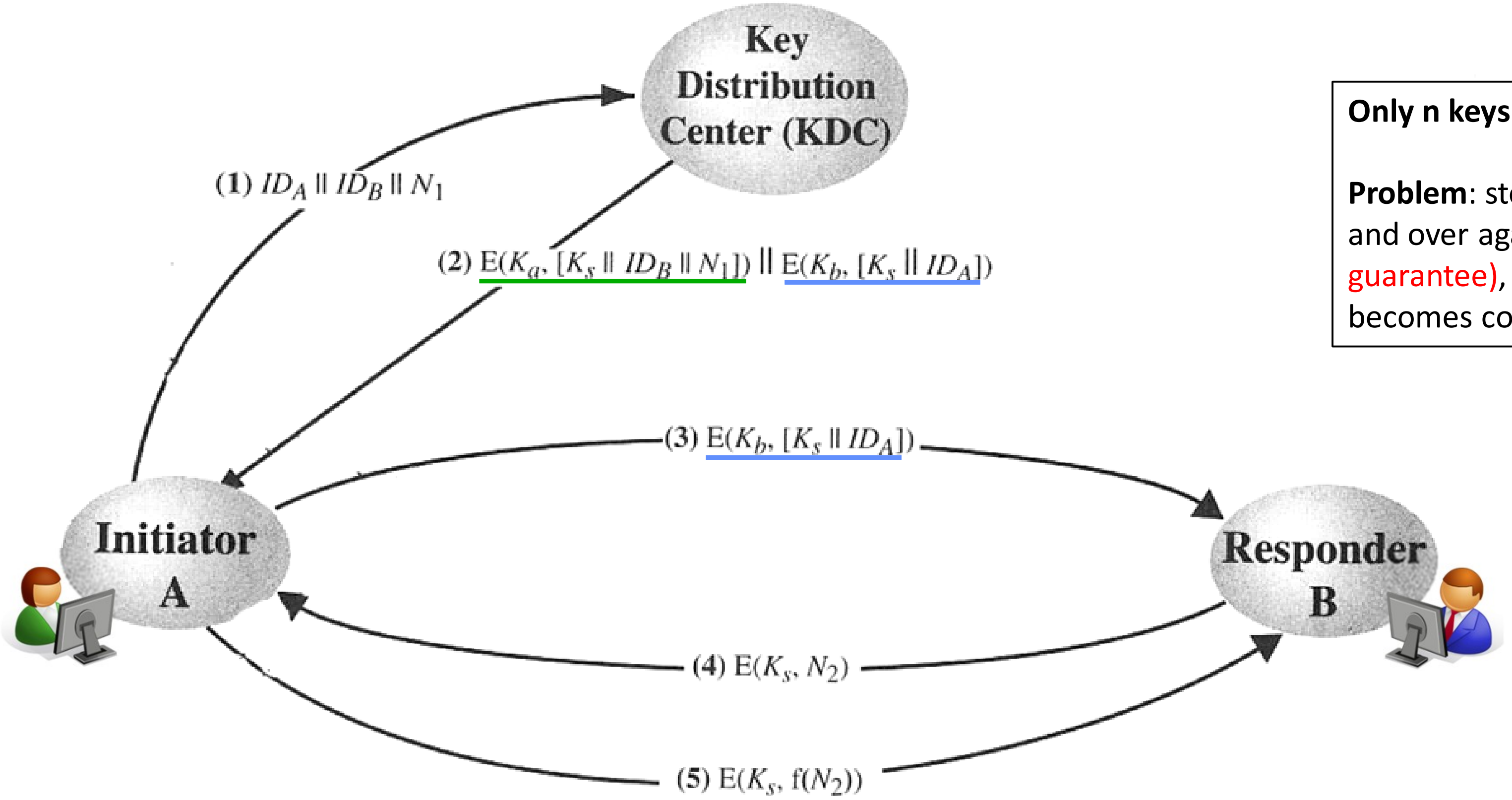
Remote authentication using encryption

Chapter 16.1 – 16.3

Key distribution with symmetric ciphers

- Public-key ciphers take time to compute
- Symmetric ciphers much faster, but requires pairwise shared keys:
  A ←→ B
  A ←→ C
  A ←→ D
  …
- O(n^2) keys needed that must be distributed on forehand
- Use of a trusted third party (KDC) can solve this problem
  - KDC: key distribution center
  - Each entity only needs one key: to the KDC
- Protection against replays and MITM attacks needed:
  - Nonces can make sure communication is fresh
  - Timestamps can invalidate old “tickets” and avoid replays, see next slide (chapter 16.2)

Using a KDC with only symmetric keys


Key Distribution Center (KDC)
(1) $ID_A \| ID_B \| N_1$
(2) $\underline{E(K_a, [K_s \| ID_B \| N_1])} \| \underline{E(K_b, [K_s \| ID_A])}$
(3) $\underline{E(K_b, [K_s \| ID_A])}$
Initiator A
Responder B
(4) $E(K_s, N_2)$
(5) $E(K_s, f(N_2))$

Only n keys needed!

Problem: step 3 can be replayed over and over again (no freshness guarantee), problematic if K_S becomes compromised.

The Kerberos Authentication System

Chapter 16.3

https://web.mit.edu/kerberos

What is Kerberos?

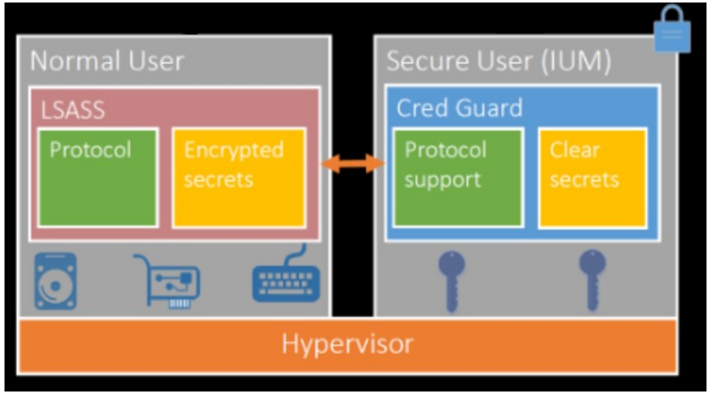
- The many-headed dog guarding the entrance of Hades in the Greek and Roman mythology
- And an AAA server guarding the network
  - Widely supported: Mac OS X and Linux/Unix systems support it
  - It’s the default authentication method in Windows
- Originally developed at MIT, early ’80s
  - The latest version (5) is described in RFC 1510 (1993)
  - Managed by the Kerberos Consortium (2007-): Apple, Microsoft, Google, Stanford, KTH, …
- Kerberos is a trusted third party used for authentication and authorization
- Authentication and authorization are two separate tasks
  - Although normally performed by the same server (hands out “tickets”)
- Application servers only need to admit already authorized users
  - Only need to look at a “service ticket”
  - Authentication and authorization already done when they receive the ticket

Design Objectives

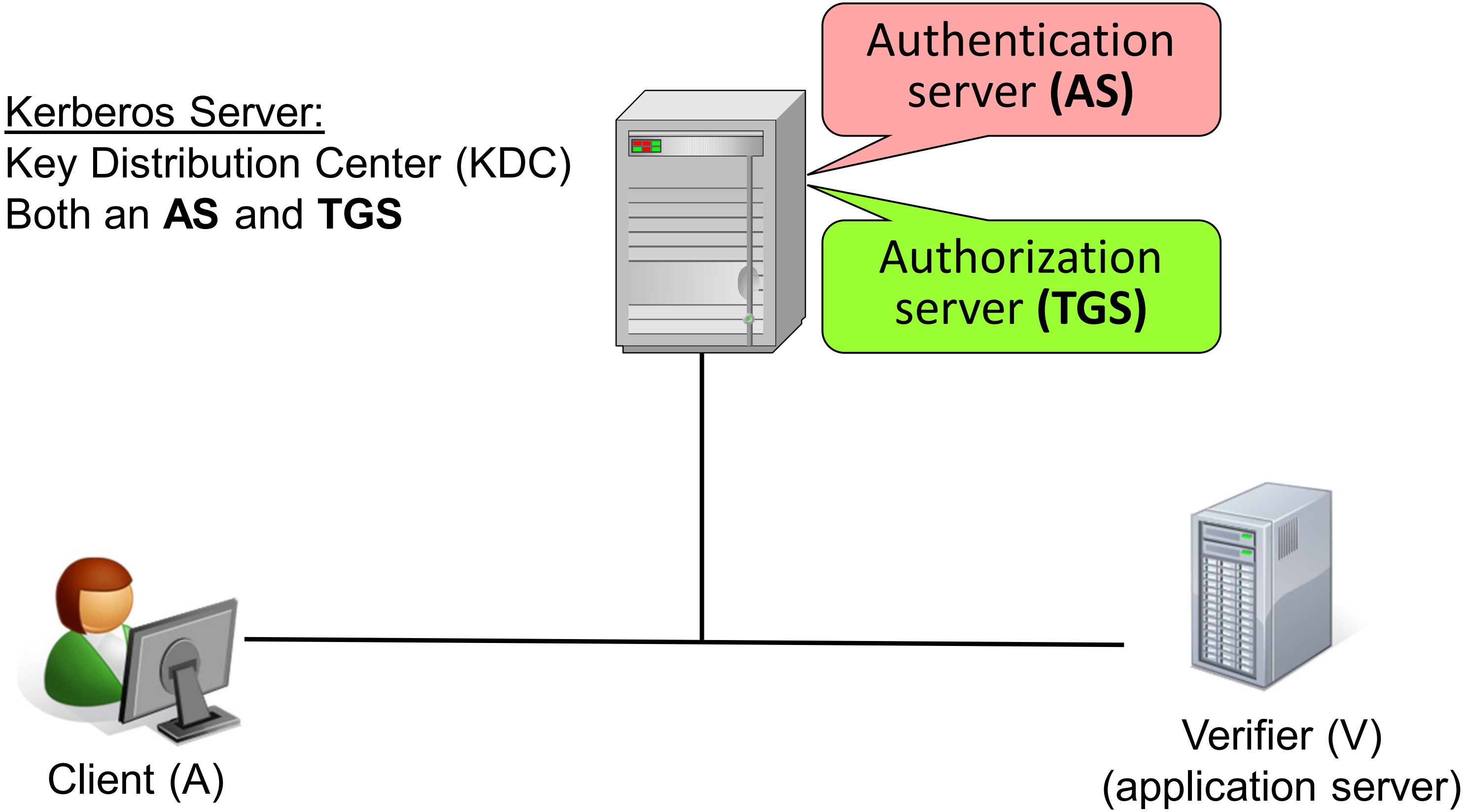
- Secure: An eavesdropper should not be able to impersonate a user
- Reliable: Distributed architecture, servers can back up each other
- Transparent: SSO – Single sign-on
- Scalable: Modular and distributed architecture
- It is suited for large environments:
  - No individual computers have to do authentication
  - Application servers only have to share a secret with the Kerberos server

Windows authentication

- Kerberos is the preferred and default authentication system in Windows
  - Introduced with Windows 2000
  - Default in Active Directory (domain authentication)
  - Also supported by Unix/Linux/MacOS systems
- Replaced the old NTLM v2 protocol: NT LAN Manager authentication (Windows NT4, 1998)
  - Still supported
  - Challenge response authentication using HMAC-MD5
  - No support any recent cryptographic methods (AES and SHA-256)
- LSASS = Local security authority sub-system
  - Keeps credentials for single sign-on (Kerberos tickets, etc.)
  - Windows 10 LSASS process can run in its own container →



The Kerberos System



Kerberos Server:
Key Distribution Center (KDC)
Both an **AS** and **TGS**

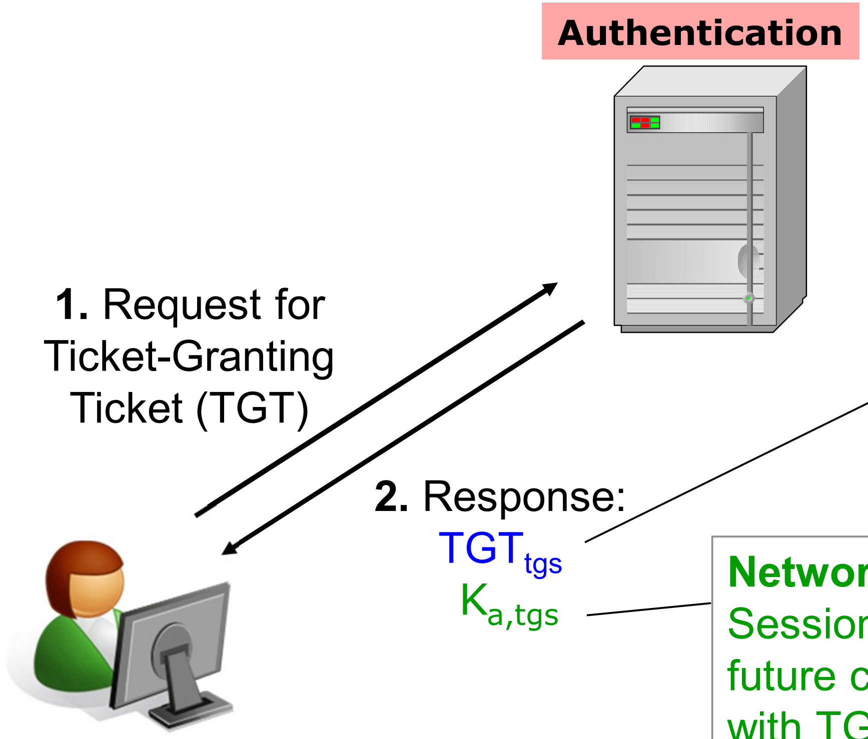
Authentication server **(AS)**

Authorization server **(TGS)**

Client (A)

Verifier (V)
(application server)

Authentication: Getting the TGT



1. Request for Ticket-Granting Ticket (TGT)

2. Response:
TGT_{tgs}
$K_{a,\text{tgs}}$

Client (A)

TGT (**Ticket-Granting Ticket**) is encrypted – only KDC can decrypt

Idea: client keeps state for KDC. Proof that the user is authenticated

Network Login Key: Session key to be used in future communication with TGS.

Authentication messages

Authentication Service Exchange: To obtain Ticket-Granting Ticket

(1) $A \rightarrow AS$: $ID_a \| ID_{tgs} \| TS_1$

(2) $AS \rightarrow A$: $E_{K_a}[K_{a,tgs} \| ID_{tgs} \| TS_2 \| Lifetime_2 \| TGT_{tgs}]$

A cannot read but keeps state for AS

TGT_{tgs}: $E_{K_{tgs}}[K_{a,tgs} \| ID_a \| AD_a \| ID_{tgs} \| TS_2 \| Lifetime_2]$

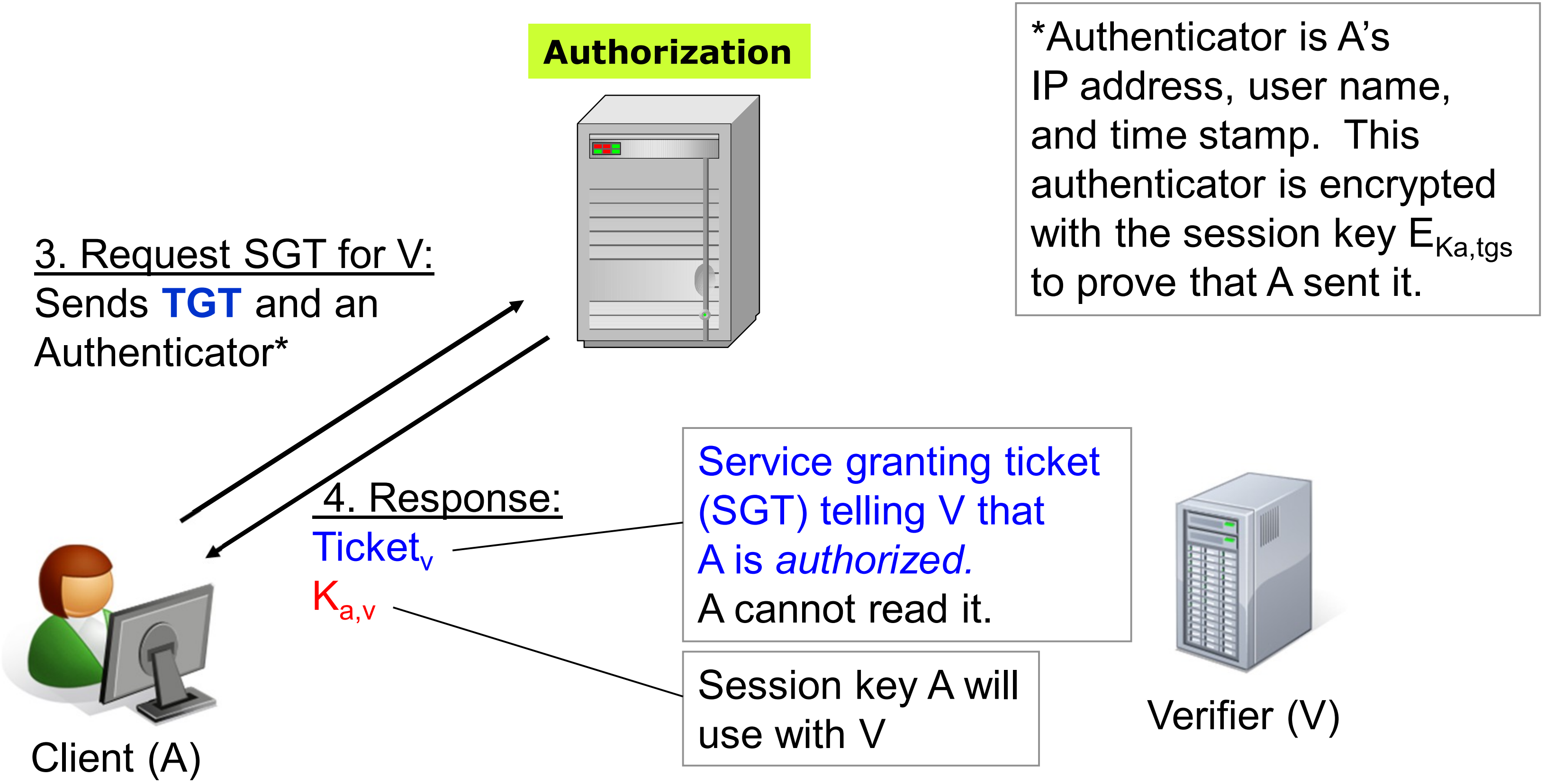
TS	=	Time Stamp
K_a	=	A's master key (next slide)
$K_{a,tgs}$	=	Session key
AD_a	=	Address of A
K_{tgs}	=	Key known only by TGS
Lifetime	=	Lifetime of the session key

Master Keys and passwords

- The master key (K_a) is a hash of the user's password
  - Long term secret
  - The reply from AS is encrypted with K_a and contains the session key $K_{a,tgs}$
  - The master key is used as little as possible
  - It is possible to fake a request for a ticket for someone else…

    … but only the correct user can decrypt and use the ticket
  - To prevent dictionary attacks, different configuration options exist (ignored here)
- A Kerberos server may contact other servers to verify user names and passwords
  - Not only password authentication is supported
- The lifetime of the TGT must be limited
  - If it is stolen (after being decrypted), it should not be valid too long
  - If lifetime is too short, clients will repeatedly ask for new TGTs
  - Kerberos 4: lifetime max 21 hours – was too short for long running applications
- The TGT contains all state information the Kerberos server needs
  - Shows that the user is authenticated
  - The AS does not have to store information about all logged in (authenticated) users

Authorization: Getting the Service Granting Ticket



Authorization

3. Request SGT for V:
Sends **TGT** and an
Authenticator*

*Authenticator is A's IP address, user name, and time stamp. This authenticator is encrypted with the session key $E_{Ka,tgs}$ to prove that A sent it.

4. Response:
Ticket_v
$K_{a,v}$

Service granting ticket (SGT) telling V that A is *authorized.*
A cannot read it.

Session key A will use with V

Client (A)

Verifier (V)

Getting the Service Granting Ticket

Ticket-Granting Service Exchange: To obtain Service-Granting Ticket

(3) A → TGS: $ID_v \| TGT_{tgs} \| Authenticator_a$

(4) TGS → A: $E_{K_{a,tgs}} [K_{a,v} \| ID_v \| TS_4 \| Ticket_v]$

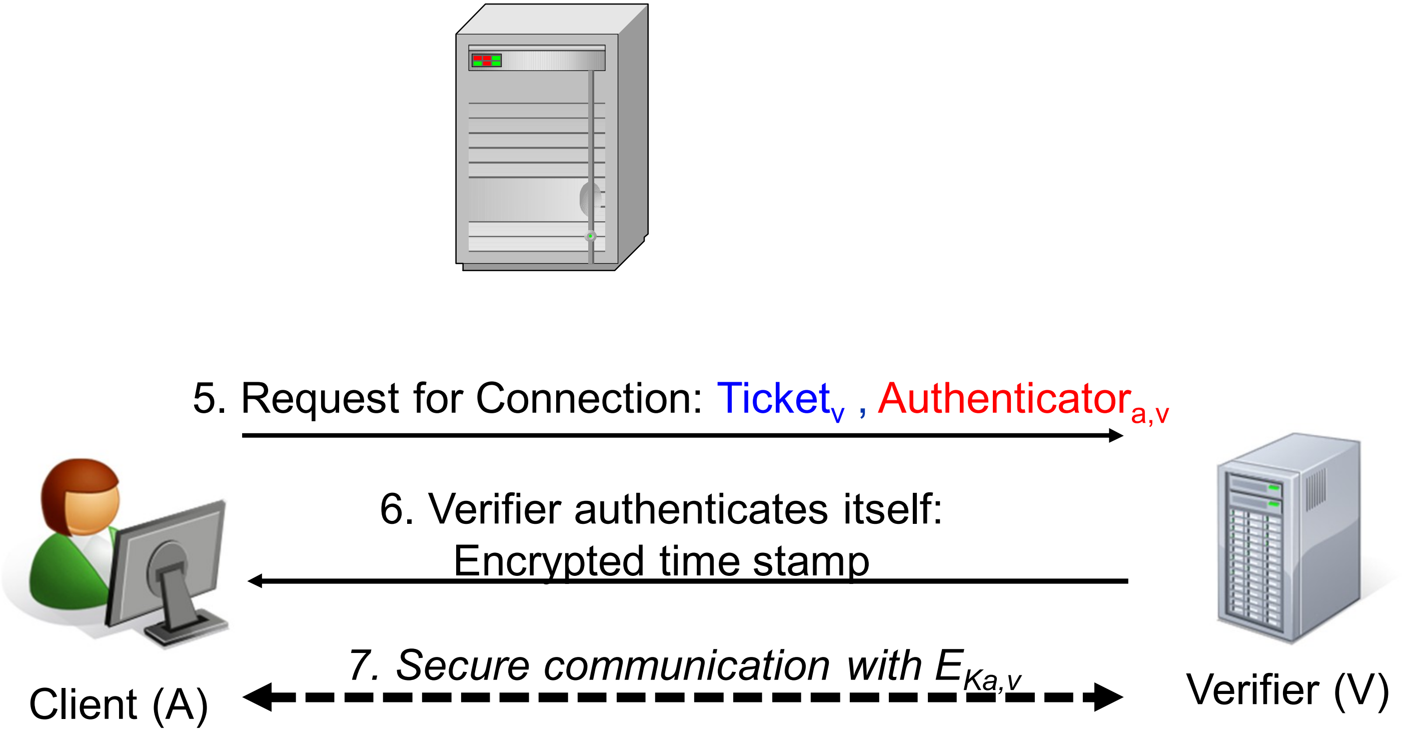
$Authenticator_a$: $E_{K_{a,tgs}} [ID_a \| AD_a \| TS_3]$

A cannot read

$Ticket_V$: $E_{K_V} [K_{a,v} \| ID_a \| AD_a \| ID_v \| TS_4 \| Lifetime_4]$

K_V = V’s master key shared with the Kerberos server
ID_V dropped in version 5 since only V can decrypt message

Service: Connecting to the verifier



5. Request for Connection: Ticket$_v$, Authenticator$_{a,v}$

6. Verifier authenticates itself: Encrypted time stamp

7. Secure communication with $E_{Ka,v}$

Client (A)

Verifier (V)

Connecting to the verifier

Client/Server Authentication Exchange: To Obtain Service

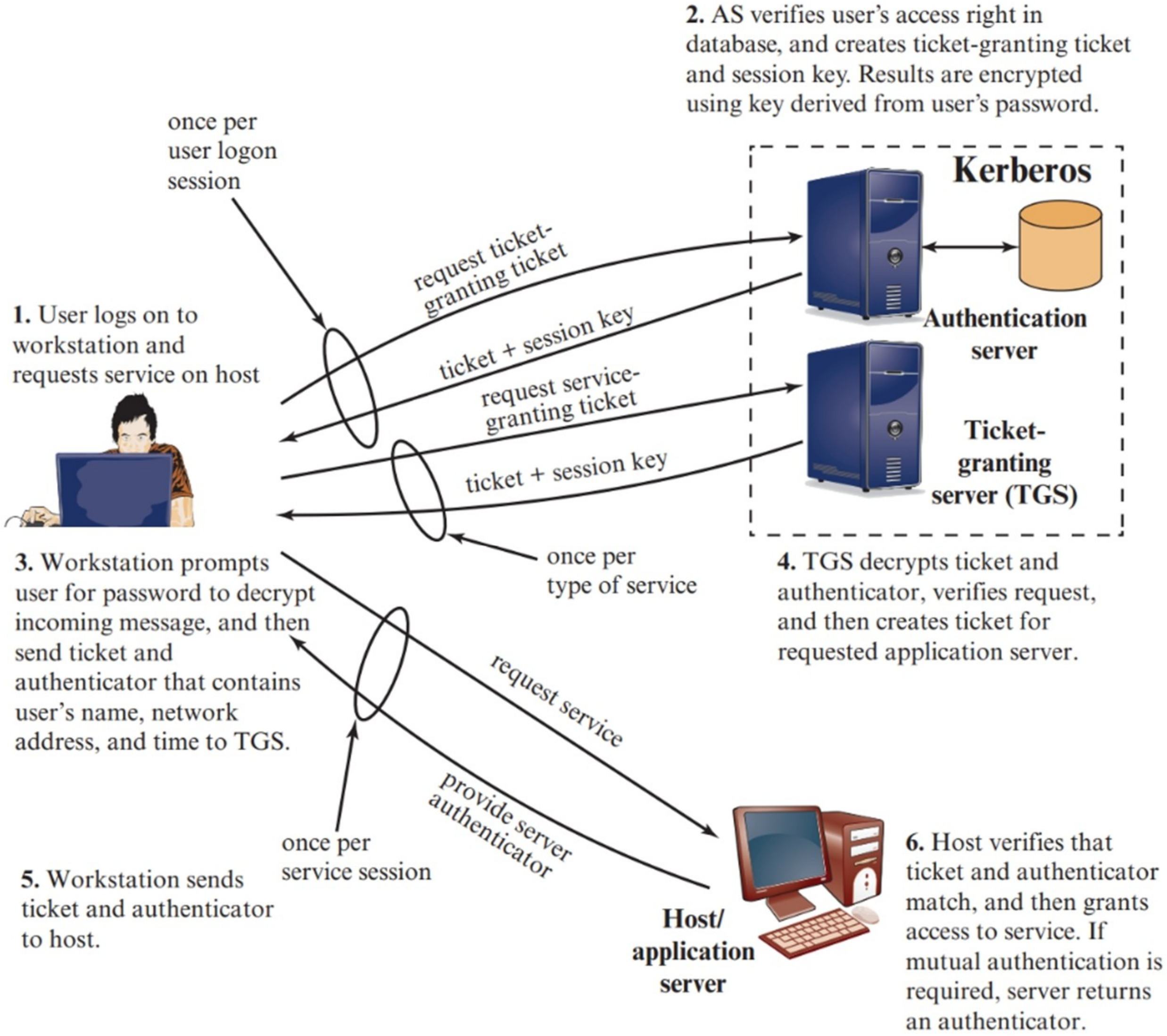
(5) A → V: $\text{Ticket}_v \,||\, \text{Authenticator}_{a,v}$

(6) V → A: $E_{K_{a,v}}[TS_5 + 1]$ (for mutual authentication)

$\text{Authenticator}_{a,v}$: $E_{K_{a,v}}[\,ID_a \,||\, AD_a \,||\, TS_5\,]$

Kerberos: The verifier (V)

- By looking at the Service Granting Ticket, V knows Kerberos has created it
  - It contains the session key to A, its IP address and identity
- The Authenticator proves that A also has the session key
  - It is time stamped to prevent replay attacks
- Ticket lifetime to services (V) must be limited
  - Governed by the domain security policy. Always < 10h (about a working day)
  - New tickets then needs to be generated with new session keys
- No public key/asymmetric encryption is used
  - Kerberos is fast
  - No certificates need to be distributed, although certificates can be used for user authentication
- Implements SSO – Single Sign-on
- Problem: Applications must be “Kerberized” (services need to support tickets)



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

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

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

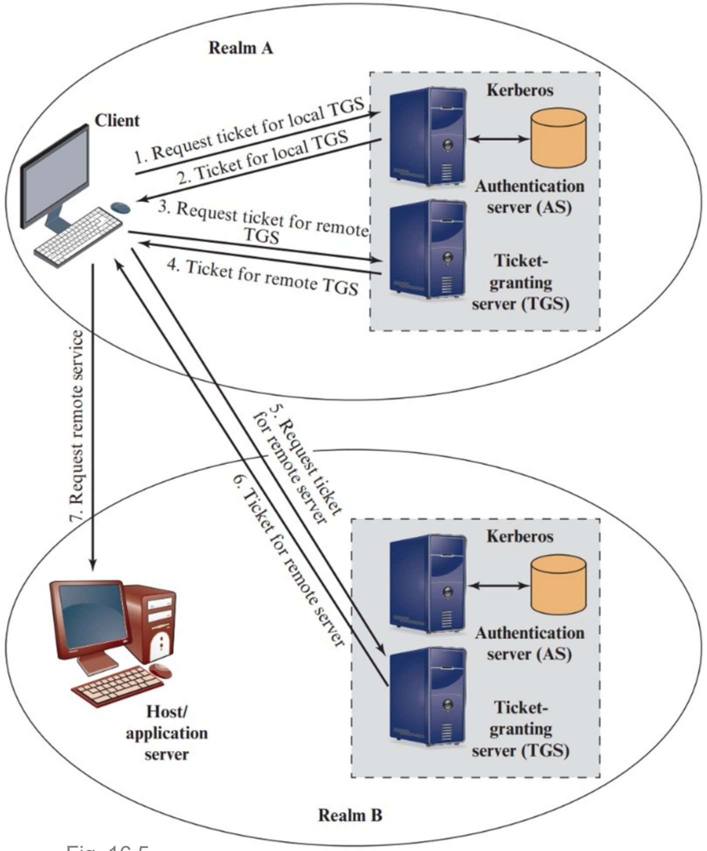
4. TGS decrypts ticket and authenticator, verifies request, and then creates ticket for requested application server.

5. Workstation sends ticket and authenticator to host.

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

Figure 16.3 Overview of Kerberos

Kerberos Realms (Domains)



Realm A
Client
Kerberos
Authentication server (AS)
Ticket-granting server (TGS)
1. Request ticket for local TGS
2. Ticket for local TGS
3. Request ticket for remote TGS
4. Ticket for remote TGS
5. Request ticket for remote server
6. Ticket for remote server
7. Request remote service
Kerberos
Authentication server (AS)
Ticket-granting server (TGS)
Host/ application server
Realm B

Fig. 16.5

- A realm or domain is a collection of computers that share and trust the same set of user accounts
- Inter-domain keys make it possible to create trusting domains:
  - Possible to get session tickets in other domains through foreign KDCs
  - Clients get a “referral” key from the local KDC
  - Client then contacts foreign KDC with this key
  - Foreign KDC can decrypt it with the Inter-domain key
  - The referral key shows that the client is trusted
- This can be done in multiple steps
  - Each server issues a new referral key
  - The final KDC may issue both a session key and a TGT to make sure the client can talk directly to this KDC next time

Kerberos

- For time stamps to work properly, clocks need to be in sync
  - Default is within 5 minutes
- Version 5 enhancements [1993]:
  - Authenticators are valid 5 minutes
  - Master key only used once (when being authenticated)
  - New encryption algorithms such as AES (not just DES)
  - V5 allows arbitrary TGT ticket lifetimes (was earlier 21 hours)
- Possible to grant another entity to request tickets on behalf of us
  - The new entity will get a *special TGT* to request session tickets
  - Example: Web server needs to contact a database server; it cannot use its own credentials if it is working on behalf of the user

Summary

- Kerberos implements single sign-on (SSO)
- Kerberos performs both authentication and authorization
  - Authorization by the Ticket Granting server
- Two types of tickets:
  - TGT - Ticket Granting Ticket
  - SGT - Service Granting Tickets
- In a realm:
  - Kerberos server (AS) stores hashed passwords for all its users
  - Kerberos server has a secret key with each application server
  - Cross-realm trust is possible
- Microsoft Active Directory is a Kerberos implementation