Kerberos for Distributed Systems Security

Cunsheng Ding
HKUST, Hong Kong, CHINA

Agenda

- Distributed system security
- Introduction to Kerberos V4
- Kerberos Realms
- Authentication with Kerberos in Windows NT 5 and Windows 2000
- Kerberos in Unix-like operating systems

Distributed Systems Security

Distributed Systems

- **A distributed system**: a collection of computers linked via some network.
- **Characteristic**: The components of the distributed system may be under the authority of different organizations, and may be governed by different security policies.
- Example: The Internet

Security Issues in Distributed Systems (1)

- Impersonation of user:
  - A user may gain access to a particular workstation and pretend to be another user operating from that workstation.
- Impersonation of workstation:
  - A user may alter the network address of a workstation so that the requests sent from the altered workstation appear to come from the impersonated workstation.

Security Issues in Distributed Systems (2)

- **Replay attacks:**
  - A user may eavesdrop on exchanges and use a replay attack to gain entrance to a server or to disrupt operations.
- **Conclusion:**
  - In any of these cases, an unauthorized user may be able to gain access to services and data that he or she is not authorized to access.

Security Services in Distributed Systems

- Authentication **********
- Guarding the boundaries of internal networks
  - Firewalls
- Access control to distributed objects
  - Access control techniques
- Availability
  - Counter DoS techniques

Security Policies

- **Fact**: In a distributed system, users are not necessarily registered at the node they are accessing an object.
- **Question**: How to authenticate a user?
- **Question**: What is the basic for access control decisions?

Basis for Authentication and Access Control

- The user identity and password;
- the network address the user operates from;
  - e.g., any machine in UST can access Elsevier database;
- the distributed service the user is invoking, i.e., the access operation.
  - Anyone can read but cannot modify documents posted on my personal web page.

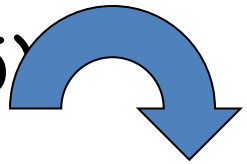
Examples: Unix System

- **ftp**: transfer files between Unix systems.
- **telnet**, **rlogin**: remote access
  - use user identity and password for authentication;
  - use the normal Unix access control.
- **New problem**: How can my password travel through the network securely?

Security Enforcement

- Once you have sorted out security policies, you have to decide where to enforce them!
  - Where in the system do you authenticate a user?
  - Where in the system do you make an access control decision?

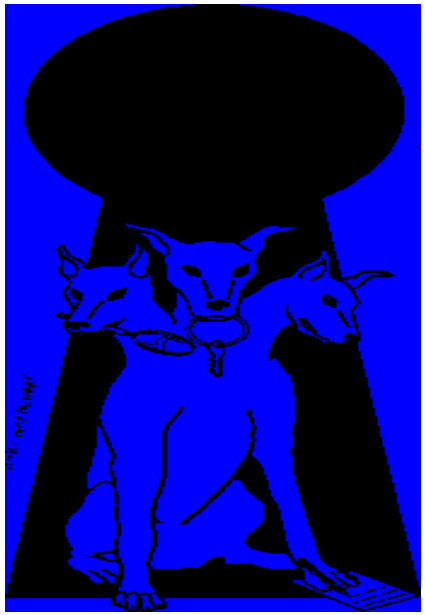
Authentication: Kerberos (v4 and V5)



Kerberos Version 4

Kerberos Version 4

- Centralized network authentication service
- Developed in the Project Athena in MIT



Environment Addressed

- An open distributed environment in which
  - Users at workstations wish to access services on servers distributed throughout the network.
  - Servers can:
    - restrict access to authorized users and
    - authenticate requests for service.
  - Workstations cannot be trusted to identify its users correctly to network services.

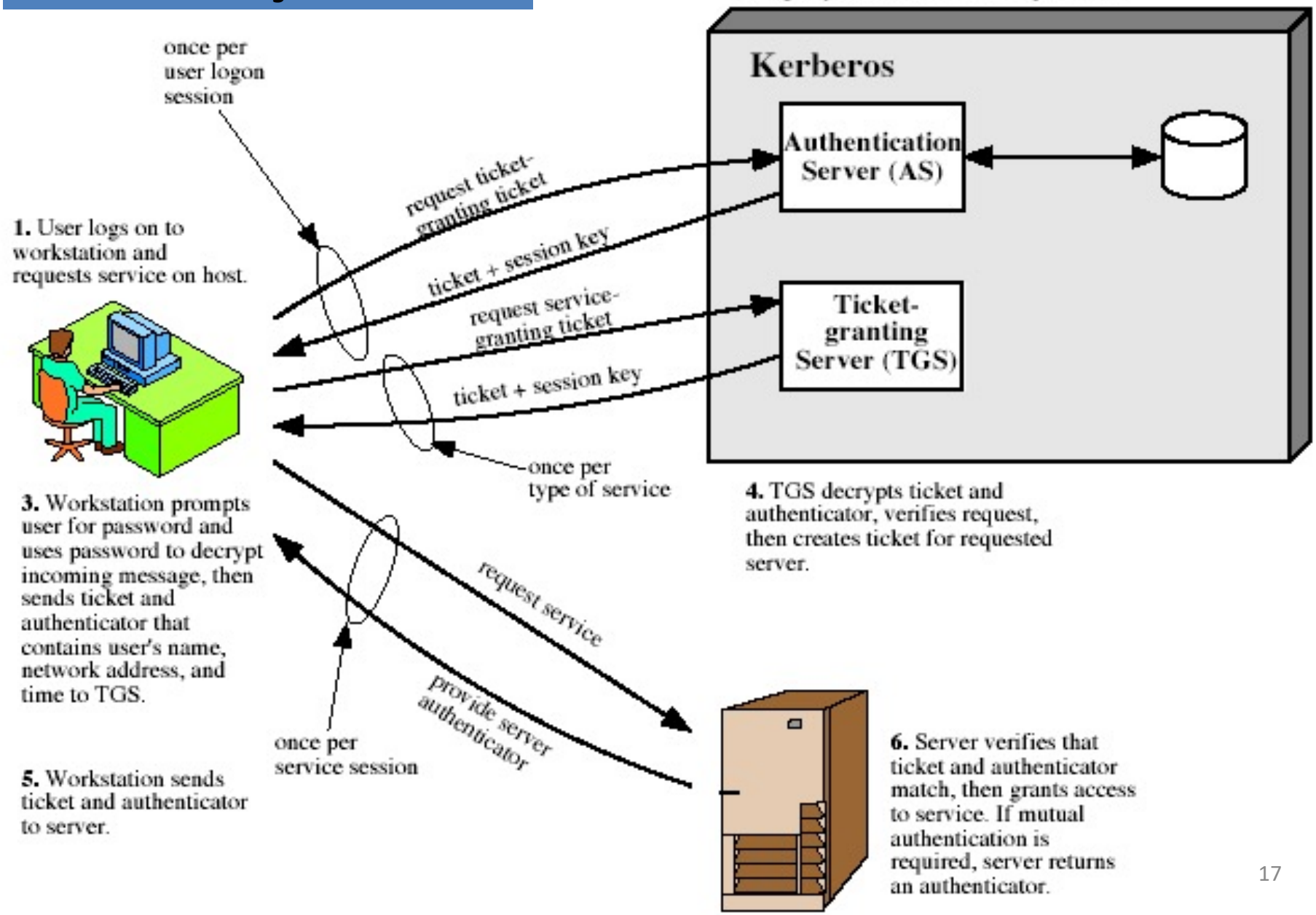
Requirements for Kerberos

- **Secure**: Opponent cannot impersonate a user and the Kerberos service should not be a weak link.
- **Reliable**: Highly reliable Kerberos service to ensure availability of supported services of application servers.
- **Transparent** : Users are only required to enter a password once and don't know the authentication.
- **Scalable**: System can support large numbers of clients and servers.

Kerberos 4 Overview

- A basic third-party authentication scheme
- Have an Authentication Server (AS)
  - users initially negotiate with AS to identify self
  - AS provides a non-corruptible authentication credential (ticket granting ticket TGT)
- Have a Ticket Granting server (TGS)
  - users subsequently request access to other services from TGS on the basis of user's TGT

1. Each user shares a key with AS
2. TGS shares a key with AS
3. All servers are registered with TGS



Further Information

- Only one symmetric cipher, i.e., DES, is used in Version 4. In version 5, AES is used.
- Each client needs to share a secret key with the AS only.
- AS and TGS share a secret key for authentication.
- Each server shares a secret key with the TGS.
- ID, timestamp, network address are used for authentication.
- Technical details of the protocol is omitted here (see Appendix).

Kerberos Realm

- Kerberos realm:
  - The environment that one Kerberos server can manage the authentication process.
- The environment of one realm:
  - The Kerberos server of one realm has all users ID & hashed password of all users in the realm.
  - The Kerberos server must share a secret key with each server.
  - All servers are registered with the Kerberos server.

Authentication with Kerberos in Windows NT and Windows 2000

Authentication in Windows NT 5 and Windows 2000

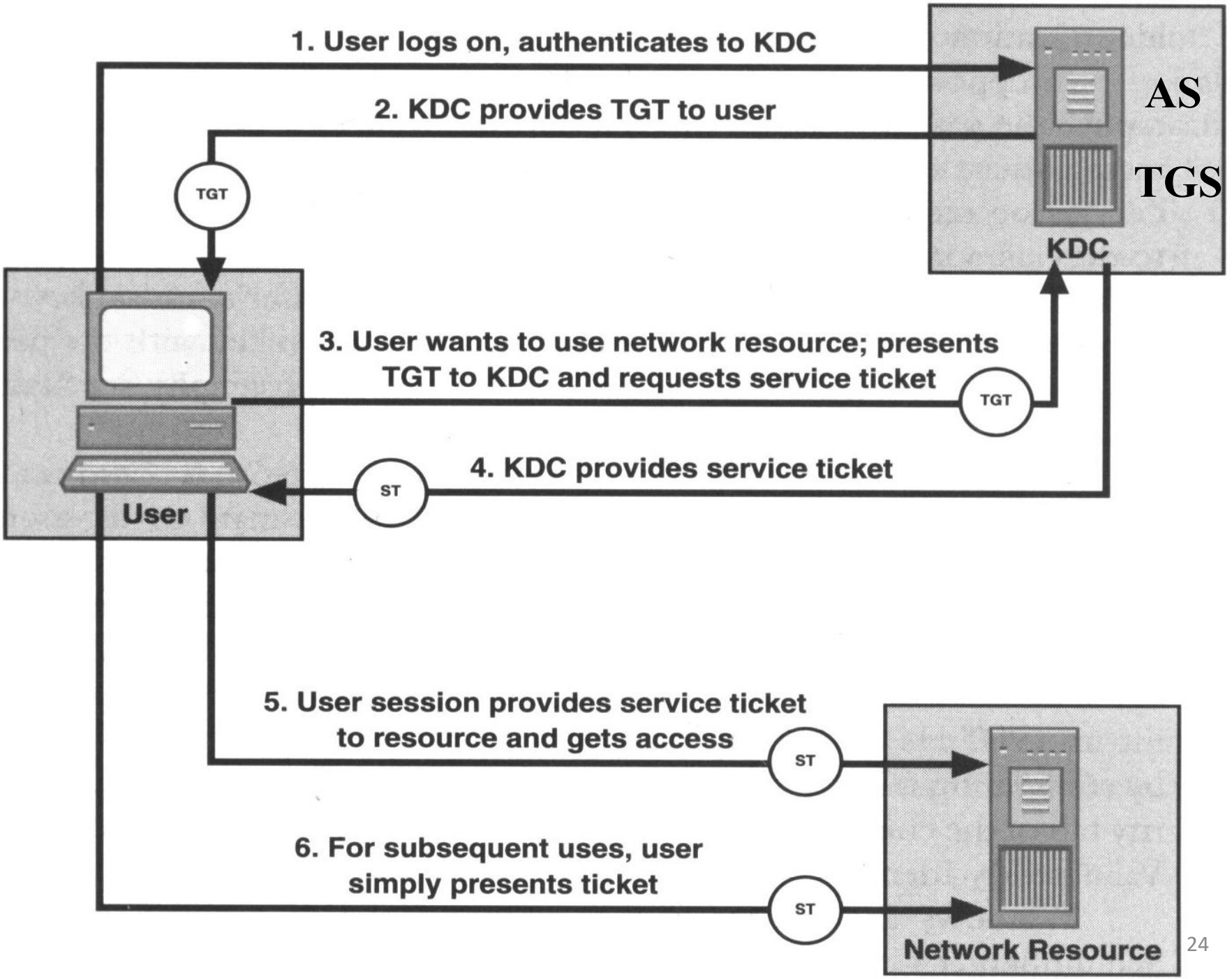
- The main objective is to present the basic idea without technical details.
- Those who wish to have details should read Kerberos 5 and details of Windows NT 5 and Windows 2000.

The Basic Idea

- Use a KDC to run the AS and TGS in Kerberos.
- The KDC is located in the Domain Controller.
- Use the TGT and service ticket as access tokens.

Initial Kerberos Ticket
Ticket Granting Ticket (TGT)

- First ticket is a Ticket Granting Ticket
  - Used by client to get tickets to other services
  - Contains *authorization data* based on group membership and privileges
- Ticket is encrypted in user's key known by the KDC
  - Requires knowledge of password to use
- Tickets are stored in a ticket cache managed by LSA (Local Security Authority).


1. User logs on, authenticates to KDC
2. KDC provides TGT to user
TGT
AS
TGS
KDC
3. User wants to use network resource; presents TGT to KDC and requests service ticket
TGT
4. KDC provides service ticket
ST
User
5. User session provides service ticket to resource and gets access
ST
6. For subsequent uses, user simply presents ticket
ST
Network Resource

Comments on Kerberos Authentication

- Single Sign-On (SSO)
  - Simple administration
  - Good administrative control
  - Good user productivity
  - Good network security

Kerberos in Unix-like Operating Systems

- FreeBSD, Apple's Mac OS X, Red Hat Enterprise Linux, Oracle's Solaris, IBM's AIX and Z/OS, HP's HP-UX and OpenVMS
- It is used for Kerberos authentication of **users** or **services**.

Two Ideas in Kerberos

- Protocol 1
  - A → E_k(ID_A|ID_B|timestamp) → B
  - What security services are provided by this protocol?
- Protocol 2
  - A → E_k(ID_A|ID_B|AD_B|ID_V|Period validity) → B
  - V is the email server, AD_B is B's network address
  - K is a secret key shared by A and V
  - It is a ticket for B issued by A. B can use it for email services many times.

Appendix: Details of Kerberos V4

Version 4 Authentication Dialogue (3)

(a) Authentication Service Exchange: to obtain ticket-granting ticket

(1) **C → AS:** $ID_c \| ID_{tgs} \| TS_1$

(2) **AS → C:** $E_{K_c}[K_{c,tgs} \| ID_{tgs} \| TS_2 \| Lifetime_2 \| Ticket_{tgs}]$

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

(b) Ticket-Granting Service Exchange: to obtain service-granting ticket

(3) **C → TGS:** $ID_v \| Ticket_{tgs} \| Authenticator_c$

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

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

$Ticket_v = E_{K_V}[K_{c,v} \| ID_c \| AD_c \| ID_v \| TS_4 \| Lifetime_4]$

$Authenticator_c = E_{K_{c,tgs}}[ID_c \| AD_c \| TS_3]$

(c) Client/Server Authentication Exchange: to obtain service

(5) **C → V:** $Ticket_v \| Authenticator_c$

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

$Ticket_v = E_{K_V}[K_{c,v} \| ID_c \| AD_c \| ID_v \| TS_4 \| Lifetime_4]$

$Authenticator_c = E_{K_{c,v}}[ID_c \| AD_c \| TS_5]$

Index

- k_c the secret key shared between C and the AS.
- $k_{c,\,tgs}$ the session key for C and TGS, generated by the AS.
- $k_{c,v}$ the session key for C and V, generated by the TGS.
- k_{tgs} the secret key shared between the TGS and the AS.
- TS, timestamp
- ID_c, C's ID
- AD_c, C's network address.