INFS 766
Internet Security Protocols

Lecture 9
Kerberos

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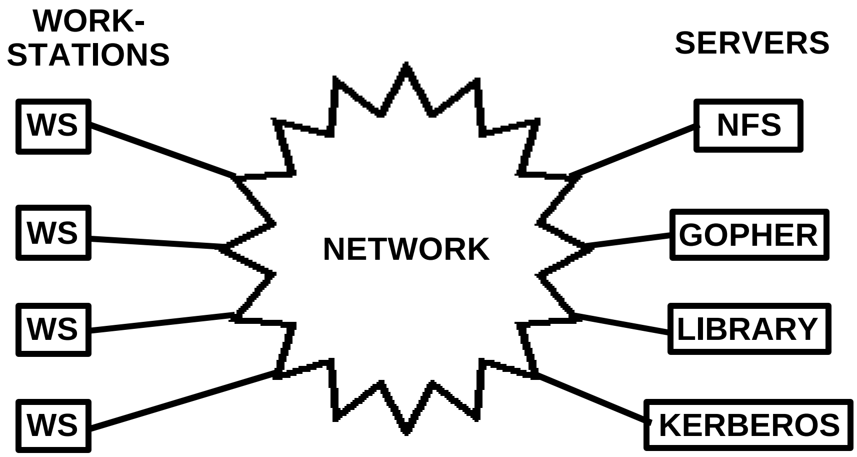
SYSTEM MODEL



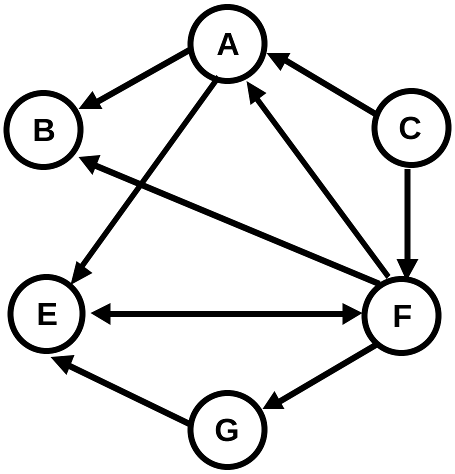
PHYSICAL SECURITY

- ❖ **CLIENT WORKSTATIONS**
  - ➢ **None, so cannot be trusted**
- ❖ **SERVERS**
  - ➢ **Moderately secure rooms, with moderately diligent system administration**
- ❖ **KERBEROS**
  - ➢ **Highly secure room, with extremely diligent system administration**

KERBEROS OBJECTIVES

- ❖ **provide authentication between any pair of entities**
- ❖ **primarily used to authenticate user-at-workstation to server**
- ❖ **in general, can be used to authenticate two or more secure hosts to each other on an insecure network**
- ❖ **servers can build authorization and access control services on top of Kerberos**

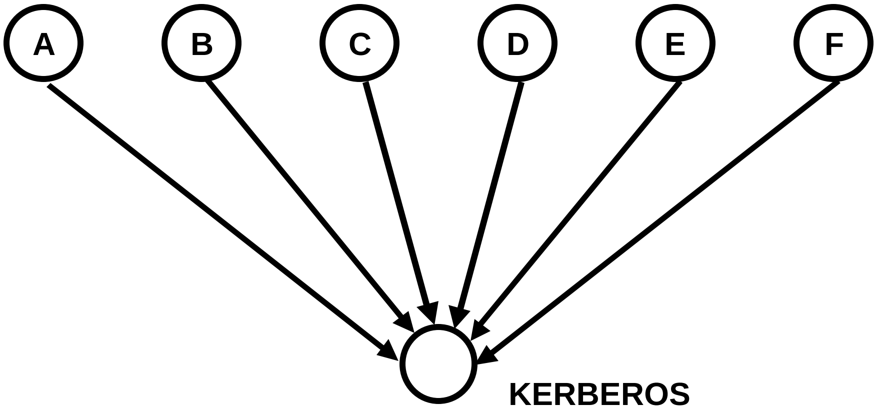
TRUST:
BILATERAL RHOSTS MODEL

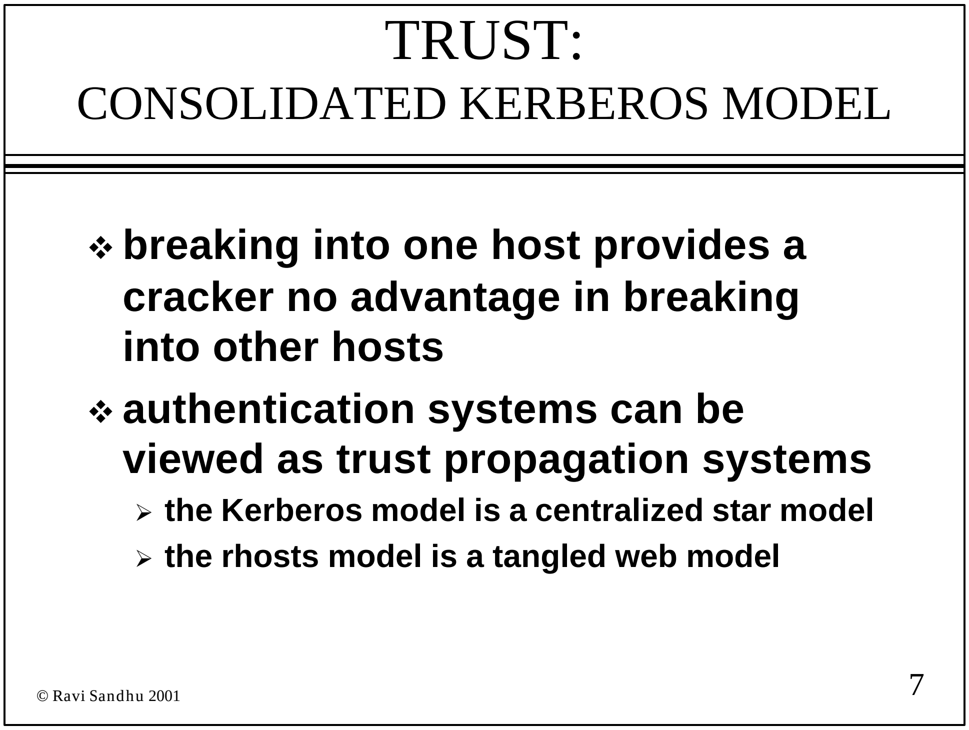


A → B

A trusts B
A will allow users logged onto B to log onto A without a password

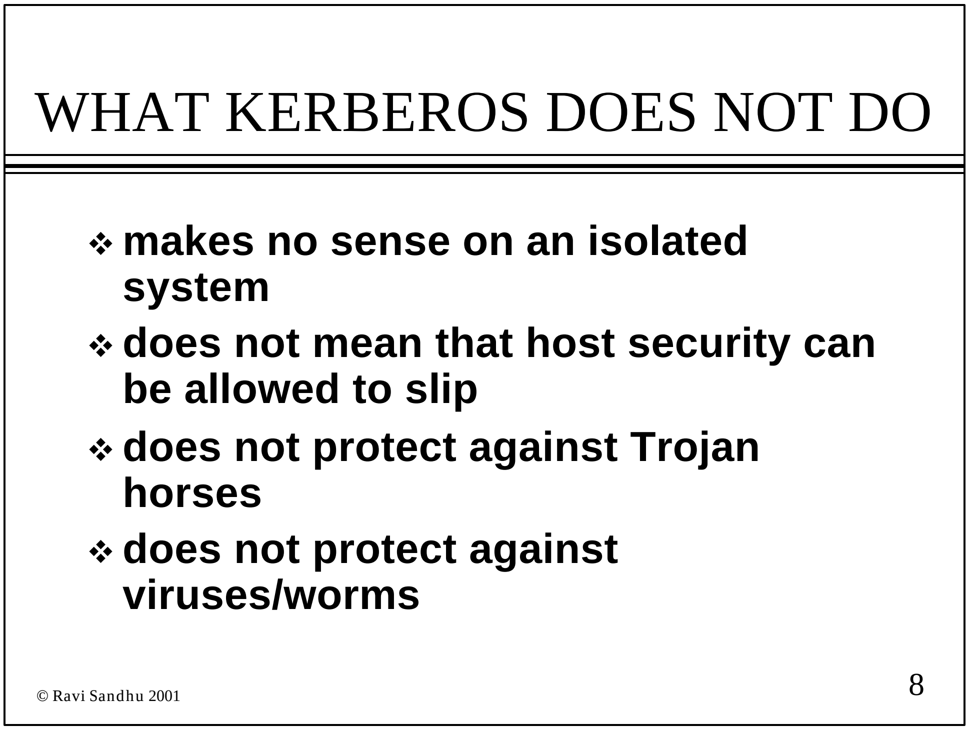
TRUST:
CONSOLIDATED KERBEROS MODEL





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
  - the rhosts model is a tangled web model



WHAT KERBEROS DOES NOT DO

- makes no sense on an isolated system
- does not mean that host security can be allowed to slip
- does not protect against Trojan horses
- does not protect against viruses/worms

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

KERBEROS DESIGN DECISIONS

- Uses timestamps to avoid replay. Requires time synchronized within a small window (5 minutes)
- Uses DES-based symmetric key cryptography
- stateless

KERBEROS VERSIONS

- We describe Kerberos version 4 as the base version
- Kerberos version 5 fixes many shortcomings of version 4, and is described here by explaining major differences with respect to version 4

NOTATION

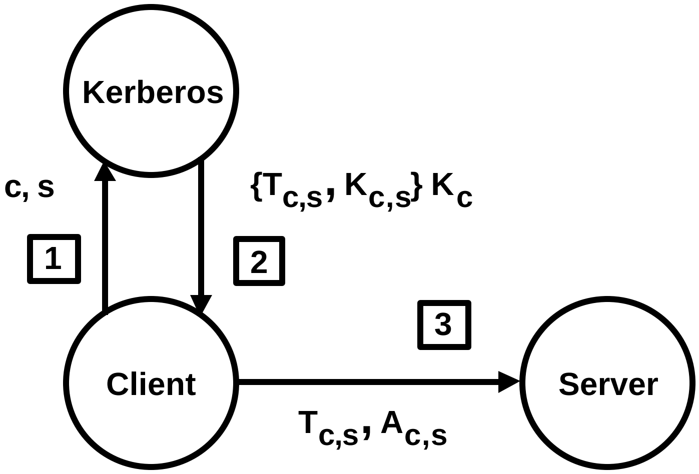
c	client principal
s	server principal
K_x	secret key of “x” (known to x and Kerberos)
$K_{c,s}$	session key for “c” and “s” (generated by Kerberos and distributed to c and s)
$\{P\}K_q$	P encrypted with K_q
$T_{c,s}$	ticket for “c” to use “s”(given by Kerberos to c and verified by s)
$A_{c,s}$	authenticator for “c” to use “s” (generated by c and verified by s)

TICKETS AND AUTHENTICATORS

- ❖ $T_{c,s}$= $\{s, c, addr, time_o, life, K_{c,s}\}K_s$
- ❖ $A_{c,s}$= $\{c, addr, time_a\}K_{c,s}$

- ❖ addr is the IP address, adds little removed in version 5

SESSION KEY DISTRIBUTION



Kerberos

Client

Server

1 c, s

2 $\{T_{c,s}, K_{c,s}\} K_c$

3 $T_{c,s}, A_{c,s}$

USER AUTHENTICATION

- **for user to server authentication, client key is the user's password (converted to a DES key via a publicly known algorithm)**

TRUST IN WORKSTATION

- **untrusted client workstation has K_c**
- **is expected to delete it after decrypting message in step 2**
- **compromised workstation can compromise one user**
- **compromise does not propagate to other users**

AUTHENTICATION FAILURES

- Ticket decryption by server yields garbage
- Ticket timed out
- Wrong source IP address
- Replay attempt

KERBEROS IMPERSONATION

- active intruder on the network can cause denial of service by impersonation of Kerberos IP address
- network monitoring at multiple points can help detect such an attack by observing IP impersonation

KERBEROS RELIABILITY

- availability enhanced by keeping slave Kerberos servers with replicas of the Kerberos database
- slave databases are read only
- simple propagation of updates from master to slaves

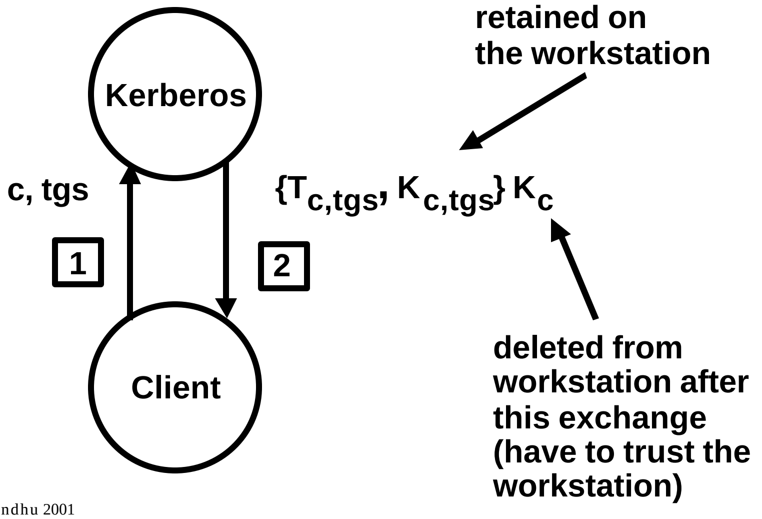
USE OF THE SESSION KEY

- Kerberos establishes a session key $K_{c,s}$
- session key can be used by the applications for
  - client to server authentication (no additional step required in the protocol)
  - mutual authentication (requires fourth message from server to client $\{f(A_{c,s})\}K_{c,s}$, where f is some publicly known function)
  - message confidentiality using $K_{c,s}$
  - message integrity using $K_{c,s}$

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)**

TICKET-GRANTING SERVICE

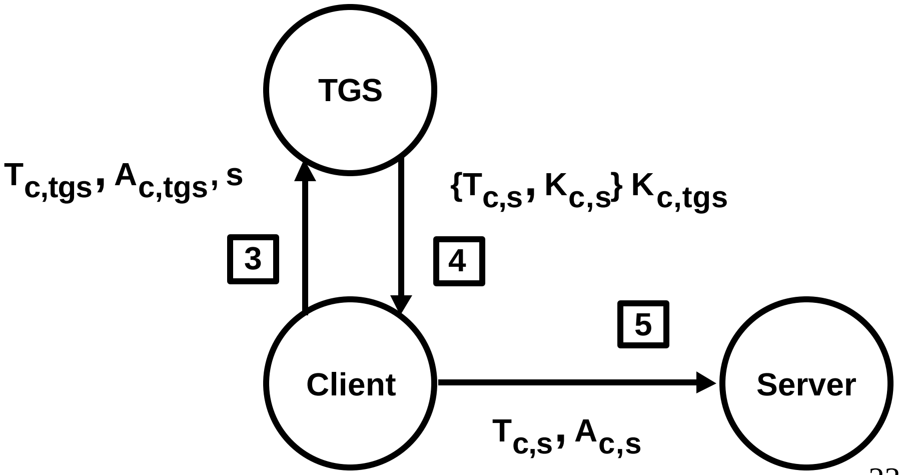


retained on the workstation

$\{T_{c,tgs}, K_{c,tgs}\} K_c$

deleted from workstation after this exchange (have to trust the workstation)

TICKET-GRANTING SERVICE



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TICKET LIFETIME

- ❖ **Life time is minimum of:**
  - ➢ **requested life time**
  - ➢ **max lifetime for requesting principal**
  - ➢ **max lifetime for requesting service**
  - ➢ **max lifetime of ticket granting ticket**
- ❖ **Max lifetime is 21.5 hours**

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NAMING

- Users and servers have same name format:
  - name.instance@realm
- Example:
  - sandhu@isse.gmu.edu
  - sandhu.root@isse.gmu.edu
  - rcmd.ipc4@isse.gmu.edu
  - rcmd.csis@isse.gmu.edu
- Mapping of Kerberos authentication names to local system names is left up to service provider

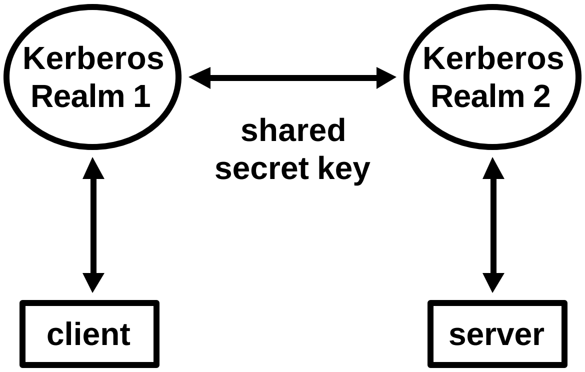
KERBEROS V5 ENHANCEMENTS

- Naming
  - Kerberos V5 supports V4 names, but also provides for other naming structures such as X.500 and DCE
- Timestamps
  - V4 timestamps are Unix timestamps (seconds since 1/1/1970). V5 timestamps are in OSI ASN.1 format.
- Ticket lifetime
  - V4 tickets valid from time of issue to expiry time, and limited to 21.5 hours.
  - V5 tickets have start and end timestamps. Maximum lifetime can be set by realm.

KERBEROS V5 ENHANCEMENTS

- Kerberos V5 tickets are renewable, so service can be maintained beyond maximum ticket lifetime.
- Ticket can be renewed until min of:
  - requested end time
  - start time + requesting principal’s max renewable lifetime
  - start time + requested server’s max renewable lifetime
  - start time + max renewable lifetime of realm

KERBEROS INTER-REALM AUTHENTICATION



KERBEROS INTER-REALM AUTHENTICATION

- **Kerberos V4 limits inter-realm interaction to realms which have established a shared secret key**
- **Kerberos V5 allows longer paths**
- **For scalability one may need public-key technology for inter-realm interaction**

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**