# INFS 766
# Internet Security Protocols

## Lecture 9
## Kerberos

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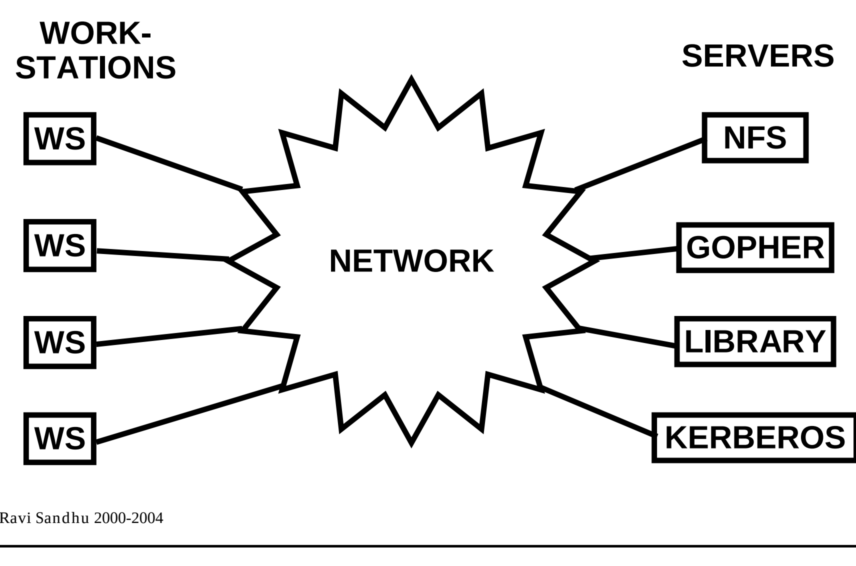
## SYSTEM MODEL



# PHYSICAL SECURITY

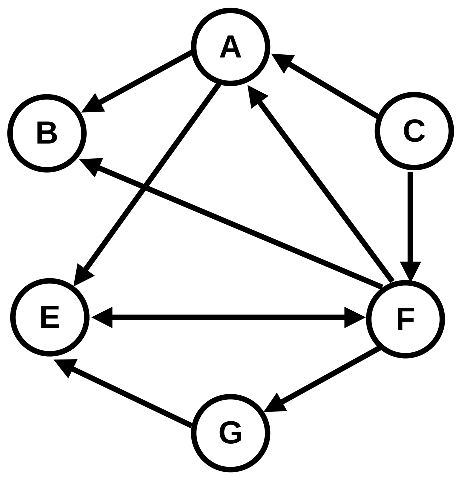
- **CLIENT WORKSTATIONS**
  - **None, so cannot be trusted**
- **SERVERS**
  - **Moderately secure rooms, with moderately diligent system administration**
- **KERBEROS**
  - **Highly secure room, with extremely diligent system administration**




# 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

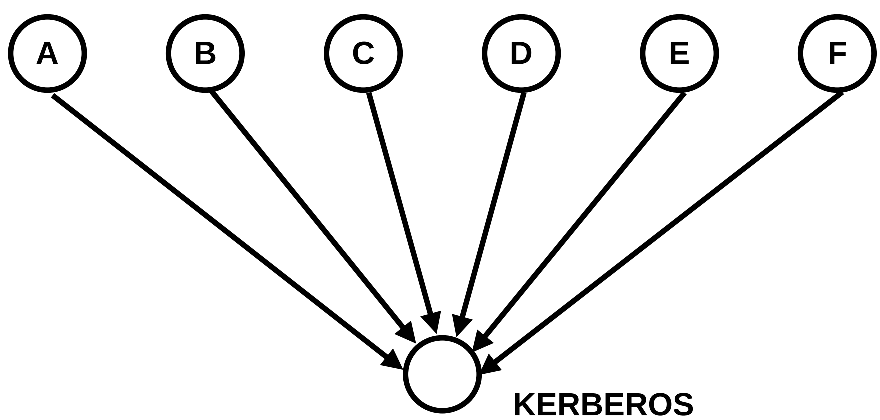




**A trusts B**
**A will allow users logged onto B to log onto A without a password**




# 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)** |

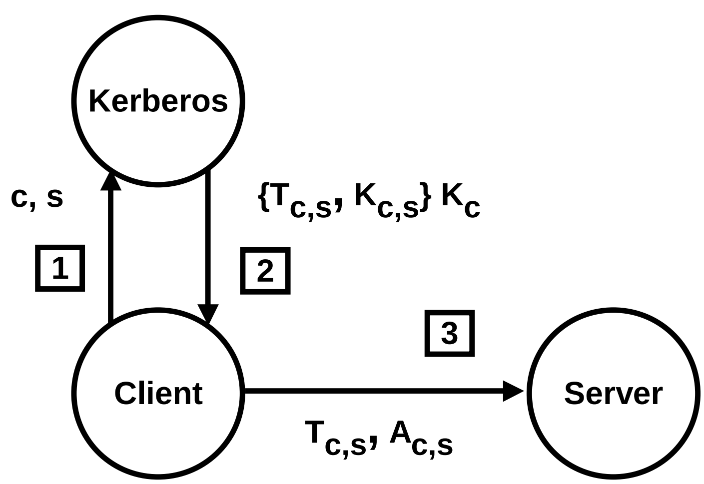
# TICKETS AND AUTHENTICATORS

- **$T_{c,s}$ = {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



# 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

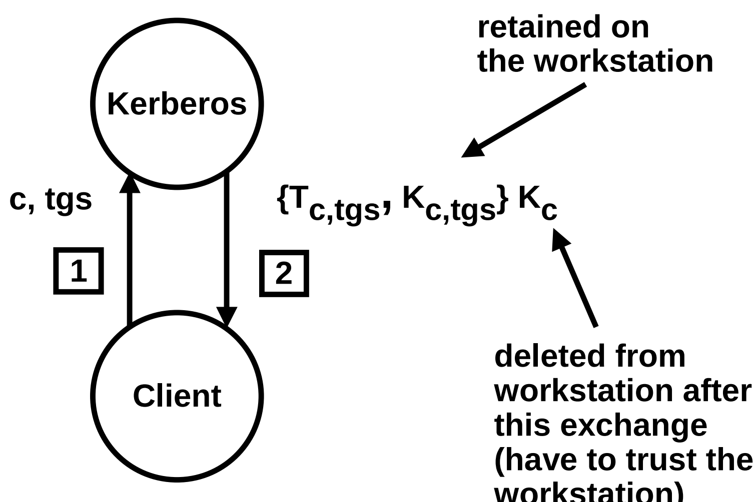
- Kerberos establishes a session key $K_{c,s}$
- session key can be used by the applications for
  - client to server authentication (no additional step required in the protocol)
  - mutual authentication (requires fourth message from server to client $\{f(A_{c,s})\}K_{c,s}$, where f is some publicly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

# TICKET-GRANTING SERVICE

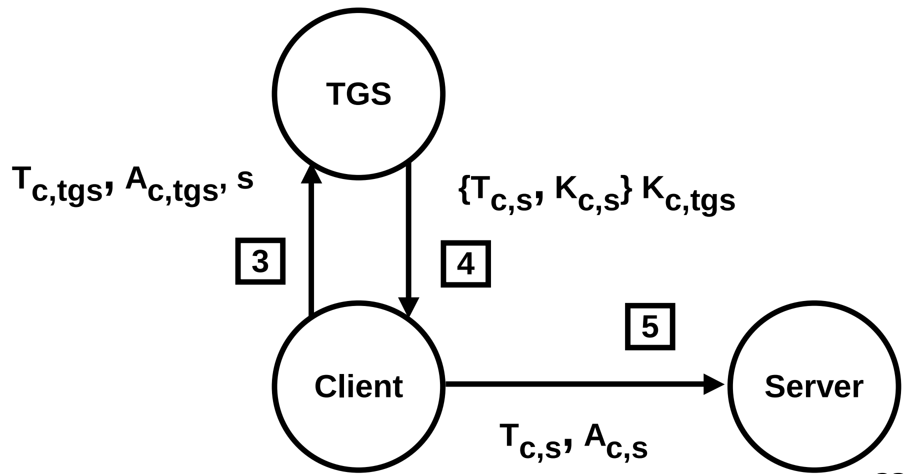
- **Problem: Transparency**
  - **user should provide password once upon initial login, and should not be asked for it on every service request**
  - **workstation should not store the password, except for the brief initial login**
- **Solution: Ticket-Granting Service (TGS)**
  - **store session key 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



# TICKET-GRANTING SERVICE







# 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**

# 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

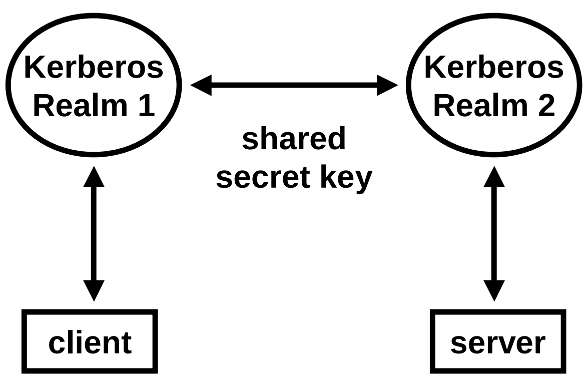
- Naming
  - Kerberos V5 supports V4 names, but also provides for other naming structures such as X.500 and DCE
- Timestamps
  - V4 timestamps are Unix timestamps (seconds since 1/1/1970). V5 timestamps are in OSI ASN.1 format.
- Ticket lifetime
  - V4 tickets valid from time of issue to expiry time, 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