

# **The Kerberos Authentication System**

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# Why Study Kerberos?

- One of **most widely used authentication systems**, implemented in many, many UNIXes for a variety of services
- Simple example of use of cryptography to solve **practical authentication problems**
- Imperfect; **weaknesses instructive**

# Kerberos: Goals

- Authentication of diverse entities, for diverse services:
  - Users, client machines, server machines
  - File systems, remote login, file transfer, printing, &c.
- Authentication in an “open environment”
  - Users may be superuser on their own workstations (so may adopt any user ID if credentials over network unauthenticated); hardware not centrally controlled
  - Same user population may use many machines and services (e.g., labs of public-access machines on a campus)
- Drop-in replacement of passwords for pre-existing protocols
  - Convenient; strength of security?

# Kerberos Model: Central Authority

- Within a site (e.g., MIT), a central database server stores **names and secret keys for all principals**
  - Keys are for 56-bit DES symmetric-key cipher
  - Now **brute-forceable**; more reasonable at time of Kerberos' first use (1988)
- All users and machines are principals, named with **human-readable names**
- All principals **trust central database server**

# Kerberos Principal Names

- Users: e.g., bkarp
  - Can have **instances**; sub-names of a principal, e.g., bkarp.mail, bkarp.root
- Machines: e.g., boffin, arkell, sonic
- Services: e.g., rlogin.sonic (instance of the rlogin service running on sonic)
- Site name: **realm**; all machines in one administrative domain share one central Kerberos database, in same realm
- name.instance@realm, e.g., bkarp@UCL.AC.UK

# Kerberos Protocol

- Goal: mutually authenticated communication
  - Two principals wish to communicate
  - Principals know each other by name in central database
  - Kerberos establishes shared secret between the two
  - Can use shared secret to encrypt or MAC subsequent communication
  - [Few “Kerberized” services encrypt, and none MAC!]
- Approach: leverage keys shared with central database
  - Central database trusted by/has keys for all principals

# Kerberos Credentials

- Client can either be user or machine, depending on context
- To talk to server  $s$ , client  $c$  needs **shared secret key** and **ticket**:
  - **Session key**:  $K_{s,c}$  (randomly generated by central database)
  - **Ticket**:  
$$T = \{s, c, \text{addr}_c, \text{timestamp}, \text{lifetime}, K_{s,c}\}_{K_s}$$
  
(where  $K_s$  is key  $s$  shares with database)
  - Only server  $s$  can decrypt ticket

## Kerberos Credentials (2)

- Given ticket, client creates authenticator:
  - Authenticator:  
 $A = \{c, \text{addr}_c, \text{timestamp}\}_{K_{s,c}}$
  - Client must know  $K_{s,c}$  to create authenticator
  - Authenticator can **only be used once**
- Client presents both ticket T and authenticator A to server when requesting an operation
  - T convinces server that  $K_{s,c}$  was given to c
  - A intended to **prevent replay of requests**
- “Kerberized” protocols use authenticator in place of password



# Getting the User's First Ticket

- User logs in at console with username and password (username is Kerberos name)
- Kerberized login program retrieves initial ticket for user:
  - Client machine sends to Kerberos database:  
 $c, tgs$   
(tgs is principal name for [ticket-granting service](#))
  - Server responds with:  
 $\{K_{c,tgs}, \{T_{c,tgs}\}_{K_{tgs}}\}_{K_c}$
  - where  
 $T_{c,tgs} = tgs, c, addr_c, timestamp, lifetime, K_{c,tgs}$
  - Client decrypts server's response with  
 $K_c = H(\text{password})$

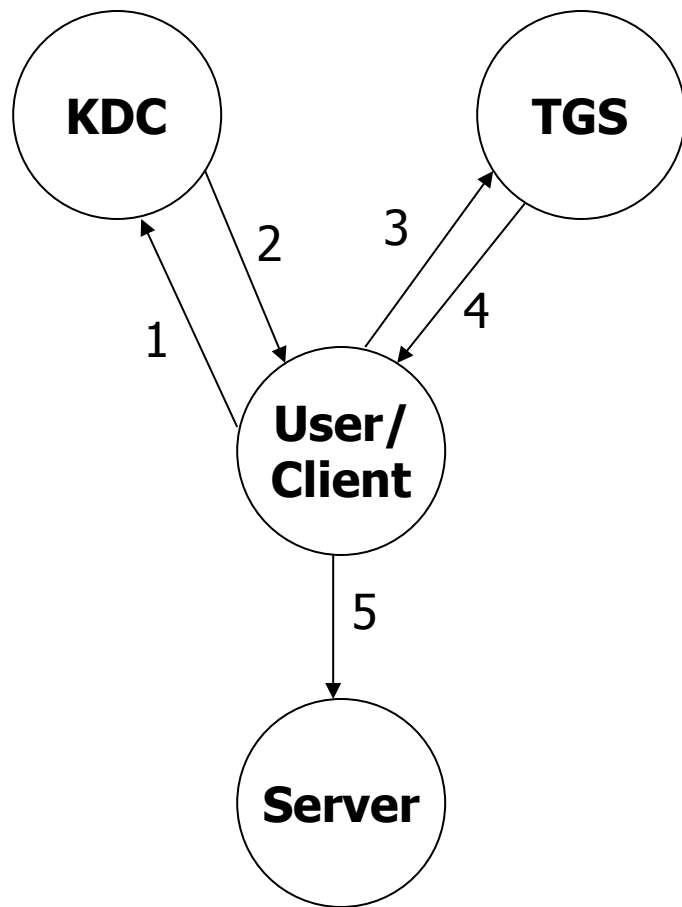
# Requesting a Service

- Client  $c$  (e.g., user bkarp) wishes to use a service on  $s$ , already holds  $K_{c,tgs}$
- Client requests ticket from tgs as follows:
  - Client sends to tgs:  
 $s, \{T_{c,tgs}\}_{K_{tgs}}, \{A_c\}_{K_{c,tgs}}$
  - tgs replies to client with ticket for service on that server:  
 $\{\{T_{c,s}\}_{K_s}, K_{c,s}\}_{K_{c,tgs}}$
  - where  $K_{c,s}$  is a **new, randomly generated session key** for use between  $c$  and  $s$

# Using a Service

- Once client holds ticket for service, uses it with authenticator to request operation from server:
  - Client sends to s:  
service name,  $\{T_{c,s}\}_{K_s}, \{A_c\}_{K_{c,s}}$
  - Server validates  $T_{c,s}$  and  $A_c$ , and executes operation if they are valid
- Server uses timestamps and expiration times to **invalidate stale, “future”, replayed requests**

# Kerberos: Summary of Message Flow



1. Request for TGS ticket:  
 $c, tgs$
2. Ticket for TGS:  
 $\{K_{c,tgs}, \{T_{c,tgs}\}_{K_{tgs}}\}_{K_c}$
3. Request for Server ticket:  
 $s, \{T_{c,tgs}\}_{K_{tgs}}, \{A_c\}_{K_{c,tgs}}$
4. Ticket for Server:  
 $\{\{T_{c,s}\}_{K_s}, K_{c,s}\}_{K_{c,tgs}}$
5. Request for Service:  
 $service\ name, \{T_{c,s}\}_{K_s}, \{A_c\}_{K_{c,s}}$

# Ticket Lifetime

- How should we choose ticket lifetimes?
- Convenience: longer ticket-granting ticket lifetime → user must type password less often
- Performance: longer service ticket lifetime → client must request new service ticket less often
- Risk: longer ticket lifetime lengthens period when ticket can be stolen, abused
- MIT Athena implementation destroys ticket-granting ticket when user logs out

# Kerberos Security Weaknesses

- Vulnerability to **replay attacks**
- Reliance on **synchronized clocks across nodes**
- Storage of tickets on workstations
- No way to change compromised password securely
- Key database focal point for attack
- Hard to upgrade key database (relied on by all nodes in system)

# Kerberos User Inconveniences

- Large (e.g., university-wide) administrative realms:
  - University-wide admins **often on critical path**
  - Departments **can't add users or set up new servers**
  - **Can't develop new services** without central admins
  - **Can't upgrade software/protocols** without central admins
  - Central admins have **monopoly servers/services** (can't set up your own without a principal)
- Rigid; what if user from realm A wants to authenticate himself to host at realm B?
- Ticket expirations
  - Must renew tickets every 12-23 hours
  - **How to create long-running background jobs?**