The Kerberos Authentication System

Brad Karp
UCL Computer Science

CS GZ03 / M030
20th November 2015

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:
    $T = \{s, c, addr_c, timestamp, lifetime, K_{s,c}\}_{K_s}$
    (where K_s is key s shares with database)
  - Only server s can decrypt ticket

Kerberos Credentials (2)

- Given ticket, client creates authenticator:
  - Authenticator:
    $A = \{c, addr_c, timestamp\}_{K_{s,c}}$
  - 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
    $K_c = H(\text{password})$

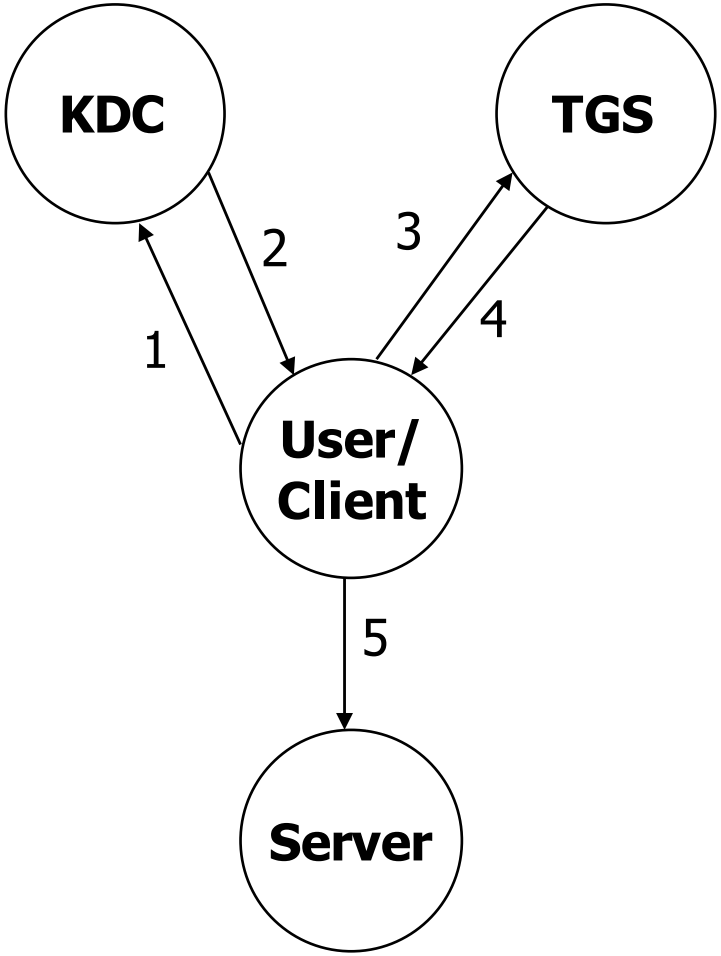
Requesting a Service

- 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; default authenticator lifetime 5 minutes
- 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?