Distributed Systems
Security – Part 2

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Applications of Cryptography

- Digital Certificates
- Access Control
- Capabalities

Certificates

Digital certificates can be viewed as an attachment to an electronic message that is used to verify that a user is who they claim to be.

Issues regarding certificate management.

- What information should a certificate hold?
- How is a certificate created?
  - How is a certificate validated?
  - What happens when a certificate needs to be revoked?

In general, certificates may only be created by trusted authorities (e.g. a bank, a well-known company).

- Often they must themselves be authorized by a higher authority in order to become a trusted authority.
- This leads to the idea of certification chains - where should it start?

Certificates

- The main problem with digital certificates is revocation.
  - To revoke a certificate, every copy of that certificate would have to be destroyed.
  - This is difficult because certificates are stored in files and files can be copied.
- Often the easy solution is to place a time limit on the certificate.
  - Once it expires, a new certificate must be obtained.
- When this is not enough, the only alternative is to inform all recipients potential that the certificate is now invalid.
  - This is a lot more complex to implement.
- X.509 is the most widely used standard for certificates.

Authentication vs Authorization

- Authentication – Are you who you say you are?

  Restrictions on who (or what) can access system

- Authorization – Are you allowed to do that?

  Restrictions on actions of authenticated users

- Authorization is a form of access control

- But first, we look at system certification…

System Certification

- Government attempt to certify “security level” of products
- Of historical interest
  - Sort of like a history of authorization
- Still important today if you want to sell a product to the government
  - Tempting to argue it’s a failure since government is so insecure, but…

Orange Book

- Trusted Computing System Evaluation Criteria (TCSEC), 1983
  - Universally known as the “orange book”
  - Name is due to color of it’s cover
  - About 115 pages
  - Developed by U.S. DoD (NSA)
  - Part of the “rainbow series”
- Orange book generated a pseudo-religious fervor among some people
  - Less and less intensity as time goes by

Orange Book Outline

- Goals
  - Provide way to assess security products
  - Provide general guidance/philosophy on how to build more secure products
- Four divisions labeled D through A
  - D is lowest, A is highest
- Divisions split into numbered classes

EAL 1 through 7

- EAL1 – functionally tested
- EAL2 – structurally tested
- EAL3 – methodically tested, checked
- EAL4 – designed, tested, reviewed
- EAL5 – semiformally designed, tested
- EAL6 – verified, designed, tested
- EAL7 – formally verified

Authentication vs Authorization

- Authentication – Are you who you say you are?
  - Restrictions on who (or what) can access system
- Authorization – Are you allowed to do that?
  - Restrictions on actions of authenticated users
- Authorization is a form of access control
- Classic view of authorization…
  - Access Control Lists (ACLs)
  - Capabilities (C-lists)

Lampson's Access Control Matrix

- **Subjects** (users) index the rows
- **Objects** (resources) index the columns

	OS	Accounting program	Accounting data	Insurance data	Payroll data
Bob	rx	rx	r	—	—
Alice	rx	rx	r	rw	rw
Sam	rwx	rwx	r	rw	rw
Accounting program	rx	rx	rw	rw	rw

x, r, and w stand for execute, read, and write privileges, respectively.

Are You Allowed to Do That?

- Access control matrix has all relevant info
- Could be 100's of users, 10,000's of resources
  - Then matrix with 1,000,000's of entries
- How to manage such a large matrix?
- Note: We need to check this matrix before access to any resource by any user
- How to make this efficient/practical?

Access Control Lists (ACLs)

- ACL: store access control matrix by column
- Example: ACL for insurance data is in blue

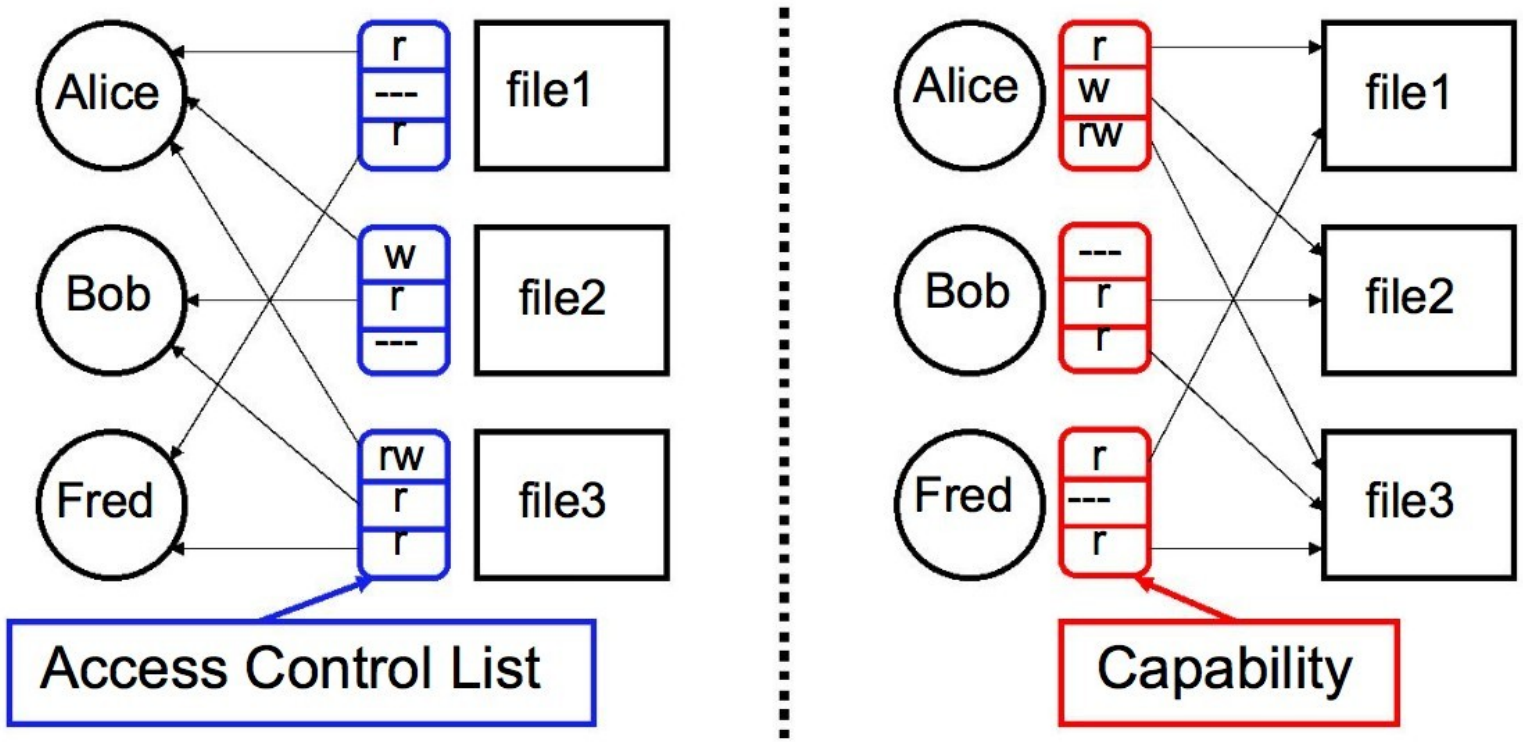
	OS	Accounting program	Accounting data	Insurance data	Payroll data
Bob	rx	rx	r	_	_
Alice	rx	rx	r	rw	rw
Sam	rwx	rwx	r	rw	rw
Accounting program	rx	rx	rw	rw	rw

Capabilities (or C-Lists)

- Store access control matrix by row
- Example: Capability for Alice is in red

	OS	Accounting program	Accounting data	Insurance data	Payroll data
Bob	rx	rx	r	_	_
Alice	rx	rx	r	rw	rw
Sam	rwx	rwx	r	rw	rw
Accounting program	rx	rx	rw	rw	rw

ACLs vs Capabilities



- Note that arrows point in opposite directions…
- With ACLs, still need to associate users to files

ACLs vs Capabilities

- ACLs
  - Good when users manage their own files
  - Protection is data-oriented
  - Easy to change rights to a resource
- Capabilities
  - Easy to delegate – avoid the confused deputy
  - Easy to add/delete users
  - More difficult to implement
  - The “Zen of information security”
- Capabilities loved by academics
  - Capability Myths Demolished

Multilevel Security (MLS) Models

Classifications and Clearances

- Classifications apply to objects
- Clearances apply to subjects
- US Department of Defense (DoD) uses 4 levels:

TOP SECRET

SECRET

CONFIDENTIAL

UNCLASSIFIED

Multilevel Security (MLS)

- MLS needed when subjects/objects at different levels access same system
- MLS is a form of Access Control
- Military and government interest in MLS for many decades
  - Lots of research into MLS
  - Strengths and weaknesses of MLS well understood (almost entirely theoretical)
  - Many possible uses of MLS outside military

MLS Applications

- Classified government/military systems
- Business example: info restricted to
  - Senior management only, all management, everyone in company, or general public
- Network firewall
- Confidential medical info, databases, etc.
- Usually, MLS not really a technical system
  - More like part of a legal structure

MLS Security Models

- MLS models explain what needs to be done
- Models do not tell you how to implement
- Models are descriptive, not prescriptive
  - That is, high-level description, not an algorithm
- There are many MLS models
- We'll discuss simplest MLS model
  - Other models are more realistic
  - Other models also more complex, more difficult to enforce, harder to verify, etc.

Bell-LaPadula

- BLP security model designed to express essential requirements for MLS
- BLP deals with confidentiality
  - To prevent unauthorized reading
- Recall that O is an object, S a subject
  - Object O has a classification
  - Subject S has a clearance
  - Security level denoted L(O) and L(S)

BLP: The Bottom Line

- BLP is simple, probably too simple
- BLP is one of the few security models that can be used to prove things about systems
- BLP has inspired other security models
  - Most other models try to be more realistic
  - Other security models are more complex
  - Models difficult to analyze, apply in practice

Biba's Model

- BLP for confidentiality, Biba for integrity
  - Biba is to prevent unauthorized writing
- Biba is (in a sense) the dual of BLP
- Integrity model
  - Suppose you trust the integrity of O but not O
  - If object O includes O and O then you cannot trust the integrity of O
- Integrity level of O is minimum of the integrity of any object in O
- Low water mark principle for integrity

Distributed Systems: Case Study: Kerberos

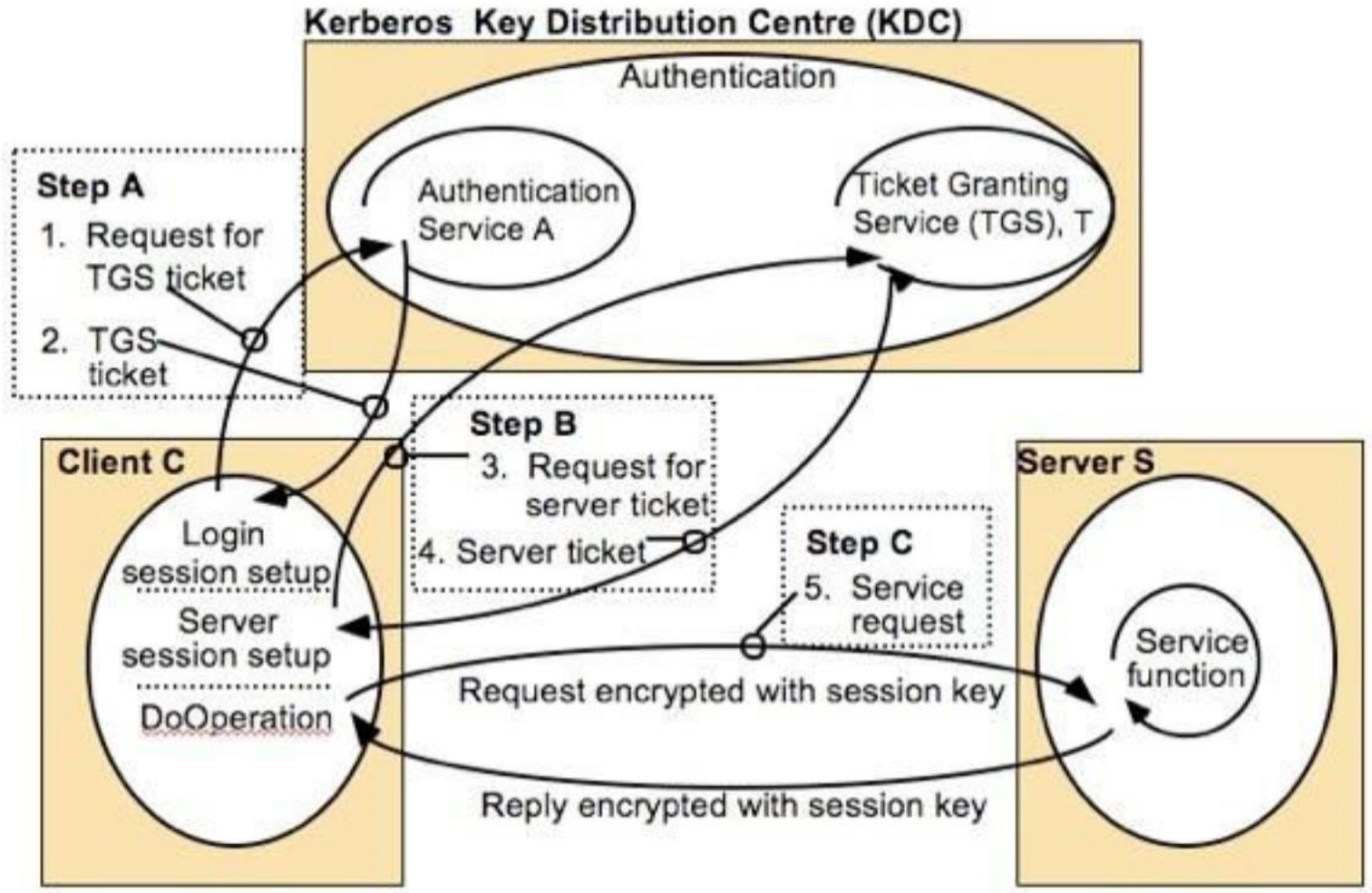
Introduction

- Kerberos is a computer network authentication protocol
  - allows nodes to communicate over non-secure network to prove their identity to one another in a secure manner
- Developed by MIT in the 1980's and soon to become an Internet Standard.
  - The default authentication service for Windows 2000.
- Shared secret-based strong 3rd party authentication
- provides single sign-on capability
- Passwords never sent across network

Adopts Mediated Authentication

- A trusted third party mediates the authentication process -
  - called the Key Distribution Centre (KDC)
- Each user and service shares a secret key with the KDC
- KDC generates a session key - securely distributes it to the communicating parties
- communicating parties prove to each other that they know each other

Kerberos System Architecture



Thank you