Access Control

What is Access Control?

- NIST IR 7298, Glossary of Key Information Security Terms, defines access control as the process of granting or denying specific requests to: (1) obtain and use information and related information processing services; and (2) enter specific physical facilities.

- RFC 4949, Internet Security Glossary, defines access control as a process by which use of system resources is regulated according to a security policy and is permitted only by authorized entities (users, programs, processes, or other systems) according to that policy.

Access Control

- We can view access control as the central element of computer security. The principal objectives of computer security are to prevent unauthorized users from gaining access to resources, to prevent legitimate users from accessing resources in an unauthorized manner, and to enable legitimate users to access resources in an authorized manner.

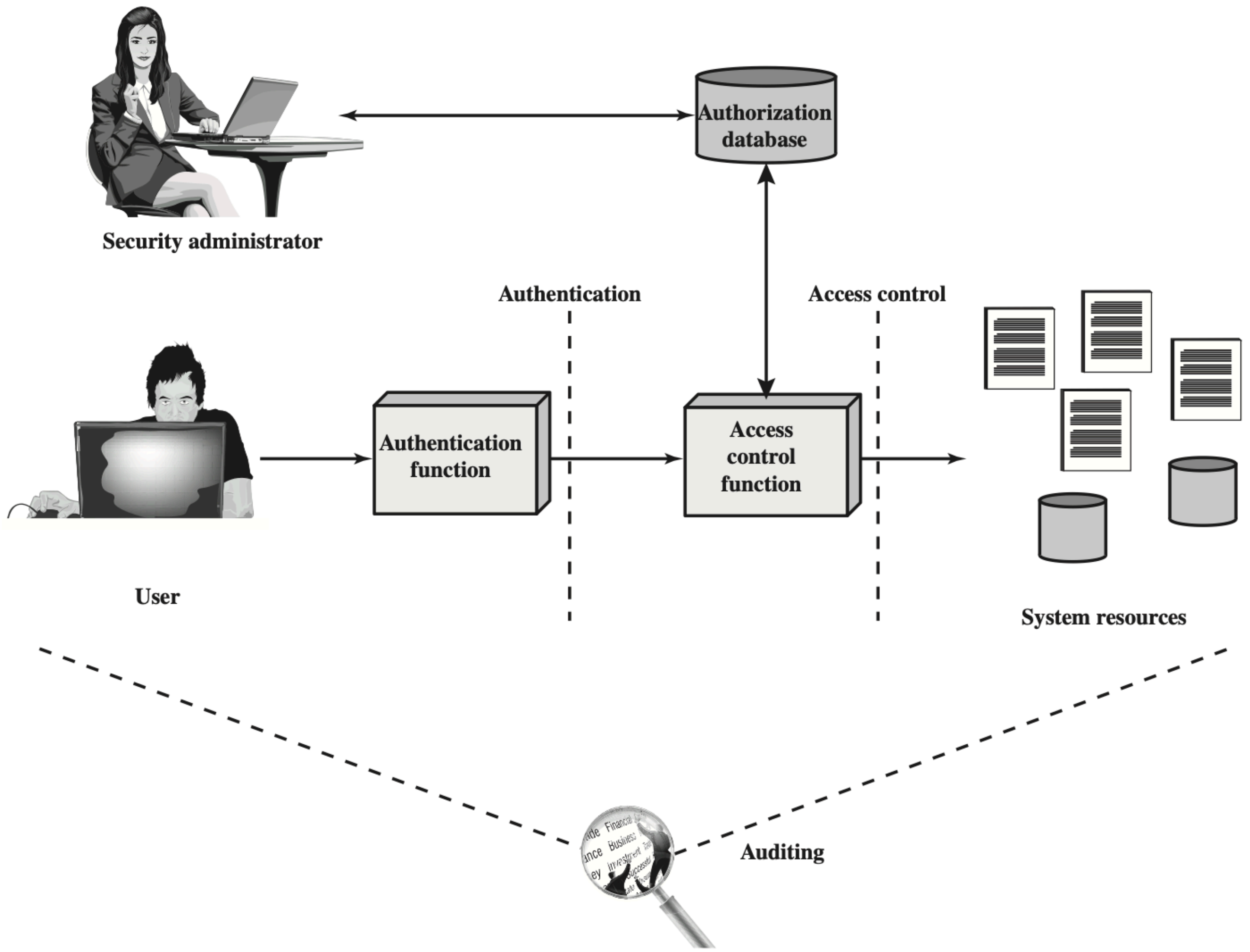
Access Control Context

- Authentication: Verification that the credentials of a user or other system entity are valid.

- Authorization: The granting of a right or permission to a system entity to access a system resource. This function determines who is trusted for a given purpose.

- Audit: An independent review and examination of system records and activities in order to test for adequacy of system controls, to ensure compliance with established policy and operational procedures, to detect breaches in security, and to recommend any indicated changes in control, policy and procedures.

Relationship Among Access Control and Other Security Functions



Access Control Policies

- Discretionary access control (DAC): based on the identity of the requestor and access rules
- Mandatory access control (MAC): based on comparing security labels with security clearances (mandatory: one with access to a resource cannot pass to others)
- Role-based access control (RBAC): based on user roles
- Attribute-based access control: based on the attributes of the user, the resources and the current environment

Access Control Requirements

- Reliable input: a mechanism to authenticate
- Fine and coarse specifications: regulate access at varying levels (e.g., an attribute or entire DB)
- Least privilege: min authorization to do its work
- Separation of duty: divide steps among different individuals
- Open and closed policies: accesses specifically authorized or all accesses except those prohibited
- Administrative policies: who can add, delete, modify rules

Access Control Elements

- Subject: entity that can access objects
  - a process representing user/application
  - often have 3 classes: **owner**, **group**, **world**
- Object: access controlled resource
  - e.g. files, directories, records, programs etc
  - number/type depend on environment
- Access right: way in which subject accesses an object
  - e.g. read, write, execute, delete, create, search

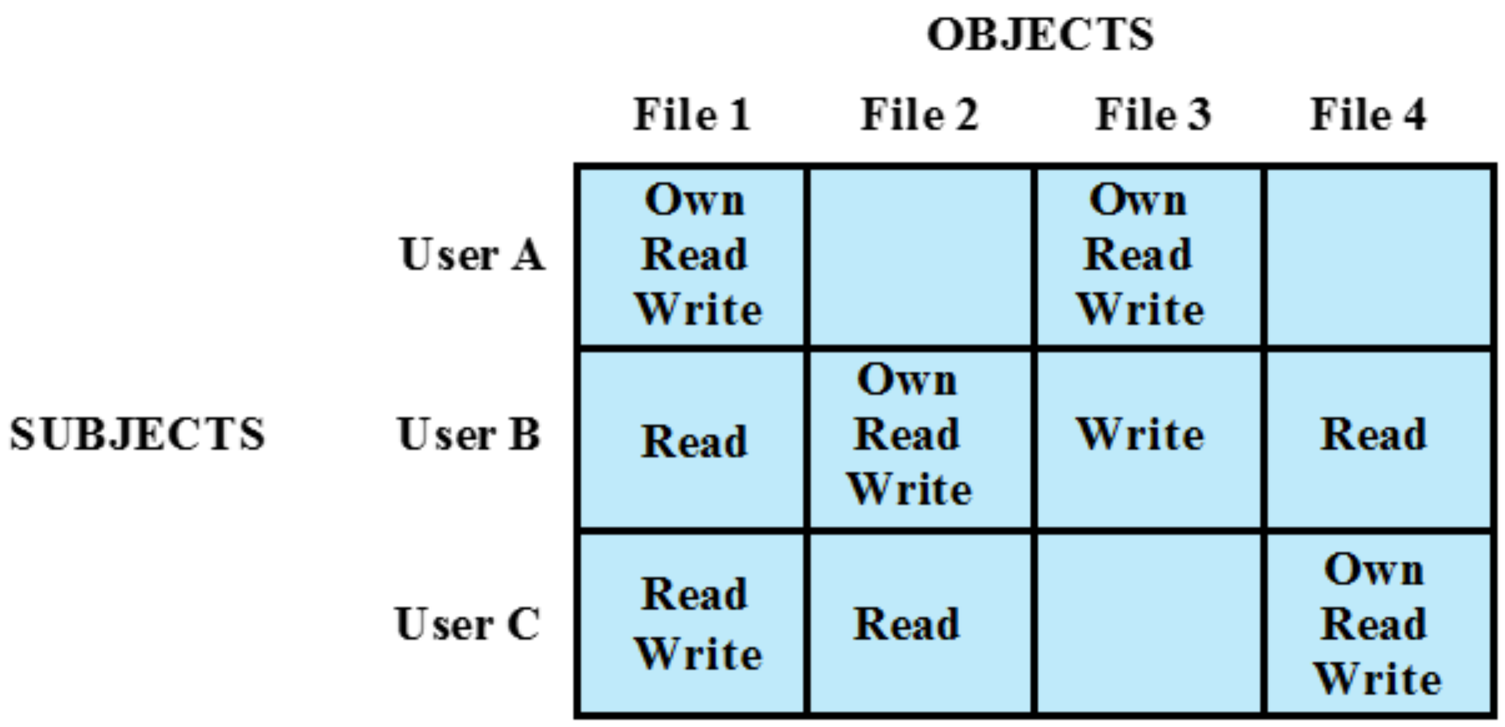
Discretionary Access Control

- Often provided using an access matrix
  - lists subjects in one dimension (rows)
  - lists objects in the other dimension (columns)
  - each entry specifies access rights of the specified subject to that object

- Access matrix is often sparse

- Can decompose by either row or column

An access matrix



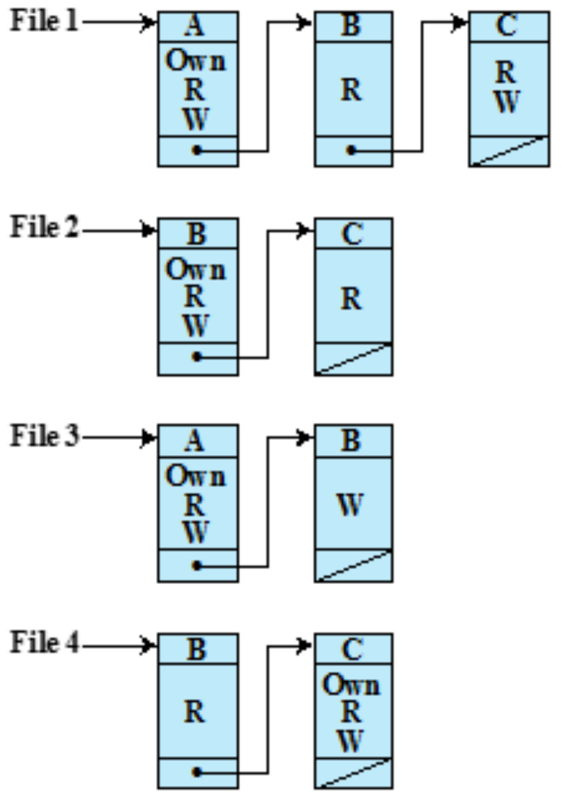
		OBJECTS			
		File 1	File 2	File 3	File 4
SUBJECTS	User A	Own Read Write		Own Read Write	
	User B	Read	Own Read Write	Write	Read
	User C	Read Write	Read		Own Read Write

(a) Access matrix

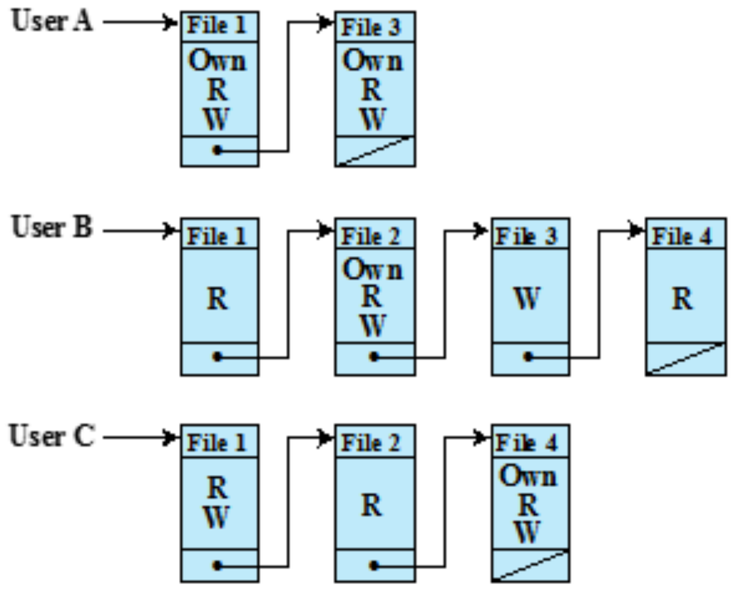
Access Control Structures

- Access control lists (decomposed by column)
- Capability tickets (decomposed by row)
- See page 119
- Also see alternative table representation on page 120 (tabular but not sparse)

Access matrix data structures



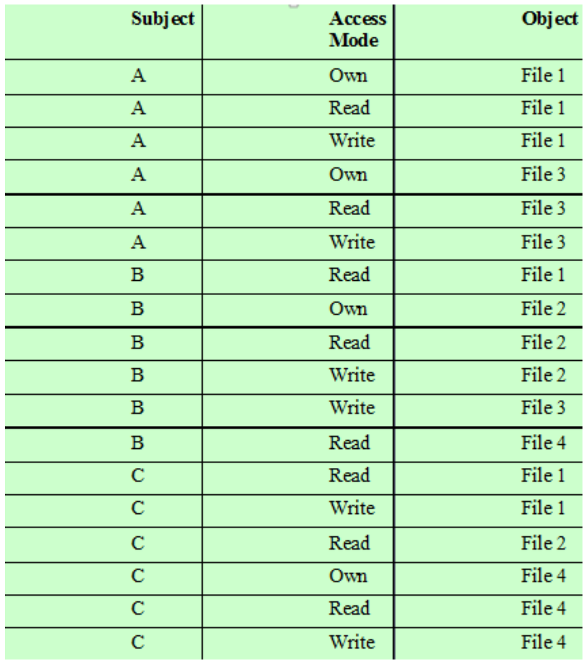
(b) Access control lists for files of part (a)



(c) Capability lists for files of part (a)

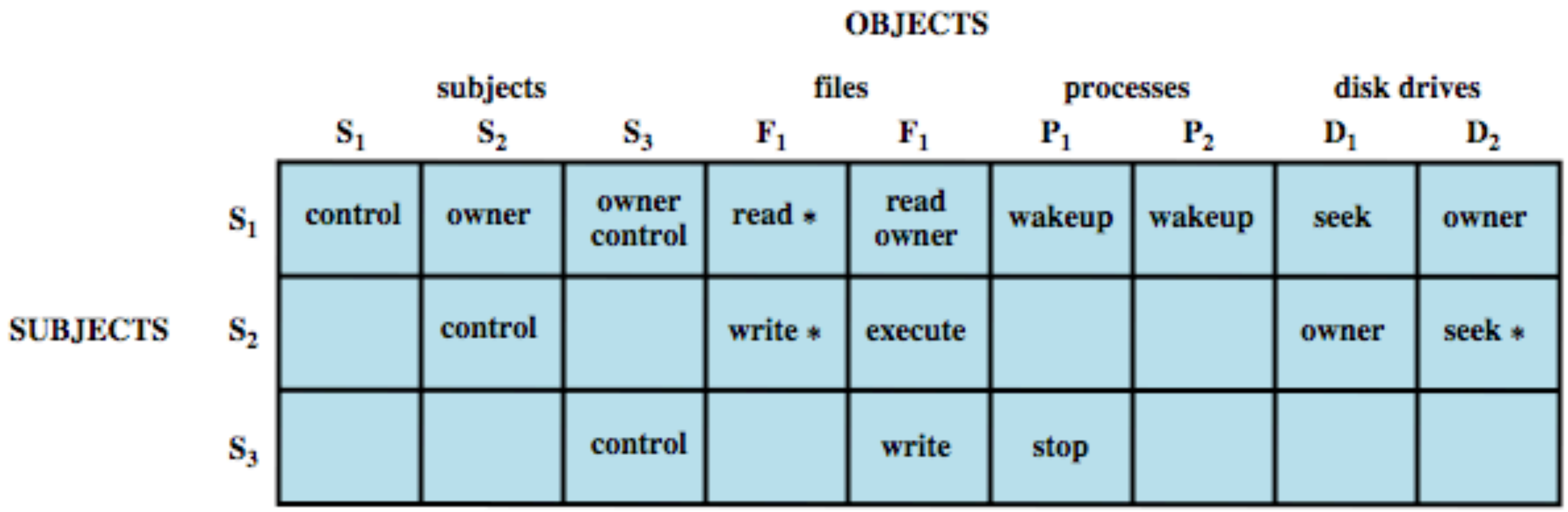
Alternate Authorization Table

- A relational database approach is not sparse like an Access Matrix and more convenient than ACL or capability lists.
  - One row for each access right of one subject to one resource
  - Sorting the table by object is equivalent to an ACL
  - Sorting the table by subject is equivalent to a capability list



Subject	Access Mode	Object
A	Own	File 1
A	Read	File 1
A	Write	File 1
A	Own	File 3
A	Read	File 3
A	Write	File 3
B	Read	File 1
B	Own	File 2
B	Read	File 2
B	Write	File 2
B	Write	File 3
B	Read	File 4
C	Read	File 1
C	Write	File 1
C	Read	File 2
C	Own	File 4
C	Read	File 4
C	Write	File 4

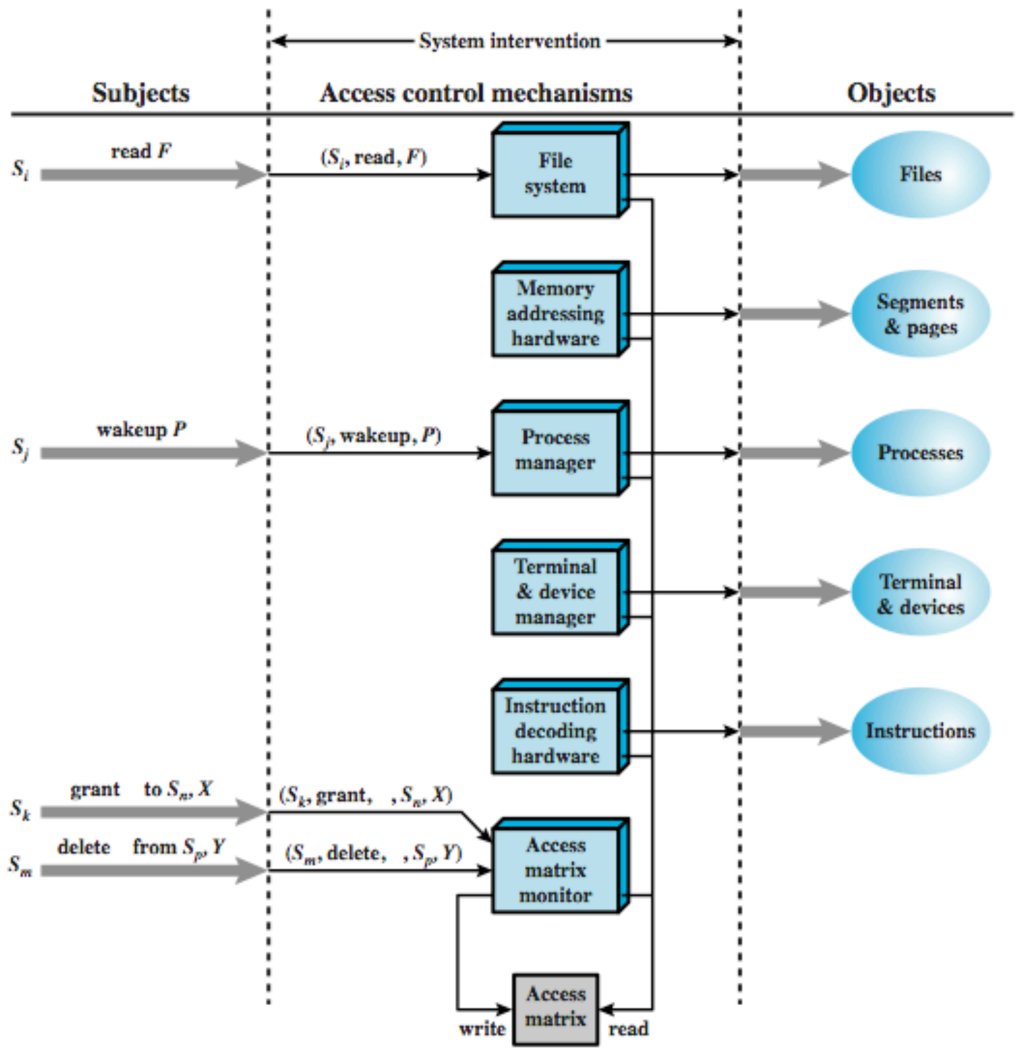
An Access Control Model



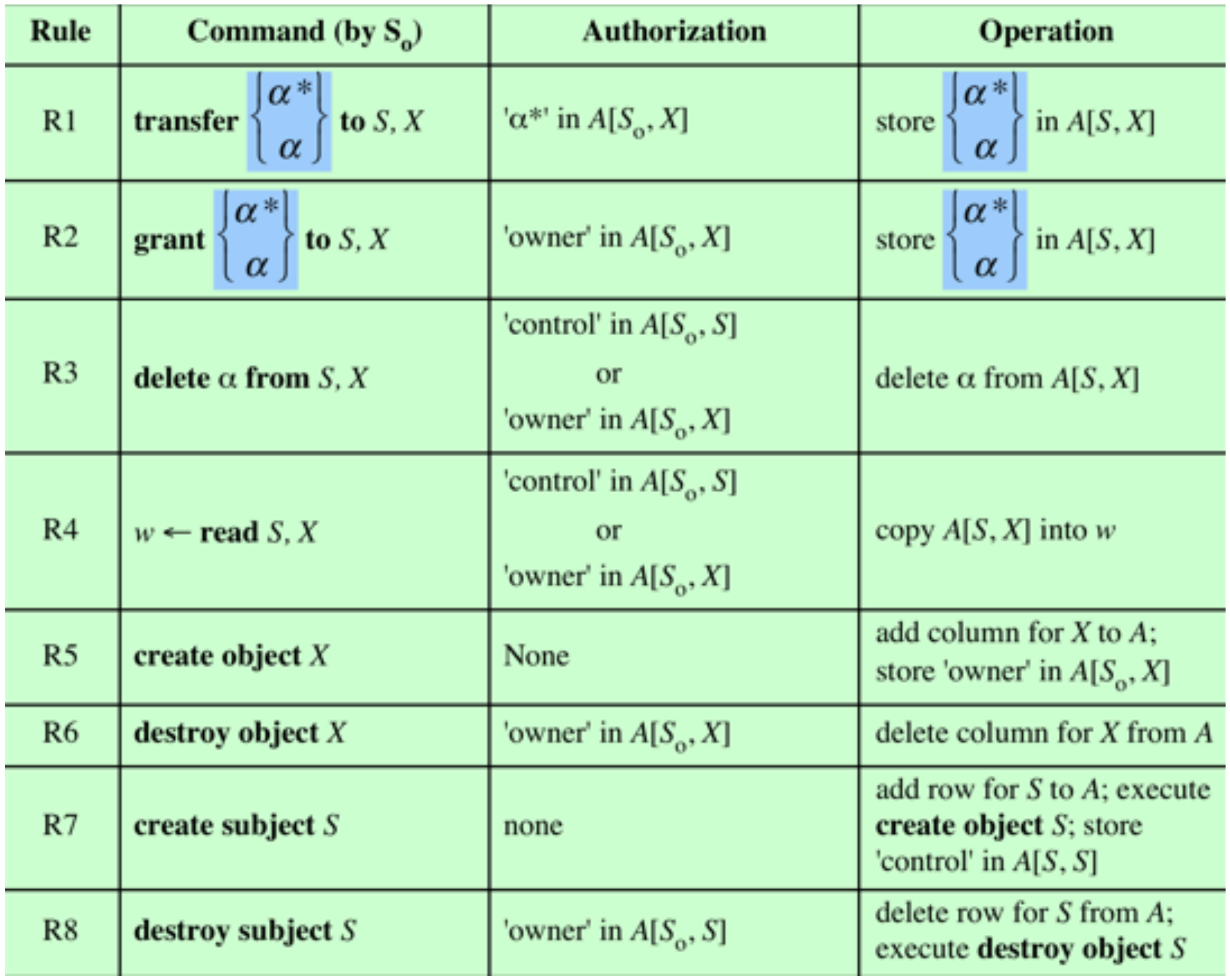
		OBJECTS								
		subjects			files		processes		disk drives	
		S_1	S_2	S_3	F_1	F_1	P_1	P_2	D_1	D_2
	S_1	control	owner	owner control	read *	read owner	wakeup	wakeup	seek	owner
SUBJECTS	S_2		control		write *	execute			owner	seek *
	S_3			control		write	stop			

* - copy flag set

Access Control Function



Access control system commands



Rule	Command (by S_o)	Authorization	Operation
R1	**transfer** $\begin{Bmatrix}\alpha^* \\ \alpha\end{Bmatrix}$ **to** S, X	'α*' in $A[S_o, X]$	store $\begin{Bmatrix}\alpha^* \\ \alpha\end{Bmatrix}$ in $A[S, X]$
R2	**grant** $\begin{Bmatrix}\alpha^* \\ \alpha\end{Bmatrix}$ **to** S, X	'owner' in $A[S_o, X]$	store $\begin{Bmatrix}\alpha^* \\ \alpha\end{Bmatrix}$ in $A[S, X]$
R3	**delete** α **from** S, X	'control' in $A[S_o, S]$ or 'owner' in $A[S_o, X]$	delete α from $A[S, X]$
R4	$w \leftarrow$ **read** S, X	'control' in $A[S_o, S]$ or 'owner' in $A[S_o, X]$	copy $A[S, X]$ into w
R5	**create object** X	None	add column for X to A; store 'owner' in $A[S_o, X]$
R6	**destroy object** X	'owner' in $A[S_o, X]$	delete column for X from A
R7	**create subject** S	none	add row for S to A; execute **create object** S; store 'control' in $A[S, S]$
R8	**destroy subject** S	'owner' in $A[S_o, S]$	delete row for S from A; execute **destroy object** S

Protection Domains: More Useful

- Set of objects together with access rights to those objects
- More flexibility when associating capabilities with protection domains
- In terms of the access matrix, a row defines a protection domain
- User can spawn processes with a subset of the access rights of the user
- Association between a process and a domain can be static or dynamic
- In user mode certain areas of memory are protected from use and certain instructions may not be executed
- In kernel mode privileged instructions may be executed and protected areas of memory may be accessed

UNIX File Concepts

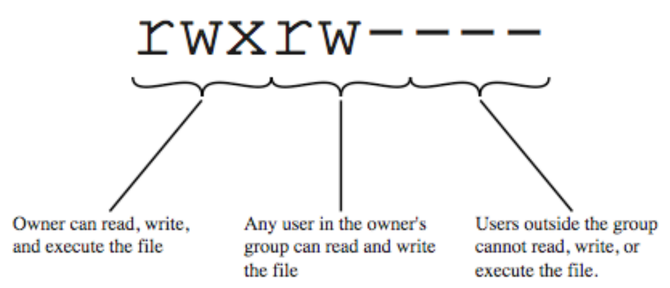
- UNIX files administered using inodes (index nodes)

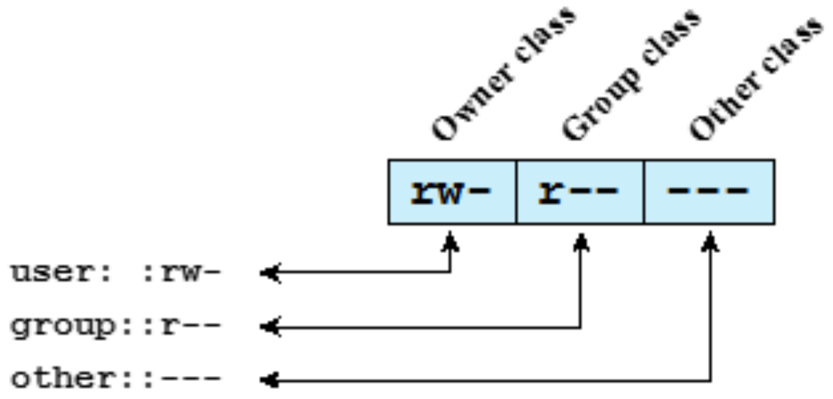
- An inode:
  - control structure with key info on file (attributes, permissions, …)
  - on a disk: an inode table for all files
  - when a file is opened, its inode is brought to RAM

- Directories form a hierarchical tree
  - may contain files or other directories
  - are a file of names and inode numbers

UNIX File Access Control

- Unique user identification number (user ID)
- Member of a primary group identified by a group ID
- 12 protection bits
  - 9 specify read, write, and execute permission for the owner of the file, members of the group and all other users
  - 2 speficiy SetID, SetGID
  - 1 is the sticky bit (only owner can remove delete, …, a directory)
- The owner ID, group ID, and protection bits are part of the file's inode


rwxrw----
Owner can read, write, and execute the file
Any user in the owner's group can read and write the file
Users outside the group cannot read, write, or execute the file.



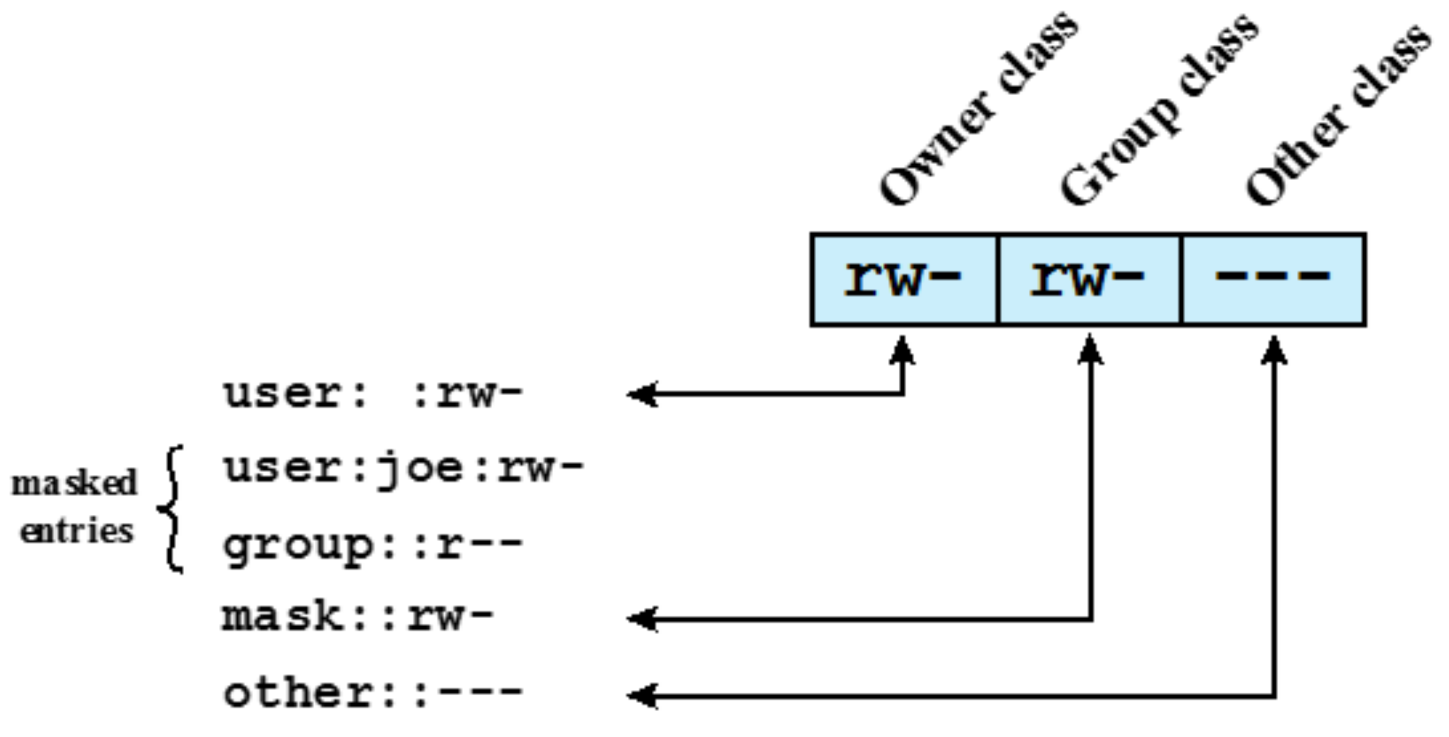
UNIX File Access Control

- "set user ID"(SetUID) or "set group ID"(SetGID)
  - system temporarily uses rights of the file owner/group in addition to the real user's rights when making access control decisions
  - enables privileged programs to access files/resources not generally accessible
- Sticky bit
  - on directory limits rename/move/delete to owner
- Superuser
  - is exempt from usual access control restrictions

UNIX Access Control Lists

- Modern UNIX systems support ACLs
- Can specify any number of additional users/groups and associated rwx permissions
- When access is required
  - select most appropriate ACL
    - owner, named users, owning/named groups, others
  - check if have sufficient permissions for access

UNIX extended access control list



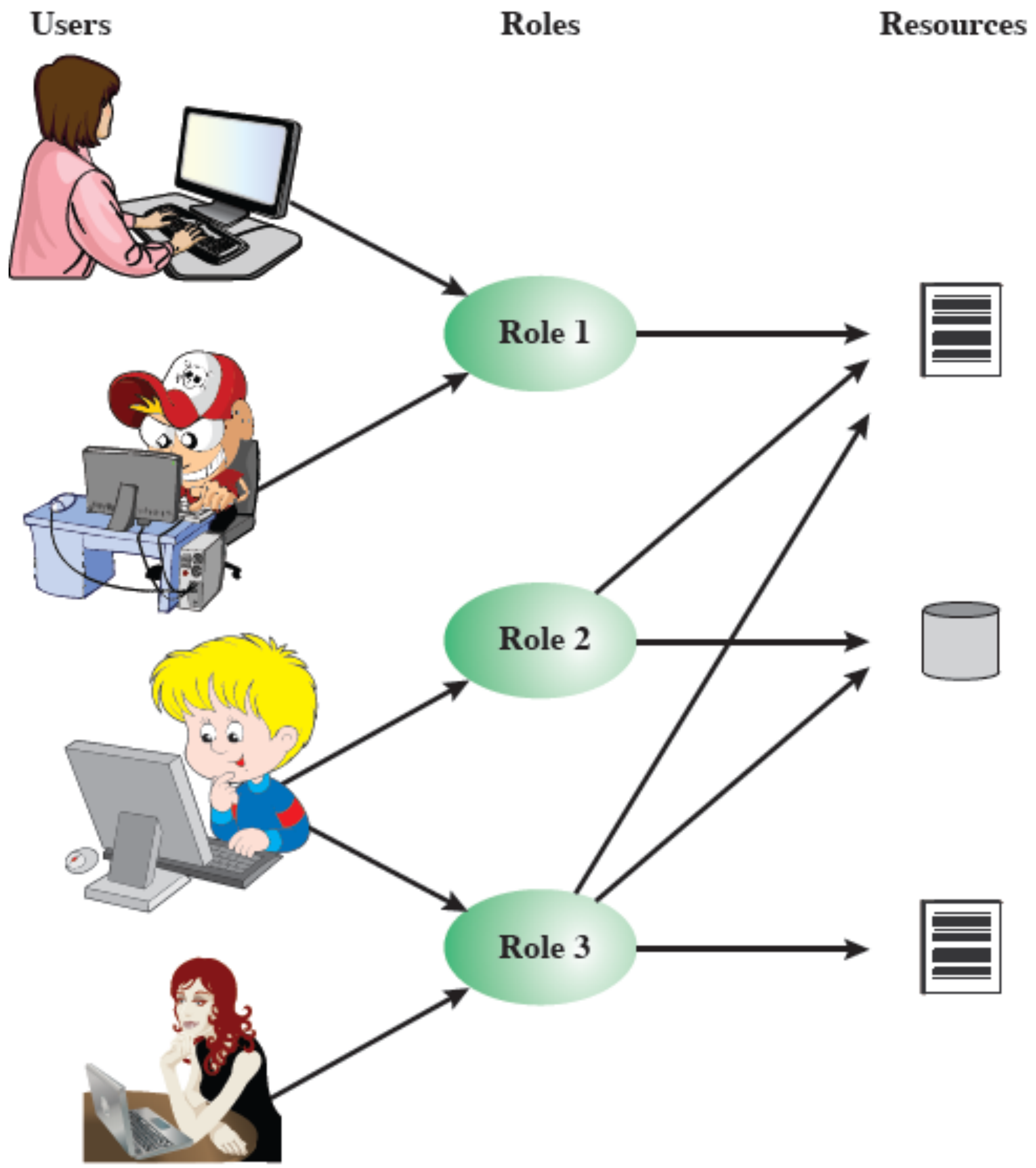
(b) Extended access control list

Role-Based Access Control

Access based on 'role', not identity

Many-to-many relationship between users and roles

Roles often static



Role-Based Access Control

Role-users and roles-object access matrix

	R_1	R_2	• • •	R_n
U_1	✖			
U_2	✖			
U_3		✖		✖
U_4				✖
U_5				✖
U_6				✖
⋮				
U_m	✖			

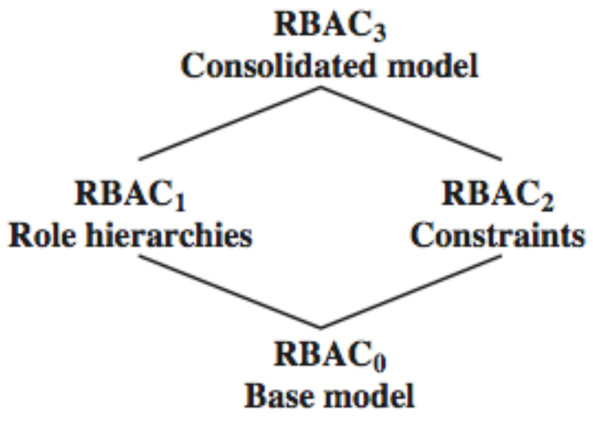
		OBJECTS								
		R_1	R_2	R_n	F_1	F_1	P_1	P_2	D_1	D_2
ROLES	R_1	control	owner	owner control	read *	read owner	wakeup	wakeup	seek	owner
	R_2		control		write *	execute			owner	seek *
	⋮									
	R_n			control		write	stop			

General RBAC, Variations

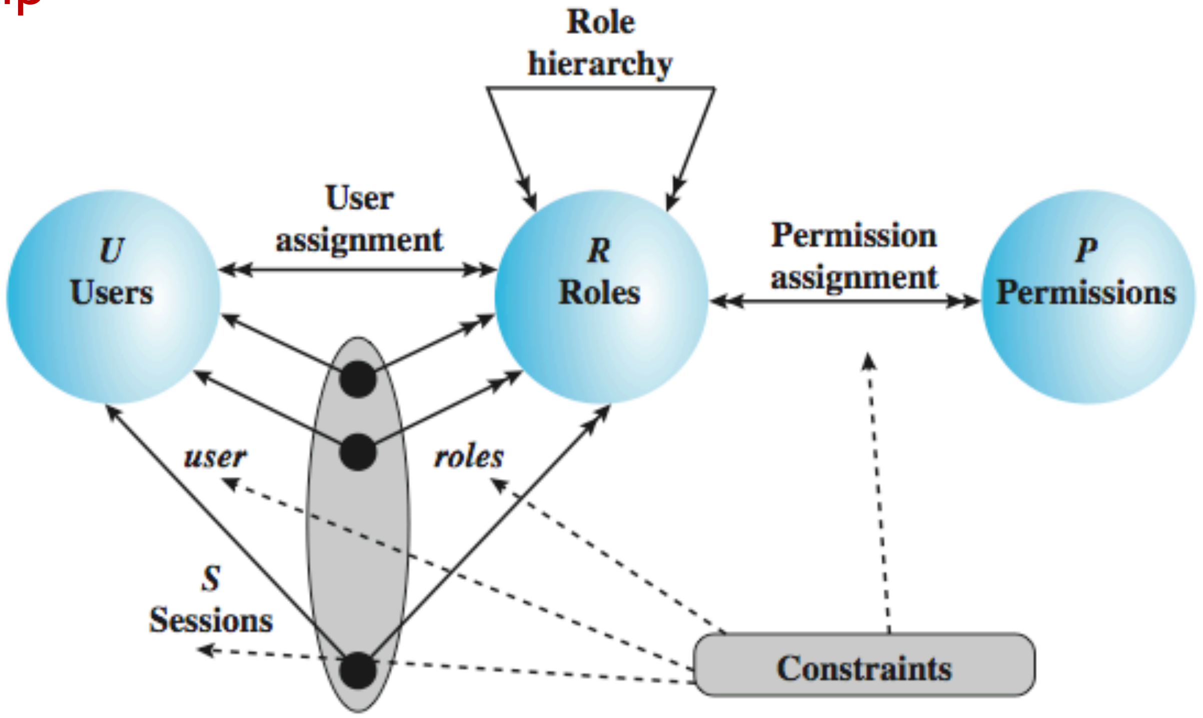
- A family of RBAC with four models
  1. RBAC0: min functionality
  2. RBAC1: RBAC0 plus role (permission) inheritance
  3. RBAC2: RBAC0 plus constraints (restrictions)
  4. RBAC3: RBAC0 plus all of the above

Role-Based Access Control

Double arrow: 'many' relationship
Single arrow: 'one' relationship



(a) Relationship among RBAC models

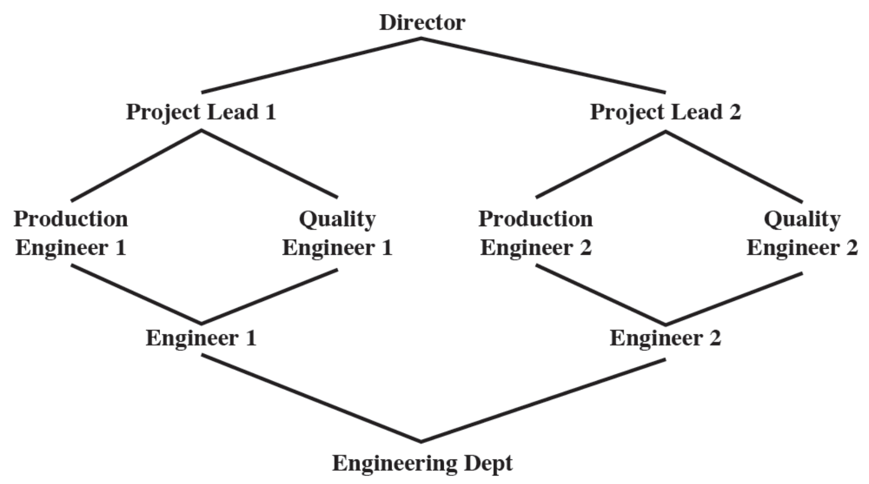


(b) RBAC models

RBAC0 Entities

- User: an individual (with UID) with access to system
- Role: a named job function (tells authority level)
- Permission: equivalent to access rights
- Session: a mapping between a user and set of roles to which a user is assigned

RBAC1 Role Hierarchies



- Director has most privileges
- Each role inherits all privileges from lower roles
- A role can inherit from multiple roles
- Additional privileges can be assigned to a role

Constraints

- A condition (restriction) on a role or between roles
  - Mutually exclusive
    - role sets such that a user can be assigned to only one of the role in the set
    - Any permission can be granted to only one role in the set
  - Cardinality**:** set a maximum number (of users) wrt a role (e.g., a department chair role)
  - Prerequisite role: a user can be assigned a role only if that user already has been assigned to some other role

Attribute-Based Access Control

- Fairly recent
- Define authorizations that express conditions on properties of both the resource and the subject
  - Each resource has an attribute (e.g., the subject that created it)
  - A single rule states ownership privileges for the creators
- Strength: its flexibility and expressive power
- Considerable interest in applying the model to cloud services

Types of attributes

- Subject attributes
- Object attributes
- Environment attributes

Subject attributes

- A subject is an active entity that causes information to flow among objects or changes the system state
- Attributes define the identity and characteristics of the subject
  - Name
  - Organization
  - Job title

Object attribute

- An object (or resource) is a passive information system-related entity containing or receiving information

- Objects have attributes that can be leveraged to make access control decisions
  - Title
  - Author
  - Date

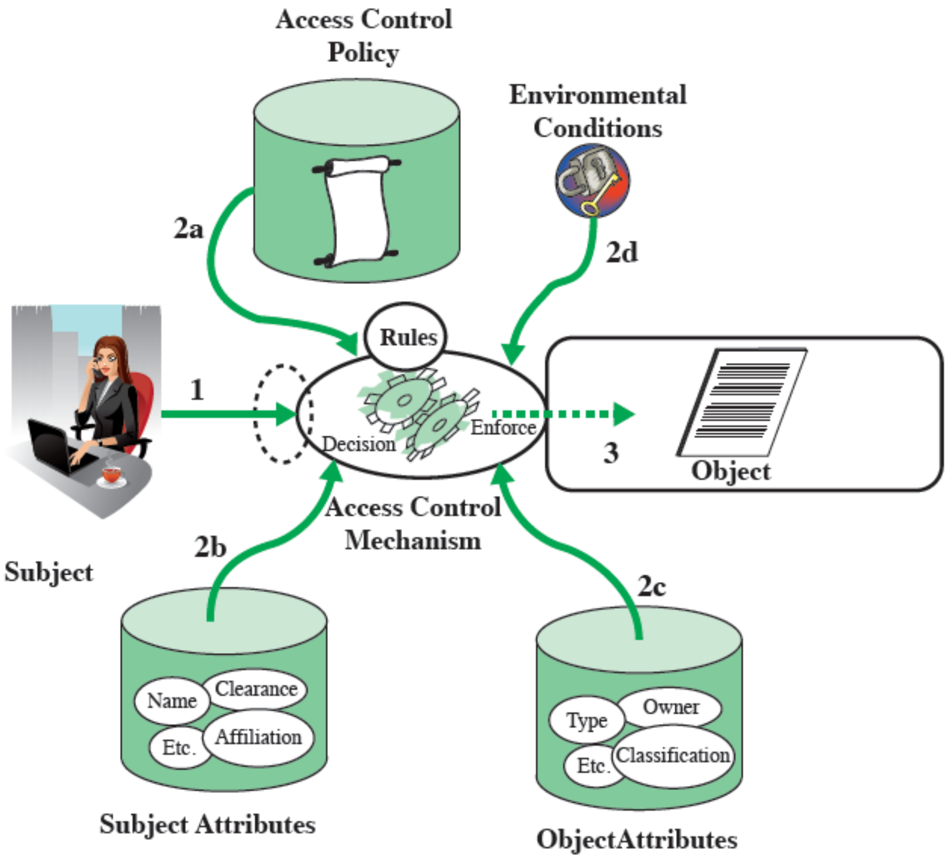
Environment Attributes

- Describe the operational, technical, and even situational environment or context in which the information access occurs
  - Current date
  - Current virus/hacker activities
  - Network security level
  - *Not associated with a resource or subject*

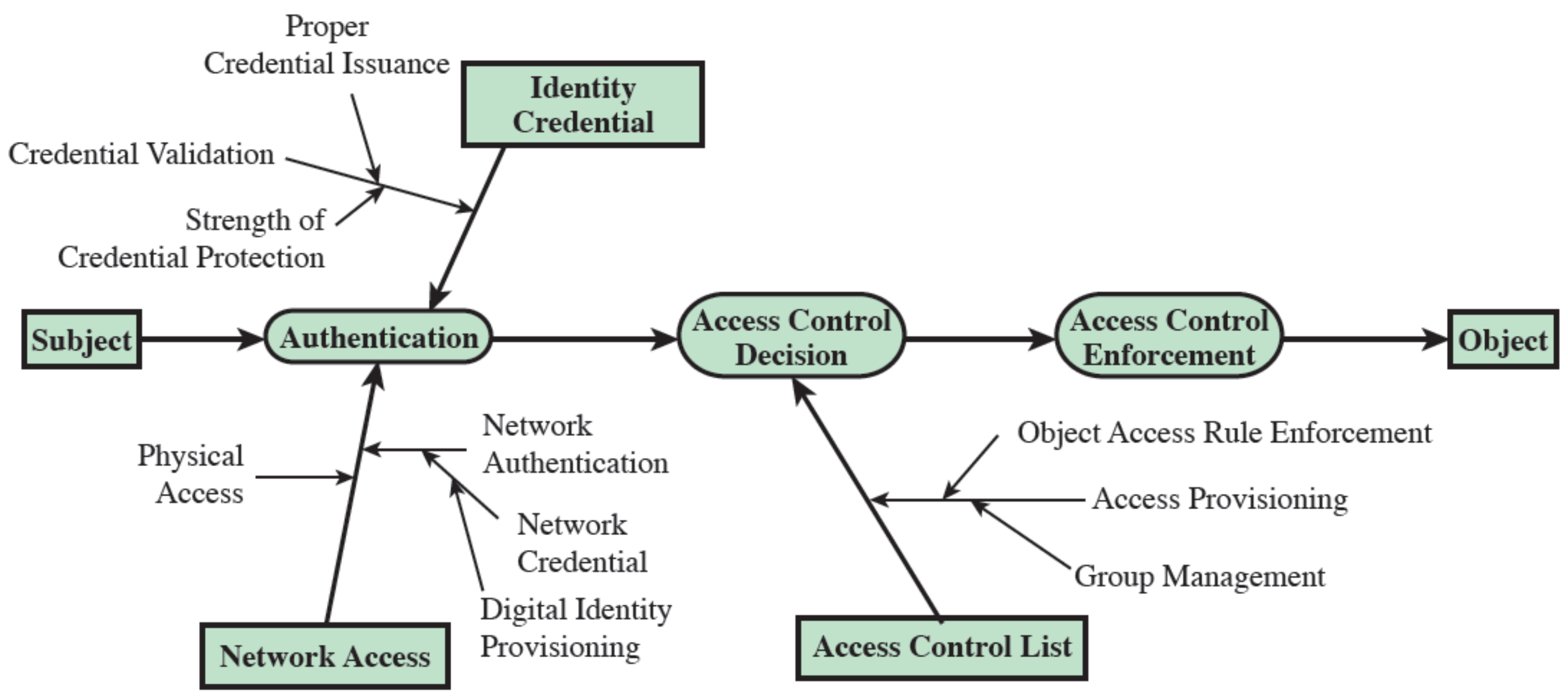
- These attributes have so far been largely ignored in most access control policies

ABAC Logical Architecture

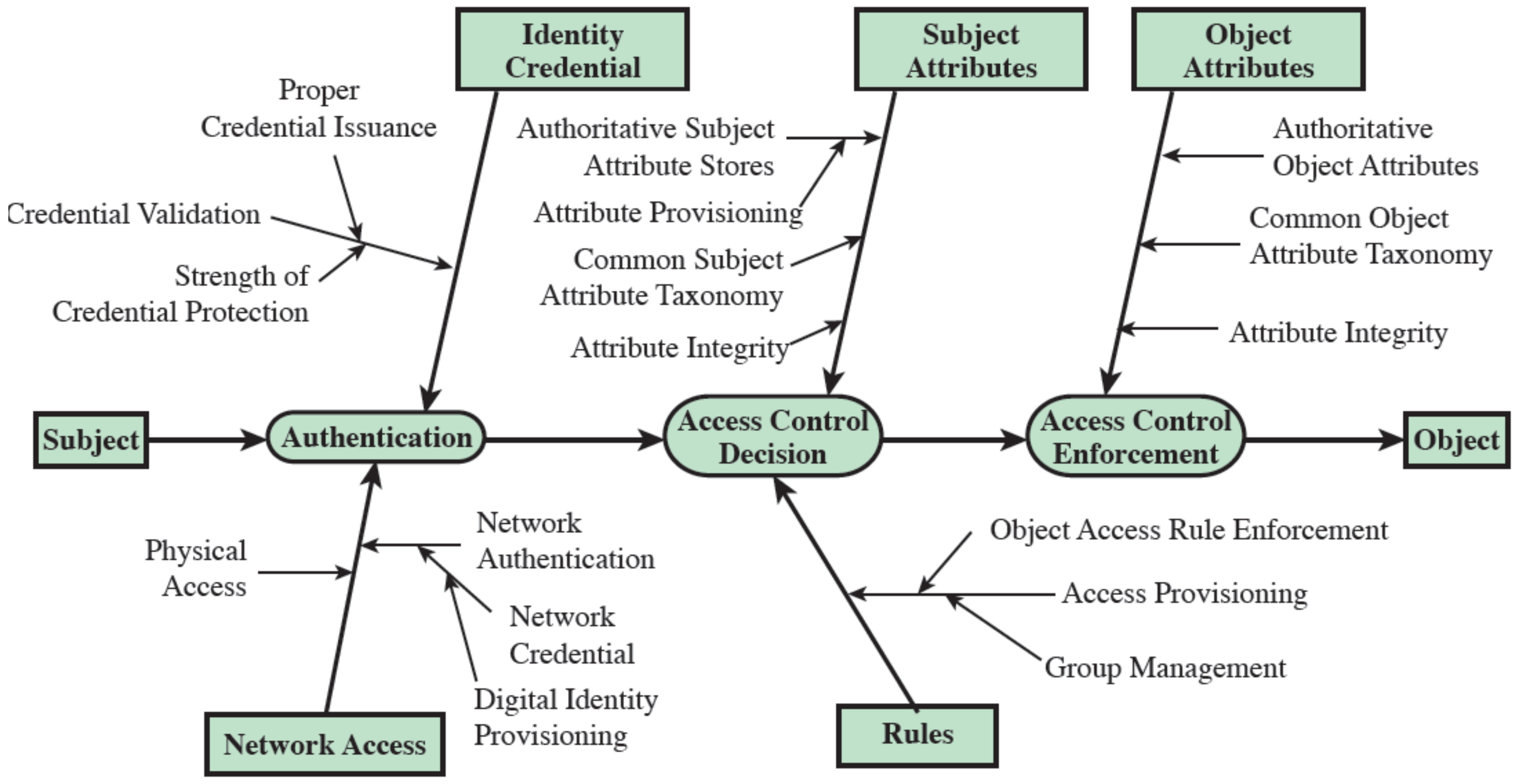
1. A subject requests access to an object
2. AC is governed by a set of rules (2a): assesses the attr of subject (2b), object (2c) and env (2d)
3. AC grants subject access to object if authorized



ACL vs ABAC trust relationships



ACL and ABAC trust relationships



ABAC Policies

- Policy - A set of rules and relationships that govern allowable behavior within and organization
    - Based on privileges of subject
- Privileges are authorized behavior of a subject
    - Also called rights, authorizations or entitlements

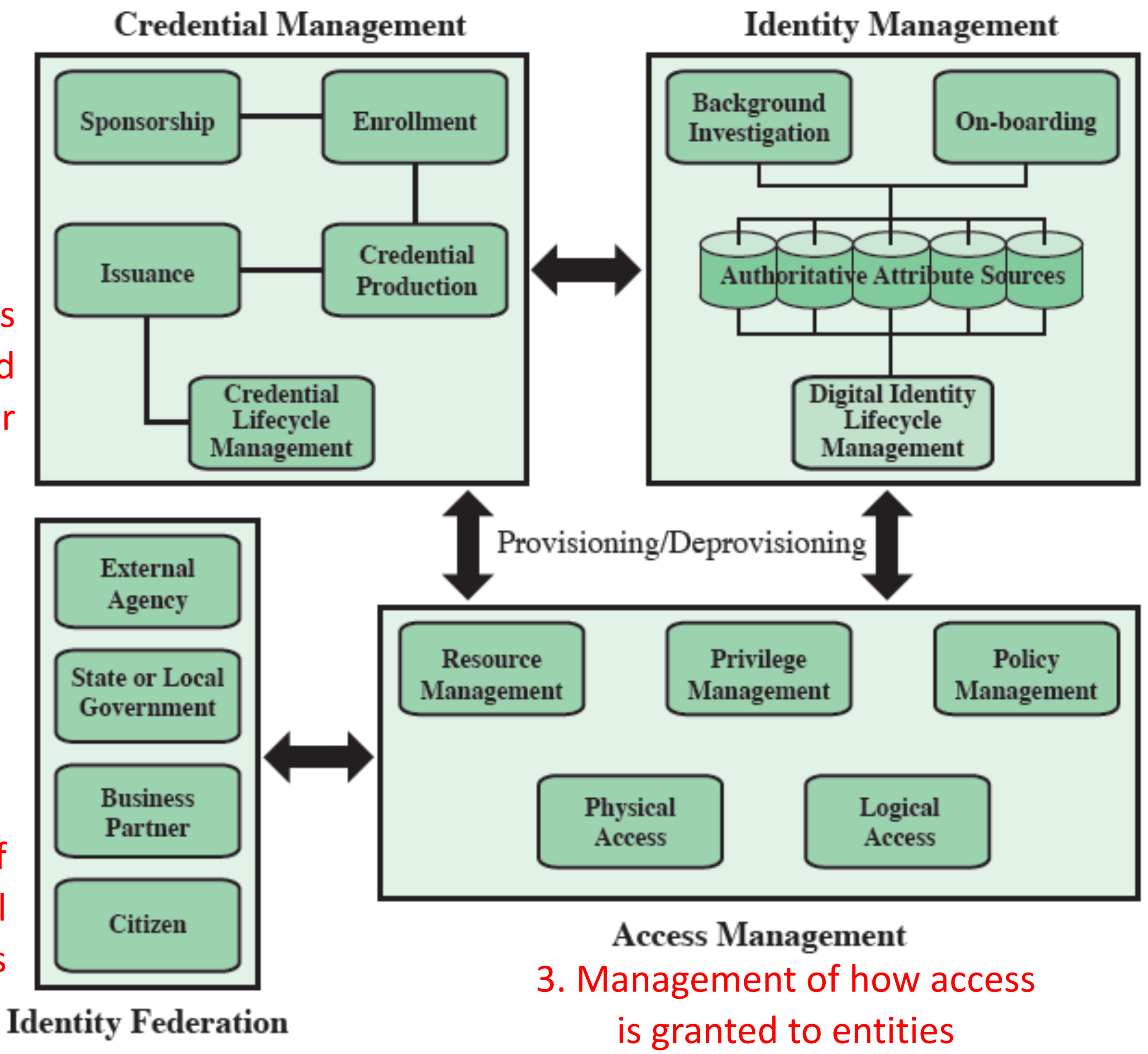
Identity, Credential, and Access Management (ICAM)

- A comprehensive approach to managing and implementing digital identities, credentials, and access control
- Developed by the U.S. government
- Designed to create trusted digital identity representations of individuals and nonperson entities (NPEs)
- A credential is an object or data structure that authoritatively binds an identity to a token possessed and controlled by a subscriber
- Use the credentials to provide authorized access to an agency's resources

ICAM

1. Connects digital identity to individuals

2. Data structures that binds a token possessed by a subscriber



3. Management of how access is granted to entities

4. Identity verification of individuals from external organizations

Identity Management

- Identity management is concerned with assigning attributes to a digital identity and connecting that digital identity to an individual or non-person entity (NPE)

Credential Management

- Skip

Access Management

- Skip

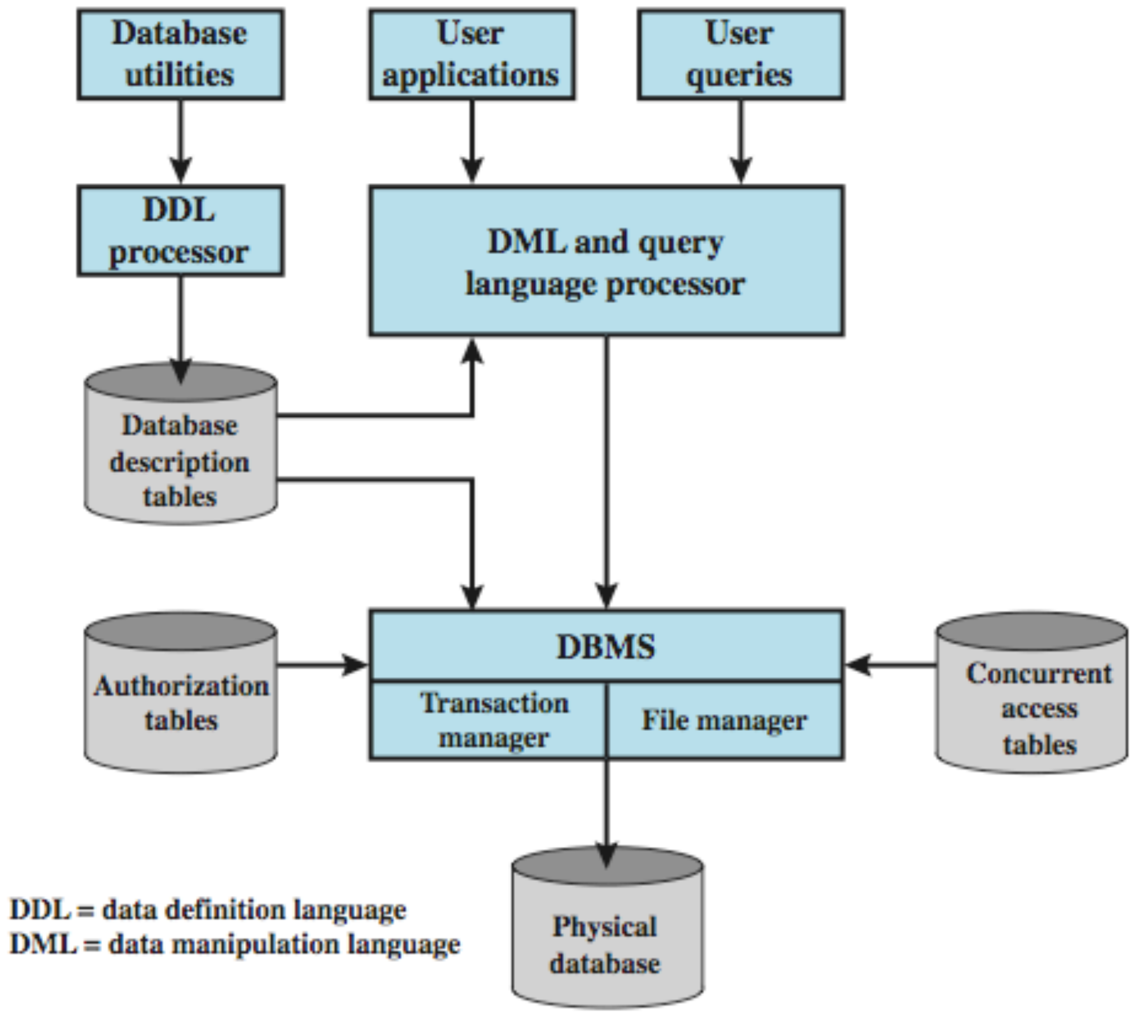
15 Minute Break

Database Security

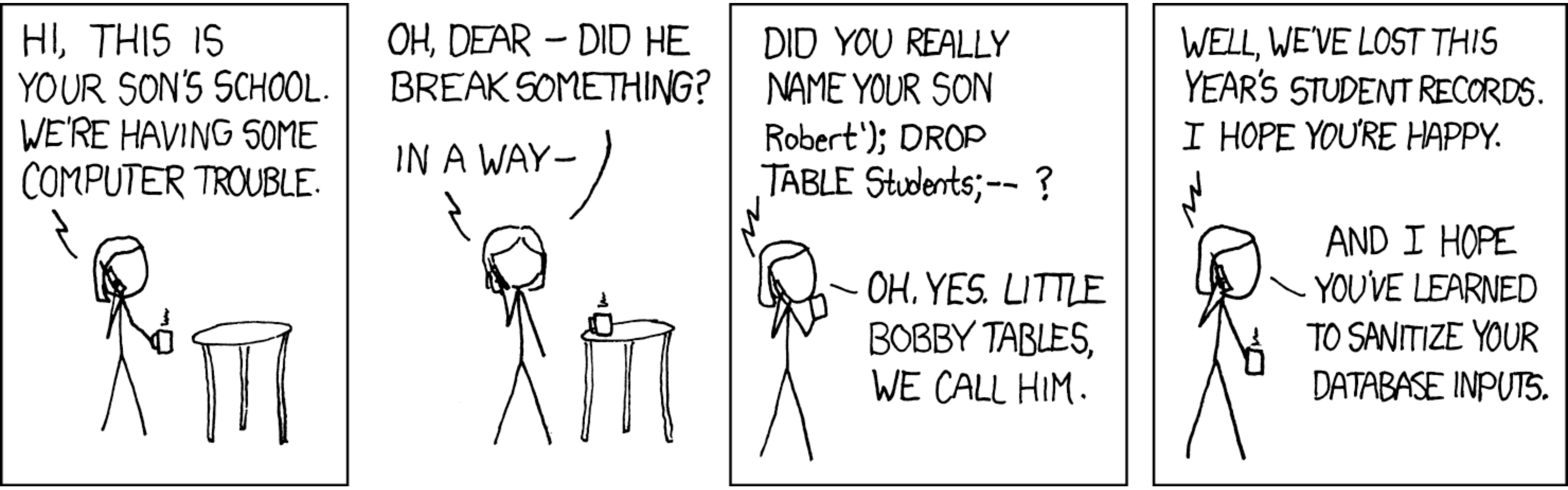
Database systems

- Structured collection of data stored for use by one or more applications
- Contains the relationships between data items and groups of data items
- Can sometimes contain sensitive data that needs to be secured
- Query language: Provides a uniform interface to the database

Database Security



xkcd 327


HI, THIS IS YOUR SON'S SCHOOL. WE'RE HAVING SOME COMPUTER TROUBLE.
OH, DEAR – DID HE BREAK SOMETHING?
IN A WAY–
DID YOU REALLY NAME YOUR SON Robert'); DROP TABLE Students;-- ?
OH. YES. LITTLE BOBBY TABLES, WE CALL HIM.
WELL, WE'VE LOST THIS YEAR'S STUDENT RECORDS. I HOPE YOU'RE HAPPY.
AND I HOPE YOU'VE LEARNED TO SANITIZE YOUR DATABASE INPUTS.

Relational Databases

- Constructed from tables of data
  - each column holds a particular type of data
  - each row contains a specific value these
  - ideally has one column where all values are unique, forming an identifier/key for that row

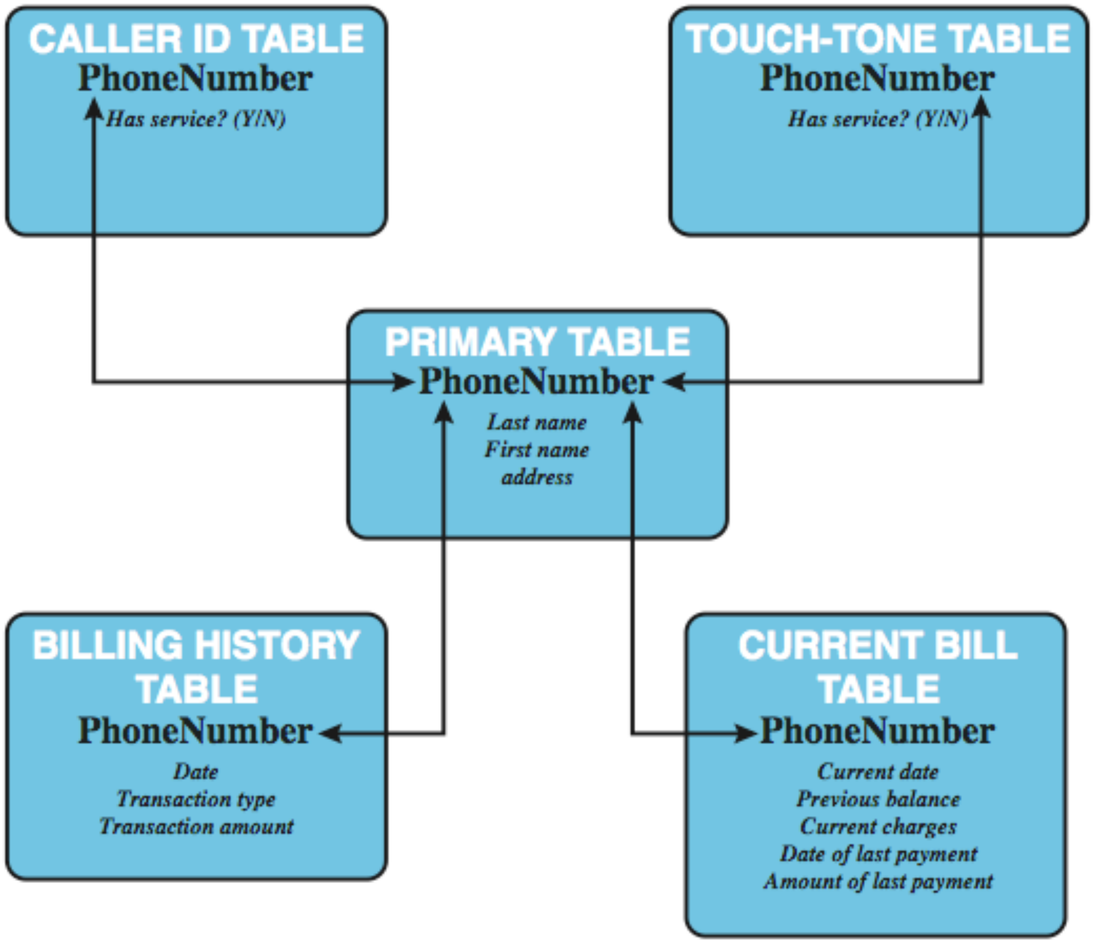
- Have multiple tables linked by identifiers

- SSE a query language to access data items meeting specified criteria

Relational databases

- Table of data consisting of rows and columns
  - Each column holds a particular type of data
  - Each row contains a specific value for each column
  - Ideally has one column where all values are unique, forming an identifier/key for that row
- Enables the creation of multiple tables linked together by a unique identifier that is present in all tables
- Use a relational query language to access the database
  - Allows the user to request data that fit a given set of criteria

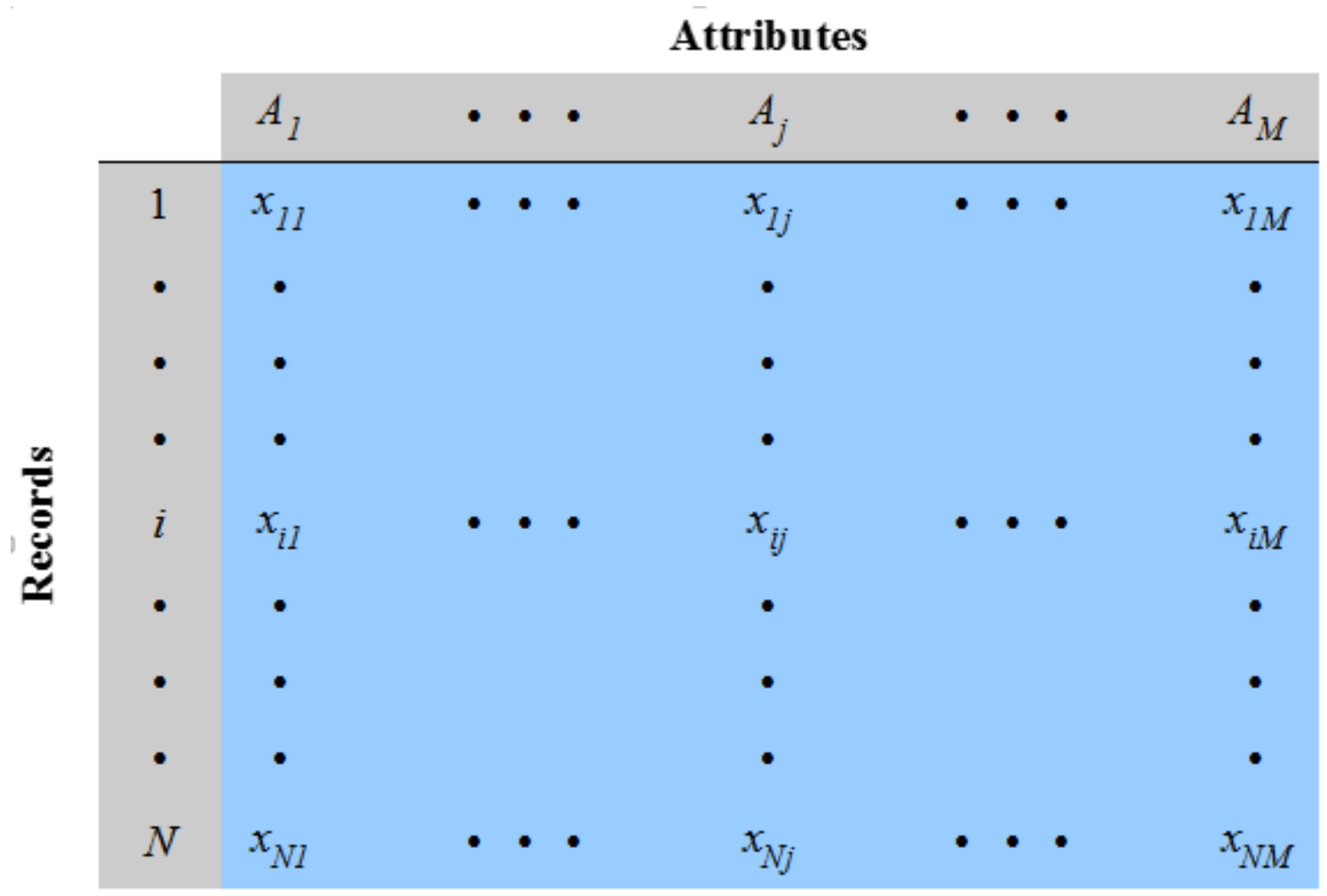
A relational database example



Relational database terms

- Relation/table/file
- Tuple/row/record
- Attribute/column/field
- Primary key: uniquely identifies a row
- Foreign key: links one table to attributes in another
- View/virtual table: Result of a query that returns selected rows and columns from one or more tables

Abstract view of a relation

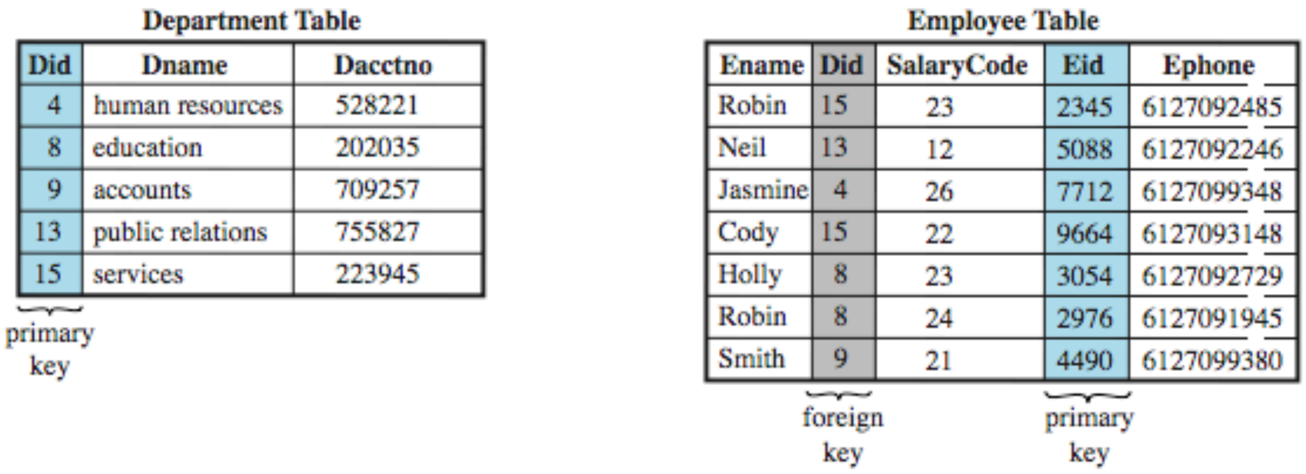


Attributes

Records

	A_1	• • •	A_j	• • •	A_M
1	x_{11}	• • •	x_{1j}	• • •	x_{1M}
•	•		•		•
•	•		•		•
•	•		•		•
i	x_{i1}	• • •	x_{ij}	• • •	x_{iM}
•	•		•		•
•	•		•		•
•	•		•		•
N	x_{N1}	• • •	x_{Nj}	• • •	x_{NM}

Relational Database Elements



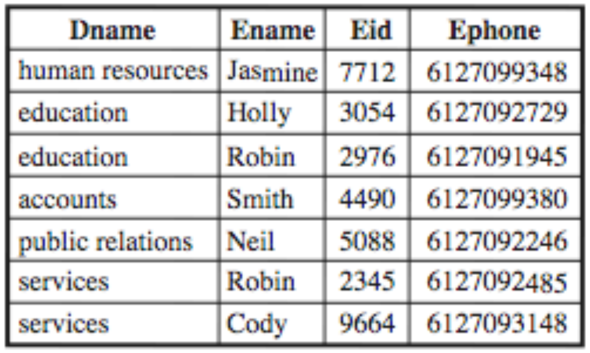
Department Table

Did	Dname	Dacctno
4	human resources	528221
8	education	202035
9	accounts	709257
13	public relations	755827
15	services	223945

Employee Table

Ename	Did	SalaryCode	Eid	Ephone
Robin	15	23	2345	6127092485
Neil	13	12	5088	6127092246
Jasmine	4	26	7712	6127099348
Cody	15	22	9664	6127093148
Holly	8	23	3054	6127092729
Robin	8	24	2976	6127091945
Smith	9	21	4490	6127099380

(a) Two tables in a relational database



Dname	Ename	Eid	Ephone
human resources	Jasmine	7712	6127099348
education	Holly	3054	6127092729
education	Robin	2976	6127091945
accounts	Smith	4490	6127099380
public relations	Neil	5088	6127092246
services	Robin	2345	6127092485
services	Cody	9664	6127093148

(b) A view derived from the database

Structured Query Language

- Structure Query Language (SQL)
  - originally developed by IBM in the mid-1970s
  - standardized language to define, manipulate, and query data in a relational database
  - several similar versions of ANSI/ISO standard

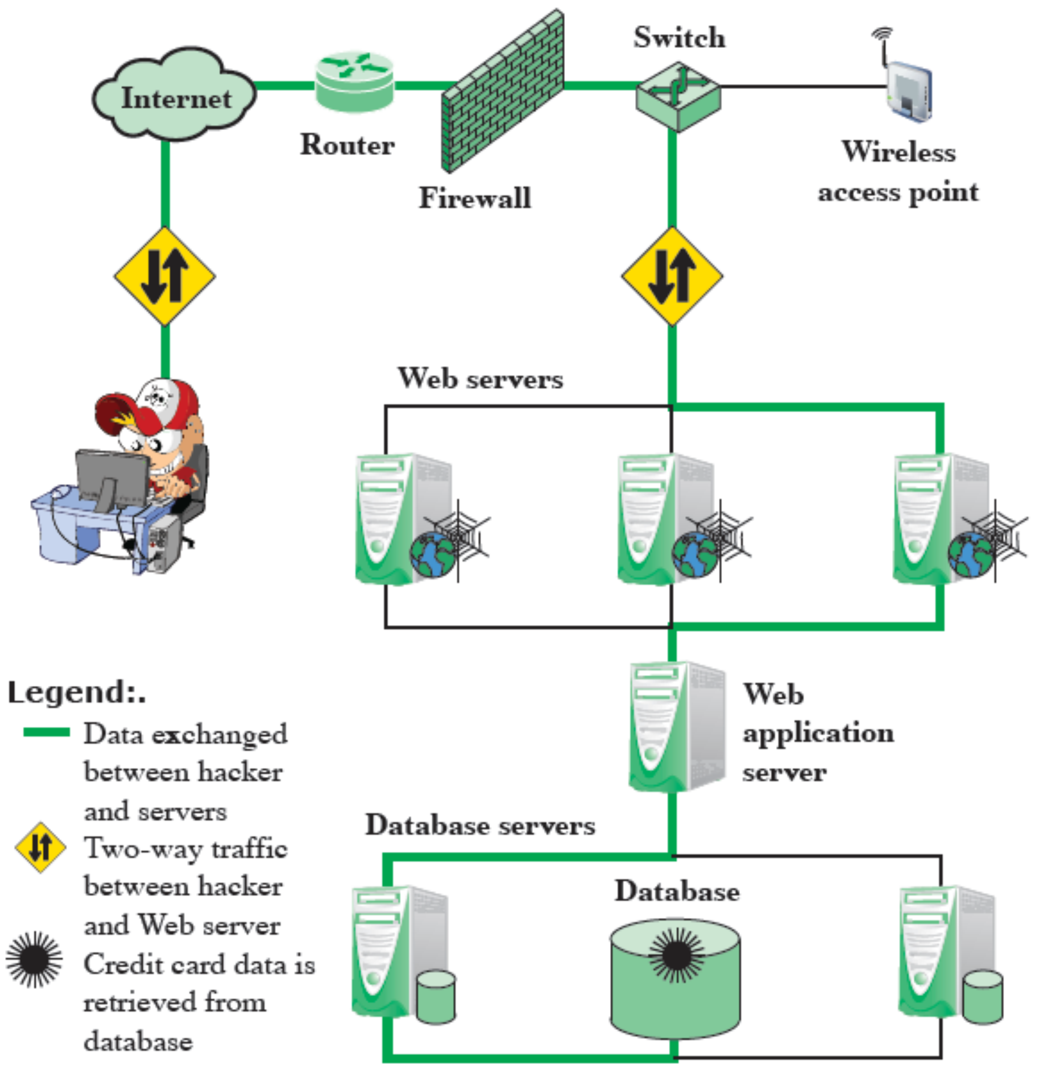
```
CREATE TABLE department (
           Did INTEGER PRIMARY KEY,
           Dname CHAR (30),
           Dacctno CHAR (6) )

CREATE TABLE employee (
           Ename CHAR (30),
           Did INTEGER,
           SalaryCode INTEGER,
           Eid INTEGER PRIMARY KEY,
           Ephone CHAR (10),
           FOREIGN KEY (Did) REFERENCES department (Did) )
```

```
CREATE VIEW newtable (Dname, Ename, Eid, Ephone)
AS SELECT D.Dname E.Ename, E.Eid, E.Ephone
FROM Department D Employee E
WHERE E.Did = D.Did
```

SQL injection attacks

- One of the most prevalent and dangerous network-based security threats
- Sends malicious SQL commands to the database server
- Depending on the environment SQL injection can also be exploited to:
  - Modify or delete data
  - Execute arbitrary operating system commands
  - Launch denial-of-service (DoS) attacks

A typical injection attack


Internet
Router
Firewall
Switch
Wireless access point
Web servers
Web application server
Database servers
Database
Legend:.
Data exchanged between hacker and servers
Two-way traffic between hacker and Web server
Credit card data is retrieved from database

SQLi Attack Avenues

- User Input - Attacker injects SQL commands by providing suitably crafted input
- Server Variables - Forging variables in HTTP headers
- Second-Order Injection - Occurs when incomplete prevention mechanisms against SQL injections are in place. A malicious user relies on data already in place in the database to trigger an attack
- Cookies: Stateful nature of cookies can allow an adversary to modify a cookies contents
- Physical user input: Normal input maliciously crafted. such as barcodes, RFID tags, etc.

Sample SQL injection

- The SQLi attack typically works by prematurely terminating a text string and appending a new command

SELECT fname

FROM student

where fname is ‘**`user prompt`**’;

User: John’; DROP table Course;--

Sample SQL injection: tautology

$query= “

SELECT info FROM user WHERE name =

`$_GET[“name”]’ AND pwd = `GET[“pwd”]`

”;

Attacker enters: ` OR 1=1 –-

In-band attacks

- **Tautology**: This form of attack injects code in one or more conditional statements so that they always evaluate to true
- **End-of-line comment**: After injecting code into a particular field, legitimate code that follows are nullified through usage of end of line comments
- **Piggybacked queries**: The attacker adds additional queries beyond the intended query, piggy-backing the attack on top of a legitimate request

Inferential attack (gathering info)

- There is no actual transfer of data, but the attacker is able to reconstruct the information by sending particular requests and observing the resulting behavior of the Website/database server
  - Illegal/logically incorrect queries: lets an attacker gather important information about the type and structure of the backend database of a Web application

Out-band attack

- Data is retrieved using a different channel
- This can be used when there are limitations on information retrieval, but outbound connectivity from the database server is lax
  - For example: An email with the results of a query is sent to a tester

SQLi countermeasures

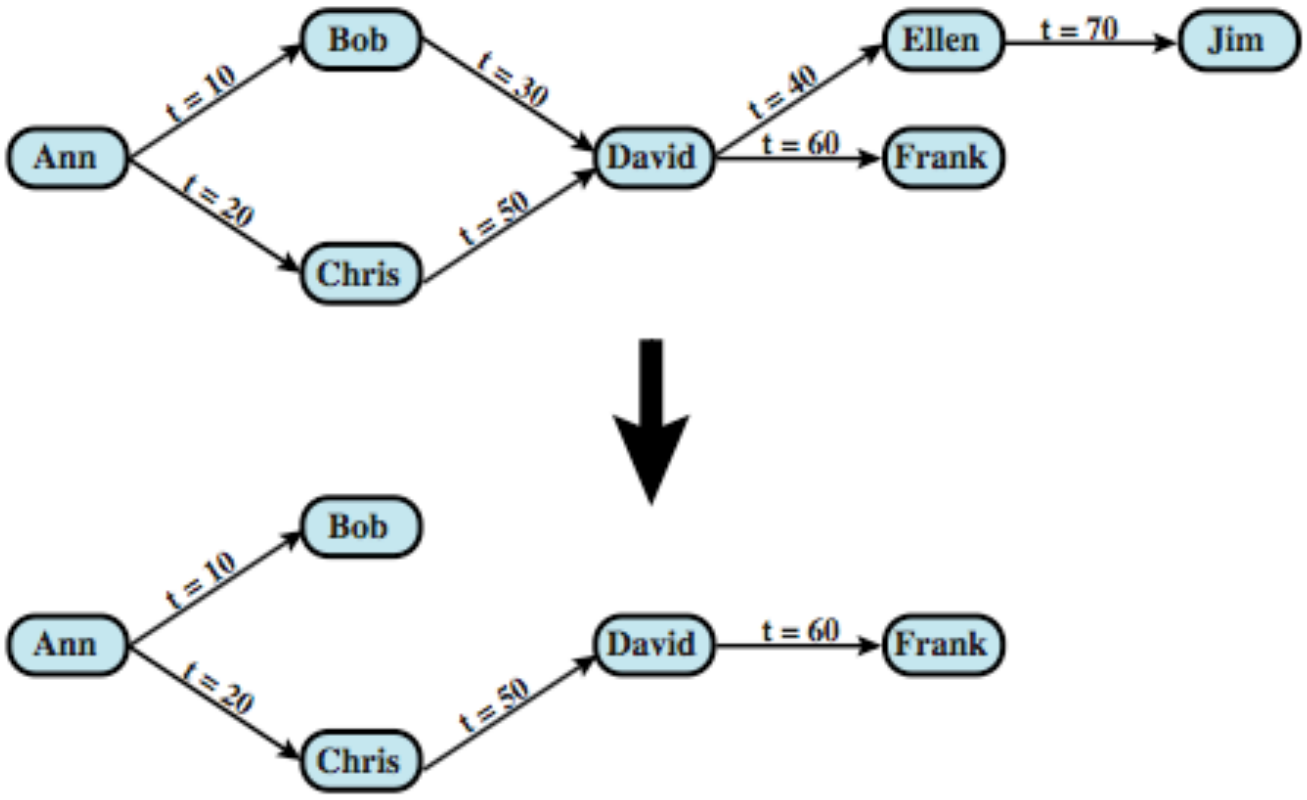
- Defensive coding: stronger data validation
- Detection
  - Signature based
  - Anomaly based
  - Code analysis
- Runtime prevention: Check queries at runtime to see if they conform to a model of expected queries

SQL Access Controls

- If the user has access to the entire database or just portions of it

- Two commands:
  - `GRANT {privileges | role} [ON table] TO {user | role | PUBLIC} [IDENTIFIED BY password] [WITH GRANT OPTION]`
    - e.g. GRANT SELECT ON ANY TABLE TO john
  - `REVOKE {privileges | role} [ON table] FROM {user | role | PUBLIC}`
    - e.g. REVOKE SELECT ON ANY TABLE FROM john
  - `WITH GRANT OPTION: whether grantee can grant “GRANT” option to other users`
- Typical access rights are:
  - `SELECT, INSERT, UPDATE, DELETE, REFERENCES`

Cascading Authorizations



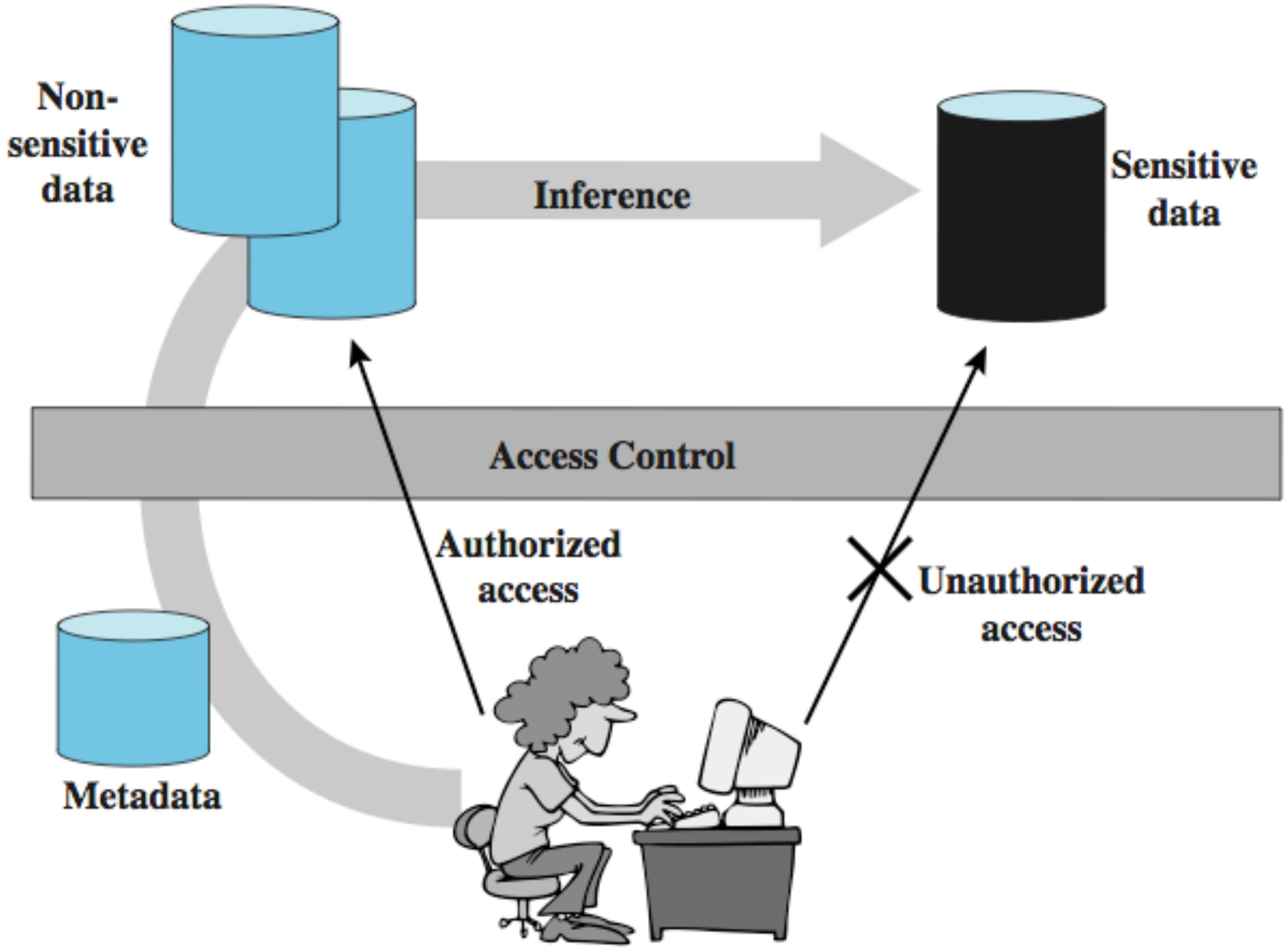
Role-Based Access Control

- Role-based access control work well for DBMS
  - eases admin burden, improves security
- Categories of database users:
  - application owner
  - end user
  - administrator
- DB RBAC must manage roles and their users

Inference

- Inference - The process of performing authorized queries and deducing unauthorized information from legitimate responses.

Inference


Non-sensitive data
Inference
Sensitive data
Access Control
Authorized access
Unauthorized access
Metadata

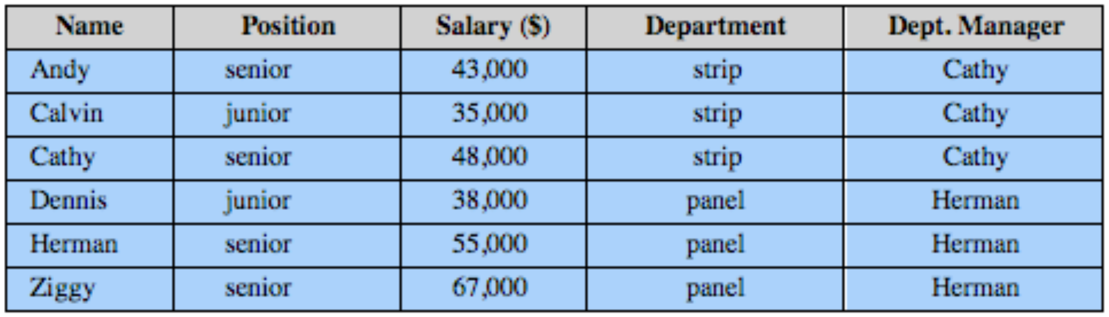
Inference Countermeasures

- Inference detection at database design
  - alter database structure or access controls
- Inference detection at query time
  - by monitoring and altering or rejecting queries

Statistical Databases

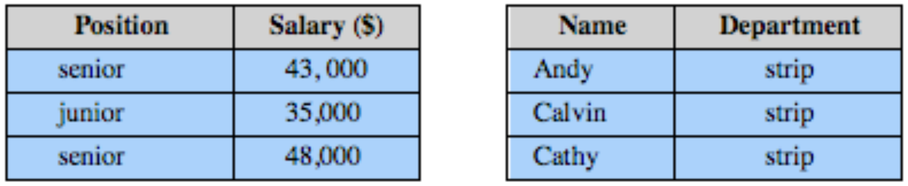
- Provides data of a statistical nature
  - e.g. counts, averages
- Two types:
  - pure statistical database
  - ordinary database with statistical access
    - some users have normal access, others statistical
- Access control objective to allow statistical use without revealing individual entries
- Security problem is one of inference

Inference Example



Name	Position	Salary ($)	Department	Dept. Manager
Andy	senior	43,000	strip	Cathy
Calvin	junior	35,000	strip	Cathy
Cathy	senior	48,000	strip	Cathy
Dennis	junior	38,000	panel	Herman
Herman	senior	55,000	panel	Herman
Ziggy	senior	67,000	panel	Herman

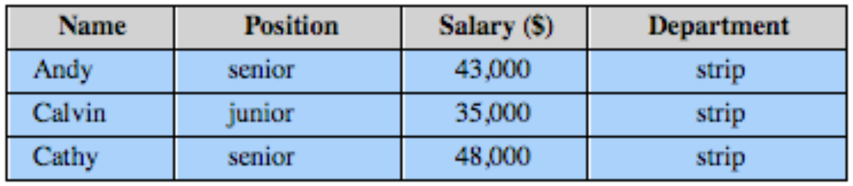
(a) Employee table



Position	Salary ($)
senior	43, 000
junior	35,000
senior	48,000

Name	Department
Andy	strip
Calvin	strip
Cathy	strip

(b) Two views



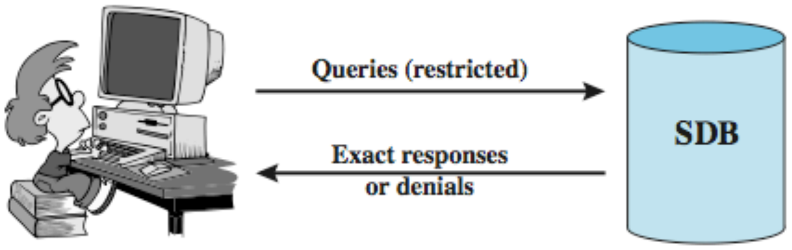
Name	Position	Salary ($)	Department
Andy	senior	43,000	strip
Calvin	junior	35,000	strip
Cathy	senior	48,000	strip

(c) Table derived from combining query answers

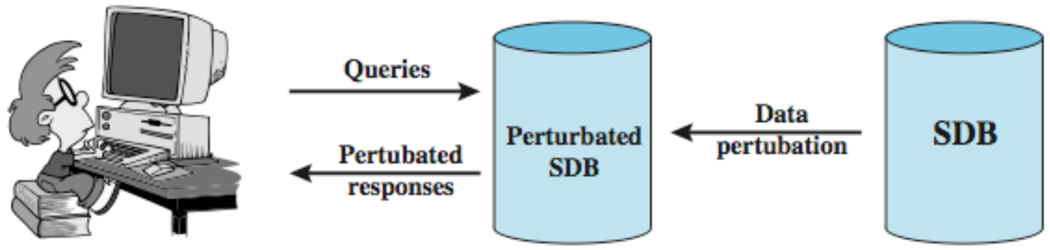
Perturbation

- Add noise to statistics generated from data
  - will result in differences in statistics
- Data perturbation techniques
  - data swapping
  - generate statistics from probability distribution
- Output perturbation techniques
  - random-sample query
  - statistic adjustment
- Must minimize loss of accuracy in results

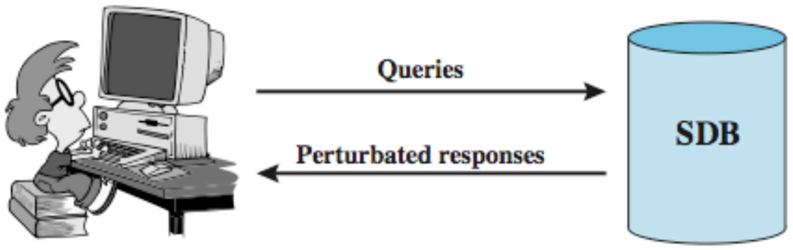
Protecting Against Inference



(a) Query set restriction



(b) Data perturbation

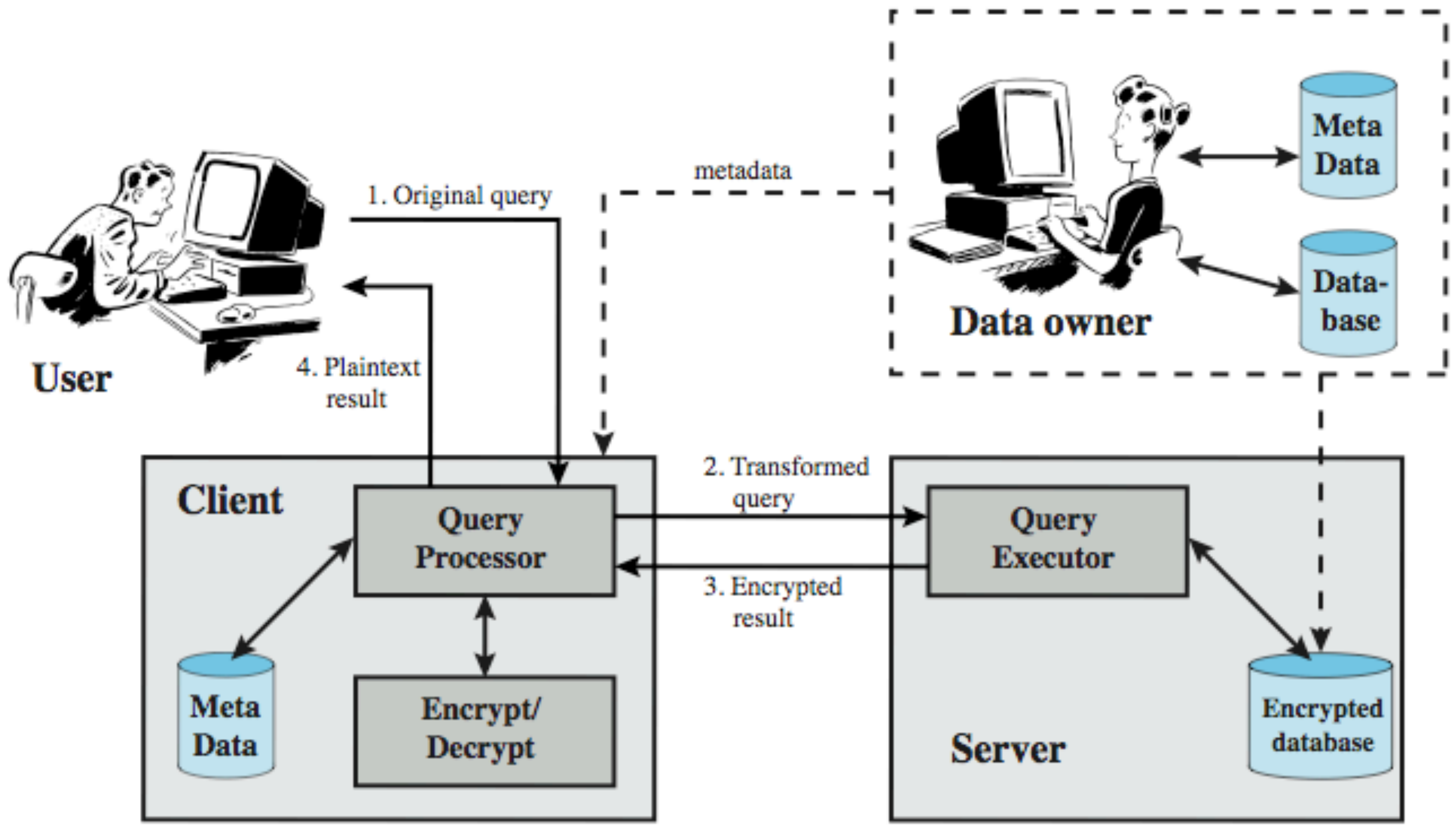


(c) Output perturbation

Database Encryption

- Databases typical a valuable info resource
  - protected by multiple layers of security: firewalls, authentication, O/S access control systems, DB access control systems, and database encryption
- Can encrypt
  - entire database - very inflexible and inefficient
  - individual fields - simple but inflexible
  - records (rows) or columns (attributes) - best
    - also need attribute indexes to help data retrieval
- Varying trade-offs

Database Encryption

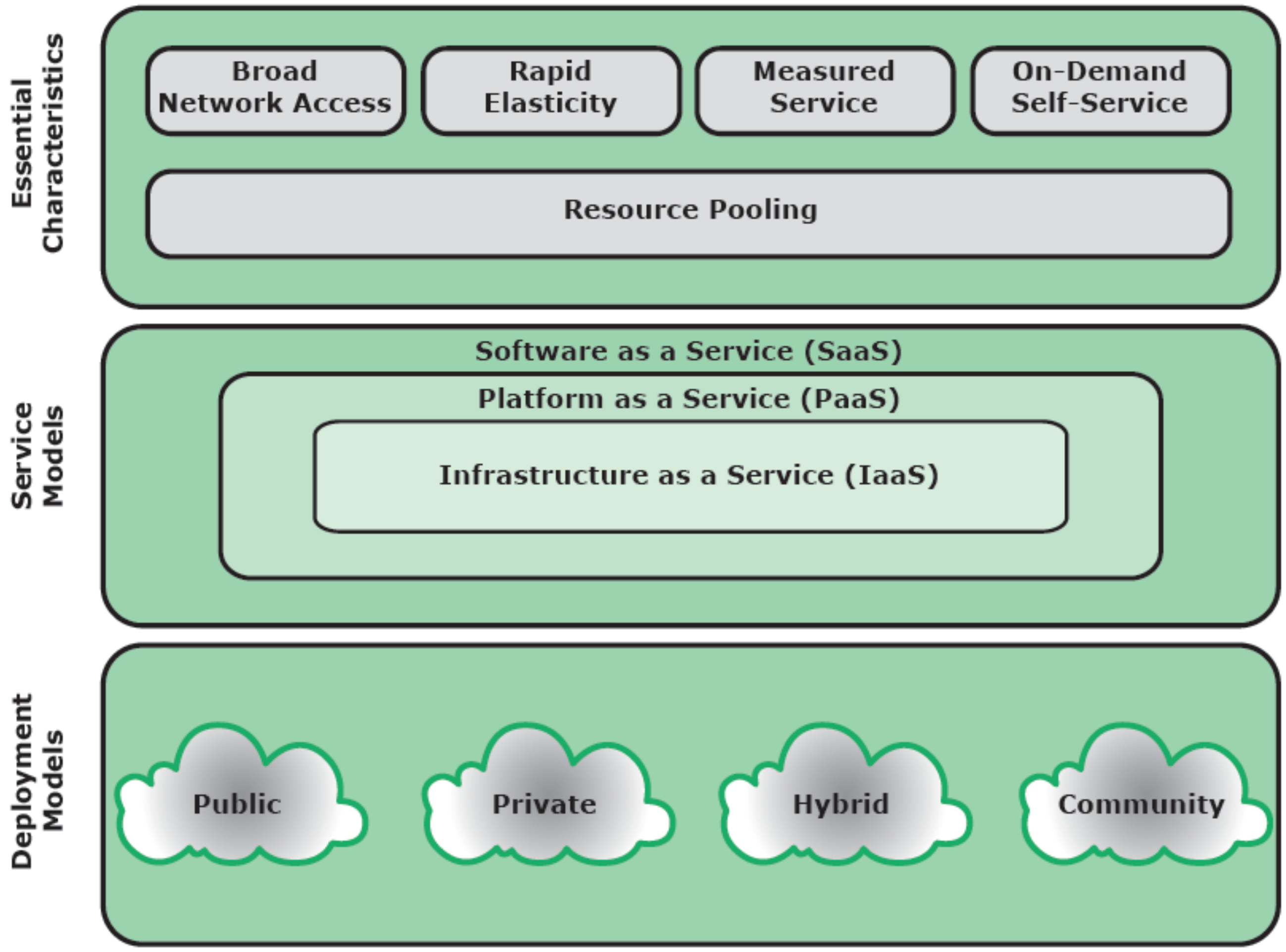


Cloud computing

- An increasing trend in many organizations to move a substantial portion (or all) of their IT to cloud computing
- NIST SP-800-145 defines cloud computing as: “A model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. …”

There is no cloud
it's just someone else's computer

Cloud computing elements



Essential characteristics: Broad network access

- Capabilities available over a network
- Accessed thru standard mechanisms
- Use by heterogeneous client platforms (desktops, laptops, tablets, cell phones)

Essential characteristics: Rapid elasticity

- The ability to expand/reduce services to specific requirements
- Large numbers of servers during the holidays
- Smaller number of resources during off-peak periods
- Release a resource when a task is completed

Essential characteristics: Measured service

- Cloud system automatically
  - Control and optimize resource use by leveraging a metering capability appropriate to the type of service
  - Storage, processing, bandwidth, active users

Essential characteristics: On-demand service

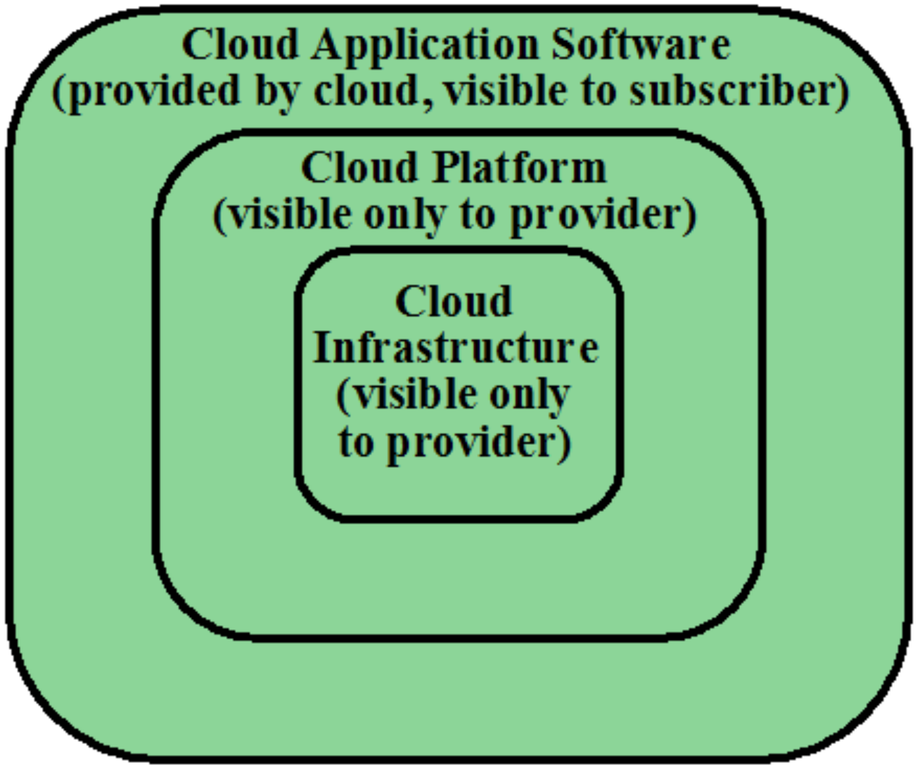
- A consumer can unilaterally provision computing capabilities without requiring human interaction
  - Server time, network storage
  - Resources wont have to a permanent part of the client's IT infrastructure

Essential characteristics: Resource pooling

- As a consequence of the previous:
  - The providers resources are pooled to serve multiple consumers using a multi-tenant model
  - Multiple resources assigned and re-assigned to clients
    - Storage, processing power, bandwidth …
  - Consumers need not to know the physical location of the service

Service model: SaaS

- provides service to customers in the form of application software
- Clients need not to install
- Clients can access application via various platforms thru a simple interface (often a browser)

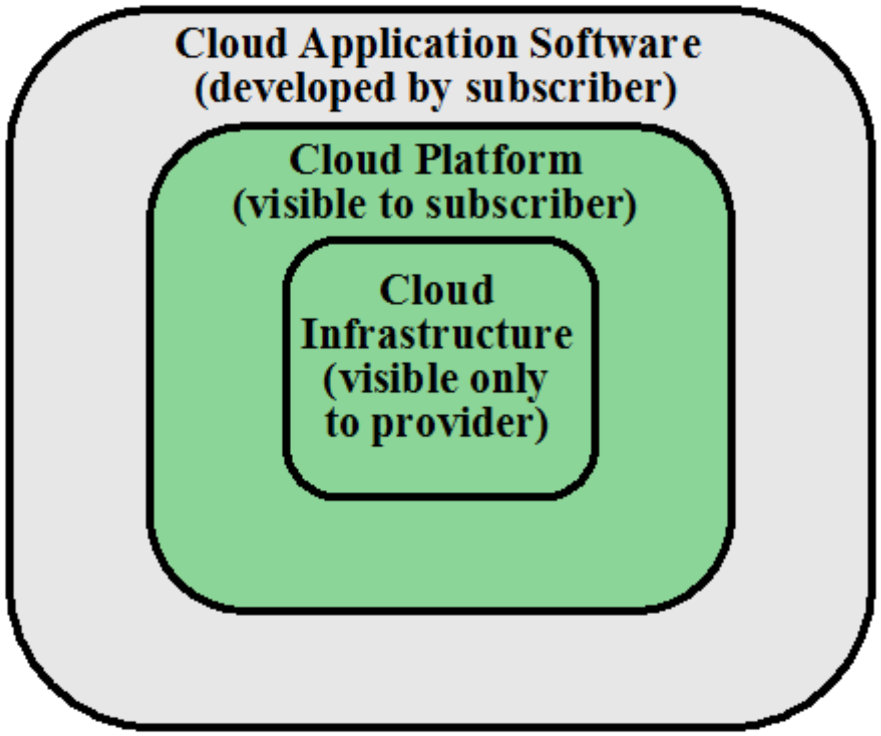

Cloud Application Software (provided by cloud, visible to subscriber)
Cloud Platform (visible only to provider)
Cloud Infrastructure (visible only to provider)

Service model: PaaS

- Provides service to customers in the form of a platform on the which the customer apps can run

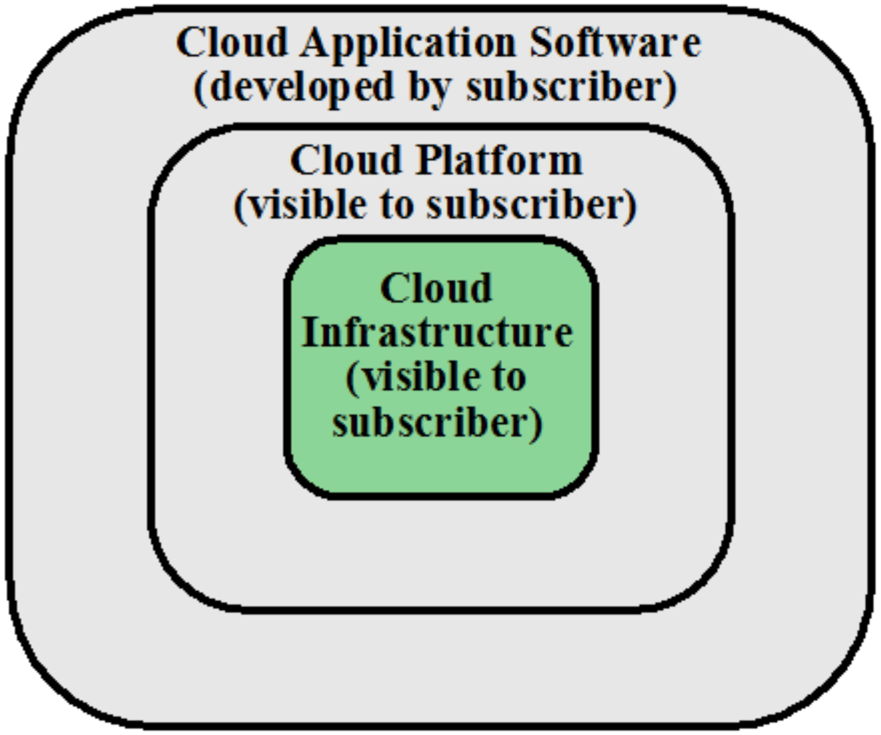
- Clients deploy on the cloud

- PaaS provides useful building block/tools

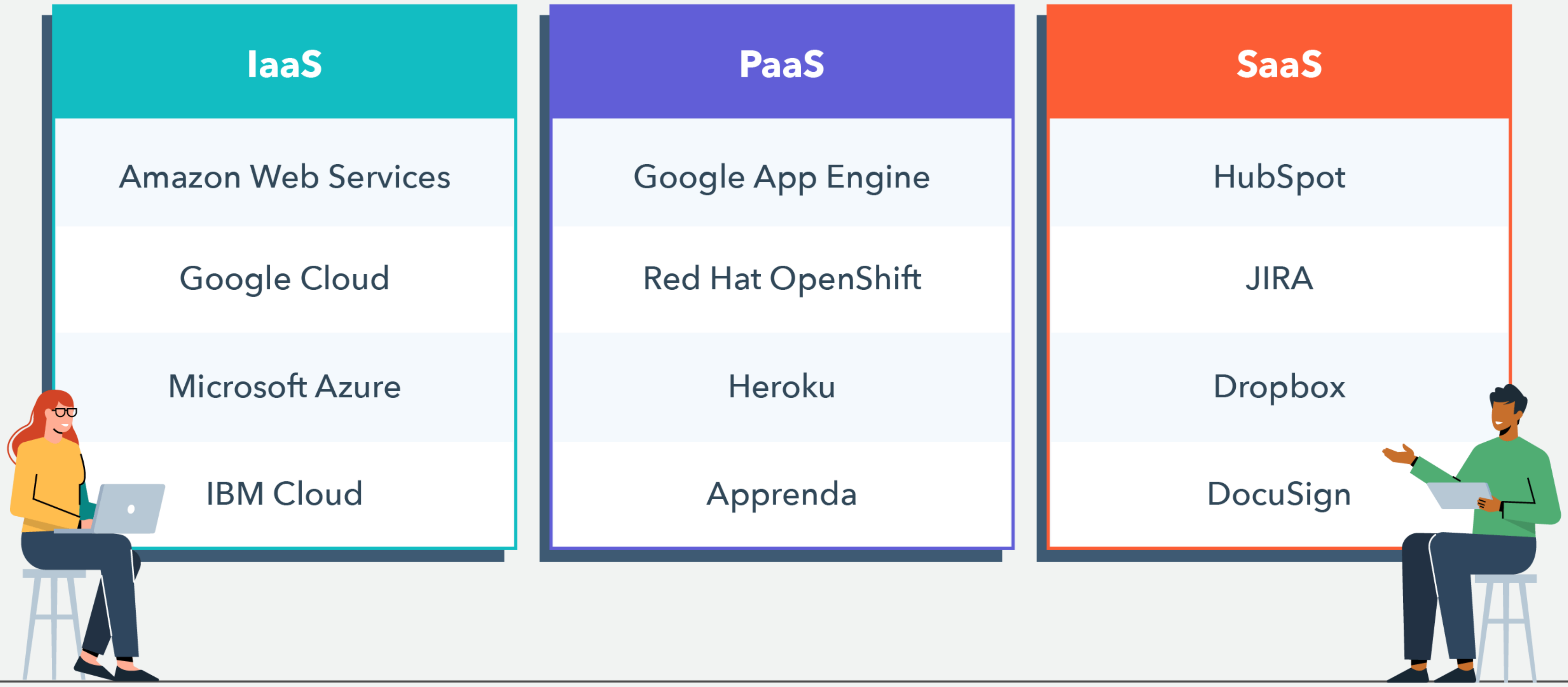


Service model: IaaS

- Provides clients access to the underlying cloud infrastructure
- VM and other abstracted hardware, OS, APIs
- Amazon Elastic Computing (EC2) and Windows Azure


Cloud Application Software (developed by subscriber)
Cloud Platform (visible to subscriber)
Cloud Infrastructure (visible to subscriber)

IaaS vs. PaaS vs. SaaS Examples



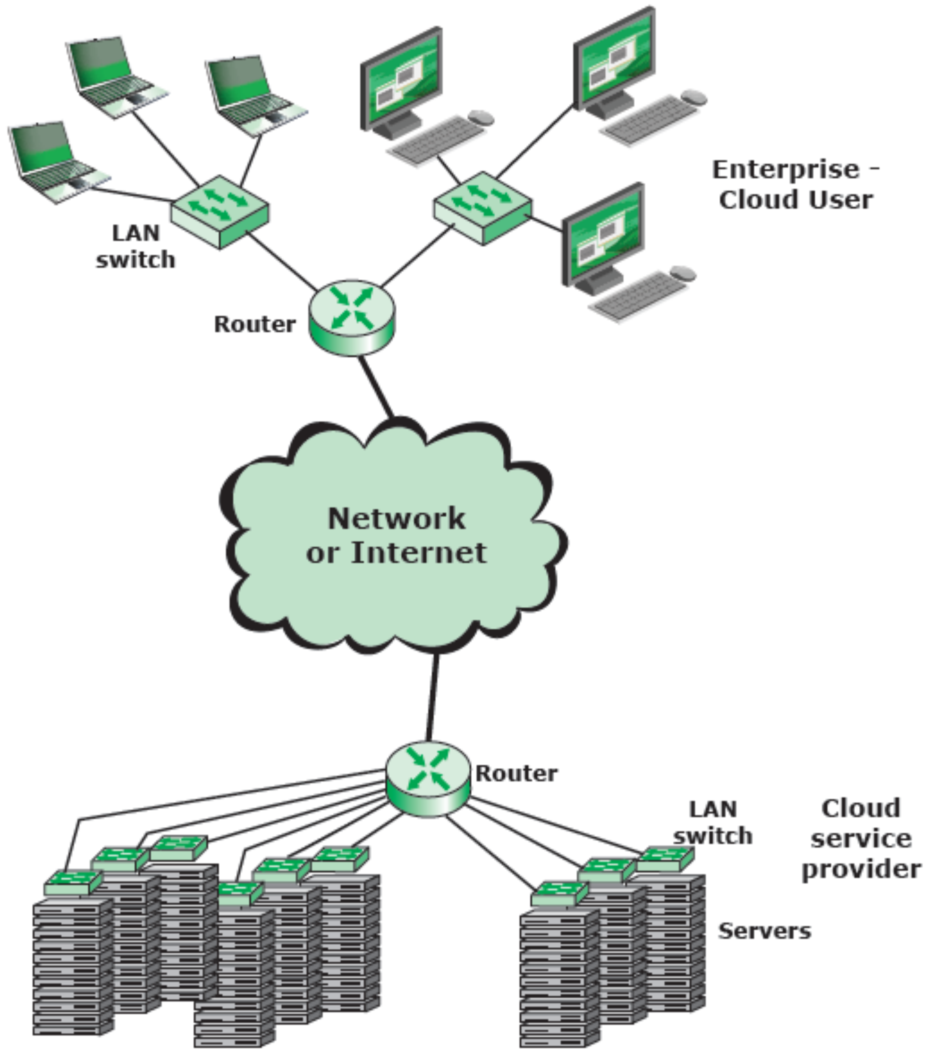
IaaS	PaaS	SaaS
Amazon Web Services	Google App Engine	HubSpot
Google Cloud	Red Hat OpenShift	JIRA
Microsoft Azure	Heroku	Dropbox
IBM Cloud	Apprenda	DocuSign

HubSpot

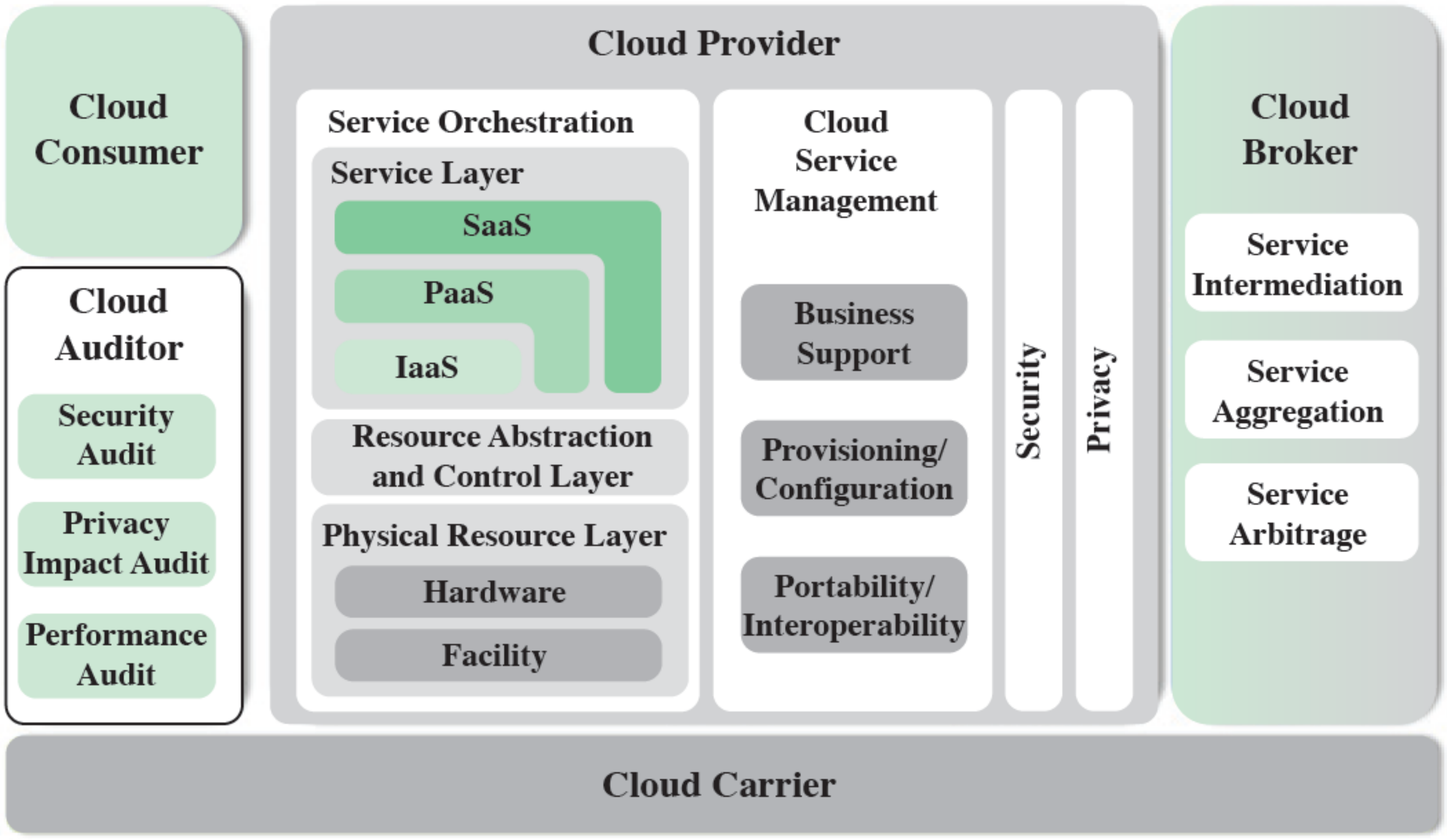
Deployment models

- **Public**: the cloud resources/services are available to the general public
- **Private**: The cloud infrastructure is solely for an organization
- **Community**: the cloud infrastructure is for a specific community and is shared by several organizations
- **Hybrid**: a composition two or more of the above

A typical cloud service



NIST's reference architecture (conceptual model)



NIST’s reference architecture (conceptual model)

- **Cloud customer**: A person or organization that uses or is interested in cloud providers services
- **Cloud provider** (CP): a person or organization that makes cloud services available
- **Cloud auditor**: A party that conducts independent assessment of sources (e.g., security)
- **Cloud broker**: A party that manages use, performance,, negotiations
- **Cloud carrier**: An intermediator that provides connectivity and service transport

Cloud provider (CP)

- For SaaS: CP deploys, configures, maintains, updates app software
- For PaaS: CP manages the computing infrastructure for the platform (middleware, database, OS, programming languages, tools)
- For IaaS: CP acquires physical computing resources: servers, network, storage, …

Cloud security risks

- **Abuse and nefarious use of cloud computing**
  - Relatively easy to register for the services
  - Many cloud services offer free trials
  - Enables hackers to get inside to conduct attacks (spamming, DoS, …)
  - The burden on CP to provide protection

- Countermeasures
  1. Stricter/restrict registration
  2. Enhanced credit card monitoring
  3. Comprehensive monitoring (traffic)

Cloud security risks

- **Insecure interfaces of APIs**
  - CPs expose a set of APIs for customers apps
  - Security depends on APIs: must be secure (from authentication to encryption)

- Countermeasures
  1. Analyzing the security of APIs
  2. Ensuring strong authentication and access control
  3. Understanding the dependency chair between the APIs

Cloud security risks

- **Malicious insiders**
  - Client organization relinquishes many (or all) of its IT and gives to the CP
  - A grave concern: malicious insider activity

- Countermeasures (by client)
  1. Comprehensive supplier assessment
  2. Specify human resource requirements as part of legal contract
  3. Require transparency

Cloud security risks

- **Shared technology issues**
  - IaaS services are delivered in a scalable way by a shared infrastructure (CPU caches, GPUs, …)
  - Probably not designed for multi-tenant architecture
  - Vulnerable to attacks (insider and outsiders)

- Countermeasures
  1. Implement best security practices during implementation, deployment, configuration
  2. Monitor environment for unauthorized activities
  3. Promote strong authentication and access control

Cloud security risks

- **Data loss or leakage**
  - Cloud storage may be the only backup storage
  - Could be devastating for many clients if data is lost

- Countermeasures
  1. Implement strong API access control
  2. Encrypt and protect integrity when in transit
  3. Analyze data protection at design and run time

Cloud security risks

- **Account or service hijacking**
  - Usually with stolen credentials
  - Compromise confidentiality, integrity and availability

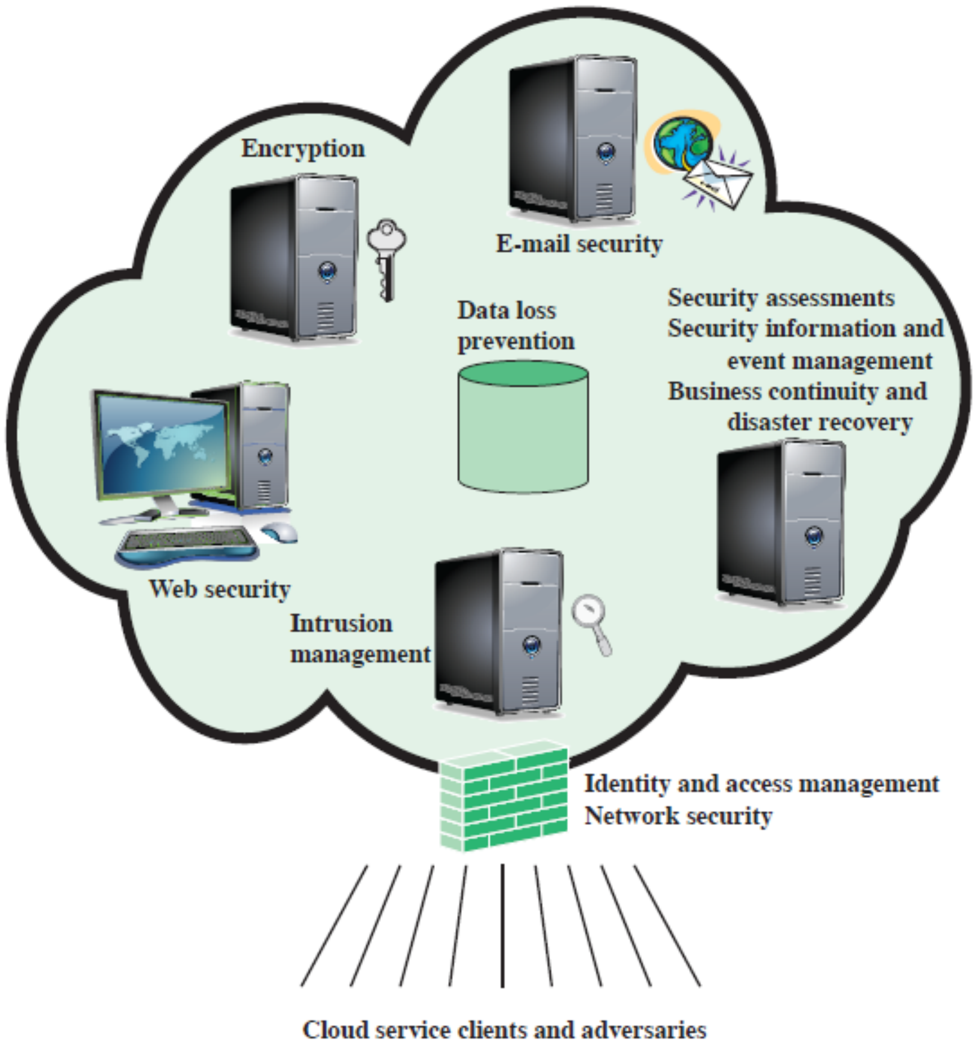
- Countermeasures
  1. Prohibit sharing of credentials between users
  2. Leverage strong multi-factory authentication
  3. Employ proactive monitoring

Data protection in the cloud

- Data must be secured while at transit, in use, or at rest
  - Client can employ encryption for transit
  - Client can encrypt data for storage (rest) but can also be CP's responsibility (key management)

Cloud security as a service

- Identify management
- Data loss prevention
- Web security
- E-mail security
- Encryption
- Business continuity
- Network security
- …


Encryption
E-mail security
Data loss prevention
Security assessments
Security information and event management
Business continuity and disaster recovery
Web security
Intrusion management
Identity and access management
Network security
Cloud service clients and adversaries