Data Security and Privacy

Topic 4: Operating System Access Control Enhancement

Information Security CS 526

Topic 16

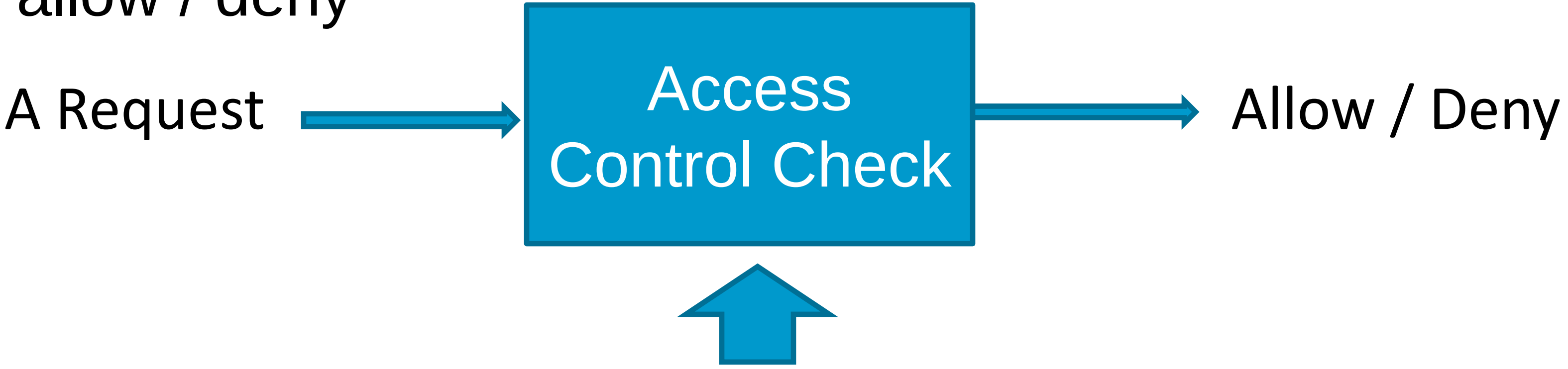
Analysis of DAC’s Weaknesses

Why Computers are Vulnerable?

- Programs are buggy
- Humans make mistakes
- Access control is not good enough
  - Discretionary Access Control (DAC) used in Unix and Windows assume that programs are not buggy

Access Control Check

- Given an access request, return an access control decision based on the policy
  - allow / deny



Group Policy Results

CONTOSO\Administrator on CONTOSO\HQ-CON-DC-01
Data collected on: 11/14/2007 6:56:41 PM

Summary	hide
Computer Configuration Summary	hide
General	hide
Computer name	CONTOSO\HQ-CON-DC-01
Domain	contoso.com
Site	Default-First-Site-Name
Last time Group Policy was processed	11/14/2007 6:56:18 PM
Group Policy Objects	show
Security Group Membership when Group Policy was applied	show
WMI Filters	show
Component Status	show
User Configuration Summary	hide
General	show
Group Policy Objects	show
Security Group Membership when Group Policy was applied	show
WMI Filters	show
Component Status	show
Computer Configuration	hide
Windows Settings	hide
Security Settings	show
Administrative Templates	hide
Policy definitions (ADMX files) retrieved from the local machine.	
System/Server Manager	show
User Configuration	hide
No settings defined.	

The Policy

Discretionary Access Control

- No precise definition. Basically, DAC allows access rights to be propagated at subject’s discretion
  - often has the notion of owner of an object
  - used in UNIX, Windows, etc.
- According to TCSEC (Trusted Computer System Evaluation Criteria)
  - *"A means of restricting access to objects based on the identity and need-to-know of users and/or groups to which they belong. Controls are discretionary in the sense that a subject with a certain access permission is capable of passing that permission (directly or indirectly) to any other subject."*
- Often compared to Mandatory Access Control

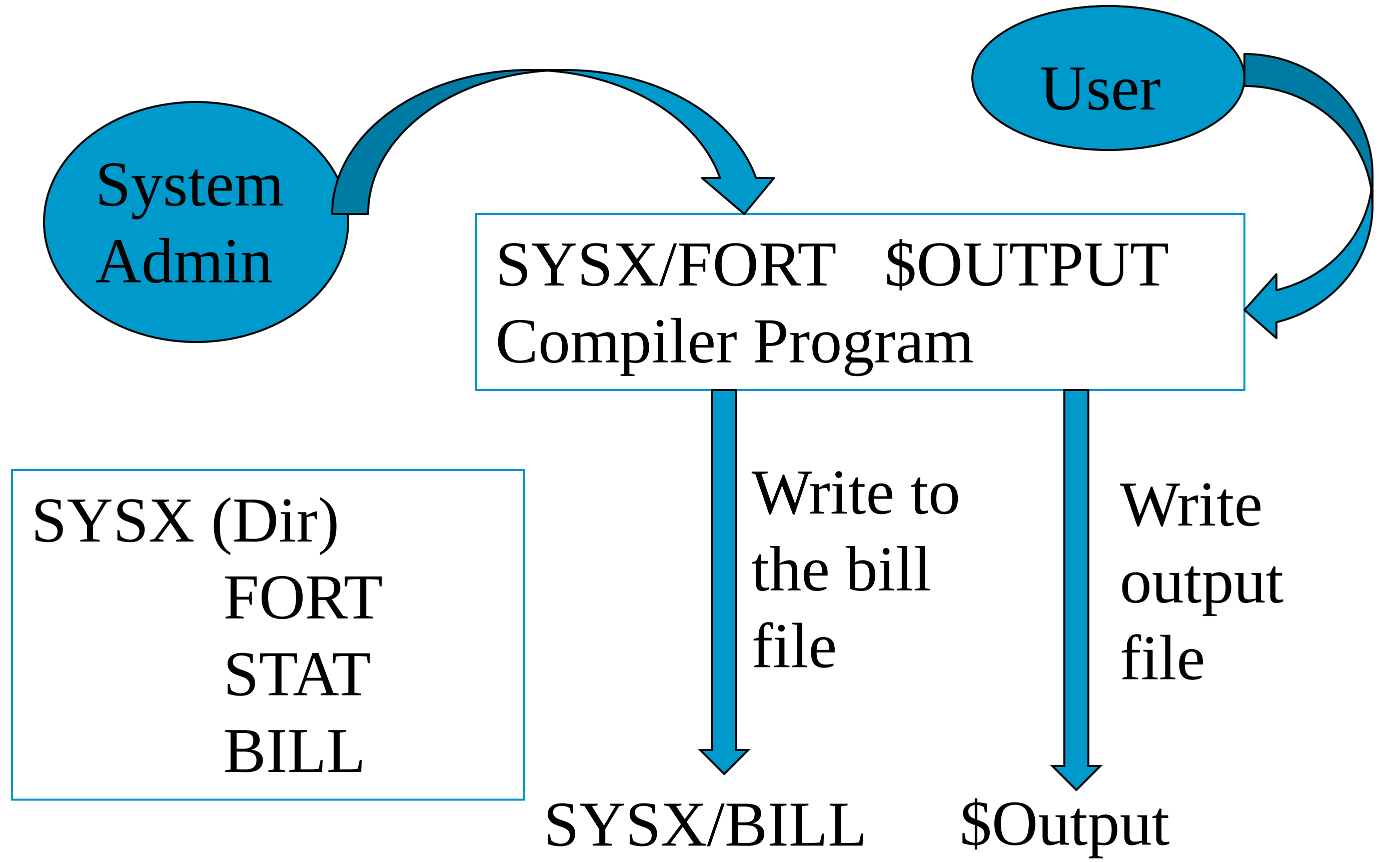
Analysis why DAC is not Good enough

- DAC causes the Confused Deputy problem
  - Solution: use capability-based systems

- DAC does not preseves confidentiality when facing Trojan horses
  - Solution: use Mandatory Access Control (BLP)

- DAC implementation fails to keep track of for which principals a subject (process) is acting on behalf of
  - Solution: fixing the DAC implementation to better keep track of principals

The Confused Deputy Problem

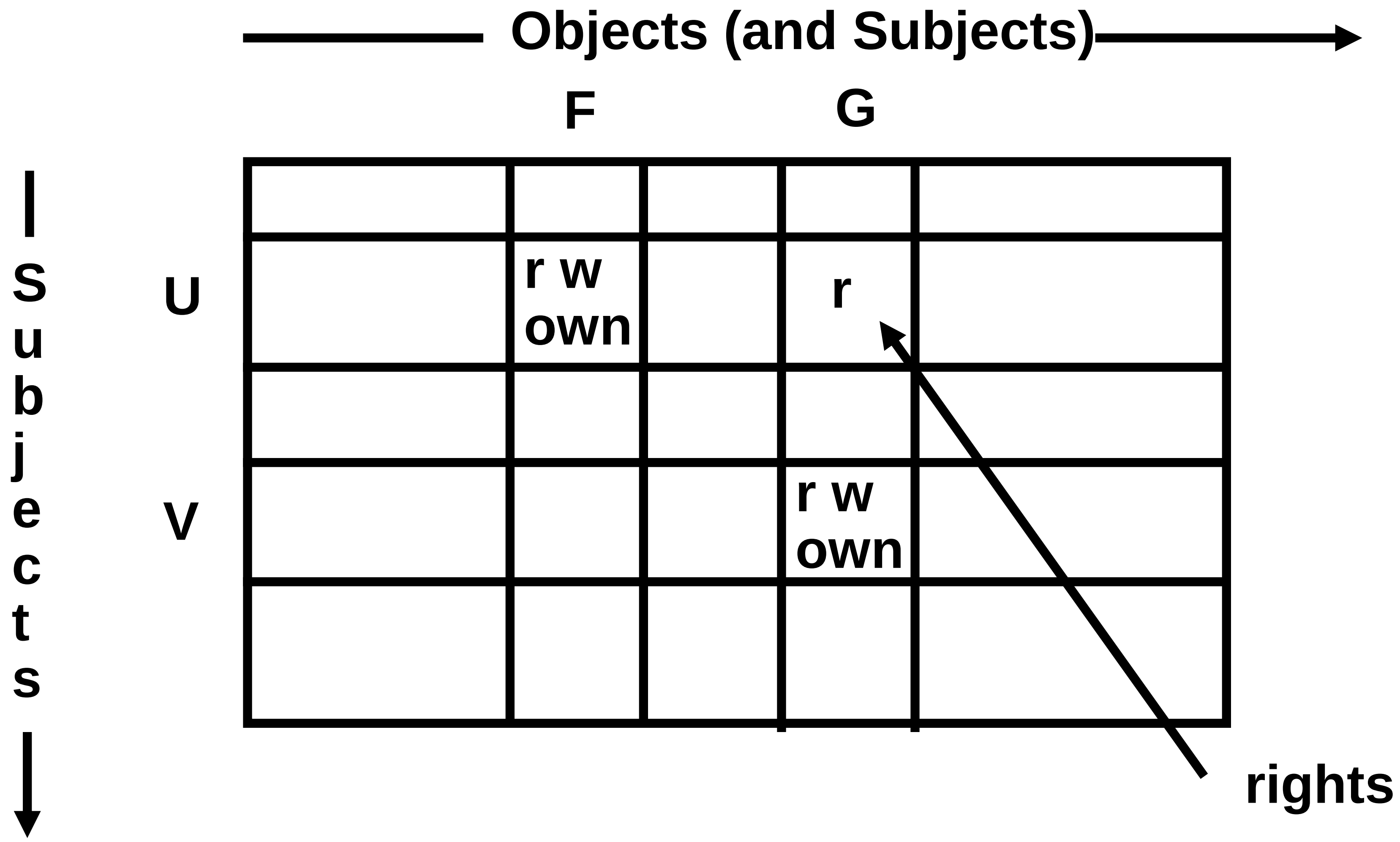


The Confused Deputy by *Norm Hardy*

Analysis of The Confused Deputy Problem

- The compiler runs with authority from two sources
  - the invoker (i.e., the programmer)
  - the system admin (who installed the compiler and controls billing and other info)
- It is the deputy of two masters
- There is no way to tell which master the deputy is serving when performing a write
- Solution: Use capability

ACCESS MATRIX MODEL



IMPLEMENTATION OF AN ACCESS MATRIX

- Access Control Lists
  - Encode columns
- Capabilities
  - Encode rows
- Access control triples
  - Encode cells

ACCESS CONTROL LISTS (ACLs)

F

U:r

U:w

U:own

G

U:r

V:r

V:w

V:own

each column of the access matrix is stored with the object corresponding to that column

CAPABILITY LISTS

U	**F/r, F/w, F/own, G/r**
V	**G/r, G/w, G/own**

each row of the access matrix is stored with the subject corresponding to that row

ACCESS CONTROL TRIPLES

Subject	Access	Object
U	r	F
U	w	F
U	own	F
U	r	G
V	r	G
V	w	G
V	own	G

commonly used in relational DBMS

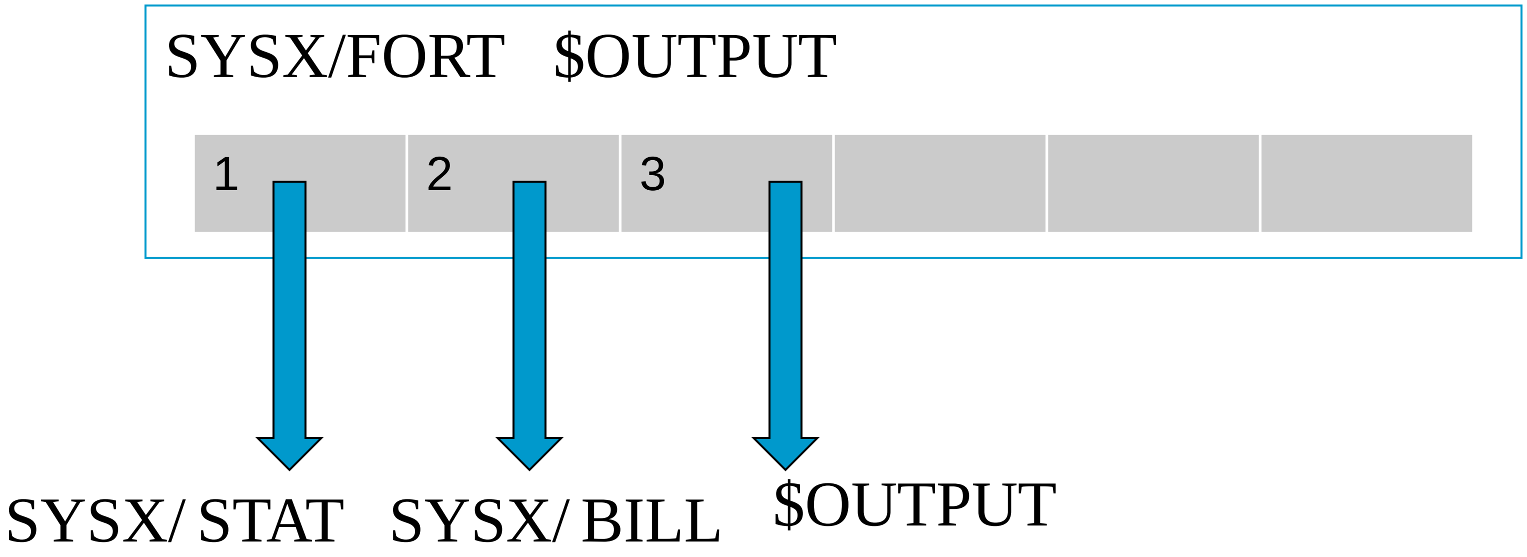
Different Notions of Capabilities

- Capabilities as a row representation of Access Matrices
- Capabilities used in POSIX/Linux as a way to divide the root power into multiple pieces that can be given out separately
- Capabilities as a way of implementing the whole access control systems
  - Subjects have capabilities, which can be passed around
  - When access resources, subjects select capabilities to access
    - An example is open file descriptors
  - We will examine this last notion in more depth

More on Capability Based Access Control

- Simulated by: a UNIX system where only owner of a file can open the file, and file sharing is done by passing opened file descriptors around
- Subjects have capabilities, which
  - Give them accesses to resources
    - E.g., like keys
  - Are transferable and unforgeable tokens of authority
    - Can be passed from one process to another
      - Similar to opened file descriptors
- Why capabilities may solve the confused deputy problems?
  - When access a resource, must select a capability, which also selects a master

How the Capability Approach Solves the Confused Deputy Problem



- Invoker must pass in a capability for $OUTPUT, which is stored in slot 3.
- Writing to output uses the capability in slot 3.
- Invoker cannot pass a capability it doesn’t have.

Capability vs. ACL

- Consider two security mechanisms for bank accounts.
- One is identity-based. Each account has multiple authorized owners. You go into the bank and shows your ID, then you can access all accounts you are authorized.
  - Once you show ID, you can access all accounts.
  - You have to tell the bank which account to take money from.

- The other is token-based. When opening an account, you get a passport to that account and a PIN, whoever has the passport and the PIN can access

Capabilities vs. ACL: Ambient Authority

- Ambient authority means that a user’s authority is automatically exercised, without the need of being selected.
  - – Causes the confused deputy problem
  - – Violates the least privilege principle

- No Ambient Authority in capability systems

Capability vs. ACL: Naming

- ACL systems need a namespace for objects
- In capability systems, a capability can serve both to designate a resource and to provide authority.
- ACLs also need a namespace for subjects or principals
  - as they need to refer to subjects or principals
- Implications
  - the set of subjects cannot be too many or too dynamic
  - most ACL systems grant rights to user accounts principals, and do not support fine-grained subject rights management

Conjectures on Why Most Real-world OS Use ACL, rather than Capabilities

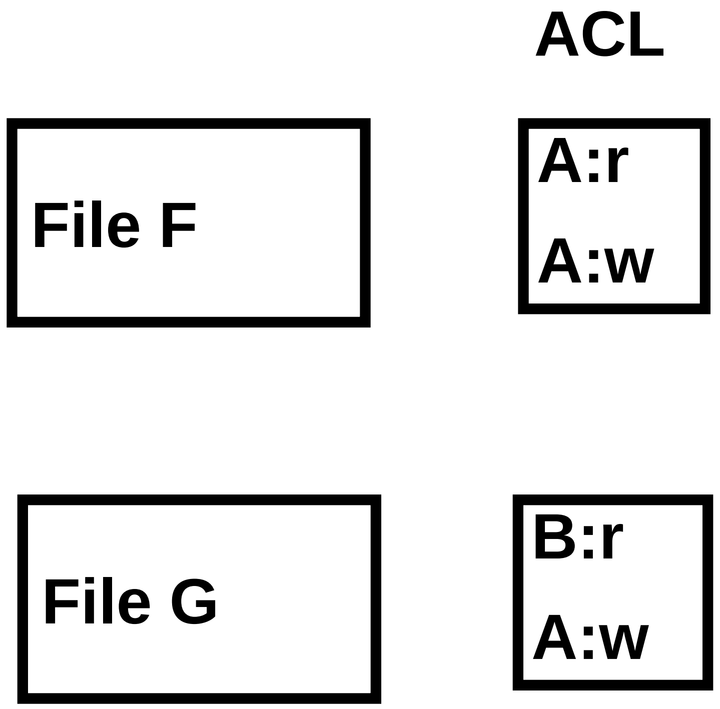
- Capability is more suitable for process level sharing, but not user-level sharing
  - user-level sharing is what is really needed

- Processes are more tightly coupled in capability-based systems because the need to pass capabilities around
  - programming may be more difficult

INHERENT WEAKNESS OF DAC

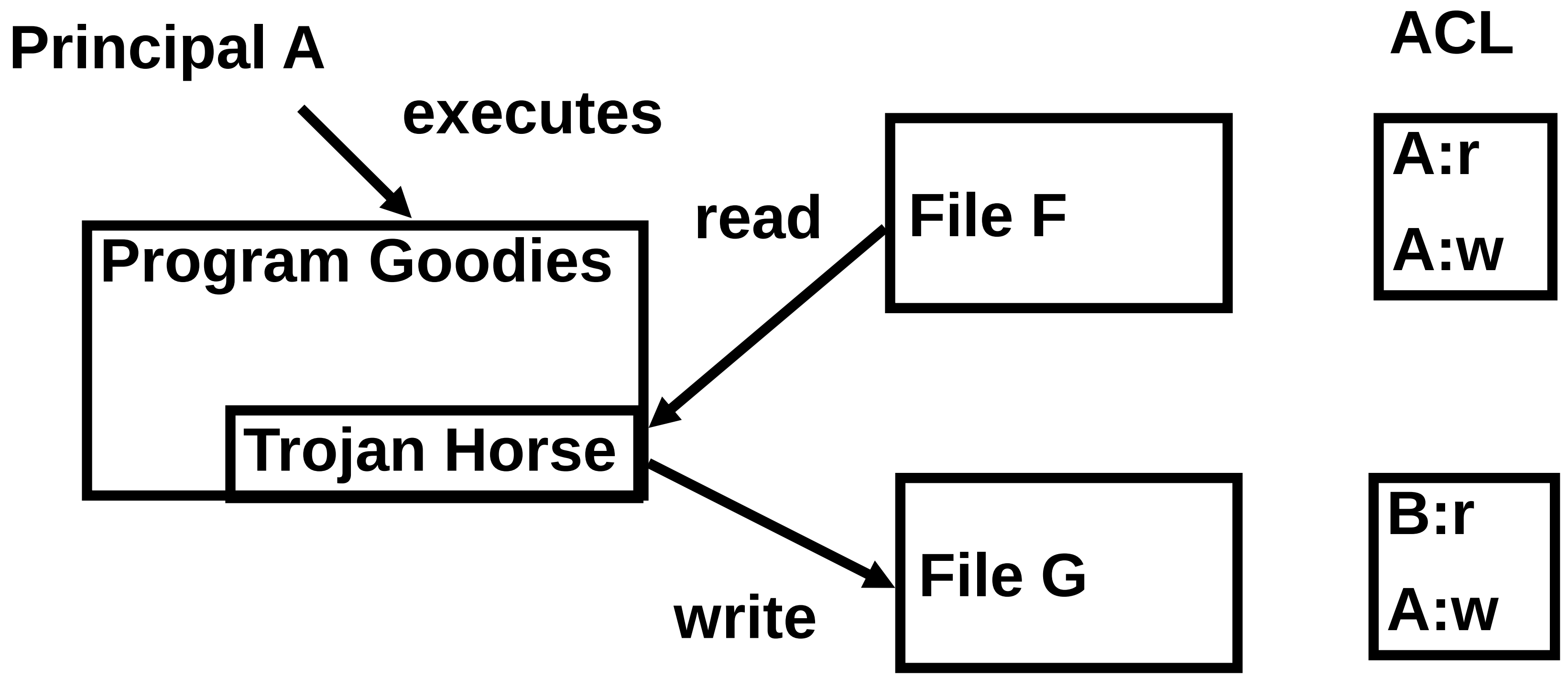
- Unrestricted DAC allows information flows from an object which can be read to any other object which can be written by a subject
  - Suppose A is allowed to read some information and B is not, A can reads and tells B
- Suppose our users are trusted not to do this deliberately. It is still possible for Trojan Horses to copy information from one object to another.

TROJAN HORSE EXAMPLE



Principal B cannot read file F

TROJAN HORSE EXAMPLE



Principal B can read contents of file F copied to file G

Buggy Software Can Become Trojan Horse

- When a buggy software is exploited, it execute the code/intention of the attacker, while using the privileges of the user who started it.

- This means that computers with only DAC cannot be trusted to process information classified at different levels
  - Mandatory Access Control is developed to address this problem
  - We will cover this in the next topic

DAC's Weaknesses Caused by The Gap

- A request: a subject wants to perform an action
  - E.g., processes in OS
- The policy: each principal has a set of privileges
  - E.g., user accounts in OS

- Challenging to fill the gap between the subjects and the principals
  - relate the subject to the principals

Unix DAC Revisited (1)

Action	Process	Effective UID	Real Principals
User A Logs In	shell	User A	User A
Load Binary “Goodie” Controlled by user B	Goodie	User A	? ?

•When the Goodie process issues a request, what principal(s) is/are responsible for the request?
•Under what assumption, it is correct to say that User A is responsible for the request?

Assumption: Programs are benign, i.e., they only do what they are told to do.

UNIX DAC Revisited (2)

Action	Process	Effective UID	Real Principals
	shell	User A	User A
Load AcroBat Reader Binary	AcroBat	User A	User A
Read File Downloaded from Network	AcroBat	User A	? ?

- When the AcroBat process (after reading the file) issues a request, which principal(s) is/are responsible for the request?
- Under what assumption, it is correct to say that User A is responsible for the request?

  Assumption: Programs are correct, i.e., they handle inputs correctly.

Why DAC is vulnerable?

- Implicit assumptions
  - Software are benign, i.e., behave as intended
  - Software are correct, i.e., bug-free
- The reality
  - Malware are popular
  - Software are vulnerable
- The problem is not caused by the discretionary nature of policy specification!
  - i.e., owners can set policies for files

Why DAC is Vulnerable? (cont')

- A deeper reason in the enforcement mechanism
  - A single invoker is not enough to capture the origins of a process
- When the program is a Trojan
  - The program-provider should be responsible for the requests
- When the program is vulnerable
  - It may be exploited by input-providers
  - The requests may be issued by injected code from input-providers
- Solution: include input-providers as the principals

Coming Attractions …

- The Bell LaPadula Model