Advanced Systems Security: Security Goals

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A Secure System

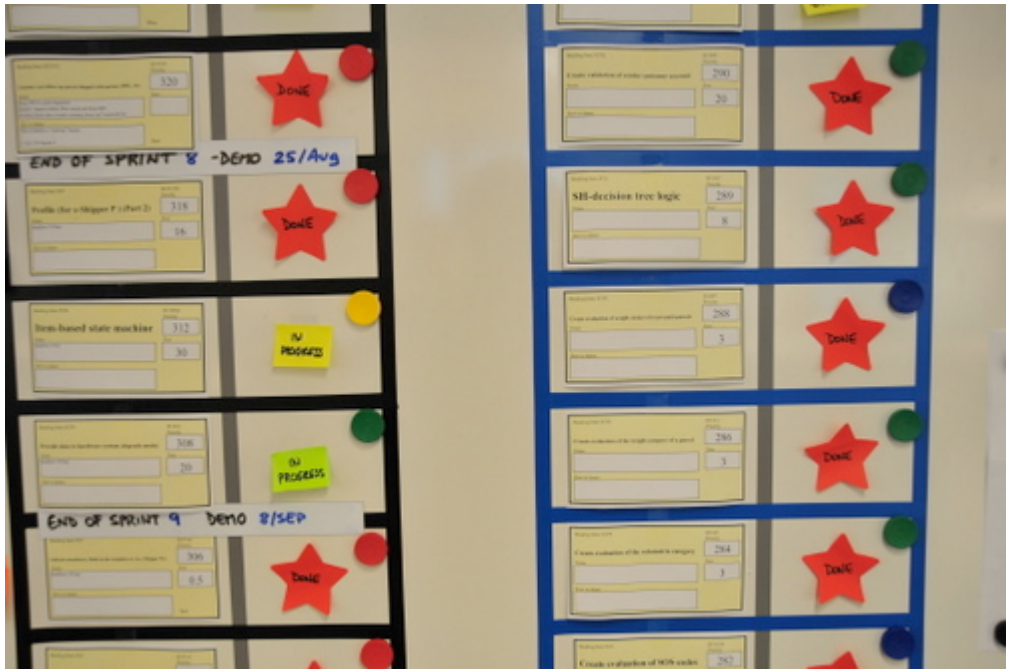
- Consists of a mandatory protection system enforced by a reference validation mechanism that satisfies the reference monitor concept
- Can we choose a mandatory protection state to enforce?
- Why is one better than another?

Mandatory Protection States

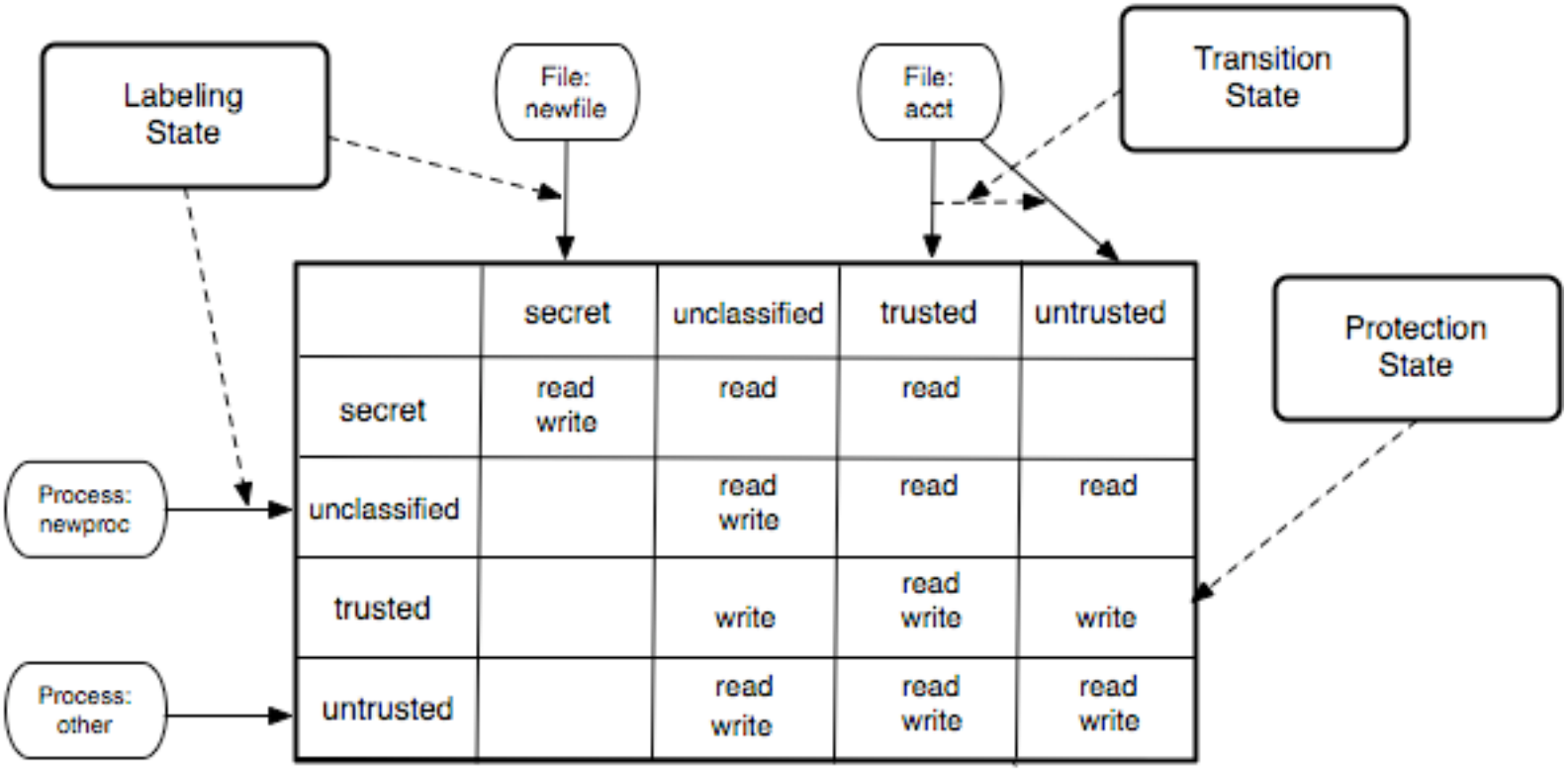
- Is smaller state better?
  - Fewer labels? Fewer permissions?
- Are more isolated labels better?
  - Fewer permissions to other labels
- How are labels related?
  - Are some better than others?
- What about labeling state and transition state?
  - What dynamics make sense?

Choosing Security Goals

- How do we define security for our systems?



Access Matrix



Access Matrix Goal

- Protection State represents policy, and the policy should enforce a goal
- Difficult to write a goal in terms of a low-level policy
- We want a goal to be easily understandable
  - Policy need not be if it complies

Least Privilege

- *The protection mechanism should force every process to operate with the minimum privileges needed to perform its task.*
- Due to Saltzer and Schroeder (of Multics project)
- One of many "design principles" in their paper "The Protection of Information in Computer Systems" (1975)
- Others
  - Principle of Psychological Acceptability
  - Principle of Fail Safe Defaults

Least Privilege

- How to compute least privilege?
  - Aim: Determines the permissions required for the program to run effectively
- Various systems provide support
  - SELinux audit2allow: take denied permissions and add them to policy
  - AppArmor Profile Wizard: Build an approximate profile statically and
  - http://www.novell.com/documentation/apparmor/book_apparmor21_admin/?page=/documentation/apparmor/book_apparmor21_admin/data/sec_apparmor_repo.html
- Run the program and see what permissions are used

Least Privilege

- Is a good goal because…
- Is a poor goal because…
- Can we use it to verify a policy is correct?

Least Privilege

- Is a good goal because…
  - Unnecessary permissions lead to problems (confused deputy)
  - Accounts for function
- Is a poor goal because…
  - Task permissions may conflict with security
  - How do we know when a permission is necessary, but makes the system insecure?
- Can we use it to verify a policy is correct?
  - No. *It defines a policy based on function, not security.*

Information Flow

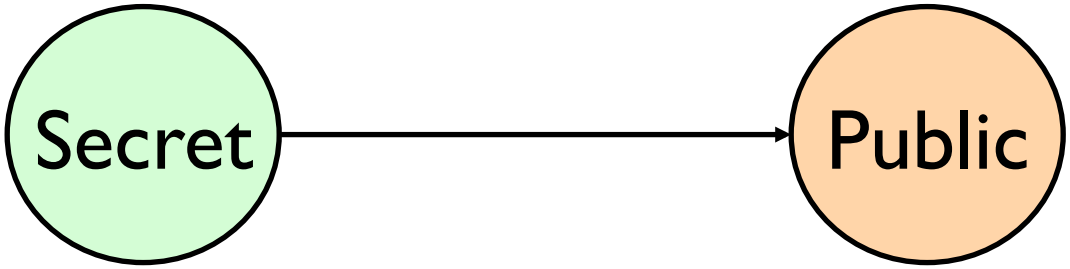
- Another approach looks at the authorized flow of information among processes via objects

Idealized Security

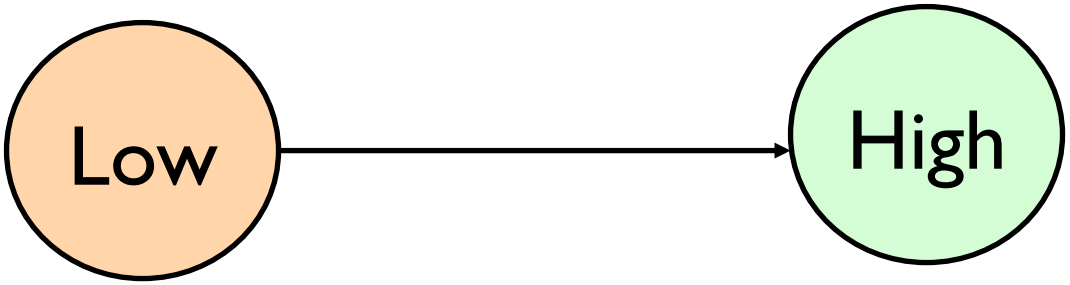
- **Multilevel Security** (MLS) for secrecy
  - Secrecy requirement: Do not *leak* data to unauthorized principals
  - Only permit information to flow from less secret to more secret principals/objects
  - E.g., Can only read a file if your clearance dominates that of the file
- **Biba Integrity**
  - Integrity requirement: Do not *depend* on data from lower integrity principals
  - Only permit information to flow from high integrity to lower integrity
  - E.g., Can only read a file if your integrity level is dominated by the file's

Information Flows

- Secrecy (MLS): If the OS permits a secret application/object to flow to a public application/ object, then there may be a leak (e.g., Trojan horse)



- Integrity (Biba): If the OS permits a low integrity input to flow to a high integrity application/object, then there may be a dependency (e.g., buffer overflow)



Information Flow Goals

- Can be represented as a graph
  - States a set of vertices (one for each label) and the directed edges between them (authorized operations)
    - Note that edge (u, v) implies either that u writes to v or v reads from u
- A goal can be stated as reachability constraint in such a graph
  - No flow from x to y in G
  - Must flow from x to z in G
- A system is secure if all reachability constraints are satisfied

Practical vs. Ideal

- Do these idealized approaches based on information flow enable practical realization of OS enforcement?
- Secrecy is possible in some environments
  - Implemented in a paper world, previously
- Integrity has not been realized in practice
  - Many processes provide high integrity services to others
- Result: Depend on many applications to manage information flows

Example: logrotate

- *Logrotate* is a service that swaps logs
- It rotates logs through sequence
  - Secrecy: Logs may span all security levels on system
  - Thus, *logrotate* is trusted in SELinux
- It reads a configuration to tell it what to do
  - Integrity: Logs must not leak into configuration files
  - Configurations must not cause file leakage

SELinux/MLS Trusted Programs

- The OS trusts that privileged applications preserve system secrecy (30+ programs)

SELinux/MLS:

Policy management tools	secadm, load_policy, setrans, setfiles, semanage, restorecon, newrole
Startup utilities	bootloader, initrc, init, local_login
File tools	dpkg_script, dpkg, rpm, mount, fsadm
Network utilities	iptables, sshd, remote_login, NetworkManager
Auditing, logging services	logrotate, klogd, auditd, auditctl
Hardware, device mgmt	hald, dmidecode, udev, kudzu
Miscellaneous services	passwd, tmpreaper, insmod, getty, consoletype, pam_console

Situation Is Much Worse

- Clients
  - Lots of client programs are entrusted with information with different secrecy/integrity requirements
  - Email, browser, IM, VOIP, …
- Servers
  - Historically, many servers have enforced security policies because they handle multiple clients
  - Web servers, databases, mail, respositories, …
- *Information flow alone is not enough to build a secure system!*

What Do We Do?

- Unsatisfying Solution #1: Ignore Exceptions
  - Processes are outside the model
  - E.g., so-called "Trusted Readers/Writers" in MLS
  - Result: Accept that some processes can violate policy, often blindly
- Unsatisfying Solution #2: Dump Info Flow Entirely
  - Change to a more general policy model
  - No meaningful security goal (is *least privilege* adequate?)
  - Result: Systems are complex -- 50K SELinux rules

Information Flow

- Is a good goal because…
- Is a poor goal because…
- Can we use it to verify a policy is correct?

Information Flow

- Is a good goal because…
  - No false negatives – an attack requires an illegal information flow
  - Can define data and functional security requirements
- Is a poor goal because…
  - Function may conflict with security
  - How do we know when a permission is illegal, but is necessary for functional requirements?
- Can we use it to verify a policy is correct?
  - Yes. *It defines a policy based on security. But what about exceptions?*

Information Flow for Others

- Q: Can we use information flow goals for non -information flow models (e.g., access matrix)?

Noninterference

- Information Flow may not be enough
- An information flow graph may not include all possible edges (covert channels)
- May create an information flow through shared, physical resources
  - Use same disk device (storage channel)
  - Use same CPU (timing channel)
- A noninterference goal requires that the user u outputs have no affect on user u' behavior, if u > u'
  - User u' is unaffected by u's operation

Noninterference

- An operation authorized at runtime may enable a covert flow
  - Allow u to write resource x
  - Allow u' to read resource y
  - Where y is dependent on the operation of writing x
  - Fill a disk; see a CPU delay; see a value of y that implies a value of x
- In general, *purge(u, hist.cmd(u))* = *purge(u', hist)* when SC(u) > SC(u')
  - u' does not see output that affected by any cmd(u)

Noninterference as a Goal

- Depends on traces of execution
  - So, such goals are difficult to express
  - No system noninterference model checking
    - Although we will discuss noninterference models for programs (decentralized label model)
    - Which are being applied to overt flows (decentralized information flow control)
- Can such goals be expressed and checked effectively?

Impact on Labeling and Transition

- How should security goals impact labeling and transitions?
- Labeling – assignment of objects to labels
  - What are the requirements for various secrecy/integrity levels?
- Transitions – conditions that determine when a label will change
  - What are the requirements for causing a label change?
- What experience do we have?

Labeling

- How do we choose the label of a subject or object when created?
  - Traditional: same label as creator
- Alternatives
  - Based on certification
    - E.g., code hashes for integrity verification
  - Based on location of created object
    - Store this with garbage, so make it garbage
  - Based on creator preference
    - Trust the creator to decide (within a range)

Transitions

- When do we change the label of a subject or object? And to what?
  - Traditional: don't change
- Alternatives
  - Based on operations performed by subject or on object
    - Low-water mark integrity; High-water mark secrecy
    - There are access control models based on these
  - Based on operations of others
    - E.g., When another process receives untrusted input, downgrade the whole system

Take Away

- To build a secure system, we need to define a mandatory protection system
  - But, what should guide the design?
- Security goals
  - Usually serves as a rough guide
- Types of security goals – biased toward security or function
  - Functional: least privilege; Security: information flow
- *Need to develop approaches to design goals for entire mandatory protection system – from function and security*