Week 12b: Security

CSC 469 / CSC 2208

Fall 2018

University of Toronto, Department of Computer Science

What it’s all about

- Managing risks. Loss of ...
  - Confidentiality/Privacy, Integrity, Availability/Access
  - Risk Analysis: cost/loss * loss freq. vs. cost to protect
    - Engineering trade-offs, not either-or decisions
    - often, Security == 1 / (functionality * convenience)
- Vulnerabilities
  - examples abound, many reasons behind
- Countermeasures
  - carefulness, cryptography, firewalls, detection, recovery

Some key security goals

- Confidentiality: keep information content away from the unauthorized
- Integrity: prevent undetected, unauthorized modification of data
- Availability: ensure that resources and services are available when needed
- Authentication: prove the identity of entities or source of information
- Non-repudiation: prevent denial of previous commitments
- Privacy and Anonymity: protect personally identifiable info

Some key security problems

- 1. Misplaced trust
- 2. Buggy implementations
- 3. Poor configuration choices
- …
- 12. Unsafe design assumptions
- …
- 997. Cryptanalysis

(https://xkcd.com/538/)

Terminology: Threats

- Threat: A potential vector (means, mechanism) for a system's security to be compromised
  - An attack exercises a threat
  - A successful attacks leads to a security compromise
- Examples of threats:
  - Network traffic arriving from the internet
  - Self-administered systems connected to a corporate (or university) LAN

Terminology: Vulnerabilities

- A vulnerability is a flaw in a system that has a security implication
- Examples:
  - Unchecked string copy allows buffer overflow
  - Administrator forgets to disable debug mode on a program during configuration, leaving unsafe but convenient features in deployed service
  - Naïve home user buys wireless router, but does not alter default password on router
- Compromises occur when an attacker matches threats with vulnerabilities

Scary aspects of “bad guys”

- Patience and time
  - Historically successful crackers have been willing to spend endless hours trying to get into systems
- Automated Tools
  - Crackers don’t even have to know anything anymore
    - Copious “cookbooks” and packaged kits
  - One clever person finds a hole, everyone runs her tools
- New profit motive
  - Rent-a-bot-net brokers

IRC Hacker Market

2006 data

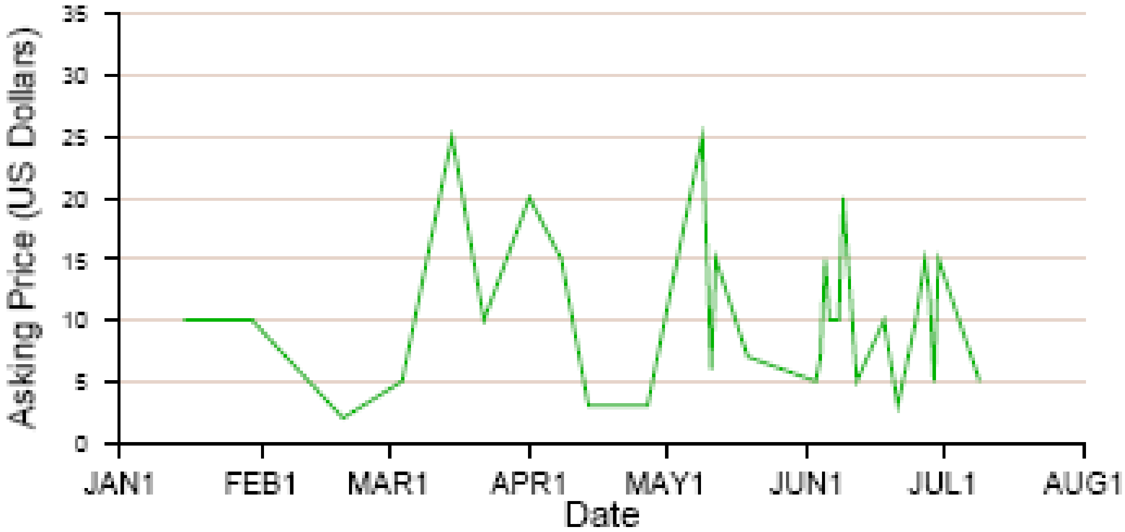
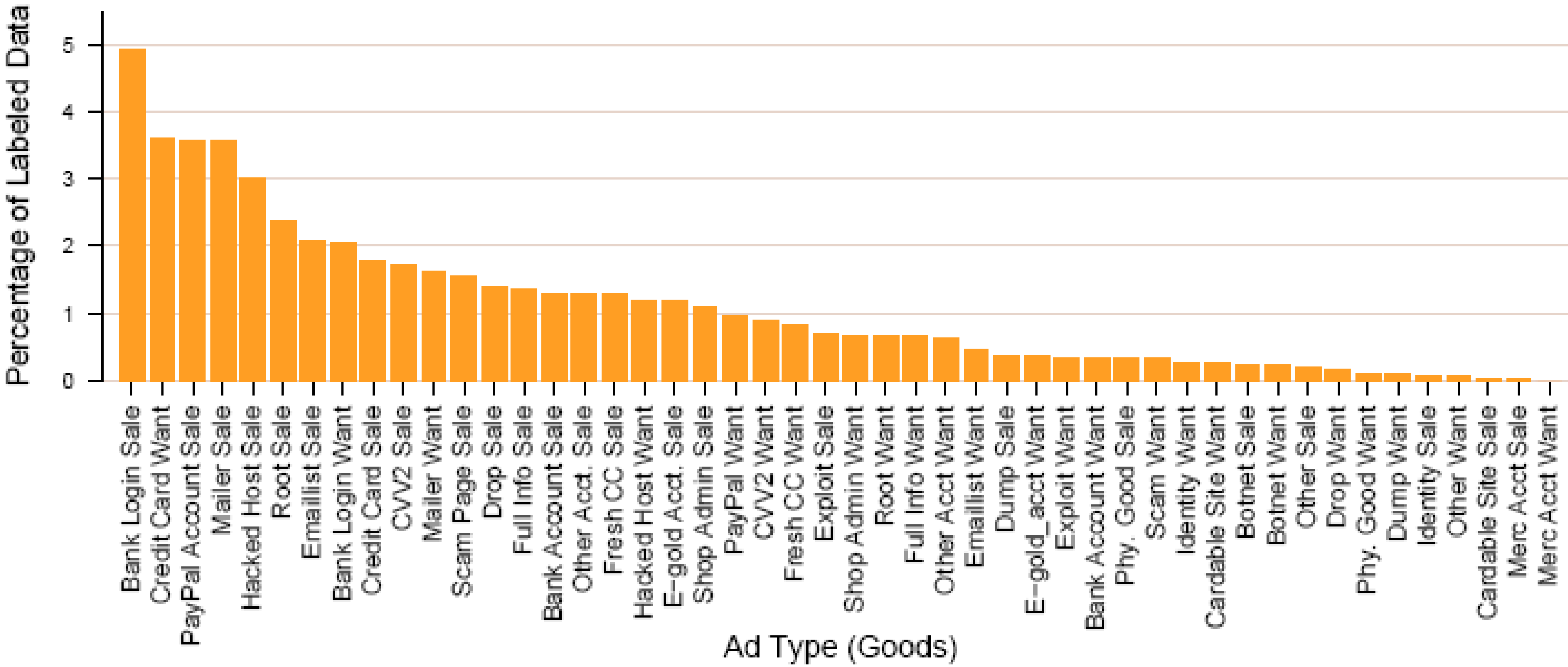


Figure 15: Price schedule for compromised hosts.

- From “An Inquiry into the Nature and Causes of the Wealth of Internet Miscreants”, Franklin et al., in Proc. Computer & Communications Security (CCS), October 2007

IRC Hacker Market



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…and if that weren't bad enough

- attackers only need one weakness
  - no need to break thru strongest wall
  - they'll try lots and exploit the weakest

Early Example: The Morris Worm

- Released on November 2, 1988
- Written by Robert T. Morris
- Invaded around 6,000 computers within hours (10% of the Internet at the time)
- Disabled many systems and services
- Morris had a friend post instructions for disabling the worm - but it was too late
- Damage estimates between $10,000 and $97 million (shows how hard it is to estimate costs)
- Details in June 1989 Comm. of the ACM "Crisis and Aftermath", Eugene H. Spafford

How the worm worked

- Copied itself to remote systems via 3 holes
- Exploit hole in finger daemon that caused buffer overflow to create remote shell
  - gets() used to read input
- Exploit hole in Unix sendmail daemon
  - listen()'s on TCP port, accept()'s connections from mailers
  - Exchanges messages about mail envelope and content
  - when running in debug mode, worm could give it commands to execute
  - sendmail ran the malicious code
- Password cracking with a dictionary of 432 words
  - accounts tested against words in a random order

"People pick bad passwords, and either forget, write down, or resent good ones."

Steven M. Bellovin

Effect of worm

- Formation of CERT
- $10,000 fine, 3 year probation, and 400 hours of community service for Morris
- Heightened awareness of computer system vulnerabilities
- Something for security professionals to quote
  - not so much a problem now ☹

https://nvd.nist.gov/general/nvd-dashboard

Example: Stuxnet (2010)

- Worm that propagates via USB sticks on Windows PCs
  - Actual target is a particular model of Siemens PLC
    - Used in many embedded industrial control systems
  - Exploits multiple vulnerabilities, including four “zero-day” exploits
  - Looks for Siemens SIMATIC WinCC/Step 7 controller software
    - If found, infects controller software (using previously unknown, unpatched vulnerability)
    - Read and alters bits of data in the contolled PLC’s
- Unusually complex, costly to develop, lots of speculation
  - Eventually confirmed (anonymous US officials) as cyberattack on Iran’s nuclear program

Example: CryptoLocker (2013)

- Propagates via email attachments
- Once activated:
  - Encrypts data files on the infected computer using strong RSA public-key cryptography
  - Sends a ransom note demaning the computer owner pay for the private decryption key via Bitcoin
  - Attempts to delete Windows Shadow Copy backups before encrypting files
- Offline backup or online pay-up…

Example: Heartbleed (2014)

- Vulnerability in OpenSSL cryptographic software library
- Bug is in the OpenSSL's implementation of the TLS/DTLS (transport layer security protocols) heartbeat extension
  - Improper input validation (due to a missing bounds check)
- Leads to the leak of memory contents from the server to the client and from the client to the server
  - In particular, leaks private keys

(https://xkcd.com/424/)

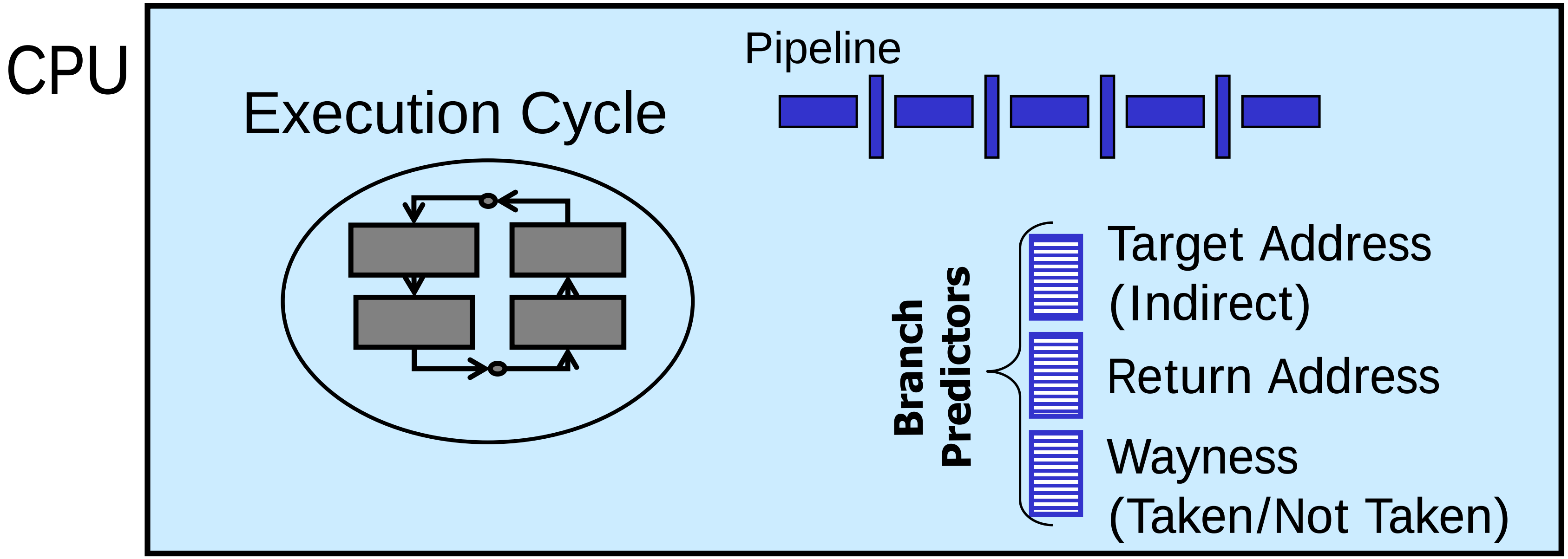
Ex: Meltdown, Spectre, Foreshadow (2018)

MELTDOWN SPECTRE FORESHADOW

Examples of *side-channel attacks*

Exploit CPU Performance Features

- Caching, speculative execution, out-of-order execution



- Meltdown: Exploits out-of-order execution
- Spectre: Exploits branch prediction

Meltdown in a Nutshell

1. Load from protected address into pointer
2. Use value to index into an array
3. Time reads from array to detect which entry was cached -> index of fast entry is value at protected memory

See slides from Foreshadow talk at USENIX Security 2018 (https://www.usenix.org/sites/default/files/conference/protected-files/security18_slides_bulck.pdf)

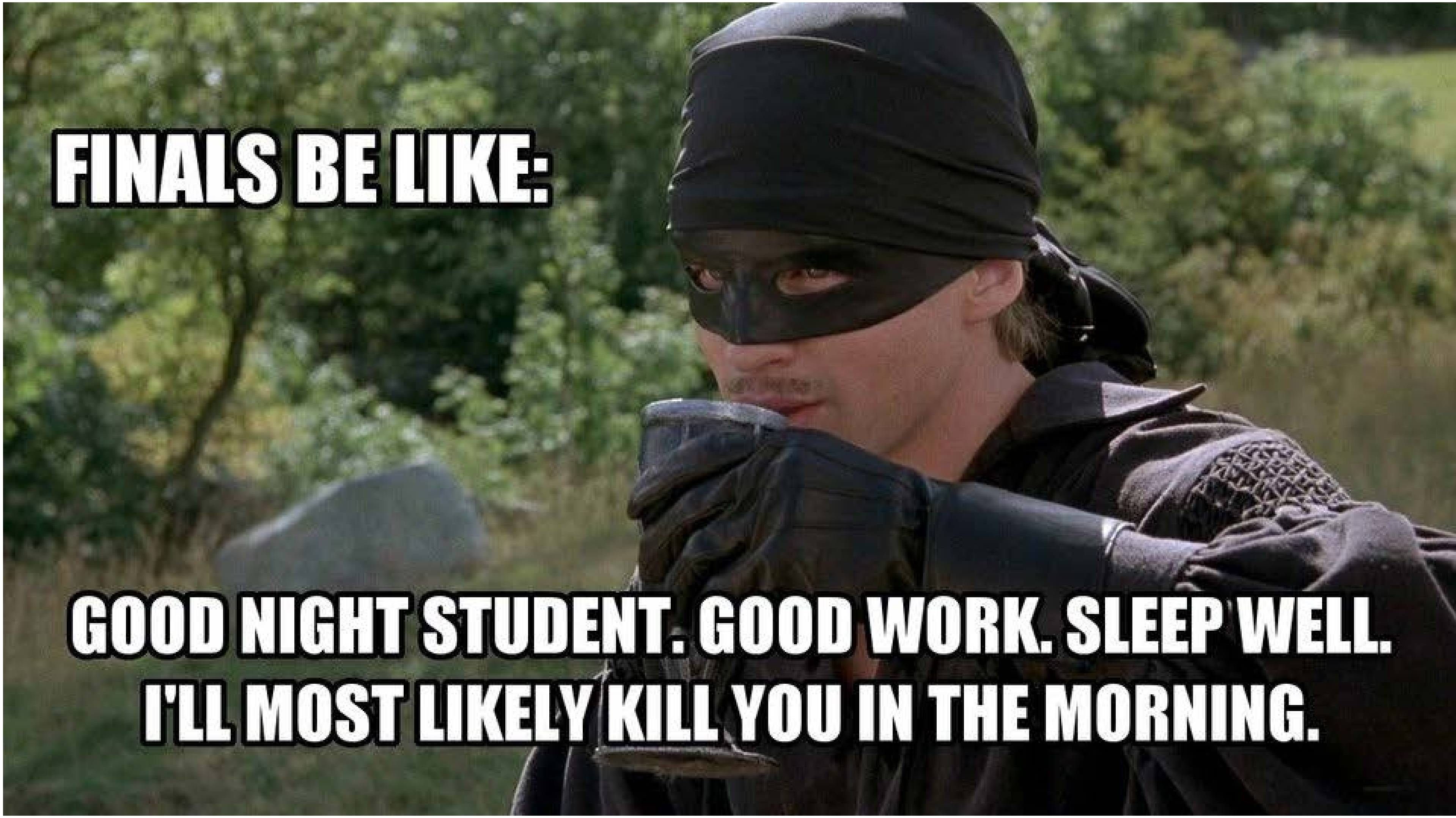
Spectre in a Nutshell

1. Run attacker code on same core as victim code
2. Train branch predictors to drive speculation down a particular branch in victim
3. Apply timing analysis to extract victim data

Buggy Code

- 85% of CERT Advisories describe problems that cannot be fixed with cryptography.
- Most of these are bugs in code
- But writing correct code is the oldest -- and probably the most difficult -- problem in computer science.
  - We're not going to solve it any time soon, possibly not ever.
- Reduction strategies
  - Structure – isolate security critical code; Safer languages
  - Reducing code complexity

Le Fin de Semester



Good luck on all your exams!

From bug to vulnerability

- So you have a buggy user-level application
  - Why is this so bad?
- In general, compromising a process allows attacker to obtain privileges of that process for arbitrary activities
  - Bad for you, but not necessarily bad for the system
  - Compromising a process with root privilege (on Unix systems) provides a lot of power
    - Read/write any file
    - Read/write kernel memory though /dev/kmem
    - Attach to and trace any running process
    - Install kernel modules / change system configuration

Insufficient Domain Separation

- Authorization domains should be clearly separated
  - otherwise, less-privileged code can get more-privileged code to do bad things
- Unfortunately, this is often not the case
- Examples:
  - environment inheritance by setuid programs in UNIX
    - e.g., max file length or number of files open

Security policies are critical

- Most organizations have a stated policy about control of private information and access to resources
- These policies can help guide protocol implementation
  - and can help with political and “clueless user” problems
- If you can’t say what’s important, how am I supposed to protect it?
  - … and why should I bother trying?

OS Security Mechanisms

- Access Controls
- FreeBSD Jails
- Flask Security Architecture (SELinux)

Access Control

- Common Assumption:
  - System knows identity of user (authentication)
  - Access requests pass through some gatekeeper (authorization)
- Implemented using Access Control Matrix
  - Access control list
  - Capability
- Two main types
  - Discretionary Access Control (DAC)
    - User sets access rights for objects they own
  - Mandatory Access Control (MAC)
    - System sets rights that users can't override

FreeBSD Jails

- Goal: isolation of processes to contain possible damage without lots of extra security management complexity
- Built on chroot concept
  - Give process (and all its children) separate view of file system tree (chdir /tmp/limited_fs; chroot /tmp/limited_fs)
  - Originally introduced for development
- Added new “jail” command
  - Each jail has own superuser
  - Privileges of superuser restricted to only affect things inside jail
  - Process in jail isolated from ones outside jail

Flask Security Architecture: Motivation

- No single definition of security suffices
- Need for many policies and even types of policies
- Computer security solutions must be flexible enough to support wide range of security policies
- This policy flexibility must be supported by the OS mechanisms

Defining Policy Flexibility

- Can’t define through a list of known policies
- Defined in context of a state machine model
  - atomic operations to transition from one state to next
  - policy can interpose atomically on set of controlled operations
  - policy may use knowledge of portion of system state
- 3 Requirements of Policy Flexibility
  - Support fine-grained access controls on low-level objects
  - Propagate access rights according to security policy
  - Deal with changes in policy over time, including revoking previously granted permissions

Policy Changes

- Even simplest policies undergo changes
- Risk of enforcing obsolete policy
- Need for effective atomicity in policy changes
- Complicated by migrated permissions
  - access rights explicitly cached in data structures
  - access rights implicitly cached by operations in progress

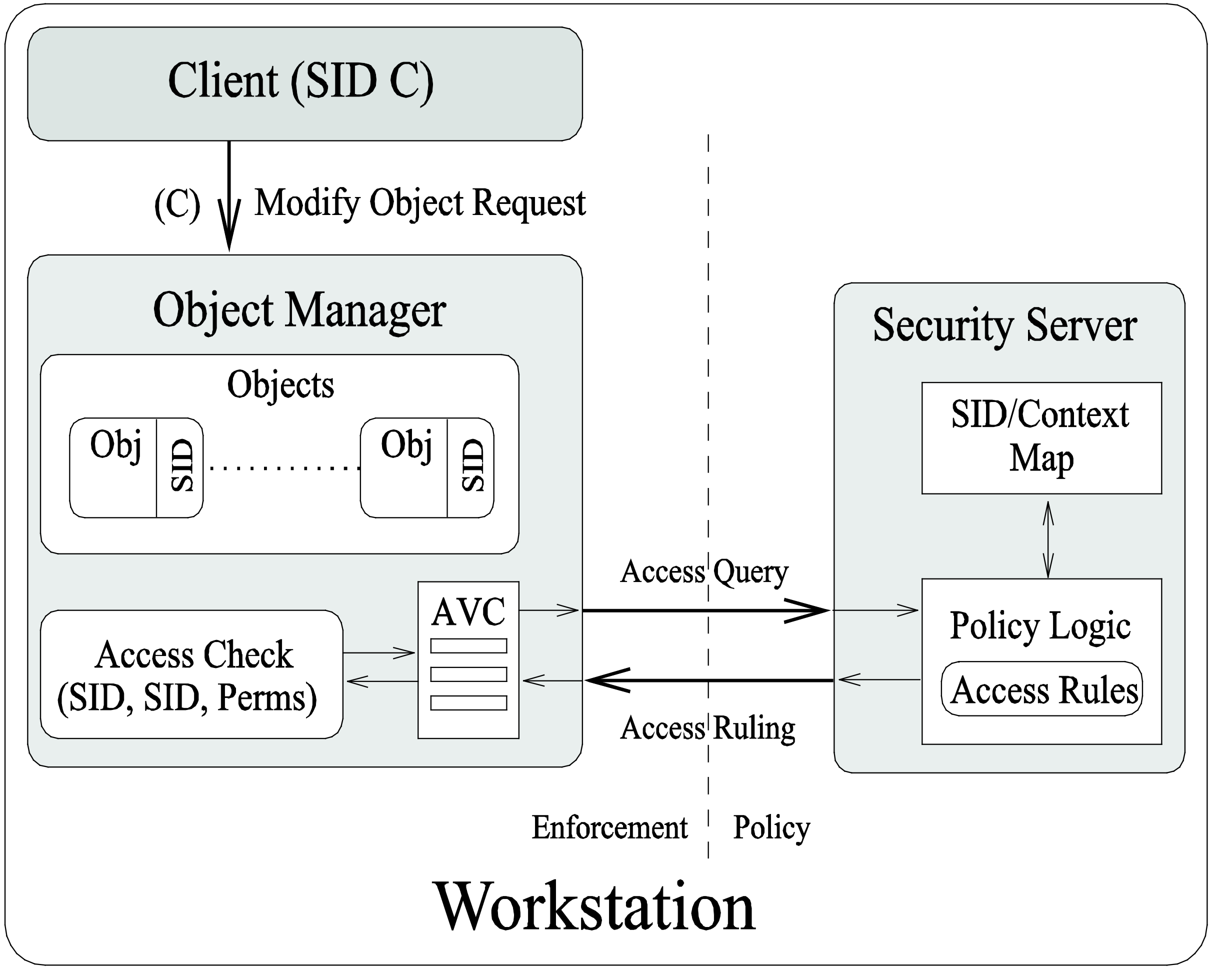
Popular Mechanisms are Insufficient

- Capability-based systems
  - propagation of access rights
  - Hydra, KeyKOS, EROS: provide enhancements to limit propagation, but still lacking in support for policies
  - SCAP, ICAP, TMach: do not define mechanisms by which policy is queried to validate capabilities
- Interposition
  - mismatch between functional interface and security needs
  - does not support revocation of migrated permissions

Flask Architecture

- Security server
  - provides labeling, access and polyinstantiation decisions
  - security contexts and security identifiers (SIDs)
- Object managers
  - bind labels to objects
  - enforce access decisions
  - direct clients to appropriate instances
- Access Vector Cache (AVC) library
  - coordinates access decisions
  - minimizes performance impact
- Underlying IPC mechanism
  - must provide identification of clients and servers

Architecture Diagram



Revocation Support

- Object manager atomicity requirements
  - Completeness
  - Promptness
- Protocol between security server and object managers
  - system-wide atomicity for policy changes
  - Security server notifies object manager AVC modules
  - AVC modules update cache state, invoke callbacks
  - Callbacks update migrated permissions
  - AVC modules notify security server of completion

Evaluation of Flexibility

- Support for policy changes
  - architecture provides support for system-wide atomicity
  - microkernel meets object manager atomicity requirements
  - other object managers lack support for migrated permissions
- Set of operations controlled by policy
  - fine-grained controls over all object services
- Set of operations that may be invoked by policy
  - object manager interfaces, AVC module interface
- System state available to policy
  - SID pairs sufficient for most policies (DTOS)
  - use prototype to research need for richer interface

Current Status

- SELinux – Security Enhanced Linux
  - Version of Linux created by the NSA and Secure Computing Corporation (SCC)
  - Incorporates University of Utah Flask security model
    - Supports mandatory access control to all objects
    - Separates Object Managers from Security Server
    - Supports various policy configurations
  - Often criticized for being too complicated
- TrustedBSD
  - Part of this system is a port of SELinux extensions to FreeBSD
  - TrustedDarwin is a port of TrustedBSD to the Darwin system
  - Some components of TrustedBSD have spilled over into OS X
    - not sure if this includes Flask implementation

seccomp

- Sandbox mechanism available in Linux
- Performs filtering on system calls
  - Filters are written in Berkeley Packet Filter (BPF) language
  - Attached by a process to itself via prctl(PR_SET_SECCOMP, SECCOMP_MODE_FILTER, filter);
  - Inherited by children
- Filter code can access system call number, arguments
  - Allows or denies the system call

Uses?