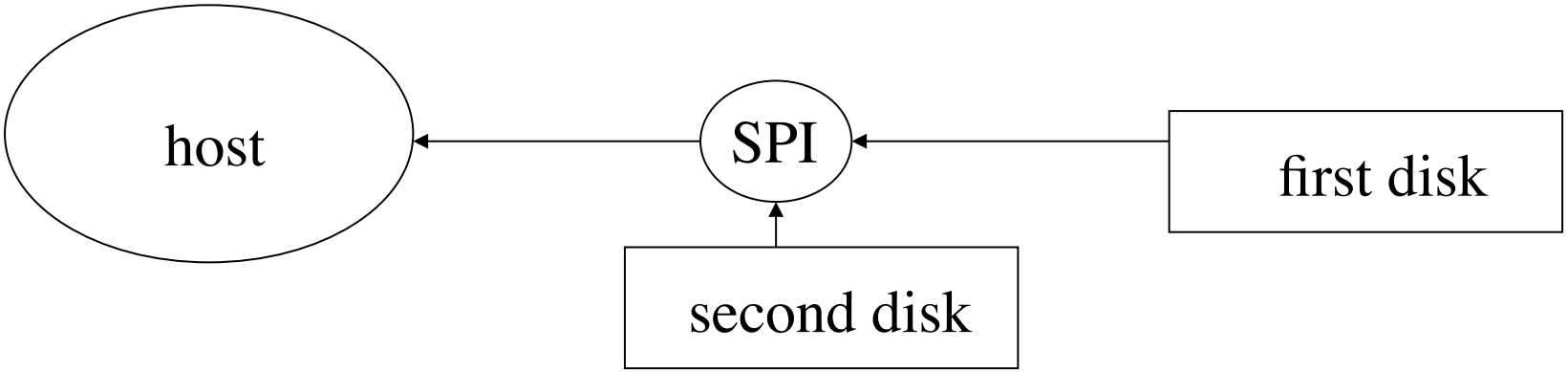
Lecture 19: Flow and Confinement

- Examples of information flow applications
- The confinement problem
  - Covert channels
- Isolation: virtual machines, sandboxes

Example Information Flow Control Systems

- Use access controls of various types to inhibit information flows
- Security Pipeline Interface
  - Analyzes data moving from host to destination
- Secure Network Server Mail Guard
  - Controls flow of data between networks that have different security classifications

Security Pipeline Interface

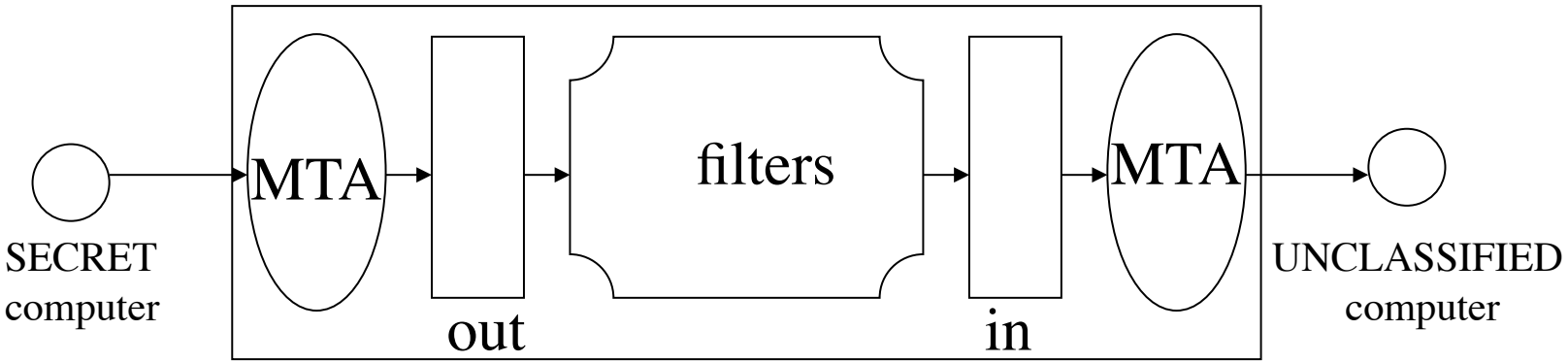


- SPI analyzes data going to, from host
  - No access to host main memory
  - Host has no control over SPI

Use

- Store files on first disk
- Store corresponding crypto checksums on second disk
- Host requests file from first disk
  - SPI retrieves file, computes crypto checksum
  - SPI retrieves file's crypto checksum from second disk
  - If a match, file is fine and forwarded to host
  - If discrepency, file is compromised and host notified
- Integrity information flow restricted here
  - Corrupt file can be seen but will not be trusted

Secure Network Server Mail Guard (SNSMG)



- Filters analyze outgoing messages
  - Check authorization of sender
  - Sanitize message if needed (words and viruses, etc.)
- Uses type checking to enforce this
  - Incoming, outgoing messages of different type
  - Only appropriate type can be moved in or out

Confinement

- What is the problem?
- Isolation: virtual machines, sandboxes
- Detecting covert channels

Example Problem

- Server balances bank accounts for clients
- Server security issues:
  - Record correctly who used it
  - Send *only* balancing info to client
- Client security issues:
  - Log use correctly
  - Do not save or retransmit data client sends

Generalization

- Client sends request, data to server
- Server performs some function on data
- Server returns result to client
- Access controls:
  - Server must ensure the resources it accesses on behalf of client include *only* resources client is authorized to access
  - Server must ensure it does not reveal client's data to any entity not authorized to see the client's data

Confinement Problem

- Problem of preventing a server from leaking information that the user of the service considers confidential

Total Isolation

- Process cannot communicate with any other process
- Process cannot be observed

Impossible for this process to leak information

  – Not practical as process uses observable resources such as CPU, secondary storage, networks, etc.

Example

- Processes *p*, *q* not allowed to communicate
  - But they share a file system!
- Communications protocol:
  - *p* sends a bit by creating a file called *0* or *1*, then a second file called *send*
    - *p* waits until *send* is deleted before repeating to send another bit
  - *q* waits until file *send* exists, then looks for file *0* or *1*; whichever exists is the bit
    - *q* then deletes *0*, *1*, and *send* and waits until *send* is recreated before repeating to read another bit

Covert Channel

- A path of communication not designed to be used for communication
- In example, file system is a (storage) covert channel

Rule of Transitive Confinement

- If *p* is confined to prevent leaking, and it invokes *q*, then *q* must be similarly confined to prevent leaking
- Rule: if a confined process invokes a second process, the second process must be as confined as the first

Lipner's Notes

- All processes can obtain rough idea of time
  - Read system clock or wall clock time
  - Determine number of instructions executed
- All processes can manipulate time
  - Wait some interval of wall clock time
  - Execute a set number of instructions, then block

Kocher's Attack

- This computes $x = a^z \bmod n$, where $z = z_0 \ldots z_{k-1}$

```
x := 1; atmp := a;
for i := 0 to k–1 do begin
  if z_i = 1 then
      x := (x * atmp) mod n;
  atmp := (atmp * atmp) mod n;
end
result := x;
```

- Length of run time related to number of 1 bits in z

Isolation

- Present process with environment that appears to be a computer running only those processes being isolated
  - Process cannot access underlying computer system, any process(es) or resource(s) not part of that environment
  - A *virtual machine*
- Run process in environment that analyzes actions to determine if they leak information
  - Alters the interface between process(es) and computer

Virtual Machine

- Program that simulates hardware of a machine
  - Machine may be an existing, physical one or an abstract one
- Why?
  - Existing OSes do not need to be modified
    - Run under VMM, which enforces security policy
    - Effectively, VMM is a security kernel

VMM as Security Kernel

- VMM deals with subjects (the VMs)
  - Knows nothing about the processes within the VM
- VMM applies security checks to subjects
  - By transitivity, these controls apply to processes on VMs
- Thus, satisfies rule of transitive confinement

Example 1: KVM/370

- KVM/370 is security-enhanced version of VM/370 VMM
  - Goal: prevent communications between VMs of different security classes
  - Like VM/370, provides VMs with minidisks, sharing some portions of those disks
  - Unlike VM/370, mediates access to shared areas to limit communication in accordance with security policy

Example 2: VAX/VMM

- Can run either VMS or Ultrix
- 4 privilege levels for VM system
  - VM user, VM supervisor, VM executive, VM kernel (both physical executive)
- VMM runs in physical kernel mode
  - Only it can access certain resources
- VMM subjects: users and VMs

Example 2

- VMM has flat file system for itself
  - Rest of disk partitioned among VMs
  - VMs can use any file system structure
    - Each VM has its own set of file systems
  - Subjects, objects have security, integrity classes
    - Called *access classes*
  - VMM has sophisticated auditing mechanism

Problem

- Physical resources shared
  - System CPU, disks, etc.
- May share logical resources
  - Depends on how system is implemented
- Allows covert channels

Sandboxes

- An environment in which actions are restricted in accordance with security policy
  - Limit execution environment as needed
    - Program not modified
    - Libraries, kernel modified to restrict actions
  - Modify program to check, restrict actions
    - Like dynamic debuggers, profilers

Examples Limiting Environment

- Java virtual machine
  - Security manager limits access of downloaded programs as policy dictates
- Sidewinder firewall
  - Type enforcement limits access
  - Policy fixed in kernel by vendor
- Domain Type Enforcement
  - Enforcement mechanism for DTEL
  - Kernel enforces sandbox defined by system administrator

Modifying Programs

- Add breakpoints or special instructions to source, binary code
  - On trap or execution of special instructions, analyze state of process
- Variant: *software fault isolation*
  - Add instructions checking memory accesses, other security issues
  - Any attempt to violate policy causes trap

Example: Janus

- Implements sandbox in which system calls checked
  - *Framework* does runtime checking
  - *Modules* determine which accesses allowed
- Configuration file
  - Instructs loading of modules
  - Also lists constraints

Configuration File

```
# basic module
basic

# define subprocess environment variables
putenv IFS="\t\n " PATH=/sbin:/bin:/usr/bin TZ=PST8PDT

# deny access to everything except files under /usr
path deny read,write *
path allow read,write /usr/*
# allow subprocess to read files in library directories
# needed for dynamic loading
path allow read /lib/* /usr/lib/* /usr/local/lib/*
# needed so child can execute programs
path allow read,exec /sbin/* /bin/* /usr/bin/*
```

How It Works

- Framework builds list of relevant system calls
  - Then marks each with allowed, disallowed actions
- When monitored system call executed
  - Framework checks arguments, validates that call is allowed for those arguments
    - If not, returns failure
    - Otherwise, give control back to child, so normal system call proceeds

Use

- Reading MIME Mail: fear is user sets mail reader to display attachment using Postscript engine
  - Has mechanism to execute system-level commands
  - Embed a file deletion command in attachment …
- Janus configured to disallow execution of any subcommands by Postscript engine
  - Above attempt fails

Sandboxes, VMs, and TCB

- Sandboxes, VMs part of trusted computing bases
  - Failure: less protection than security officers, users believe
  - "False sense of security"
- Must ensure confinement mechanism correctly implements desired security policy