Toward Automated Authorization Policy Enforcement

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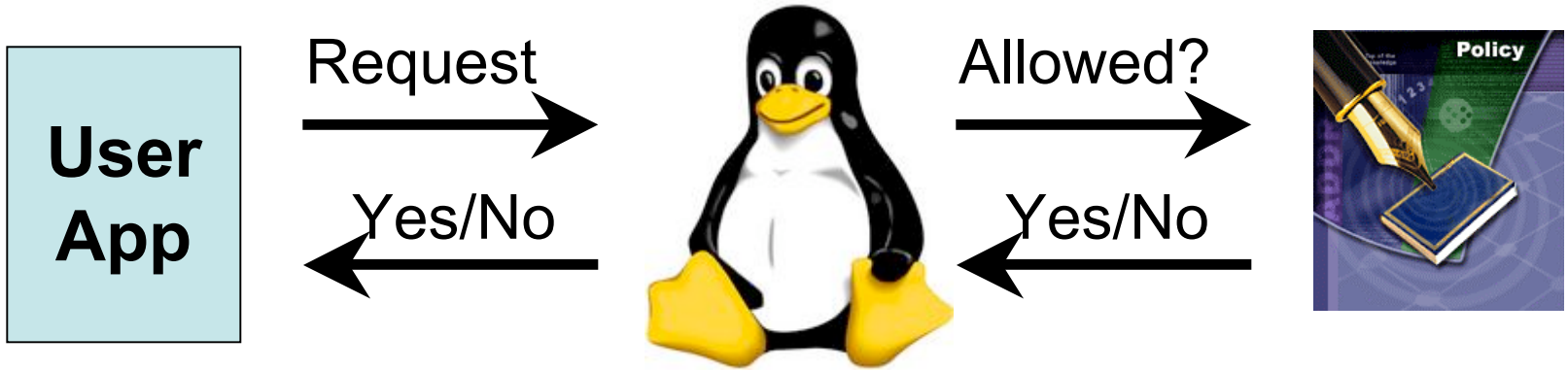
Introduction

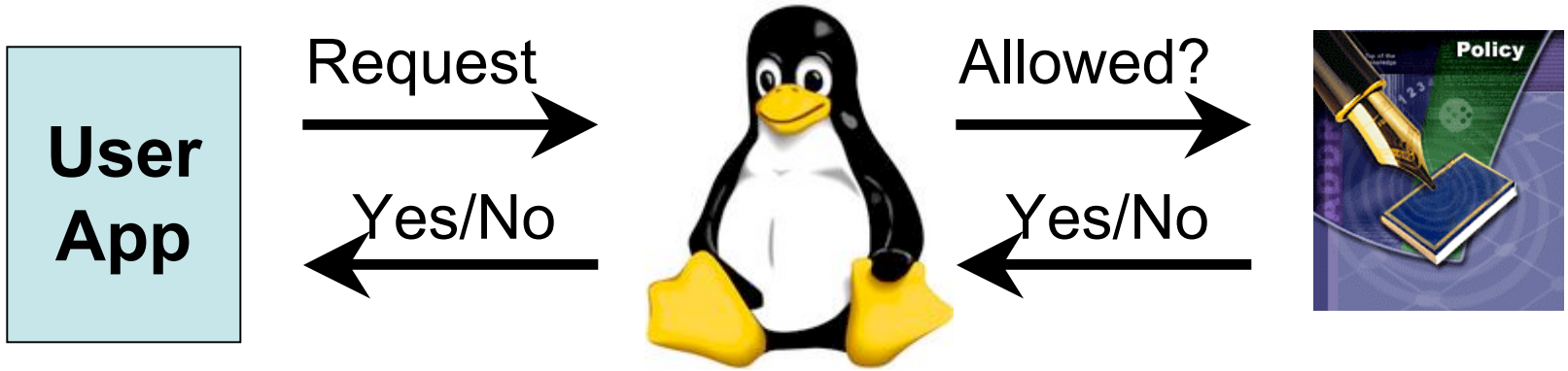
- SELinux helps meet information-flow goals



- Expressive access-control policy language
- Security-enhanced operating system

Security-aware Applications

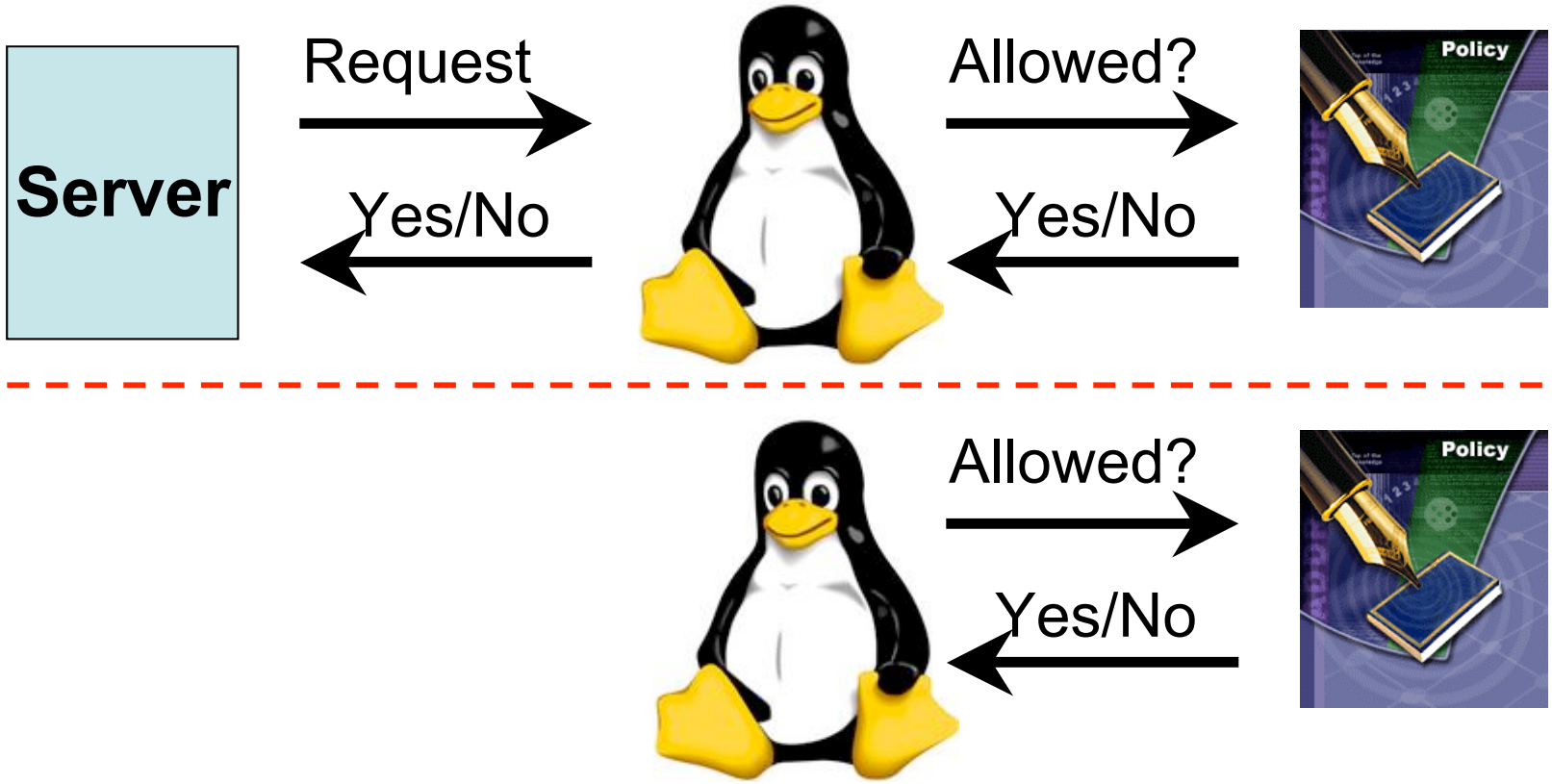
- Need for security-aware applications



- Can we build applications that can enforce mandatory access control policies?

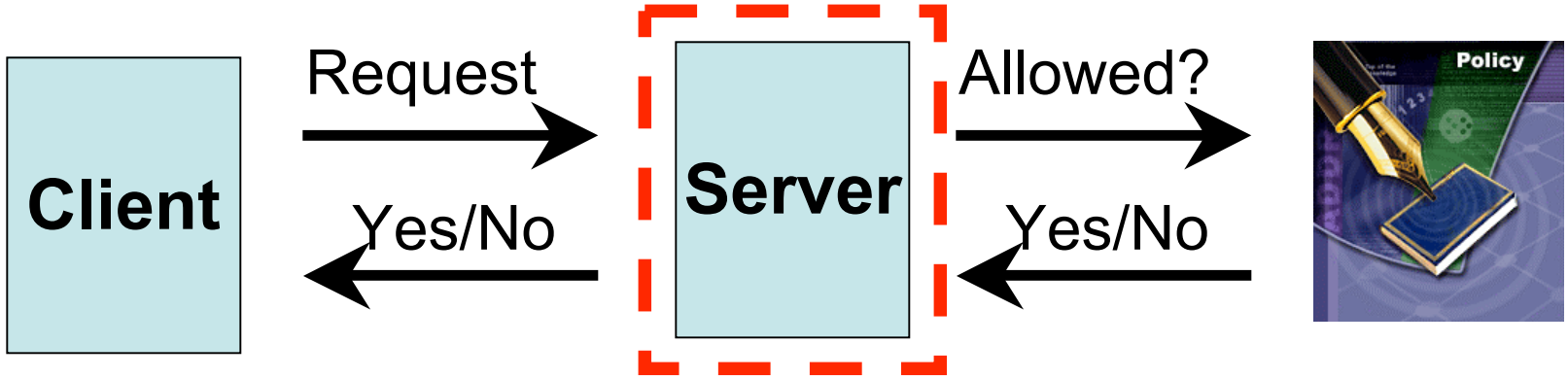
Security-aware Applications

- Need for security-aware applications



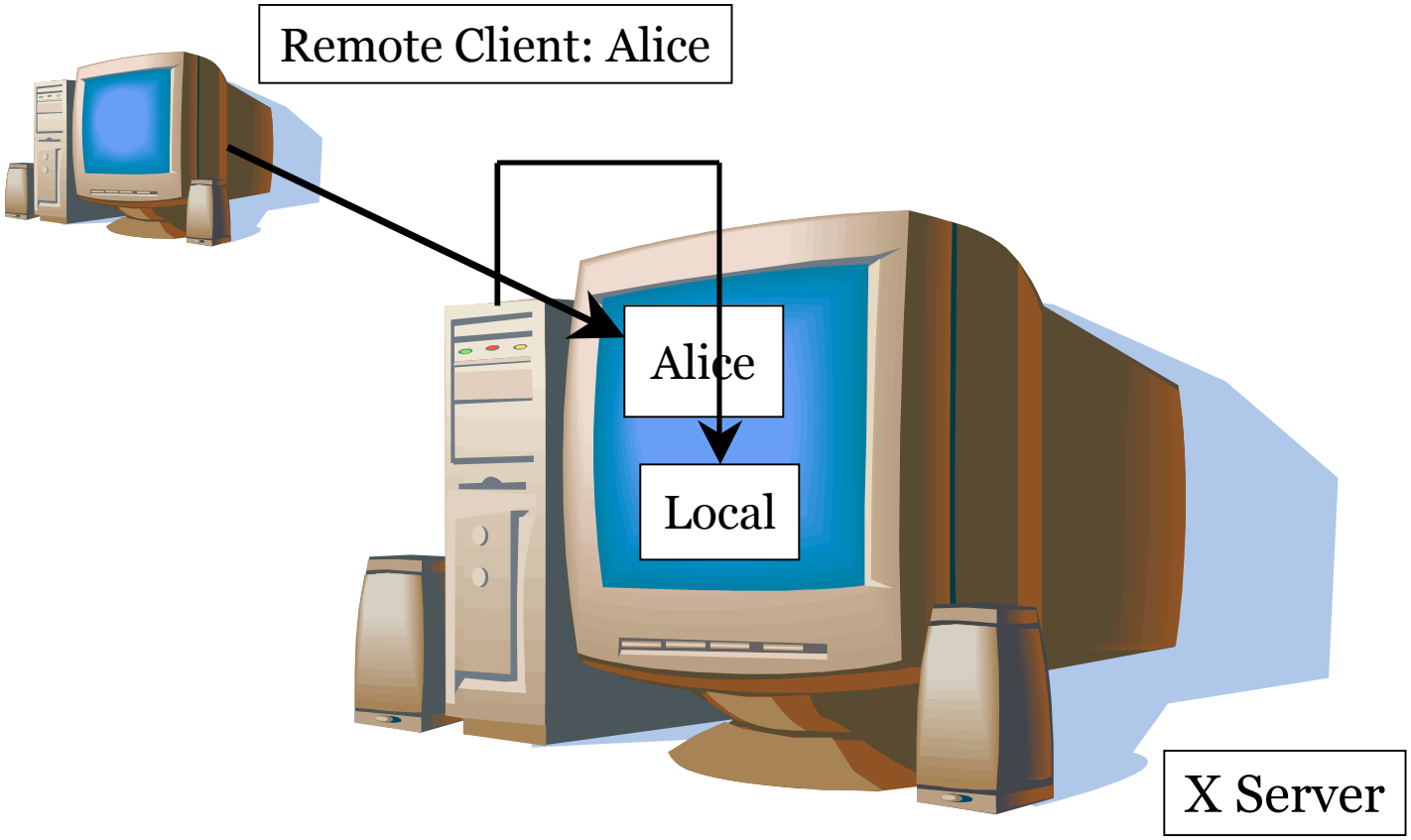
Security-aware Applications

- Need for security-aware applications



- Our work: How to build security-aware applications?
- Focus is on mechanism, not policy

Motivating Example



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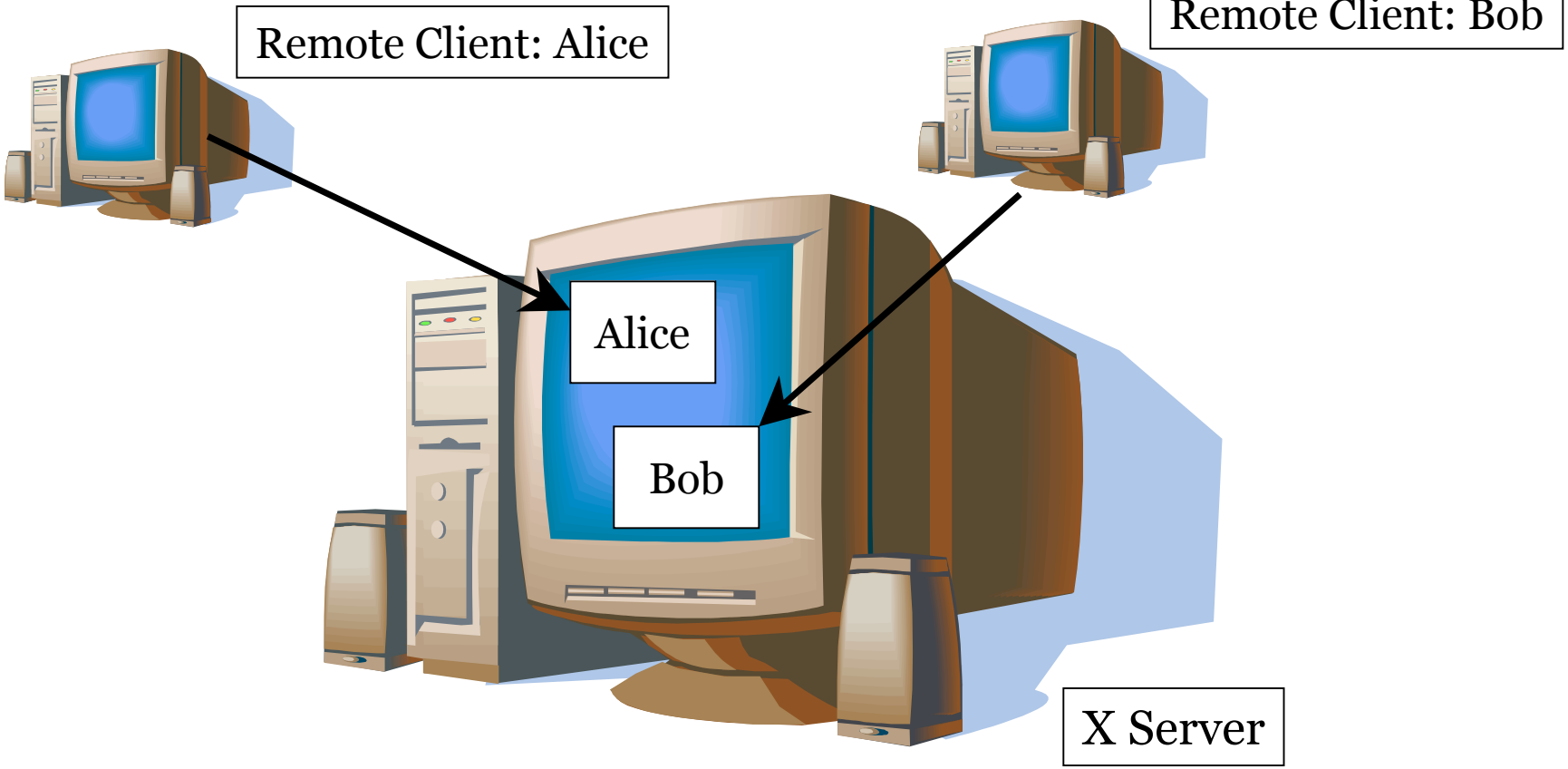

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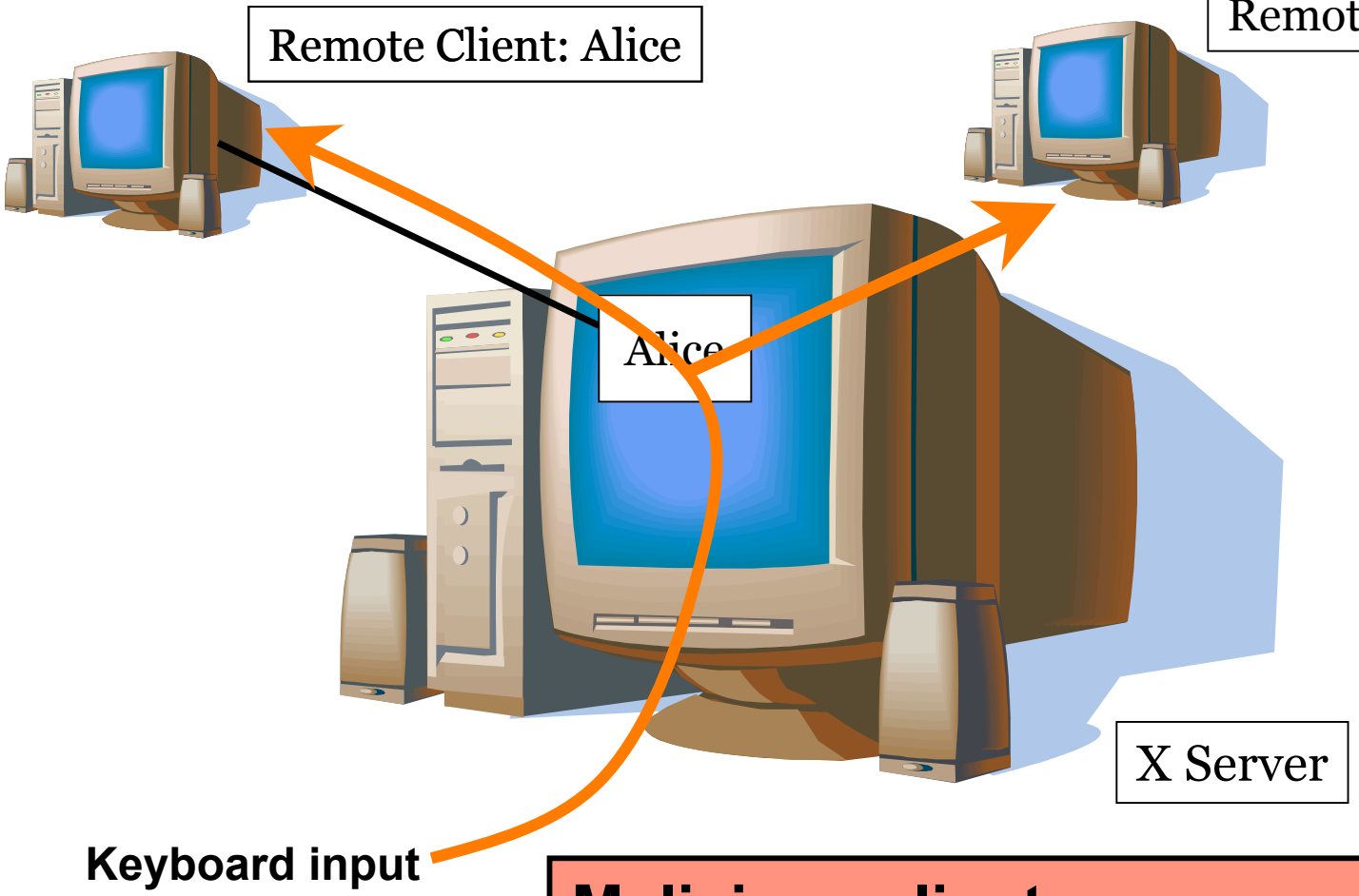
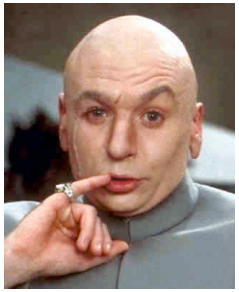
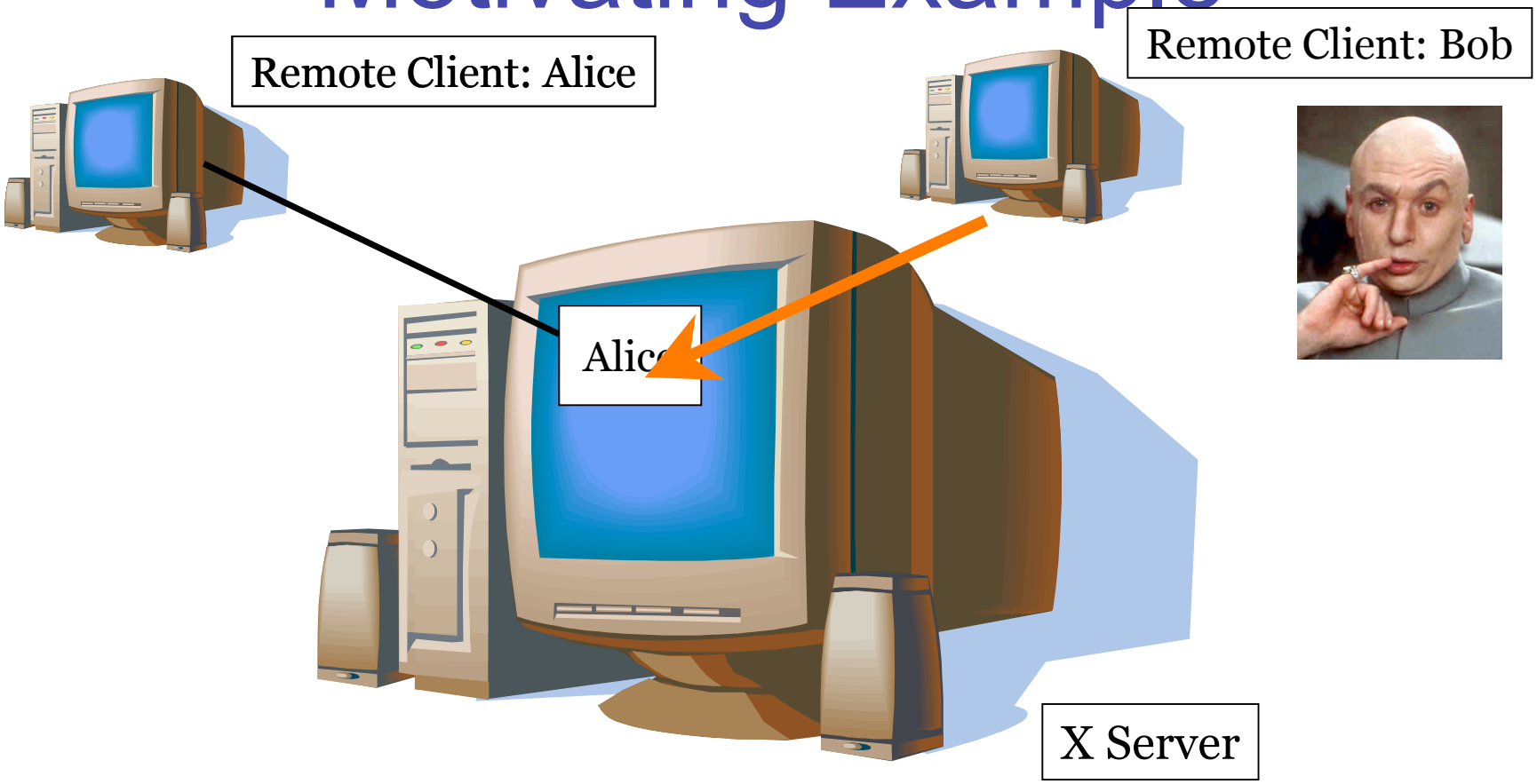




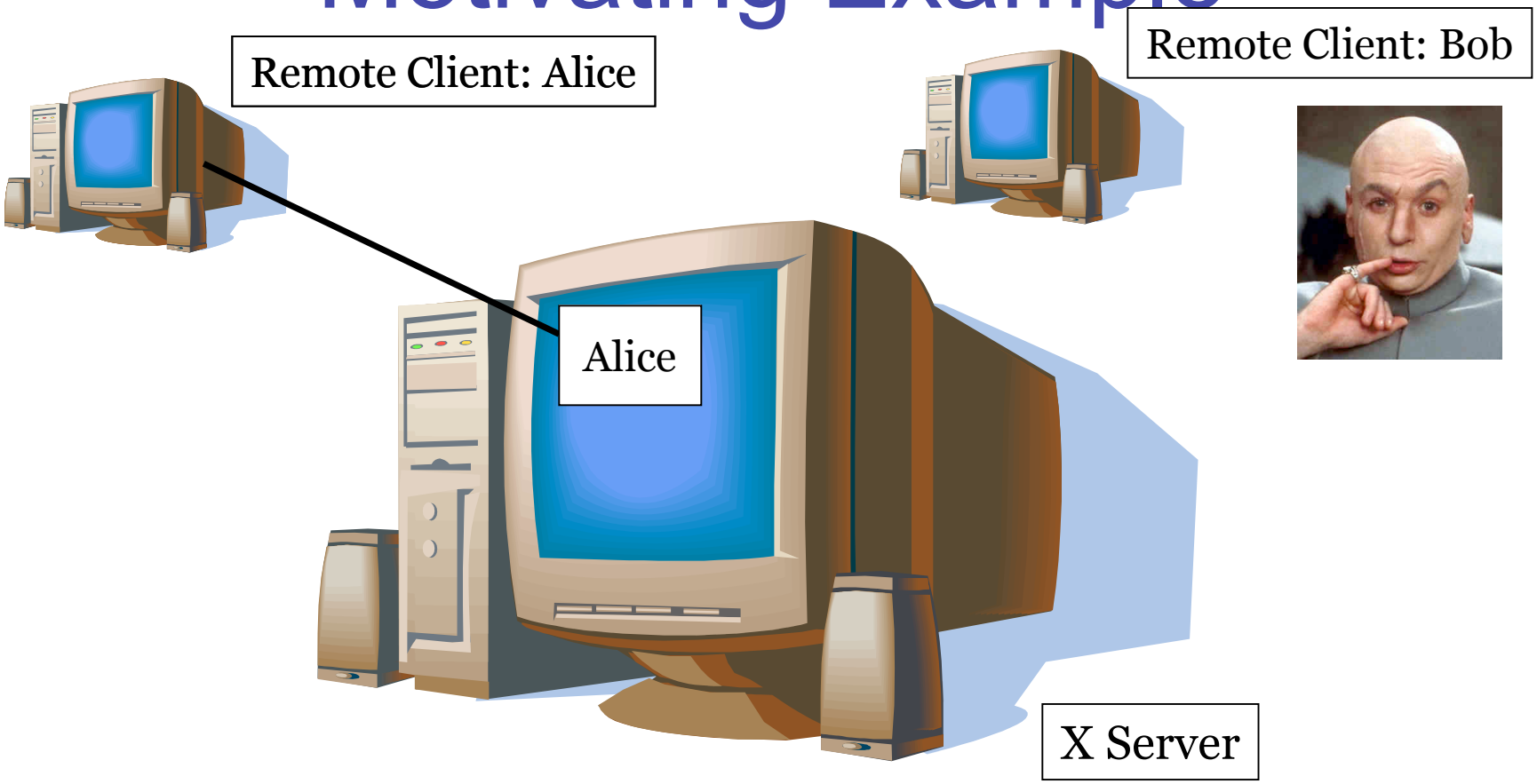
Malicious client can snoop on input violating Alice's confidentiality

Motivating Example



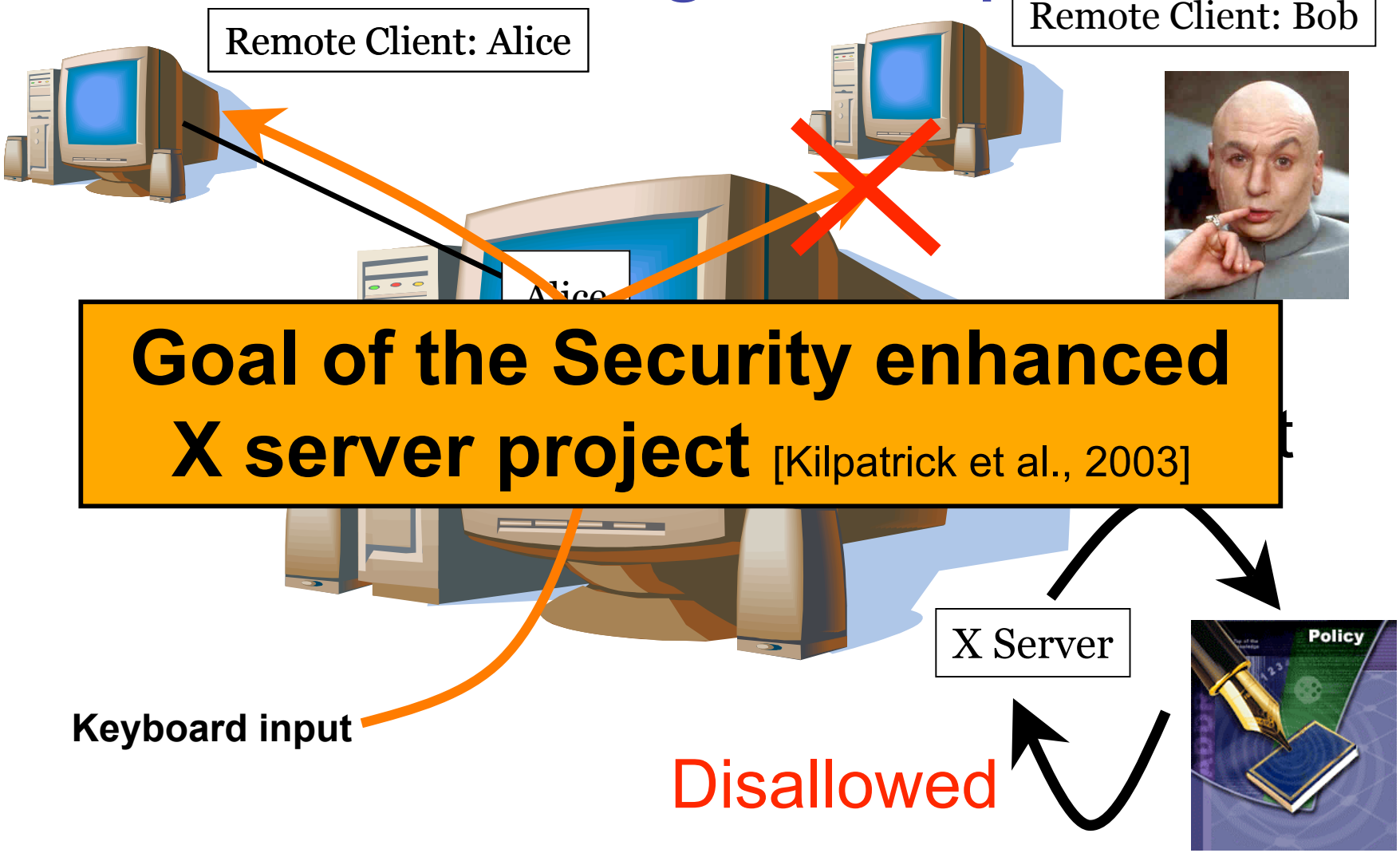
Malicious client can alter settings on other client windows

Motivating Example



No mechanism to enforce authorization policies on client interactions

Motivating Example



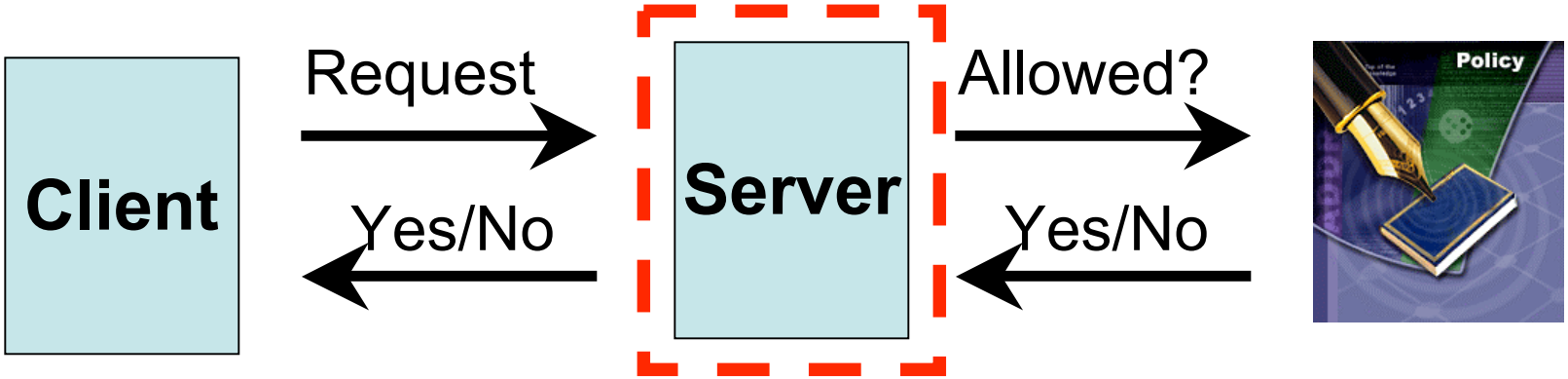
Need for Security-awareness

- More examples: user-space servers
  - Samba
  - Web servers
  - Proxy and cache servers
  - Middleware
- Common features
  - Manage multiple clients simultaneously
  - Offer shared resources to clients
  - Perform services on behalf of their clients

Main Claim

To effectively meet security-goals, all applications managing shared resources must be made security-aware

Focus of our work



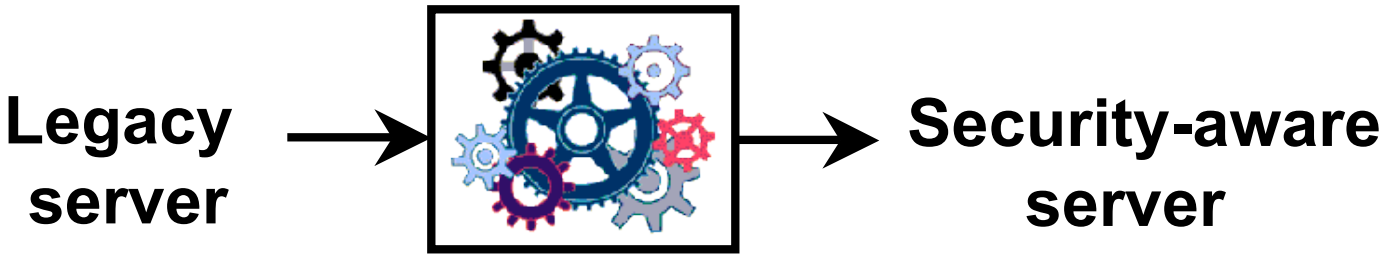
- How to build security-aware applications?
- Focus is on mechanism, not policy
  - Can use tools like Tresys' SELinux Policy Management Toolkit

Security-aware Applications

Our work:
Tool support to retrofit legacy servers
for authorization policy enforcement

- Retrofit existing, legacy code
  - Linux Security Modules project [Wright *et al*., 2002]
  - Security-enhanced X project [Kilpatrick *et al*., 2003]
  - Privilege separated OpenSSH [Provos *et al*., 2003]

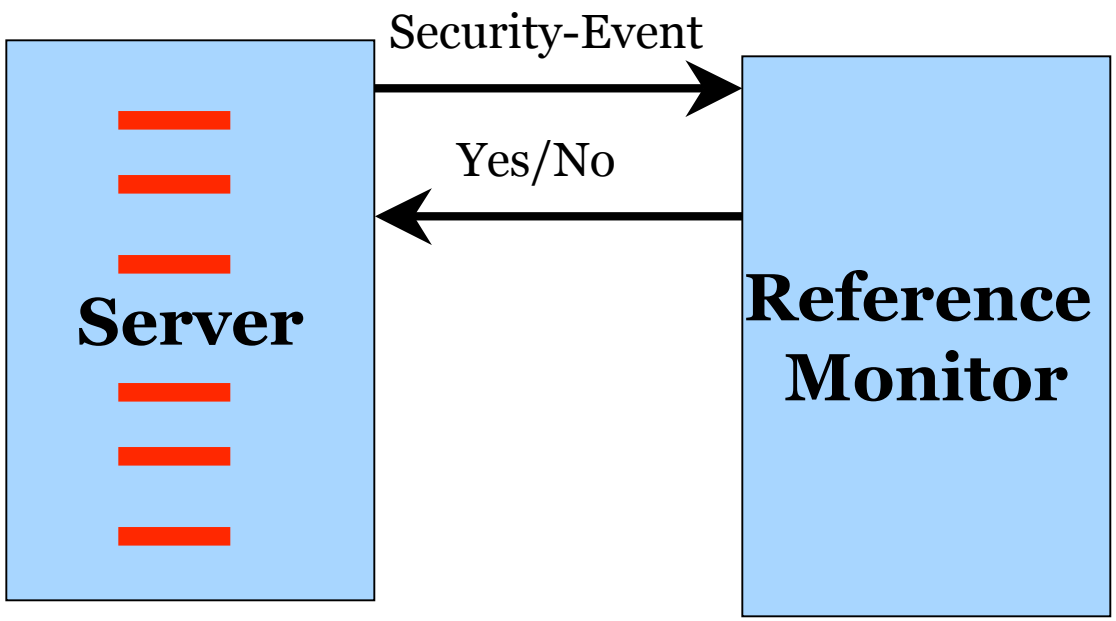
Our Work



- Tools to analyze and retrofit legacy code
- Two case studies:
  - Retrofitting the X server [IEEE S&P 2006]
  - Retrofitting Linux [ACM CCS 2005]

Main Goal

Main challenge: Where to place reference monitor hooks?



Authorization Policies

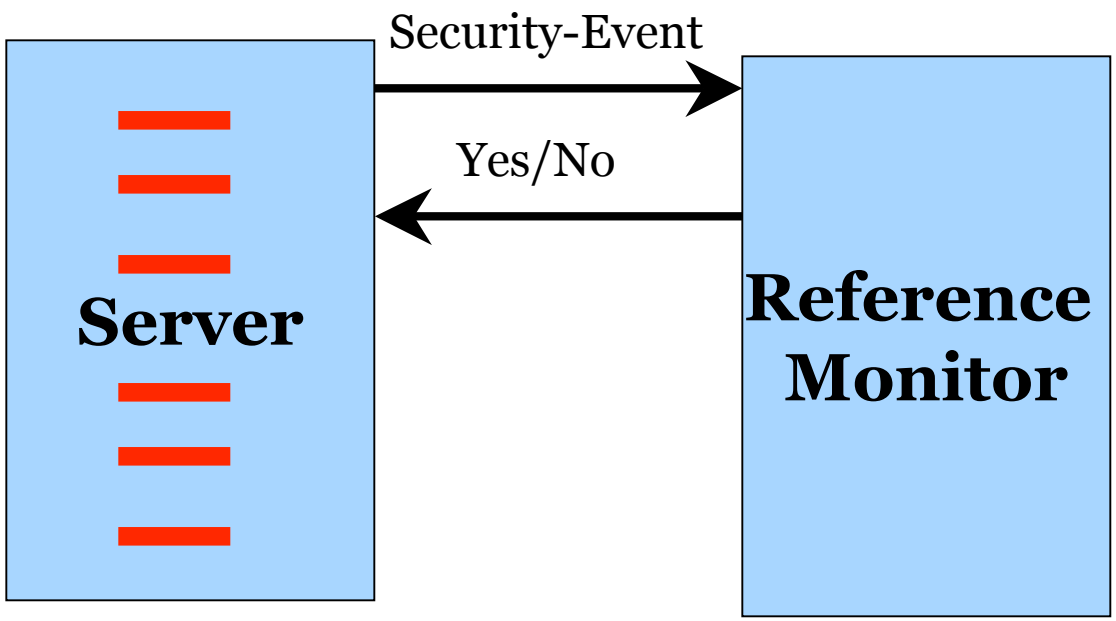
- Access-control matrix [Lampson'71]

	/etc/passwd	/usr/vg/a.out	/var/log
root	r/w	r/w/x	r/w
vg		r/w/x	r

- Three entities: ‹subject, object, operation›
  - Subject (user or process)
  - Object (resource, such as file or socket)
  - Security-sensitive operation (access vectors)

Main Goal

- Analysis techniques to find where server performs security-sensitive operations



Key Insight: Fingerprints

- Each security-sensitive operation has a fingerprint
- Intuition: Denotes key code-level steps to achieve the operation

Examples of Fingerprints

- Three access vectors from SELinux
- **`DIR_WRITE :-`**
  - ***Set*** `inode->i_ctime` **&**
  - ***Call*** `address_space_ops->prepare_write()`
- **`DIR_RMDIR :-`**
  - ***Set*** `inode->i_size` **TO 0 &**
  - ***Decrement*** `inode->i_nlink`
- **`SOCKET_BIND :-`**
  - ***Call*** `socket->proto_ops->bind()`

Examples of Fingerprints

- Access vectors for the X server
- **WINDOW_MAP:-**
  - ***Set*** `WindowPtr->mapped` **TO** `TRUE` **&**
  - ***Set*** `xEvent->type` **TO** `MapNotify`
- **WINDOW_ENUMERATE:-**
  - ***Read*** `WindowPtr->firstChild` **&**
  - ***Read*** `WindowPtr->nextSib` **&**
  - ***Compare*** `WindowPtr` $\neq$ `0`

Key Insight: Fingerprints

- How to find fingerprints?
- How to use fingerprints to place hooks?

Using Fingerprints: An Example

- X server function **`MapSubWindows`**

```
MapSubWindows(Window *pParent, Client *pClient) {
    xEvent event;
    Window *pWin;
    …
    pWin = pParent->firstChild; …
    for (;pWin != 0; pWin=pWin->nextSib) {
       pWin->mapped = TRUE;
       …
       event.type = MapNotify;
    }
}
```

Examples of Fingerprints

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  - ***Set*** `WindowPtr->mapped` **TO** `TRUE` **&**
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Performs **`Window_Map`**

Examples of Fingerprints

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Using Fingerprints: An Example

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MapSubWindows(Window *pPar
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    …
    pWin = pParent->firstChild; …
    for (;pWin != 0; pWin=pWin->nextSib) {
       // Code to map window on screen
       pWin->mapped = TRUE;
       …
       event.type = MapNotify;
    }
}
```

Performs **`Window_Enumerate`**

Using Fingerprints

- Fingerprints located using static analysis
- Key advantage: statically find all locations where fingerprints occur
- Can add hooks to all these locations

Adding Hooks: An Example

- X server function **`MapSubWindows`**

```
MapSubWindows(Window *pParent, Client *pClient) {
    xEvent event;
    Window *pWin;
    // Code to enumerate child windows
    avc_has_perm(pClient, pParent, WINDOW_ENUMERATE);
    pWin = pParent->firstChild; …
    for (;pWin != 0; pWin=pWin->nextSib) {
       // Code to map window on screen
       avc_has_perm(pClient, pWin, WINDOW_MAP);
       pWin->mapped = TRUE;
       …
       event.type = MapNotify;
    }
}
```

Key Insight: Fingerprints

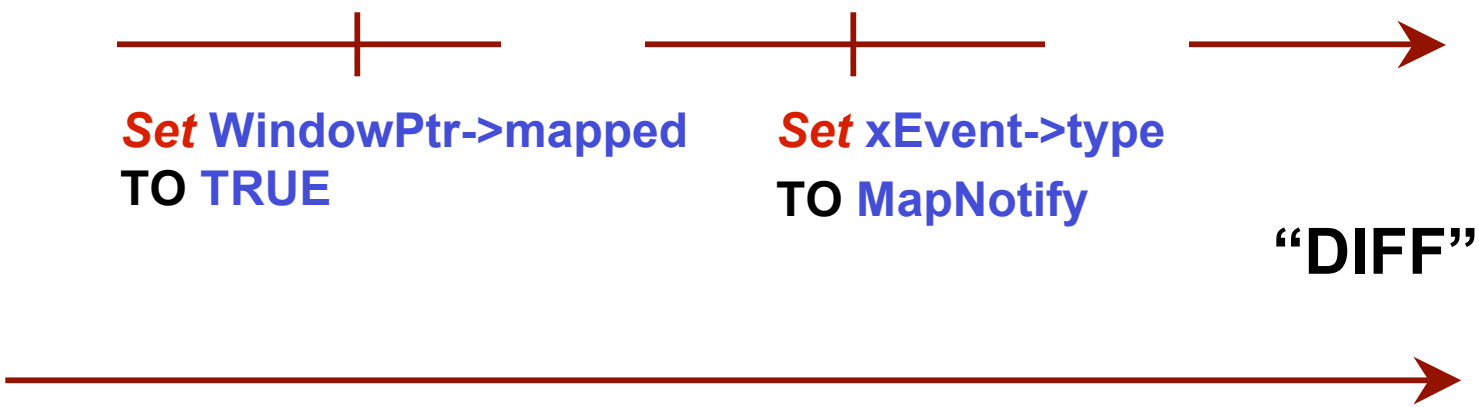
- How to find fingerprints?
- How to use fingerprints to place hooks? ✓

Finding Fingerprints

- Using analysis of runtime traces
- Key Insight:
  - If server does a security-sensitive operation its fingerprint must be in the trace
- Example:
  - Get X server to perform **`WINDOW_MAP`**

Finding Fingerprints

- Main challenge:
  - Locating fingerprints in the runtime trace
- Key insight:
  - Compare several runtime traces



Trace 1: Server does not perform **`WINDOW_MAP`**

Finding Fingerprints

- Main challenge:
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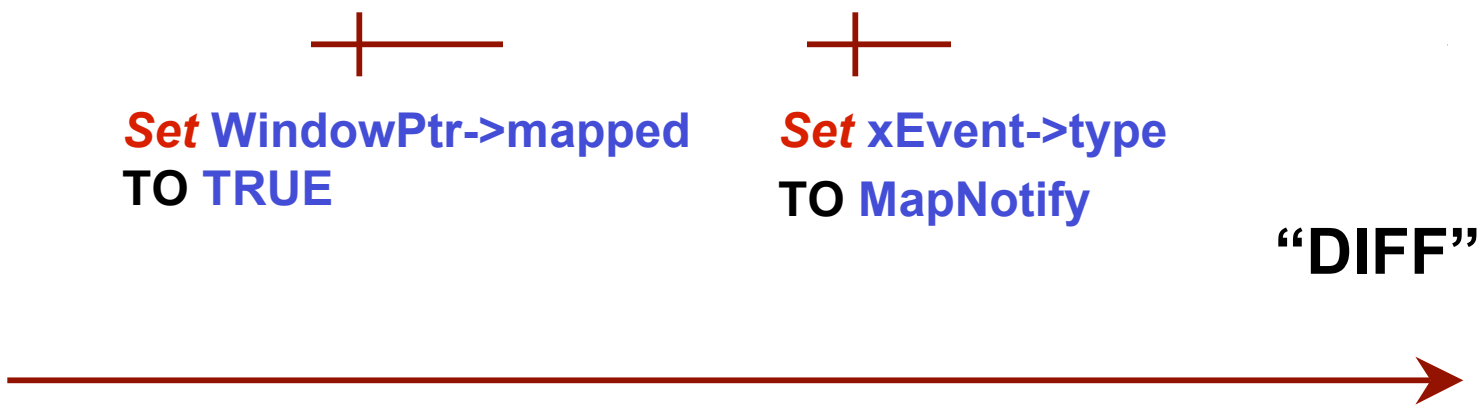

Trace 2: Server does not perform **`WINDOW_MAP`**

Key Insight: Fingerprints

- How to find fingerprints? ✓
- How to use fingerprints to place hooks? ✓

Results

- Retrofitted version of X server
- Fingerprint-finding technique is effective:
  - Fewer than 10 functions to be examined to write fingerprints
  - In comparison, each trace exercises several hundred distinct X server functions
- Details in upcoming IEEE S&P 2006 paper

Examples of fingerprints

Operation	Fingerprint
WINDOW_CREATE	*Call* CreateWindow
WINDOW_DESTROY	*Call* DeleteWindow
WINDOW_UNMAP	*Set* xEvent->type TO UnmapNotify
WINDOW_CHSTACK	*Call* MoveWindowInStack
WINDOW_INPUTEVENT	*Call* ProcessPointerEvent, *Call* ProcessKeybdEvent

Slide to take home

- Goal: Placing authorization hooks in servers
- Key insight: Security-sensitive operations have fingerprints

- Finding fingerprints: Using “diff” of runtime traces
- Placing hooks: By statically locating fingerprints

Questions?

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