PRECIP: Towards Practical and Retrofittable Confidential Information Protection

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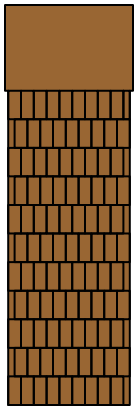
How to protect your information from spyware?

However…

Prevent it !

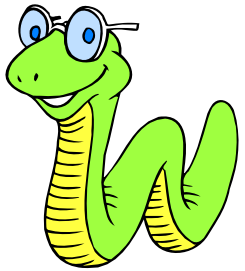


Detect it !

However…

The last defense line

- Contain unauthorized surveillance

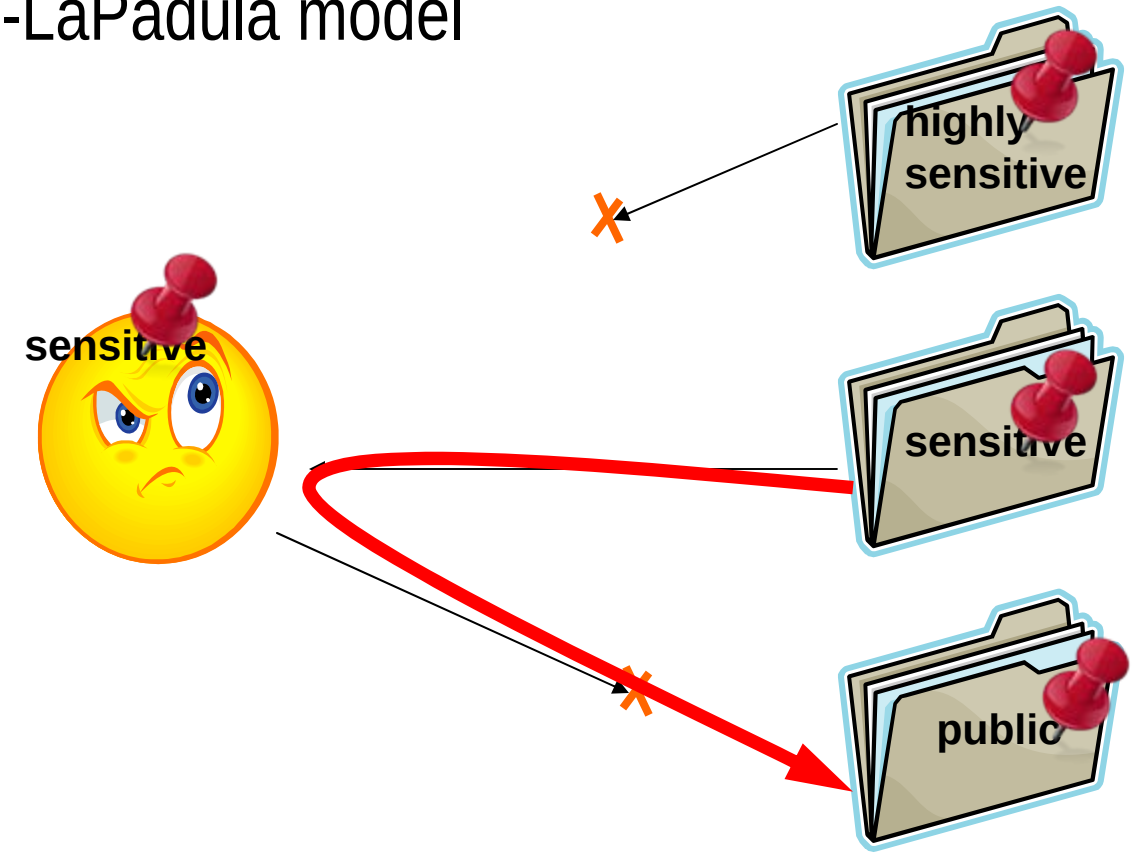


Spyware containment

- Existing access control mechanisms are insufficient
  - Spyware can watch *authorized party*'s access to a secret
- Alternative: information flow security
  - Track sensitive data
  - Prevent them from flowing into unauthorized parties

Information flow security

- The Bell-LaPadula model



However, this is insufficient for a modern OS

- User input object
  - keyboard, mouse…
  - When does it become sensitive?
- Other shared object
  - screen, clipboard …
  - sensitive? public?
- Multitasked subject
  - Work concurrently on public and sensitive data
  - Which output is sensitive?

Requirements for a usable IF model

- Work on a modern OS
- Efficient enough for online operation
  - Instruction-level tracking can be too slow
- Retrofittable to legacy systems
  - Avoid modifying the source code of app, of OS

PRECIP

A first step towards practical and retrofittable confidential information protection

- Track an application's input/output *dependence*
- Model input object and shared object
- Designed for online operations
- Retrofittable to legacy applications and OS

The model

- Subjects and objects
  - Local objects (files, buffers, keyboard, screen,…)
  - Remote objects (website…)
  - **User input objects (UIO):** objects for transferring inputs (keyboard)
- Channels
  - Connect subject to subject, subject to object, object to subject
  - A path is composed of multiple channels
- Messages
  - Information on a channel in the form of “messages”
  - Examples: keyboard events, mouse events, data through a “read” call

The model (cont'd)

- Dependency relation
  - Output messages depend on some input messages
  - An input to the PRECIP model
- Sensitivity levels
  - high: "sensitive", low: "public"
- Trusted and untrusted subjects
  - Untrusted: unknown dependency relations
  - Trusted: all dependency relations are known

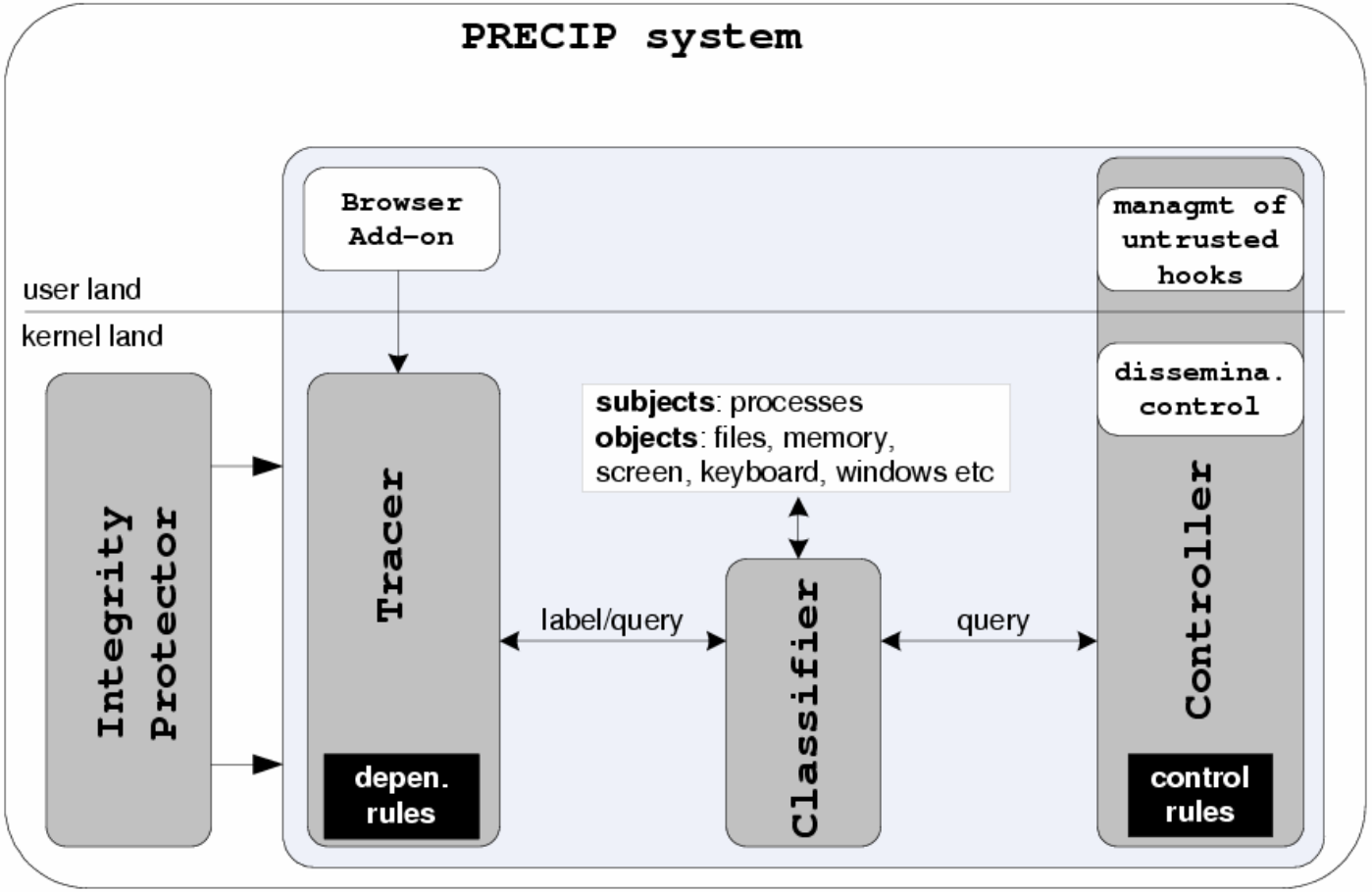
Security objective

- Information is sensitive if
  - it depends (directly or transitively) upon a message from an sensitive object, or sensitive inputs from an UIO
- Information leakage happens if
  - Sensitive info gets into an untrusted subject or a remote public object
- Objective: Sensitive information shouldn't be leaked

Policies achieving the objective

- Tracing rules
  - Sensitive msg: either from a sensitive obj or dependent upon a sensitive msg
  - Obj $\Rightarrow$ sensitive if it receives a sensitive msg
  - UIO $\Rightarrow$ sensitive iff a path connects it to a sensitive obj
  - Obj $\Rightarrow$ public if it is cleaned
- Control rules
  - Block sensitive msg to public remote obj and untrusted sub
  - Sensitive info to a local obj $\Rightarrow$ block the msg or mark the obj sensitive

Application of PRECIP to Windows XP



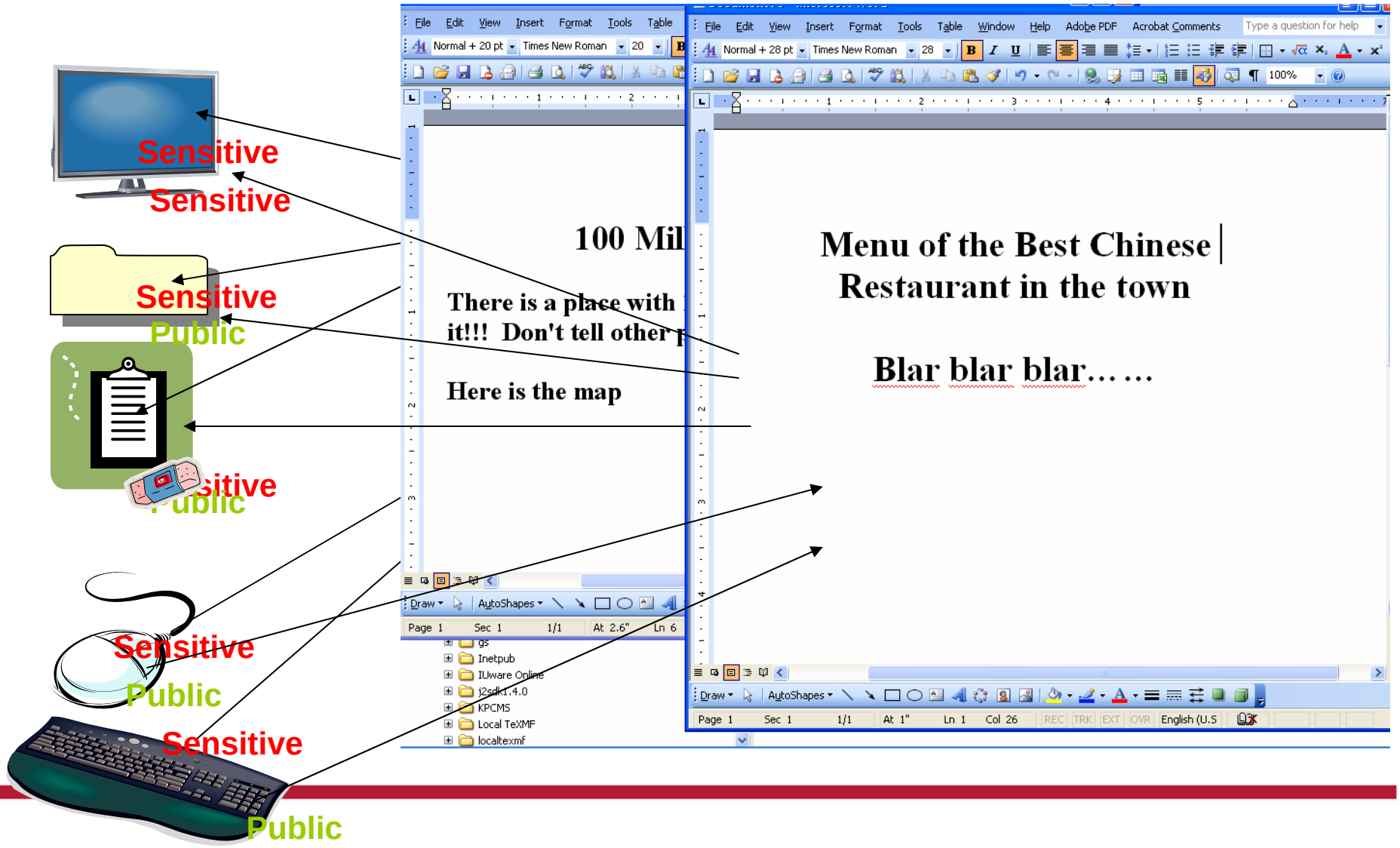
Adversary model

- Spyware is not inside the kernel when PRECIP is installed
  - However, our integrity protector can preventspyware to be installed through system calls
- PRECIP is not designed for preventing exploit of software vulnerabilities
  - We use existing tools to do the job

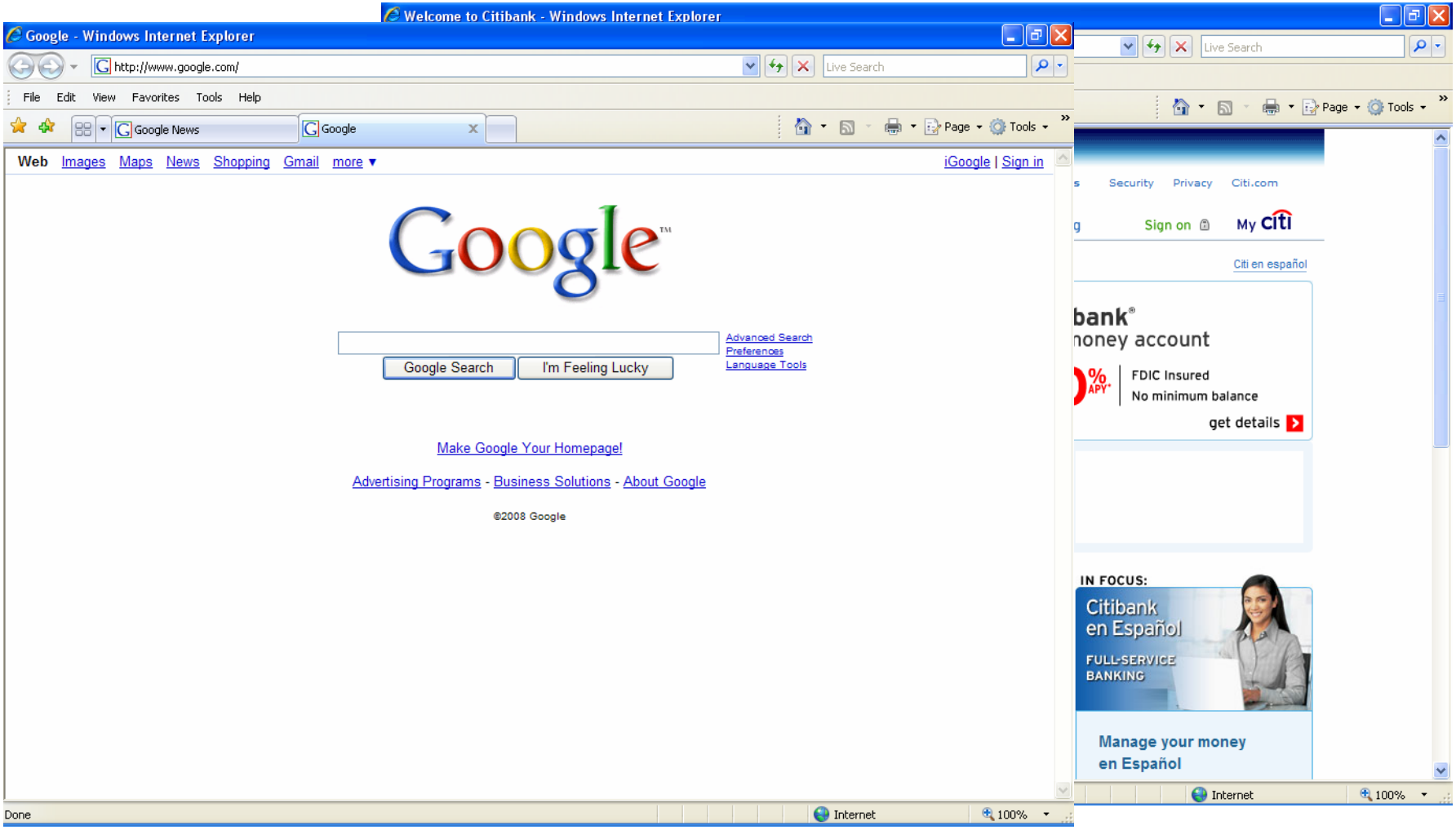
Classification and labeling

- Trust levels
  - Classify applications according to dependency rules
  - Mark an executable using its NTFS file stream
- Sensitivity levels
  - Automatic classification: using a file's DAC

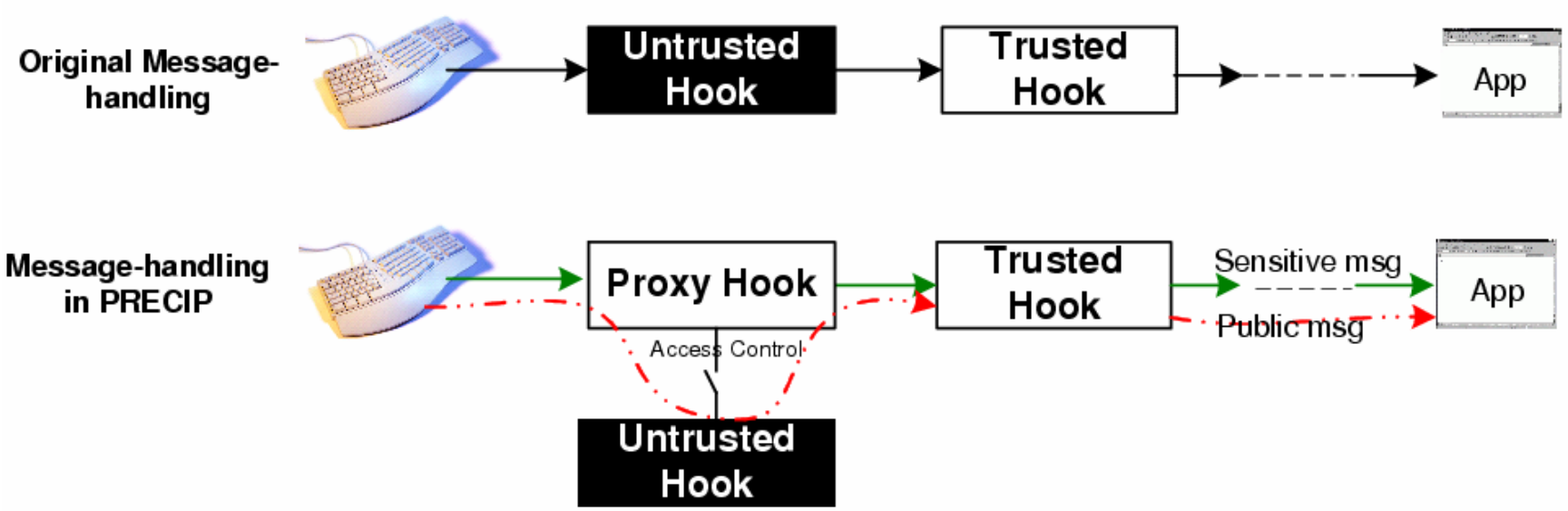
Dependency rules for editing/viewing App



Dependency rules for web browsers



Management of hooks



Integrity protection

- Prevent unauthorized access of subject's and object's labels, contents and PRECIP settings
  - Regulate calls related to file system, auto-start extensibility points and process
- Only allow signed kernel drivers to be loaded
  - A policy also used in Windows Vista

Evaluation

- Dependency rules
  - Test dependency rules on Microsoft office, Adobe Acrobat and Notepad
  - Quite effective in most cases
- Effectiveness
- Performance

Effectiveness

	Name	Type	Control Actions
1	KidLogger [50]	Key Logger	bypass the hook host.
2	Home KeyLogger [8]	Key Logger	bypass the hook host.
3	RunHook [19]	Key Logger	bypass the hook host.
4	Synthesized-1[27]	Key Logger	block two system calls: `NtUserGetKeyboardState` and `NtUserGetKeyState`.
5	Synthesized-2[34]	Key Logger	block one system call: `NtUserGetAsyncKeyState`.
6	GhostlyEye[7]	Screen Grabber	block one system call: `NtGDIStretchBlt`
7	Any Capture[4]	Screen Grabber	block two system calls: `NtGDIStretchBlt` and `NtGDIBitBlt`
8	Hidden Recorder[12]	Screen Grabber	block one system call: `NtGDIBitBlt`.
9	Sub7[15]	File Stealer	untrusted process does not allow to open sensitive files.
10	Cerberus[5]	Lightweight ftpd	untrusted process does not allow to open sensitive files.

Performance

- Performance of hook management
  - Baseline (no proxy): 691.015 microseconds
  - PRECIP: 784.809 microseconds
  - Overhead: 13.57%
- Performance of the kernel driver
  - Evaluated using WorldBench 5.0

Benchmark	Baseline	with PRECIP	Overhead
Office XP SP2	784 s	838 s	6.89%
Photoshop 7.0.1	647 s	675 s	4.33%
Mozilla 1.4	1122 s	1265 s	12.75%

Table 4. Overhead of the Kernel Driver.

Limitations

- Dependency rules are empirical
  - Research: automatic analysis of an application to generate rules
- Integrity model as a complementary
- Model is incomplete
  - Multiple sensitivity levels
  - Compartmentalization

Related research

- Language-based information flow security
  - For design of a new program
- Instruction-level tracking
  - Hard to use online without hardware support
- New systems such as Abestos, IX, Flume,…
  - Need to modify OS
- Sandboxing techniques
  - Too coarse-grained

Conclusions

- Propose a new confidentiality model for practical and retrofittable IF protection
- Application of the model to Windows XP
- Future research
  - Improve the model
  - Improve the techniques for enforcing the model