Building accurate intrusion detection systems

Diego Zamboni
Global Security Analysis Lab
IBM Zürich Research Laboratory

Outline

- Brief introduction to intrusion detection
- The MAFTIA project
- Accurate intrusion detection systems
- Our work (GSAL @ IBM ZRL)

Skip

Why intrusion detection?

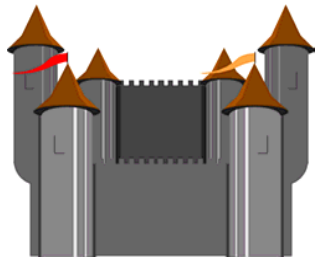
Experience shows that...

- ... users want features despite risks
  - –javascript, shared files, e-mail attachments, ...
- ... it's hard to get rid of existing problems
  - –unsupported OS release, TCP/IP, ...
- ... new systems contain “old” vulnerabilities.
- ... secure + secure ≠ secure.
- ... people make mistakes.

Intrusion detection

- Seminal paper in 1980 by Anderson
- "Modern" intrusion detection started in 1987 with paper by Dorothy Denning
- Is the new "hot buzzword"
  - Many comercial products
  - Many research projects
- No magical solution

Analogy: protecting your home



- Prevention
  - Locked doors, secured windows, wall around property, etc.
- Detection
  - Motion detectors, fire alarm, dog, etc.

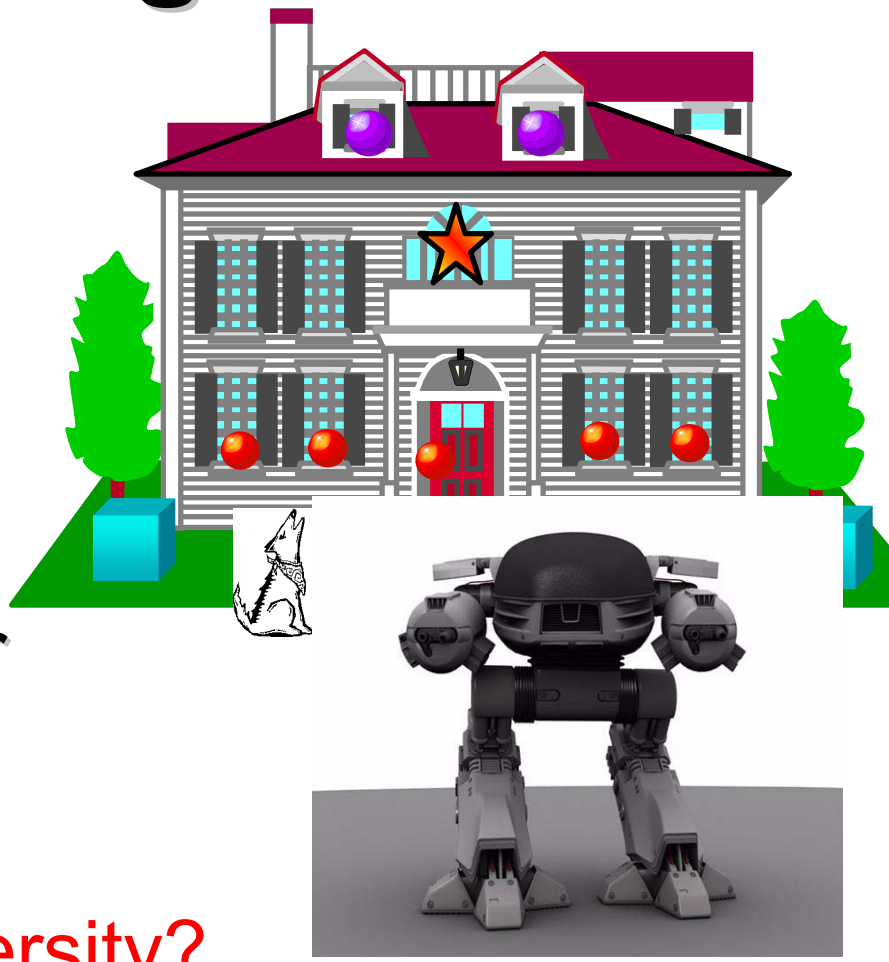
- We need both
- We may also need a response
  - Call police, disable intruders, etc.

Diversity is a good thing

- Multiple specialized sensors

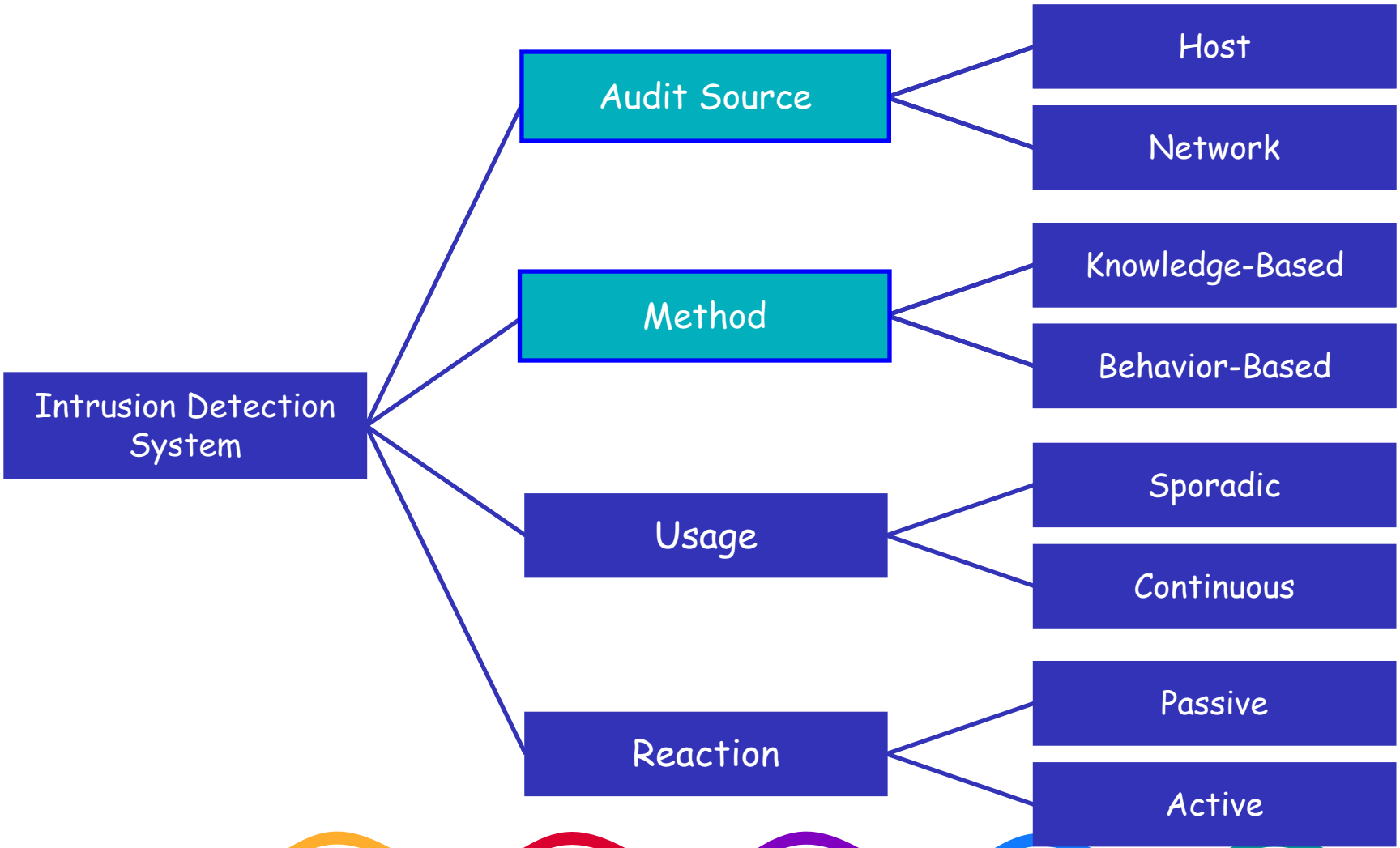
vs

- Single large monolithic sensor



But how to make sense of this diversity?

Characteristics of IDSs



Audit source

- Network
  - Headers or content of network packets
  - ✗ Behavior must be deducted
  - ✗ Subject to insertion/evasion attacks
  - ✓ Easier to deploy
  - ✓ No performance impact
- Host
  - Audit trails (log files)
  - ...or direct monitoring
  - ✓ Can directly observe behavior
  - ✗ More difficult to deploy
  - ✗ Possible performance impact

Method

- Knowledge-based

(aka misuse detection)

  - Known events are suspicious

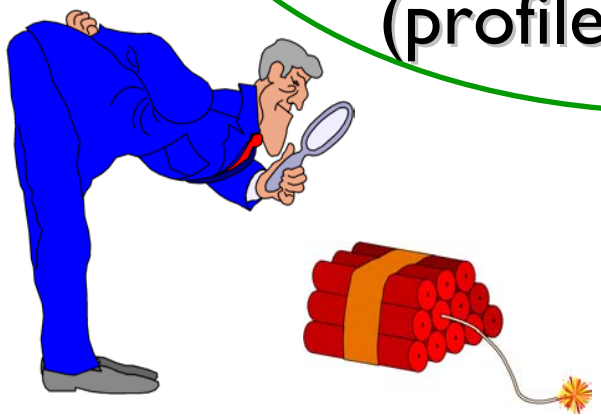
(signatures)

- Behavior-based

(aka anomaly detection)

  - Unknown events are suspicious

(profiles)



Outline

- Brief introduction to intrusion detection
- The MAFTIA project
- Accurate intrusion detection systems
- Our work (GSAL @ IBM ZRL)

MAFTIA

- Malicious and Accidental Fault Tolerance for Internet Applications
  - How to build reliable and secure systems out of insecure components?
- European project
  - 3 years
  - 6 partners
  - 6 technical workpackages

Why is ID a part of the picture?

- Things **will** go wrong
- Even when our system recovers or resists failures and attacks, we want to know that something happened
- IDSs need to be protected too
  - How to prevent the IDS itself from being disrupted?
  - Make sure what the IDS reports is true
  - *Who watches the watcher?*

Outline

- Brief introduction to intrusion detection
- The MAFTIA project
- Accurate intrusion detection systems
- Our work (GSAL @ IBM ZRL)

(some) Limitations of existing IDSs

- Unable to detect unknown attacks
  - sometimes not even known attacks!
  - constant updating needed
- Large number of false alarms
- IDSs assume they cannot be corrupted

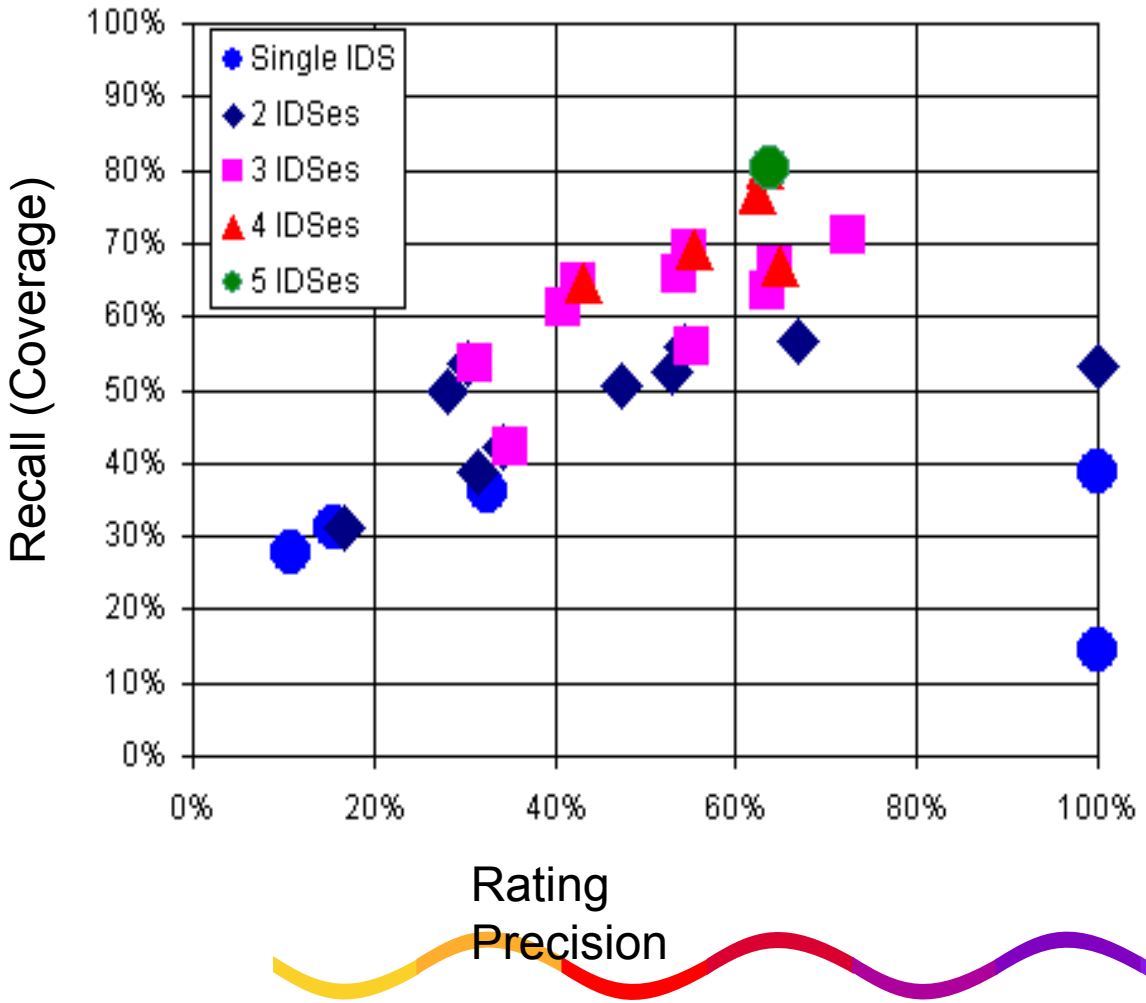
Characteristics we would like in an Intrusion Detection System

- Good coverage
- No false alarms
- Resilient sensors
- No training needed
- Capability for automatic updating

Outline

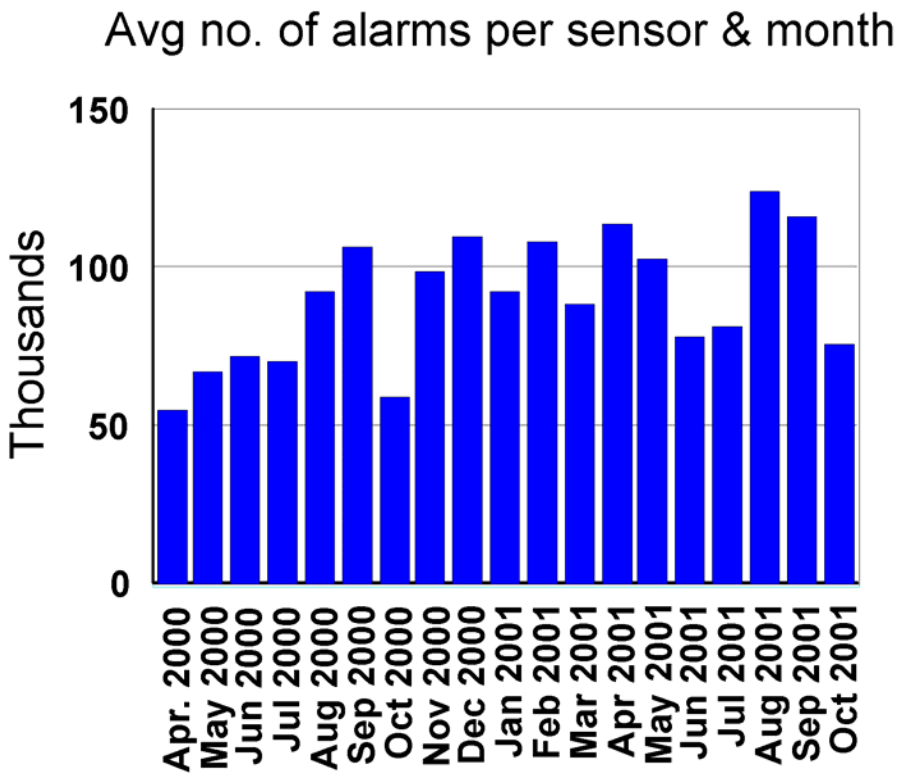
- Brief introduction to intrusion detection
- The MAFTIA project
- Accurate intrusion detection systems
- Our work (GSAL @ IBM ZRL)

Combining sensors to maximize coverage



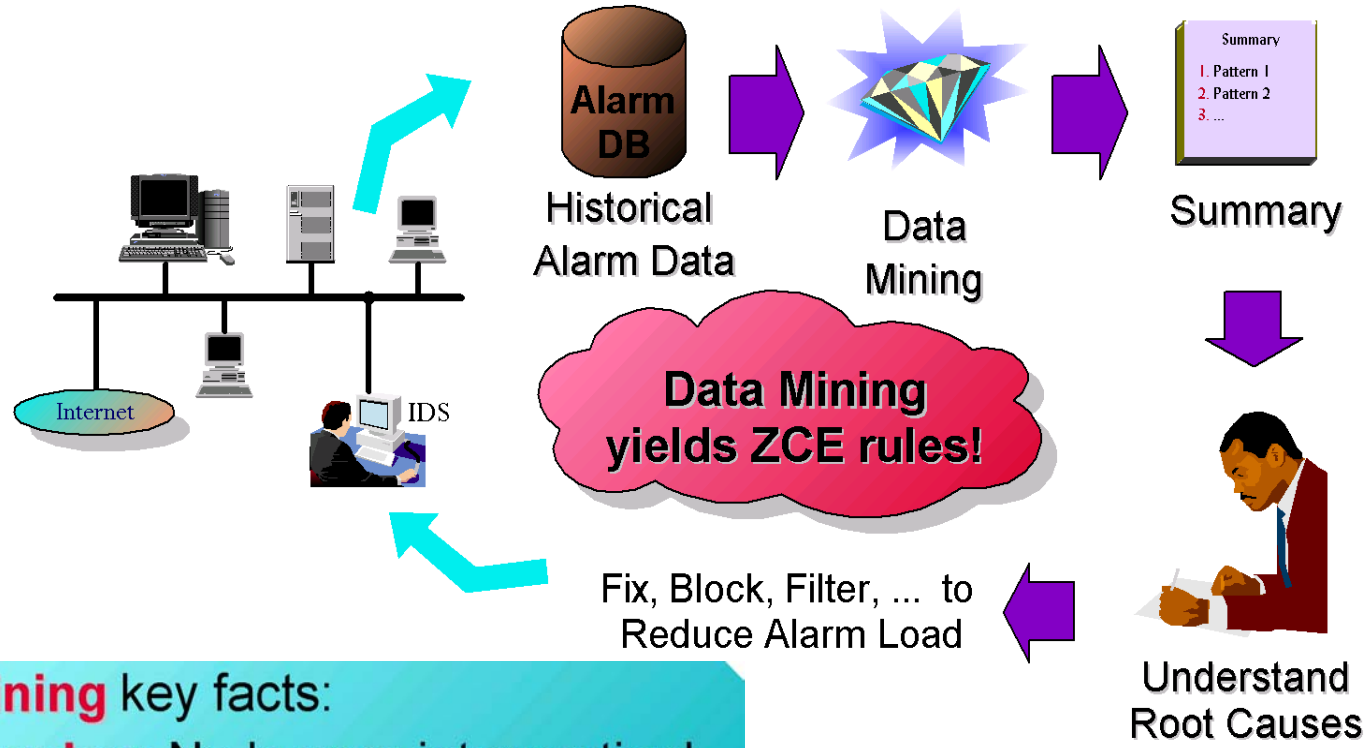
- Goal: find the combination of IDSes that meets our requirements (e.g. 80% coverage, 80% rating precision)
- Optima at concurrent 100% coverage and 100% rating precision

Dealing with false alarms (1/2)



- Problems:
  - –>95% false positives !
  - –Alarm flood worsens as number of signatures rises.
- Conclusion:
  - –This noise makes it impossible to correlate events of those sensors.
  - –We need to figure out how to automatically remove it.

Dealing with false alarms (2/2)



- ✓ **Data Mining** key facts:
  - ✓ **Self-tuning:** No human intervention!
  - ✓ **Stellar results:** 2-4 pages long, extremely easy to understand!
  - ✓ **High impact:** 90% alarm reduction!
  - ✓ **Validated:** On >100 million alarms!

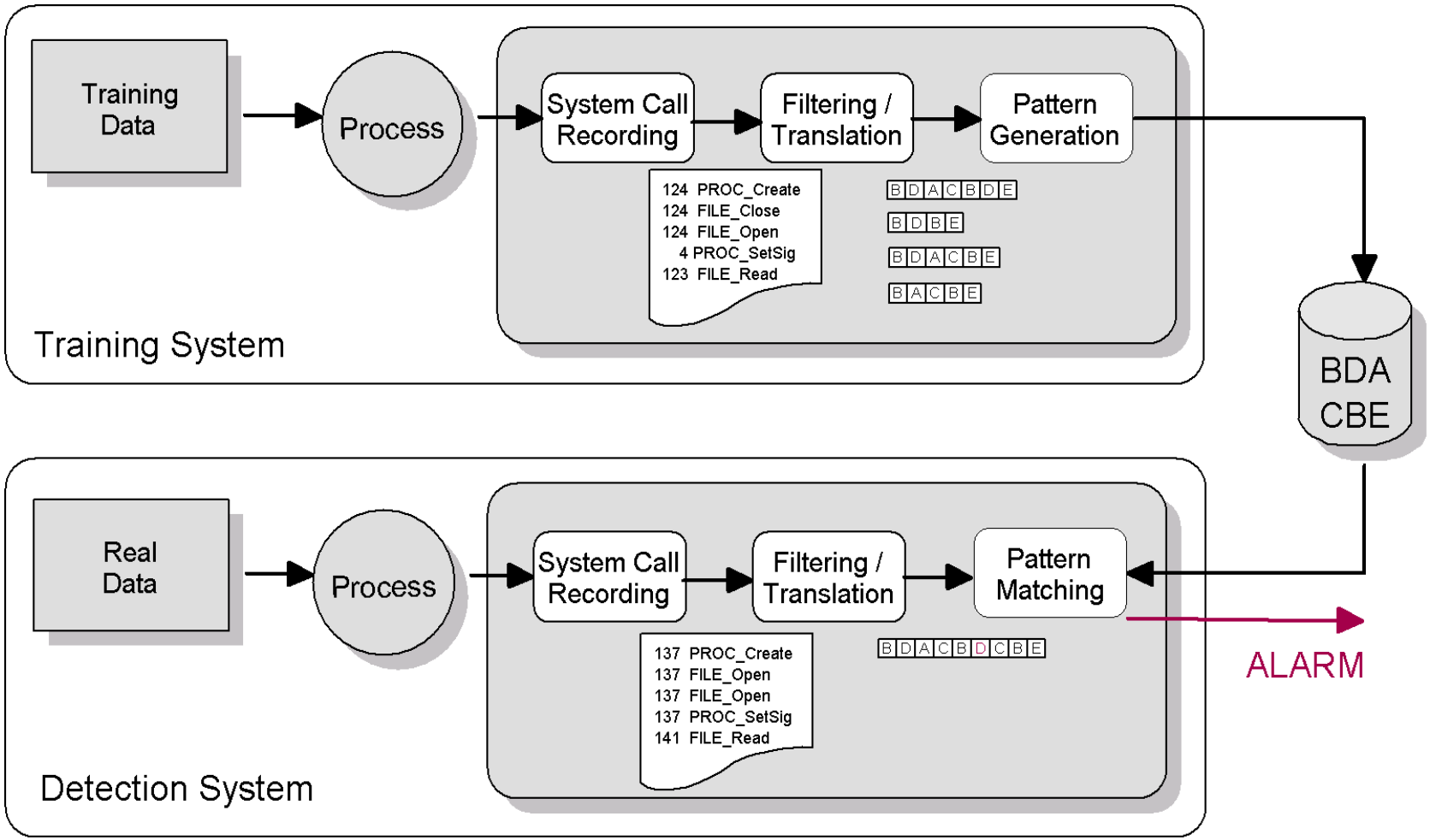
Building good intrusion detection sensors

- Host-based sensors
  - ✓ Increased accuracy and access to good data
- Behavior-based sensors
  - ✓ Can react to unknown attacks
  - ✗ They tend to generate lots of false alarms

DaemonWatcher

- Detect suspicious behavior of UNIX processes
- Principle:
  - A process is characterized by the sequences (patterns) of system calls it generates
  - The patterns can be used to model the normal behavior of a process
  - Intrusions are assumed to exercise abnormal paths in the executable code

DaemonWatcher



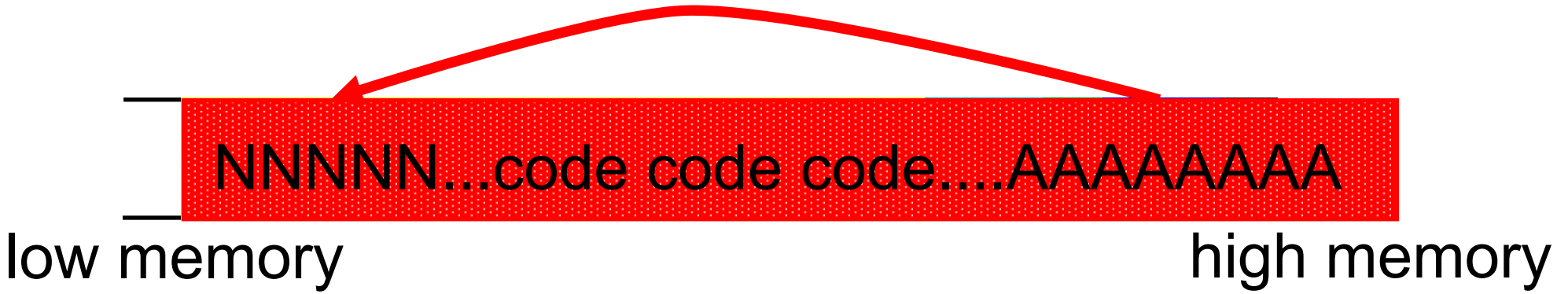
DaemonWatcher: related work

- UNM
  - The first to propose this approach
  - Used fixed-length sequences of system calls
- CMU
  - Analyzed the choice of sequence length

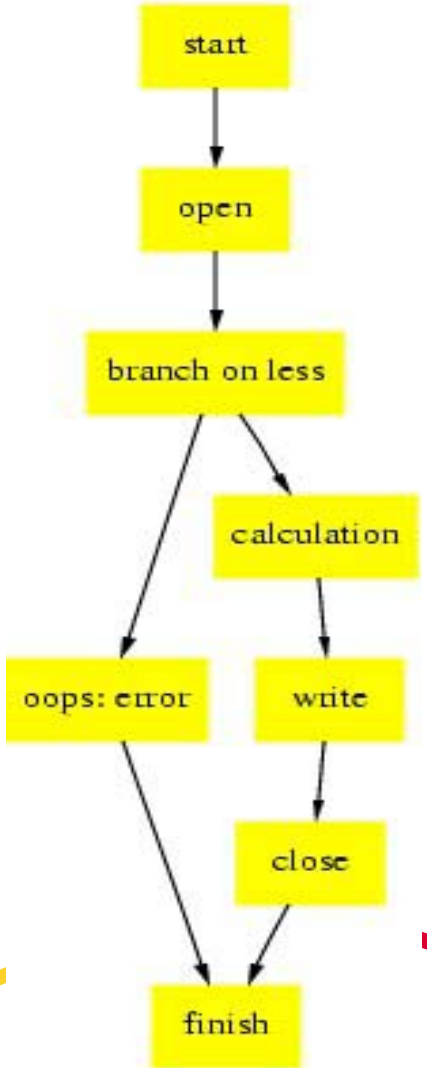
Exorcist

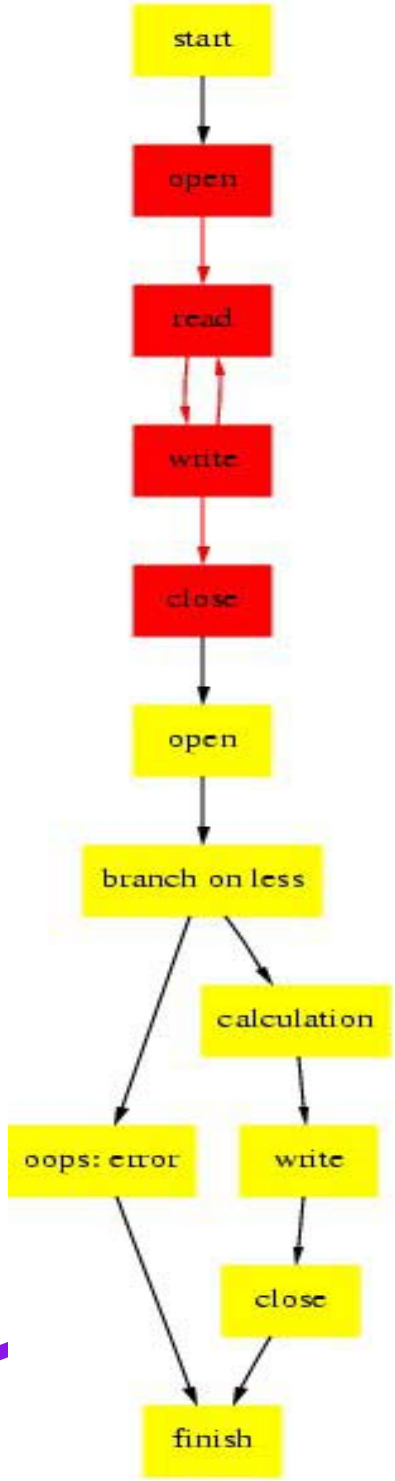
- Detects code insertion attacks
  - Buffer overflow, parasitic viruses
- Host-based
- Behavior-based, but **no training phase**
  - Profile is built by static analysis
- Components:
  - Analysis phase
  - Sensor

Buffer overflow

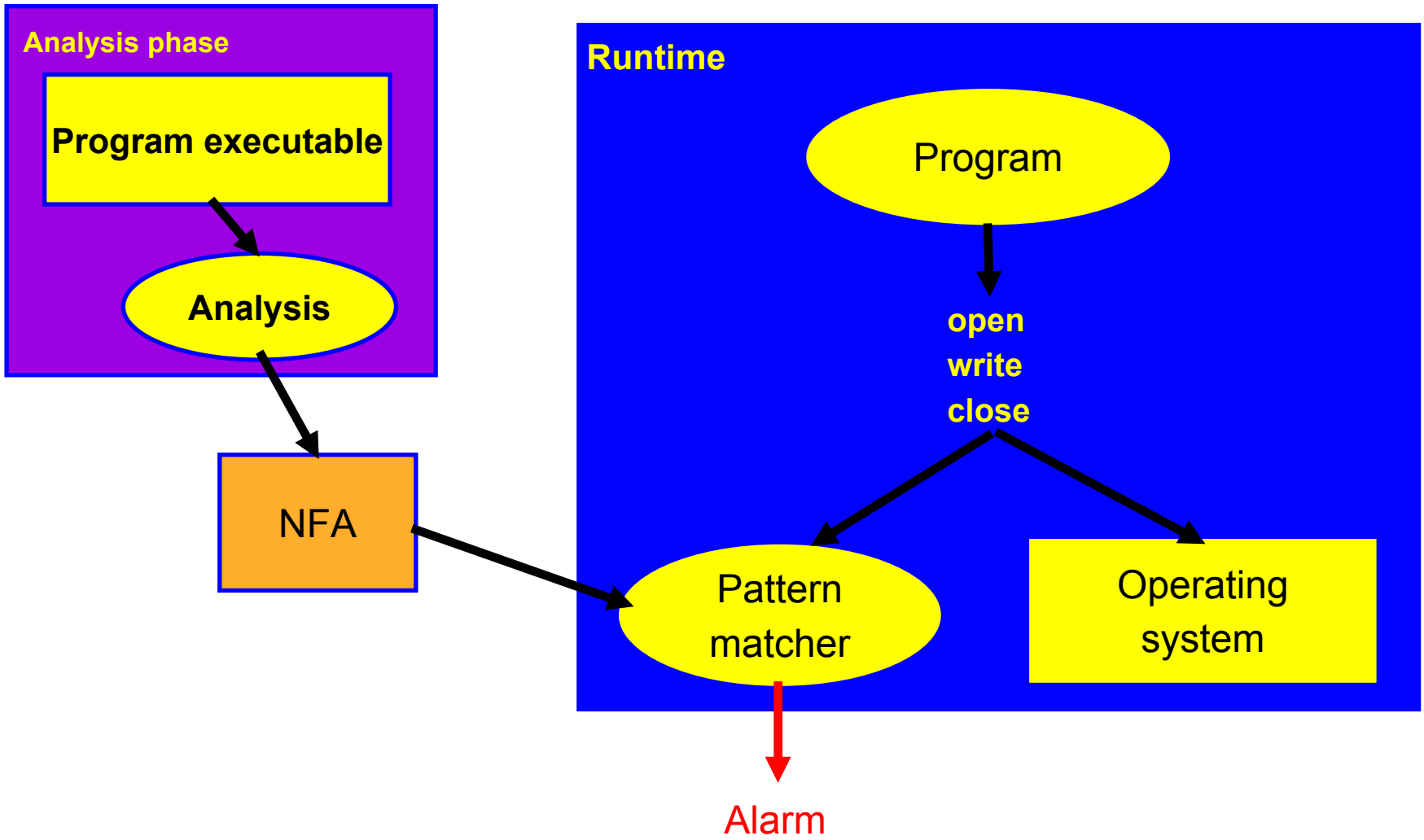


Parasitic virus





Exorcist overview



Analysis phase

- The executable is analyzed using no external information
- Binary code transformed to Control Flow Graph
- End product is an NFA

✓ Very limited data flow analysis

✓ No dependencies on source code availability

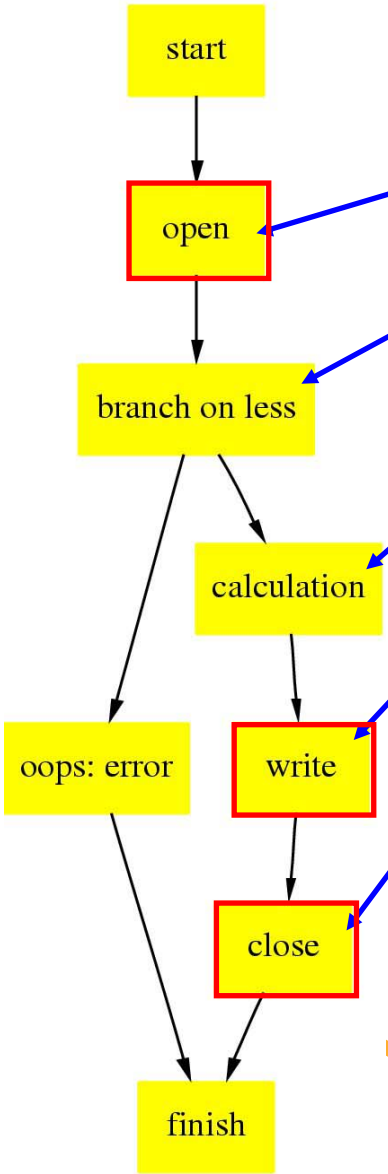
✓ No training required

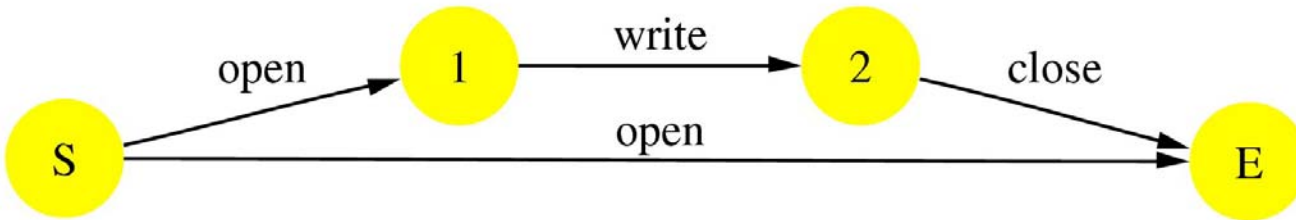
✗ Compiler, library and processor dependencies

  – e.g. Assumes static linking, ELF files, gcc, glibc 2.x

Analysis phase

```
int main(char **argv, int argc) {
  int fd=open("test", O_RDWR);
  char *stuff;
  if (fd >= 0) {
    stuff = "Howdy";
    write(fd, stuff, strlen(stuff));
    close(fd);
  }
  return 0;
}
```

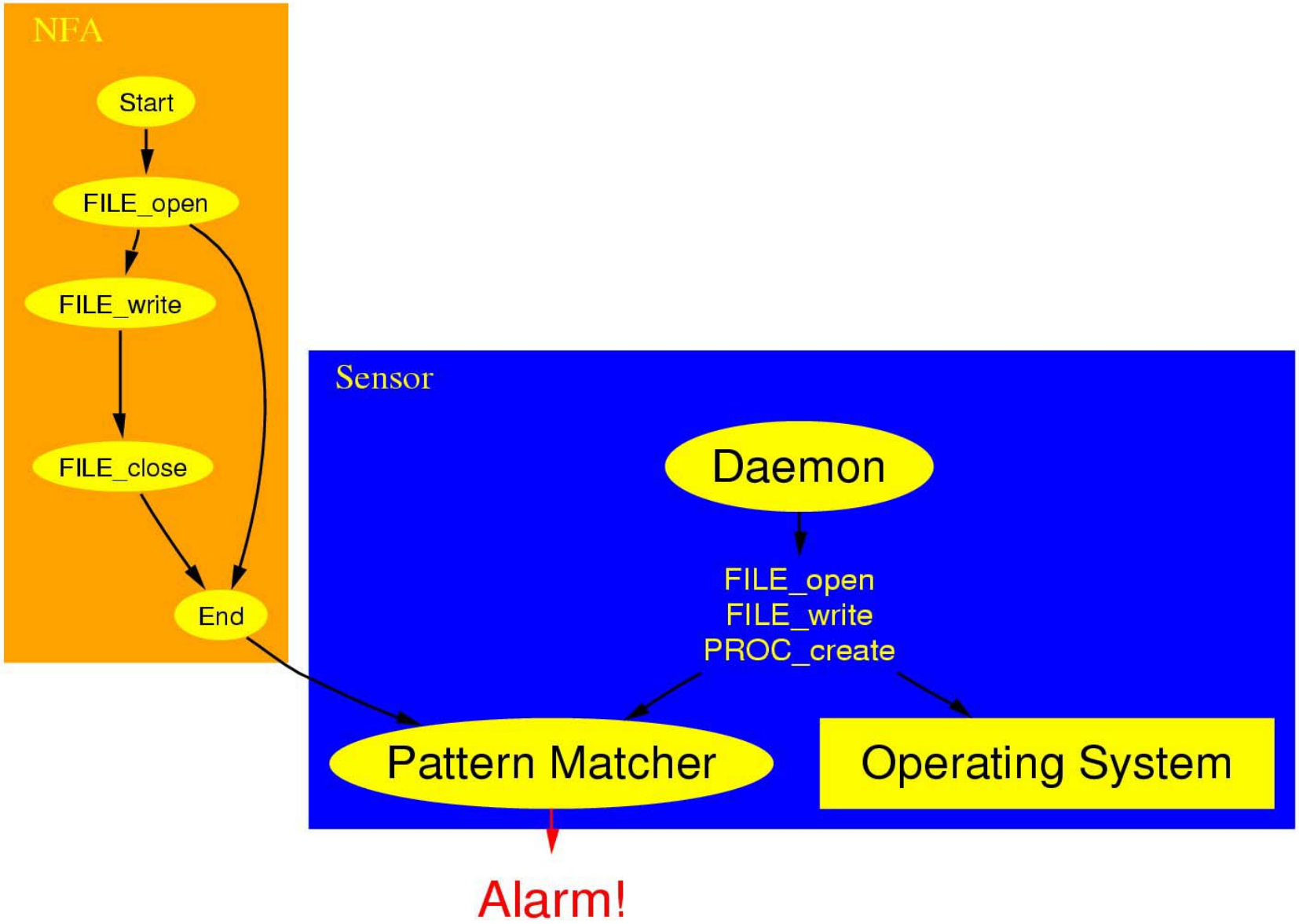




The Exorcist sensor

- Implemented in the Linux kernel
  - User-space sensor for testing (based on strace)
- Match against stream of syscalls, using an NFA
- Syscall parameters are not considered
- Signals caught and handled separately
- Threads are currently not handled

Sample Exorcist alarm



Other approaches

- Closely related work:
  - stide (UNM), DaemonWatcher (IBM ZRL)
  - David Wagner's static analysis (UC Berkeley)
- Policy-based protection:
  - BlueBox (IBM Watson)
  - RSBAC (Amon Ott, rsbac.org)
  - LIDS
- Other buffer overflow protection mechanisms:
  - StackGuard, StackGhost, PAX, etc.

Exorcist benefits and drawbacks

- ✓ No training needed
  - Only update profile when program changes
- ✓ Sensor resistant to attacks
- ✓ False-positive free by design
- ✓ Detects new attacks
- ✓ Can potentially stop attacks
- ✗ Prone to mimicry attacks
- ✗ Currently requires patching the kernel

Exorcist present and future

- Being tested internally
  - Performance tests, accuracy tests
- Windows version? (DLL + threads)
- Product or Open Source?
- Improve analysis phase
- ob. Autonomic Computing
  - can identify new attacks
  - can automatically protect new programs
  - can be part of an immune system infrastructure