Intrusion Detection

System Security (CM0625, CM0631) 2024-25
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Introduction

Intrusion detection

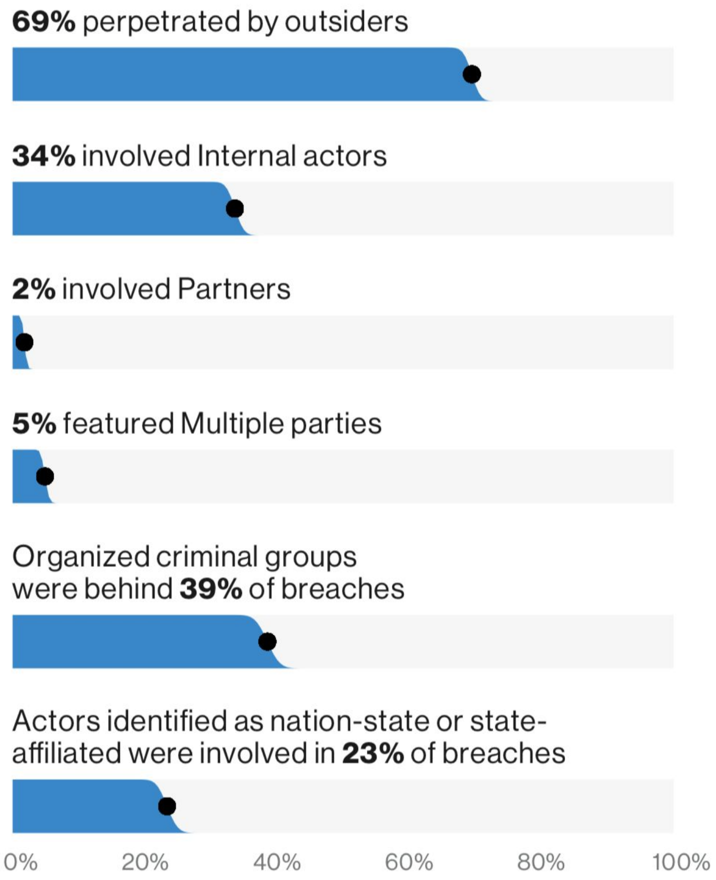
Intrusion: **unauthorized** act of **bypassing** the security mechanisms of a system

Intrusion detection: analysis of information from a computer or a network to **identify** possible intrusions

Introduction

Intruders

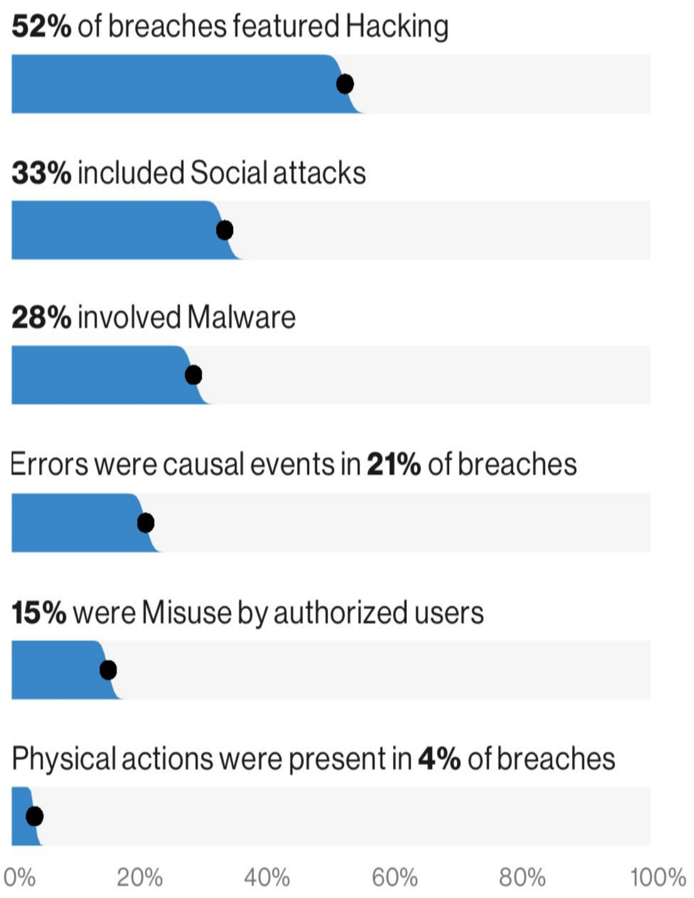
Verizon Data Breach Investigations Report 2019



Introduction

Causes and tactics

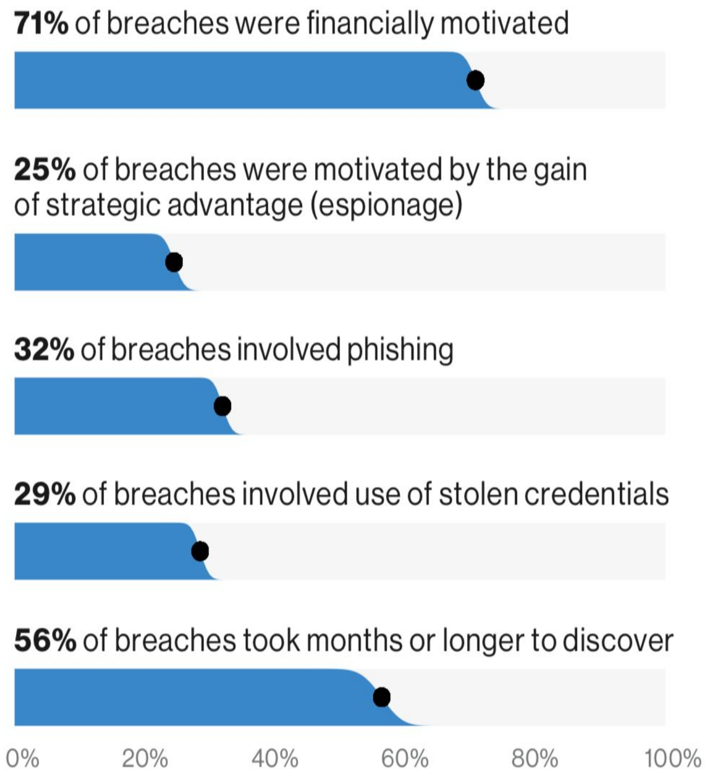
[Verizon Data Breach Investigations Report 2019]



Introduction

Other ....

[Verizon Data Breach Investigations Report 2019]



Classes of intruders

Cybercriminals: individuals or members of an organized crime group with a goal of **financial reward**

Activists (a.k.a. hacktivists): individuals or groups motivated by **social** and **political** causes
Examples: Anonymous, LulzSec, WikiLeaks, ...

State-sponsored organizations: groups of hackers sponsored by governments to conduct **espionage** or **sabotage** activities

Others: hackers motivated by **technical challenges** or by peer esteem and reputation, usually advancing the ***state-of-the-art*** in hacking techniques

Intruder's skills

Apprentice: has minimal technical skill, primarily uses existing attack toolkits. Also known as "***script-kiddie***". Comprises the <u>largest number of attackers</u>

Journeyman: modifies and extends existing tools, finds **new** variants of vulnerabilities

⇒ Harder to detect than "kiddies"

Master: high-level technical skills. Can find new (**0-day**) vulnerabilities and develop **new** attack toolkits. Typically employed by state-level organizations

⇒ Very hard to detect and stop

Examples of intrusions (NIST SP 800-61)

Remote server **compromise** (e.g., getting root access)

Web server **defacing**

Password cracking

Leakage of credit card numbers and credentials

Accessing **sensitive data** without authorization

Packet **sniffing** on a network

Credential theft through **phishing**

Using unattended, **logged-in workstation** without permission

Intruder behaviour (1)

Target acquisition and information gathering: attacker **identifies** and **characterizes** the target system

- **examine** corporate website
- use network exploration / **scanning** tools such as DNS lookup and NMAP
- identify potential **vulnerable** services
- **interact** by email

Initial access: is the initial **access** to the target system by the attacker, based on previous phase

- exploit a **vulnerability**
- guess weak **credentials**
- install **malware** by phishing

Intruder behaviour (2)

Privilege escalation: attacker exploits a **local vulnerability** to increase privileges

- **search** for local vulnerabilities
- install **sniffers** to capture administrator passwords

⇒ exploit local vulnerabilities or administrator passwords to gain elevated **privileges**

Information leakage and system exploit: **leak** sensitive data and use local data to **access** other systems

- **scan** and examine files
- **transfer** sensitive data outside
- use guessed or captured passwords to **access** other target systems

Intruder behaviour (3)

Maintaining access: enable **continued** access to the system(s)

- install remote administration tools and **rootkits** with **backdoors**
- use admin **password** to access
- modify or **disable** intrusion detection systems

⇒ **hide** presence

Covering tracks: remove **evidence** of attack activity

- use **rootkits** to hide installed/modified files
- remove **logs**

Intrusion Detection System (IDS)

IDS: Hardware or software that analyzes information from a computer or a network to **identify** possible intrusions

Sensors: **collect** data that might contain evidence of intrusion

- network **packets**
- **logs**
- **syscall** traces

Analyzers: receive input from sensors and **determine** if an intrusion occurred

- guidance on possible **actions**
- stores data for **future** analysis

User interface: **displays** results of analysis (possible intrusions) and allows for system configuration

Why shall we bother about IDSs?

1. If an intrusion is detected **quickly enough**, then the intruder can be **identified** and **ejected** from the system before too much damage is done or too much data are compromised.

   In case of immediate reaction, damage can be **fully prevented**

2. An effective IDS acts as a **deterrent**, reducing the attack attempts

3. Intrusion detection enables the **collection** of information about intrusion techniques that can be used to **strengthen** system and network **security**

Detecting intruder behaviour

Honest and malicious behaviours differ ... but they also **overlap**

False positives: honest users identified as intruders (**loose** interpretation)
⇒ False alarms

False negatives: intruders identified as honest users (**tight** interpretation)
⇒ Missed alarms

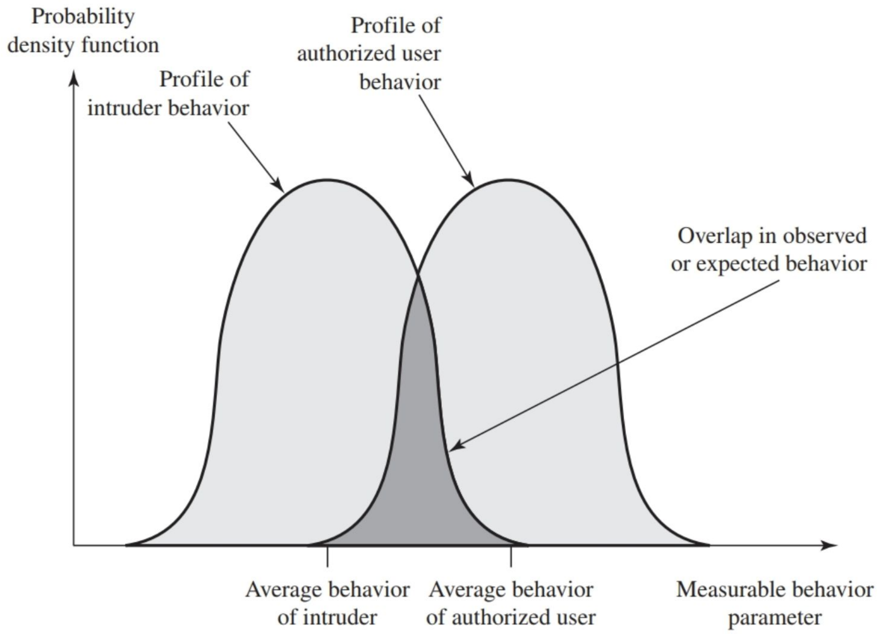


Figure from Lawrie Brown, William Stallings. *Computer Security: Principles and Practice*, 4/E, Pearson.

False positive paradox

Base-rate fallacy: mind tend to **ignore** base-rate when **more specific** rate information is provided

Example: **breathalyzers** with 5% false positive rate (and no false negatives)

- If test on (random) Bob is positive what is the probability that **Bob is really drunk**?
- **Answer**: 95% ?
- **No!** it depends on the base-rate

Example: Assume 1/1000 drivers drunk, on average

- 1/1000 gives **true positive**
- 5% of 999 = 49.95 give **false positive**

⇒ 1 / (49.95+1) = **1.96%** of positive tests is really drunk!

(of course without **other evidence**.... like driving zig-zag!)

IDS base-rate fallacy

Systems with **few intrusions** (with respect to the false positive rate) present the **base-rate fallacy** issue

Example:

- 1/10000 **malicious** behaviour
- 5% false positive rate

⇒ 0.2% of positives **will be true**

IDS becomes **useless** with too many false positives

No trivial solution:

⇒ It would be necessary to make detection **extremely tight** introducing **false negatives**

Analysis approaches

Anomaly detection: involves the collection of data relating to the behavior of legitimate users so to create a **model** of user behaviour

- current observed behavior is **analyzed** with respect to the legitimate user model
- classified as *intrusion* when **difference** is over a threshold

Signature or heuristic detection: also known as misuse detection, uses

- a set of known malicious data patterns (**signatures**)
- attack rules (**heuristics**)

⇒ This approach can only identify **known attacks** for which it has patterns or rules (**no 0-day**!)

Anomaly-based detection

A **model** of honest user is built from sensor data, collected in a *training phase* (no intrusion)

Approaches:

Statistical: statistical profile of observed metrics

👍 Simple and efficient
👎 Non-flexible (which metrics?)

Knowledge based: rules that classify legitimate behaviour

👍 Robust and flexible
👎 Difficult to develop, requires experts

Machine learning: classification model, automatically built

👍 Flexible and automated
👎 Training expensive, accuracy not yet optimal (+ adversarial ML)

Signature and Heuristic Detection

Signature-based: match known malicious **patterns** (large enough to minimize false positives)

Example: anti-virus

👍 **Fast**, widely accepted

👎 Continuous review of malware and attacks to **create the signatures**

👎 Inability to detect new, **0-day** attacks

Heuristic-based: **rules** that identify intrusions or suspicious behaviour, often derived by analyzing existing attack tools

👍 **Fast**, widely accepted

👎 Rules are **specific** to the machine and operating systems

👎 If rules are known, attackers can find ways to **circumvent** them

IDS classification

Host-based IDS (HIDS): Monitors the events occurring in a **single host**, such as process identifiers and the system calls they make

Network-based IDS (NIDS): Monitors **network traffic** for particular network segments or devices and analyzes **protocols** to identify suspicious activity

Distributed or hybrid IDS: Combines information from a number of sensors, often both host and network-based, in a **central analyzer** that is able to better identify and respond to intrusion activity

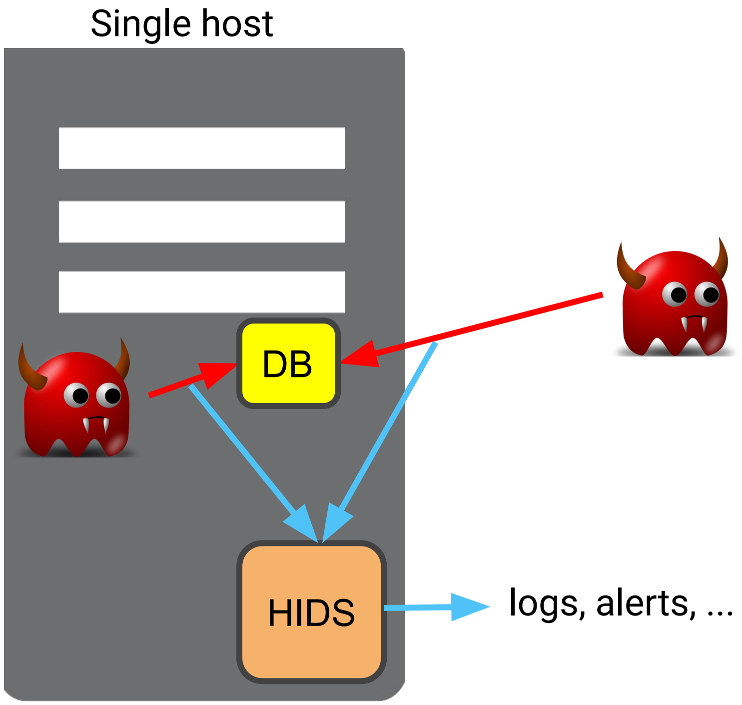
⇒ sums up the **advantages** of multiple HIDS and NIDS

Host-based IDS (HIDS)

HIDS: an IDS running directly on a host to protect its applications

⇒ **detects** intrusions, **logs** suspicious events, send **alerts**

⇒ detects both **internal** and **external** intrusions



HIDS sensors (1)

System call traces: sequence of **syscalls** invoked by processes

Syscall traces provide accurate information about the **interaction** of processes with the OS

Anomaly-based: create **models** of honest syscall traces

Heuristic-based: **rules** that detect suspicious syscall invocation

Log files: modern systems already log **events** which can be directly used as sensors for HIDS

- 👍 **Less overhead** than syscall traces
- 👎 Less information, **lower detection** rate
- 👎 Might be easier for the intruder to **manipulate**

HIDS sensors (2)

File checksums: compare crypto **checksum** with stored ones. Look for changes to important files

👍 Easily detects **integrity** attacks
👎 **Overhead** managing checksums
👎 **Complex** to configure: which files to monitor to reduce false positive while detecting intrusions?

Example: Tripwire

Registry access: monitor access to the **registry** (Windows OS **specific**)

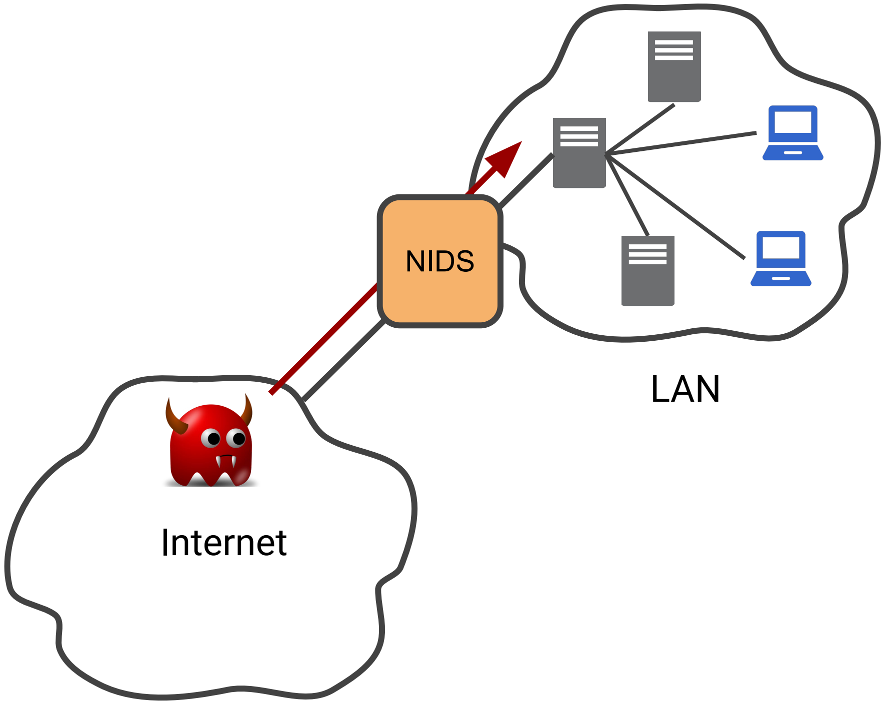
Files: Signature-based HIDS that look for known **signatures** such as in anti-virus programs (file system, attachments, …)

Accesses to resources: Heuristic-based HIDS that look for known **suspicious** access requests

Network-based IDS (NIDS)

NIDS: an IDS that monitors traffic at selected points on a network

Inspects **network packets** directed to (potentially vulnerable) hosts

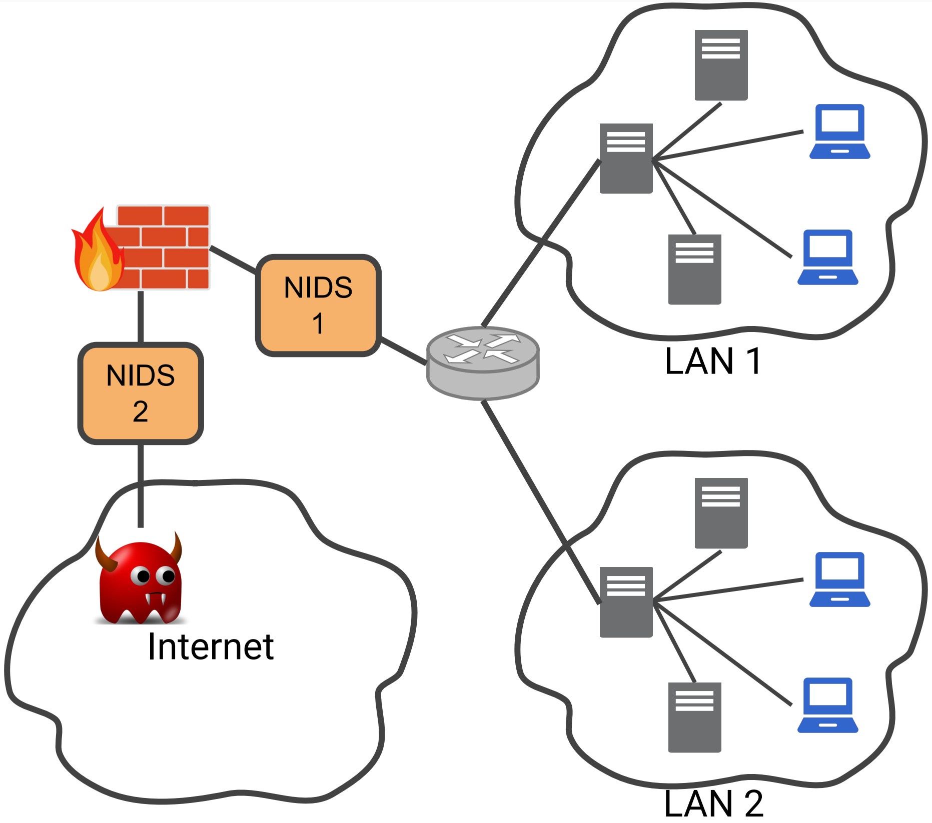


NIDS sensor deployment (1)

On the **external perimeter**:

👍 Detects **external** intrusions
👍 Detects firewall **misconfiguration** (if after the firewall, NIDS 1)
👍 Can detect **outgoing** malicious traffic

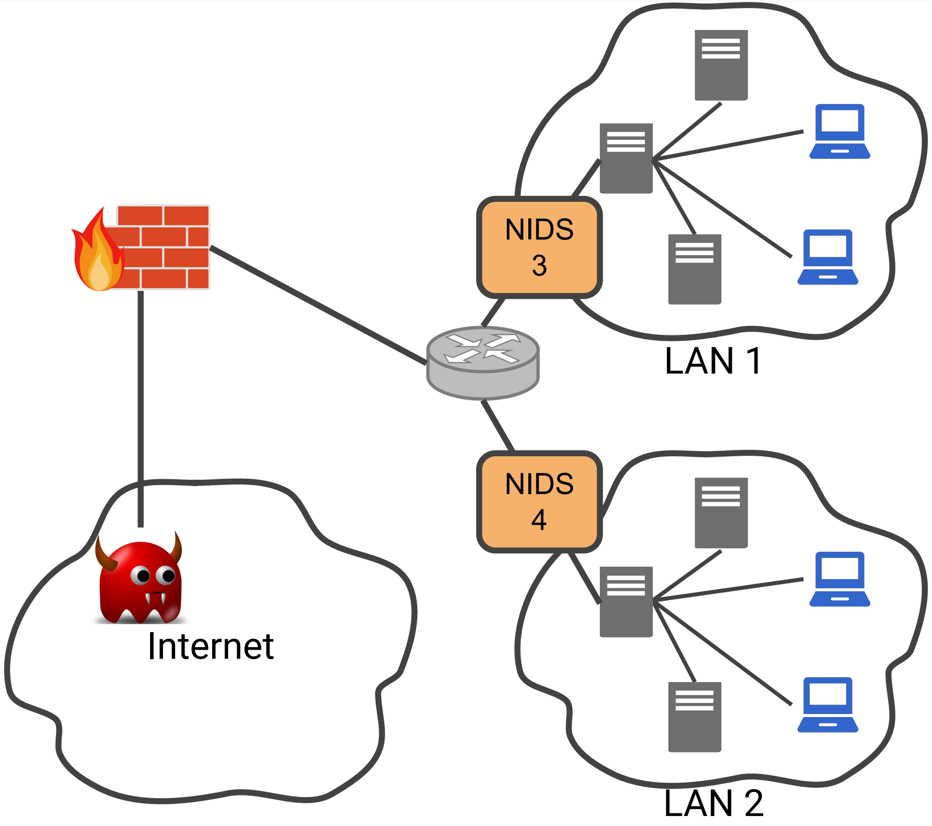
👎 Does **not** detect **internal** attacks
👎 High **load** if before the firewall (NIDS 2)



NIDS sensor deployment (2)

Before the **LANs**:

- 👍 Detects both **internal** and **external** intrusions
- 👍 Detects firewall **misconfiguration**
- 👍 Can detect **outgoing** malicious traffic
- 👍 Can be configured on **specific** resources



Anomaly-based NIDS detection

Denial-of-service (DoS): involve **anomalous** increased packet traffic or increased connection attempts

Scanning: A scanning attack occurs when an attacker probes a target network or system by sending different kinds of packets. It can an be detected by **atypical** flow patterns

Worms: show anomalous behaviour on the network:

- propagate quickly and use large amounts of **bandwidth**
- cause hosts to **communicate** (that typically do not)
- cause hosts to use **ports** that they normally do not use
- many worms perform **scanning**

Signature-based NIDS detection

Application layer attacks: **patterns** of attacks targeting application layer protocols

Transport layer attacks: unusual packet fragmentation, TCP-specific attacks such as **SYN floods**

Network layer attacks: **spoofed IP** addresses and illegal IP header values

Unexpected application services: detect if activity on a transport connection is **consistent** with the expected application protocol

Policy violations: Examples include use of inappropriate websites and use of **forbidden** application protocols