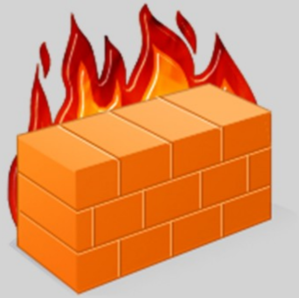
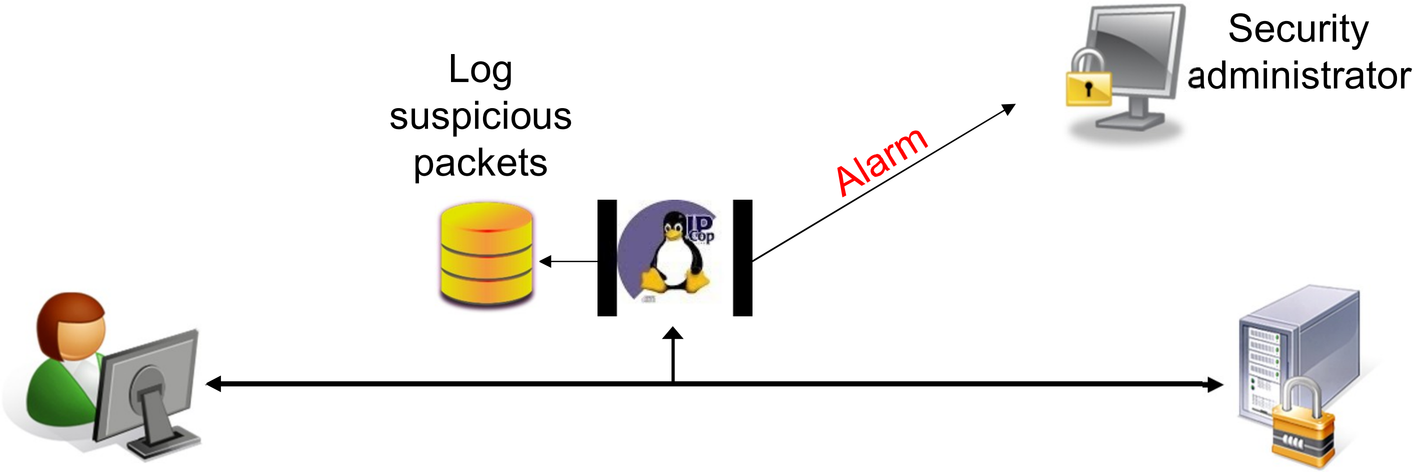
IDS and IPS Systems



Intrusion detection and prevention systems

Chapter 21.2

Intrusion Detection System (IDS)



An **IDS** is passive and sends alarms when rules are triggered

An **IPS** (intrusion prevention system) can **take actions** and for example block packets and modify some firewall settings: “block all from 10.1.1.44” for 10 minutes. IPS systems may enable DoS attacks!

Intrusion Detection System (IDS)

NIDS: **Network-based** IDS looks at traffic on a network segment

HIDS: **Host-based** IDS located in individual hosts (clients, servers)

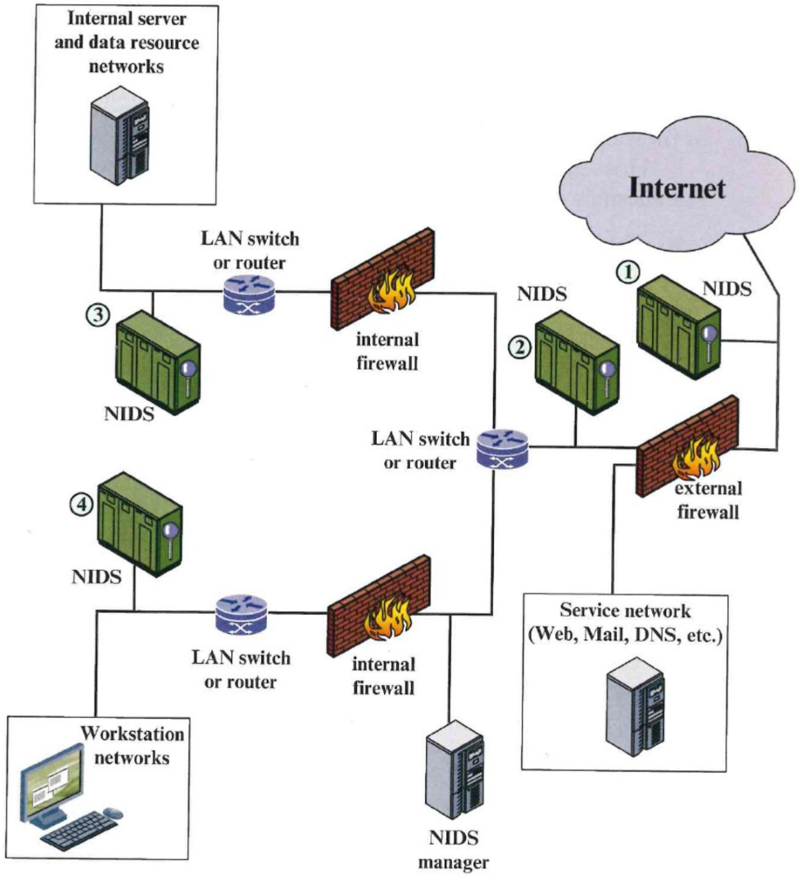
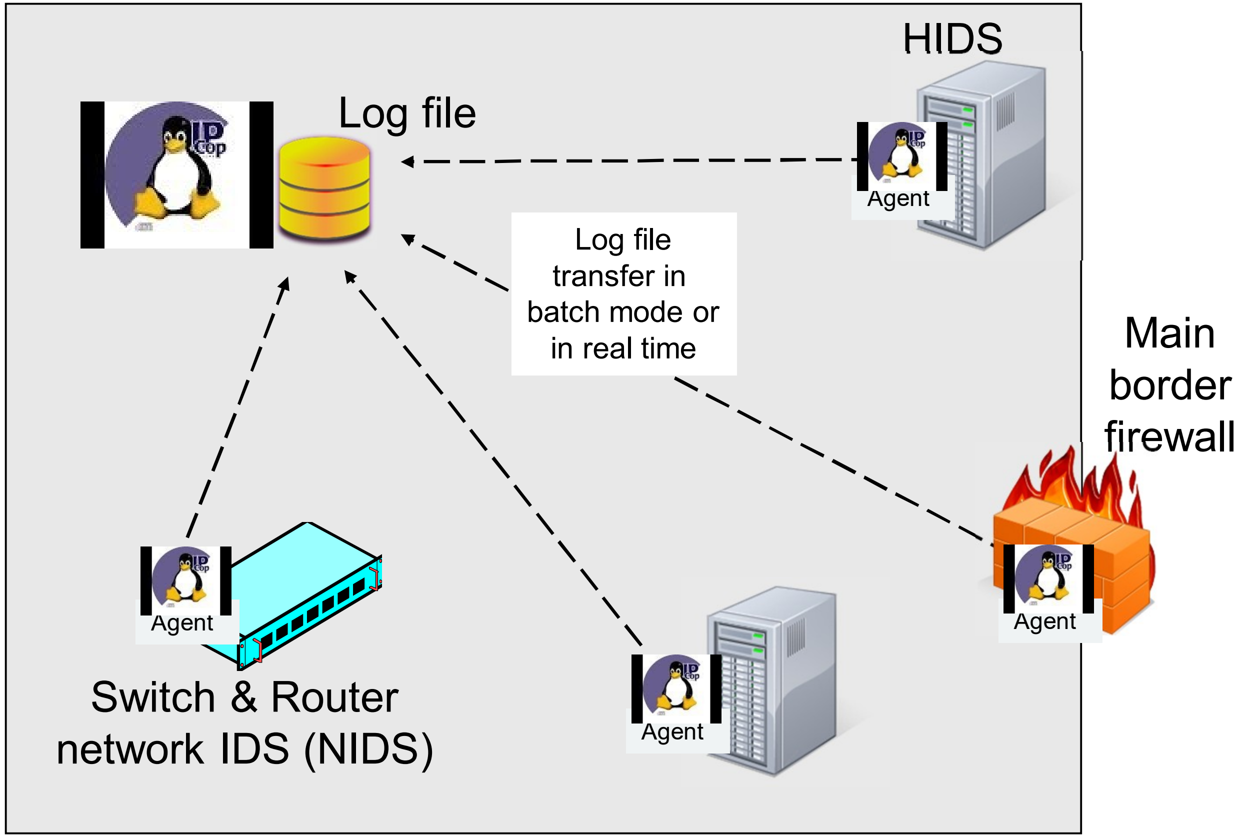
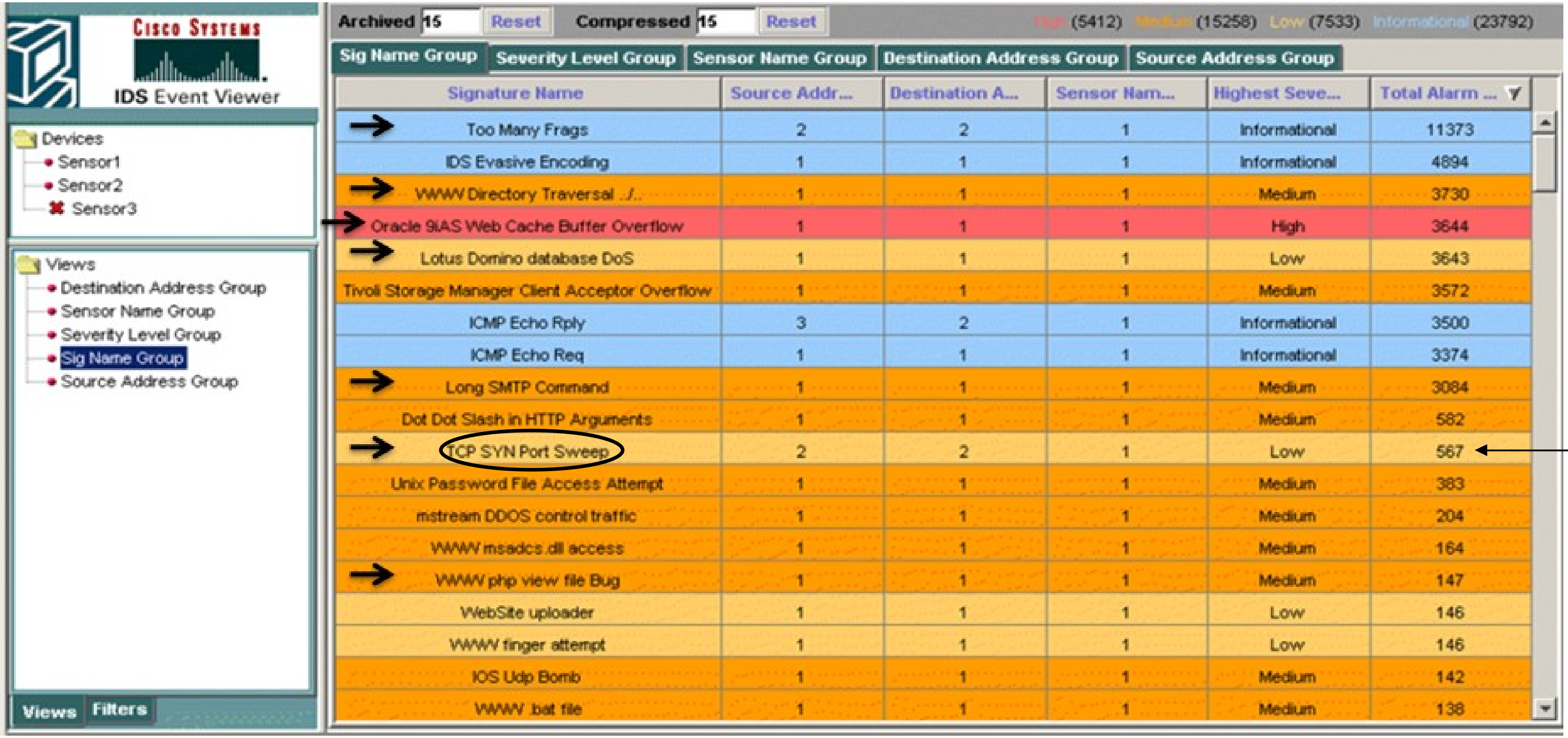


Figure 21.6 Example of NIDS Sensor Deployment

IDS with centralized monitoring/management



Intelligent logging with analysis

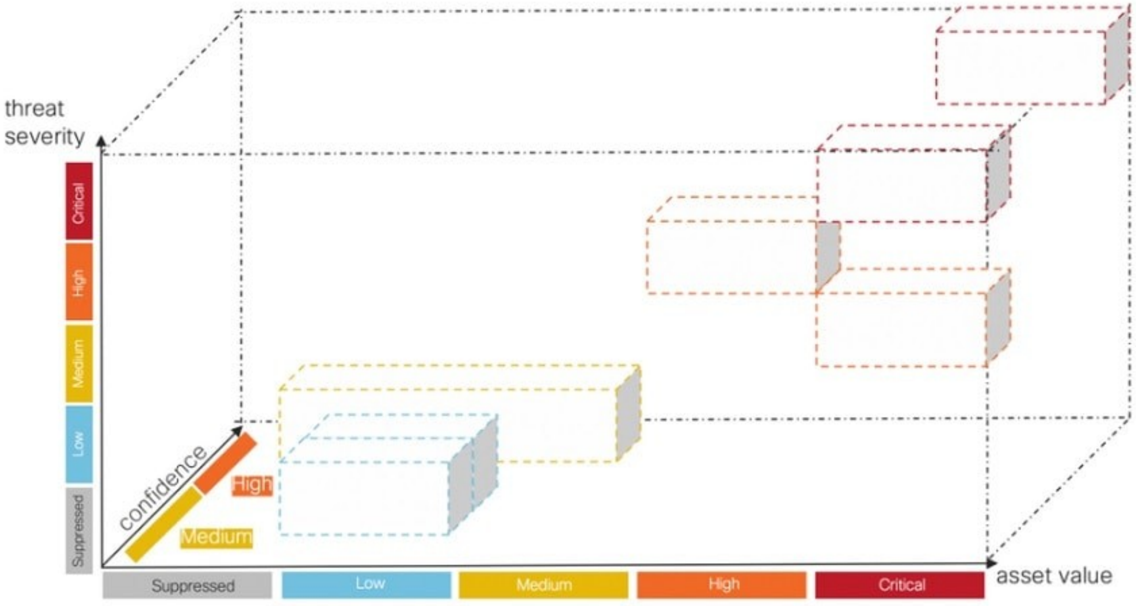


Signature Name	Source Addr...	Destination A...	Sensor Nam...	Highest Seve...	Total Alarm ...
Too Many Frags	2	2	1	Informational	11373
IDS Evasive Encoding	1	1	1	Informational	4894
WWW Directory Traversal ../..	1	1	1	Medium	3730
Oracle 9iAS Web Cache Buffer Overflow	1	1	1	High	3644
Lotus Domino database DoS	1	1	1	Low	3643
Tivoli Storage Manager Client Acceptor Overflow	1	1	1	Medium	3572
ICMP Echo Rply	3	2	1	Informational	3500
ICMP Echo Req	1	1	1	Informational	3374
Long SMTP Command	1	1	1	Medium	3084
Dot Dot Slash in HTTP Arguments	1	1	1	Medium	582
TCP SYN Port Sweep	2	2	1	Low	567
Unix Password File Access Attempt	1	1	1	Medium	383
mstream DDOS control traffic	1	1	1	Medium	204
WWW msadcs.dll access	1	1	1	Medium	164
WWW php view file Bug	1	1	1	Medium	147
WebSite uploader	1	1	1	Low	146
WWW finger attempt	1	1	1	Low	146
IOS Udp Bomb	1	1	1	Medium	142
WWW .bat file	1	1	1	Medium	138

One event generated from many packets

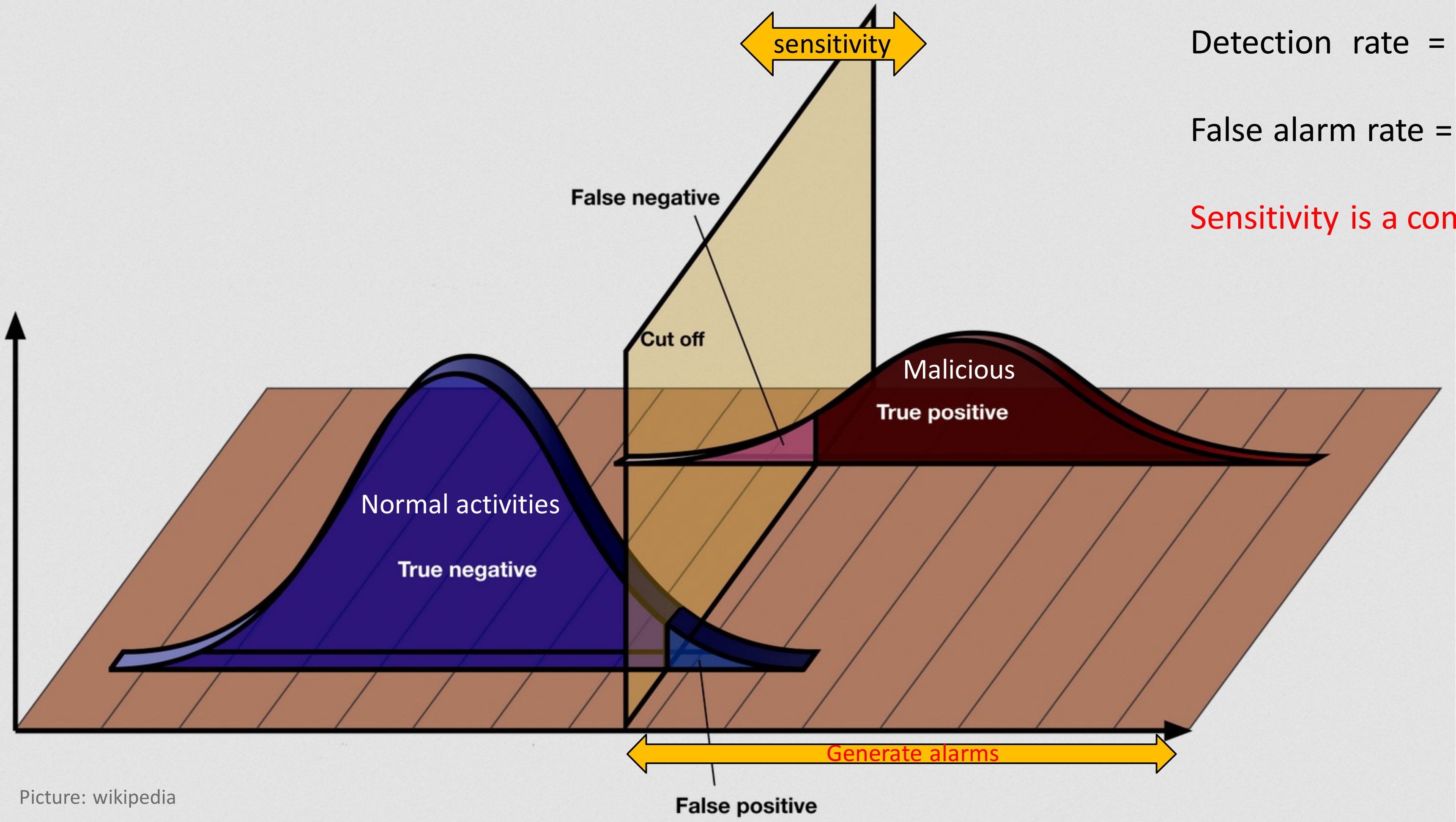
AI/ML is present in IDS systems

The analytics engine applies machine learning to incoming data streams and projects the detections into a 3-dimensional space:



https://www.cisco.com/c/en/us/td/docs/security/stealthwatch/global-threat-alerts-in-secure-network-analytics/m_dashboard.html

Sensitivity is a compromise



Picture: wikipedia

$$\text{Detection rate} = \frac{TP}{TP+FN}$$

$$\text{False alarm rate} = \frac{FP}{FP+TN}$$

Sensitivity is a compromise

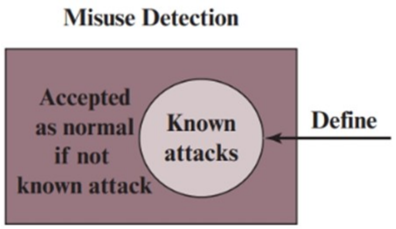
Signature and Anomaly Based Detection

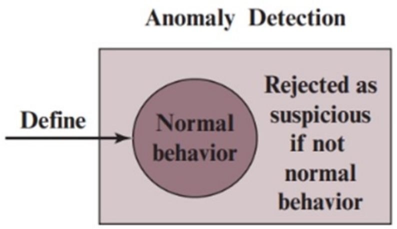
Signature based (misuse)

- Signatures/specifications for known attacks
- Few false alarms
- Cannot stop new attacks where no signatures exist
- Cannot detect zero-day attacks targeting vulnerabilities that are not yet known
- Compare with anti-virus software
- Free multi-platform tool owned by Cisco

Anomaly based

- Detects anomalous, unusual, behavior
  - Traffic or behavior new to the network
  - Can look at statistical patterns
- The only way to stop zero-day attacks
- Needs training – but what is normal?
- Risk for too many false alarms
- Hard to know what it has really learned
- Compare with anti-spam software





Snort packet processing

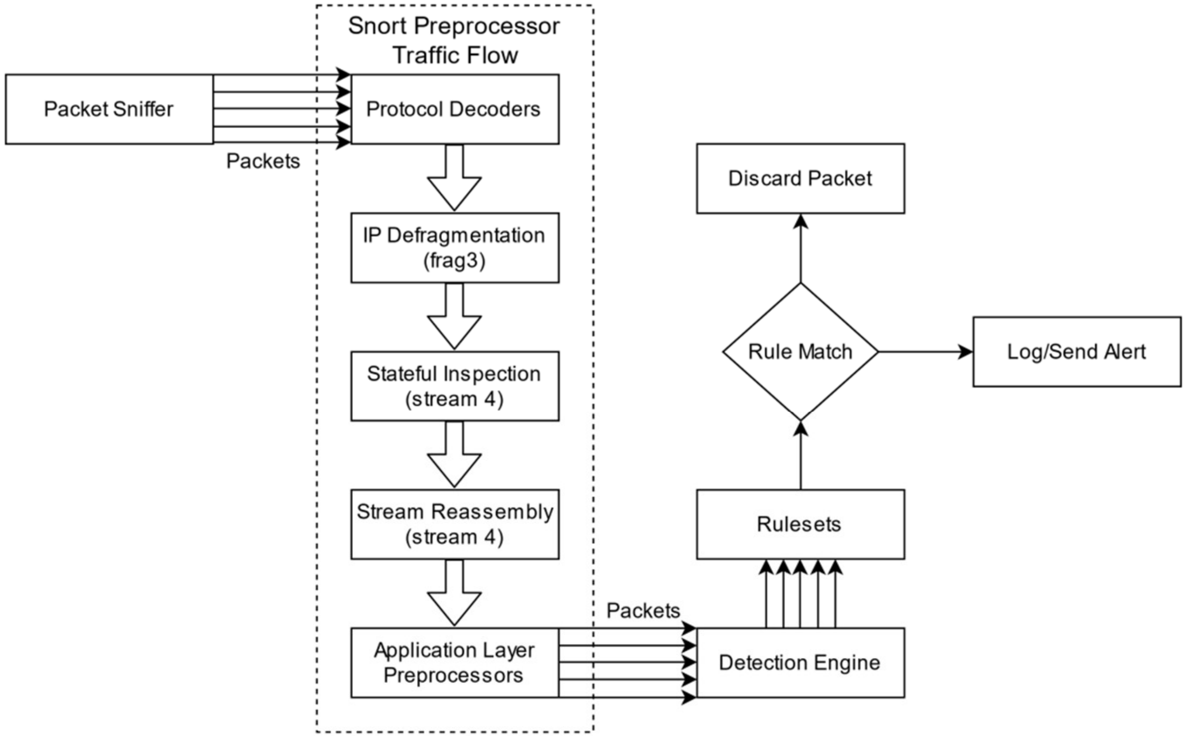


Figure 2.4: A simplified view of the Snort architecture and packet processing flow [20, pp. 40, 44, 227].

Master Thesis, V. Rydfalk, Linköping University
http://liu.diva-portal.org/smash/get/diva2:1575399/FULLTEXT01.pdf

[20] Book: Snort intrusion detection and prevention toolkit. [Brian Caswell, Jay Beale, and Andrew Baker]

Rule Examples

Rule header

Rule options

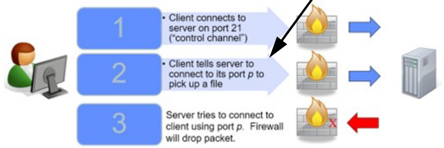
```
alert tcp !10.1.1.0/24 any -> 10.1.1.0/24 139  (msg: “External Netbios traffic seen";)
alert tcp any any -> any 80  (content: "GET /cgi-bin/; msg: “Attempt to access /cgi-bin";)
alert tcp any any -> any any  (flags: SF; msg: “SYN-FIN scan”;)
```

Log, alert, drop
IP, ICMP, TCP, UDP, …
Source
Source port
Direction
Destination
Destination port

Snort subscriber ruleset: Managed by CISCO
Snort community ruleset: Open source, daily updates, a subset of subscriber ruleset

IDS Rules [Cisco IOS Firewall]

- **1100 IP Fragment Attack**
  - Triggers when any IP datagram is received with the "more fragments" flag set to 1 or if there is an offset indicated in the offset field.
- **1101 Unknown IP Protocol**
  - Triggers when an IP datagram is received with the protocol field set to 101 or greater. These protocol types are undefined or reserved and should not be used.
- **1102 Impossible IP Packet**
  - This triggers when an IP packet arrives with source equal to destination address. This signature will catch the so-called Land Attack.
- **2154 Ping of Death Attack**
  - Triggers when an IP datagram is received with the protocol field in the IP header set to 1 (ICMP), the Last Fragment bit is set, and (IP offset * 8) + (IP data length) > 65535
- **3040 TCP - no bits set in flags**
  - Triggers when a TCP packet is received with no bits set in the flags field.
- **3041 TCP - SYN and FIN bits set**
  - Triggers when a TCP packet is received with both the SYN and FIN bits set in the flag field.
- **3042 TCP - FIN bit with no ACK bit in flags**
  - Triggers when a TCP packet is received with the FIN bit set but with no ACK bit set in the flags field.
- **3050 Half-open SYN Attack/SYN Flood**
  - Triggers when multiple TCP sessions have been improperly initiated on any of several well-known service ports. Detection of this signature is currently limited to FTP, Telnet, HTTP, and e-mail servers (TCP ports 21, 23, 80, and 25 respectively).
- **3153 FTP Improper Address Specified**
  - Triggers if a port command is issued with an address that is not the same as the requesting host.
- **3154 FTP Improper Port Specified**
  - Triggers if a port command is issued with a data port specified that is less than 1024 or greater than 65535.
- **4050 UDP Bomb**
  - Triggers when the UDP length specified is less than the IP length specified.
- **4100 TFTP Passwd File**
  - Triggers on an attempt to access the passwd file (typically /etc/passwd) via TFTP.



Evading firewalls and Network IDS (NIDS) systems

See Security in IP and in TCP, both papers by CPNI, especially chapter 4.1 in IP paper.

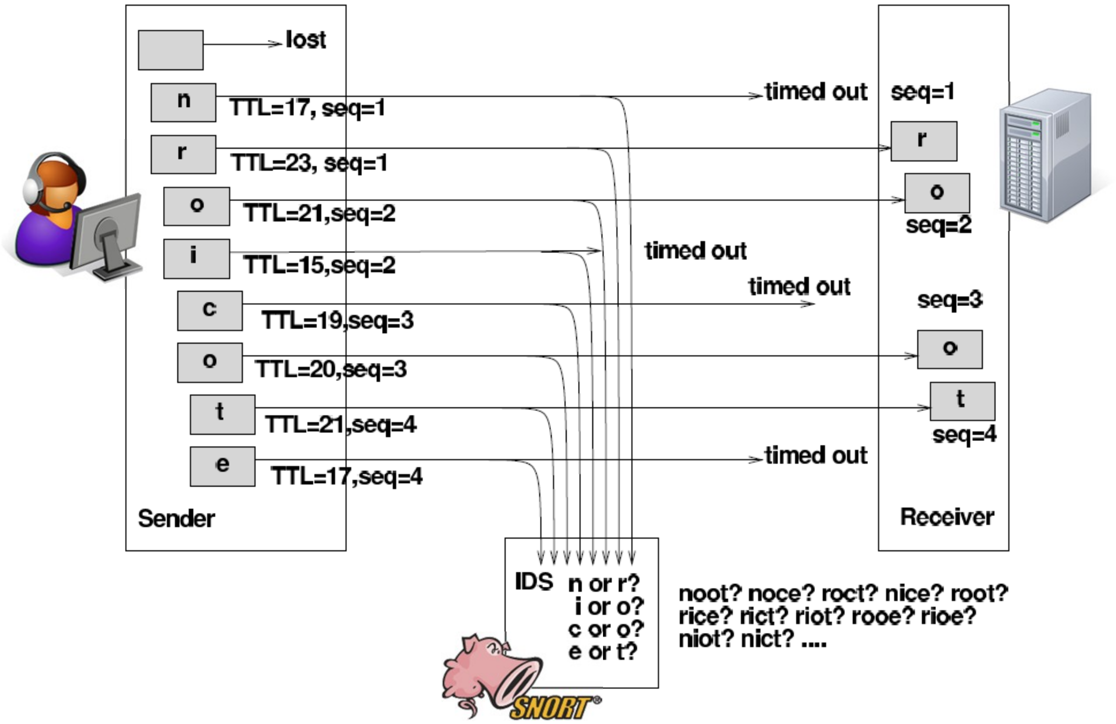
Different techniques

- Main problem: NIDS must **know how end-systems interpret packets**
- Three main categories of problems
  - Insert: NIDS accepts packets end-systems reject
  - Evade: NIDS discards packets end-systems accept
  - DoS: NIDS system cannot keep up with the load
- Examples of packets that may or may not be accepted by hosts:
  - IPv4, TCP and UDP checksum error (no checksum in IPv6)
  - IP length != link layer length
  - TCP options present that may or may not be accepted
  - Expiring TTLs
  - IP fragmentation (different reassembly policies)
  - Overlapping TCP segments

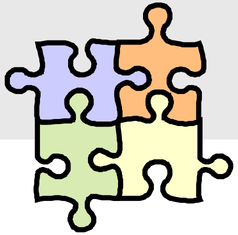
- The analysis of application-level protocols can be extremely complex

Expiring TTLs to evade IDS

- Can/should a firewall or IDS system analyze all combinations?
- Firewall can:
  - Discard small TTL values that may time-out
  - Normalize TTL values in border firewalls
- RFC 5082: Generalized TTL Security Mechanism
  - Set incoming TTL to 255
  - Internal packets will have significantly lower numbers
  - Systems can distinguish source by looking at TTL

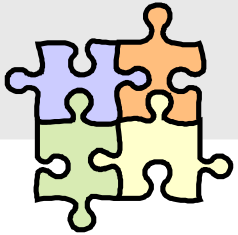


IP Fragment Reassembly Timeout



- Max time to wait for all fragments
  - All systems have a timer (RFC 792) – but waiting time differs
  - RFC 1122: 1-2 minutes, Linux 30 seconds
- If IDS system has shorter timeout than receiving host:
  - Attacker sends frag-1
  - IDS times out…
  - Attacker sends frag-2
  - Host reassembles datagram
  - IDS times out on frag-2
- If IDS has longer timeout (Snort default timeout 1 minute, Linux 30 seconds):
  - Attacker sends frag-1
  - Host times out…
  - Attacker sends frag-2
  - IDS reassembles datagram (looks ok)
  - Attacker resends different frag-1 (host still has frag-2, IDS may have dropped old fragments)
  - Host reassembles malicious datagram
  - IDS times out, drops frag-1

Different IP reassembly policies



- Waiting consumes resources: DoS attack possible
  - Transmission of multiple last fragments (offset 64k) to allocate space
  - Defense: limit global buffer space allocated to fragments – should not affect regular traffic (Linux, BSD)
  - Some systems flush 50% of the fragment buffer when the threshold is reached
  - So what should the IDS system do?
- IP reassembly policies:
  - **First**: Always keep the first received fragment for each offset (never overwrite)
  - **Last**: Always keep the last received fragment (overwrite older) [RFC 791]
  - **Linux**: Left-trim i.e. keep fragments with lower offset
  - **BSD**: Right-trim
  - More possibilities exist… Poor IDS system!

- Snort: Available types are first, last, BSD, BSD-right, Linux, Windows and Solaris. Default is BSD
- In IPv6, routers do not fragment datagrams
  - Source must always send datagrams smaller than MTU <u>but can fragment</u>
  - Reassembly algorithm similar to IPv4
  - RFC 2460 contains rules: 60 second timeout for reassembly, check size <65,536, etc…

IP Fragment Reassembly

symantec.

- Two fully overlapping segments

AAAAAAAA

BBBBBBBB

CCCCCCCC

- Windows Vista and XP: prefer previous data (favor old)

CCCCCCCCAAAAAAAA

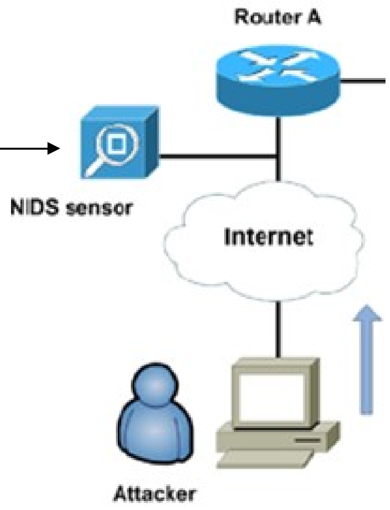
- Linux: favor new

CCCCCCCCBBBBBBBB

https://hoagland.org/presentations/CanSecWest07-Vista-Ntw-Attack-Surface.pdf

TCP sessions and IDS systems

- **"Handshake synchronization"**
  - Require SYN/ACK or full three-way handshake (TWH)
  - Good: impossible to force IDS to begin a session by sending only one faked segment
- **"Synchronize on data"**
  - IDS starts even if no TWH is seen
  - Advantage: Can pick up connections established before IDS was started
  - Disadvantage: Faked packets not part of any connection can trigger IDS to keep state
  - Ingress filtering needed
  - If new TWH seen, ignore old data?
- IDS system may not be able to see the direction of traffic on a network
  - Attacker may send a faked SYN, SYN/ACK and ACK to fool IDS system to start keeping state
  - Ingress filtering makes sure no one from the outside can fake traffic with an origin from the internal network (i.e. the SYN/ACK)
- Connection teardown
  - Always wait for FIN or RST?
  - Timeout?



More issues with TCP

- NIDS must also understand ACKs, SACK and ICMP
  - Some hints to NIDS may be found in received ICMP messages
- TCP implementations may differ:
  - Accept data even if ACK flag not set?
  - Accept data in SYN segments?
  - Checksum errors in segments – some systems don't check
  - Accept or ignore options in non-SYN segments not negotiated earlier? Discard data too?
- In addition: TCP segments may also overlap
  - Not the same as IP fragmentation but problems are similar
  - TCP contains offset (seq. number) → overlaps possible
  - RFC 793: Trim to contain only new data – but not always followed (next slide)

TCP Segment Reassembly

Note: Not fragmentation, this is overlapping TCP segments

- Four overlapping segments:

```
    is_is
        _bad
      at_m
That
```

- Vista: `This_is_bad`
- XP: `That_is_bad`
- Linux: `That_is_mad`

- Old data is always preferred over newer data (Vista)
- Behavior is novel
  - NIDSs will have to implement new strategy to prevent evasion attacks

Summary – Evading IDS and FW

- Complex problem to deal with (lots of combinations)
  - Many ways to reassemble IP fragments (last, first, etc.)
  - Reassembly time-out, TTL, …
  - TCP segments may also overlap, problems with following TCP state machines, etc.
- Firewalls and NIDS need to deal with IP fragmentation and overlaps
  - Analyze all reassembly combinations (opens for DoS attack?)
  - Normalize TTL values in border router
  - Analyze datagrams differently depending on the target system (Snort)
  - Consider discarding all fragments from the Internet (at least prevents some problems)
  - Always perform ingress filtering
- DoS attacks can be spawned against an NIDS
- IDS systems still need a lot of more research