

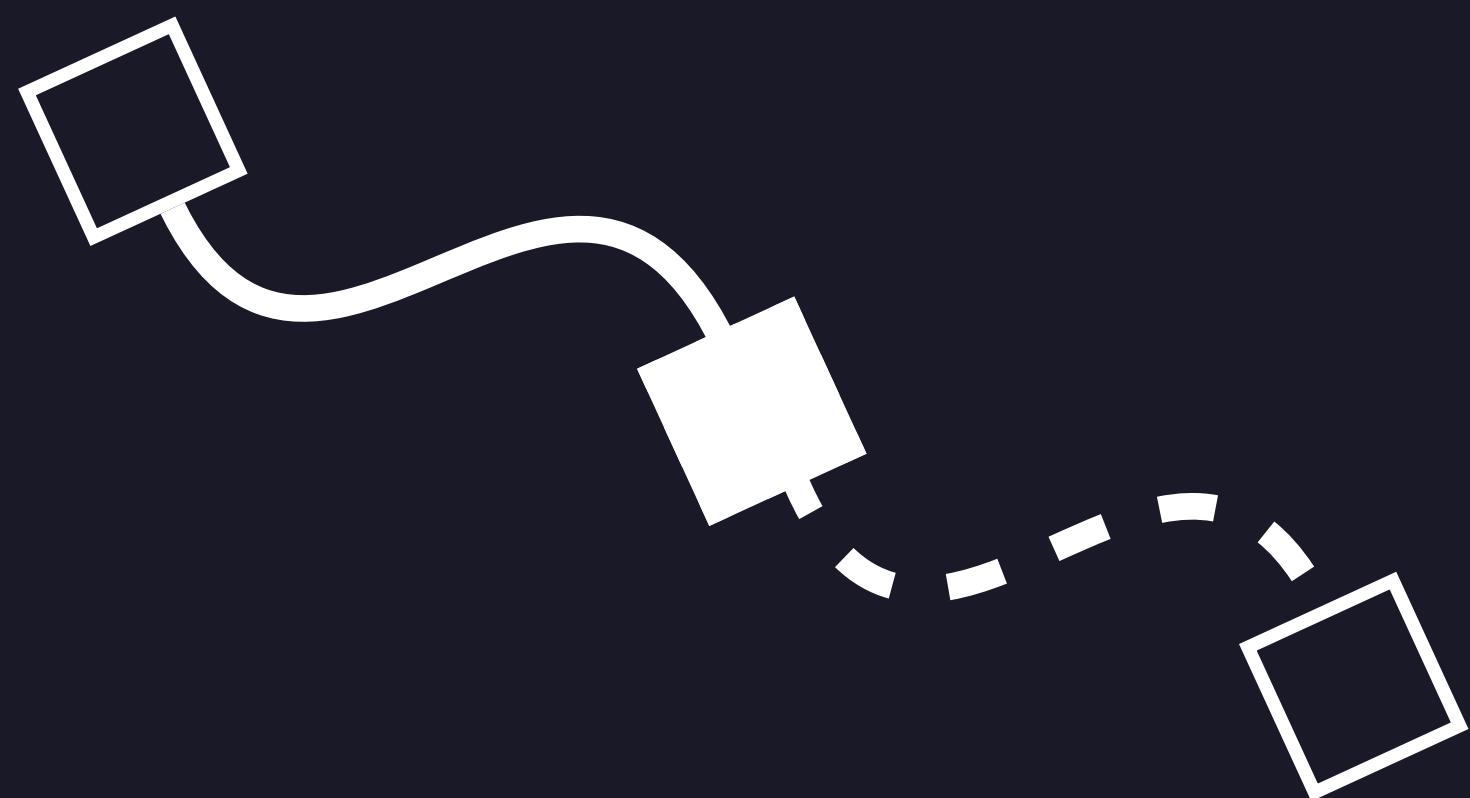
Enhancing security in industrial control systems through programmable kernel-level microsegmentation

**UniGe - Computer Science
Software Security and Engineering**

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Advisor - Enrico Russo, Giacomo Longo

Examiner - Giovanni Lagorio



Outline

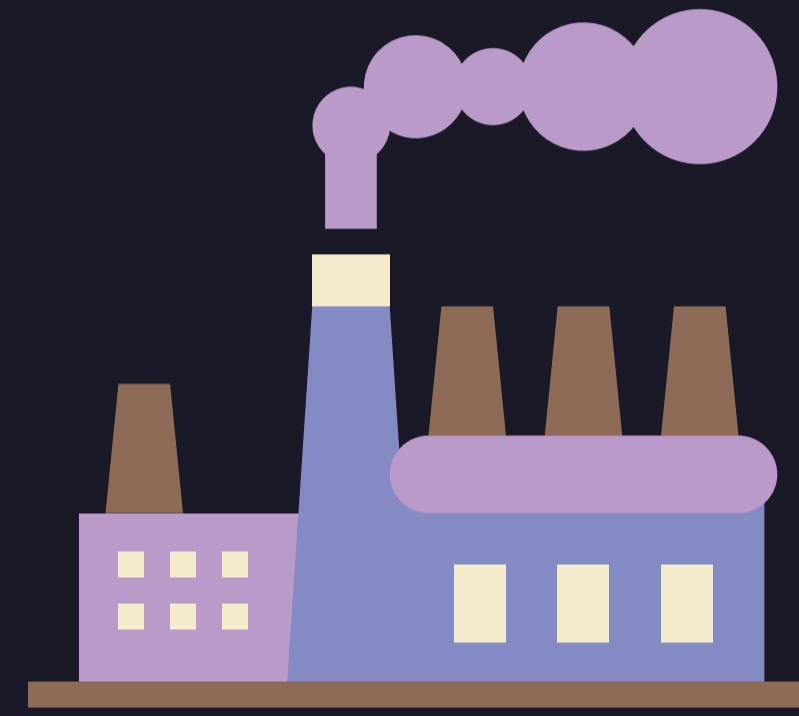
- A bit of background
- Problem's analysis
- Constraints check for an ideal solution
- Explore the proposed solution

**Enhancing security in
industrial control systems
through programmable
kernel-level microsegmentation**

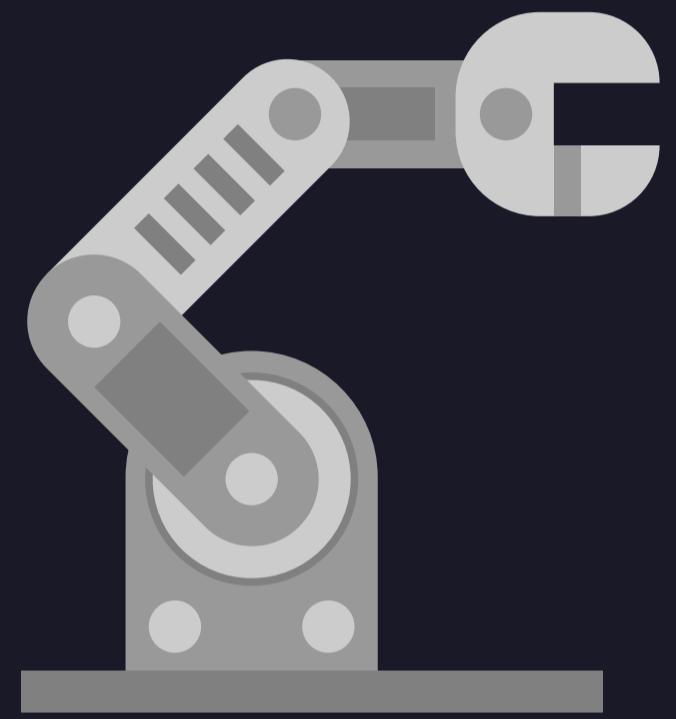
Operational Technology (OT) systems

“...OT systems are hardware and software solutions that monitor and control physical devices, processes, and infrastructure in industrial environments...”

Operational Technology (OT) systems



Machine
Industry



Automation
Systems



Transportation
Systems

Maritime OT systems

Legacy
Systems

Critical
Assets

Standardized
Protocols

By design
internal network communication
is unrestricted, unfiltered
and omnidirectional

Unrestricted

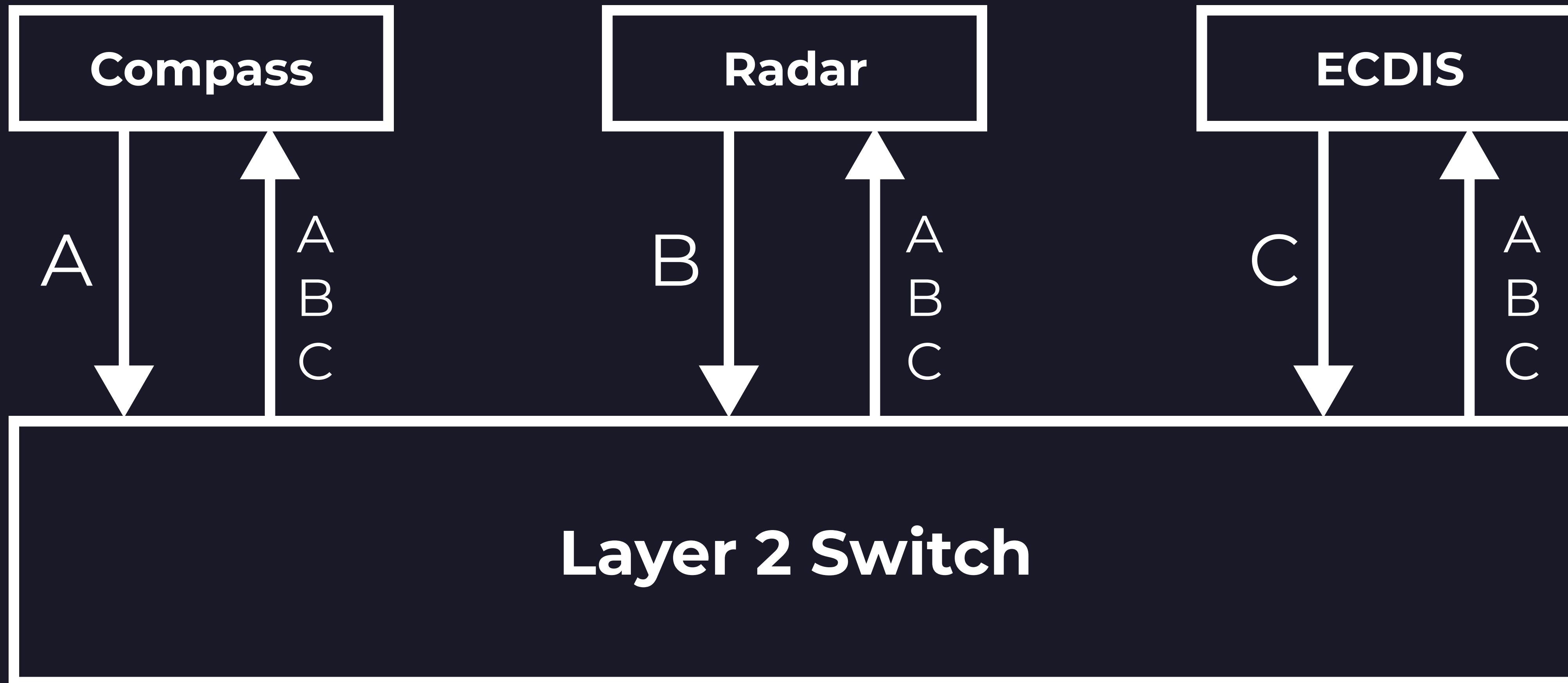
Everyone can send
any kind of message

Omnidirectional

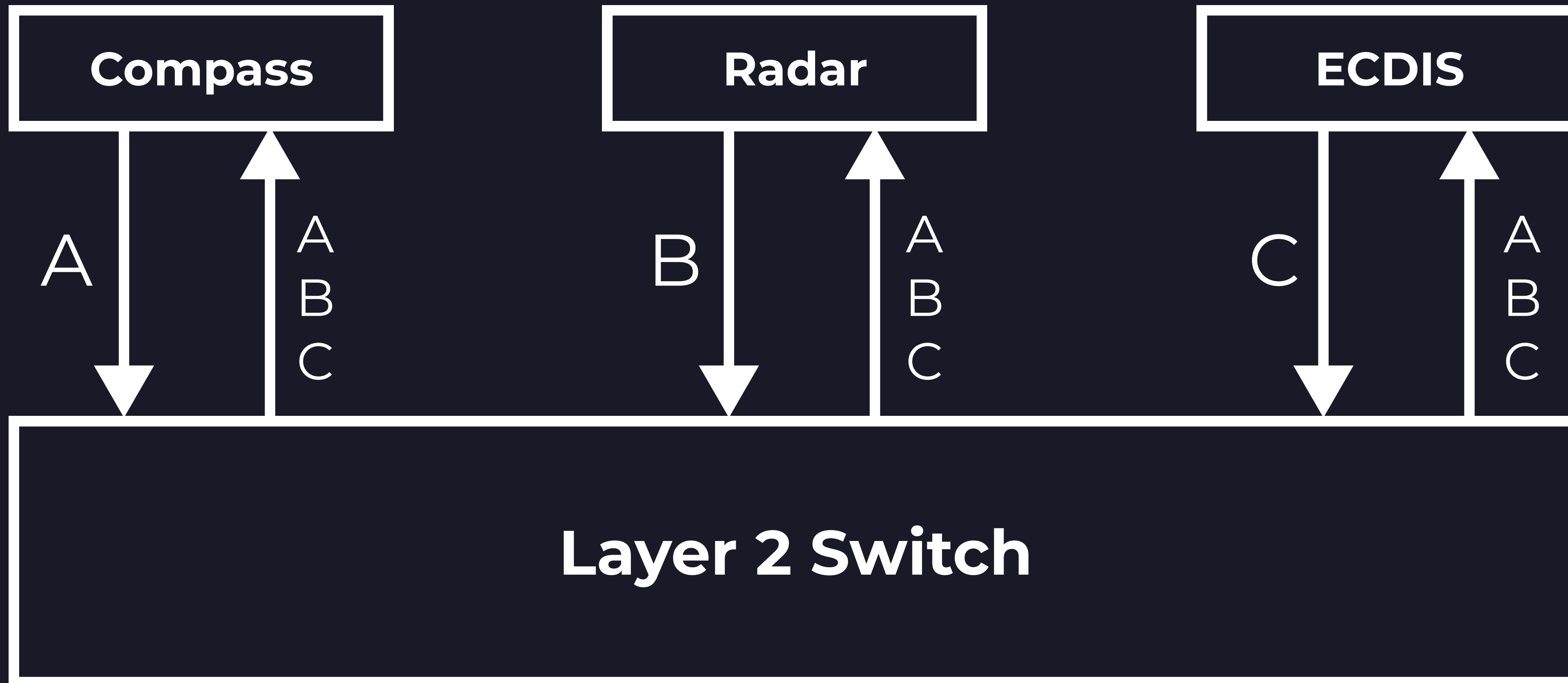
Everyone speaks
to everybody

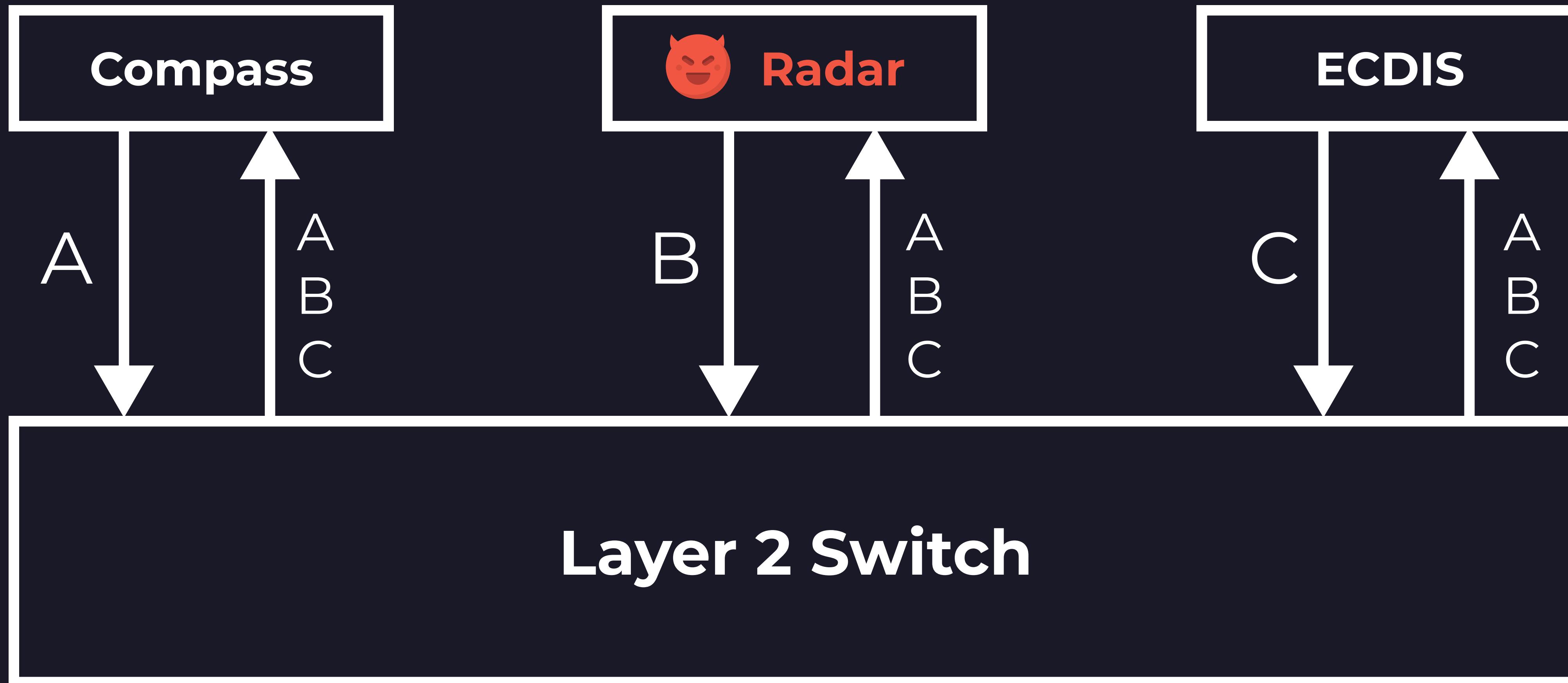
Unfiltered

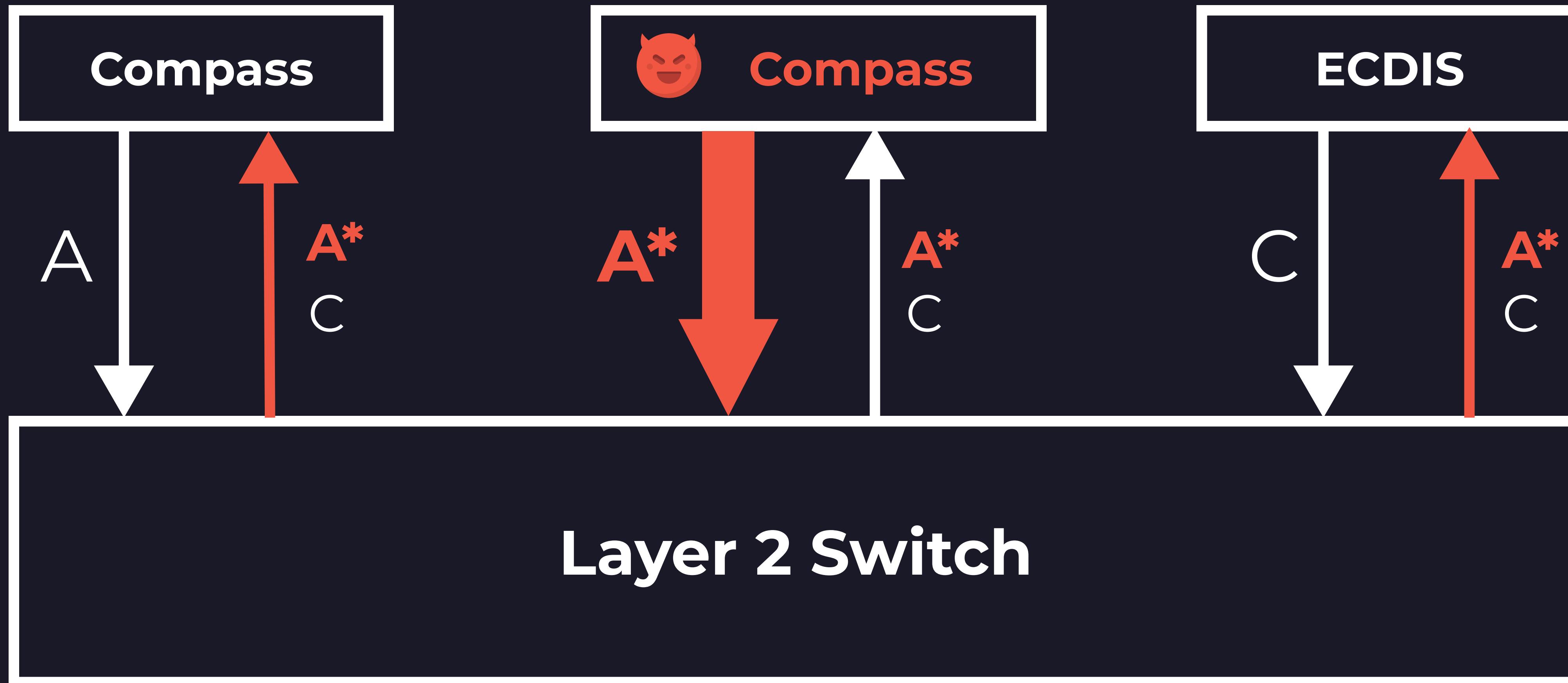
Everyone can receive
any kind of message











Enhancing security in industrial control systems through programmable kernel-level microsegmentation

The Solution's Constraints

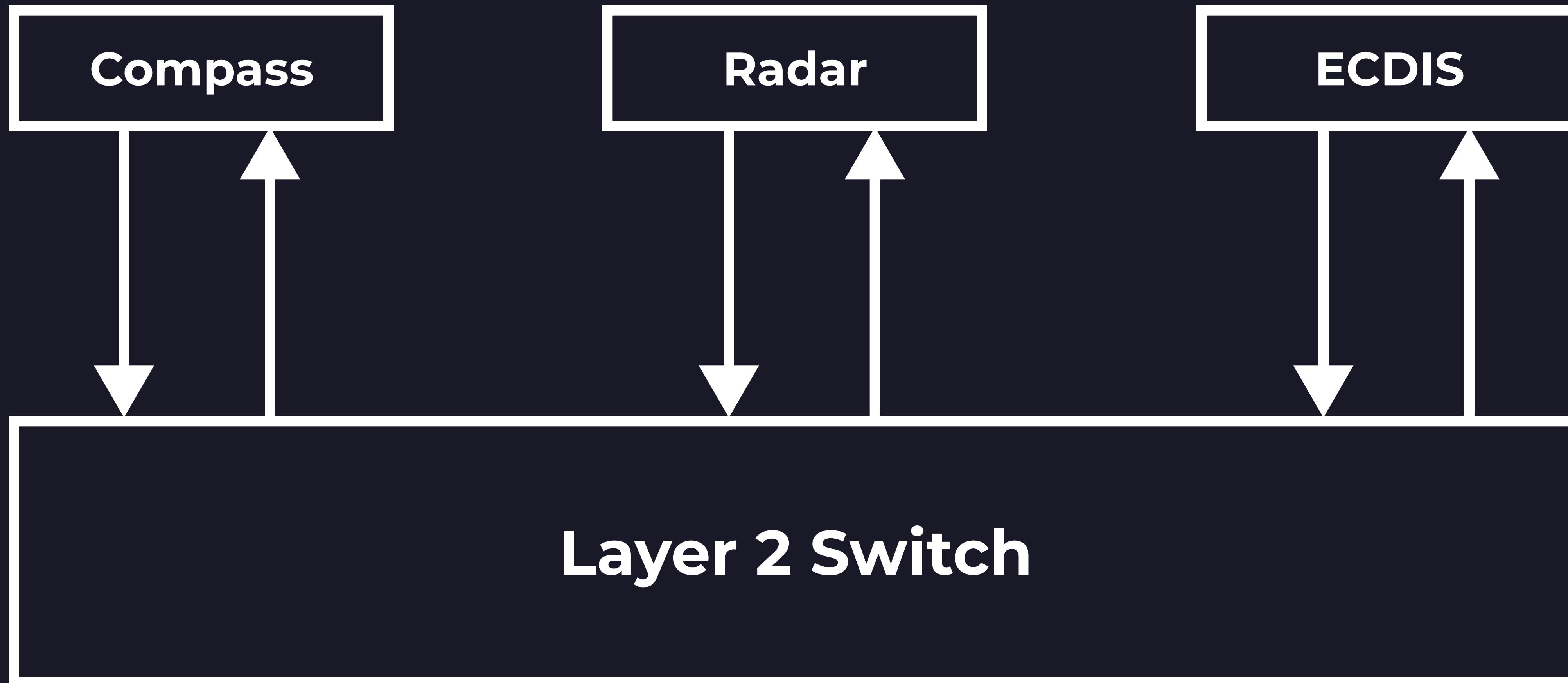
Transparency and Negligible Overhead

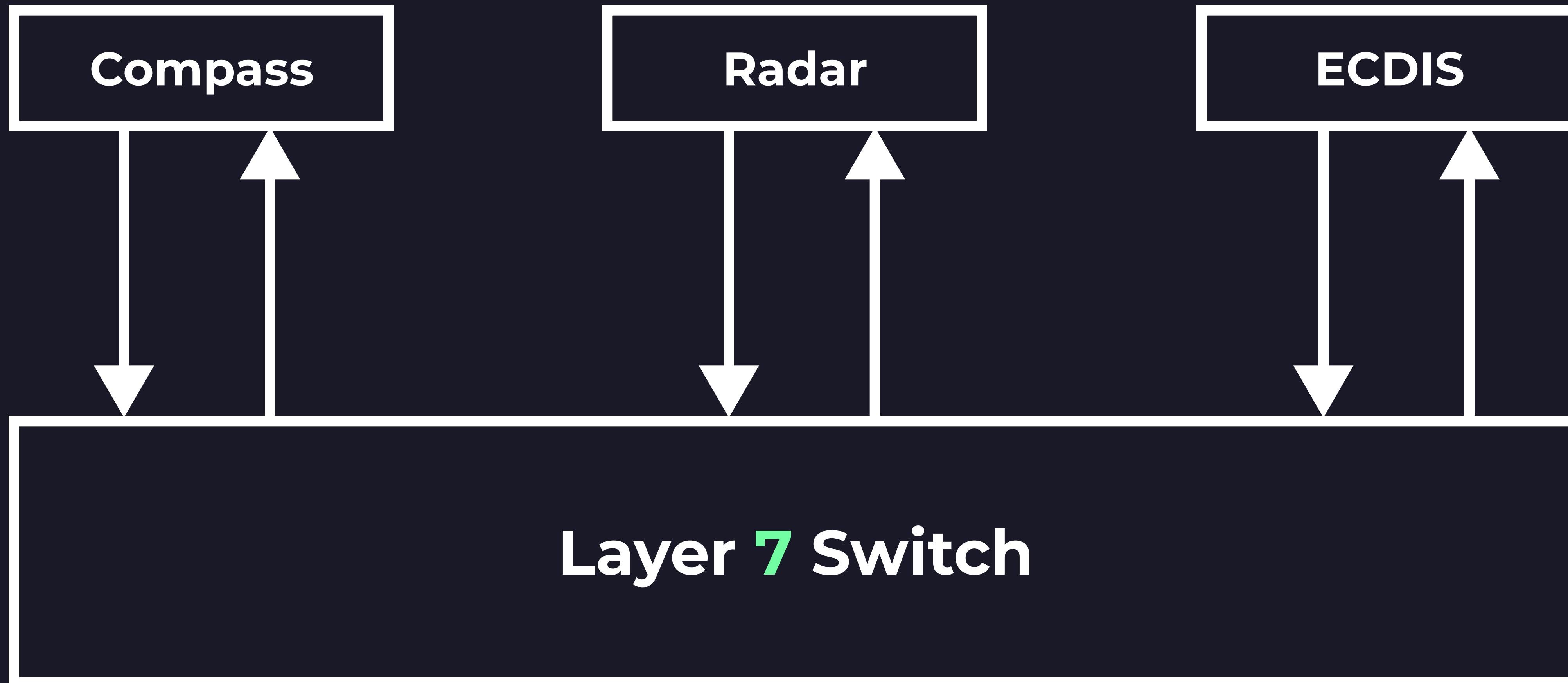
Our solution

An Application Layer Switch that
leverages Kernel Level technologies
to handle network traffic

Software Defined Networking

Using a software solution
to solve an hardware problem





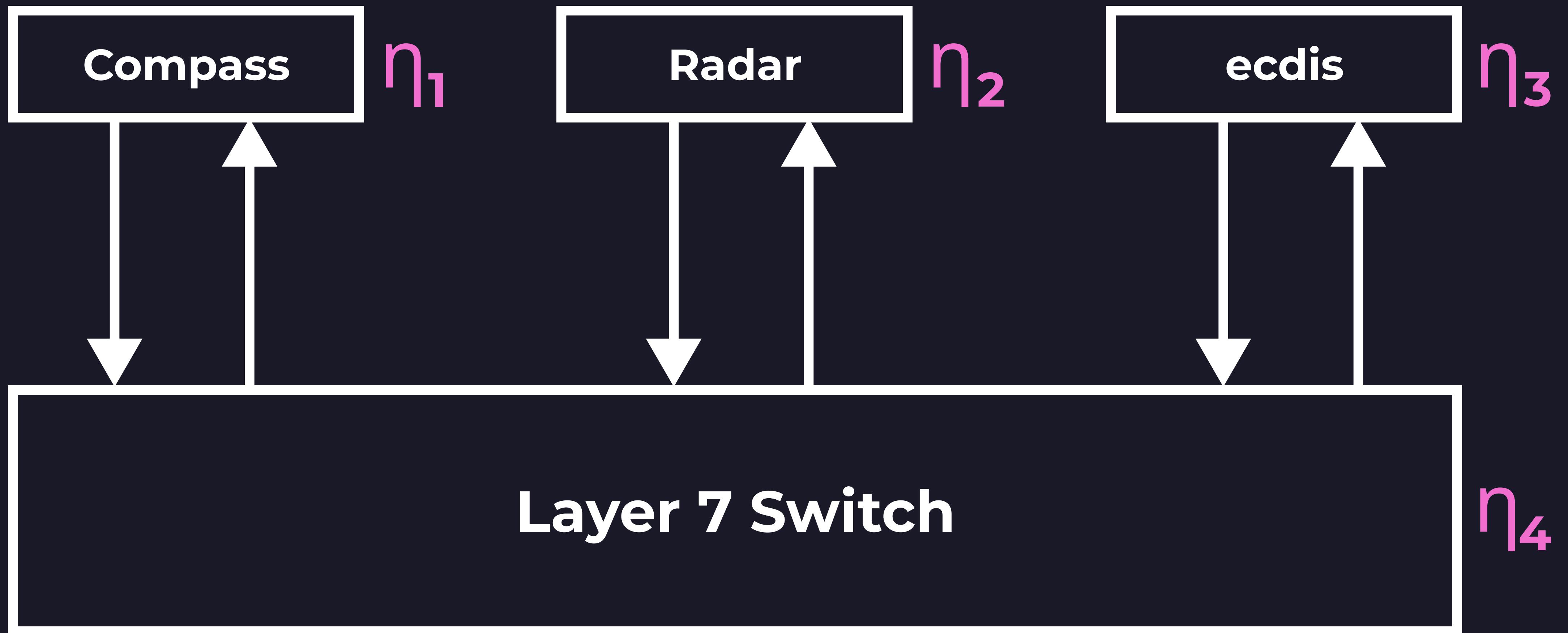
The Solution's Constraints

Transparency and Negligible Overhead

- No changes to the system's behaviour
- No need for new communication standards
- No need for additional hardware/software solutions

$$0 < n \leq 1$$

Failure Probability
of a System's Component



$$P(\text{System Works}) = (1-\eta_1)(1-\eta_2) \cdots (1-\eta_n)$$

$$P(\text{System Fails}) = 1 - P(\text{System Works})$$

The Solution's Constraints

Transparency and Negligible Overhead

User Space

Application



Kernel Space

Linux
Network
Stack

Network Interface

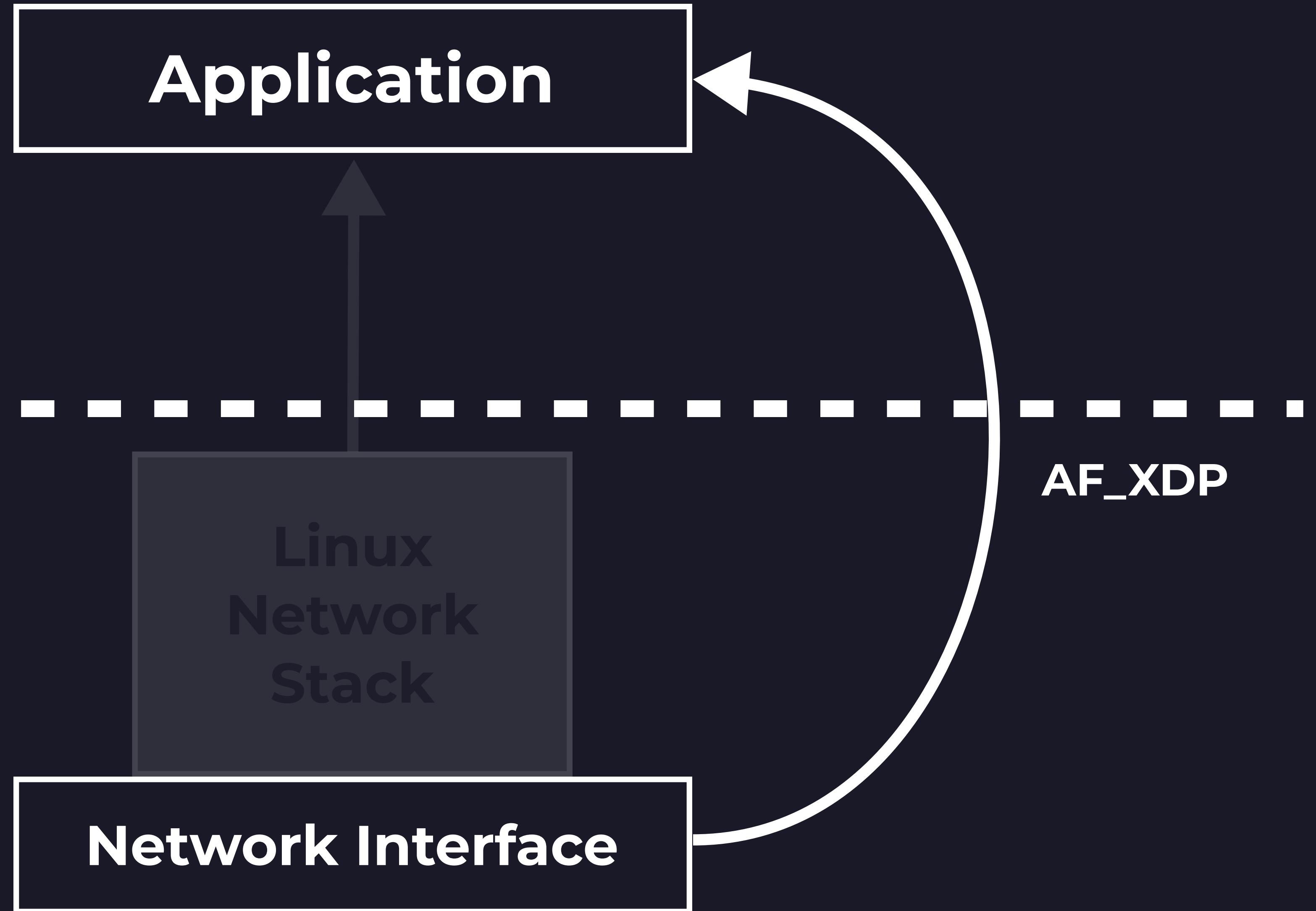




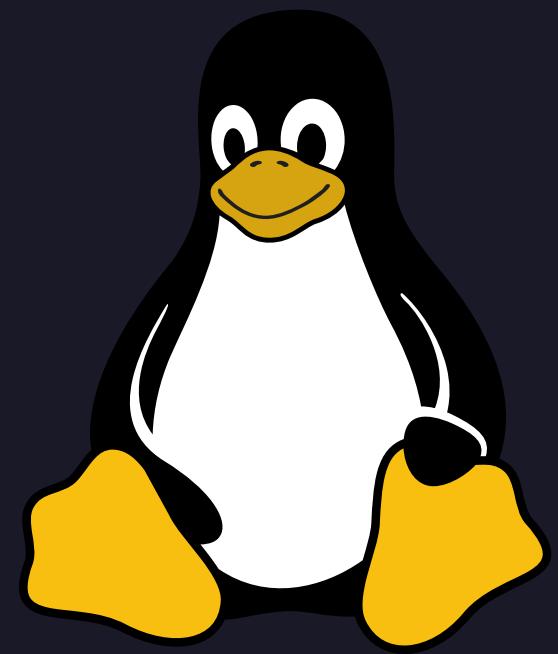
Extended Berkeley Packet Filter (EBPF)
and
the new Address Family Express Data Path (AF_XDP)
for fast network packet processing

User Space

Kernel Space



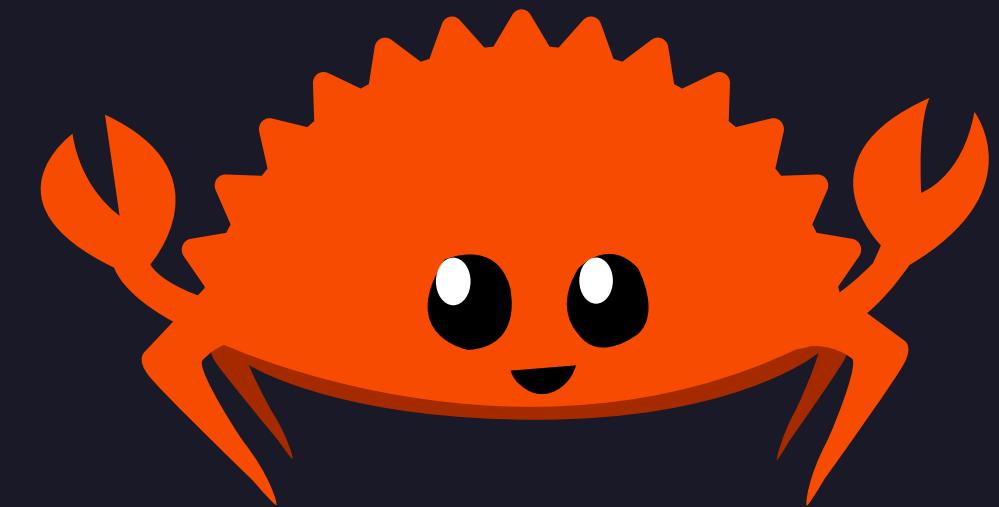
The implementation



Linux



EBPF



Rust

User Space

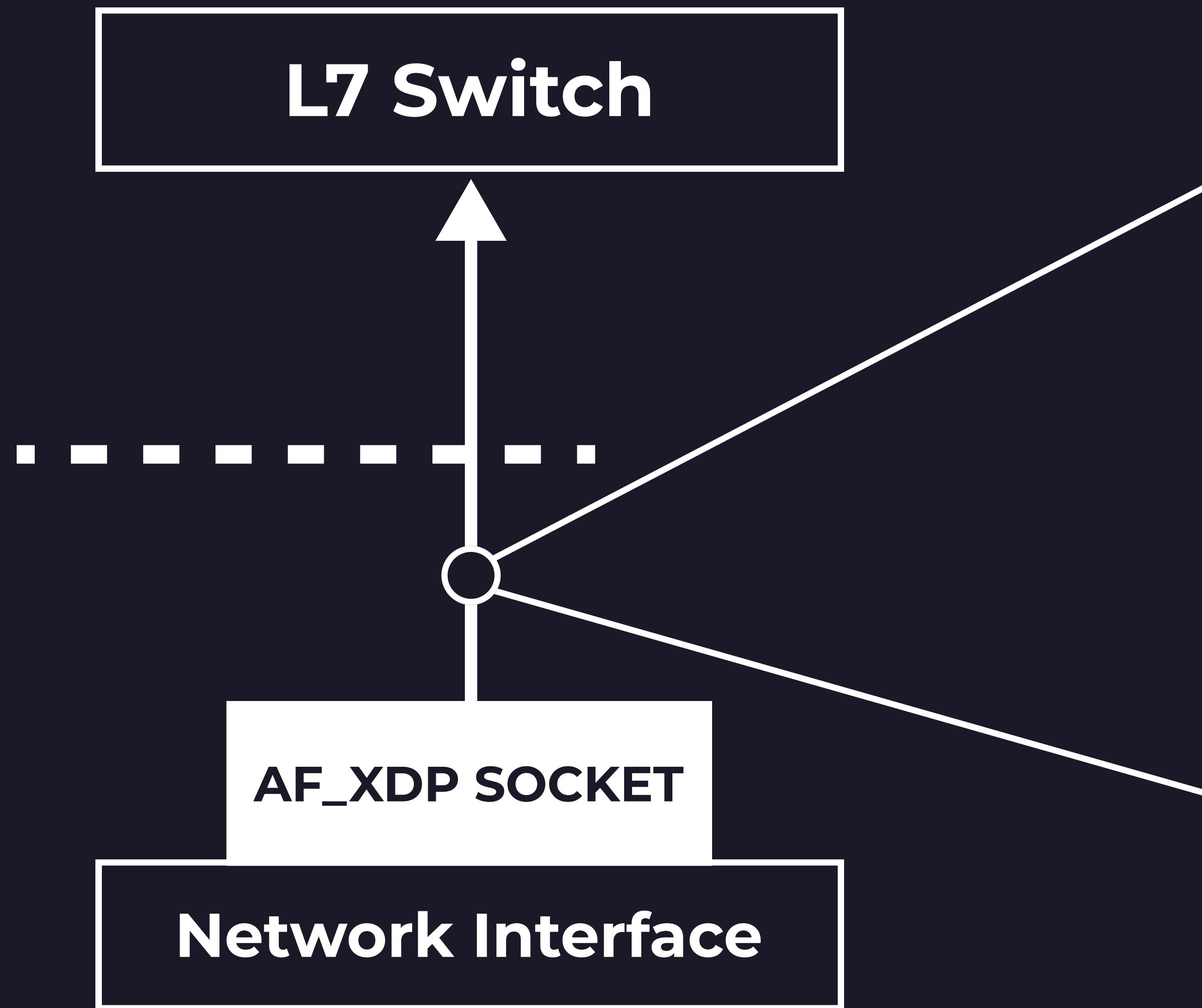
L7 Switch



Kernel Space

AF_XDP SOCKET

Network Interface



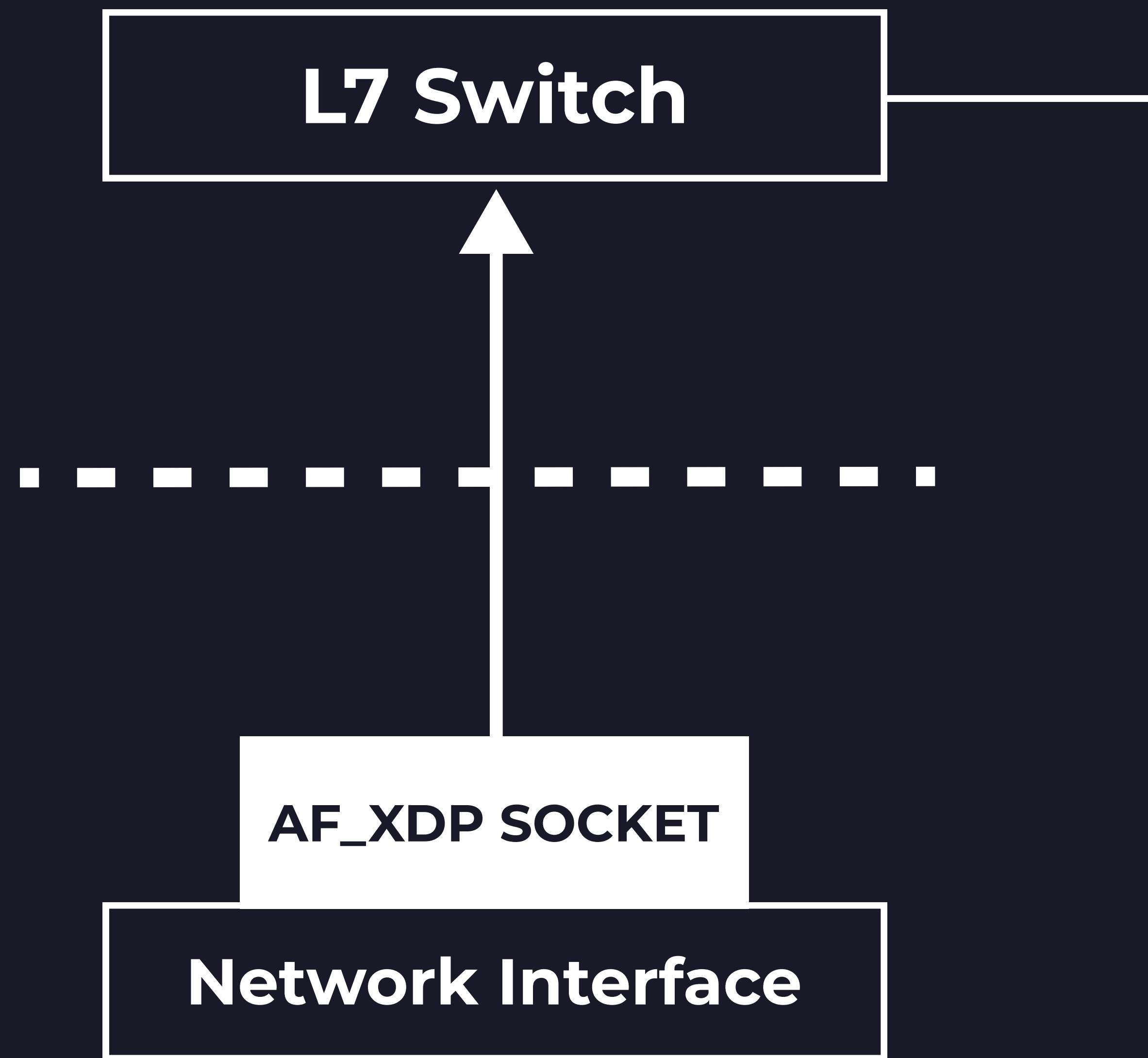
NMEA

National Marine Electronics Association

\$GPAAM,A,A,0.10,N,WPTNME*32

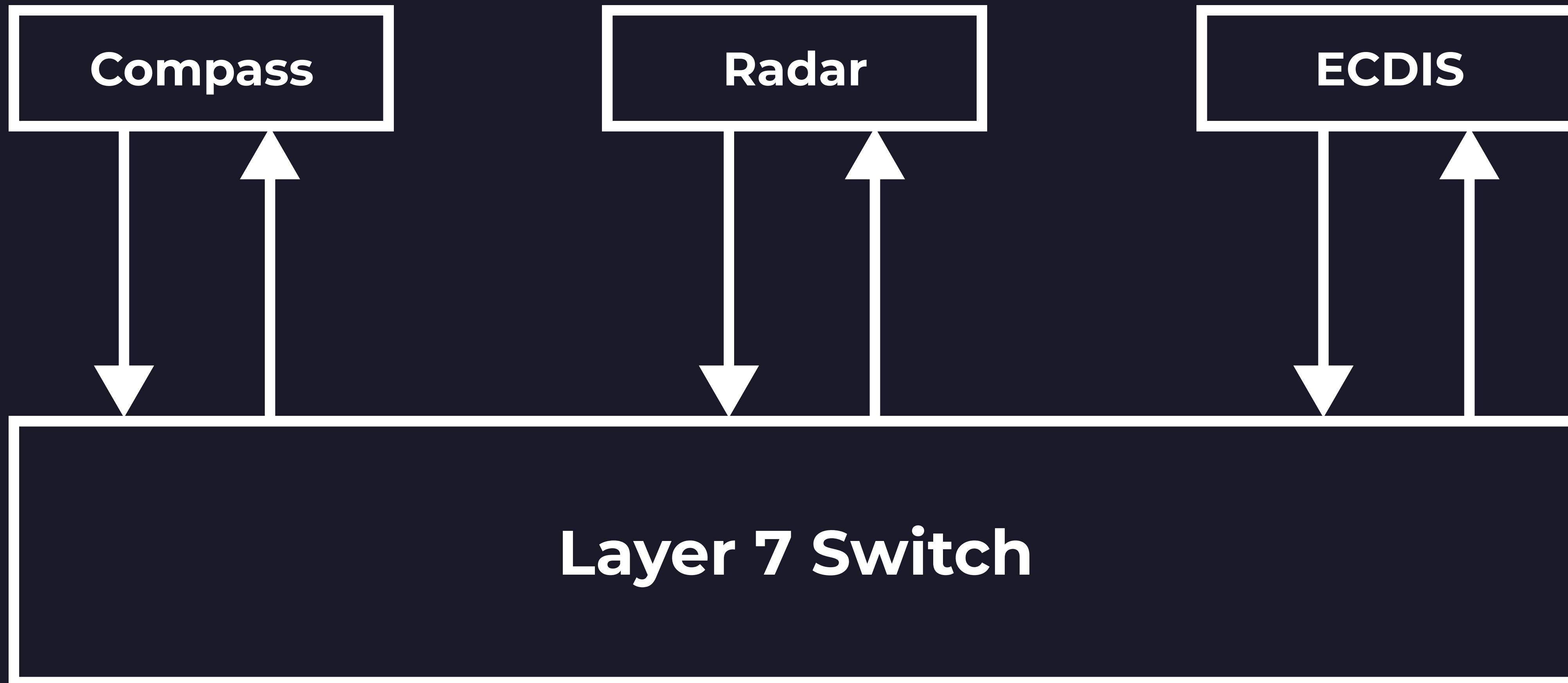
\$SDDBT,7.8,f,2.4,M,1.3,F*0D

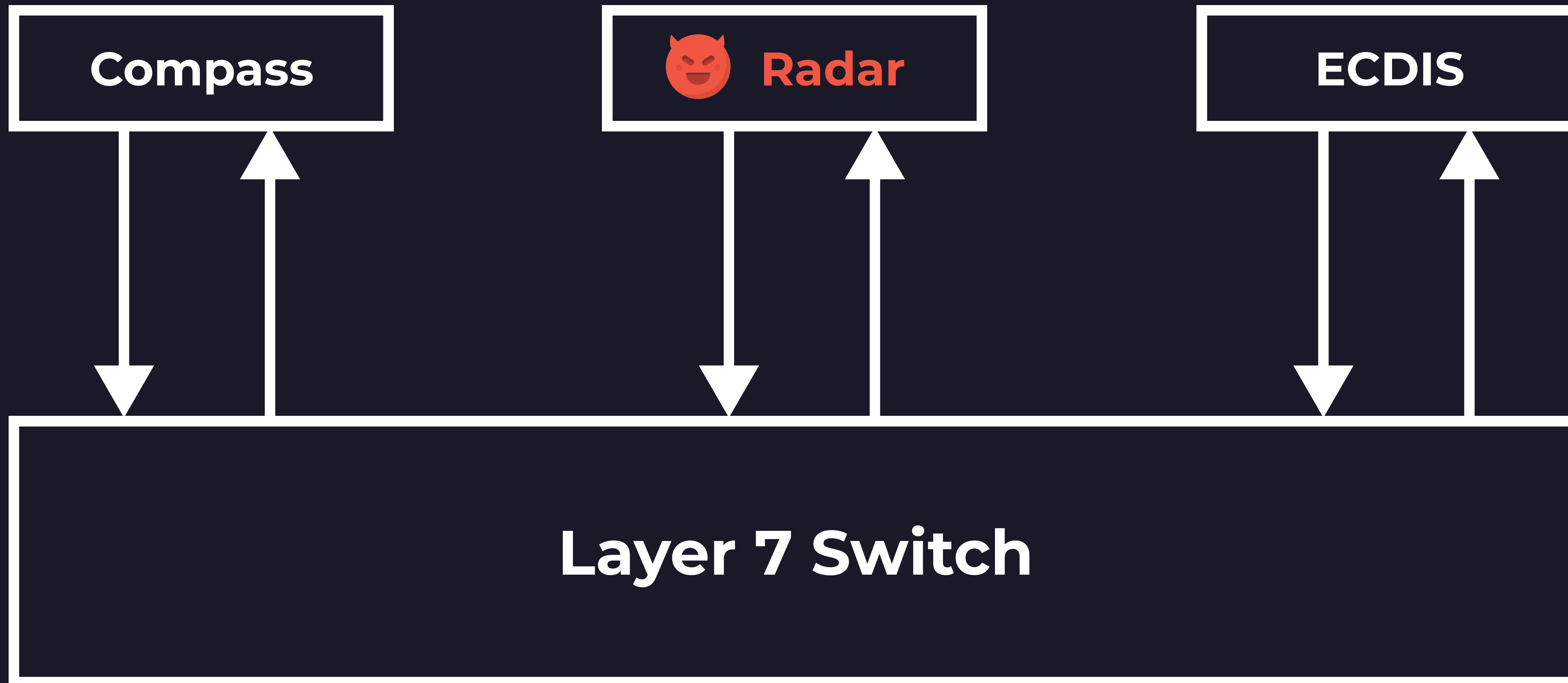
\$GPDTM,W84,C*52

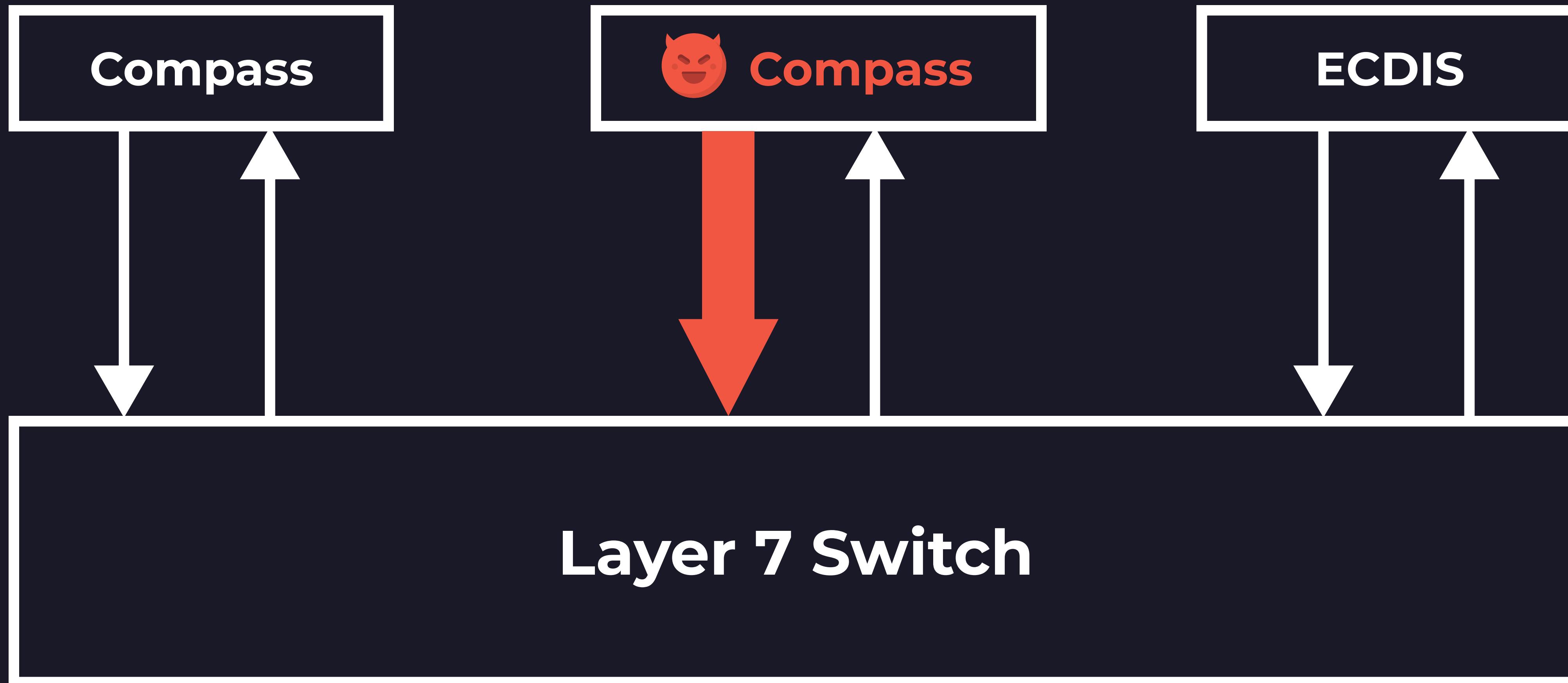


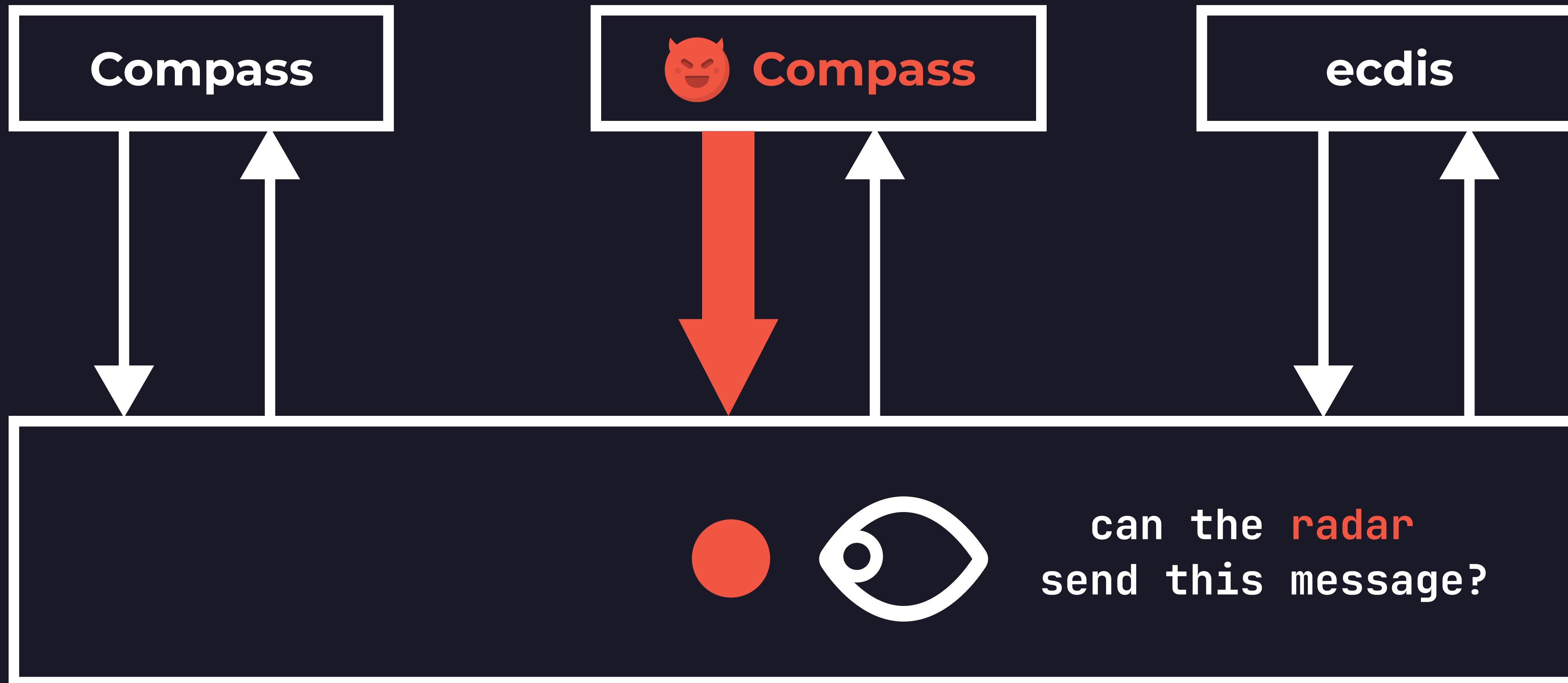
Policy_0

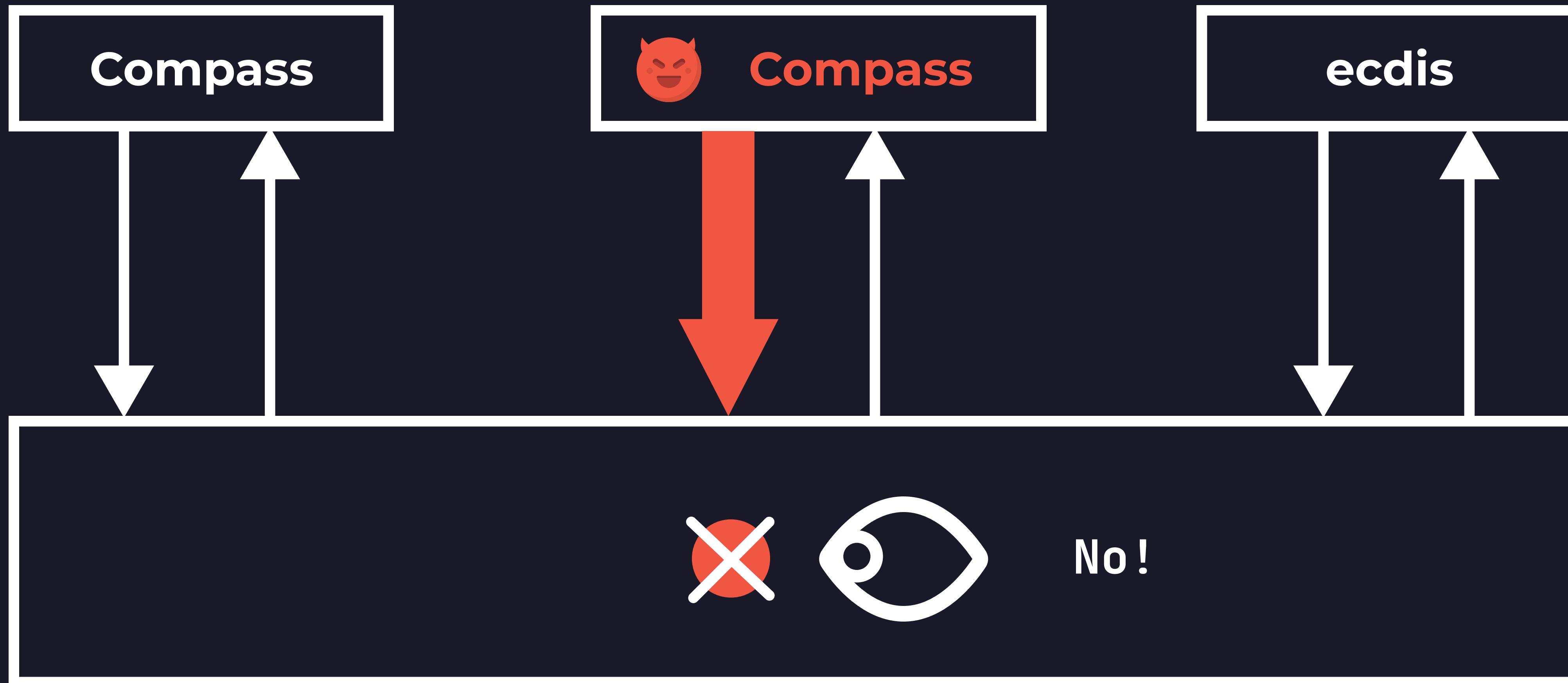
```
{  
    name = "compass",  
    iface = "compass_nic",  
    mac = "54:00:00:00:00:10",  
    ip = "10.42.0.10",  
    sends = ["$IIHDT"],  
    receives = []  
},  
{  
    name = "gps",  
    ...  
}
```

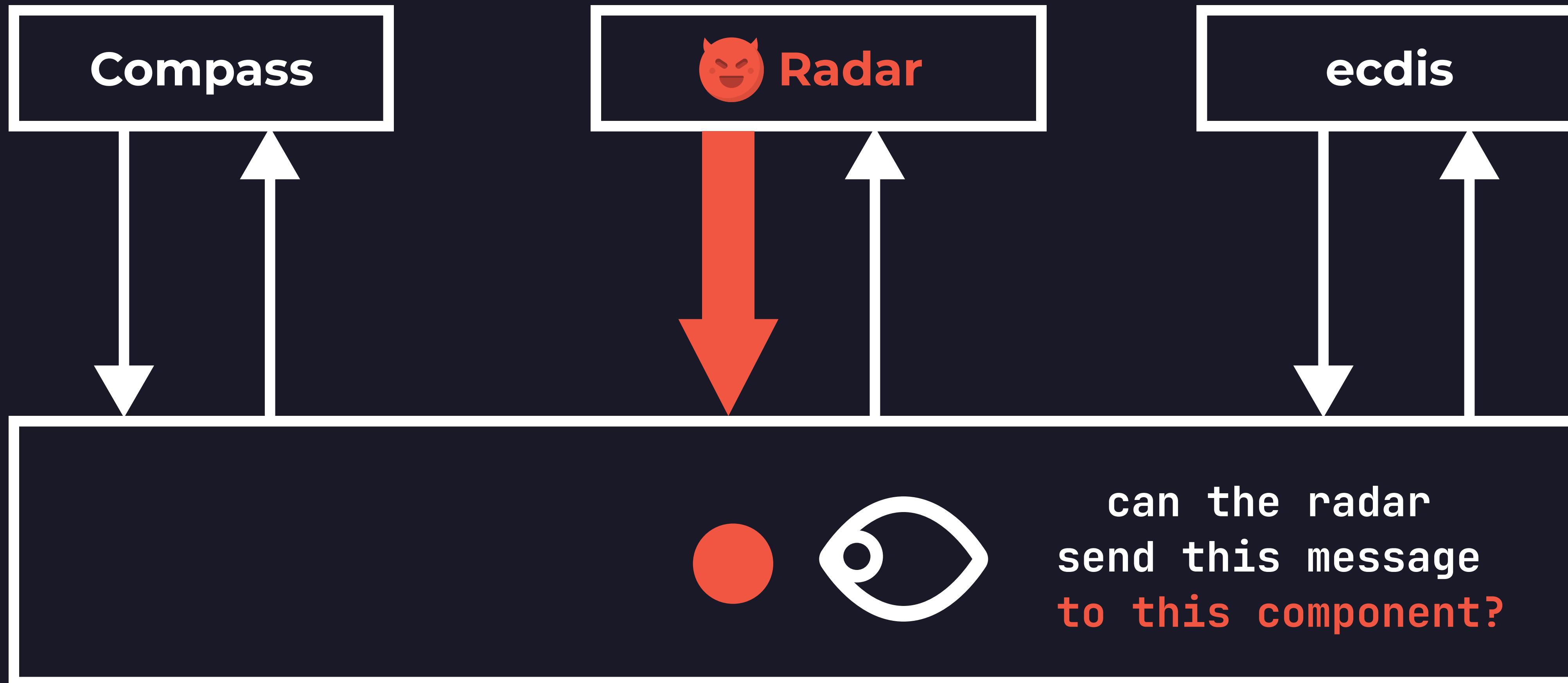


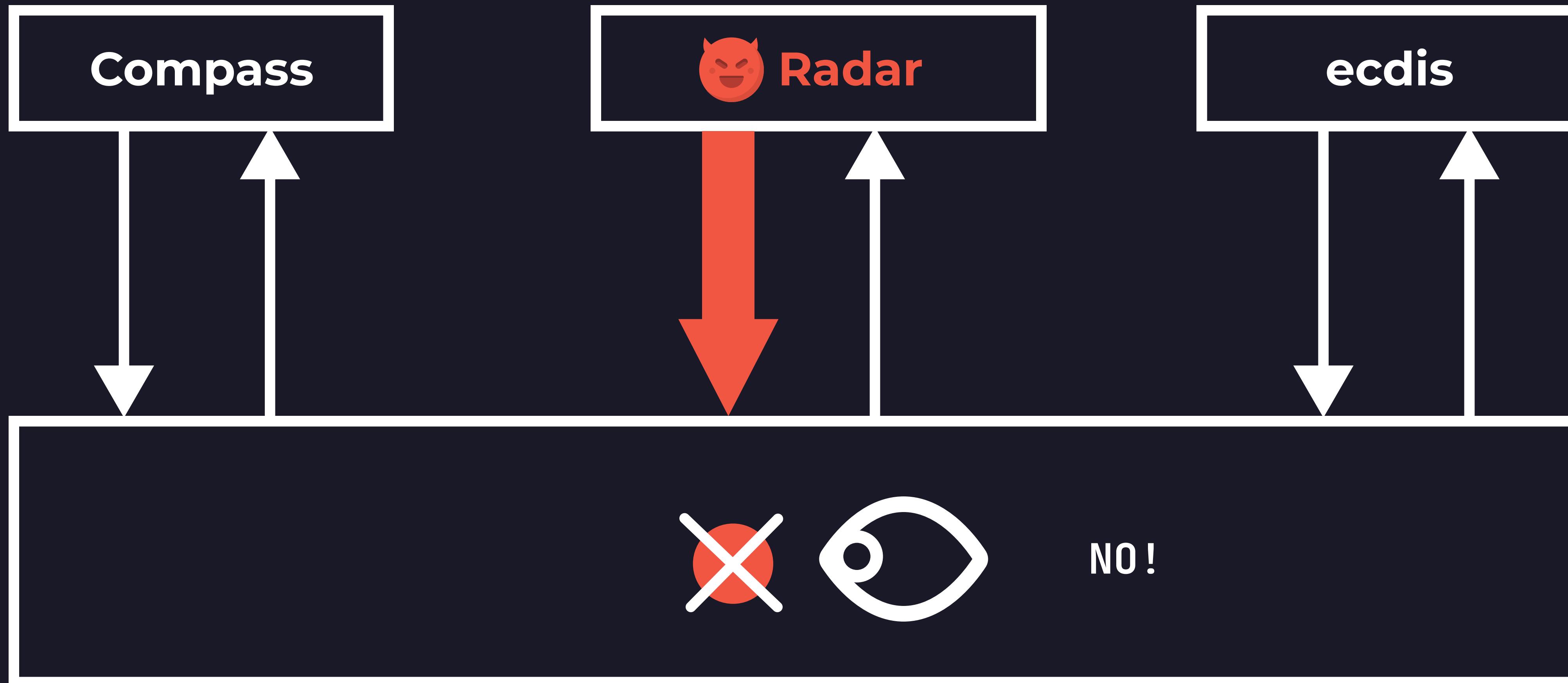












Before

Internal network communication is unrestricted, unfiltered and omnidirectional

After

Internal network communication is restricted, filtered, information flow is directable

Before

Internal network communication is unrestricted, unfiltered and omnidirectional

After

Internal network communication is restricted, filtered, information flow is directable, **modular and centrally manageable**

Does it work?

**Testing the
software correctness
is trivial... what about performance?**

Linux Network Stack Baseline

Standard datagram size of

1460 B

Bitrate of

1000 Mbit/s

Testing in Linux Network Namespaces

mean over 500 runs per role

Role	Bitrate [Mbit/s]	Datagram Size [B]
SENDER	995	1460 (Standard UDP)
RECEIVER	995	1460 (Standard UDP)
SENDER	4793	8972 (Jumbo Frames)
RECEIVER	4793	8972 (Jumbo Frames)

Recap

Analyzed OT Systems' vulnerabilities

Checked the solution's constraints

Shown the solution's implementation

Assessed the solution's validity and performance

Does it work?

**Does it work?
Yes!**

Questions?

