Extensible and Scalable Network Monitoring Using OpenSAFE

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Outline

Motivation

We want to monitor the network.

Specifically, we want to allow administrators to *easily*:

- collect network usage statistics
- detect intrusions
- provide forensic evidence

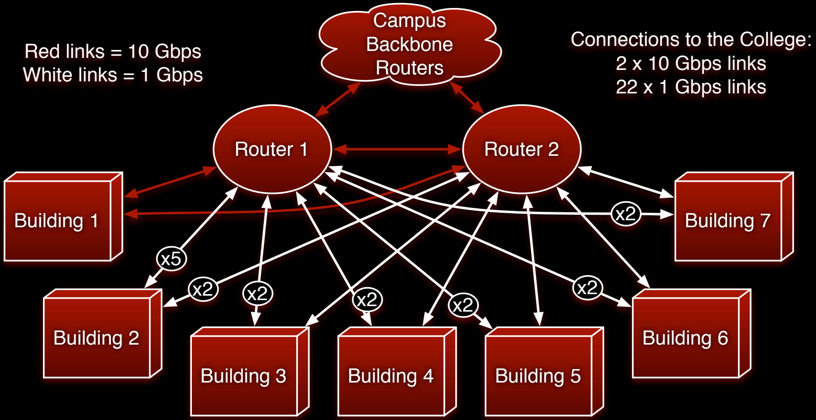
Challenges

Middleboxes are commonly used, however, they present challenges...

1. Speed
2. Cost
3. Flexibility
   1. Setup: rewire
   2. Change: rewire
   3. Add new middlebox: rewire

...making them ill suited for network monitoring.

Example: College of Engineering



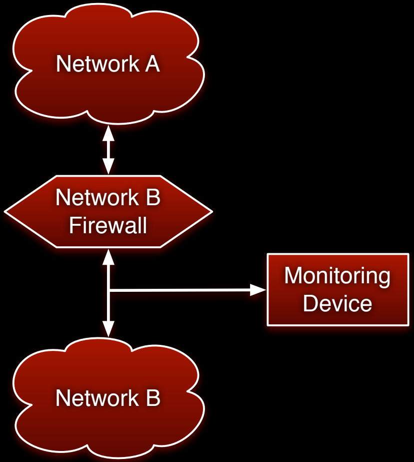
How do people actually do it?

Mirror (or tap) an interesting network interface to another switch port, then listen to that port with something like Snort.

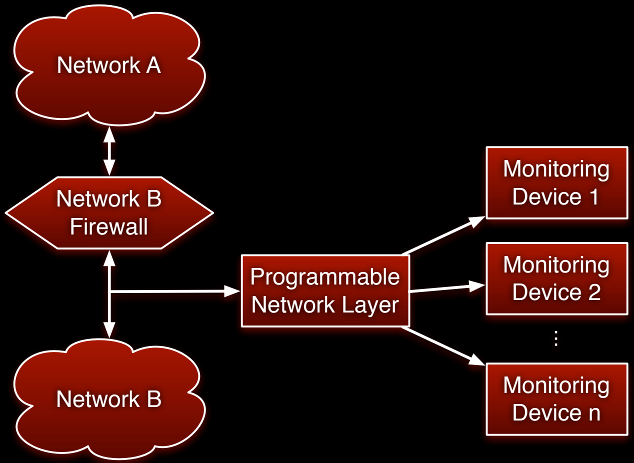
Advantage over a middlebox: monitoring has no impact on the production traffic and routes.

Disadvantages: the traffic can run you over, and it's still hard to add new detectors.

What it looks like today



What we want to do



OpenSAFE

OpenSAFE uses a programmable network fabric to...

- Selectively match network flows
- Arbitrarily direct network flows to other switch ports at line rate
- Direct exceptions to a software component
- Enable the use of commodity network hardware

Why not implement it in software?

We could use something like Click to dynamically manage detectors.

Major problem: software is not fast enough!

Solution: Hardware!

Easiest: Custom ASICs

1. Expensive
2. Non-standard
3. Potentially hard to configure

But we have something that can do this. . .

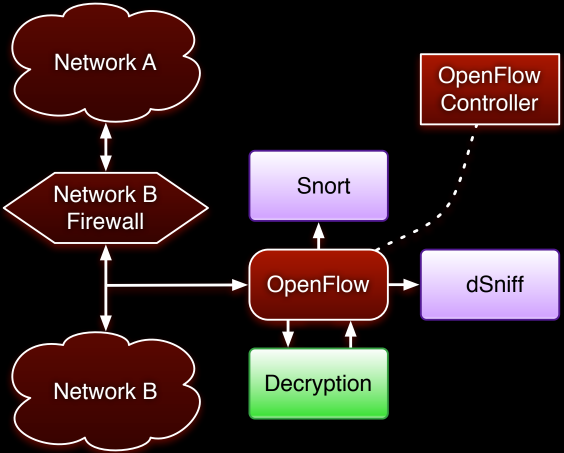
Programmable Network Fabric

While OpenSAFE would be compatible with any programmable network fabric, we implemented OpenSAFE in OpenFlow since it is available today.

The key elements are:

1. speed
2. heterogeneity
3. flexibility
4. cost

Example OpenSAFE Layout



ALARMS

ALARMS: A Language for Arbitrary Route Management for Security

Basic building blocks are **paths** of:

- Inputs: copy of traffic from a mirror switch port
- Selects: restricts the set of traffic for this rule
- Filters: pass the traffic through an application
- Sinks: where to finally direct the traffic

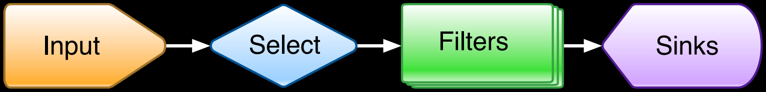
Combining these gives us a rich set of configurations.

Simple Example

We will use the following example over the next few slides:

Take all TCP port 80 traffic, send it to a counter, and then send it to a machine running `tcpdump`.

Paths



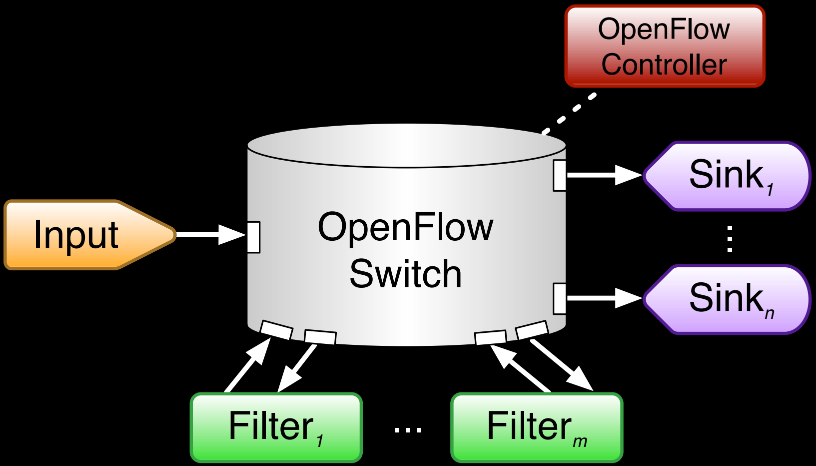
A path is:

A source switch port with selection criteria

. . . which goes into zero or more filters

. . . then out to one or more sinks

OpenSAFE Schematic



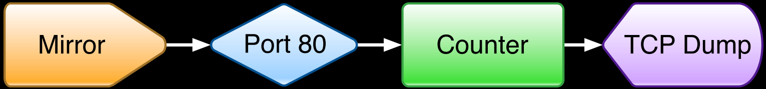
Policy naming

In OpenSAFE all switch ports are named.

Logically, ALARMS articulates paths of named switch ports.

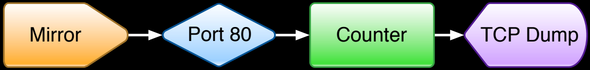
Revisiting our example

. . . becomes . . .



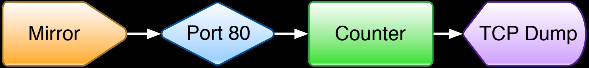

```
mirror[http] -> counter -> tcpdump;
```

Let's get some more paths




```
mirror[http] -> counter -> tcpdump;
```

Let's get some more paths




```
mirror[http] -> counter -> tcpdump;
```


```
mirror[https] -> decrypt ->
  counter -> tcpdump;
```

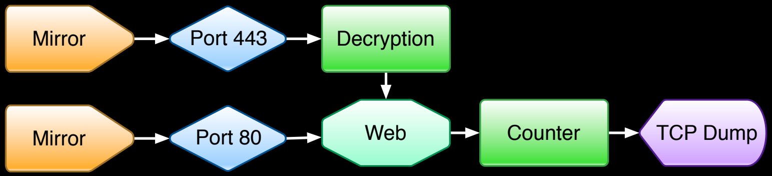
Waypoints

As more rules are added, often the rules follow the same paths making rule management difficult.

Solution:

Waypoints are *virtual* destinations for paths.

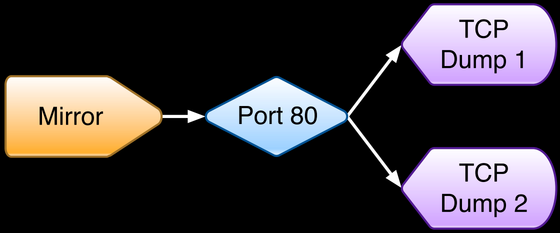
Waypoint example




```
mirror[https] -> decrypt -> web;
mirror[http] -> web;
web -> counter -> tcpdump;
```

Multiple Destinations

In ALARMS, multiple destinations are easy:




```
mirror[http] -> {ALL, tcpdump1, tcpdump2};
```

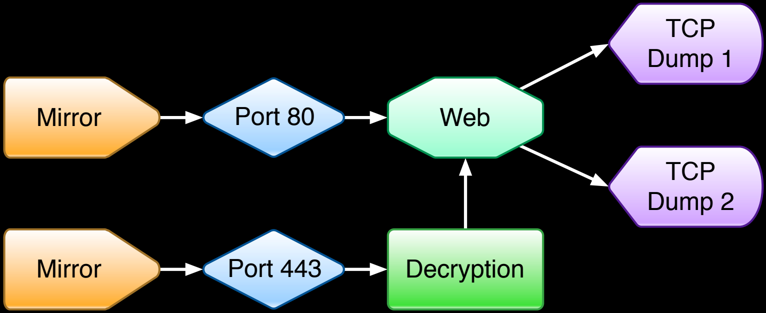
Distribution rules

When parallel filters or sinks are used, distribution rules describe how **traffic flows** should be spread.

Rules include:

Any	Randomly pick a switch port
All	Replicate packet to all switch ports
Round Robin	Cycle through the switch ports
Hash	Apply a hash function

Multiple Destinations




```
web -> {ALL, tcpdump1, tcpdump2};
```

Mapping the language into OpenFlow

We want to handle lots of traffic, so need high performance.

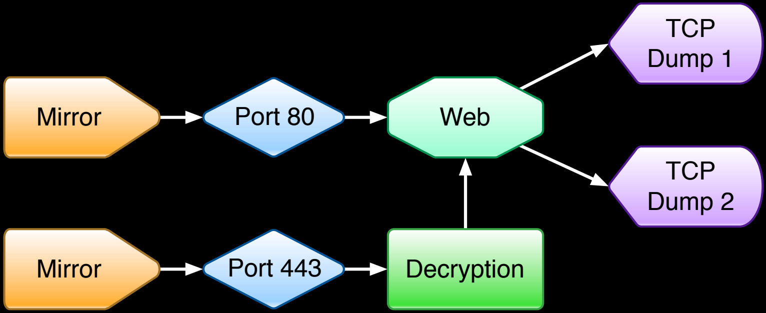
Hardware is fast. Software is slow.

Install as many precomputed flow entries as possible.

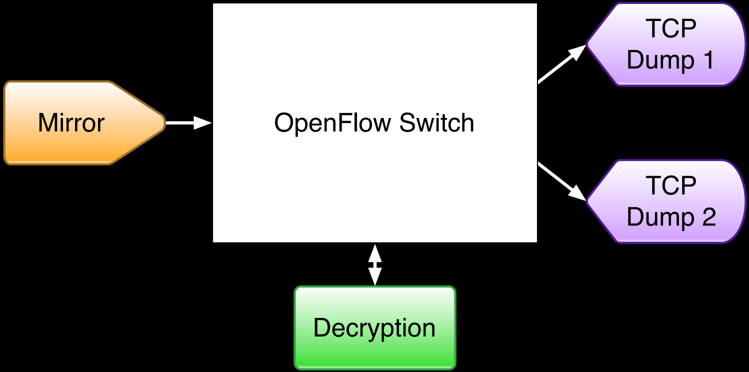
However, when the hardware does not support functions we must go to software. In OpenFlow this includes Any, Round Robin, and Hash distribution rules.

How it works under the hood

Starting with the last path diagram we had before. . .



How it works under the hood



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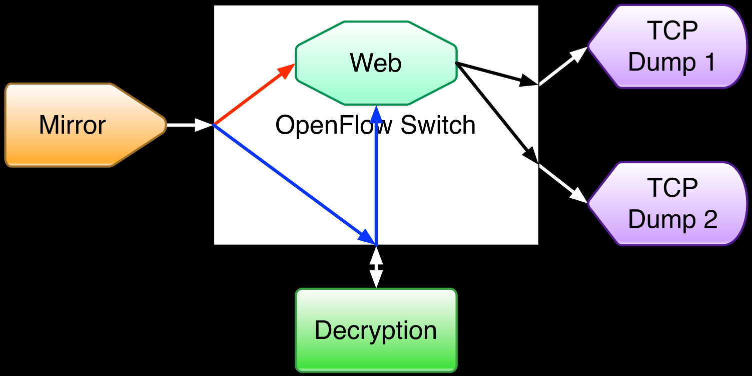
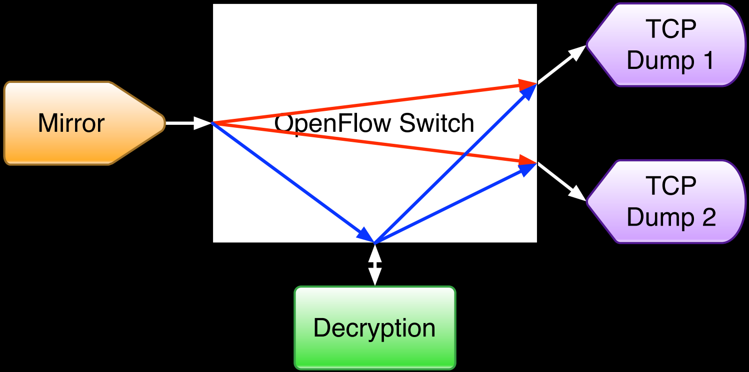


How it works under the hood



Related Work: Ethane

Ethane (the predecessor to OpenFlow) is an enterprise-wide security solution.

The focus here is to insert a tool just at the border, optimized for the border.

Related Work: Policy-aware switching

Policy-aware switching, proposed by Joseph et al. is somewhat similar to Ethane.

It removes the centralized controller, and has each switch determine the next hop.

Also, the policy specification language, like Ethane, is centered around deciding appropriate paths for a flow.

What next?

In the future, we'd like to expand our system by exploring:

- incorporating dynamic feedback from filters and sinks
- precomputing more dynamic distribution rules

Conclusion

OpenSAFE greatly simplifies high-speed network monitoring.
It is also:

- Cost effective by using commodity hardware
- Flexible and easy to modify
- Capable of operating at high line rates

Questions?

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