In-band Network Telemetry (INT)

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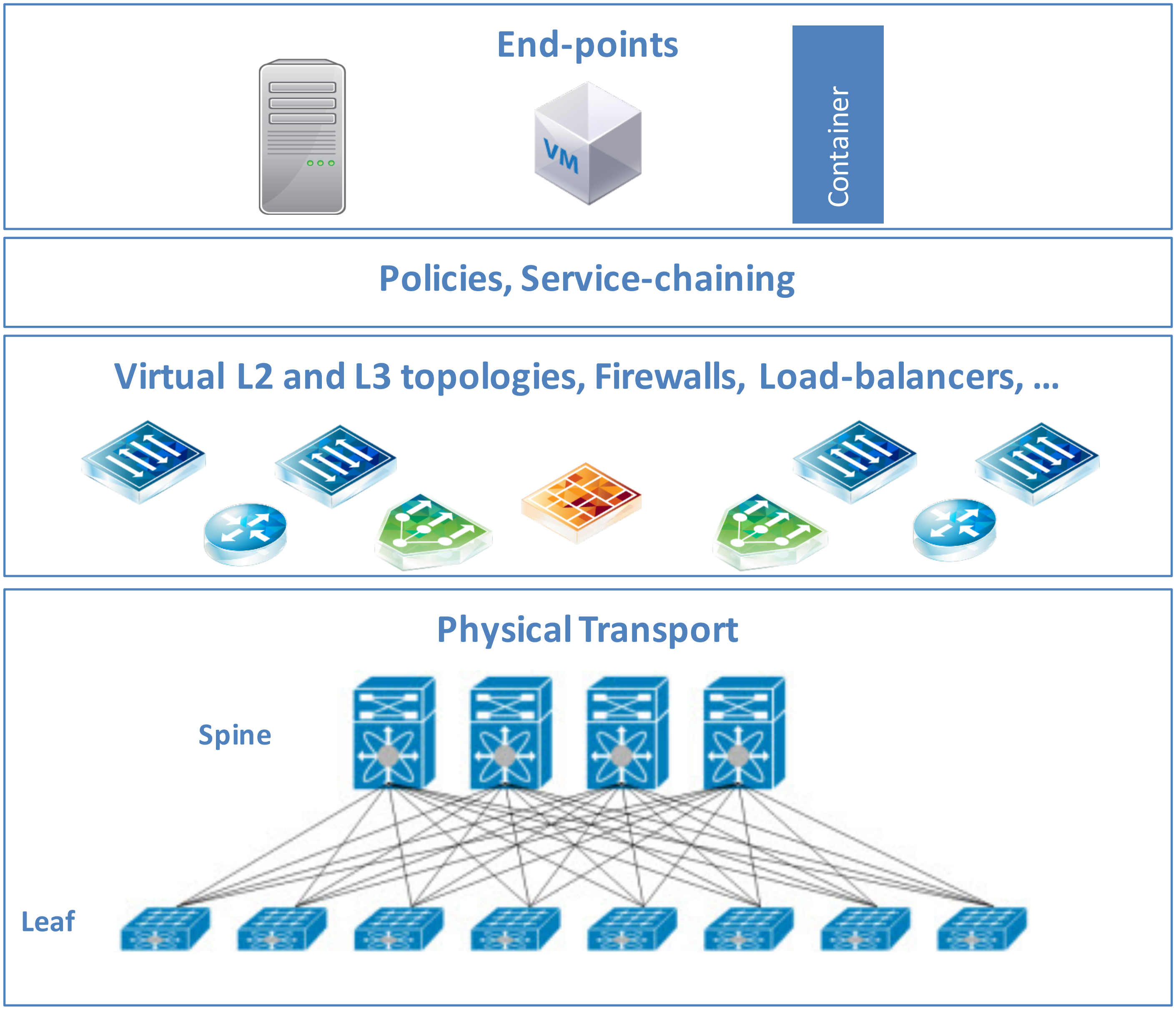
Datacenter Network Topologies



Current monitoring methods are inadequate

- Not fast enough
  - Involve CPU and control planes
  - Network state changes rapidly
- Do not provide end-to-end state
  - Difficult to correlate per-element state with the actual path of a flow

INT : In-band Network Telemetry

- Mechanism for collecting network state in the dataplane
  - As close to realtime as possible
  - At current and future line rates
  - With a framework that can adapt over time

- Examples of network state
  - Switch ID, Ingress Port ID, Egress Port ID
  - Egress Link Utilization
  - Hop Latency
  - Egress Queue Occupancy
  - Egress Queue Congestion Status
  - ....

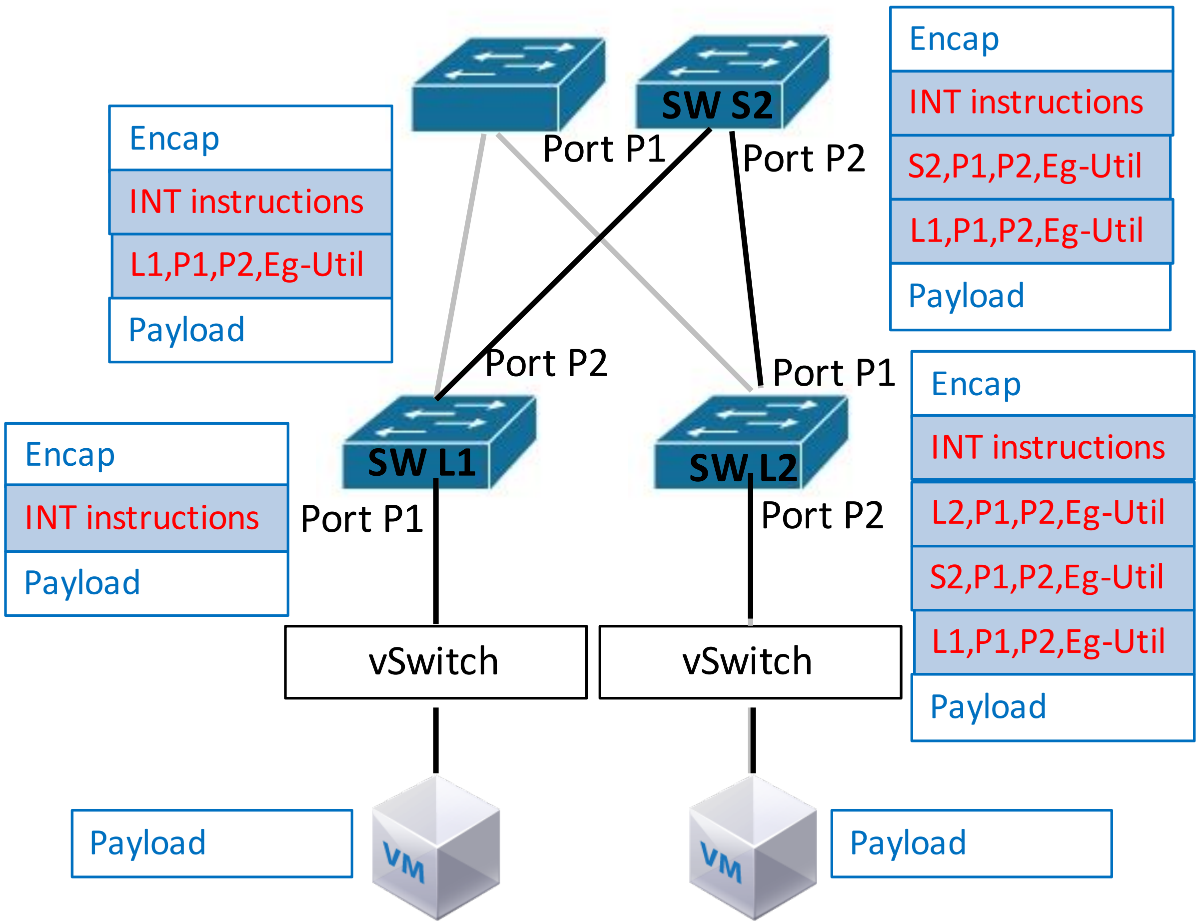
INT Example

Switch ID

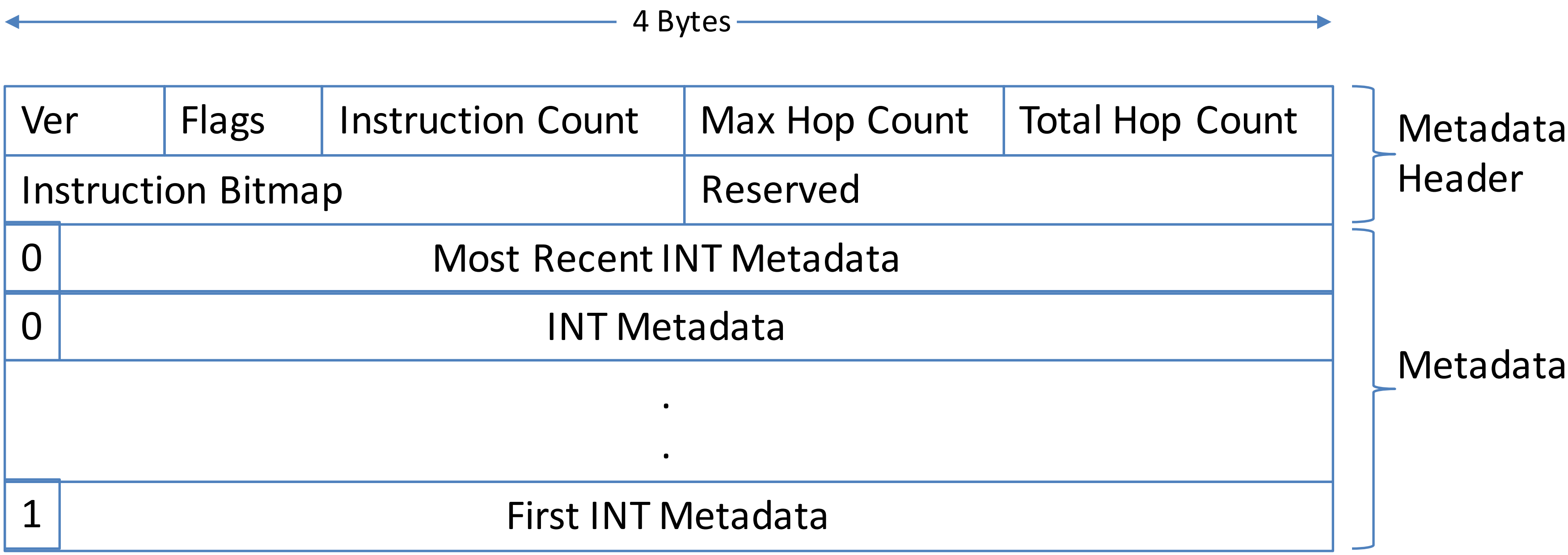
Ingress Port ID

Egress Port ID

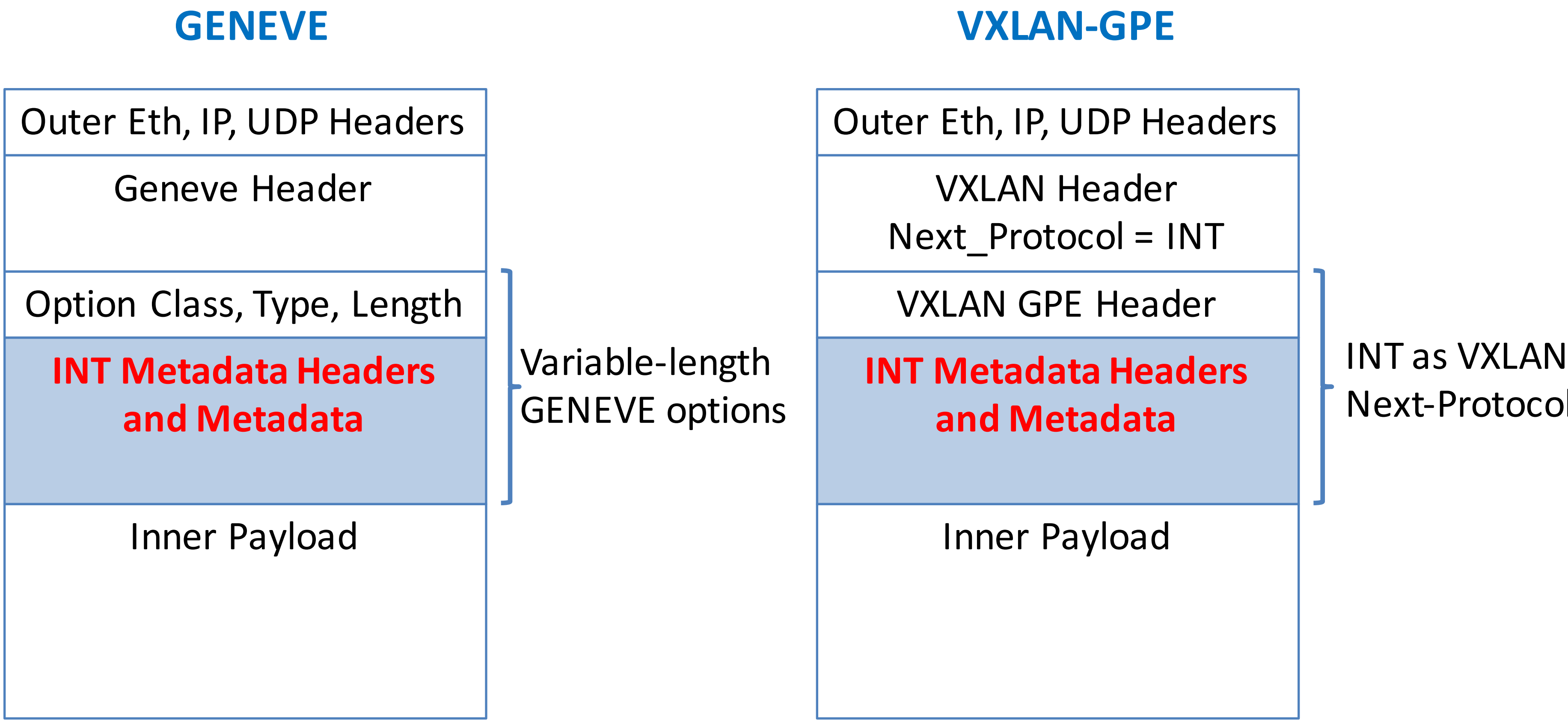
Egress Link Utilization



INT Header Format



INT Header: Potential Locations



INT metadata may also be carried as

- **Network Service Header Metadata**
- **TCP options/payload**
- **UDP payload**

INT using P4

- P4 enables flexible packet parsing and modification for INT

- P4 allows INT to adapt to
  - Any Encapsulation format
  - Any State required to be collected
  - Any feature, protocol – current and future

INT : P4 Code Snippet

Header Definitions

```
header_type vxlan_gpe_t
{
   fields {
      flags : 8;
      reserved : 16;
      next_proto : 8;
      vni : 24;
      reserved2 : 8;
   }
}
```

```
header_type vxlan_gpe_int_header_t
{
   fields {
      int_type       : 8;
      rsvd           : 8;
      len            : 8;
      next_proto     : 8;
   }
}
```

```
header_type int_header_t {
   fields {
      ver                 : 2;
      flags               : 9;
      ins_cnt             : 5;
      max_hop_cnt         : 8;
      total_hop_cnt       : 8;
      instruction_mask    : 16;
   }
}
```

Parser Definitions

```
parser parse_gpe_int_header {
   extract(vxlan_gpe_int_header);
   set_metadata(int_metadata.gpe_int_hdr_len,
                      latest.len);
   return parse_int_header;
}
```

```
parser parse_int_header {
   extract(int_header);
   ....
}
```

INT : P4 Code Snippet

Exact-match
Table Definition

```
table int_inst {
   reads {
      int_header.instruction_mask : exact;
   }
   actions {
      int_set_header_i0;
      int_set_header_i1;
      int_set_header_i2;
      int_set_header_i3;
      .....
   }
```

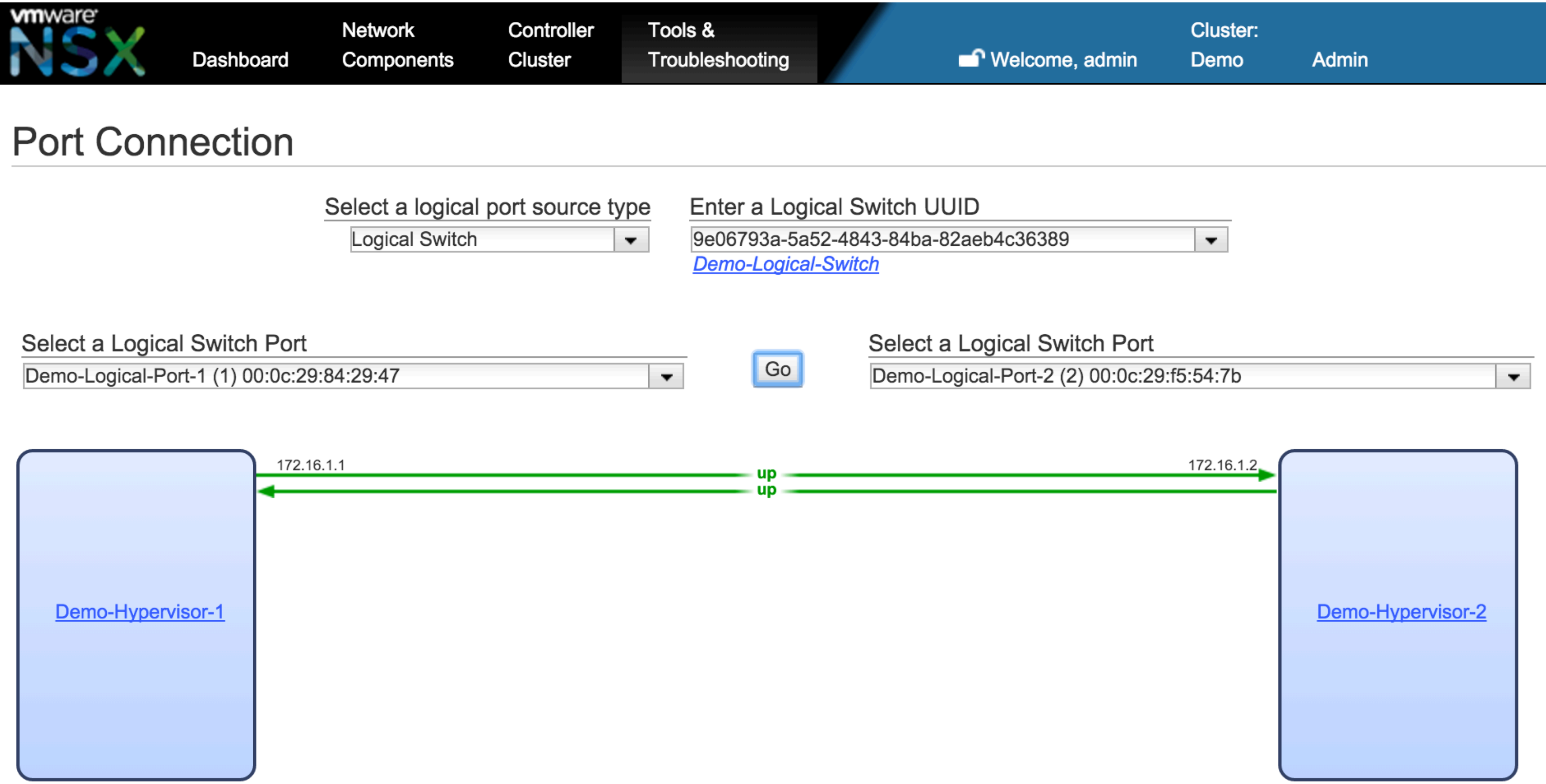
Action
Definitions

```
action int_set_header_i0() {
}
action int_set_header_i1() {
   int_set_header_3();
}
action int_set_header_i2() {
   int_set_header_2();
}
action int_set_header_i3() {
   int_set_header_3();
   int_set_header_2();
}
.....
```

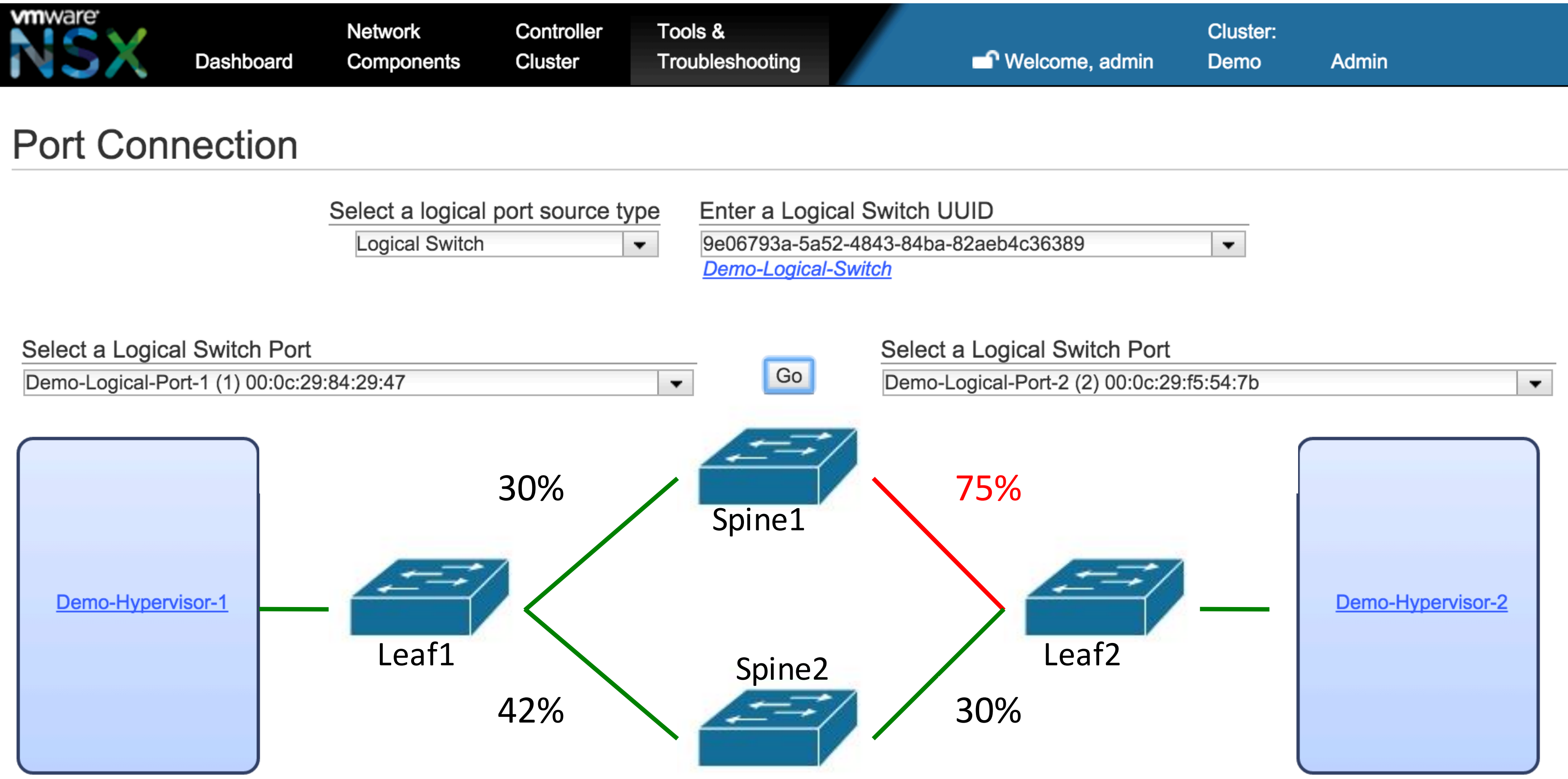
INT Application

Real-time monitoring and troubleshooting

Overlay Network Monitoring today

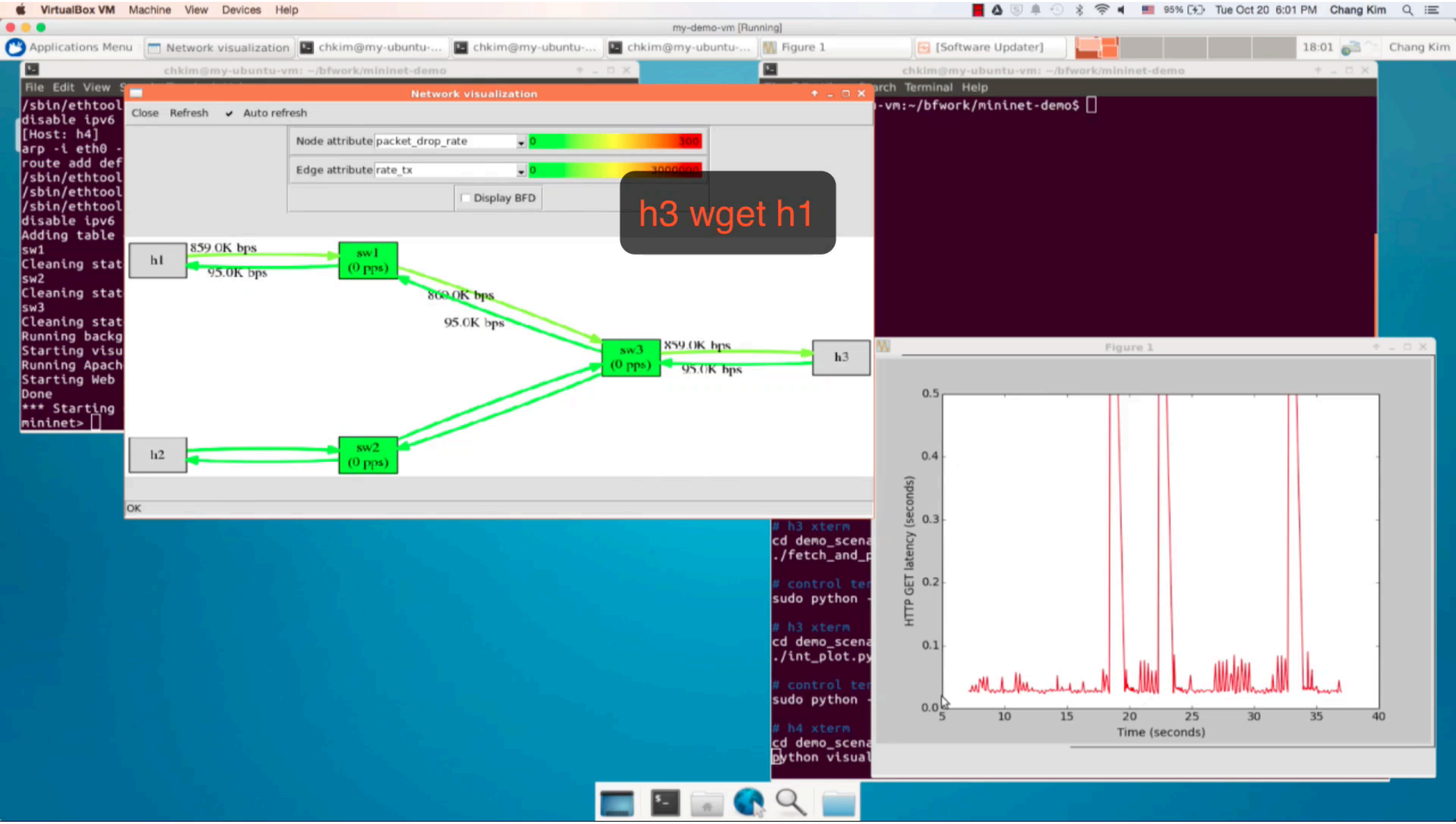


Real-time Network Monitoring



Next: Pick a flow on the source logical port and view the path it takes and exact network state it experiences

Real-time troubleshooting demo



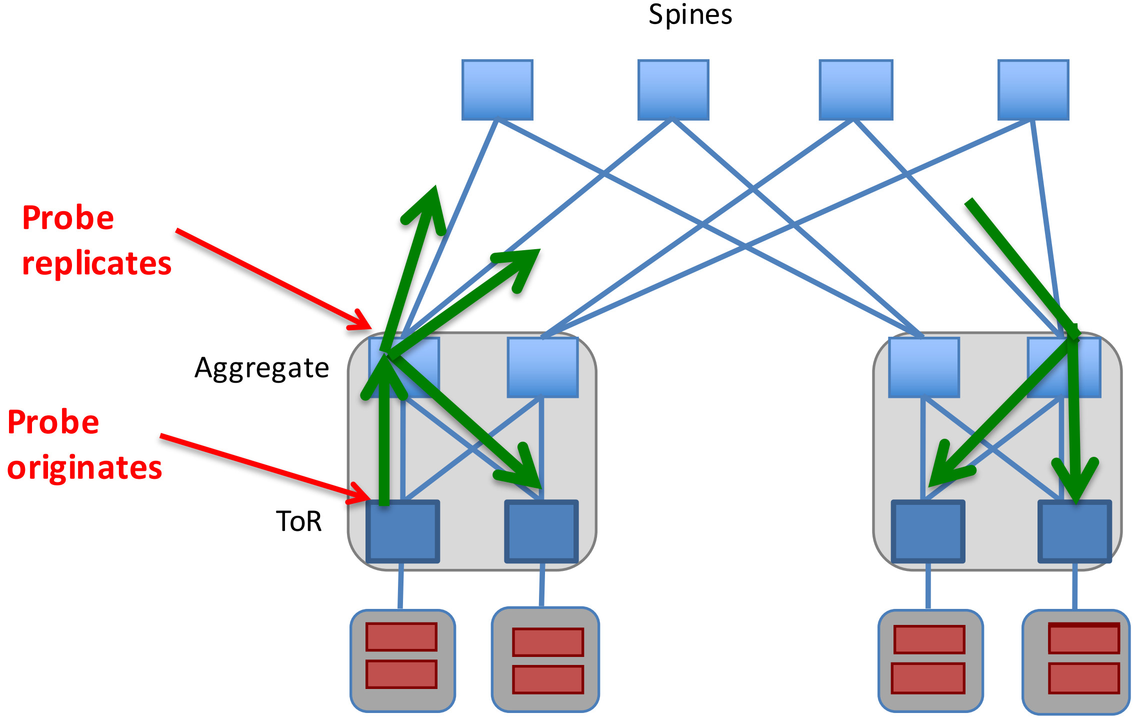
INT Application

Hop-by-Hop Utilization-Aware Load-balancing Architecture

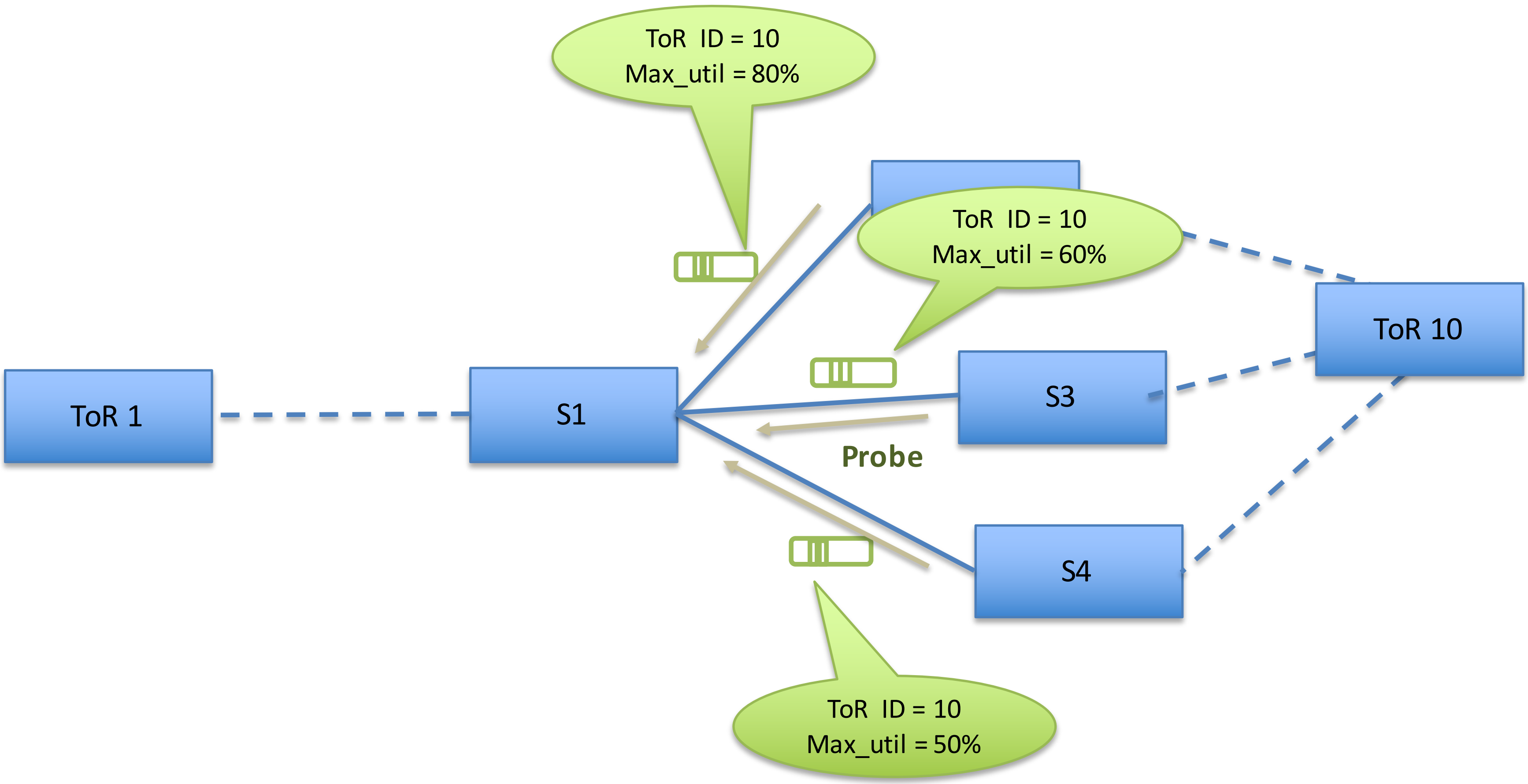
HULA: INT + Flowlet routing

1. Periodic INT probes
   - disseminate path utilization to switches
2. Flowlet detection and path selection
   - happens at all switches
   - hop-by-hop adaptive routing

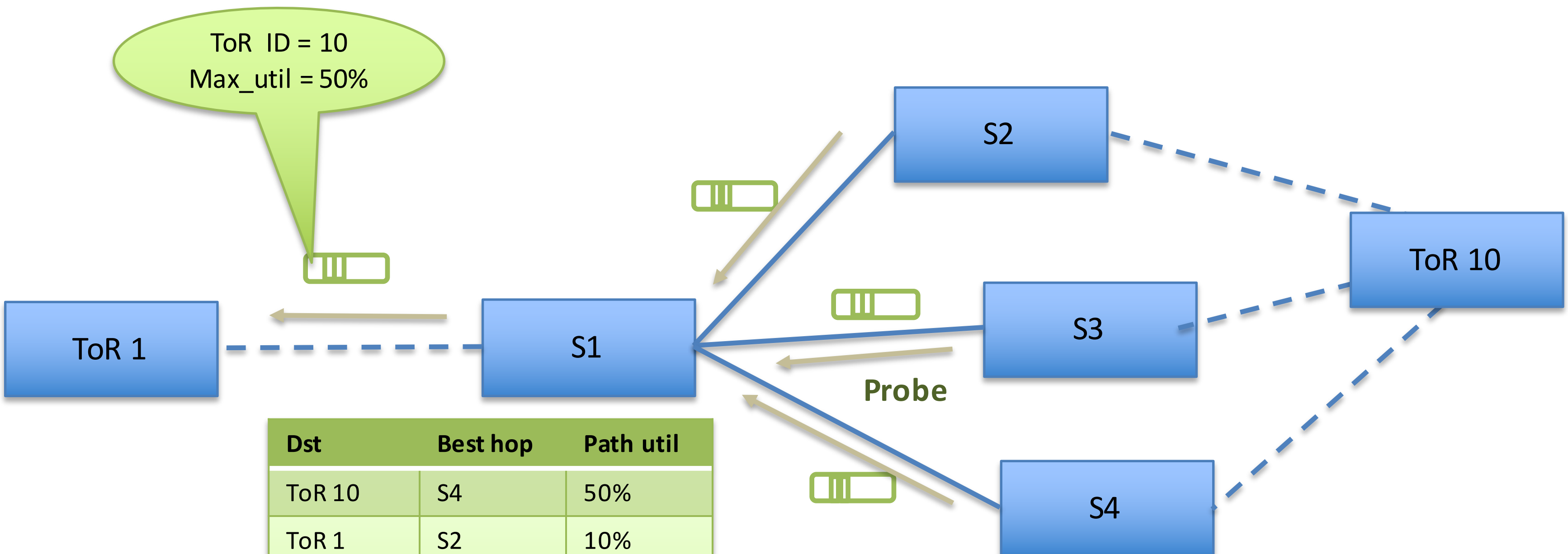
INT probes traverse multiple paths



Probes carry path utilization



Probes update switch state



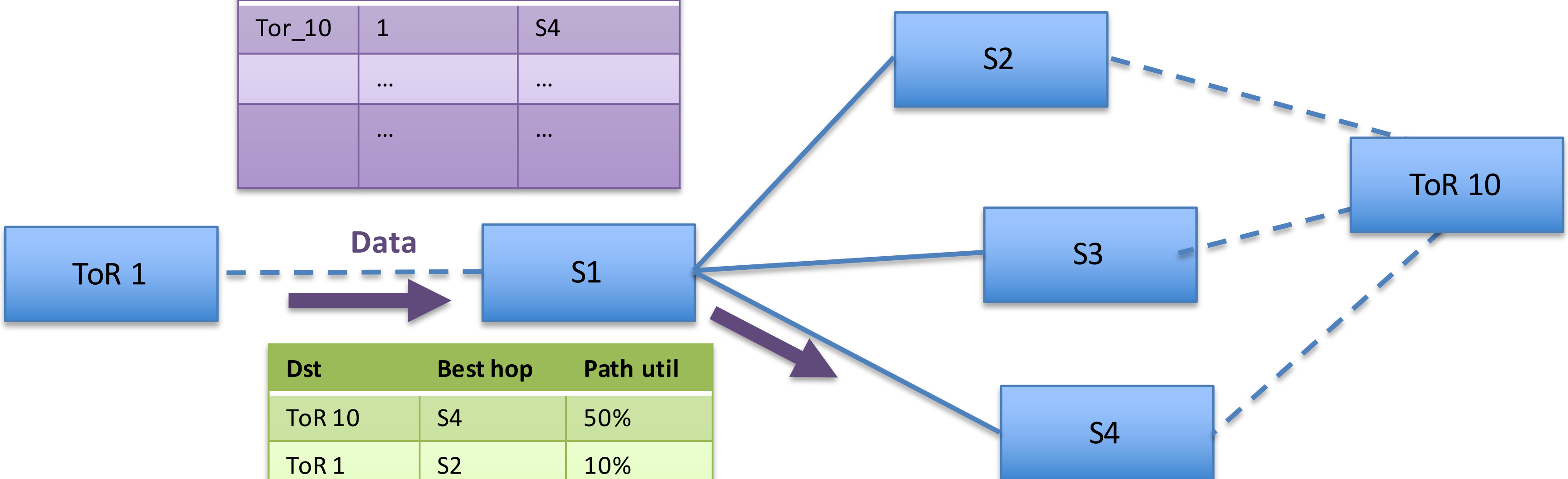
Dst	Best hop	Path util
ToR 10	S4	50%
ToR 1	S2	10%
…	…	

Path Util table

Switches load balance flowlets

Flowlet table

Dst	Flowlet #	Next hop
Tor_10	1	S4
	…	…
	…	…



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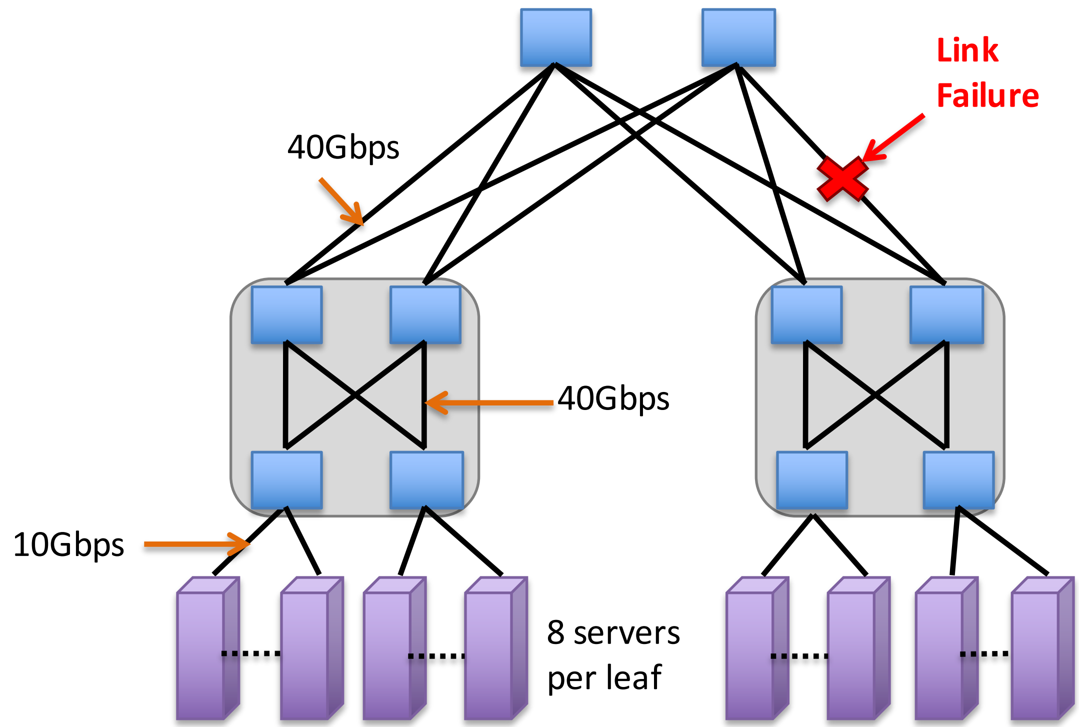
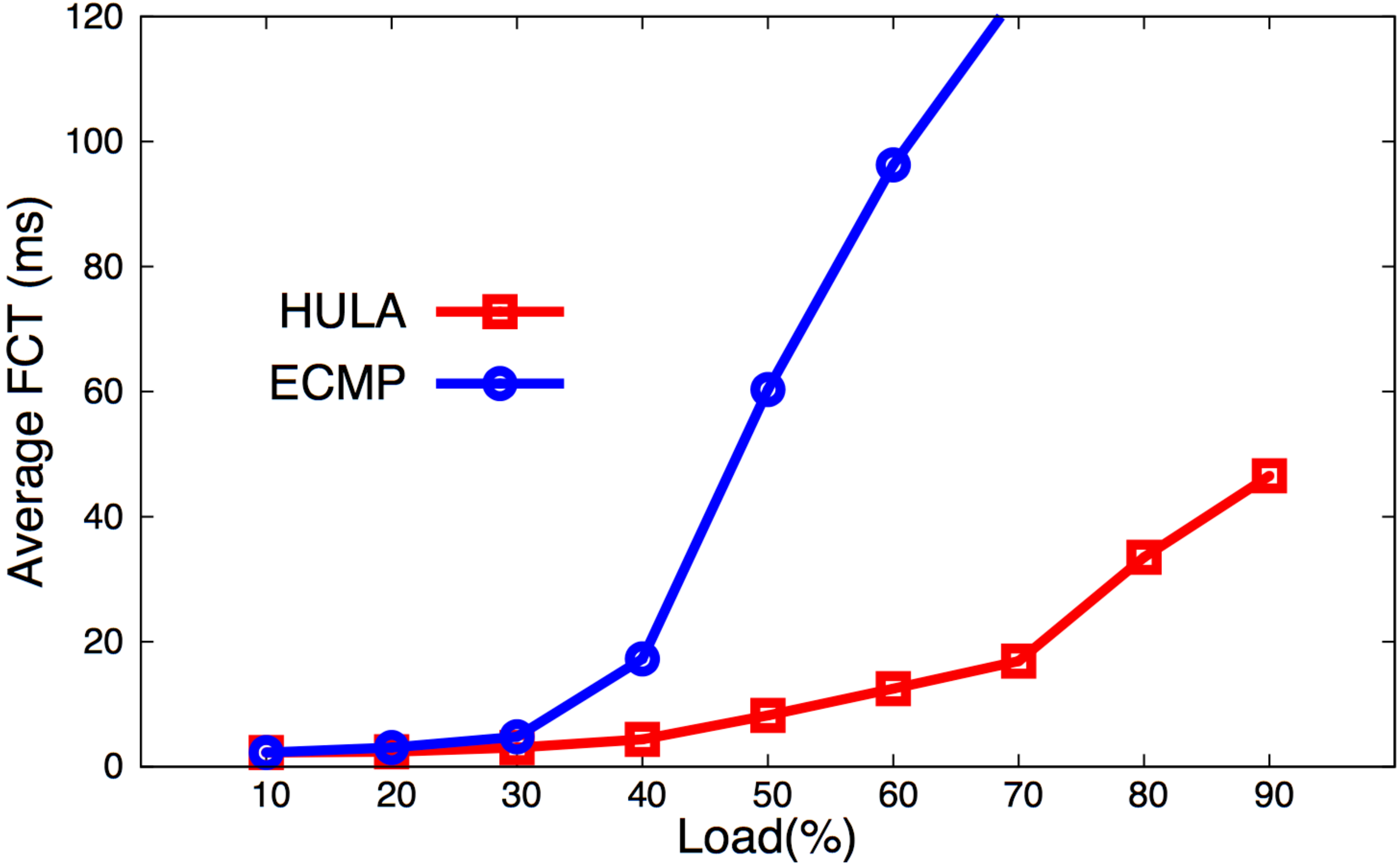
Path Util table

Simulation: Topology Asymmetry



HULA Vs. ECMP



Average FCT (ms)
120
100
80
60
40
20
0
HULA
ECMP
10
20
30
40
50
60
70
80
90
Load(%)

HULA - Advantages

- Topology oblivious
- Adaptive to network dynamics
- Scalable to large topologies
- No separate source routing required
- Programmable in P4!
  - Processing probes
  - Flowlet routing

Summary

- INT provides real-time network state directly in the dataplane
  - Scales to arbitrarily large networks
  - Scales to current and future link speeds
  - Can adapt to any network, any encap, any application

- Knowledge of real-time network state opens up new possibilities
  - Enhanced monitoring and troubleshooting
  - Network-state aware routing
  - …

More information

http://p4.org/p4/inband-network-telemetry/

Blog post with links to

- INT demo video
- INT specification
- P4 source code repository

More information on Utilization aware routing will be posted on p4.org in the near future

INT Specification – Collaborative Effort

http://p4.org/wp-content/uploads/fixed/INT/INT-current-spec.pdf

In-band Network Telemetry (INT)

September 2015

Changhoon Kim, Parag Bhide, Ed Doe: *Barefoot Networks*
Hugh Holbrook: *Arista*
Anoop Ghanwani: *Dell*
Dan Daly: *Intel*
Mukesh Hira, Bruce Davie: *VMware*

Thank You