NETWORK VIRTUALIZATION IN MULTI-TENANT DATACENTERS

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with

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Plenty of primitives but **no** network virtualization per se.
MULTI-TENANT DATACENTERS

Result with the aforementioned primitives:

- Slow provisioning
- Limited VM placement
- Mobility is limited
- Hardware dependent
- Operationally intensive
- …
NETWORK HYPERVERVISOR

VMs

Server Hypervisor

Decoupled

Network Hypervisor

Standard x86

Standard IP connectivity

x86

L2, L3, L4-L7 Services

Logical Networks

App

App

App

App

App

App

App
AGENDA

• Overall design of NVP network hypervisor.
• Design challenges.
• Hard lessons learnt.
• What’s next in network virtualization?
WHAT IS A NETWORK HYPERVISOR?

Packet Abstraction + Control Abstraction = Network Hypervisor
WHAT ARE THE ABSTRACTIONS?

Packet abstraction

- Compliance with standard TCP/IP stack is a necessity:
  - L2, L3 semantics (unicast, ARP, …)

Control abstraction

- Networking has no single high level control interface.
  - There's a low-level one though!

Tenant’s Control Plane

Logical Datapath

- Packet In
  - ACL
  - L2
  - L3
  - ACL
- Packet Out
GENERALITY OF DATAPATH

One logical switch

2-tier logical topology

Arbitrary logical topology

Faithful reproduction of physical network service model.
WHERE TO IMPLEMENT?

- Independence from physical hardware.
- Programmatic control.
- Operational model of compute virtualization.

No extra x86 hops: just the source and destination hypervisor!
INSIDE THE VIRTUAL SWITCH

Logical Topology

First-hop vSwitch

Execute 1st logical datapath
Identify logical ingress port

Determine the next logical datapath

2nd logical datapath

Determine the next logical datapath

3rd logical datapath

Send to tunnel
1. Controllers learn the location of VMs.

2. Controllers proactively compute & push all forwarding state required to connect each VM.

Forwarding State = F(configuration, VM locations)

Repeat above as logical configuration or physical configuration (VM placement) changes.

**Challenge:** How to compute $O(N^2)$ volume of low-level OpenFlow and OVSDB state, when inputs change all the time.
STATE COMPUTATION

Forwarding State = \( F(\text{configuration}, \text{VM locations}) \)

1. How to Scale Computation
   - **Incremental** computation and pushing for quick updates.

2. How to Guarantee Correctness
   - Avoid all handwritten finite state machines, **machine generated** instead.

- Datalog based declarative language to program \( F \).
- Shard the computation across controller cluster.

**Declarative RT**
LESSONS LEARNT: ABSTRACTIONS

- Assumptions about logical network structure often embedded into the workload.
- A single L2 domain sufficient for initial, simple workloads.
- To support more complex workloads without changing them, more complex logical topologies become a necessity.
LESSONS: FAILURE ISOLATION

Two Channels, No Atomic Updates

• Proactive pushing of all state not enough to decouple controllers from data plane.
• Connection may die while pushing updates.

Data plane may operate over incomplete state!

One Channel, Atomic Updates

• Atomically applied, batched updates.
• Connection failure does not result in incomplete state.

At most old state.
LESSONS: SCALING
OPENFLOW IS EXPENSIVE

Too primitive

- Simple operations take several flow entries.
- For example, tunnel failover, encapsulation header ops.
- Lots of redundancy.

Too tightly coupled

- Each switch requires some flow customization; can’t just blindly replicate flows.
- To compute flow entries, may have to wait for responses from the OVS configuration database.

Replace a OF & OVSDB with a network virtualization specific protocol.

OpenFlow becomes a protocol internal to the hypervisor.
CONCLUSION: WHAT'S NEXT

Without Network Virtualization

• Workload may run on a topology where addresses provide little information.

• For instance, firewall rules defined over exact /32 addresses!

With Network Virtualization

• New “out-of-band” header fields without breaking legacy TCP/IP stacks.

• Huge implications to enforcing security policies: groups, users in packet…

Logical headers for TCP/IP endpoints in VMs.
Logical topology per workload requirements.

New information, visible only to logical elements.

Network Hypervisor

Encapsulation header
THANK YOU! QUESTIONS?