Software Defined Networking

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In this course, you will learn about software defined networking and how it is changing the way communications networks are managed, maintained, and secured.

Module 1: History of SDN

- This lesson: *Network Virtualization*
- What is network virtualization?
- What is its history? (w/examples)
  - 1990s (and before): Switchlets
  - Mid-2000s: VINI, Cabo
  - Looking forward
- Network virtualization and SDN

Evolution of Supporting Technologies (Three Lessons)

- **Central network control:** Dates back (at least) to AT&T's network control point (1980s)
- **Programmability in networks:** Active networks (1990s)
- **Network virtualization:** Switchlets (1990s), VINI (2000s)

What is Network Virtualization?

- Representation of one or more logical network topologies on the same infrastructure.
- Many different instantiations
  - Virtual LANs (VLANs)
  - Various technologies and network testbeds
  - Today: VMWare, Nicira, etc.

Benefits of Network Virtualization

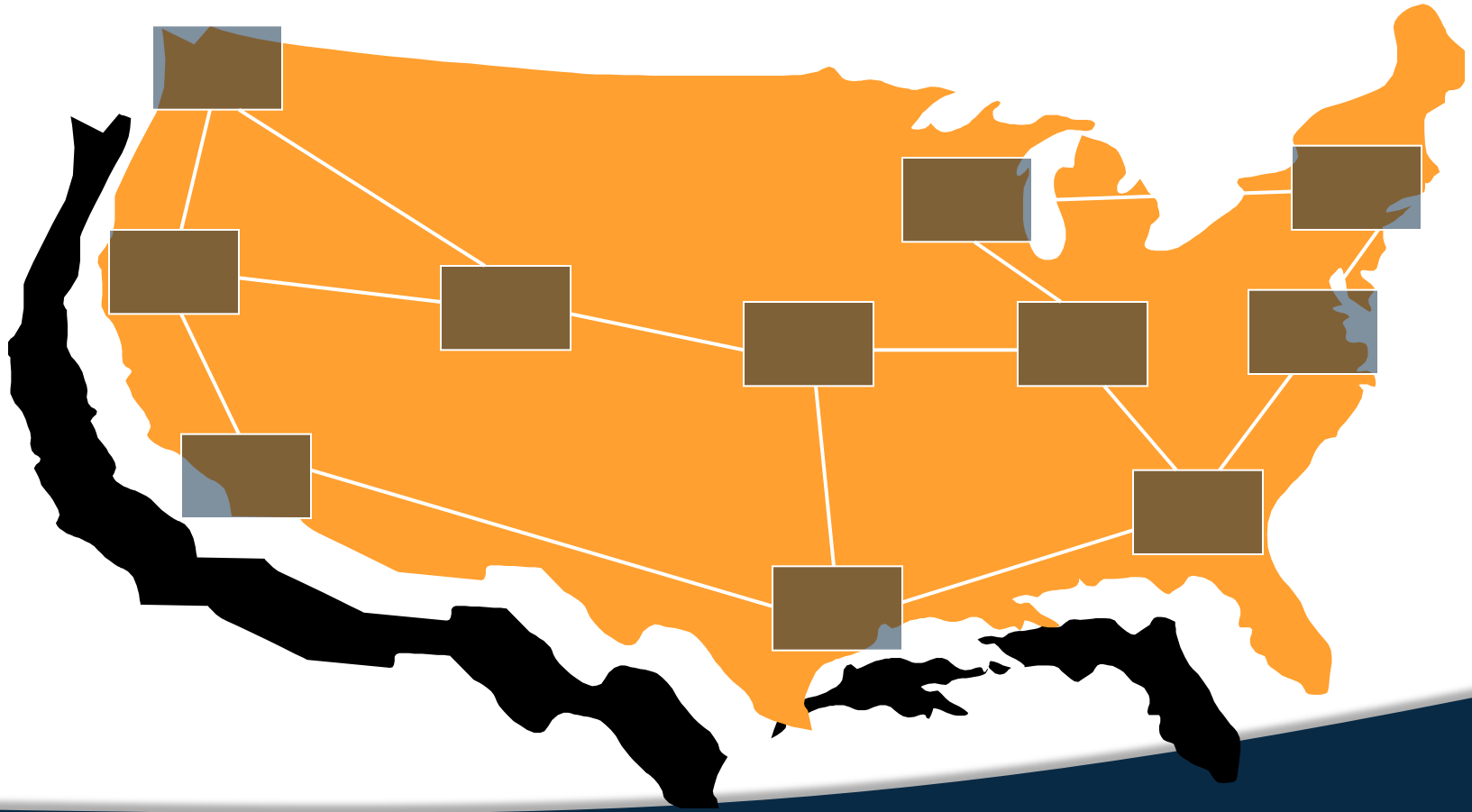
Sharing

- Multiple logical routers on a single platform
- Resource isolation in CPU, memory, bandwidth, forwarding tables, …

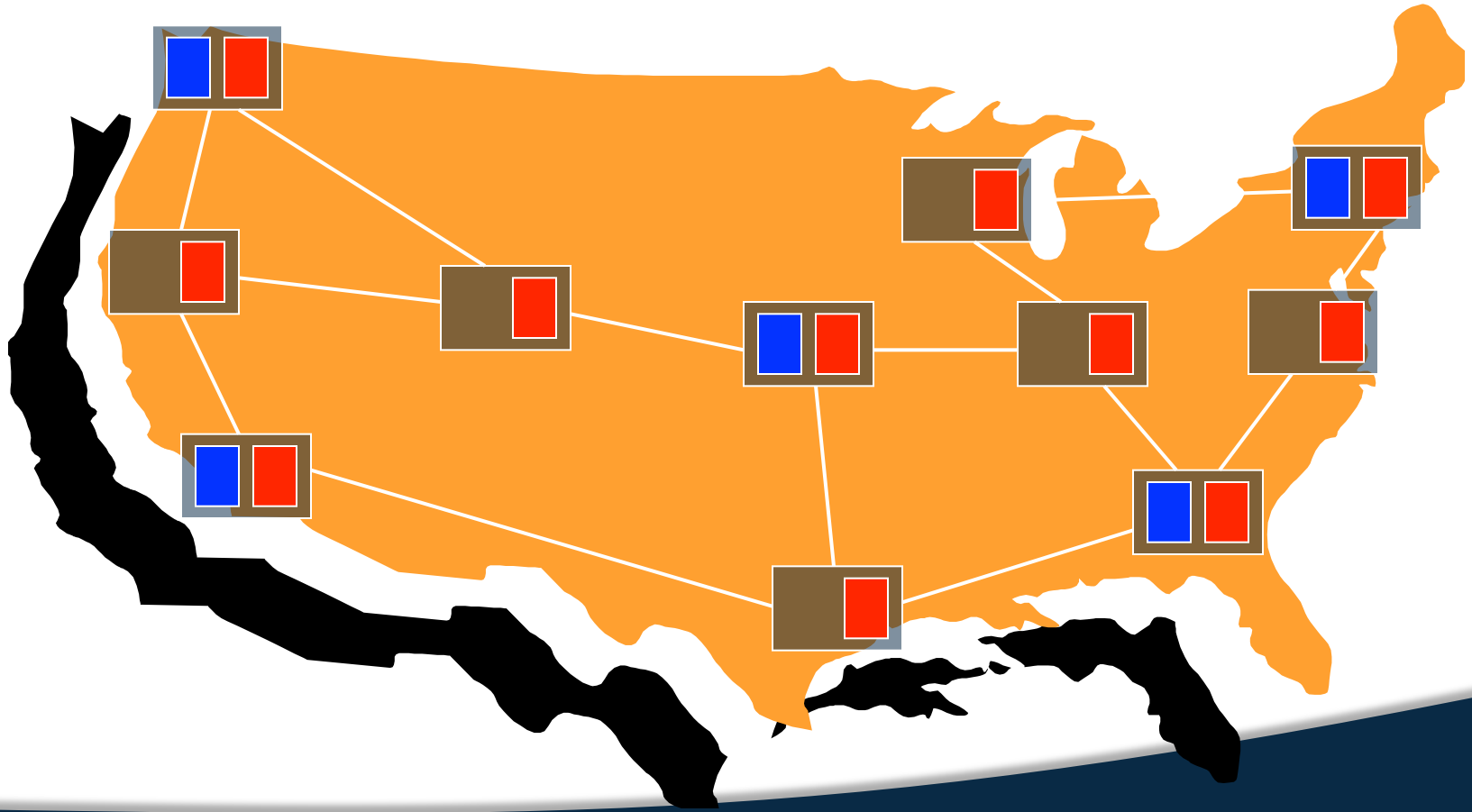
Customizability

- Customizable routing and forwarding software
- General-purpose CPUs for the control plane
- Network processors and FPGAs for data plane

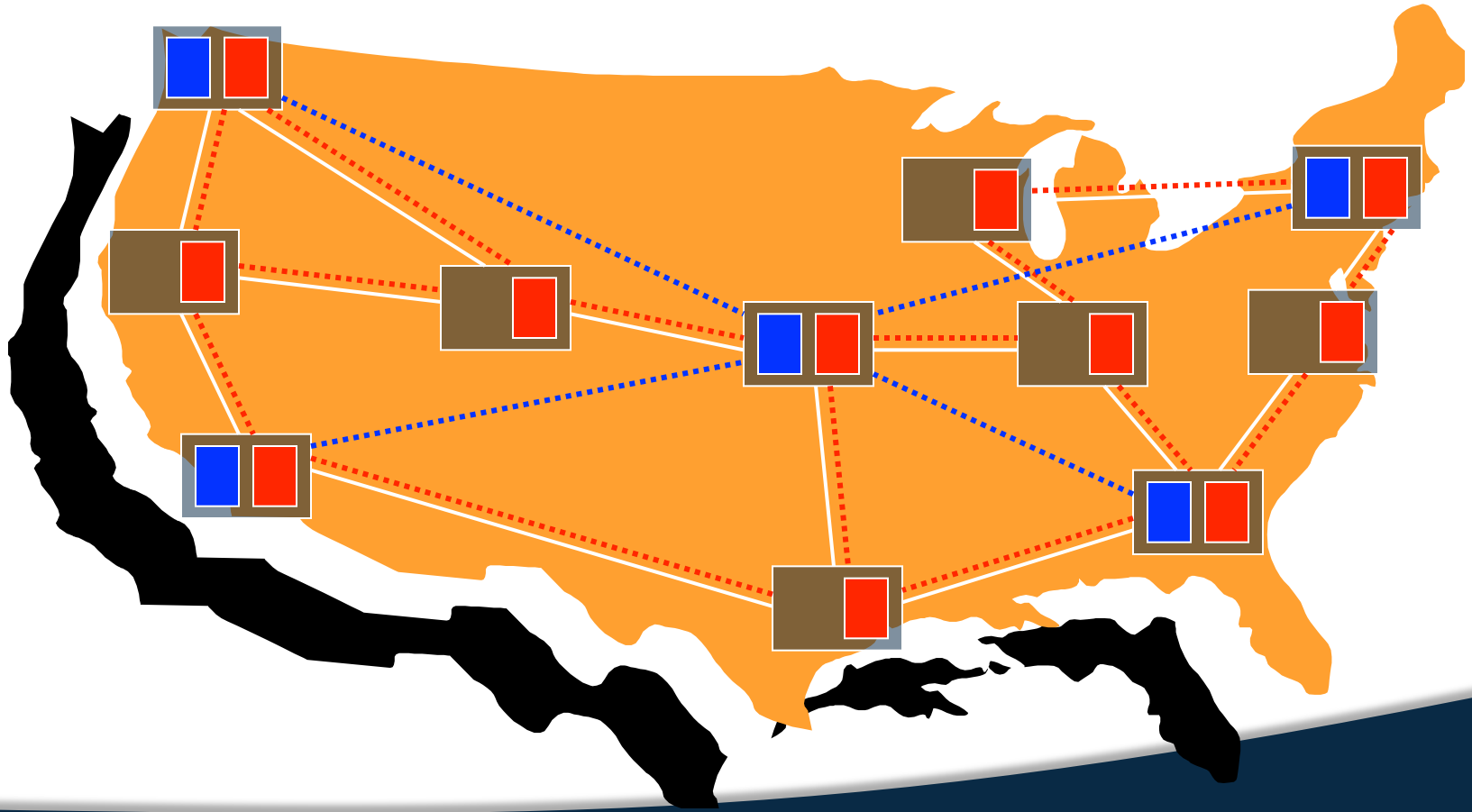
Fixed Physical Infrastructure



Shared By Many Parties



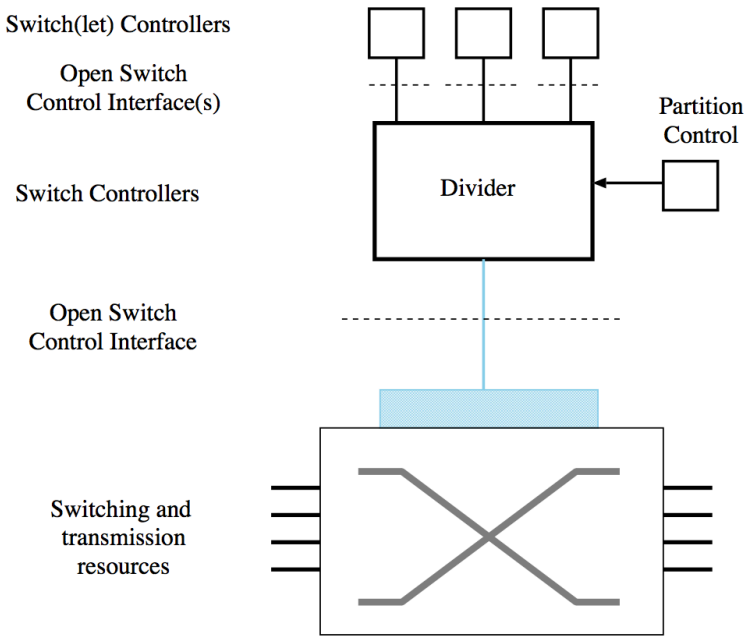
Arbitrary Virtual Topologies



Three Examples of Virtual Networks

- Tempest: Switchlets (1998)
  - Separation of control framework from switches
  - Virtualization of the switch
- VINI: A Virtual Network Infrastructure (2006)
  - Virtualization of the network infrastructure
- Cabo: Separates infrastructure, services (2007)

The Tempest Architecture: Switchlets

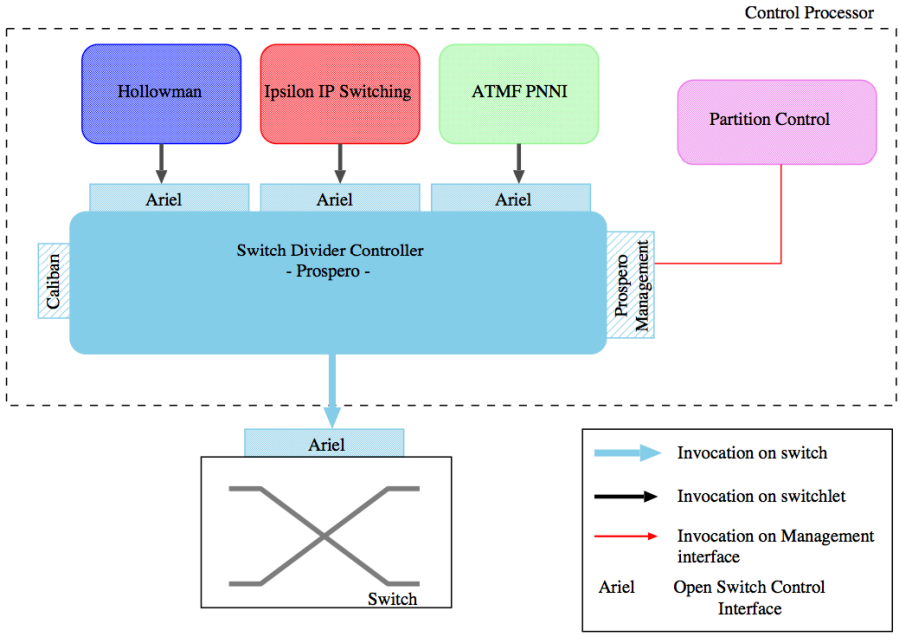


Open Signalling in the Tempest

- Multiple control architectures over ATM
- Separation of switch controller and fabric via open signaling
- Partitioning of switch resources across controllers

van der Merwe, Jacobus E., et al. "The tempest-a practical framework for network programmability." *Network, IEEE* 12.3 (1998): 20-28.

Switch Divider



- Partitions port space, bandwidth, buffers
- Different controllers control each switchlet

> As anyone who can obtain a virtual network will effectively be a network operator, we hope to see an increase in the creativity that can be brought to bear upon the problem of network control. We have demonstrated that the Tempest framework provides this flexibility while permitting comparable efficiency to current solutions.

van der Merwe, Jacobus E., et al. "The tempest-a practical framework for network programmability." *Network, IEEE* 12.3 (1998): 20-28.

VINI: Virtual Network Infrastructure

Bridge the gap between "lab experiments" and live experiments at scale.

- Runs real routing software
- Exposes realistic network conditions
- Gives control over network events
- Carries traffic on behalf of real users
- Shared among many experiments

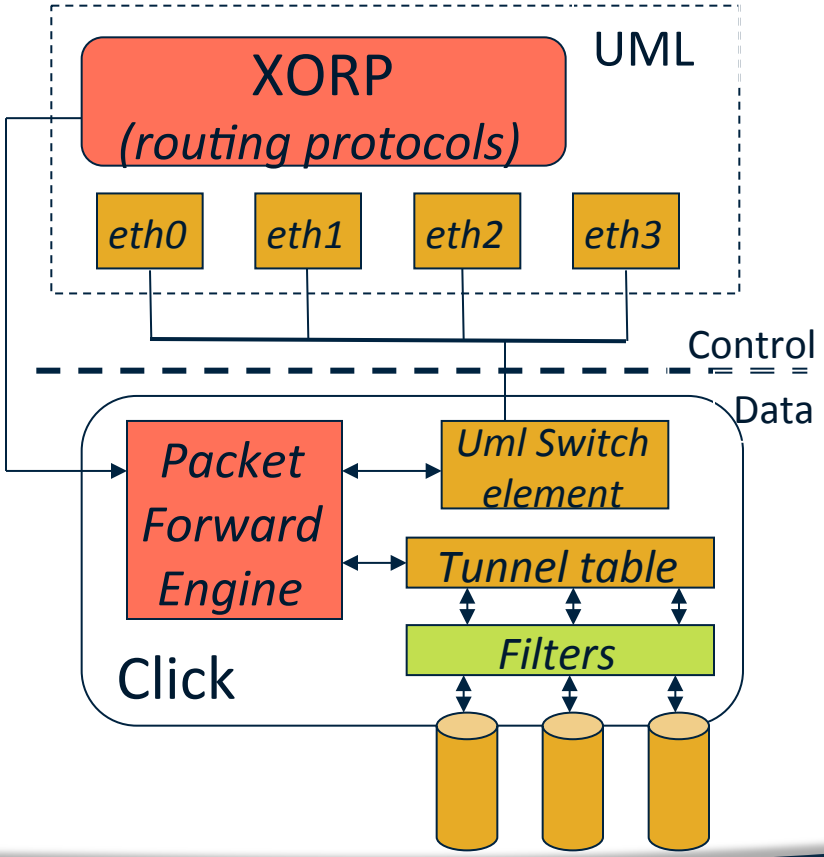
Bavier, Andy, et al. "In VINI veritas: realistic and controlled network experimentation." *ACM SIGCOMM Computer Communication Review*. Vol. 36. No. 4. ACM, 2006.

XORP: Control Plane

XORP
(routing protocols)

- BGP, OSPF, RIP, PIM-SM, IGMP/MLD
- **Goal: run real routing protocols on virtual network topologies**

Click: Data Plane

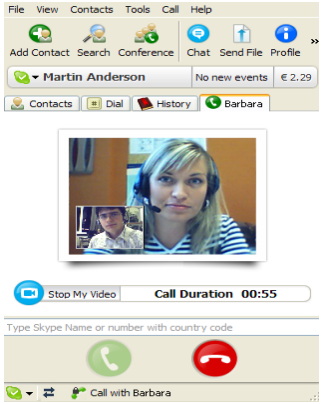


- Performance
  - Avoid UML overhead
  - Move to kernel, FPGA
- Interfaces ⇨ tunnels
  - Click UDP tunnels correspond to UML network interfaces
- Filters
  - “Fail a link” by blocking packets at tunnel

Concurrent Architectures are Better than One

Infrastructure Providers

Service Providers



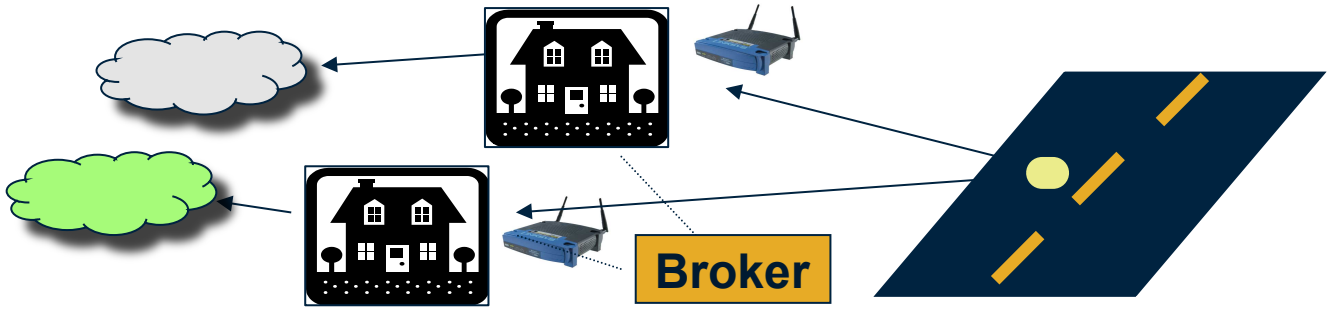
- **Infrastructure providers:** Maintain routers, links, data centers, and other physical infrastructure
- **Service providers:** Offer end-to-end services (*e.g.,* layer 3 VPNs, SLAs, etc.) to users

Today: ISPs try to play both roles, and cannot offer *end-to-end* services

Feamster, Nick, Lixin Gao, and Jennifer Rexford. "How to lease the Internet in your spare time." *ACM SIGCOMM Computer Communication Review* 37.1 (2007): 61-64.

Examples in Communications Networks

- Two commercial examples in IP networks
  - Packet Fabric: share routers at exchange points
  - FON: resells users' wireless Internet connectivity



- FON economic refactoring
  - Infrastructure providers: Buy upstream connectivity
  - Service provider: FON as the broker

Summary

- What is network virtualization?
  - Separate logical network from the infrastructure
- What is the history?
  - Virtual switches (1990s: Switchlets), networks (2006: VINI), services (2007: Cabo)
- What is the legacy for SDN?
  - Separate service from infrastructure
  - Multiple controllers of a single switch
  - Logical network topologies

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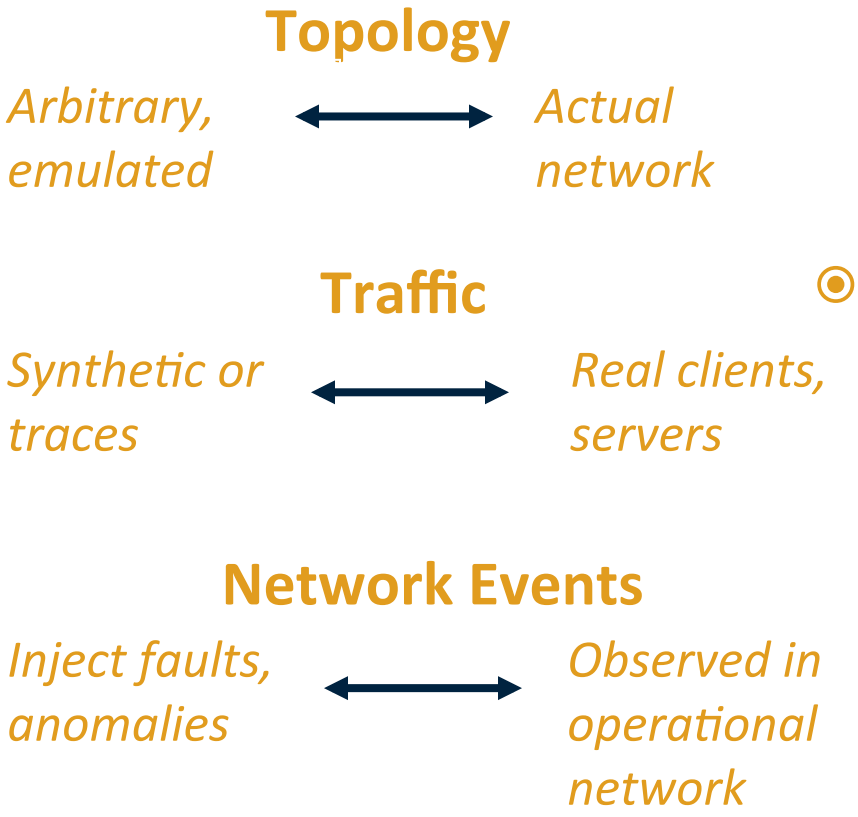
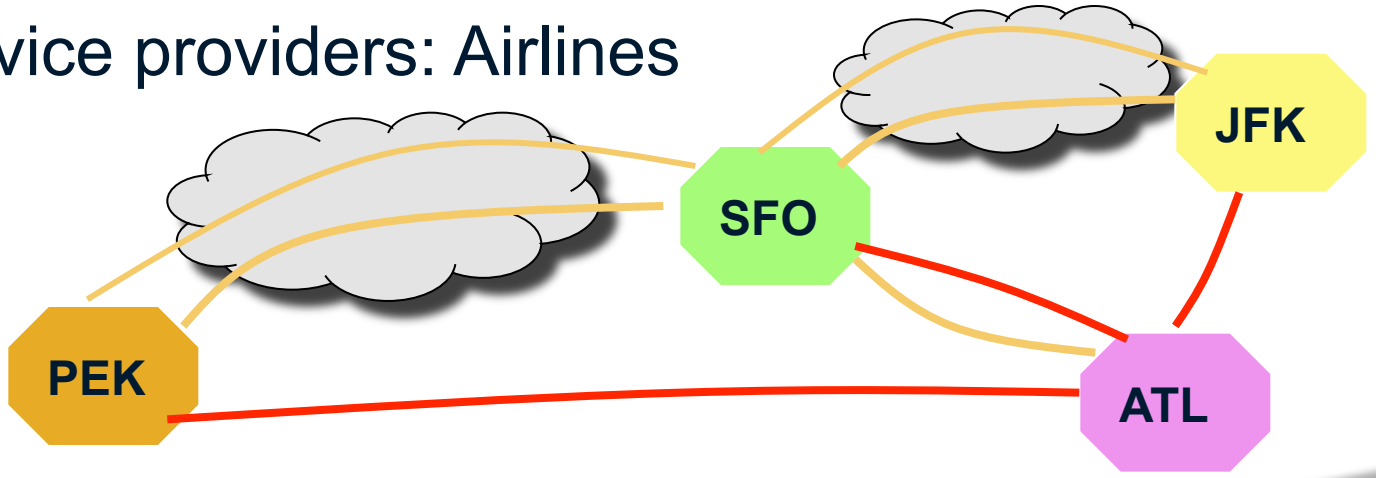
Goal: Control and Realism



- **Control**
  - *Reproduce results*
  - Methodically change or relax constraints
- **Realism**
  - Long-running services
  - Connectivity to real Internet
  - Forward high traffic volumes (Gb/s)
  - Handle unexpected events

Similar Trends in Other Industries

- Example: Commercial aviation
  - Infrastructure providers: Airports
  - Infrastructure: Gates, “hands and eyes” support
  - Service providers: Airlines

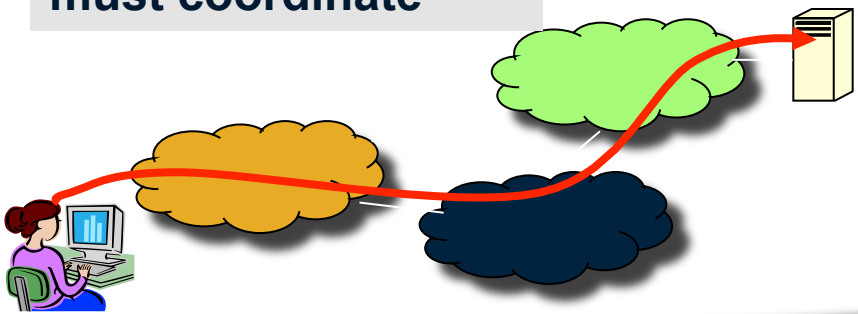


Enabling End-to-End Services

- Secure routing protocols
- Multi-provider Virtual Private Networks
- Paths with end-to-end performance guarantees

Today

Competing ISPs with different goals must coordinate



Cabo

Single service provider controls end-to-end path