OpenFlow/Software Defined Networking: Enable Network Innovations

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Team at Stanford

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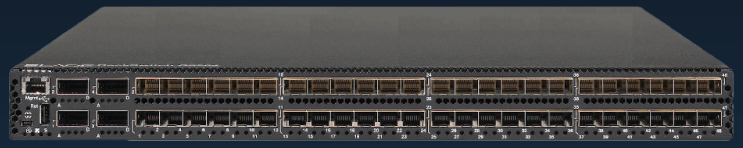
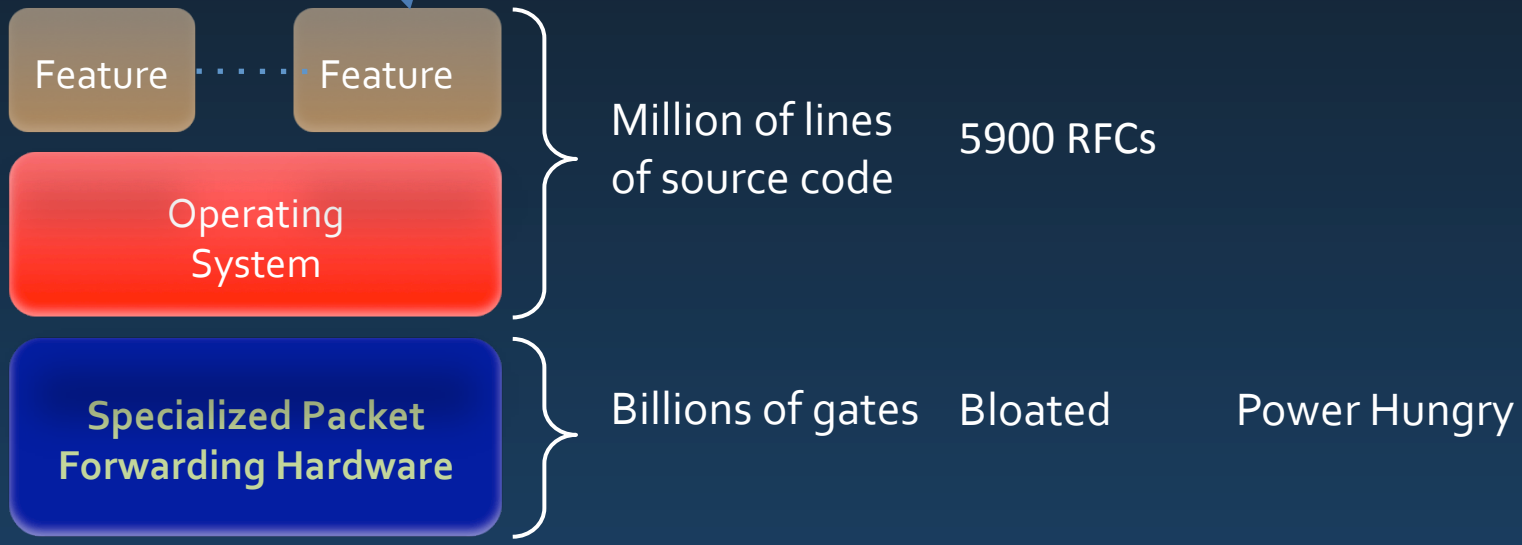
With Scott Shenker and team at Berkeley and Martin Casado at Nicira

What is the Problem?

Routing, management, mobility management,
access control, VPNs, …



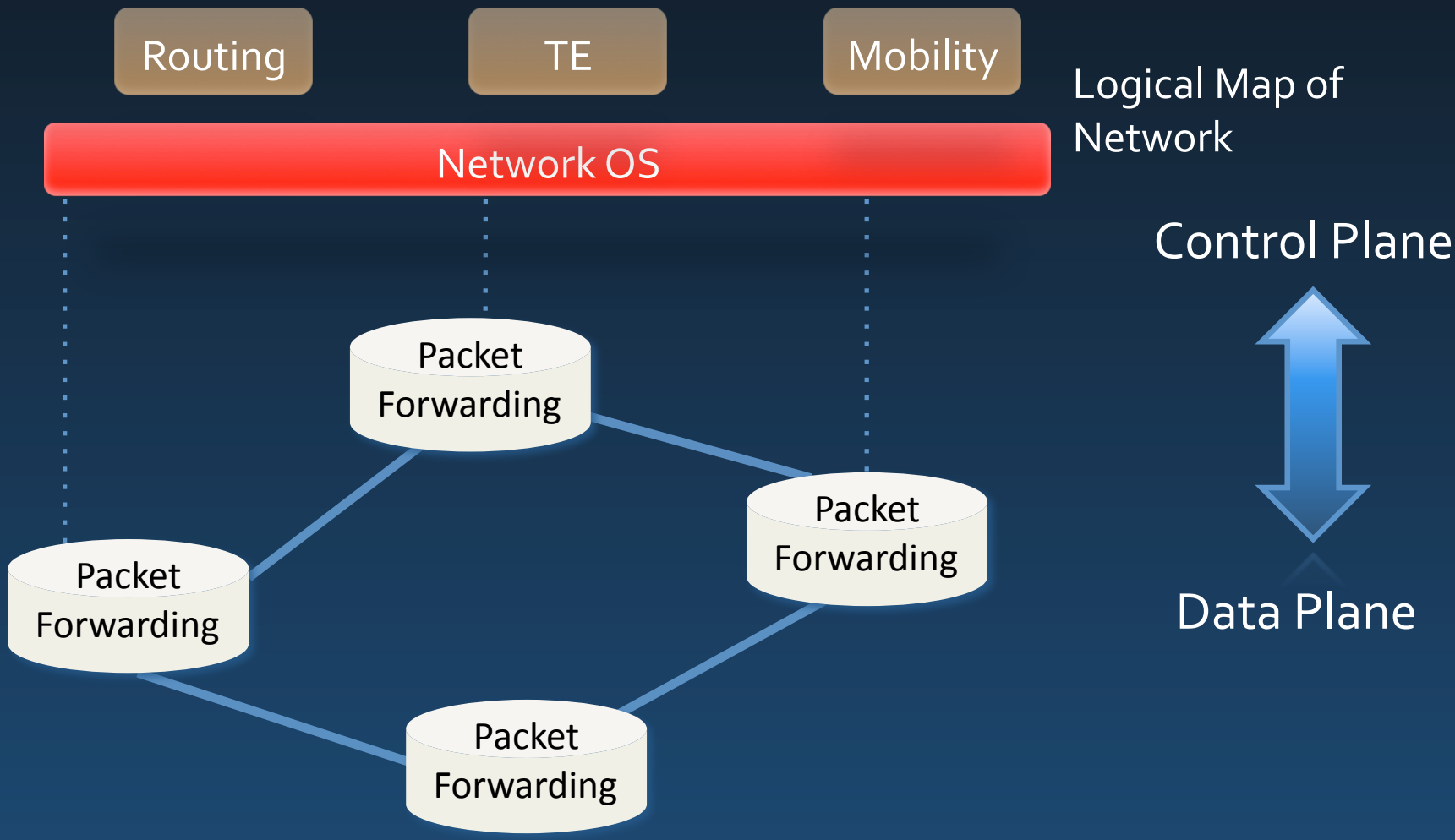


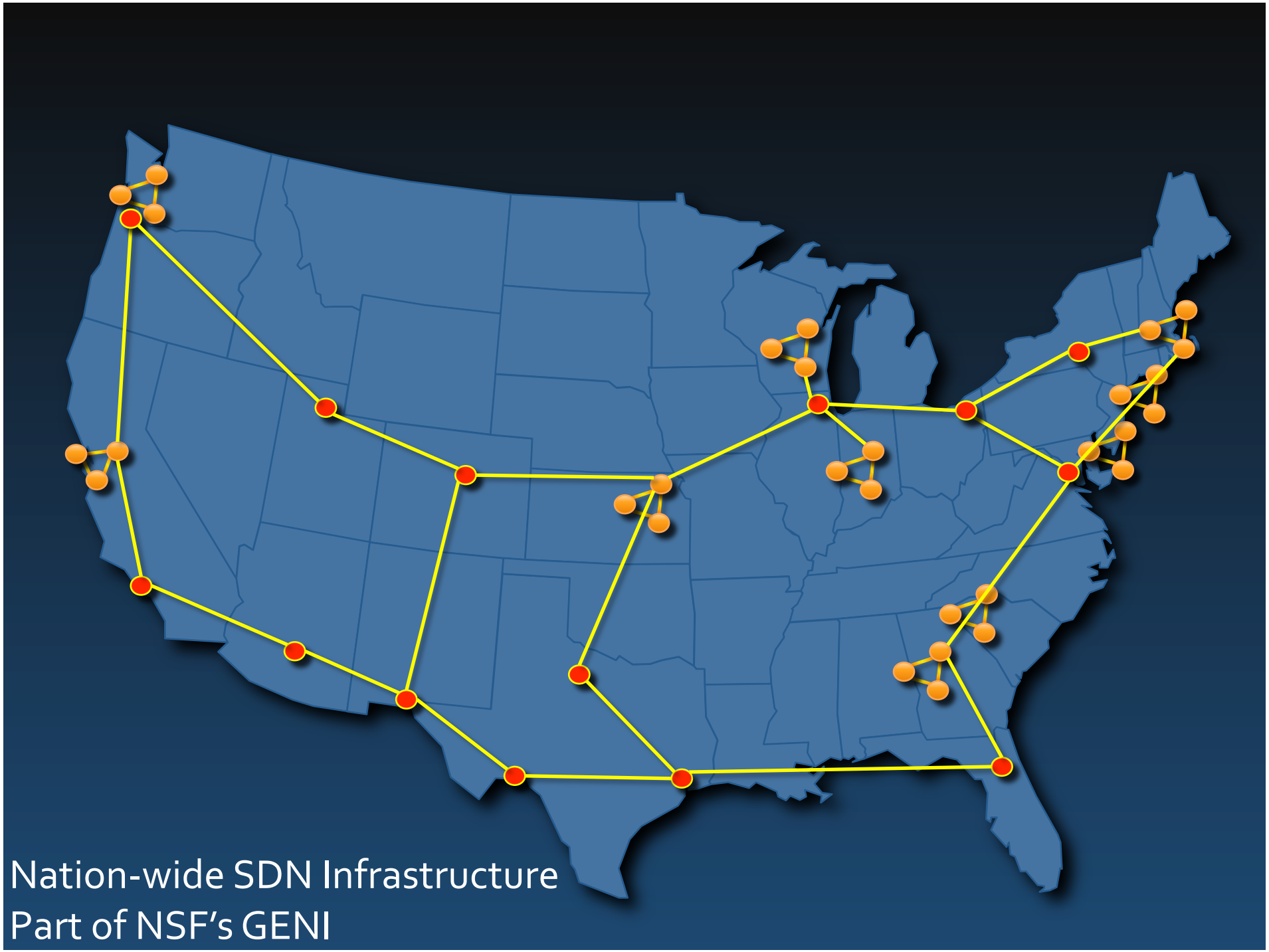
Vertically integrated, complex, closed, proprietary

Not suitable for experimental ideas

Not good for network owners & users; Not good for researchers.

SDN in a Nutshell




Nation-wide SDN Infrastructure
Part of NSF's GENI

Example Research Enabled

- Data center: energy conservation, routing, and management
- Seamless use of diverse wireless networks
- Network based load balancing
- Packet/circuit convergence, traffic engineering
- Simpler control plane for converged packet/circuit MPLS networks
- Slicing and scalable remote control/management of home networks
- Distributed snap shot of VMs (by DOCOMO researchers)
- Inter-domain routing with pathlets (by UIUC)
- Redundant traffic elimination [for CDNs] (by Univ of Wisconsin)
- And many more …

Early Ecosystem

Interest from providers/data center operators

Google Microsoft Deutsche Telekom Level(3) BT

amazon.com facebook NTT docomo verizon

Deployments in R&E Networks

Vendors

NEC hp JUNIPER NETWORKS ARISTA cisco extreme networks ciena HUAWEI FUJITSU DELL NETGEAR big switch networks nicira BROADCOM MARVELL

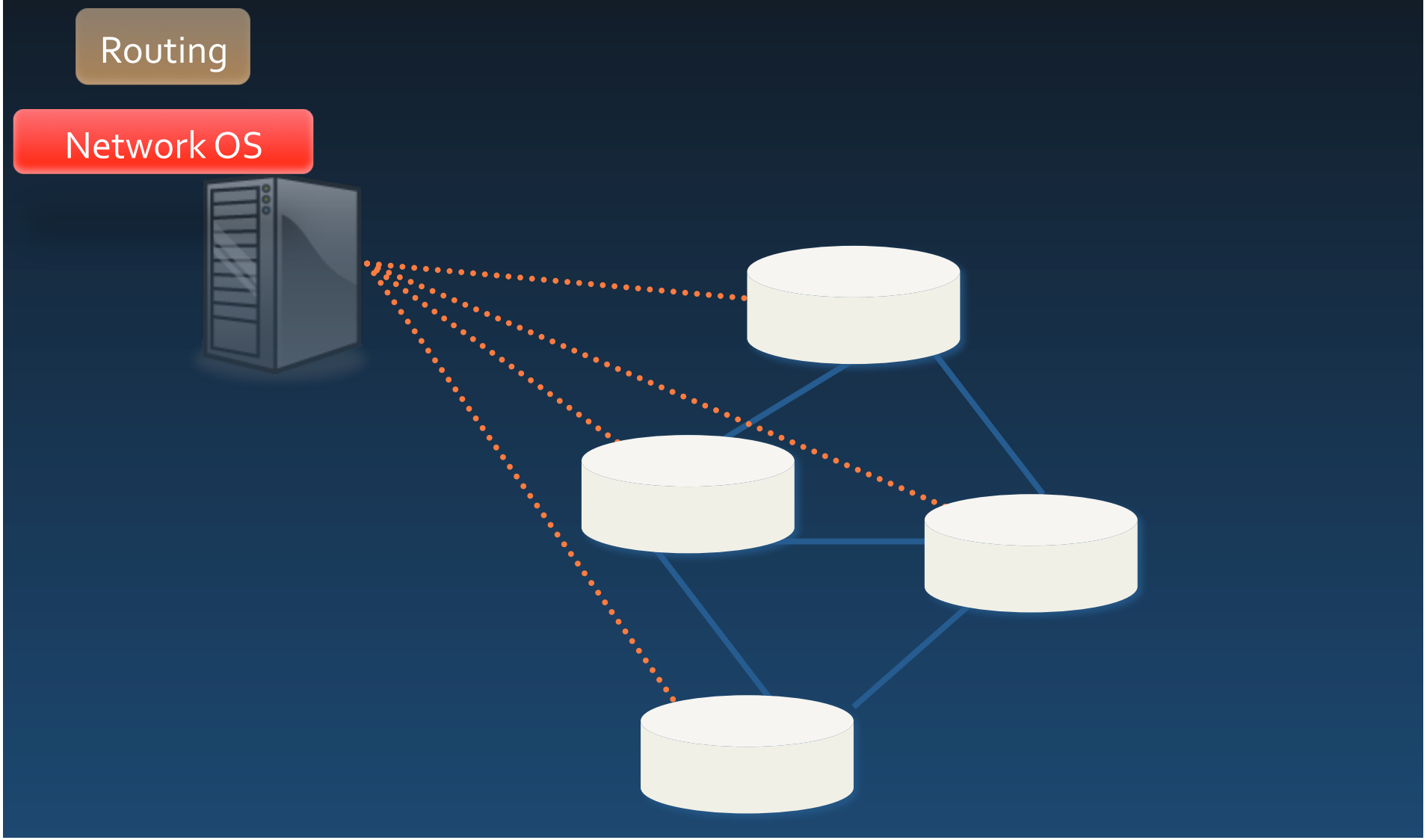
Commitment varies

Important Questions

- How OpenFlow/SDN works?
- Why researchers like it?
- Why providers like it?
- What is next?

OPEN/OpenFlow Basics

Step 1:
Separate Control from Datapath



Step 2:
Cache flow decisions in datapath

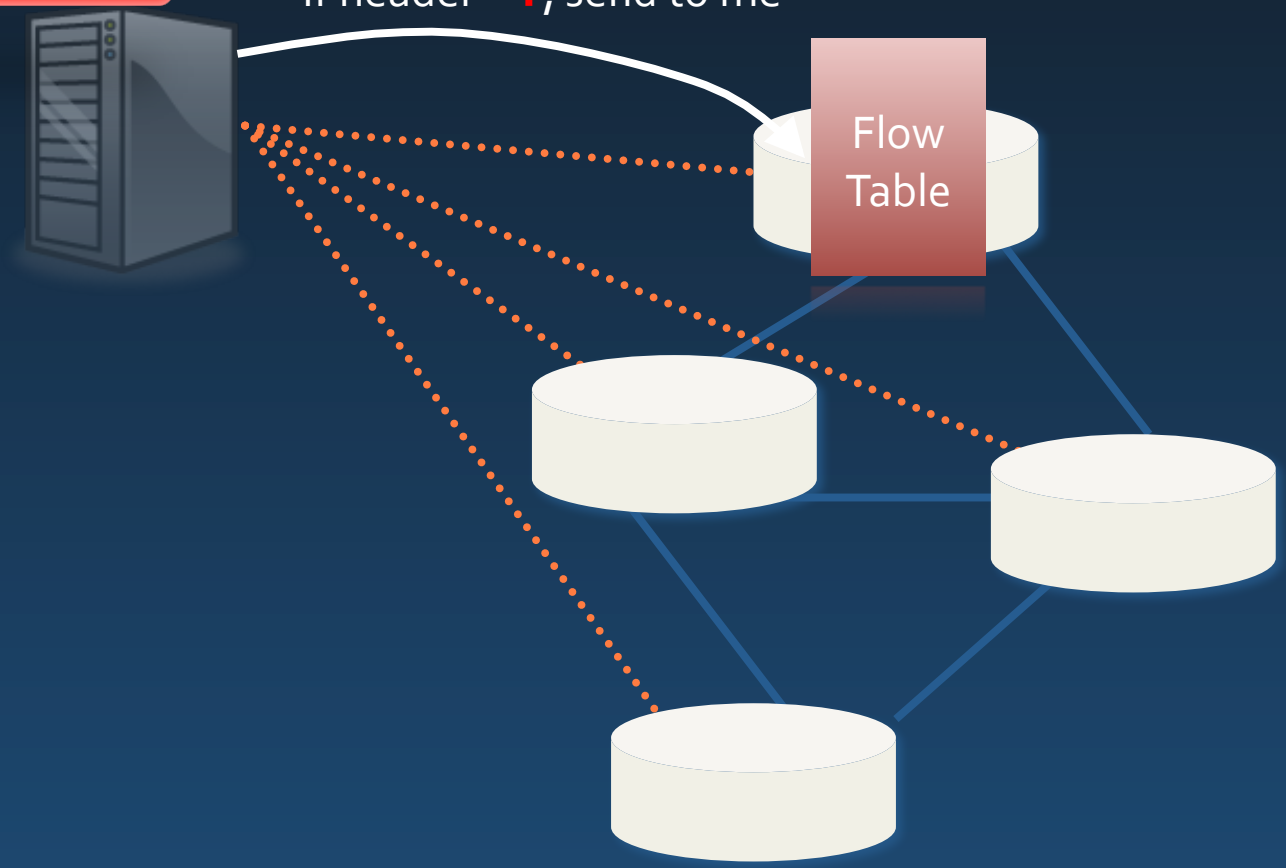
Routing

Network OS

"If header = *x*, send to port 4"

"If header = *y*, overwrite header with *z*, send to ports 5,6"

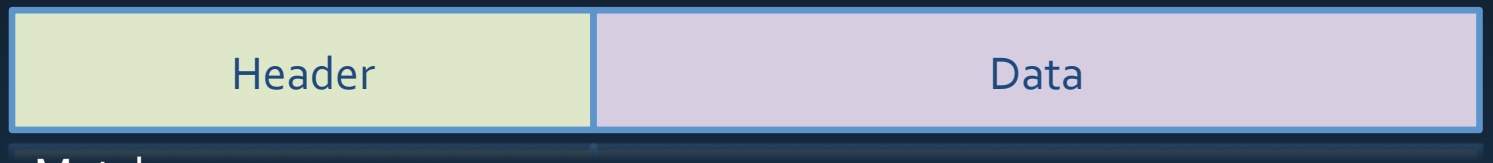
"If header = ?, send to me"



Plumbing Primitives

<Match, Action>

Match arbitrary bits in headers:



- Match on any header, or new header
- Allows any flow granularity

Action

- Forward to port(s), drop, send to controller
- Overwrite header with mask, push or pop
- Forward at specific bit-rate

Why Researchers Like SDN?

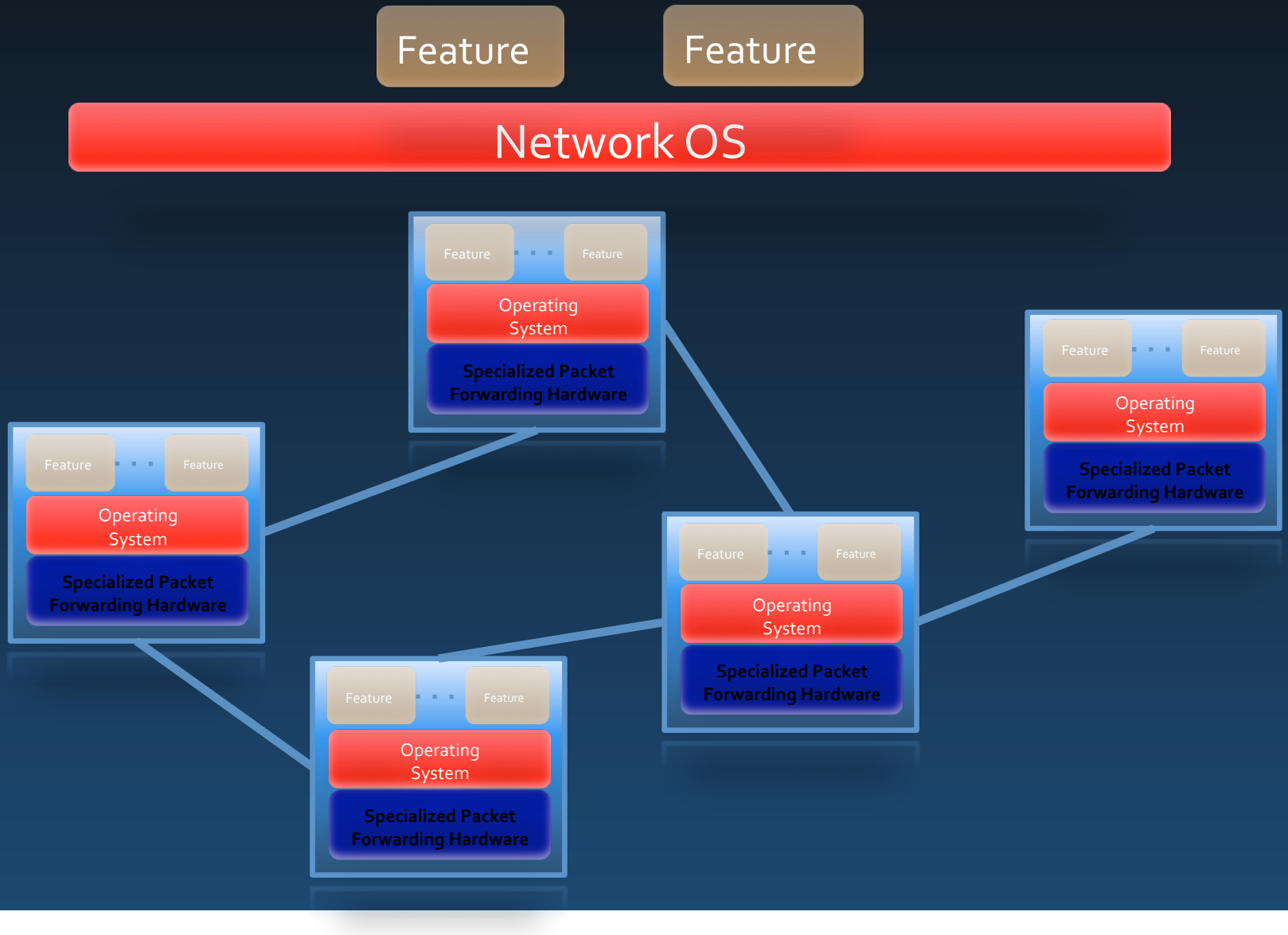
Internet has many problems

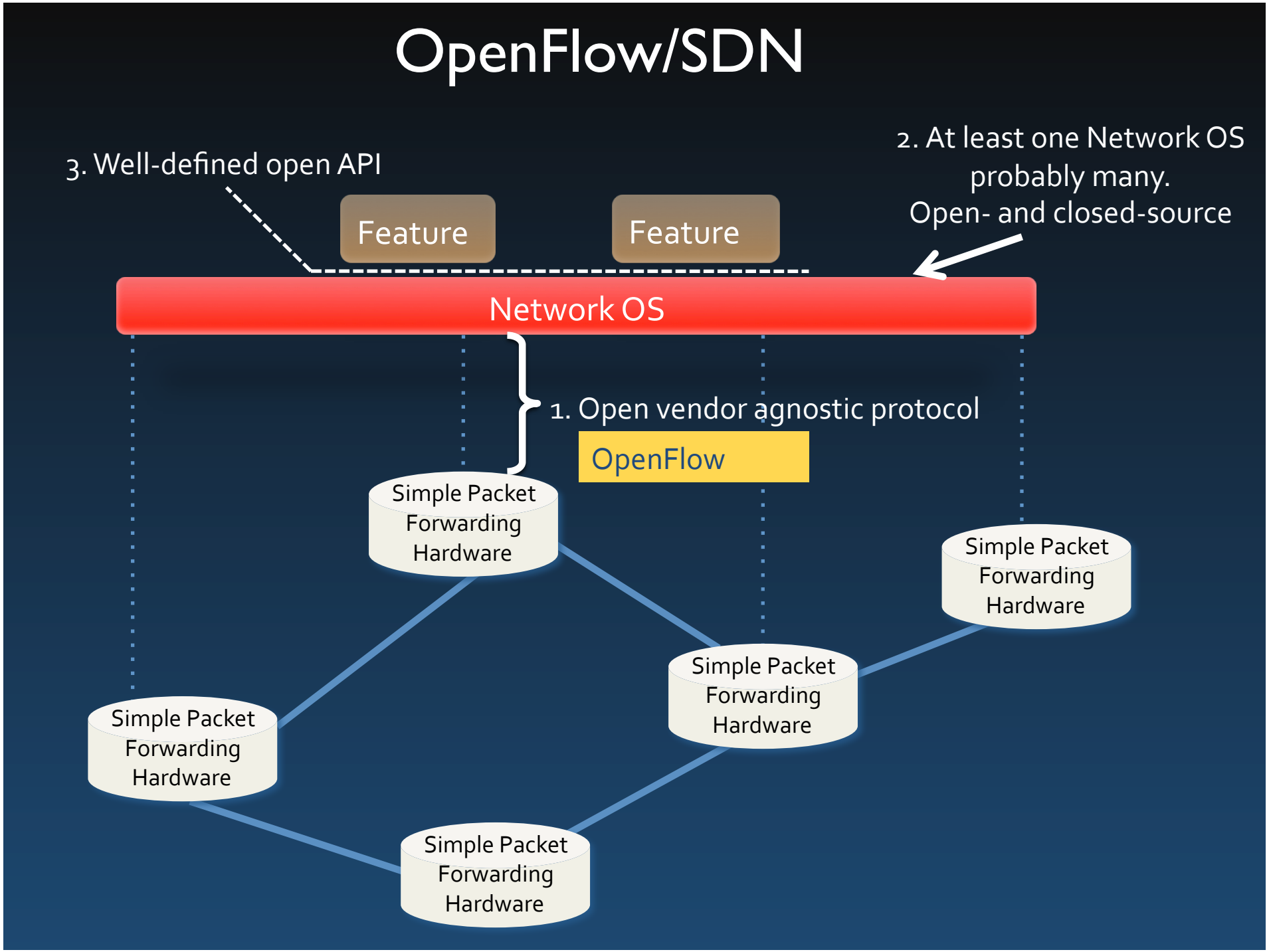
Plenty of evidence and documentation

Internet's "root cause problem"

It is Closed for Innovations

From Vertically Integrated to …

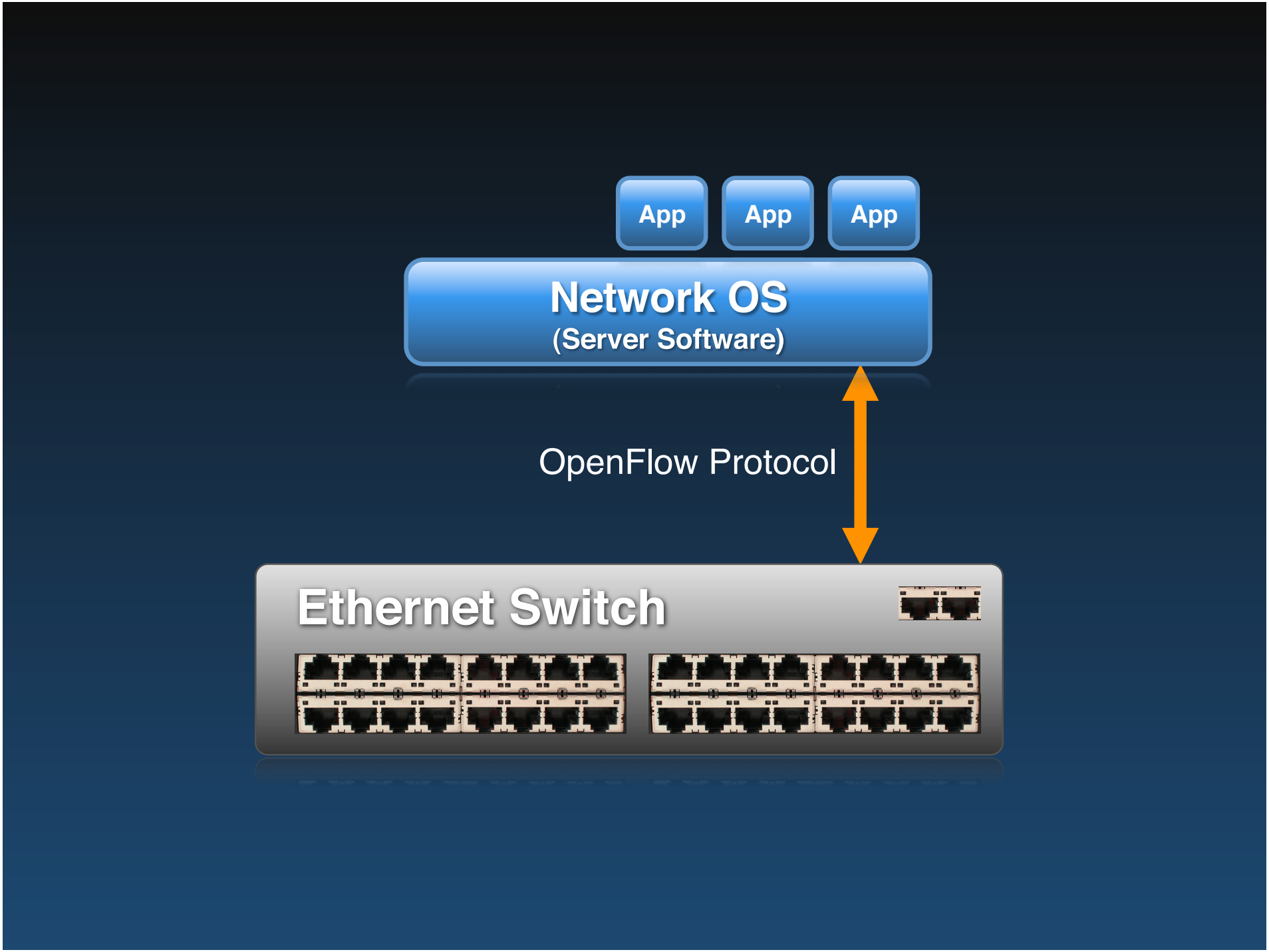



OpenFlow/SDN
3. Well-defined open API
2. At least one Network OS
probably many.
Open- and closed-source
Feature
Feature
Network OS
1. Open vendor agnostic protocol
OpenFlow
Simple Packet Forwarding Hardware
Simple Packet Forwarding Hardware
Simple Packet Forwarding Hardware
Simple Packet Forwarding Hardware
Simple Packet Forwarding Hardware

Promising

but

How do we build SDN Network for Internet-Scale experiments?


App
App
App
Network OS
(Server Software)
OpenFlow Protocol
Ethernet Switch

OpenFlow Enabled "Switches"

Prototypes or products

Wireline switches

- HP, NEC, Juniper, Quanta, Netgear, …
- 12+ vendors demonstrating at Interop

Switching chips

- Reference designs: Broadcom, Marvell

Transport switches

- Ciena, Fujitsu

WiFi APs and WiMAX Basestations

Network OS

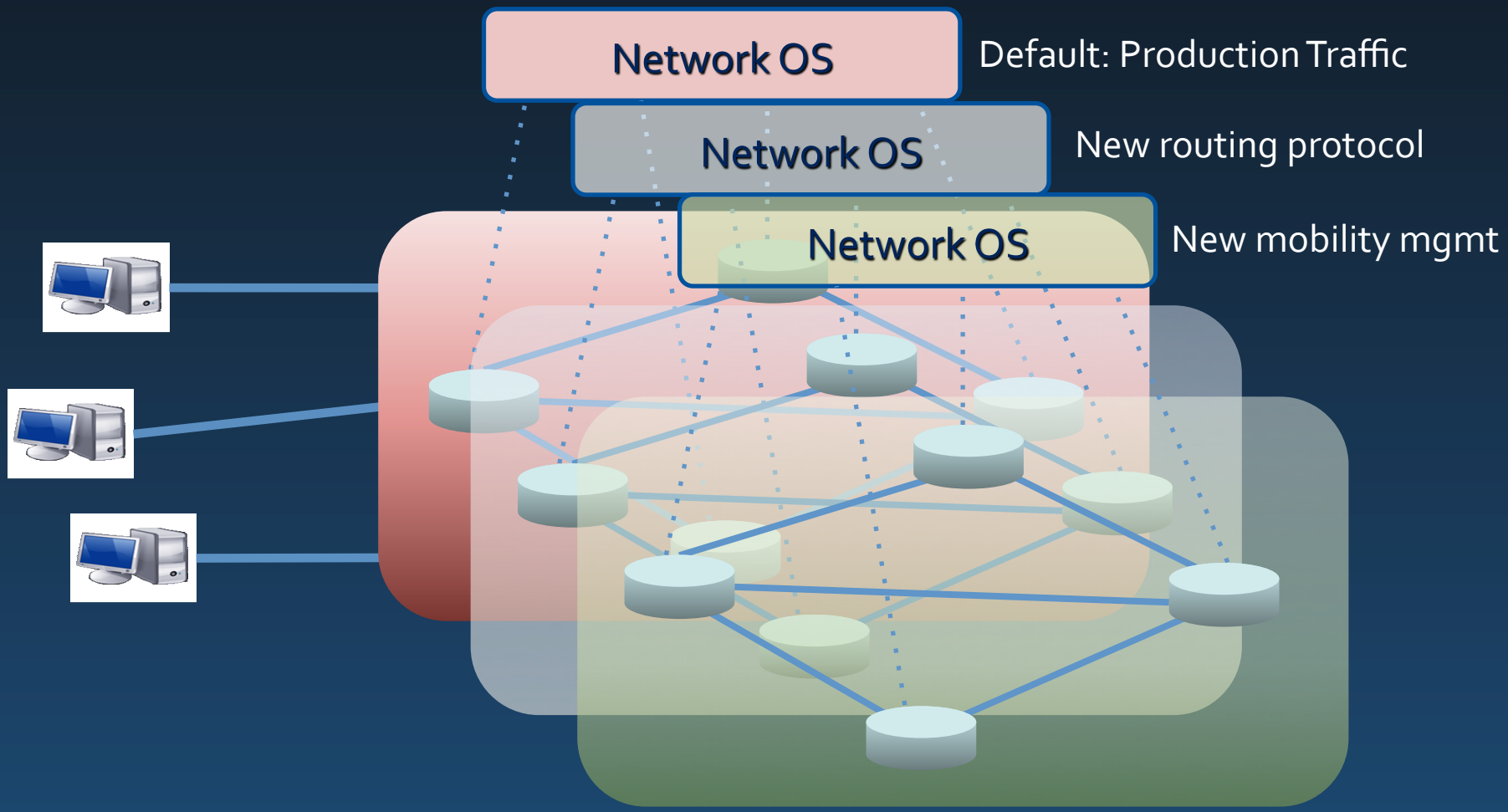
Research

- NOX (C++/Python) http://noxrepo.org
- Beacon (Java) coming soon.
- Others in development

Commercial

- ONIX [OSDI 2010, Google, Nicira, NEC]
- Expect others

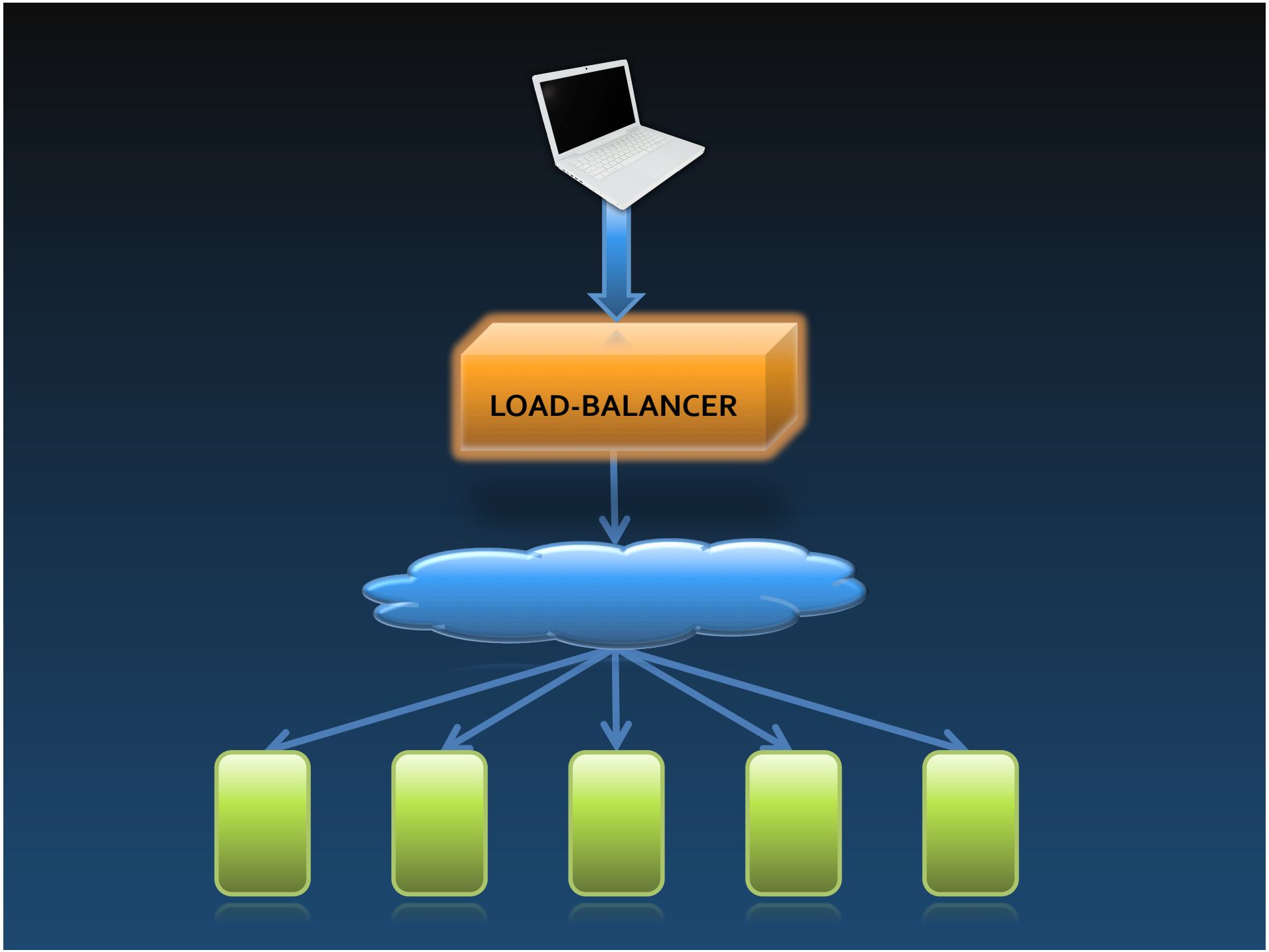
Slicing and Virtualization

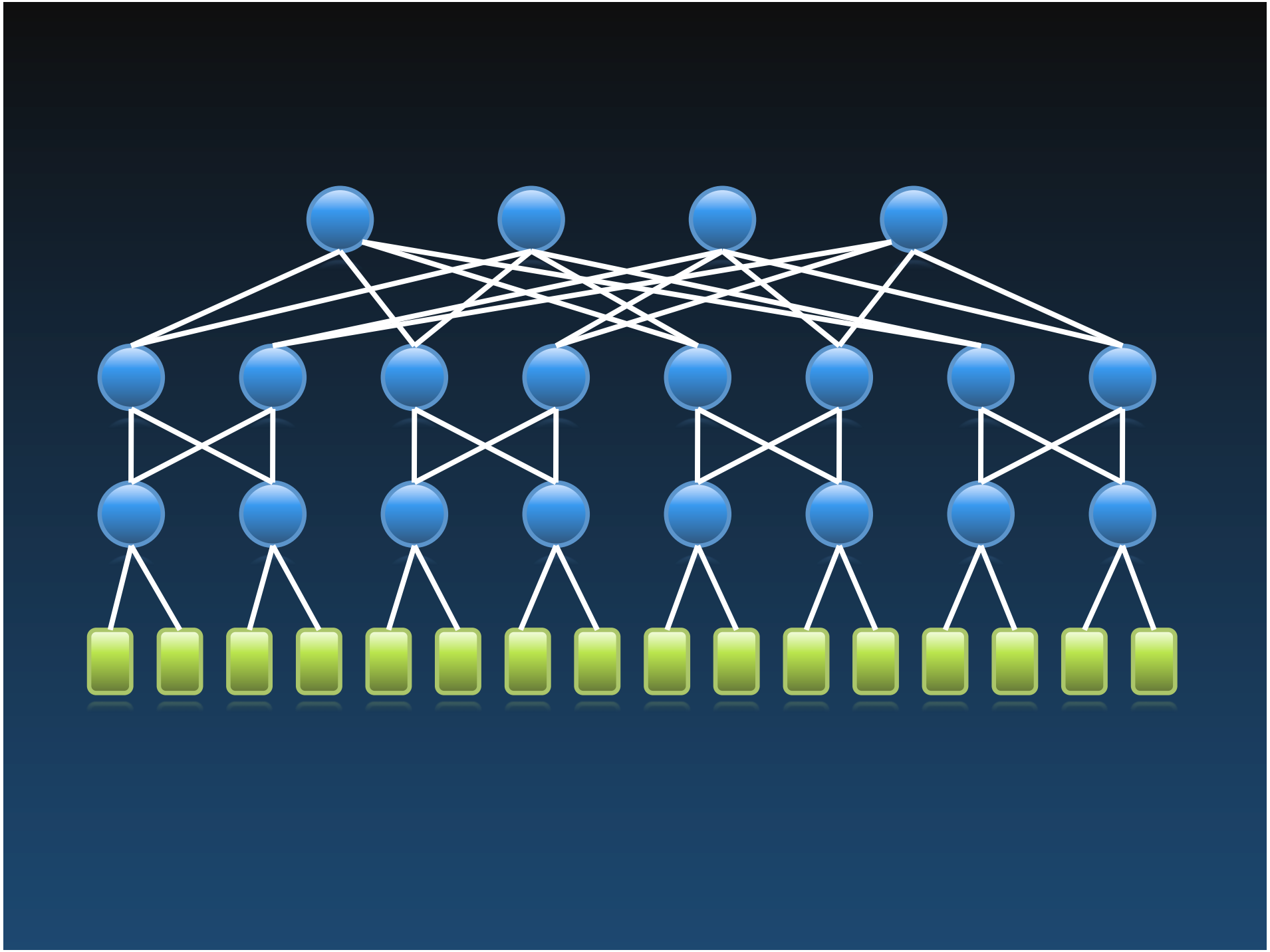


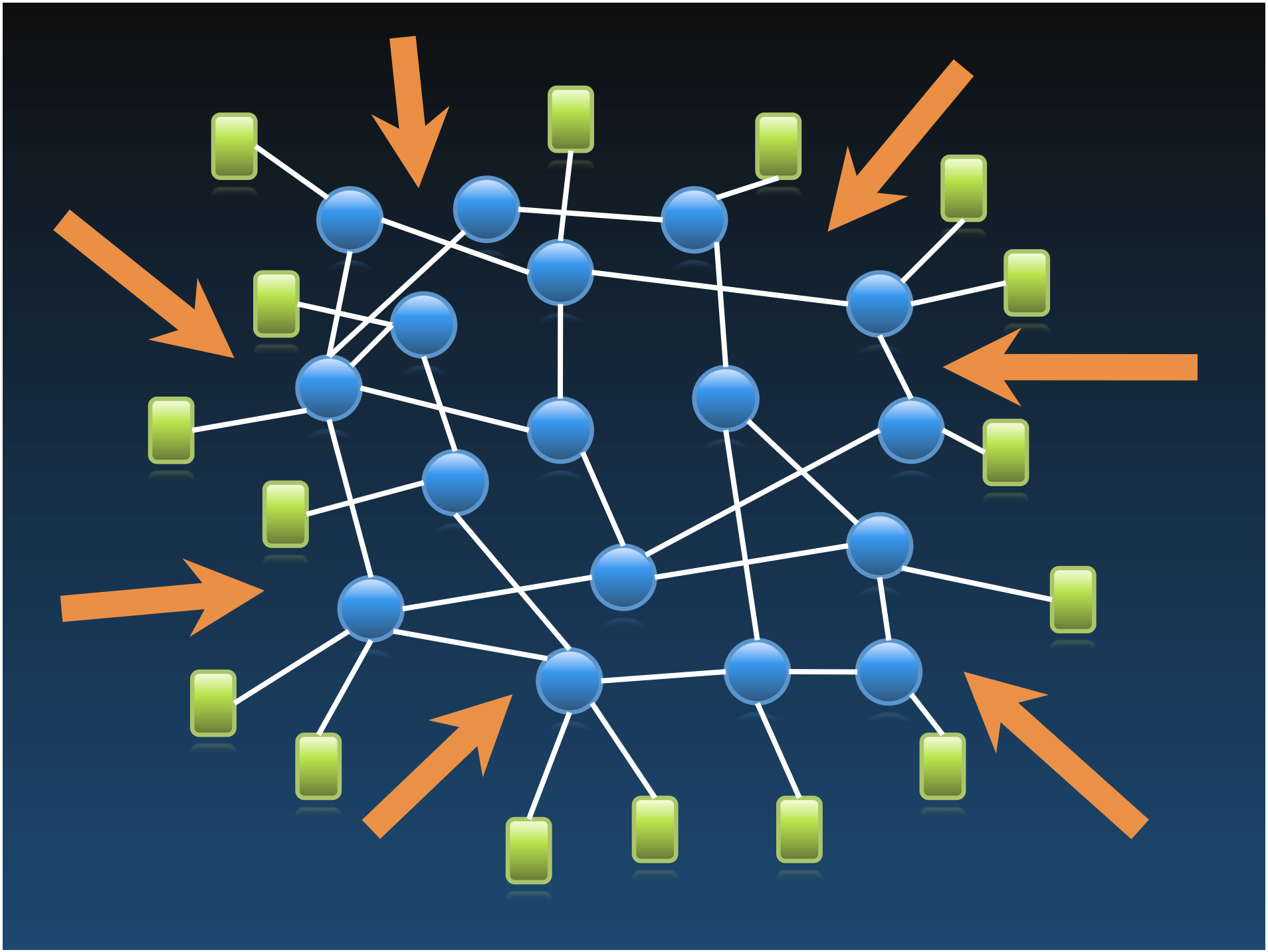
Research Experiments

Example 1
Load-balancing as a network primitive

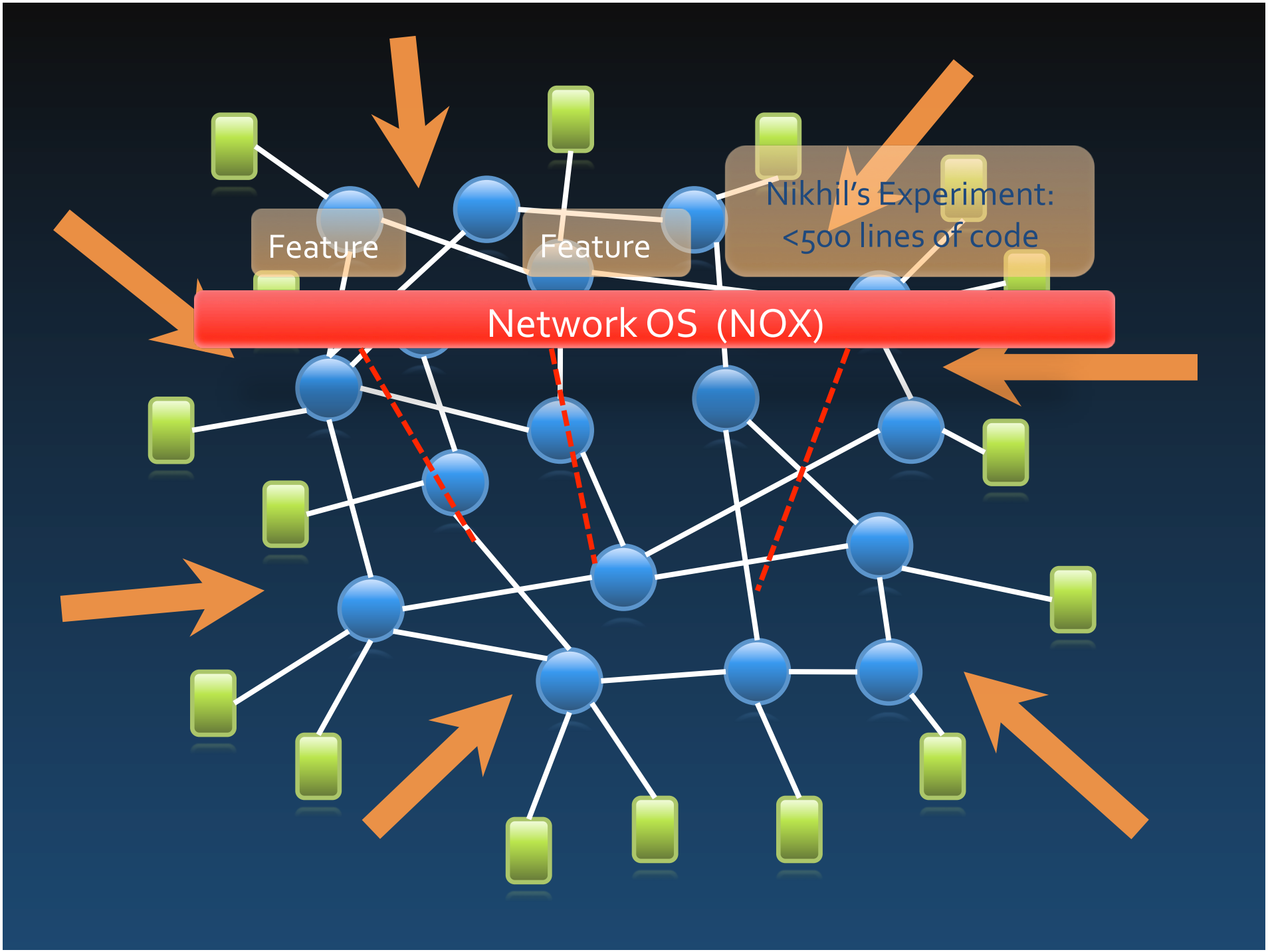
Nikhil Handigol, Mario Flajslik, Srini Seetharaman


LOAD-BALANCER





Load Balancing is just Smart Routing


Feature
Feature
Nikhil's Experiment:
<500 lines of code
Network OS (NOX)

Example 2
Using all the wireless capacity around us

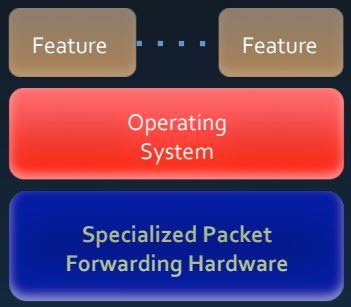
KK Yap, Masayoshi Kobayashi, Yiannis Yiakoumis, TY Huang


KK's Experiment:
<250 lines of code
Feature
Network OS (NOX)

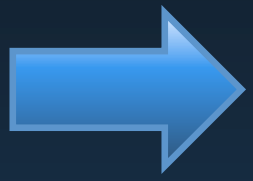
More Experiments and Videos

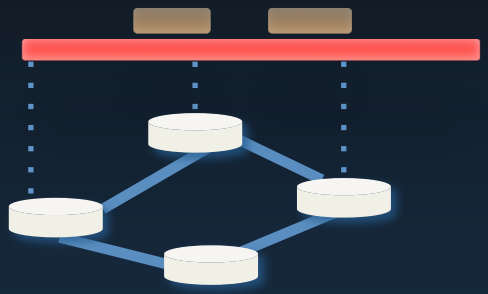
http://www.openflow.org/videos/

Why Researchers Like SDN?



Vertically integrated, closed, proprietary





OpenFlow/SDN

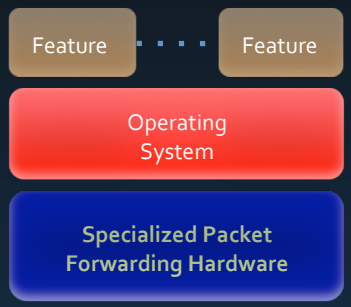
SDN enables

- Research and innovation in networking
- Experimentation at scale in a production setting

Leading to impact on actual practice of networking

Why Providers Like SDN?

Why Providers Like SDN?



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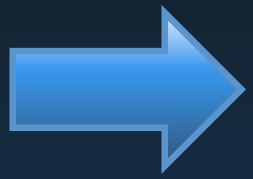
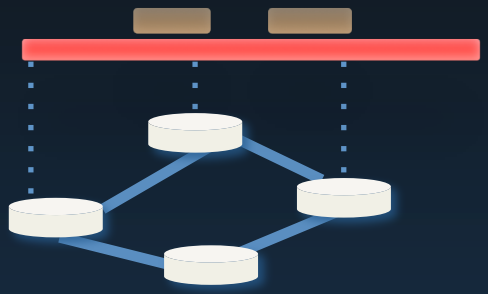




OpenFlow/SDN

- Much lower Capex and Opex
  - Simpler boxes and more competition
- Increased rate of innovation to enable
  - Solutions to persistent Internet problems
  - Creation of new revenue generating services

Telco Operators

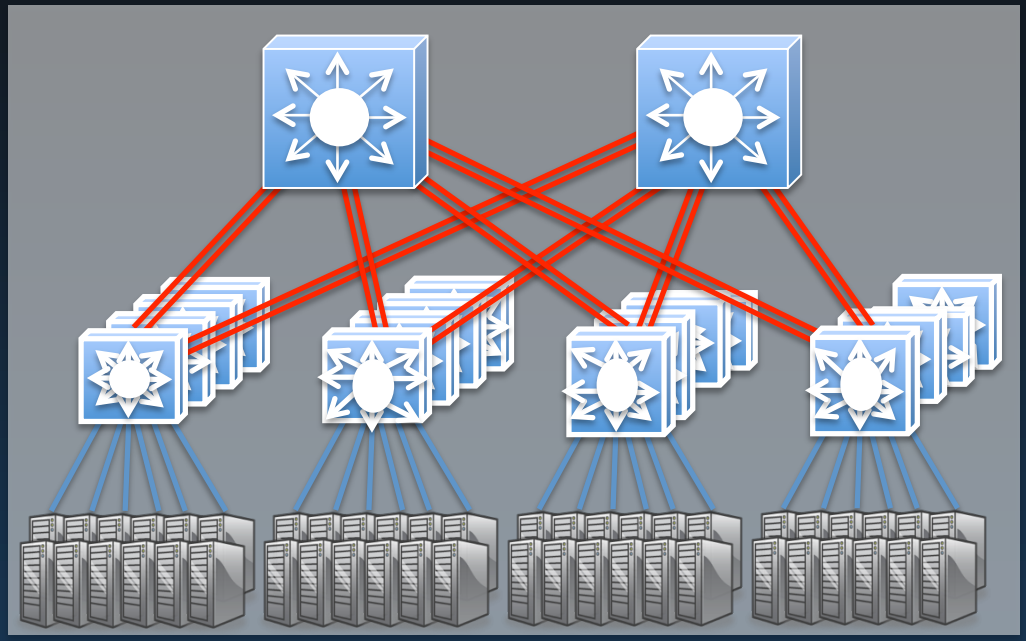
- Global IP traffic growing 40-50% per year
- End-customer monthly bill remains unchanged
- Therefore, CAPEX and OPEX need to reduce 40-50% per Gb/s per year
- But in practice, reduces by ~20% per year
- SDN has the potential to
  - significantly reduce capex and opex
  - help create new revenue generating services

Cellular Providers

- Billions of mobile users with exponential growth in data
- Cellular providers need
  - Support for mobility and security
  - Increasing wireless capacity that is not there
- Recently made transition to IP
  - But IP is terrible at mobility and security
  - Not flexible enough to allow change
- SDN has the potential to
  - significantly reduce capex and opex
  - help find solutions to mobility, security, capacity problems

Data Center Owners

A new data center



Cost

200,000 servers
Fanout of 20 ➔ 10,000 switches
$5k vendor switch = $50M
$1k commodity switch = $10M

Savings in 10 data centers = $400M

Control

More flexible control
Tailor network for services
Quickly improve and innovate

Open Network Foundation

www.opennetworkingfoundation.org

to continue standardization of OpenFlow and other SDN interfaces/APIs

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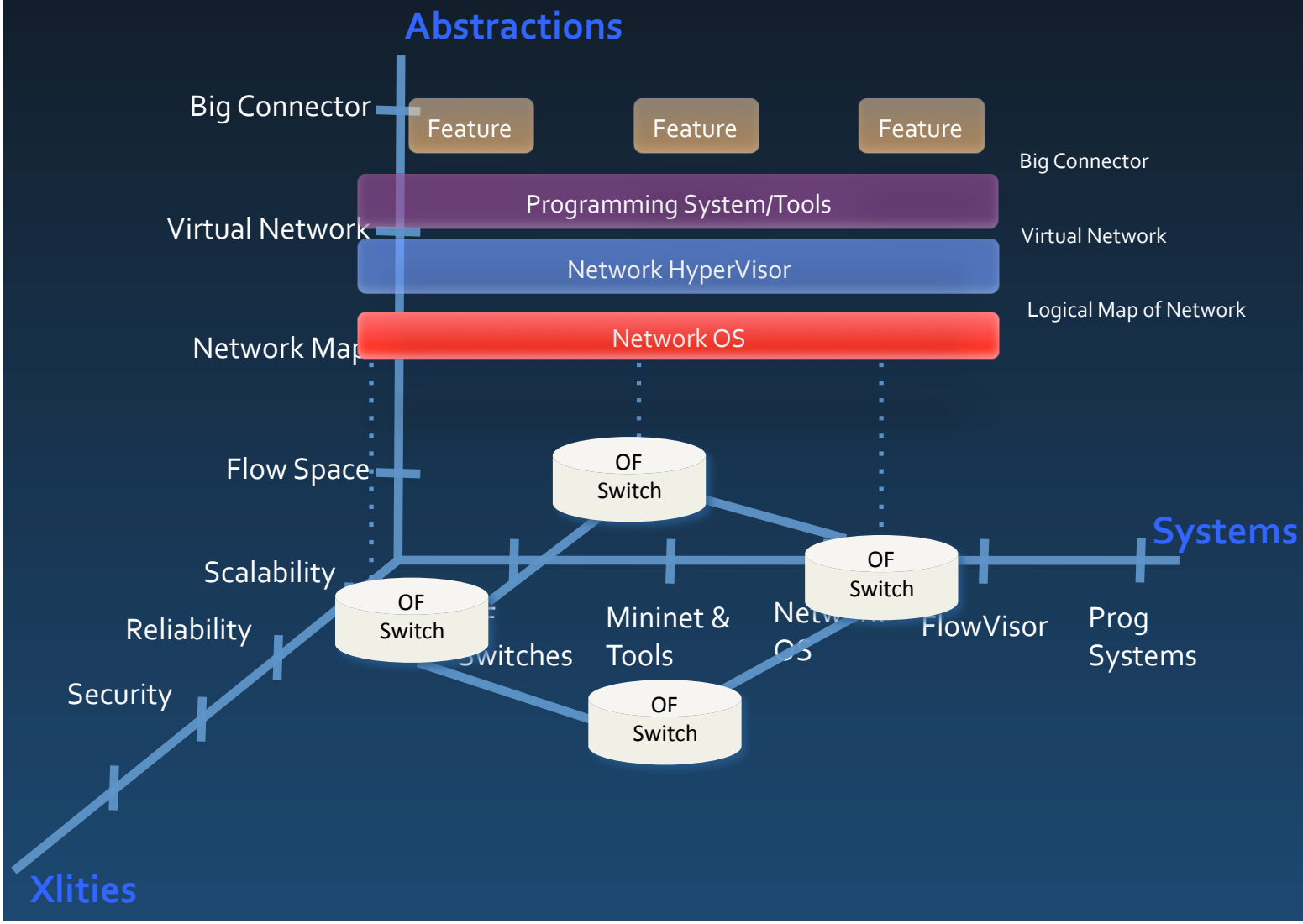
What is next?

Research and Development Agenda

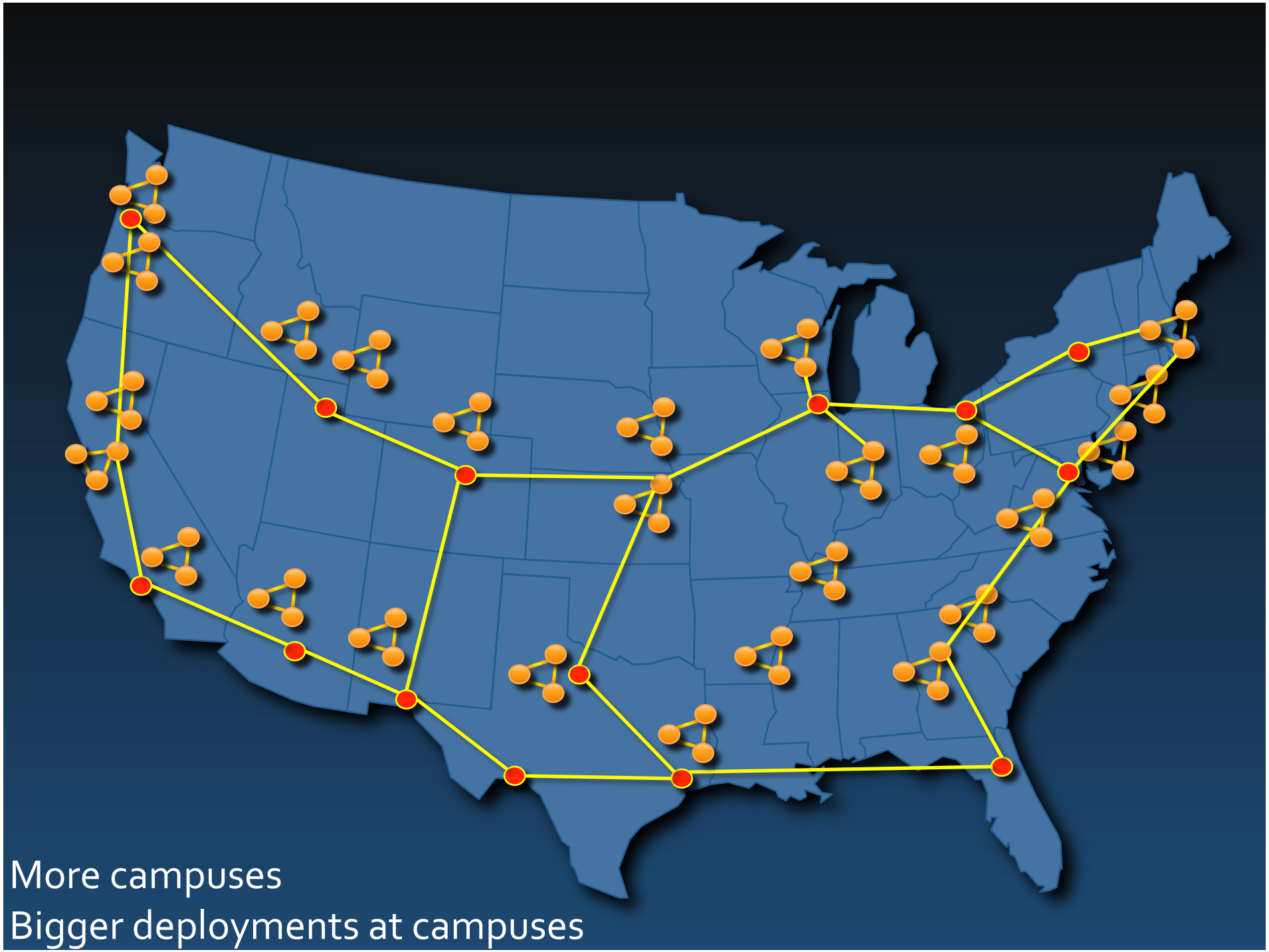
- Continue to develop SDN
  - Scientific foundation
  - Technologies and systems

  Enable research community
- Explore various domains of use
  - Data center, enterprise, service provider, home, …
  - Showcase deployments
- Demonstrate new use cases on SDN
  - Enable research community
- Build partnerships to accomplish goals
  - We cannot do it all

Scope of Activities



Internet2 NDDI


More campuses
Bigger deployments at campuses

How can we bring SDN to your agency and your researchers and users?

Final Takeaways

- OpenFlow/SDN enables innovation within
  - Enterprise, backbone, cellular, home & data center networks
  - Represents a promising architecture direction
- Providers like it for their own reasons
  - Enabling an ecosystem
  - OpenFlow being deployed in R&E networks around the world

Time to engage and help shape this important revolution in networking