



Stanford Clean Slate Program

<http://cleanslate.stanford.edu>



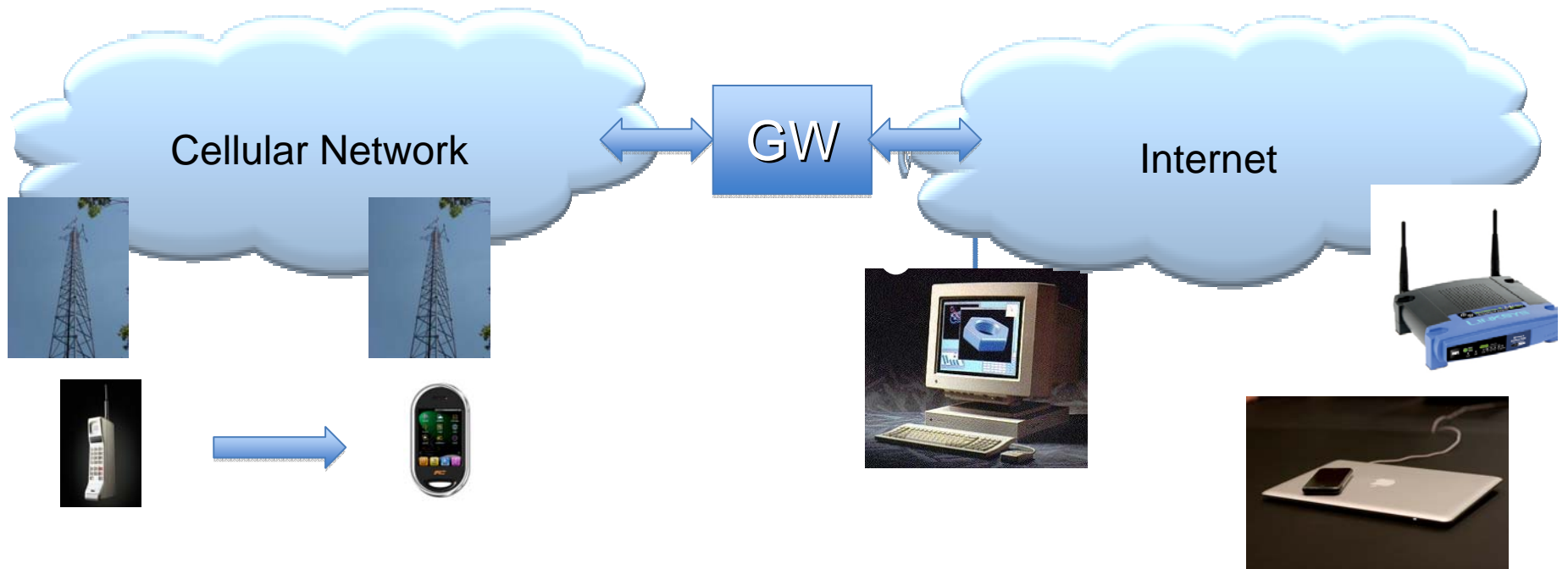
OpenFlow Wireless

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Funded by Cisco, Deutsche Telekom, DoCoMo, Ericsson, Google, LightSpeed, MDV, NEC, NSF, Xilinx

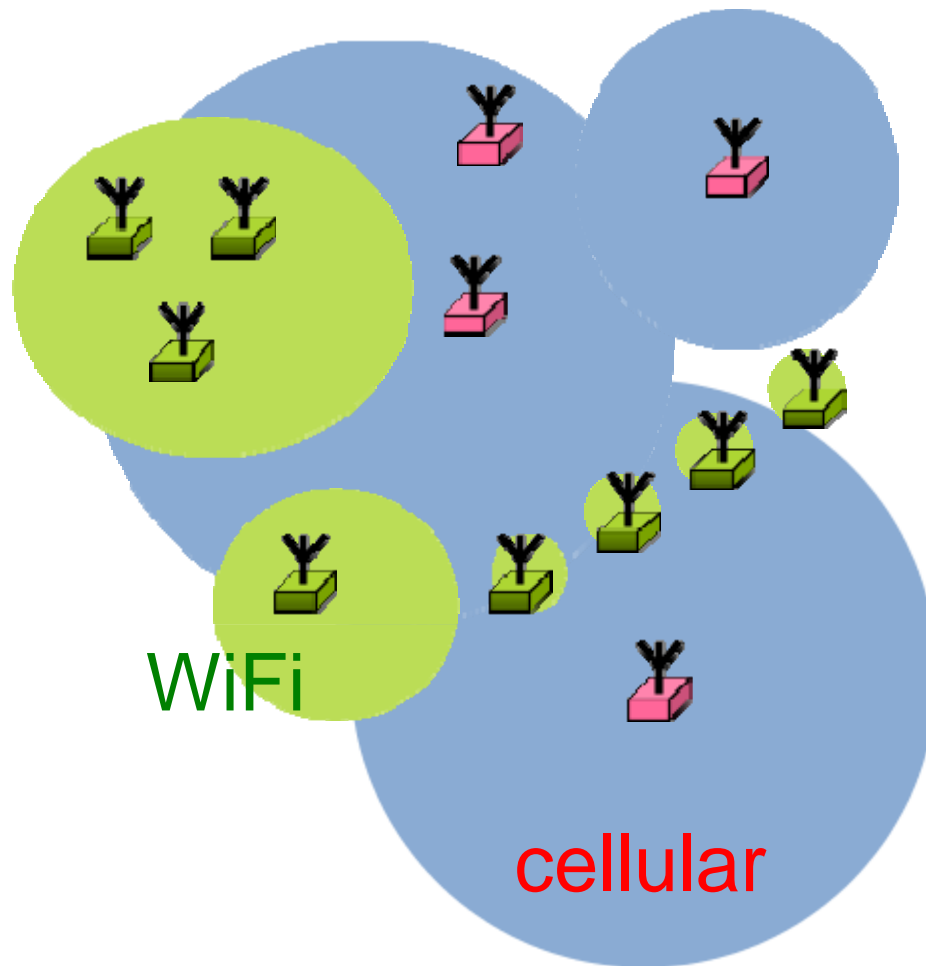
Cellular Networks and Internet



- Two phenomenally successful infrastructures
- Smart phones and data starting to dominate
- Lots of action and growth

So what is wrong?

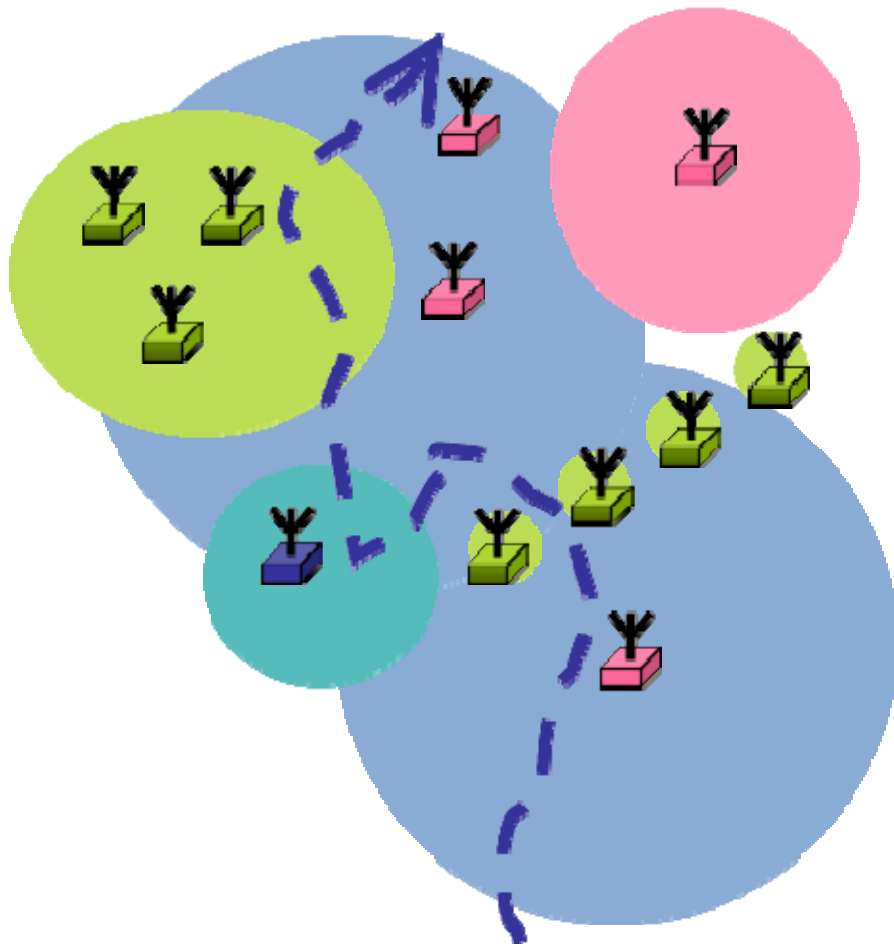
Mobile Network Infrastructure Today



- Many cellular networks visible (5-7 common), many wifi networks visible (10-15 common).
- But not practically available to me – closed infrastructures.
- Seamless mobility impossible

Why can't I use of all the infrastructure around me?

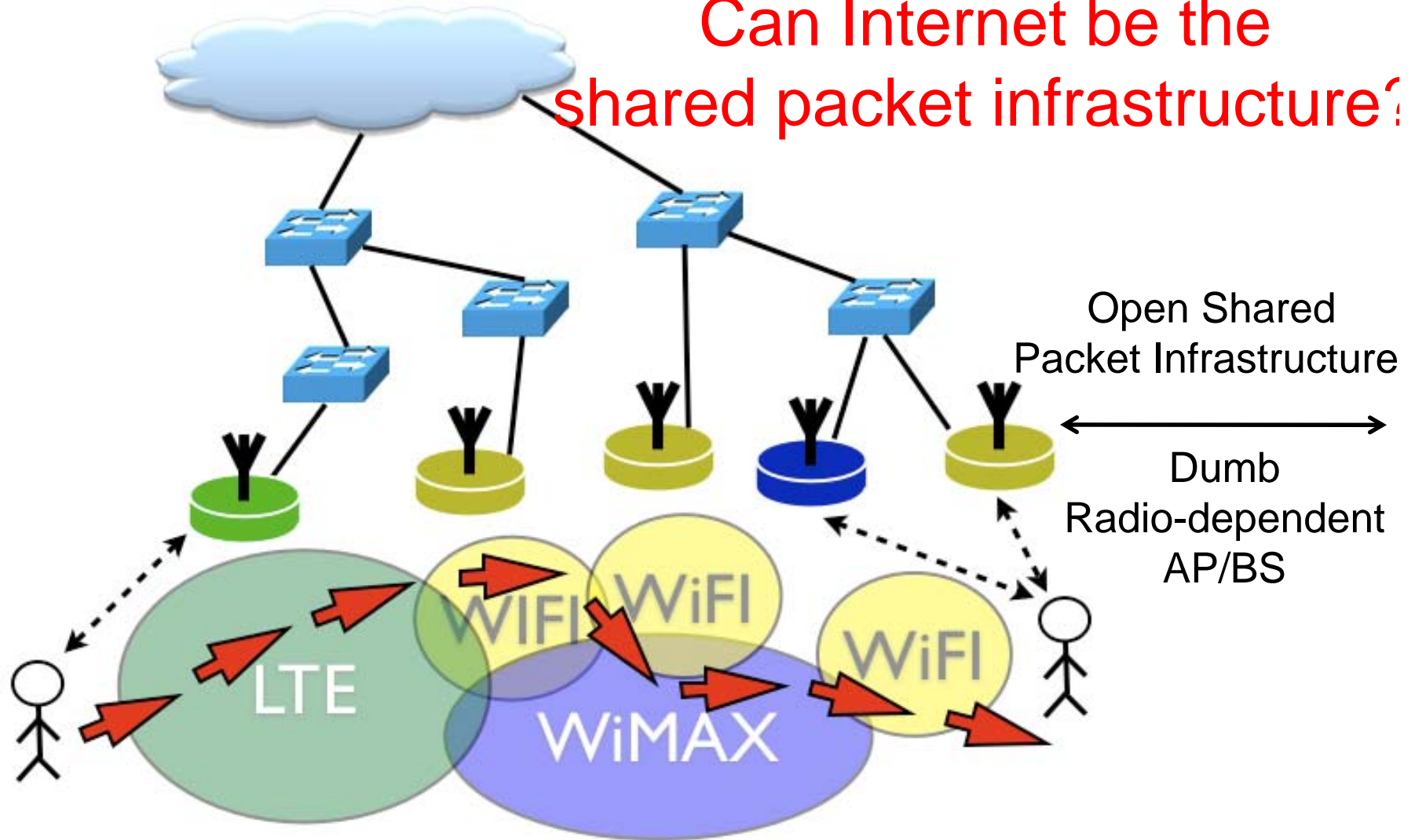
Ideally, in Future Wireless Network Substrate we want



- Simultaneous access to all infrastructure
- Continued connectivity and seamless mobility as I move
- Maximal user choice
- Allow innovation, instead of closing the infrastructure

Ideally we want

Can Internet be the shared packet infrastructure?



Internet has many problems

Plenty of evidence and documentation

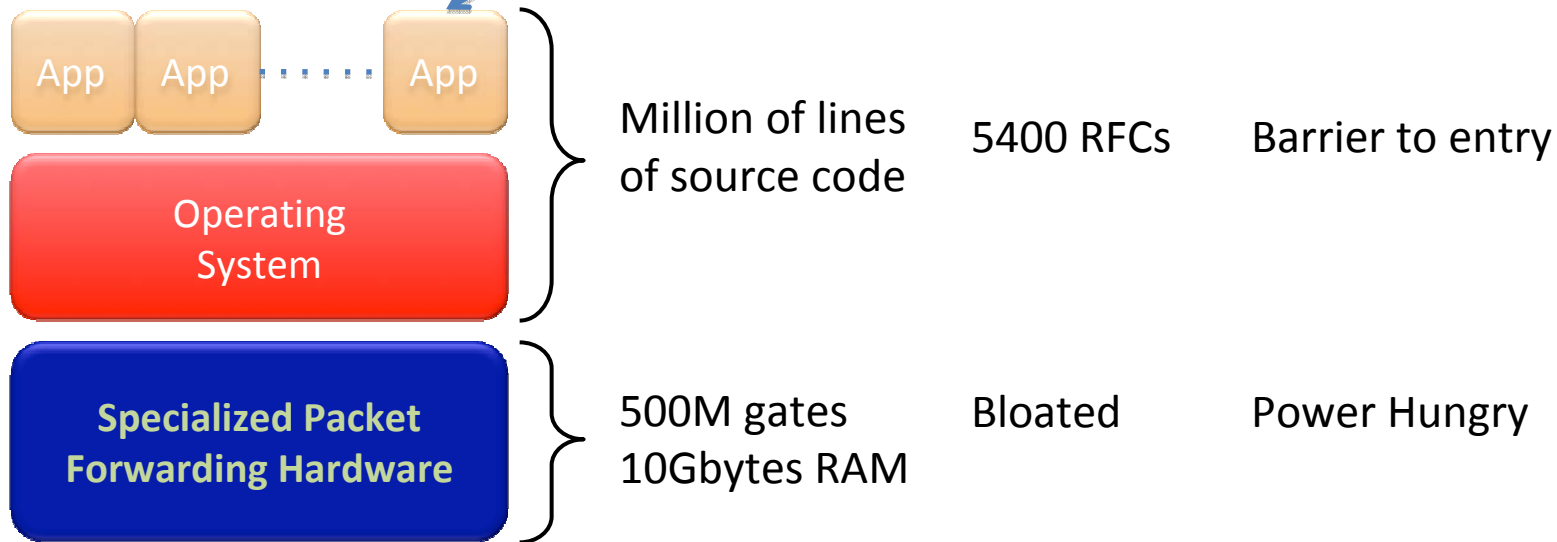
Internet's "root cause problem"

It is Closed for Innovations



We have lost our way

Routing, management, mobility management, access control, VPNs, ...

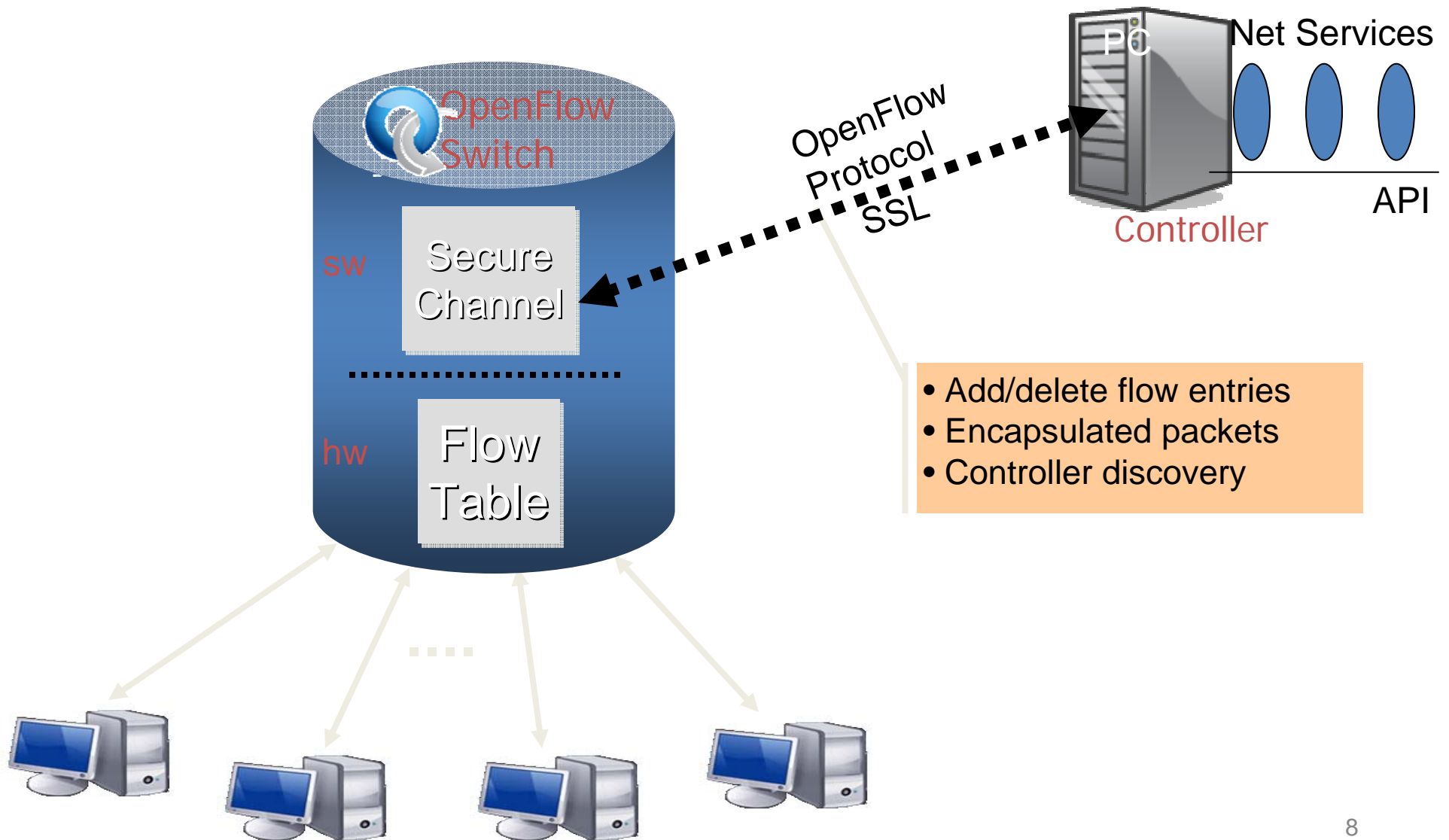


Many complex functions baked into the infrastructure

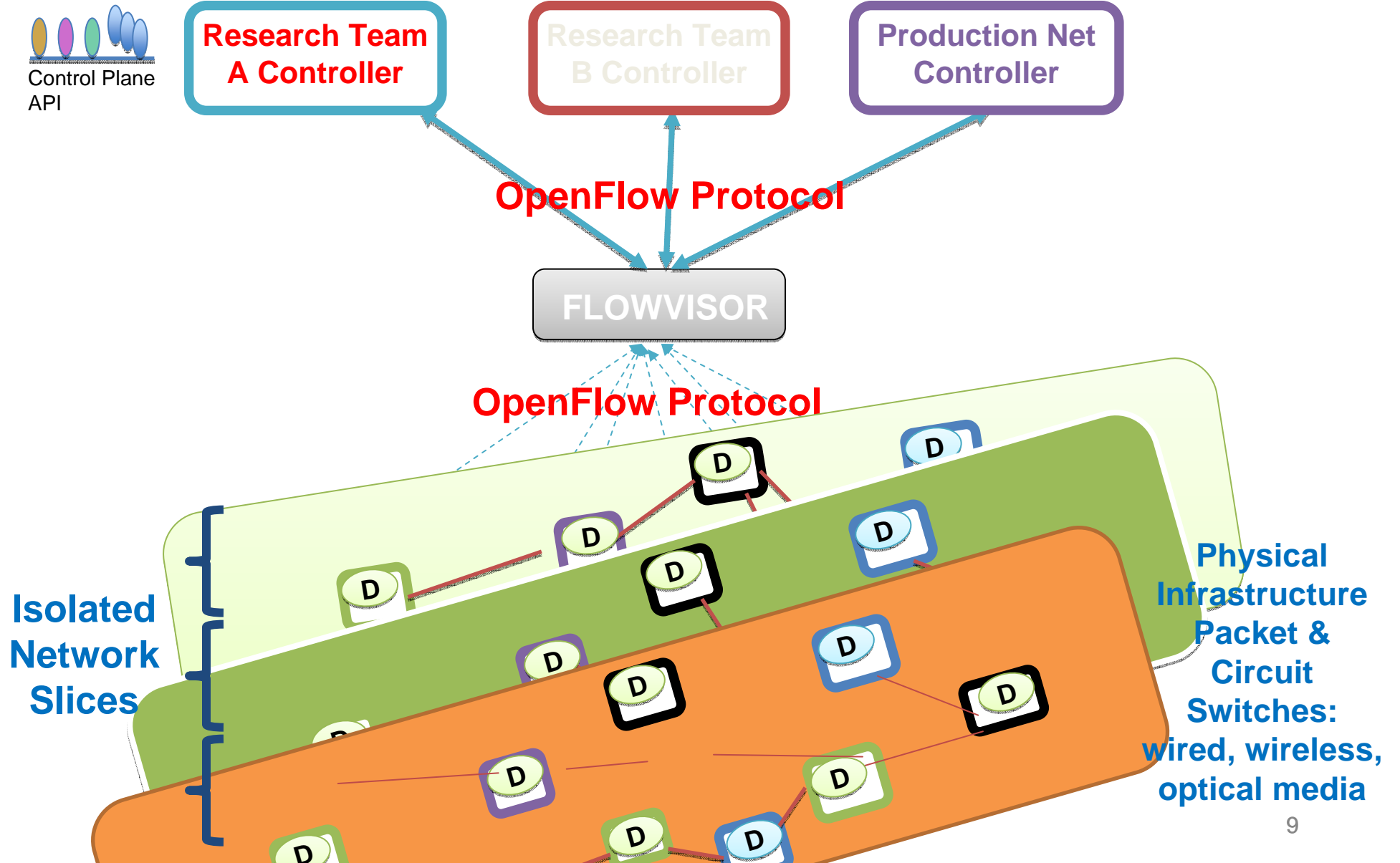
OSPF, BGP, multicast, differentiated services, Traffic Engineering, NAT, firewalls, MPLS, redundant layers, ...

An industry with a “mainframe-mentality”

OpenFlow: Enable Innovations “within” the Infrastructure



Sliced and Virtualized OpenFlow Infrastructure



Example Network Services

- New routing protocol: unicast, multicast, multipath, load-balancing
- Inter-domain routing
- Network access control
- VLAN management
- Mobile VM management
- Mobility and handoff management
- Energy management
- Network measurement and visualization
- IPvX
- ...

OpenFlow Enabled Equipments



Core Router

Cisco Catalyst 6k (prototype)



Juniper MX-series



HP Procurve 5400



Enterprise Campus Data Center

Cisco Catalyst 3750 (prototype)



Arista 7100 series (Q4 2010)



Quanta LB4G



NEC IP8800



Circuit Switch



Ciena CoreDirector

Wireless

WiMAX (NEC)



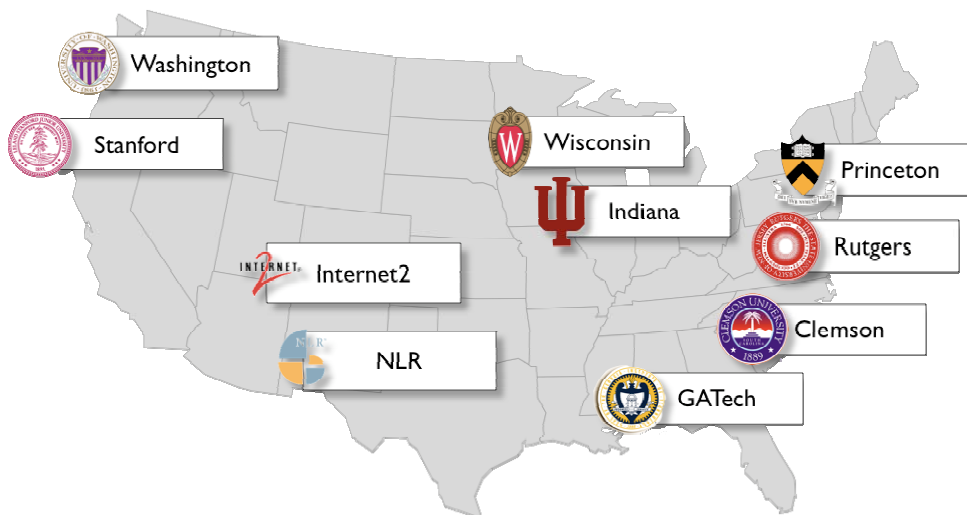
WiFi



More to follow...

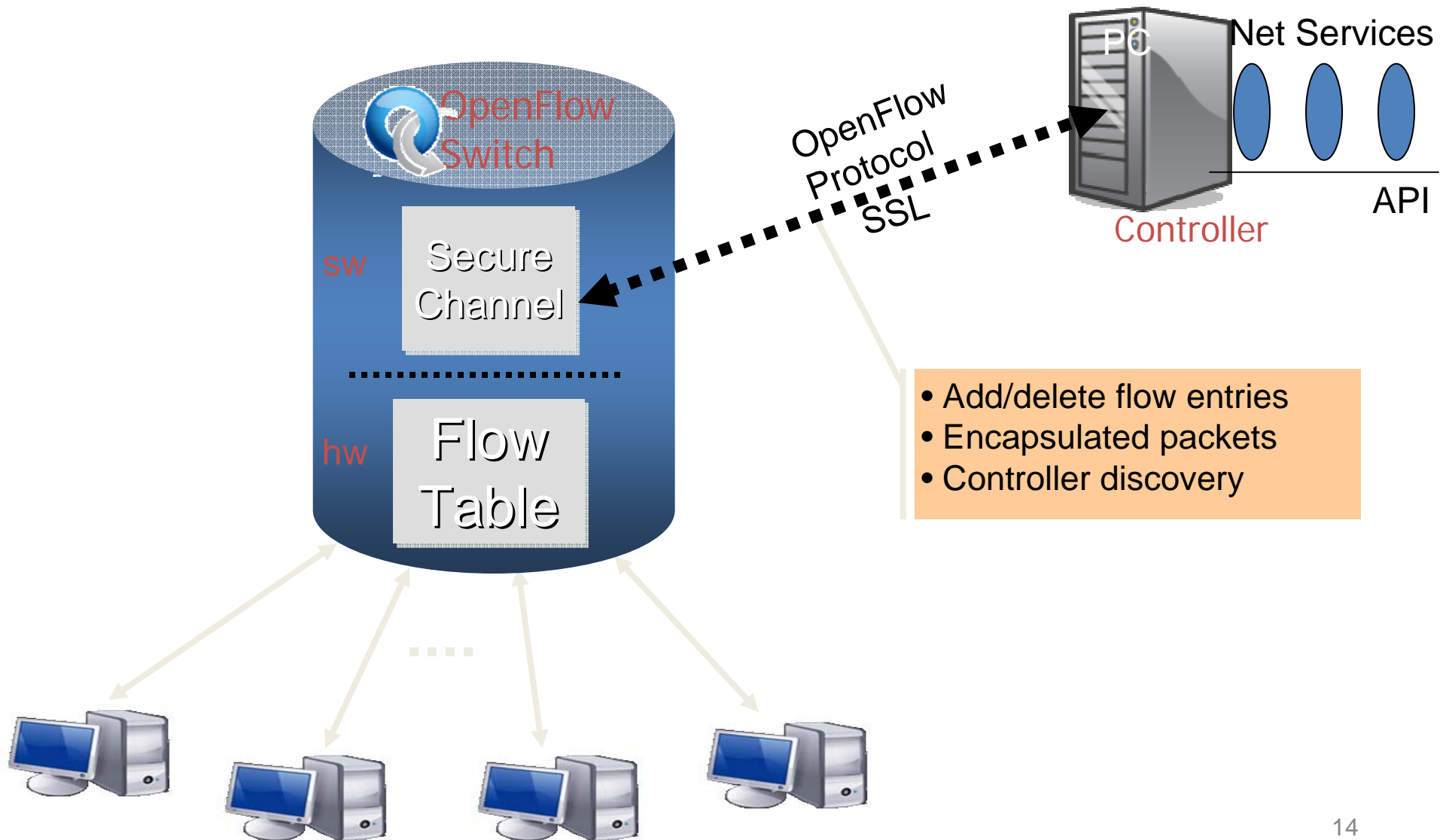
OpenFlow Deployment

- US
 - Deployed as GENI substrate
 - 8 Univ. interconnected by 2 National Backbones (in 2010)
 - Potential 25 universities in the next step
- Europe
 - 5 EU Universities interconnected by GEANT2
- Japan
 - 3-4 Universities interconnected by JGN2plus
- Interest in Korea, China, Canada, Brazil, ...

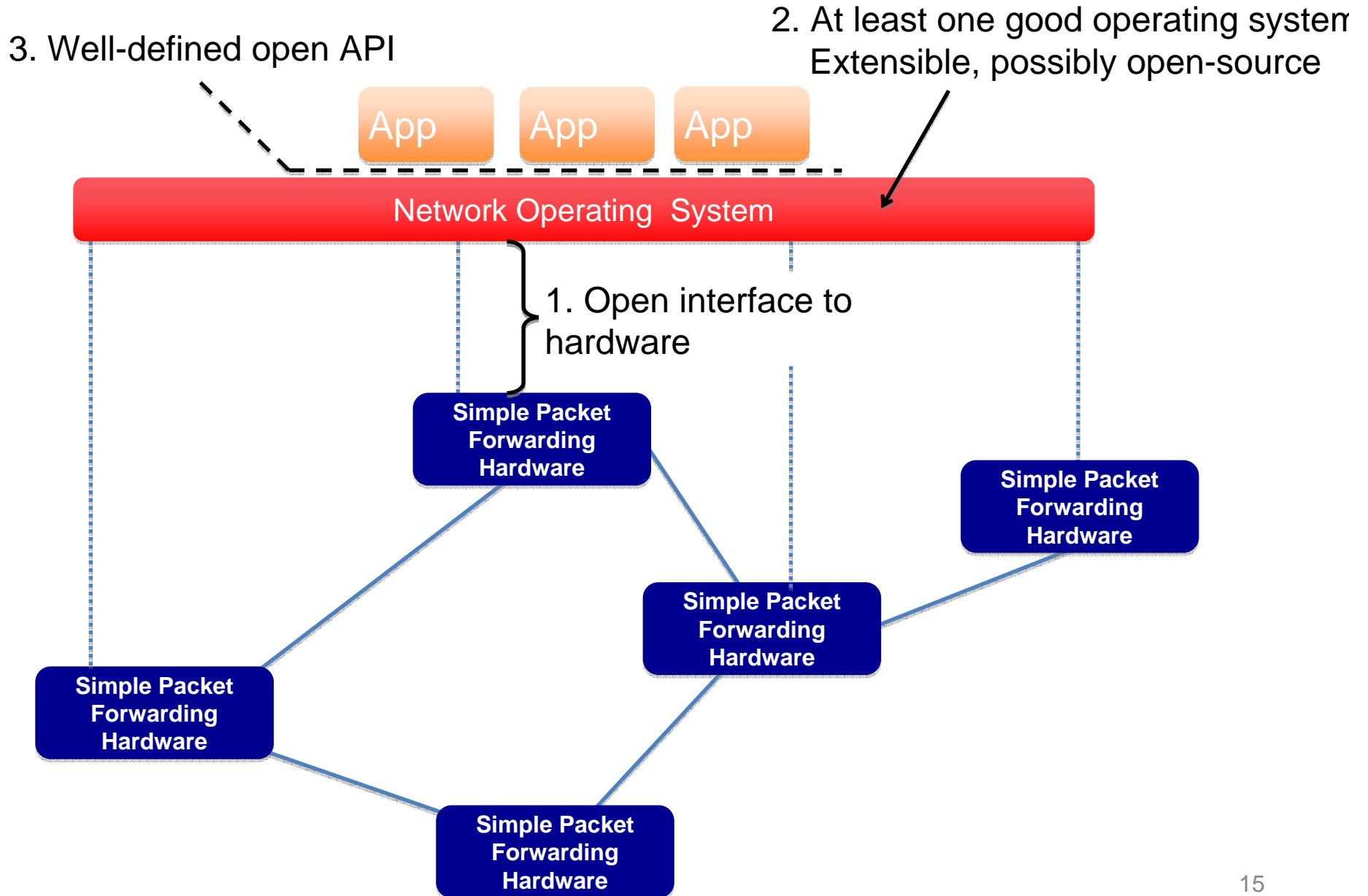


OpenFlow: A Hack to Experiment?
Is there a bigger architecture story with
business implications?

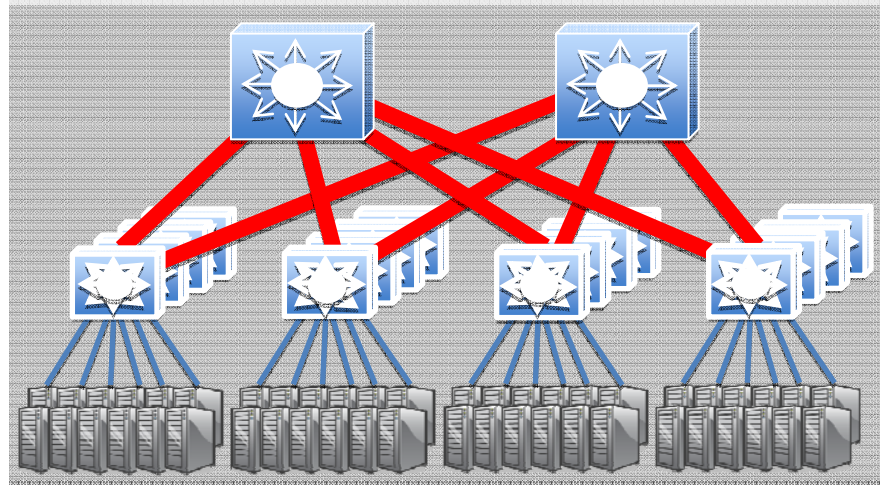
OpenFlow: Enable Innovations “within” the Infrastructure



Architecturally what It Means



Why Providers Care: New Data Center



Cost

200,000 servers

Fanout of 20 \Rightarrow 10,000 switches

\$5k commercial switch \Rightarrow \$50M

\$1k custom-built switch \Rightarrow \$10M

Savings in 10 data centers = **\$400M**

Control

- Optimize for features needed
- Customize for services & apps
- Quickly improve and innovate

The value prop applies to enterprise and service provider networks₁₆

Ecosystem Coming Together

Universities

Vendors

Providers

(Hardware/Software)

Researchers

Research &
Education
Network

Switch/Router Vendors

- Enterprise & Backbone
- Packet & Circuit
- Wireless

Chip Vendors

- Broadcom, Marvell, Dune,

New Class

- Nicira

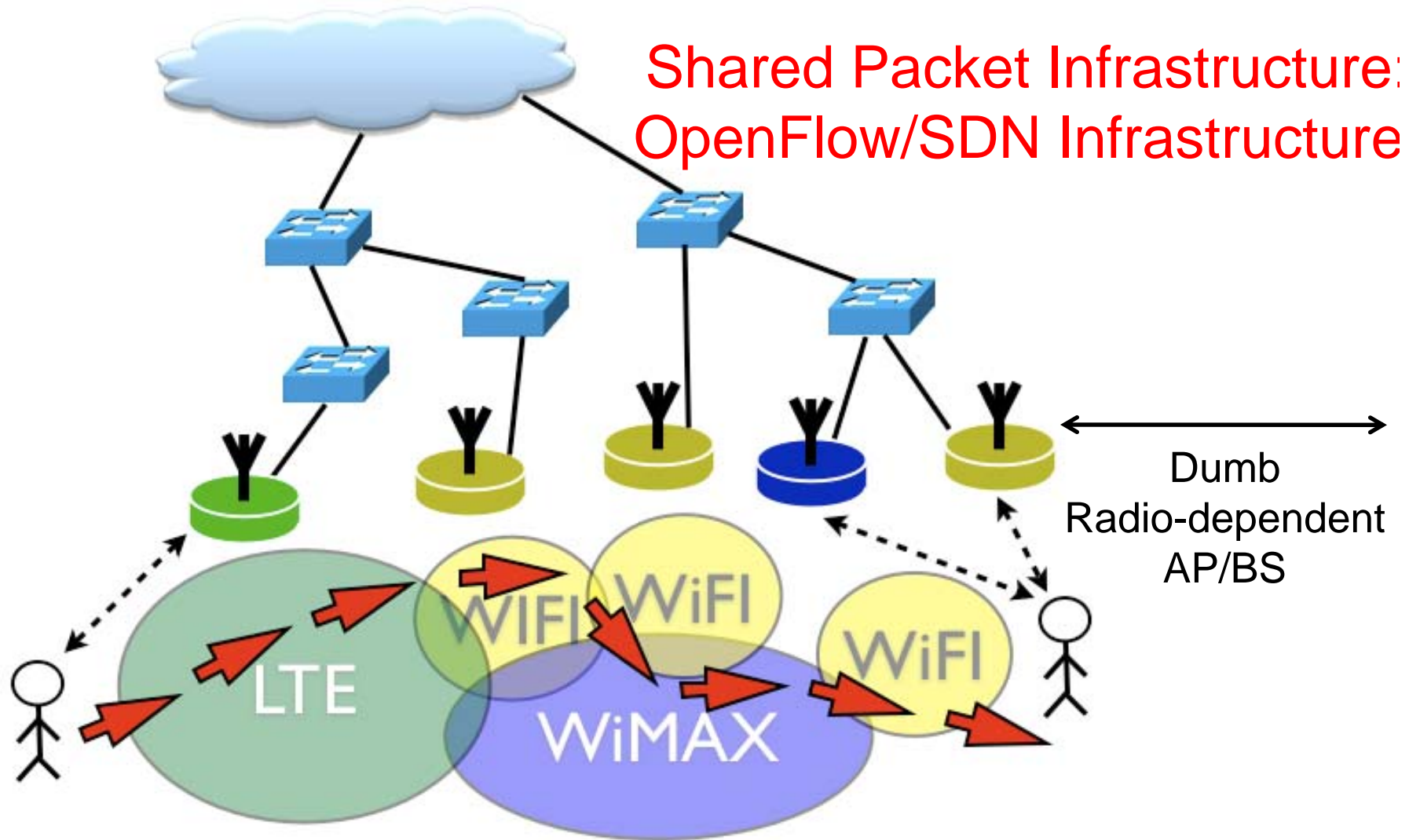
Data Center

Google, Amazon,
Microsoft, ..

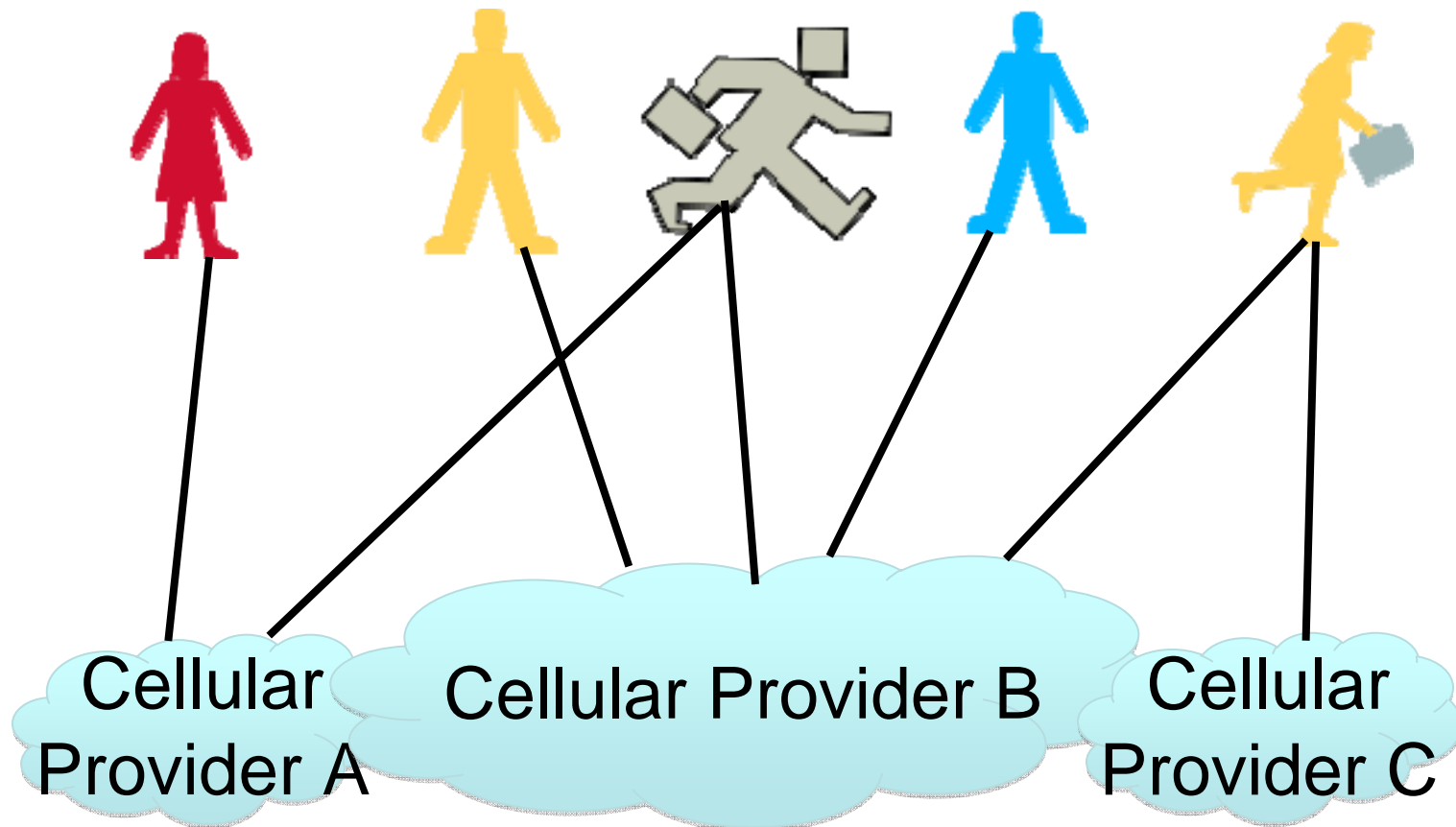
NW Provider

DT, DoCoMo
(Level3, BT,
Verizon,..)

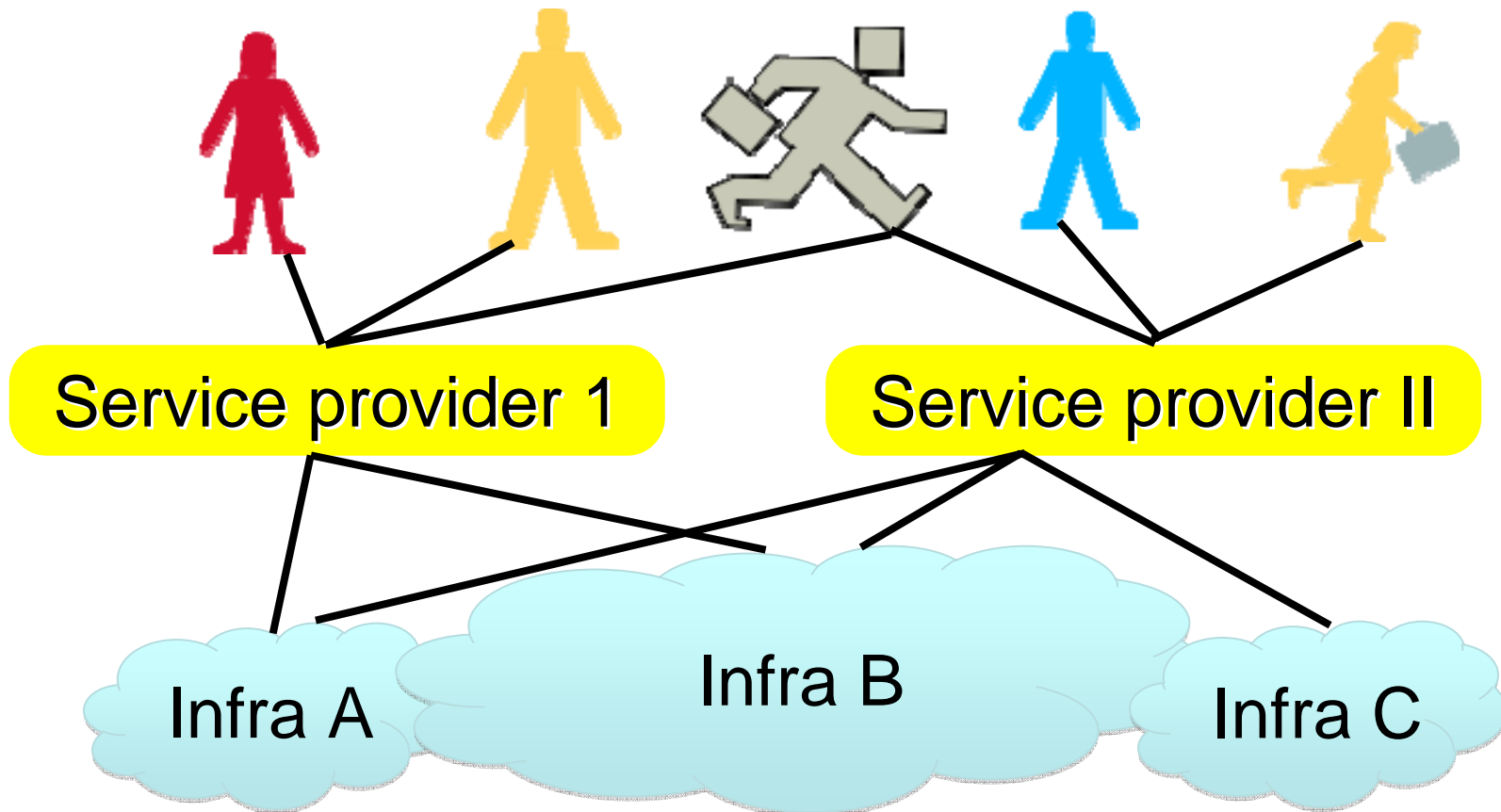
Ideally we want



Mobile Networks Today...

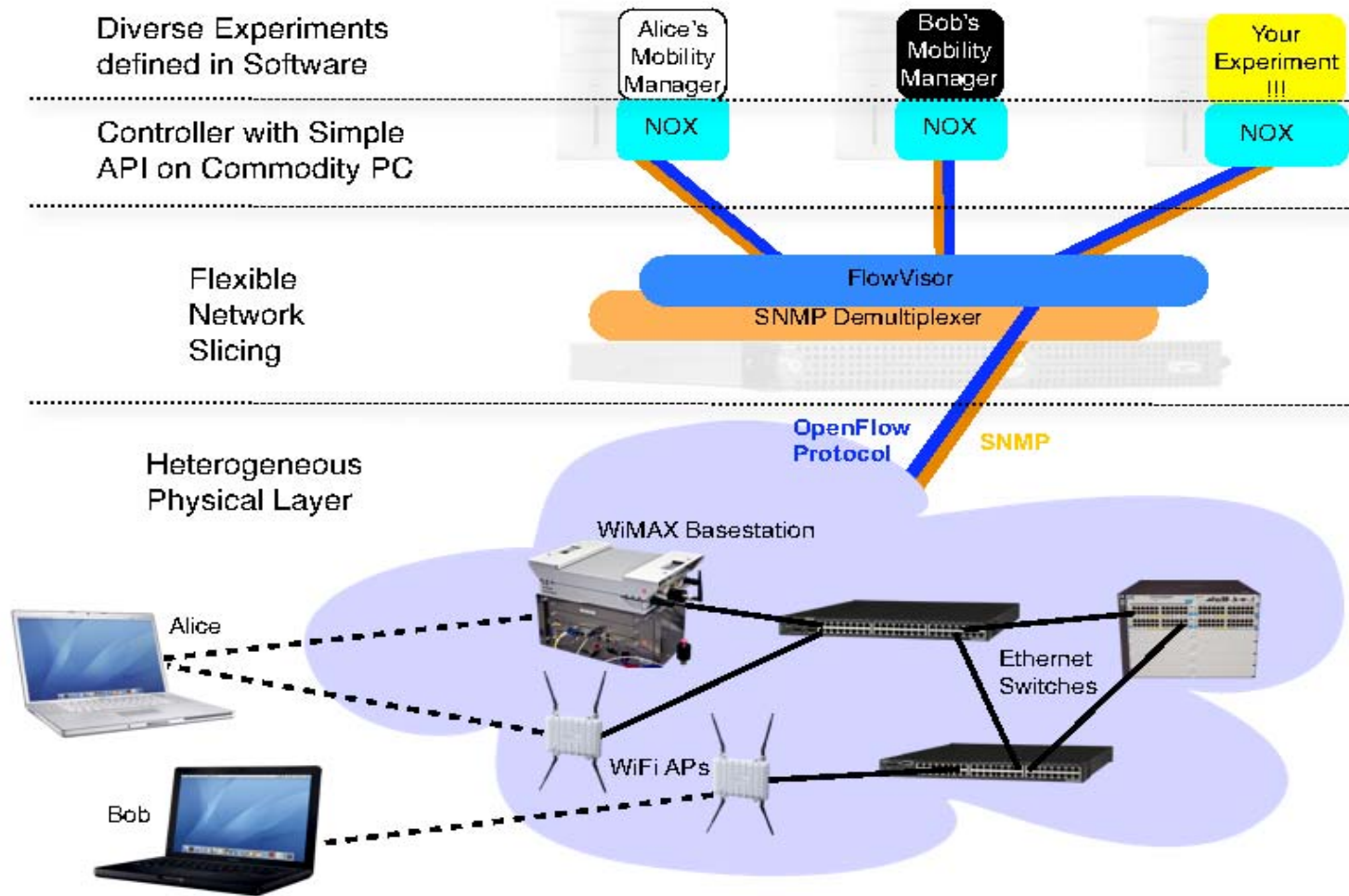


Our Vision of Tomorrow



Separating the infrastructure from the service providers.

OpenFlow Wireless Platform: WiFi, WiMAX, Wired Networks

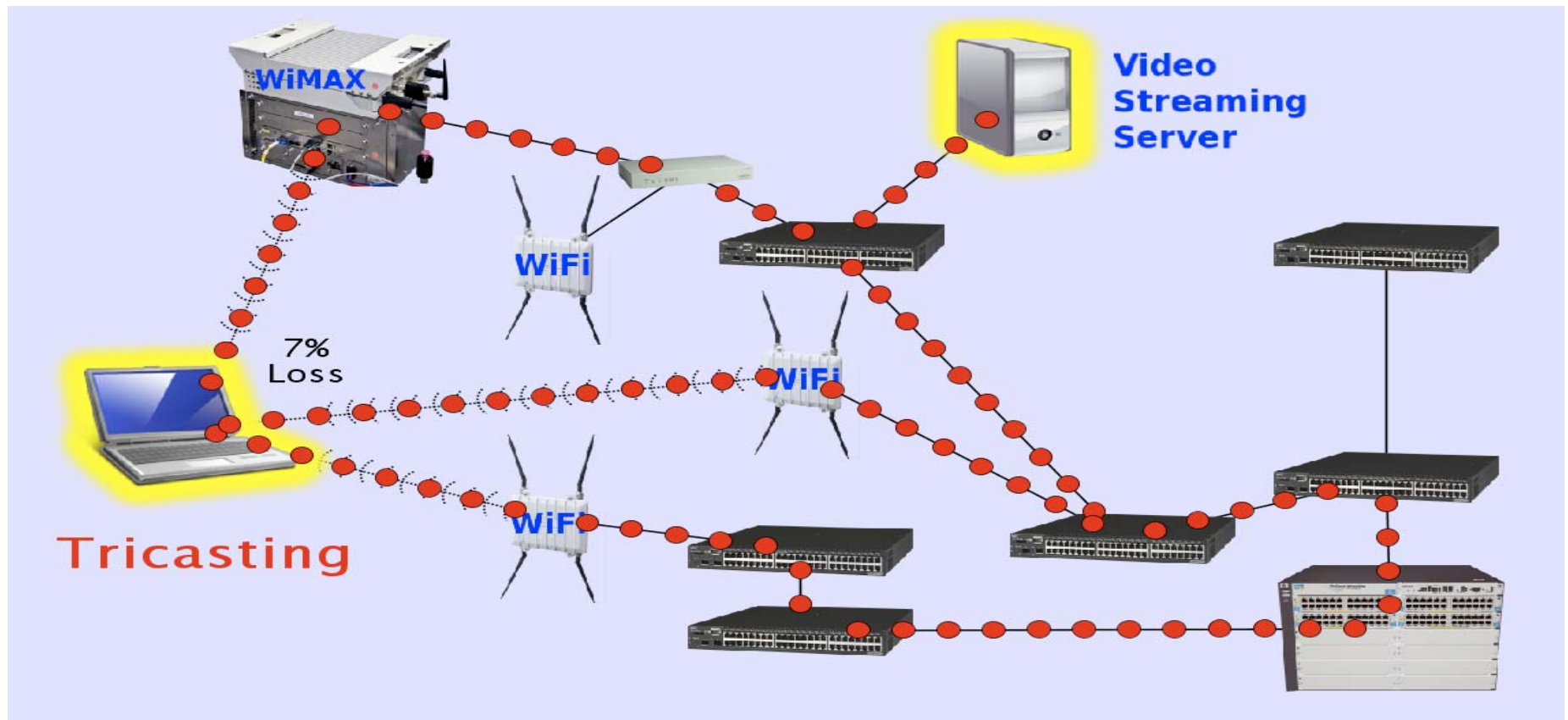


Stanford Deployment

- Deployed
 - 80+ WiFi APs across School of Engineering
 - 2 WiMAX basestations
 - Multiple switches in wiring closets
- Planned WiMAX deployment
 - To deploy outdoor WiMAX basestation to serve School of Engineering
 - To use stack from Open Programmable WiMAX

Current Demo at Stanford

How innovation in mobility management can use the platform demonstrate "macrodiversity" performed over WiFi and WiMAX



WiFi-WiMAX Handover

- Technology agnostic
 - Shown handover between WiFi-WiMAX
- Device/technology/application customizable

<http://www.openflowswitch.org/wp/n-casting-mobility-using-openflow/>

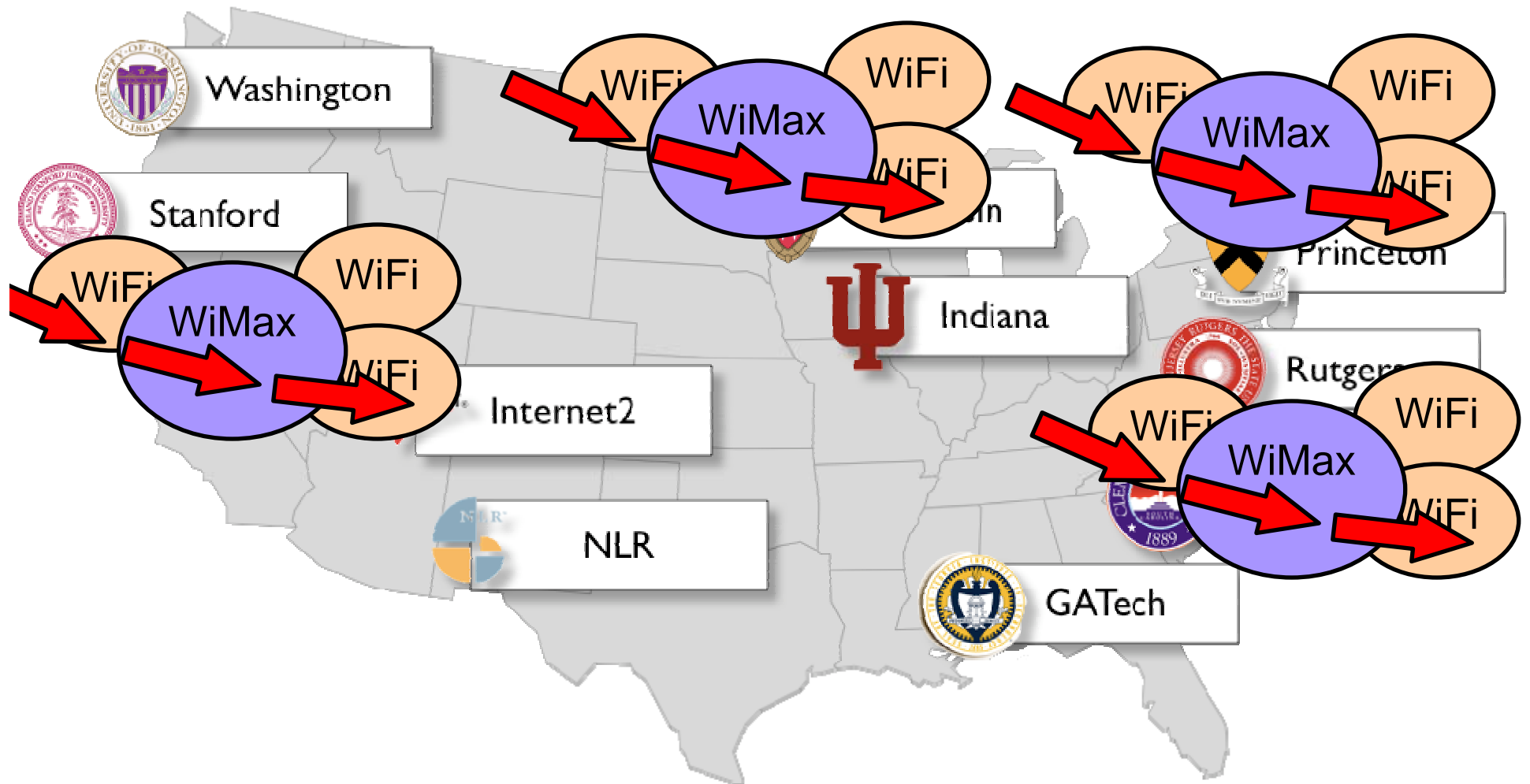


Unicasting



Tricasting

OpenFlow Wireless Extension for GENI Networking Substrate



Software-defined Networks and OpenFlow

April 2010



With Martin Casado and Scott Shenker
And contributions from many others



Thank you!

OpenFlow Wireless Components

- OpenFlow as common API to forwarding elements (switches, APs, base-stations)
- Remote configuration of devices
- Virtualization using FlowVisor in forwarding
- Uses NOX as controller with simple API
 - e.g. rerouting (done in 12 lines)

OpenFlow: Architecture Concepts

- Separate data from control
 - A standard protocol between data and control
- Define a “generalized flow” based data path
 - Very flexible and generalized flow abstraction
 - Delay or open up layers 1-7
- Logically centralized “open” controller with API
 - For control and management applications
- Virtualization of data and control planes
- Backward compatible
 - Though allows completely new header