



Programmable Open Mobile Internet 2020

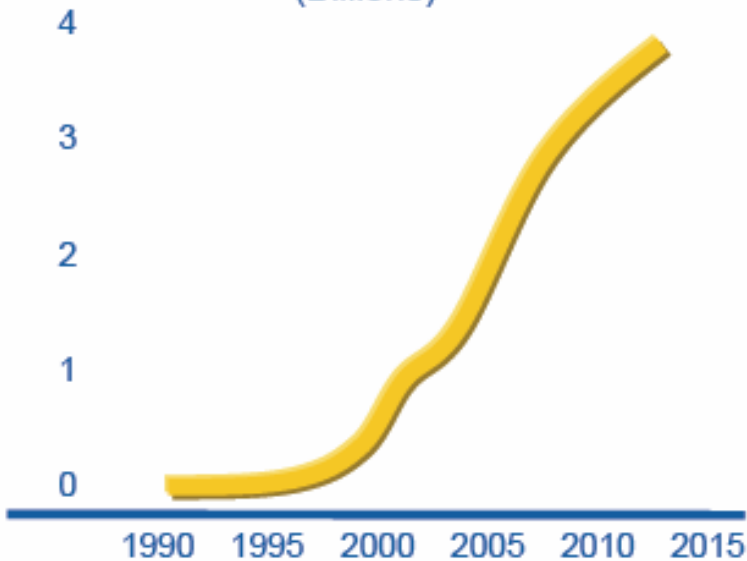
Guru Parulkar

Stanford Clean Slate Internet Design Program

Revolution in Mobile Computing

Millions → Billions

Mobile Phone Subscribers
(Billions)



Democratization of computing

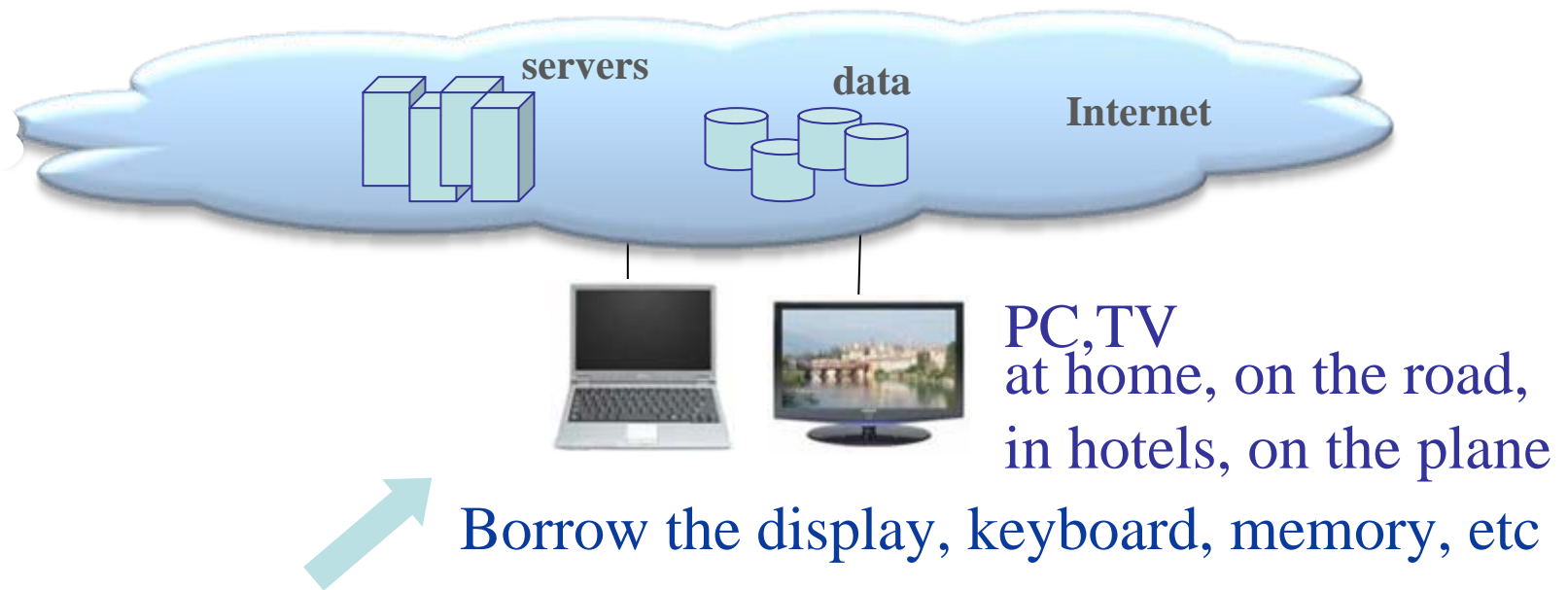


Entirely new uses of mobile computing

Power-limitation of handheld \Rightarrow computation will move to the cloud

Need to back up and refresh our lost data \Rightarrow data will move to the cloud

Vision: Three Tiers of Computing

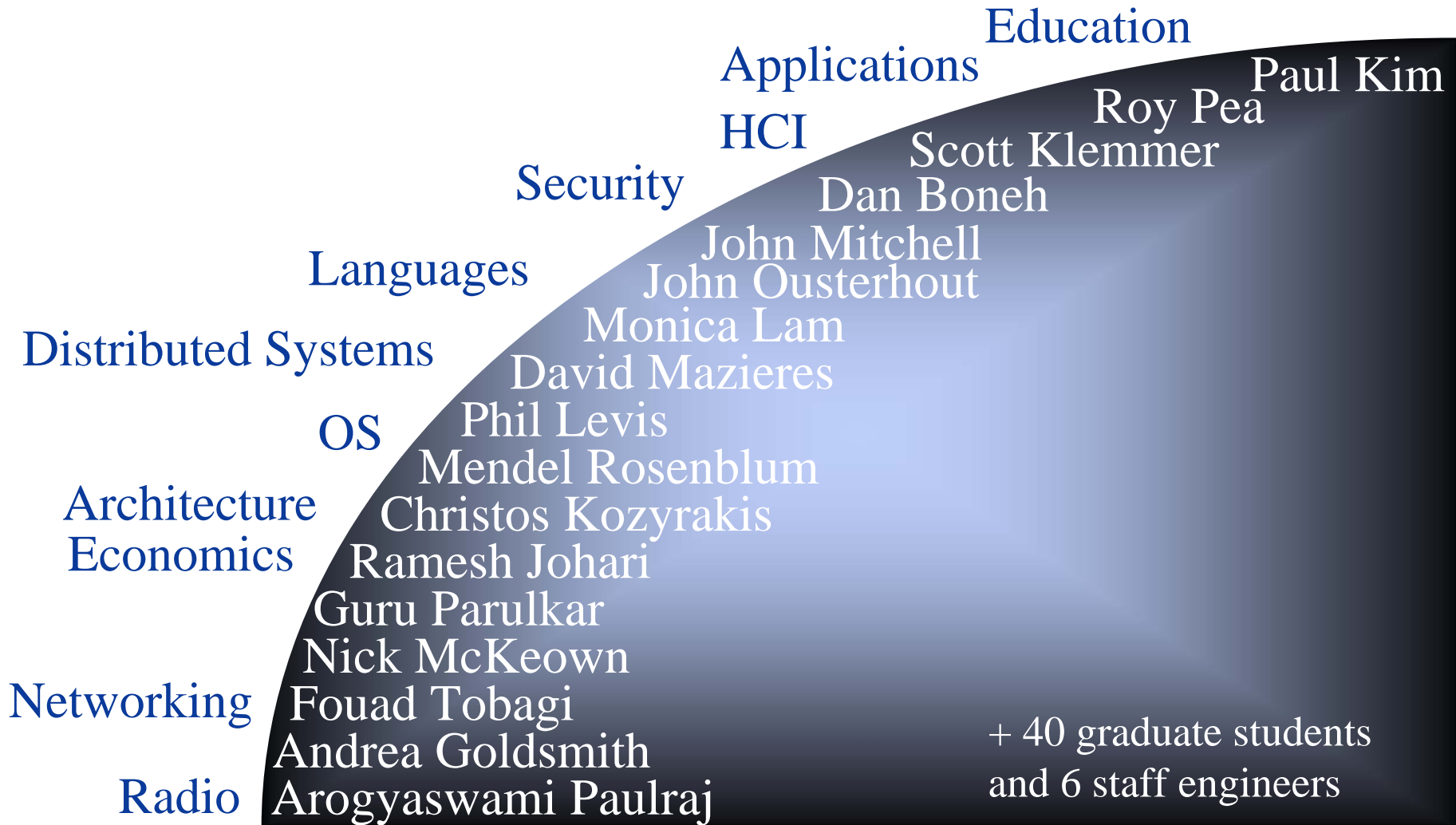


Great opportunities

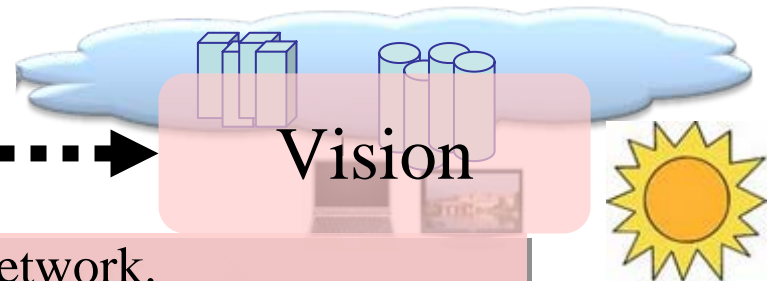
- Revolution in Mobile Computing will change our field.
- Opportunity to bring change before ossification.

make payments, open physical tools

Stanford Team



Today



Vision

- Problem with the network.
- 3G: Cellular networks ⇔ IP
- IP: Bad for mobility, security, management
- Need a network that continually evolves

Where we will go otherwise



- Barriers
1. Big-brother portals will own our data
 2. We will be locked-in to applications
 3. Wireless capacity will stay closed
 4. Network will stay ossified



Our Approach

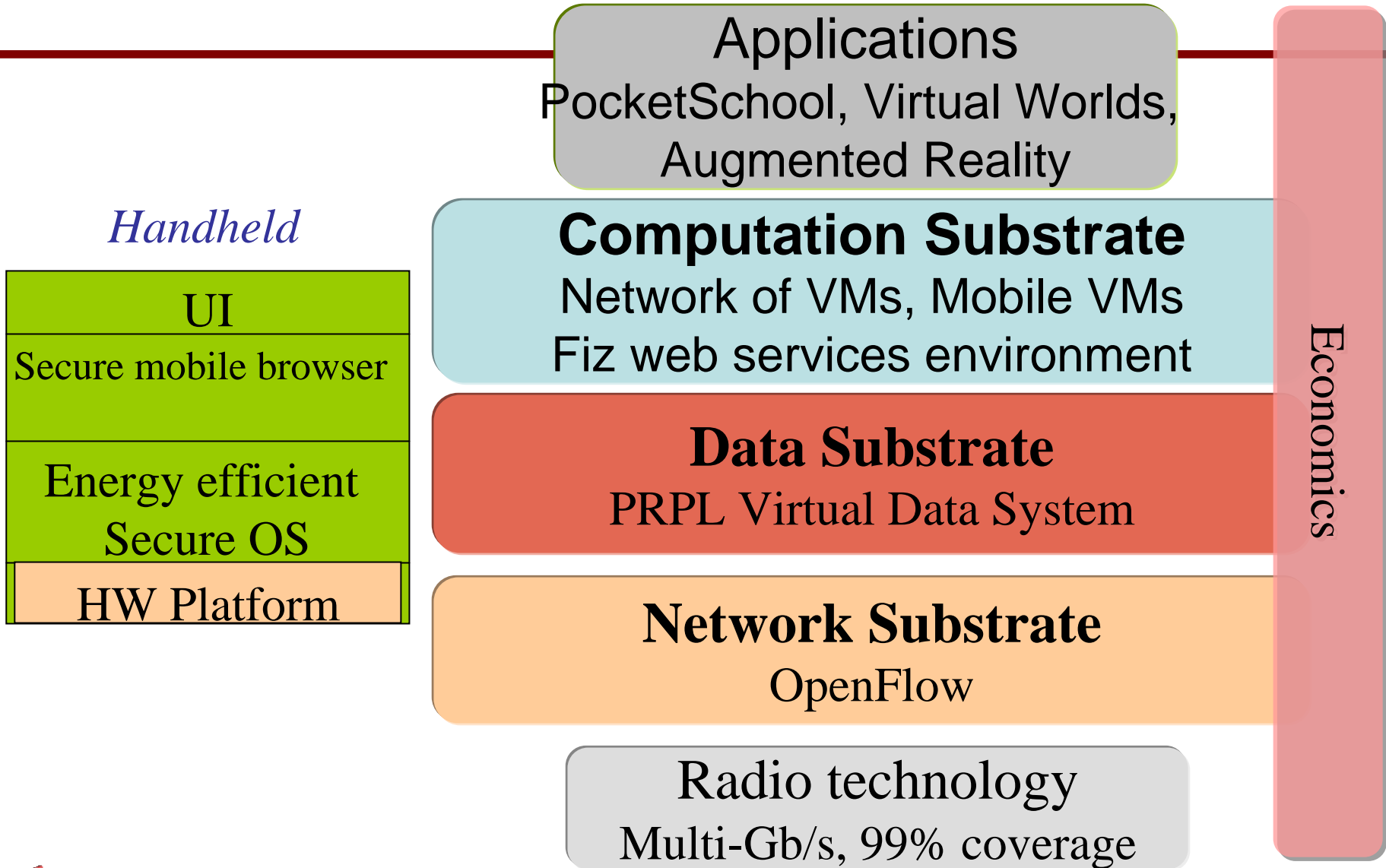
To reinvent Internet infrastructure and services

**by creating “platforms for innovations” in
networking, computing, and storage and
making them available to research and user
communities**

with emphasis on mobile computing



The Big Picture



The Big Picture

Handheld

UI

Secure mobile browser

Energy efficient
Secure OS

HW Platform

Learn more

Nick McKeown

Guru Parulkar

<http://OpenFlowSwitch.org>



Applications
Network of VMs. Mobile VMs

OpenFlow

- Continued innovation by users, owners and operators
- Easy to experiment with mobility, security and mgmt

PKPL virtual Data System

Network Substrate

OpenFlow

Radio technology

Multi-Gb/s, 99% coverage

Economics

The Big Picture

Learn more

Monica Lam



Application
PocketSchool, Virtual worlds,
Augmented Reality

PRPL Platform

- Allow users to control who can access and mine their data
- PRPL protocol allows services to be separated from data
- We can choose where our data resides

Data Substrate

PRPL Virtual Data System

Network Substrate

OpenFlow

Radio technology

Multi-Gb/s, 99% coverage

Handheld

UI

Secure mobile browser

Energy efficient
Secure OS

HW Platform

Economics

T

VM as granularity of computing

- Large services built from 100s or 1000s of VMs
- VMs stay seamlessly connected, tracking users
- Made possible by OpenFlow

Handheld

UI

Secure mobile browser

Computation Substrate

Network of VMs, Mobile VMs
Fiz web services environment

Economic

Energy efficient
Network of VMs
Mendel Rosenblum



Data Substrate

Fiz environment

John Ousterhout



Network Substrate

OpenFlow

Radio technology

Multi-Gb/s, 99% coverage

The Big Picture

Applications
PocketSchool, Virtual Worlds,
Augmented Reality

OS

- Make users aware of how they use energy
- Energy management per thread
- Integrate with Information Flow Control
- “Capacitors”

Information Substrate

Network of VMs, Mobile VMs
Services environment

Energy efficient
Secure OS

HW Platform

Learn more

Phil Levis

David Mazieres



OpenFlow

Radio technology
Multi-Gb/s, 99% coverage

Economics

The Big Picture

Applications

PocketSchool, Virtual Worlds,
Augmented Reality

Secure Mobile Browser

- Build on hugely successful work
- Exploit the move from desktop to mobile browsers

Information Substrate

of VMs, Mobile VMs

Secure mobile browser

Learn more

Dan Boneh

John Mitchell



Energy efficient
Secure OS

HW Platform

Network Substrate

OpenFlow

Radio technology

Multi-Gb/s, 99% coverage

Economics

The Big Picture

User Interface

- New populations of users
- Need to quickly repurpose and test new Uis
- Today's technology is rudimentary
- Decouple UI from application

Applications

Pool, Virtual Worlds,
Augmented Reality

Handheld

UI

Secure mobile browser

Energy efficient
Secure OS

HW Platform

Computation Substrate

Learn more
Scott Klemmer



PRPL Virtual Data System

Network Substrate

OpenFlow

Radio technology
Multi-Gb/s, 99% coverage

Economics

The Big Picture

Handheld

UI

Secure mobile browser

Energy efficient
Secure OS

HW Platform

Applications
PocketSchool, Virtual Worlds,
Augmented Reality

Learn more

A. Paulraj



Faster radios

- Today: WiMAX gives ~20Mb/s
- 1Gb/s predicted by 2013
- Extrapolating: Set the stage for 10Gb/s
- Need cooperation of handhelds: Distributed MIMO, client relaying, accumulation coding

Radio technology
Multi-Gb/s, 99% coverage

Economics

The Big Picture

Learn more

Ramesh Johari



Applic
PocketSchool, Worlds,

Augmented Reality

Handheld

UI

Secure mobile browser

Energy efficient
Secure OS

HW Platform

Infrastructure owner's dilemma

- Do I lock-in a profitable, known, homegrown service now, knowing others can pass me by?
- Or do I open up my infrastructure, and risk being commoditized?

Network Substrate

OpenFlow

Radio technology

Multi-Gb/s, 99% coverage

Economics

Summary

❖ **Big changes on the horizon**

- Opportunity to rethink the Internet infrastructure

❖ **Stanford's Clean Slate Program**

- Reinvent the Internet by creating platforms for innovations

❖ **WEB/Computing substrate: Fiz and network of VMs**

- Enable scalable, highly interactive, rich media applications

❖ **Data substrate: PRPL Platform**

- Separate data from applications in cloud: give control of data to owners
- Allow any application to use any data under the control of its owner

❖ **Networking substrate: OpenFlow Platform**

- Enable users to create their own network services
- Network services: access control, routing, mobility management, ...

❖ **Handheld software: OS, browser, UI platforms**

Agenda

- 9:00 - 9:45am Mobile Technologies and Services**
-- Jan Uddenfeldt, Ericsson
- 9:45 - 10:30am Cinder: Energy Aware Secure OS for Mobile Handheld Devices**
-- Phil Levis, Stanford
- 10:30 - 11:00am Break**
- 11:00 - 11:45am Learning Networks of Places and People from Location Data**
-- Tony Jebara, Sense Networks
- 11:45 - 12:30pm Building Social Networking Future without Big Brother**
-- Monica Lam, Stanford
- 12:30 - 1:30pm Lunch**

Agenda

12:30 – 2:00pm Lunch

2:00 – 2:45pm Startup Scene in Mobile Wireless
-- Jake Seid and Barry Eggers, Lightspeed Venture

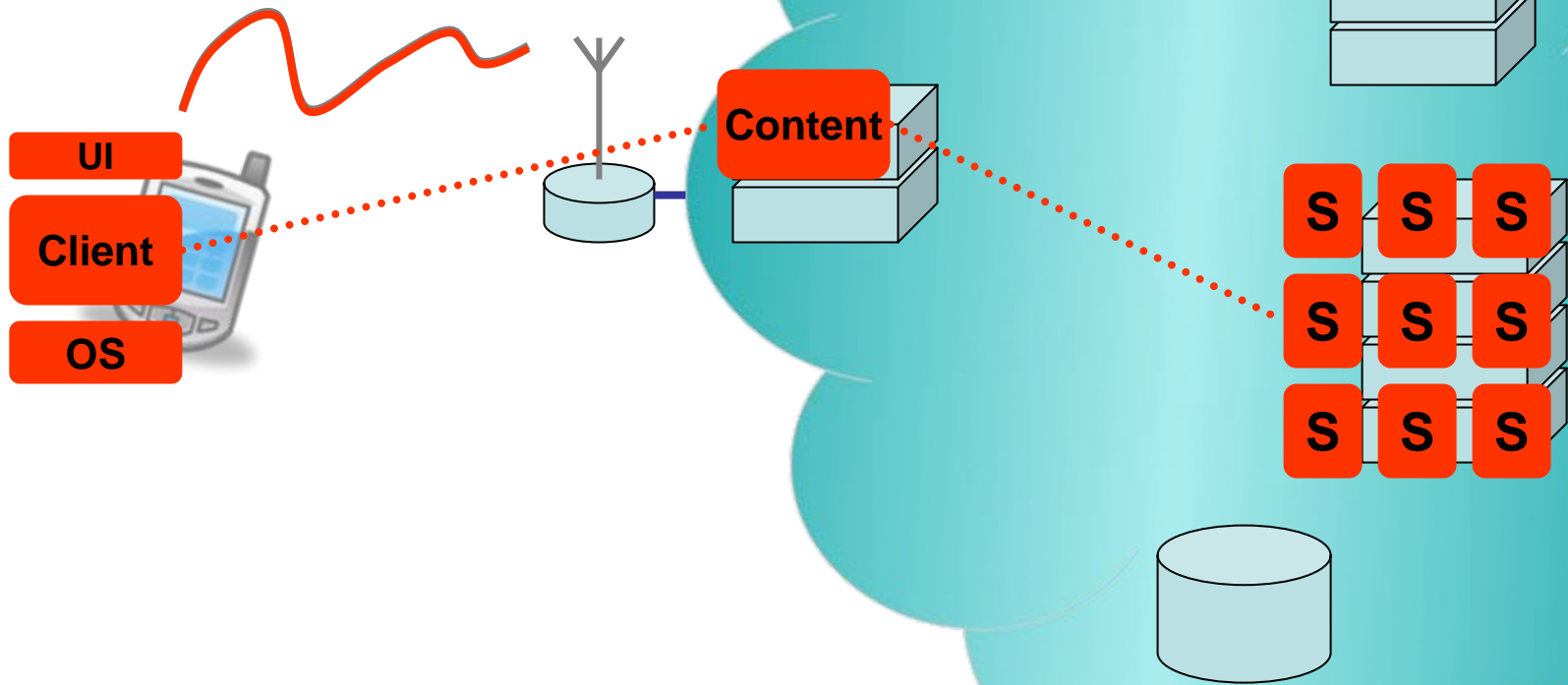
2:45 – 3:30pm Cloud As A Semantic Platform
-- Bob Iannucci, Nokia

3:30 - 4:00pm Break

4:00 - 4:45pm OpenFlow: Networking Substrate to Enable Internet Innovations
-- Nick McKeown, Stanford

4:45 - 5:15pm OpenFlow Demonstrations
-- Guido Appenzeller and Nick McKeown, Stanford

5:15 - 5:30pm Wrap Up



Computation Substrate

Network of VMs, Mobile VMs

Network Substrate

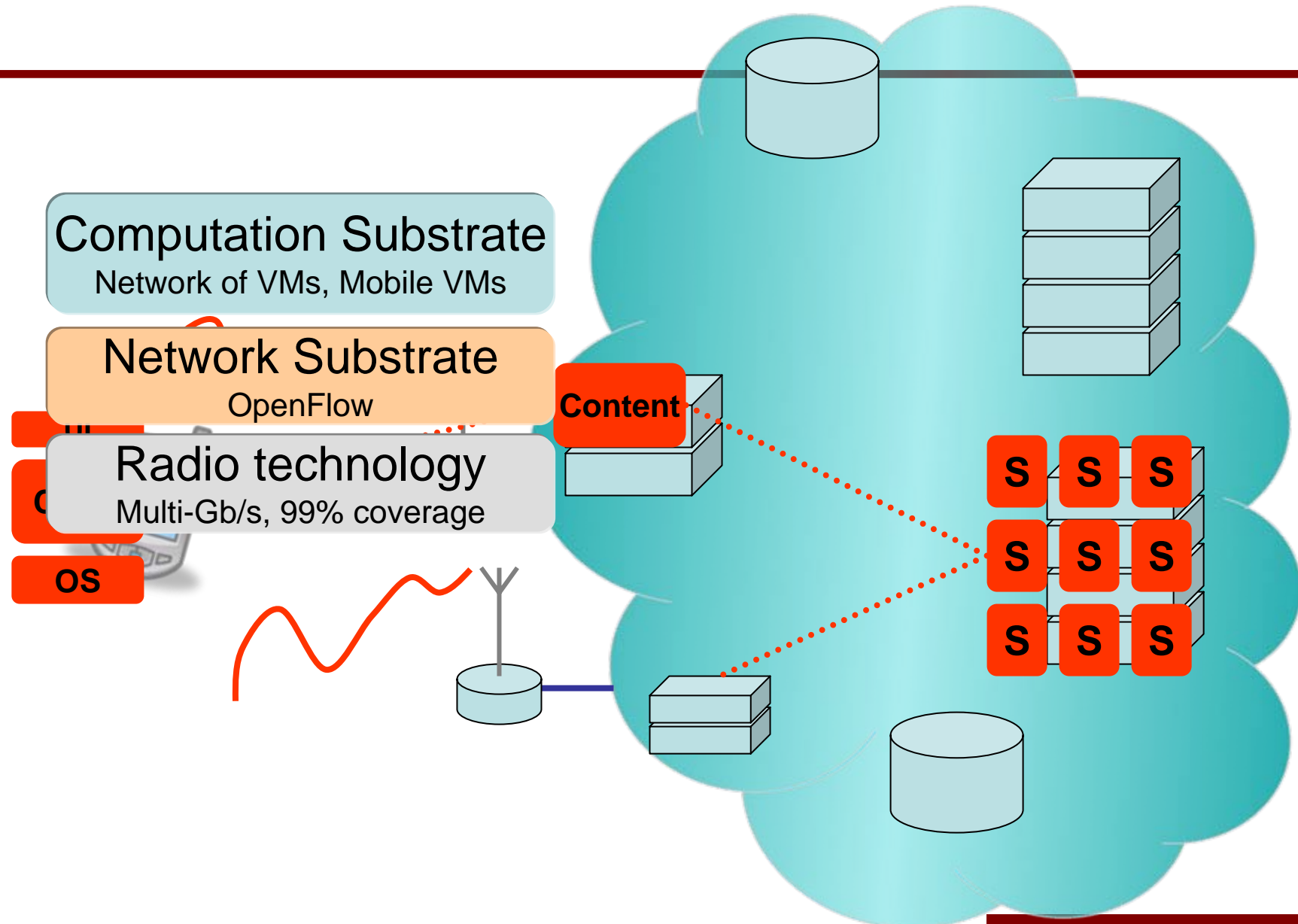
OpenFlow

Radio technology

Multi-Gb/s, 99% coverage

OS

Content



Data Substrate
PRPL Virtual Data System

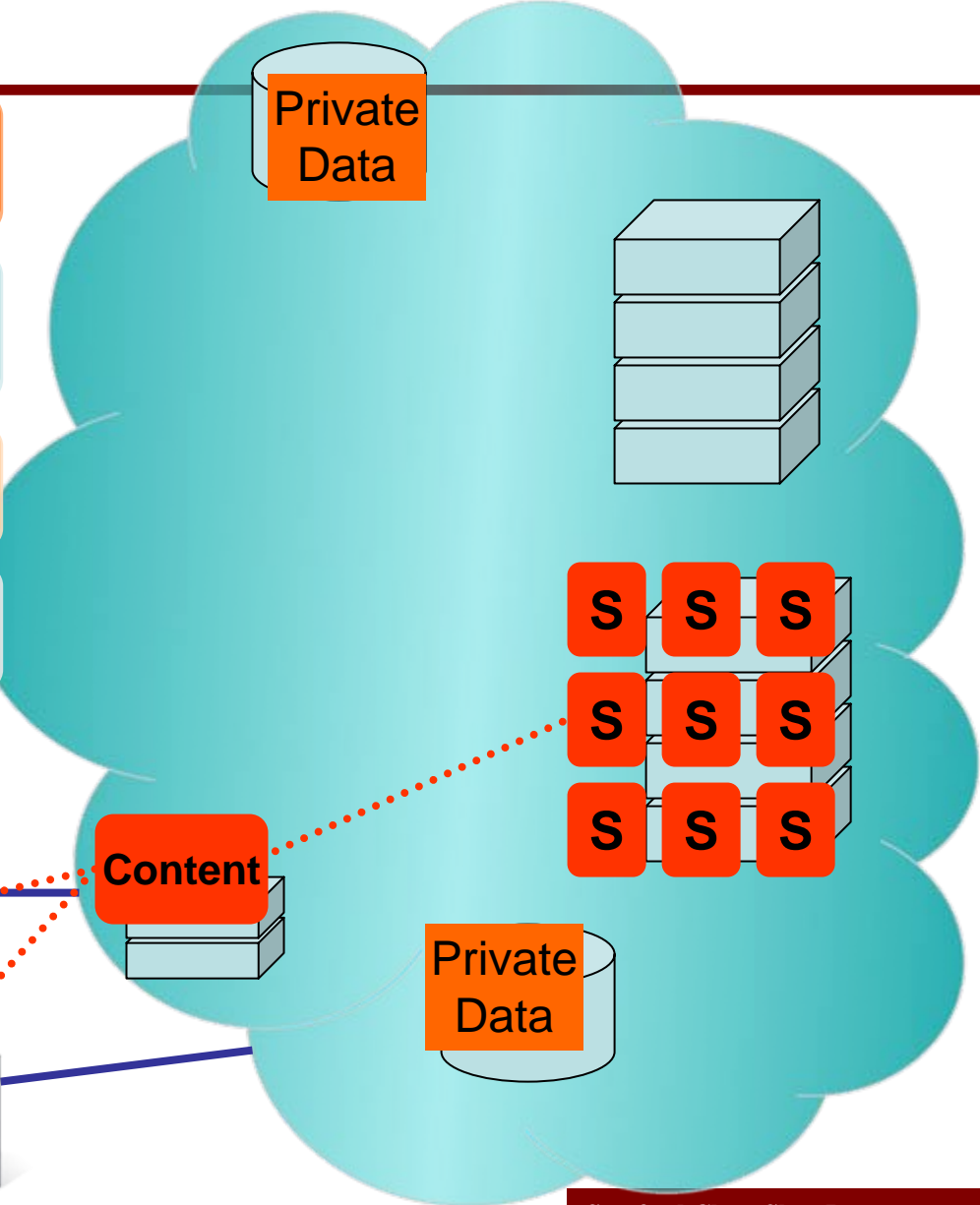
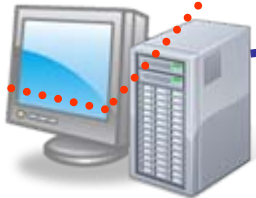
Computation Substrate
Network of VMs, Mobile VMs

Network Substrate
OpenFlow

Radio technology
Multi-Gb/s, 99% coverage

Energy aware OS

Private Data
UI
Client
OS



Content

Private Data