OpenRadio
Virtualizing Cellular Wireless Infrastructure

Sachin Katti
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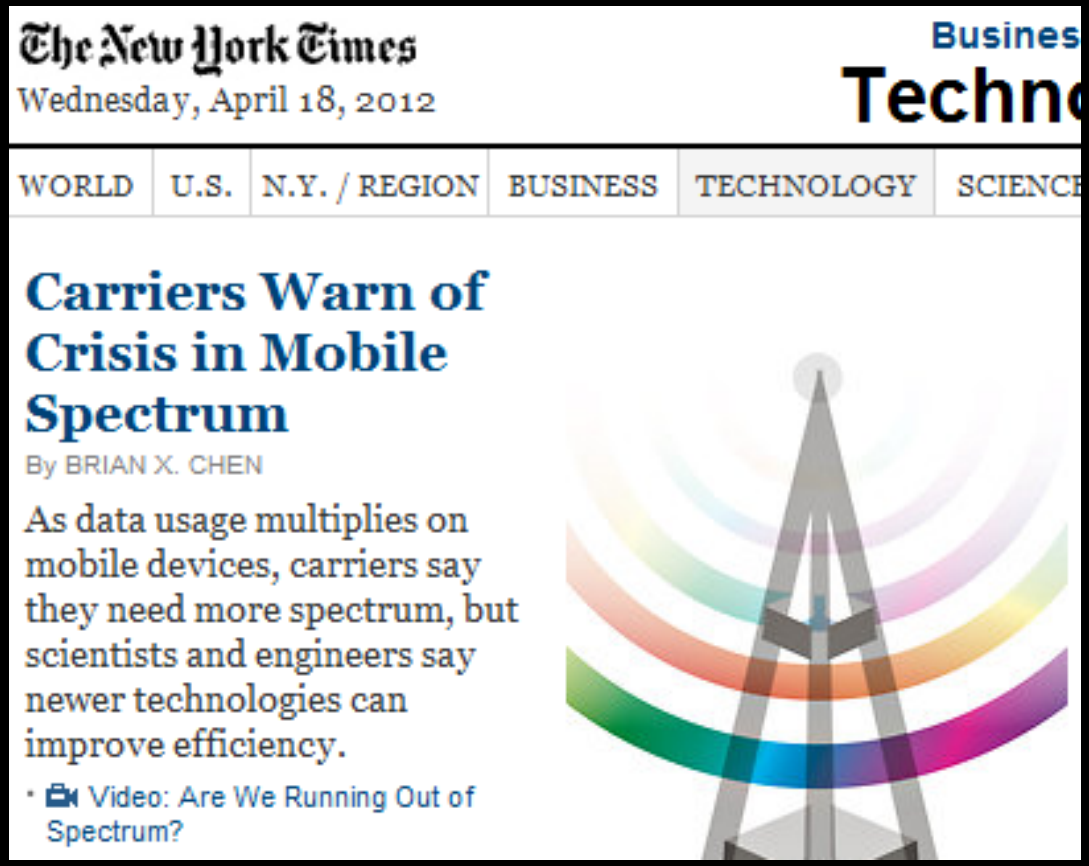
EE&CS, Stanford University

Wireless Connectivity

New York Times today



The New York Times
Wednesday, April 18, 2012

Busines
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WORLD | U.S. | N.Y. / REGION | BUSINESS | TECHNOLOGY | SCIENCE

Carriers Warn of Crisis in Mobile Spectrum

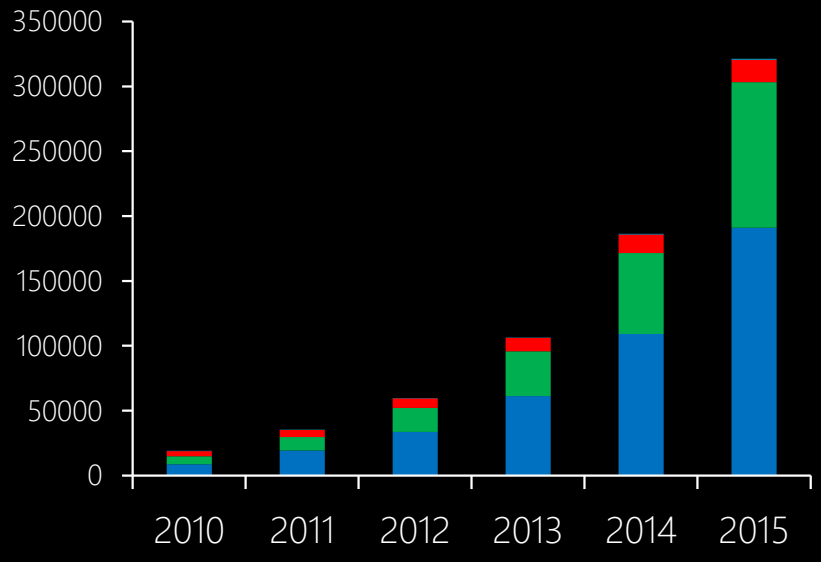
By BRIAN X. CHEN

As data usage multiplies on mobile devices, carriers say they need more spectrum, but scientists and engineers say newer technologies can improve efficiency.

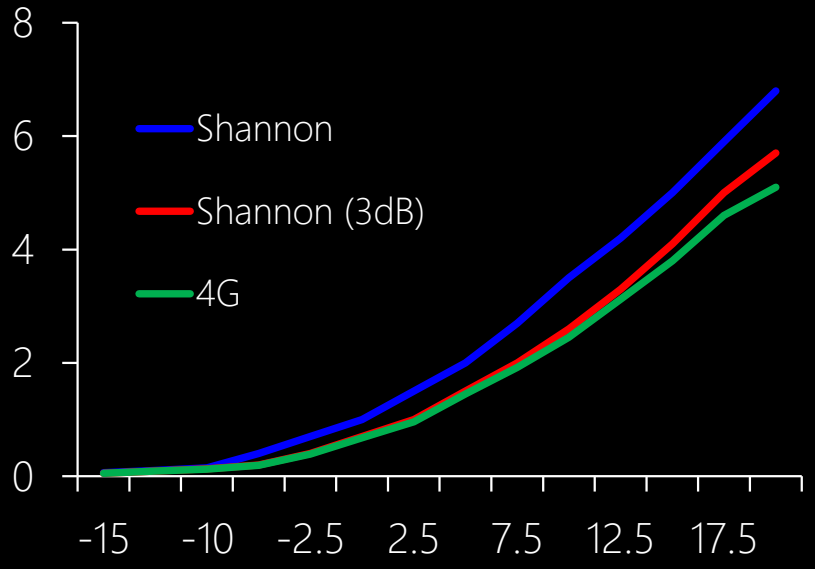
• Video: Are We Running Out of Spectrum?

Wireless Connectivity

Exponential Traffic Growth



Limited Capacity Gains

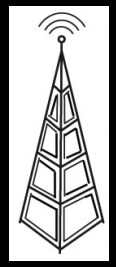


Exponential growth + Limited spectrum/capacity gains

→ Poor wireless connectivity

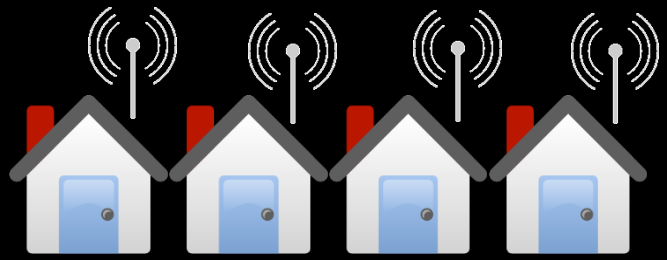
Femtocell

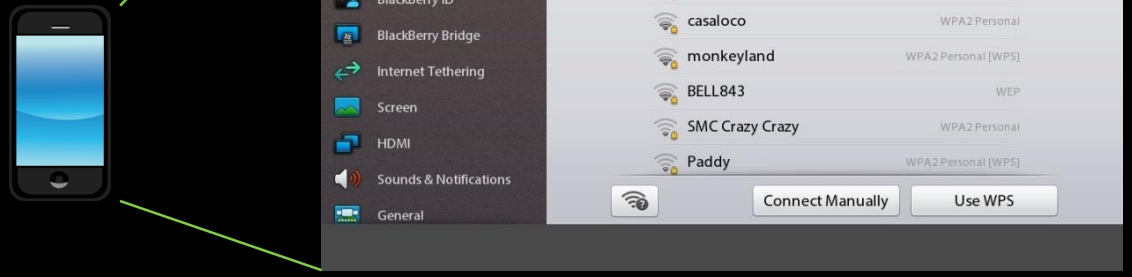
3G



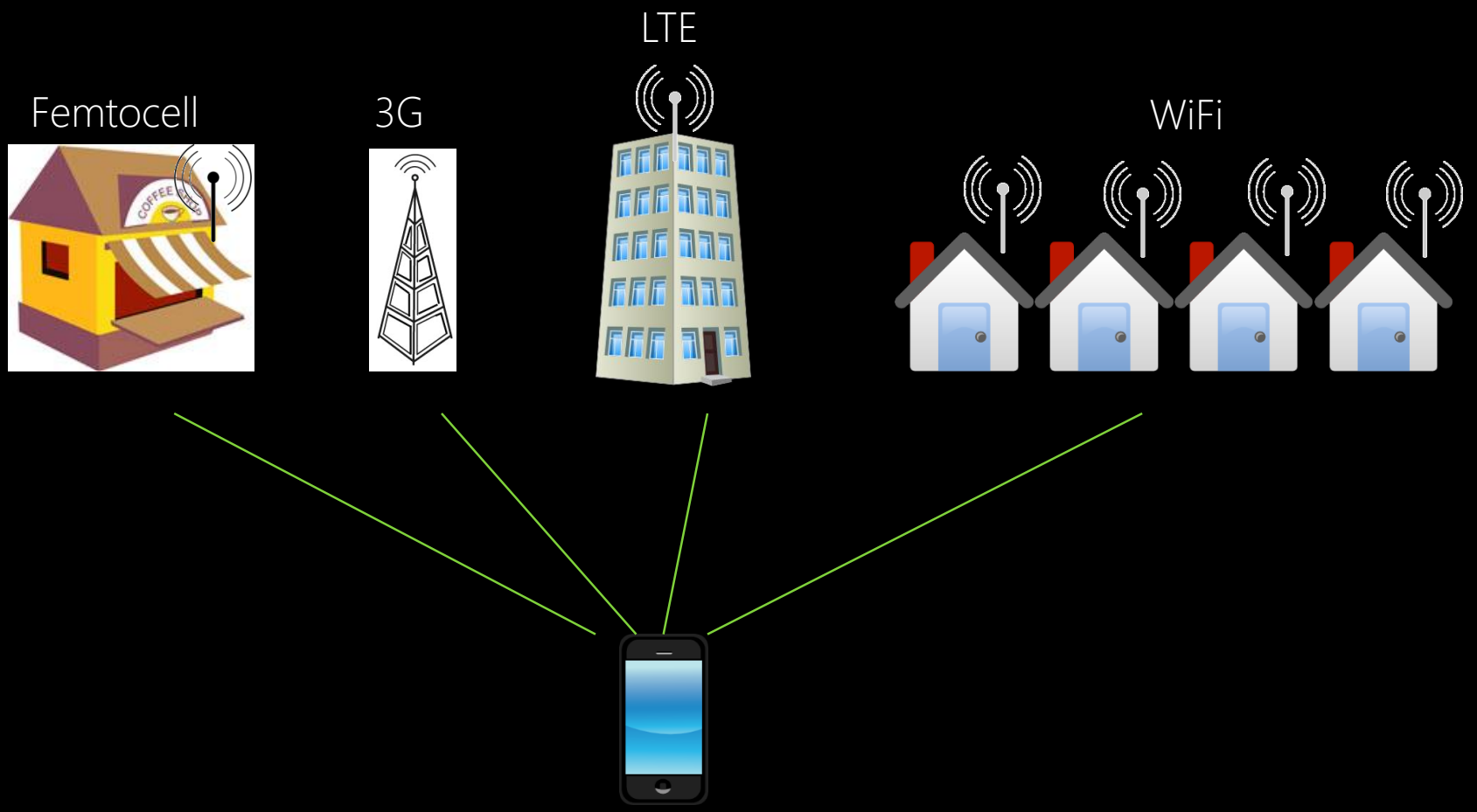
LTE

WiFi

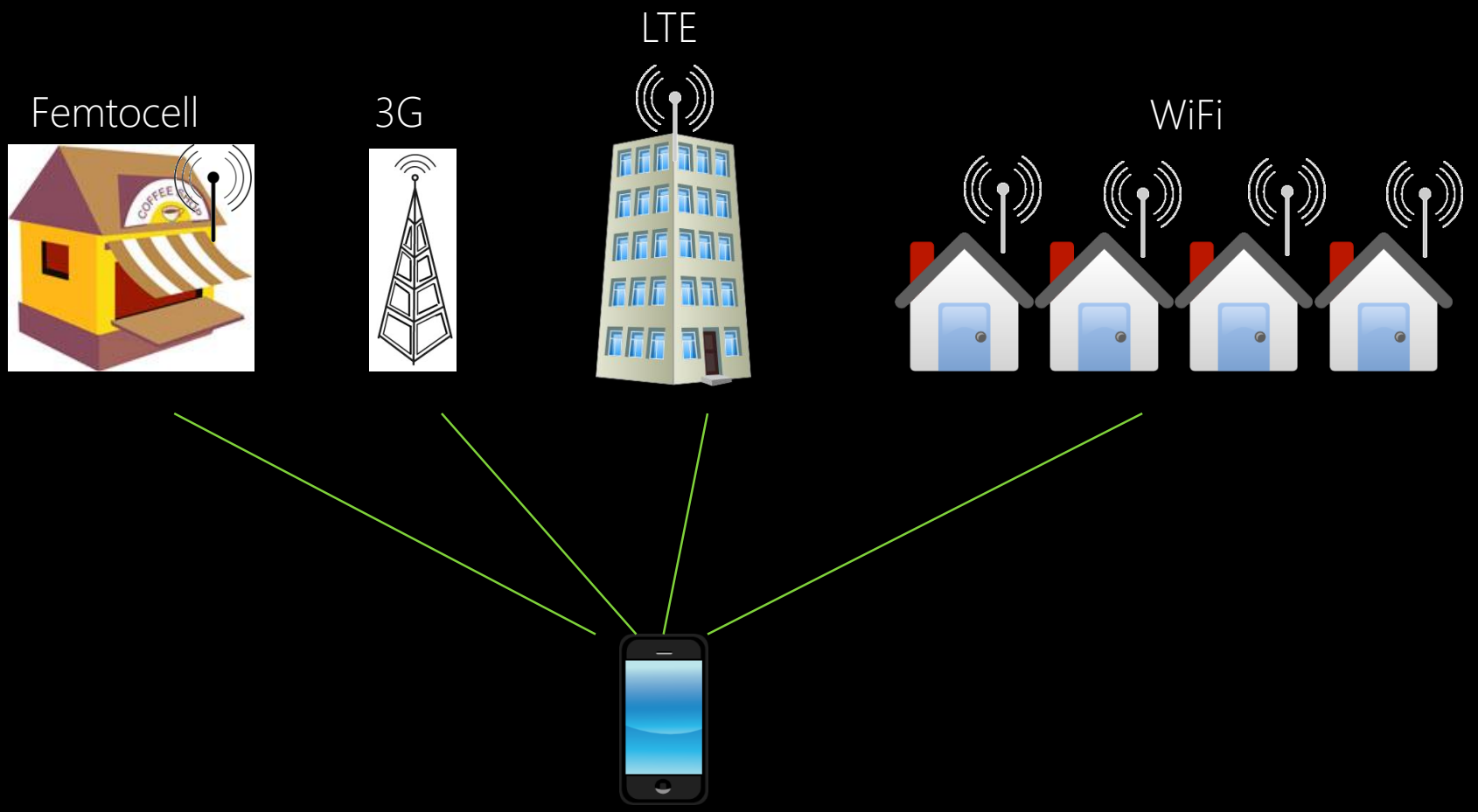




Paradoxically, surrounded by wireless APs (WiFi, 3G, 4G, picocells, femtocells, whitespace ….)



Why cant my wireless ISP seamlessly connect me to the best AP available?



Why cant my wireless ISP seamlessly connect me to multiple APs if I want more speed?

Cloud Services over Wireless Networks

Our media and apps are moving to the cloud

- High quality media streaming (video, music)
- Interactive computing applications (Chrome OS, Onlive Desktop, mobile gaming)

We are becoming impatient!

- Expect rich, high definition, and responsive services
- NYT: Download times need to be less than 250ms

NETFLIX

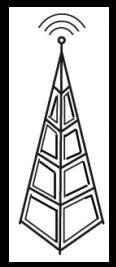
onLive

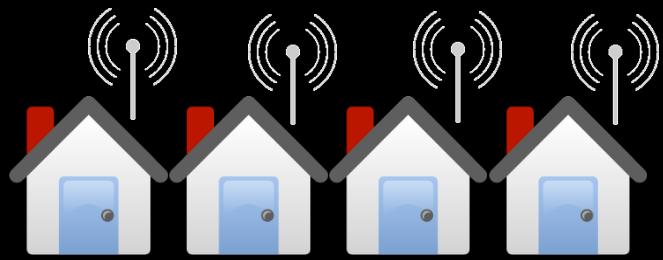
LTE

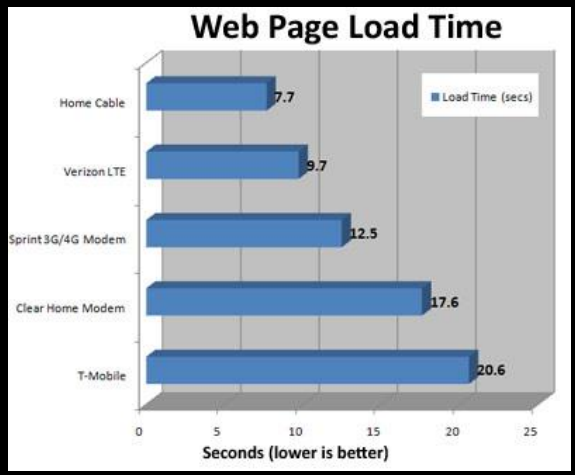
Femtocell

3G

WiFi





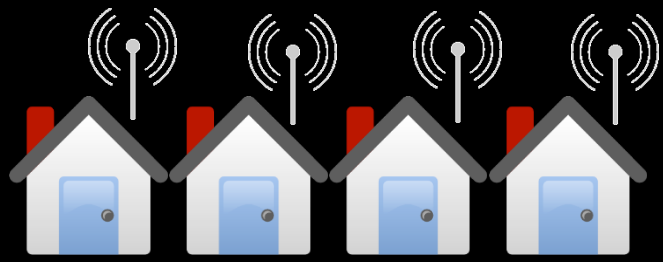


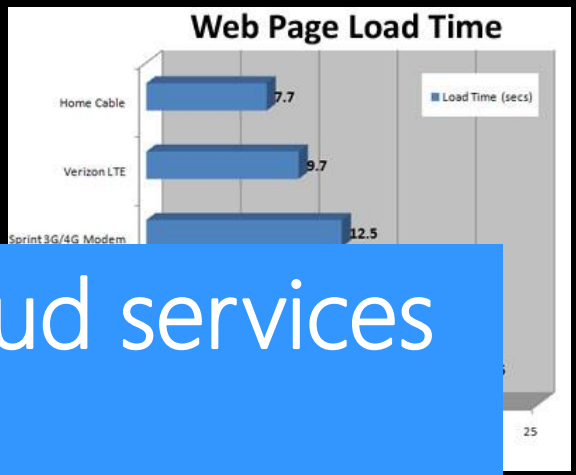
LTE

Femtocell

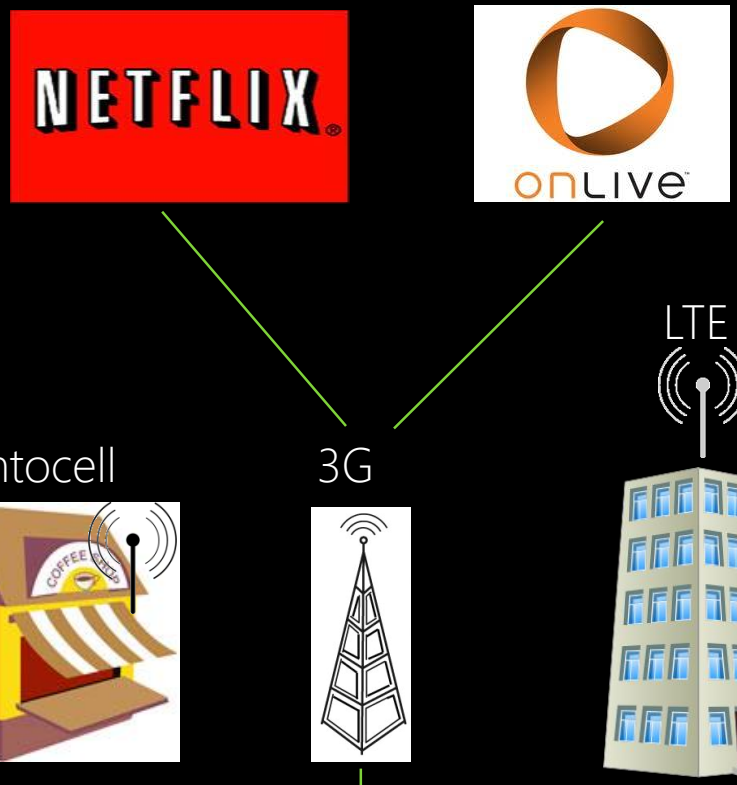
3G

WiFi





User experience with rich cloud services over mobile wireless is poor



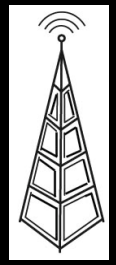
To cope, resort to reverse engineering

- Probe for bandwidth/latency
- Resort to hacks (e.g. multiple TCP connections)
- ……

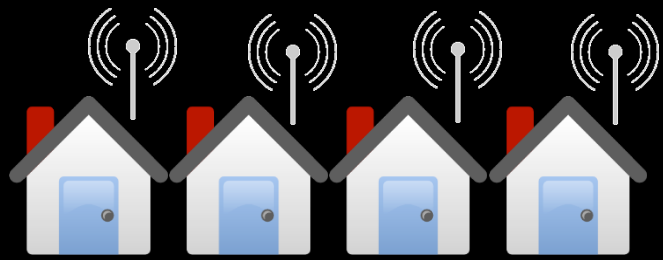
LTE

Femtocell

3G

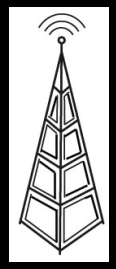


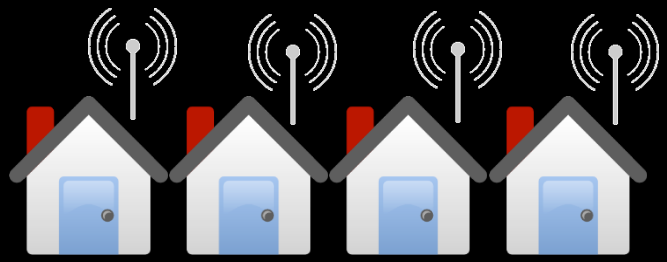
WiFi



Why not directly ask the network its current state?

Further, why not directly request the connectivity you need?





More generally, why isnt the network a platform for apps rather than a bitpipe?

- Network knows user location, connectivity, billing ….
- Enable applications to customize the network

Symptoms of an Underlying Root Cause

Wireless networks are complex & closed

Do not expose network state

- Hard to know available APs, their speeds, load etc

Do not provide external control

- Hard to request flow specific services from network

OpenRadio: SDN for Wireless

Wireless network architecture that provides software interfaces to:

1. Query wireless networks about availability, quality, speed, user location …

2. Control granularly how individual user or application traffic is handled by the network

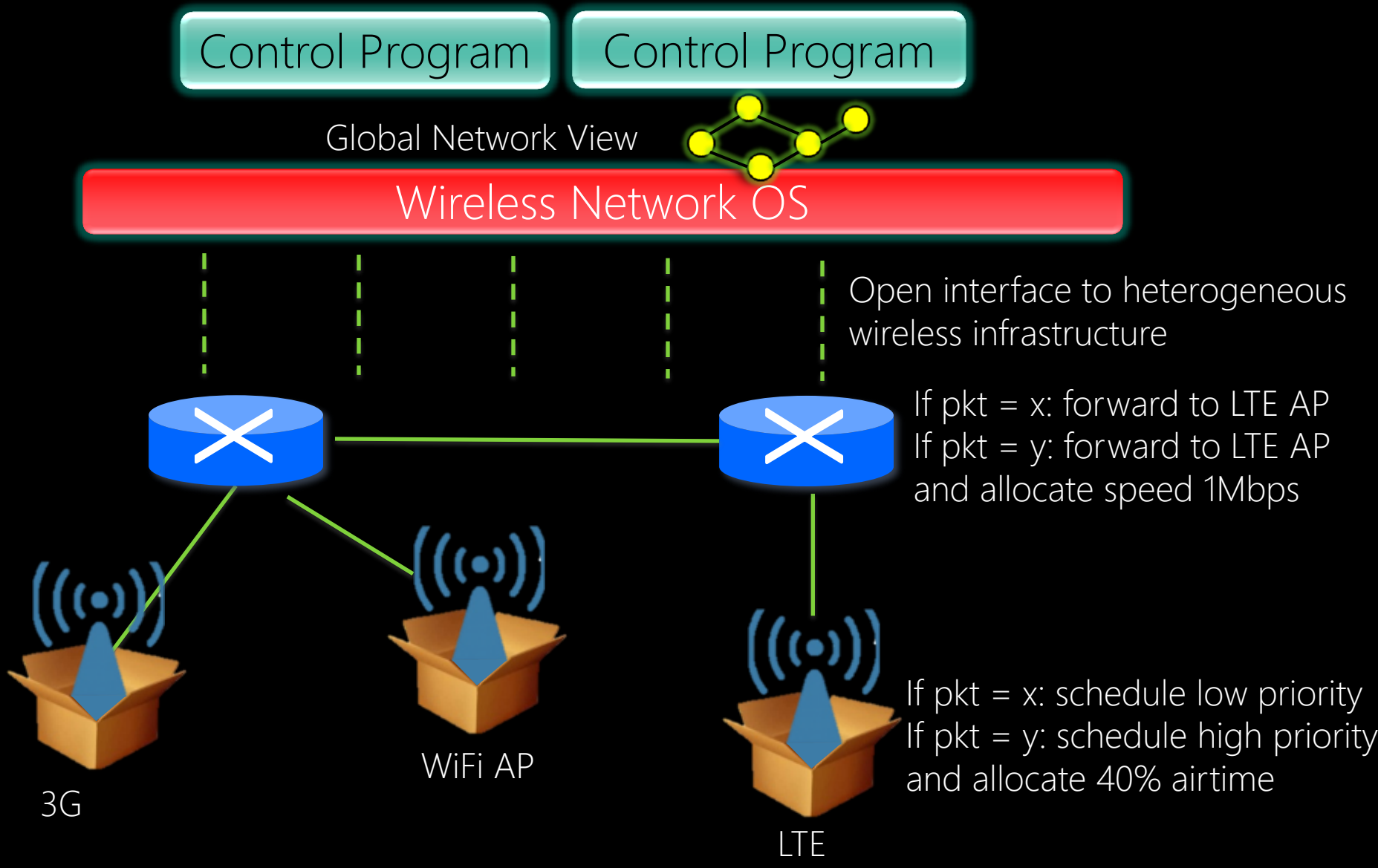
OpenRadio: Control Interface

Match/Action interface for the wireless SDN stack

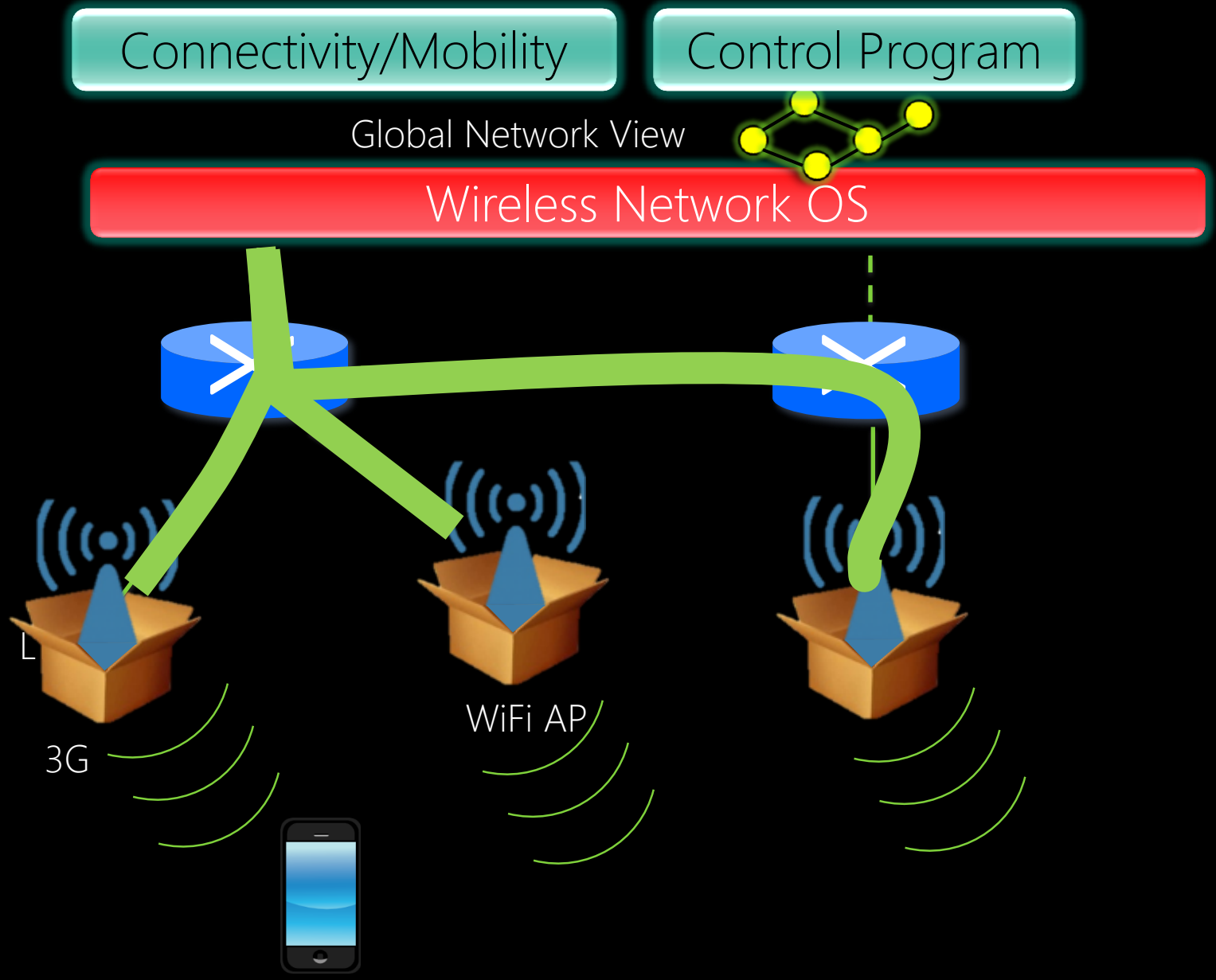
Match: Identify and tag flows of individual users and/or applications

Action: Control how packets are routed, what speeds & priorities they get, and how they are scheduled at the AP

OpenRadio: Architecture



E.g: Seamless Connectivity to the best APs



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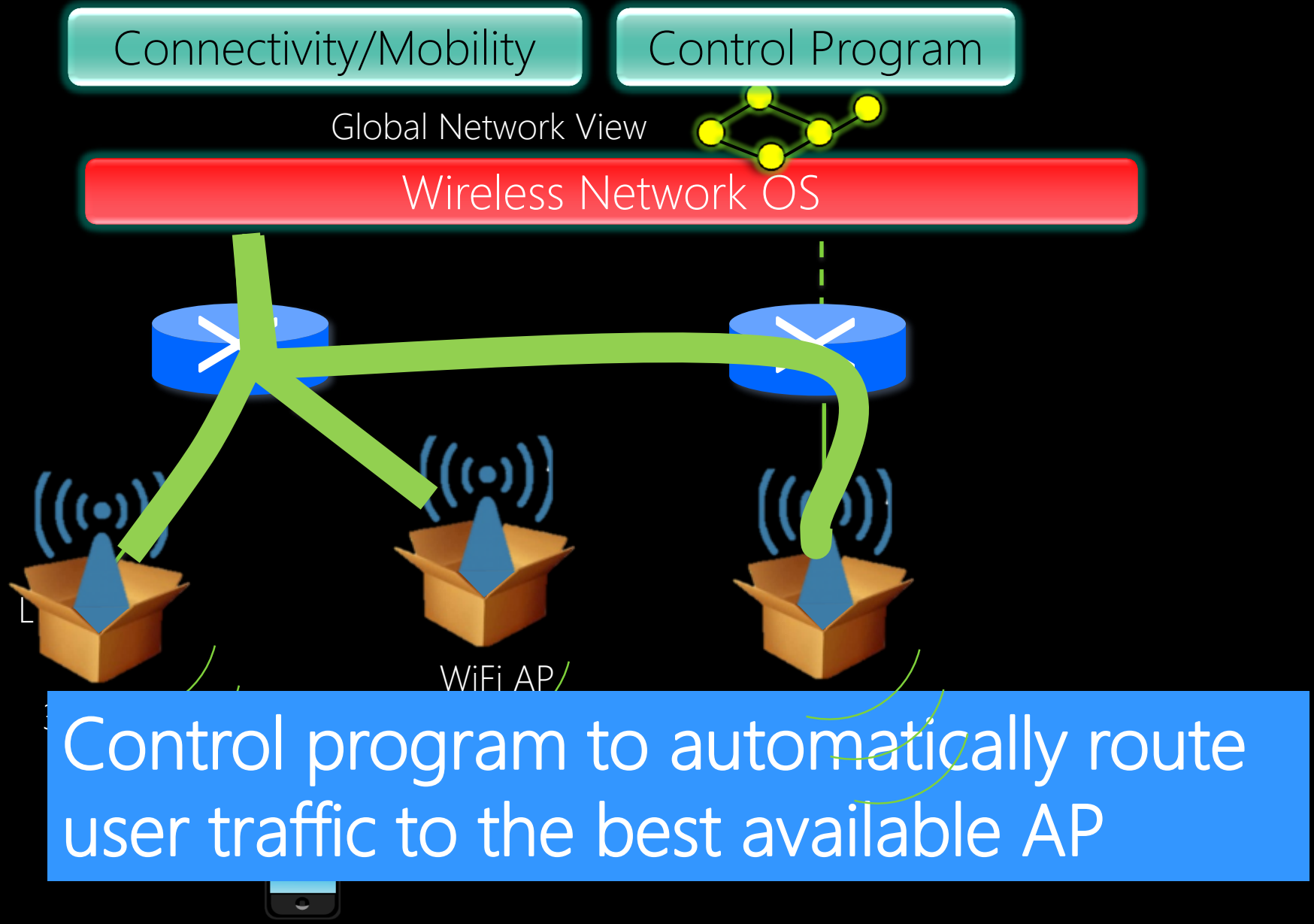
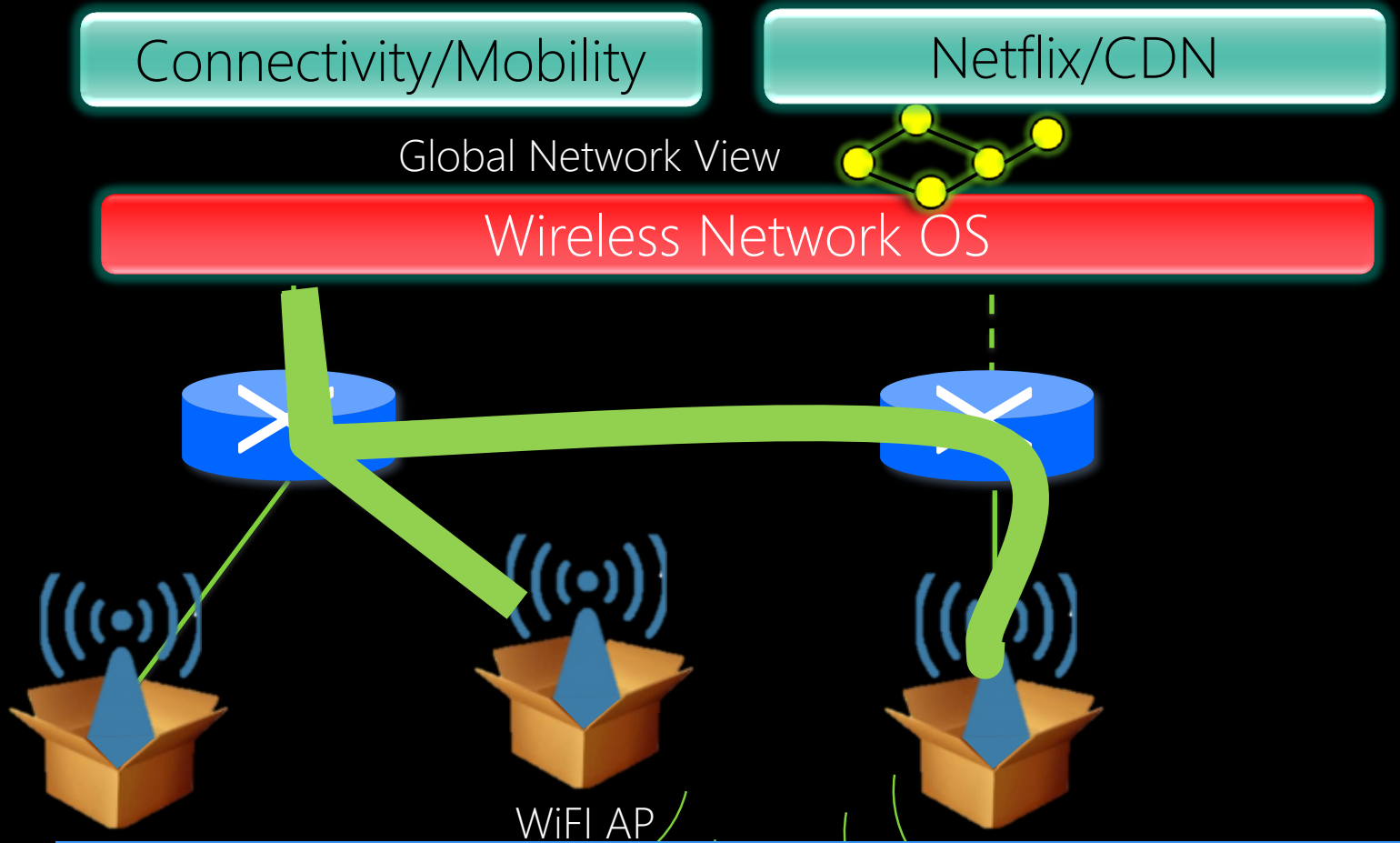


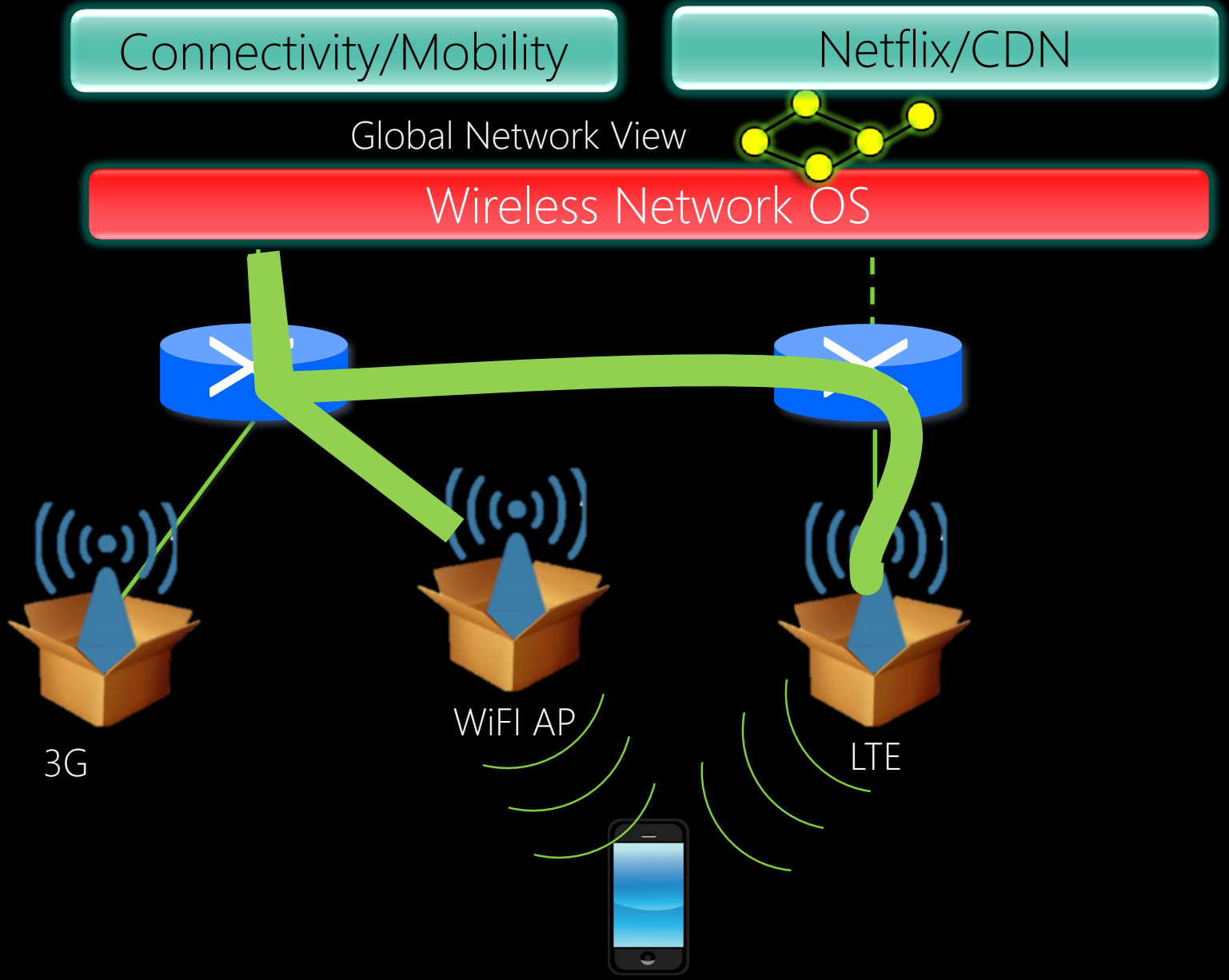
Control program to automatically route user traffic to the best available AP

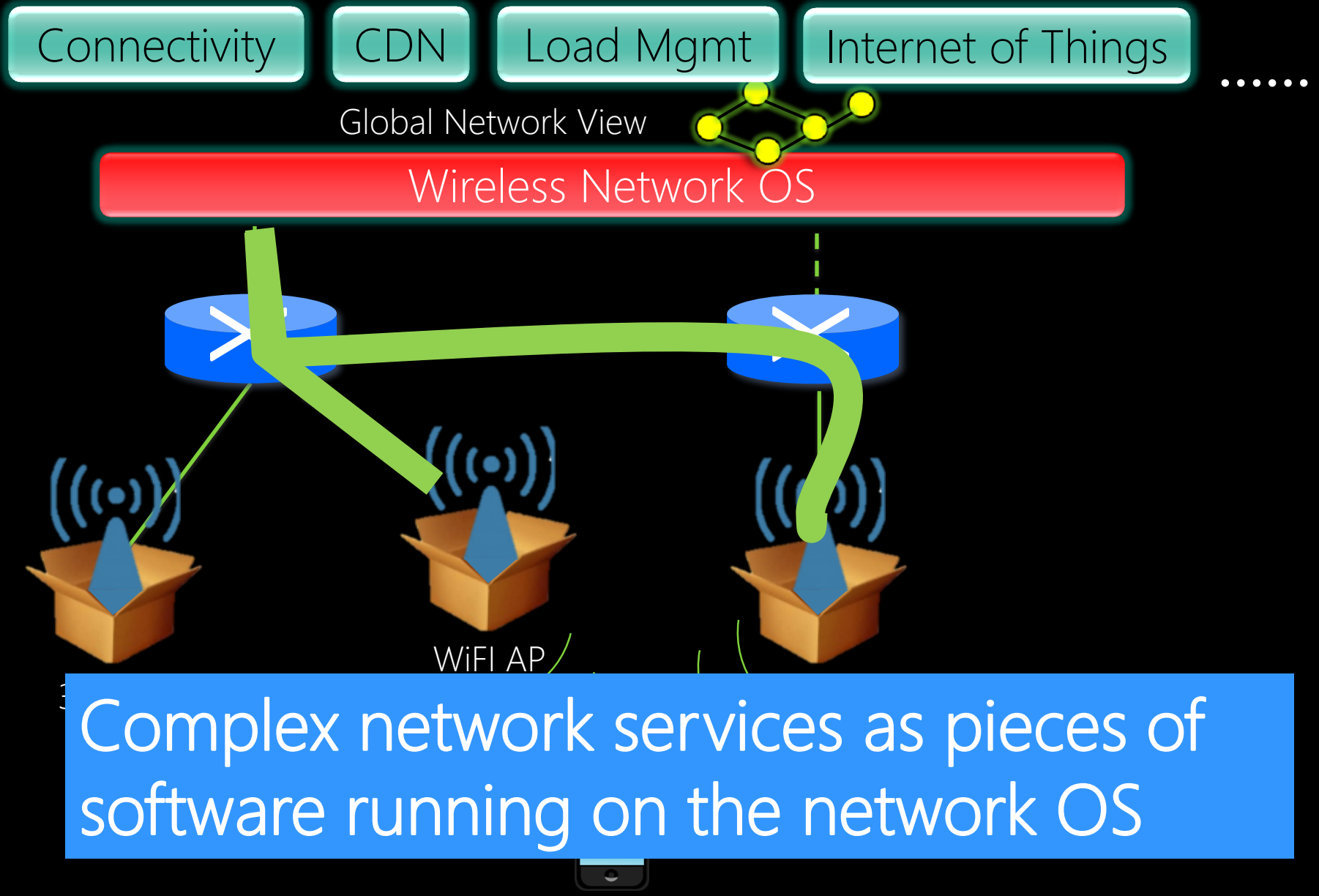
E.g: Dynamic High Speed Pipe for Video



Stitch a high speed pipe from available APs for HD video streams

E.g: Dynamic High Speed Pipe for Video





Complex network services as pieces of software running on the network OS

OpenRadio: Design

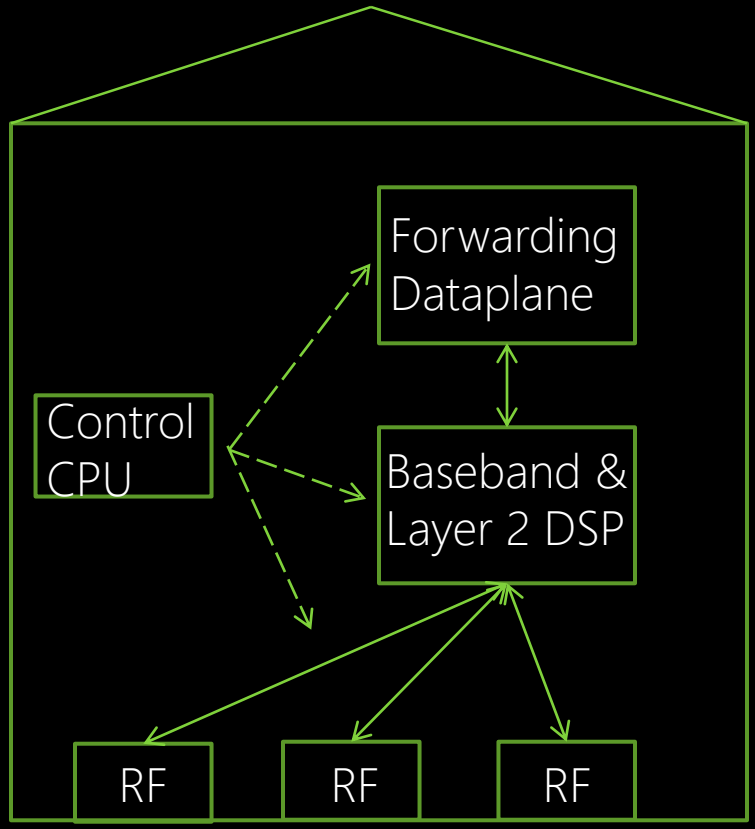
- Data Plane: Basestations and backhaul network
  - Can we build a programmable data plane using merchant silicon?

- Control Plane: Modular software abstractions for building complex network applications
  - What are the right abstractions for wireless?

OpenRadio: Cellular APs

OpenRadio APs built with merchant DSP & ARM silicon

- Single platform capable of **LTE, 3G, WiMax, WiFi**
- OpenFlow for Layer 3
- Inexpensive ($300-500)



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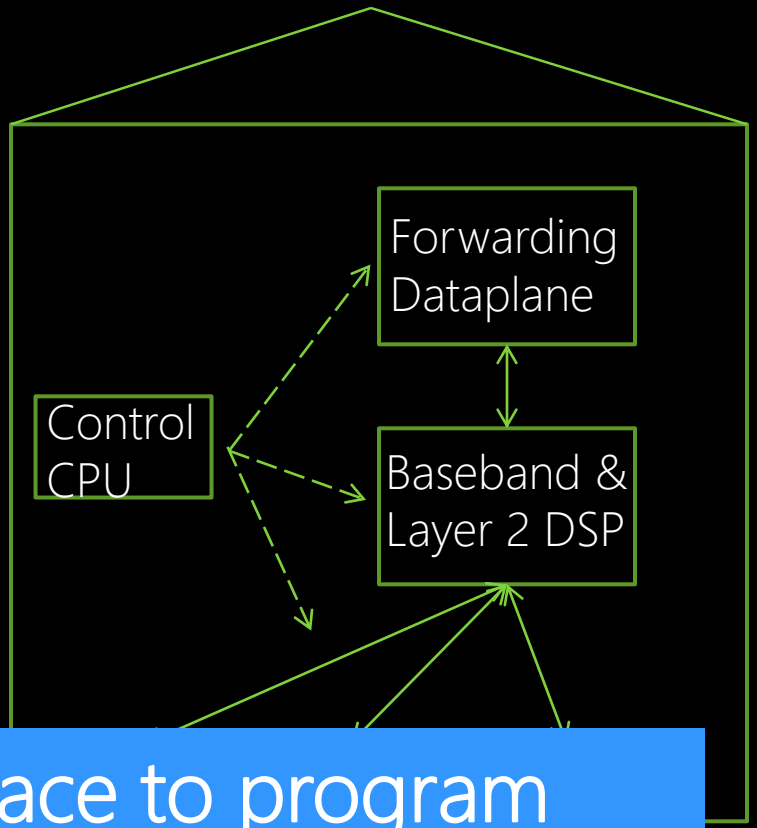


Exposes a match/action interface to program how a flow is forwarded, scheduled & encoded

OpenRadio: Cellular APs

Programmable, high performance, and multi-protocol (LTE, WiFi, WiMax, future LTE flavors)

Feasible because:

- PHY layers of all these protocols share the same signal processing blocks
- Hybrid DSP/x86 chips capable of running modern wireless protocols in software
  - Texas Instruments, Intel, Freescale …

OpenRadio: WiFi APs

OpenRadio-WiFi: Enhance commodity WiFi APs with firmware to have programmability

- Built on top of OpenWRT
- Interfaces to program specific flows
- Interfaces to forward, allocate rates and priorities for individual flows

OpenRadio: Control Plane

Network OS that provides software abstractions to simplify development of new services:

- Hides network heterogeneity (WiFi, 3G, LTE)
- Hides complexity of finding network state
- Hides complexity of controlling flow behavior

OpenRadio: Current Status

- OpenRadio APs with full WiFi & LTE software on **TI** C66x DSP silicon
- OpenRadio commodity WiFi APs with a firmware upgrade
- Network OS under development
- Prototype kits available later this year

To Conclude…

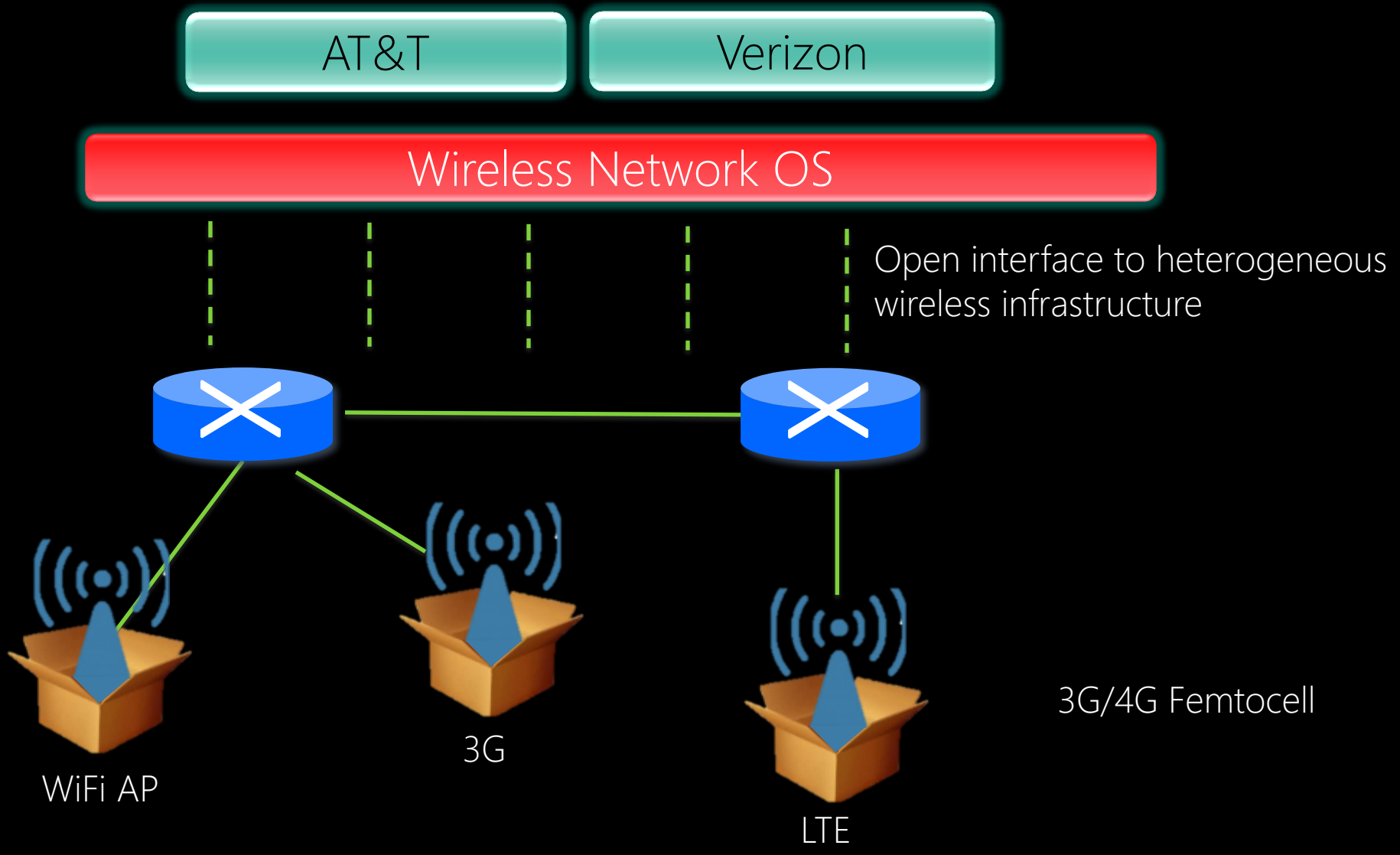
OpenRadio: SDN approach to wireless

Provides programmatic interfaces to monitor and program wireless networks

- High performance substrate using merchant silicon

Complex network services as software apps

Our Vision: Virtualized Wireless Networks



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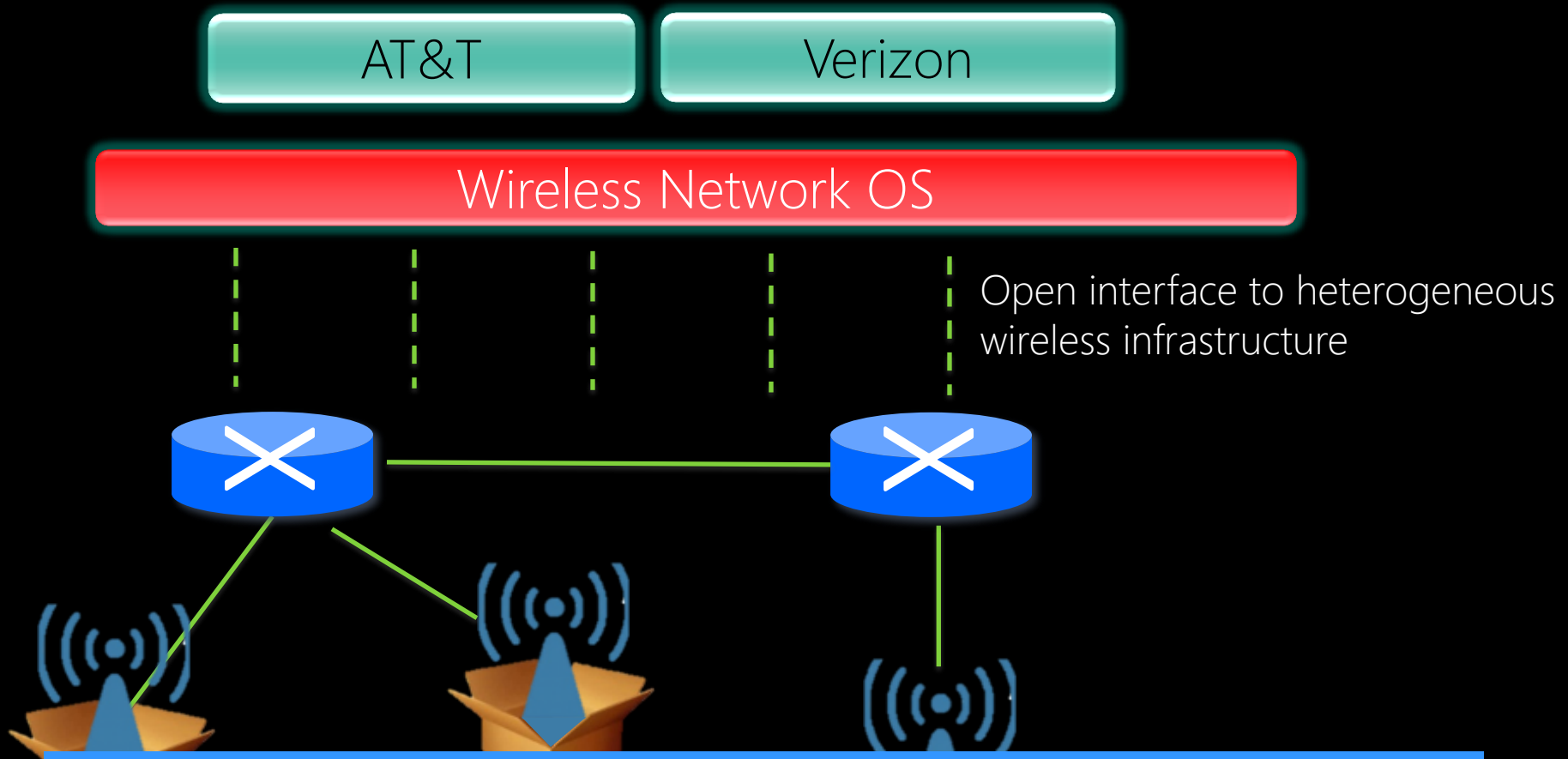

Shared physical wireless infrastructure decoupled from network service