5G is a **Software** Play

Edge-Cloud will Power Tomorrow’s Wireless

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Are we ready?

1G
1st Generation wireless network
- Basic voice service
- Analog-based protocols

2G
2nd Generation wireless network
- Designed for voice
- Improved coverage and capacity
- First digital standards (GSM, CDMA)

3G
3rd Generation wireless network
- Designed for voice with some data consideration (multimedia, text, internet)
- First mobile broadband

4G
4th Generation wireless network
- Designed primarily for data
- IP-based protocols (LTE)
- True mobile broadband

5G

The Need for Speed in kilobits per second

2.4 kbps  64 kbps  2,000 kbps  100,000 kbps
Takeways

• Software enables **rapid innovation** in telecom

• Rethink software stack for **efficiency** and **availability**

• **Re-architect** the Edge Cloud for 5G networks

• Explore novel **value-added services**
Hardware is cheap and getting cheaper

(even post Moore’s Law)
Spectrum is scarce

Poor spatial reuse; poor power efficiency; high inter-cell interference
More hardware (antennas + computing)
Higher spectrum efficiency
5G: more hardware, higher spectral efficiency, lower latency

- Massive MIMO
- Small cell/dense deployment
- mm-Wave radios
Argos V1 (2011): World’s first Massive MIMO Testbed
Platforms for Advanced Wireless Research

TESTBED

POWDER-RENEW

THE UNIVERSITY OF UTAH  RICE

Salt Lake City, UT

PAWR PROJECT OFFICE

usignite  Northeastern University
It took seven years!

2011

Ph.D. 2017

Skylark Wireless
CTO
Specialized equipment => Slow innovation

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5G
Specialized equipment => Slow innovation

1980s

1G
1ST GENERATION wireless network
- Basic voice service
- Analog-based protocols

1990s

2G
2ND GENERATION wireless network
- Designed for voice
- Improved coverage and capacity
- First digital standards (GSM, CDMA)

2000s

3G
3RD GENERATION wireless network
- Designed for voice with some data consideration (multimedia, text, internet)
- First mobile broadband

2010s

4G
4TH GENERATION wireless network
- Designed primarily for data
- IP-based protocols (LTE)
- True mobile broadband

2020s

5G

THE NEED FOR SPEED in kilobits per second

2.4 kbps
64 kbps
2,000 kbps
100,000 kbps
5G infrastructure needs a **software** approach
Lessons:

#1: **Software** innovates **faster**
#2: Resource **integration** is **bad**
Basestation=RF+Accelerator+software
• Slow technology evolution
• Impossible inter-cell resource sharing
• Difficult inter-cell coordination

Basestation = RF + Accelerator + Software
Disaggregated radio access

Disaggregated local data center = Accelerator + Software

Basestation = RF + Accelerator + Software
Cellular network recent past

Small cell, MU-MIMO, inter-cell coordination
Software has already eaten Internet and cellular core

Cellular network today

Small cell, massive MIMO
Cellular network tomorrow

Disaggregated local data centers

Small cell, massive MIMO

Internet

Core Network

SDN and NFV

Radio Access

Server cluster

Accelerator rack
• Fast technology evolution
• Resource consolidation
• Value-adding services
Software enables inexpensive dense deployment and fast innovation.

An array of cheap access points serving mobiles.

Overarching challenge: Handover at vehicular speeds, picocell cell sizes.

Song et al (SIGCOMM’17)
ParkMaster: Smartphone-based on-the-road parking intelligence

- Close to zero-cost system for parking availability monitoring
- In-frame car localization algorithm
- Lightweight car tracking algorithm

Grassi et al (SEC 2017)
Continuous mobile vision

2012
Continuous mobile vision

2012
Continuous mobile vision

2020
Software systems must be Efficient (like baremetal) Available (like commodity data center)

Accelerator Rack

Heterogeneous edge data center

FlexCore, NSDI’17
Rethink the software stack for **efficiency** & **availability**
Linux is fundamentally flawed for these goals

- C is not safe
- Weak modularization
If Linux/C is airport security check we need TSA Pre


Time of enforcement

Theseus/Rust

Linux/C

Design time  Implmtn. time  Compile time  Install time  Load time  Run time  Post mortem
5G is a **Software** Play

- Software enables **rapid innovation** in telecom

- Rethink software stack for **efficiency** and **availability**

- **Re-architect** the Edge Cloud for 5G networks

- Enable novel **value-added services**
Thank you!