BEYOND 5G: RESEARCH AND TESTING

A VIEW FROM THE NATIONAL SCIENCE FOUNDATION

Thyaga Nandagopal

Deputy Division Director,

Directorate of Computer and Information Sciences & Engg

National Science Foundation

5G (AND OTHER WIRELESS TECH) ADVANCES

- Breakthrough use of mm-wave spectrum
  - Small cells, limited mobility
  - Likely to prevail in indoor and hot-spot scenarios
- 5G NR
  - More bandwidth, higher modulation
  - More spectrum through federal spectrum sharing
  - Peak per-device data rates likely to hit Gbps
  - Network architecture innovation will drive gains, especially with artificial intelligence (AI)
- IoT-specific networks
  - LoRA, NB-IoT – higher scales and densities
- WiFi to continue becoming faster

BEYOND 5G: NOT JUST WIRELESS

- End-to-end innovations will be needed
- Re-imagine network architecture
  - Radio Access Network, Evolved Packet Core
  - But, also internet routing, edge computing
- Don't stop there
  - Data flows on an end-to-end basis
  - Understand and re-imagine how information is produced and consumed
  - Incorporate non-human centered communication

CHALLENGES

- Very few experts who have end-to-end perspective
  - And still understand wireless
    - Wireless will never become 'Ethernet without wires'
    - Spectrum issues are complex
  - Across academia and industry
- Research breakthroughs need this perspective
  - To produce new abstractions
- Barriers to practical deployments are high
  - Industry is siloed into sectors
  - Wired and wireless are still separate business units
- Significant workforce development challenge

OPEN PROBLEMS (UNSOLVED BY 4G OR 5G)

- Meaningful Spectrum Sharing
  - Only coarse granular and one-way
  - Missing dynamic sharing at finer-granularity and two-way
  - Respectful of the goals of all users of spectrum

- Inter-operability and seamless cross-technology mobility
  - Between Wi-FI and cellular
  - No multi-interface operation
  - No multi-operator network support

- Shared infrastructure – multi-tenancy 5G RAN/Core
  - True potential for NFV

BEYOND 5G RESEARCH

- Address open problems (on previous slides)
- Sub-TeraHertz (100 GHz – 1 THz) and TeraHertz:
  - Multiple ladders of challenges to be solved
  - PHY layer issues first
  - Channel sounding, propagation
  - Antennas, Beamforming, tracking, Tx/Rx chains
  - … these are the easy parts !
- Quantum Communications:
  - Real uses beyond establishing secure key exchange?
- AI/ML:
  - Embrace data end-to-end – wireless is just enabler

EFFORTS AT NSF

- Investments of roughly $50M each year in wireless
  - Basic research
  - More than $150M/year in end-to-end research that assumes wireless to be an integral component
- Multitude of efforts to promote translation of outcomes
  - Convergence Accelerators
  - Transition to Practice (TTP)
  - Partnerships for Innovation (PFI)
  - Small Business Innovation Research (SBIR), Tech Transfer
  - Innovation Corps (I-Corps)
- Gap in between research and commercialization
  - VALIDATION !

TESTBED FOCUS @ NSF

- Platforms for Advanced Wireless Research (PAWR)
  - $100M Public Private Partnership (29 companies)
  - 7-year program, started in 2018 (NSF: $7M/year)
- Mid-Scale Research Infrastructure (MSRI) program
  - Two tracks: MSRI-1 (< $20M/award), MSRI-2 (< $70M/award)
  - MSRI-1 calls in FY19 and FY21, MSRI-2 in FY20
- CISE Community Research Infrastructure (CCRI)
  - Up to $5M per award
- Major Research Instrumentation (MRI)
  - Up to $6M per award
- Cyberinfrastructure for Sustained Scientific Innovation (CSSI)
  - Up to $5M per award
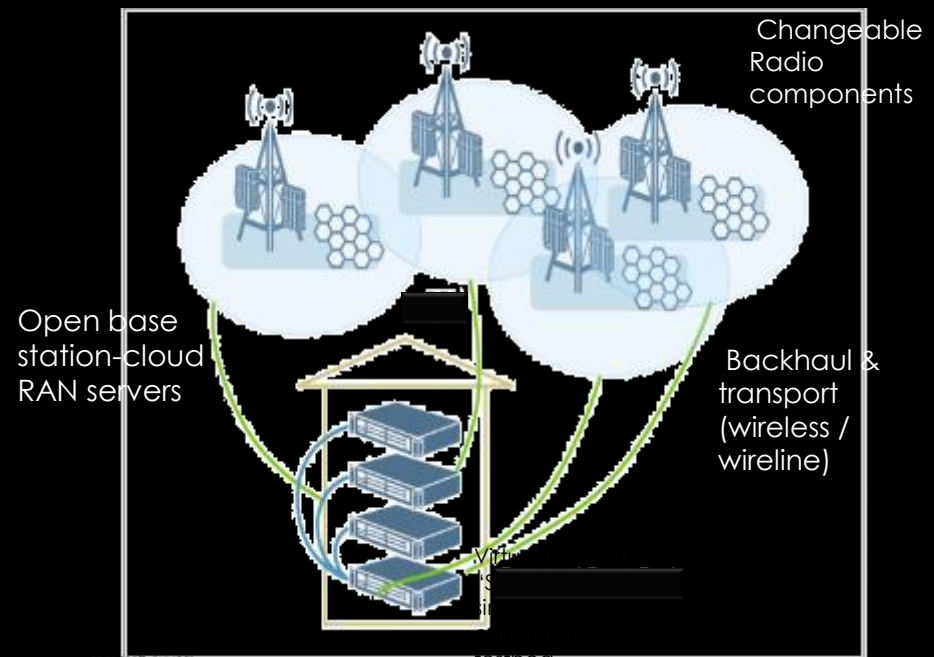
PLATFORMS FOR ADVANCED WIRELESS RESEARCH (PAWR)

Infrastructure Provides

- SDR radio layer
- Fiber backhaul
- Software configurable infrastructure (SDN, NFV)
- Ability to add or swap components for projects
- Time or geographical sharing of environment

Flexible enough to support multiple research areas

- Small cells and/or mmwave/THz mesh access-backhaul
- Flexible spectrum usage - FCC Innovation Zone (experimental spectrum use)
- SDN, NFV, MEC architectures to support infrastructure
- Cellular and WiFi wireless technology
- Network performance and analytics

Sites support SDR radio technology: 10-20 sites per PAWR

Changeable Radio components

Open base station-cloud RAN servers

Backhaul & transport (wireless / wireline)

Edge Cloud Programmable Infrastructure: SDN / NFV

PAWR: ENABLING BEYOND 5G

- https://www.advancedwireless.org
- Dynamic Spectrum Sharing, Massive MIMO, Edge Clouds and IoT
  - https://powderwireless.net
  - Salt Lake City
- Millmeter-wave, Dynamic Optical Networking
  - https://cosmos-lab.org
  - New York City
- Mobility (Drones, Vehicles – manned, unmanned)
  - TBA
- Smart Rural Communities (Agriculture)
  - TBA

SUMMARY

- NSF has been instrumental in laying down foundations for 3G, 4G and 5G

- Critical role in workforce development for the US

- Ongoing investments looking beyond 5G
  - Basic Research
  - Testbeds
  - Translational Opportunities