

A Vision for NextG Networks and Systems: a view from the National Science Foundation

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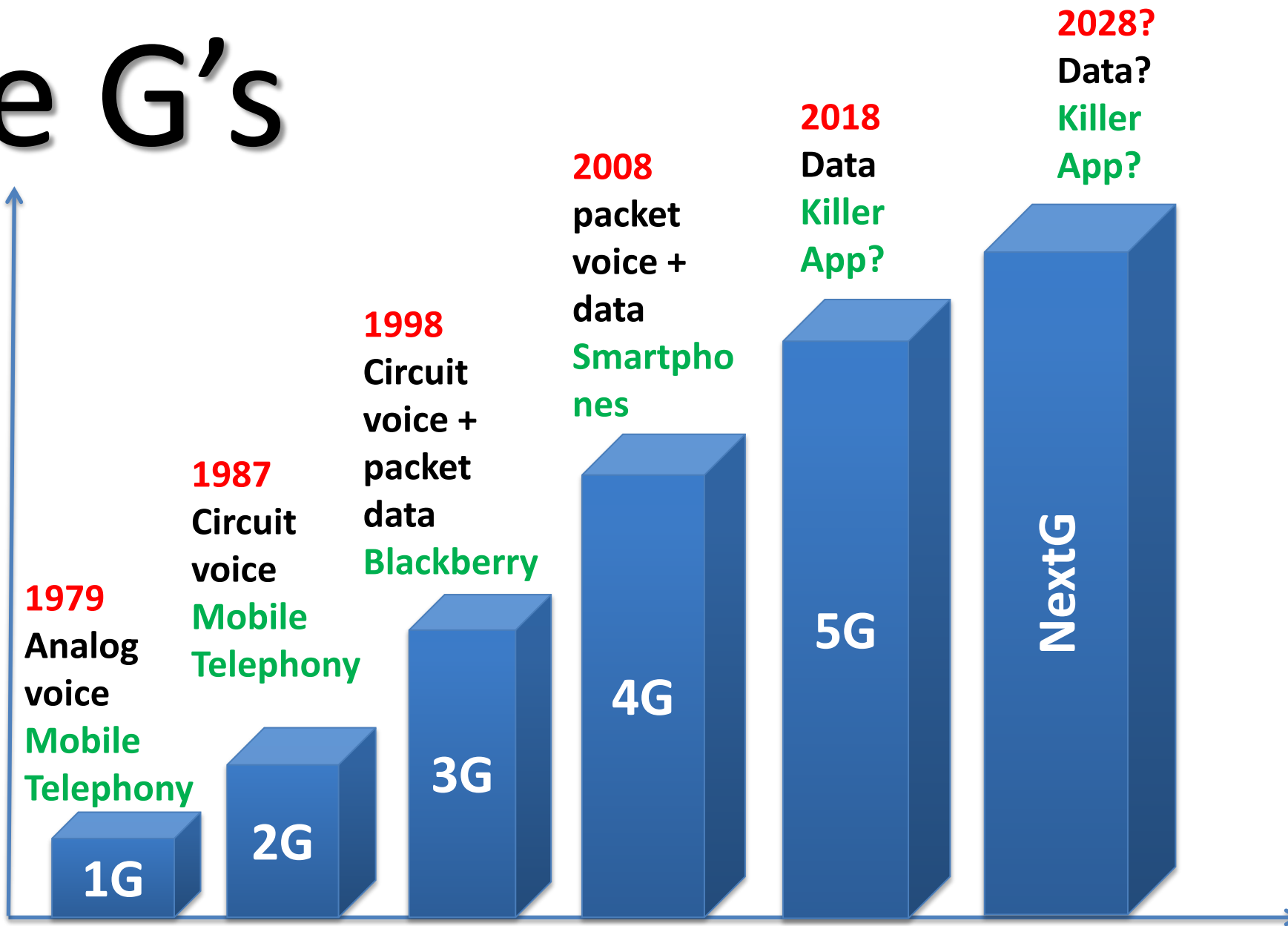


National Science Foundation

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The G's



Advancing
wireless
research:

the role of NSF
(past)



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NSF-funded research enabling today's 5G networks:

- Three-tier CBRS spectrum sharing
 - (CNS-0831791 & CNS-0831762)
- Use of Millimeter-wave spectrum for 5G
 - (IIP-0933985, CNS-1320472 & ECCS-1555332)
- 5G Network Architecture (CNS-1317153)
- Massive MIMO Advances
 - (CNS-1012921 & CNS-1405937)
- Software-defined networks (CNS-0832820)
- Building out NSFNET, Internet2, and enabling companies like Qualcomm and Google.
- ... among others!

Advancing wireless research:

the role of NSF (present)



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- ***\$100M annually and increasing, on average***
 - <https://www.nsf.gov/cise/advancedwireless/>
- ***Foundational R&D***
 - Core research, Cross-Programs
 - One-to-one Partnerships (e.g., *DARPA, Intel, VMware*)
 - Multi-sector partnerships
- ***Testing infrastructure***
 - Platforms for Advanced Wireless Research (<https://beyond5g.org>)
- ***International Partnerships***
 - Finland, France, Ireland, Israel, Japan, S. Korea
- ***Center-Scale Activities***
 - 3 Centers with \$20M+ investments

Advancing
wireless
research:

What comes
after 5G?

The views expressed here are solely my own, and do not represent the views of the National Science Foundation, and should not be construed as such.



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NextG
is much
more than 6G

***Not just cellular, not just wireless,
not a single set of standards***



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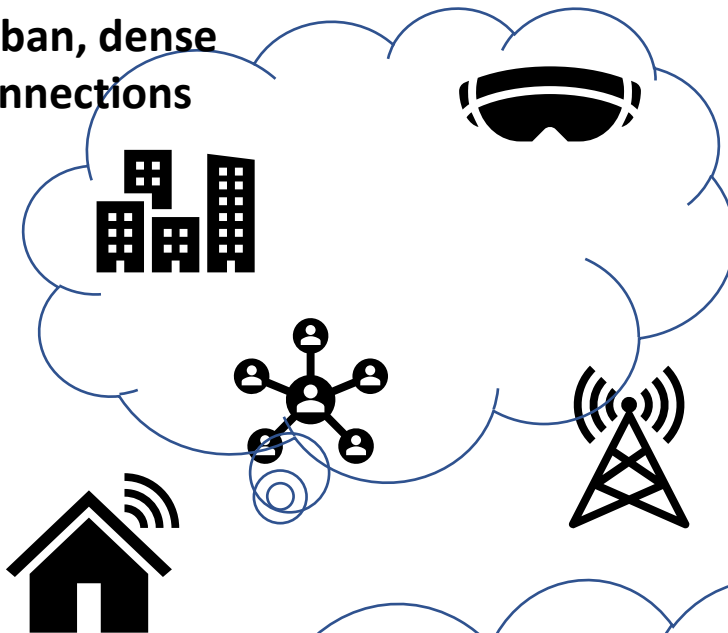
NextG is about:

- Convergence
 - Wired and wireless, communications and sensing, het nets (6G, satellite, WiFi), compute and comms (mobile edge computing), software-driven communication systems
- Spectrum sharing
 - Repurpose bands for optimal use, better sharing with trust
- Resilience
 - Reliability, Adaptability and Security
- Ultra-low latency
 - Enabling new novel applications
- Wider broadband reach
 - low-cost backhaul, lowering cost of access, rural broadband
- Intelligence

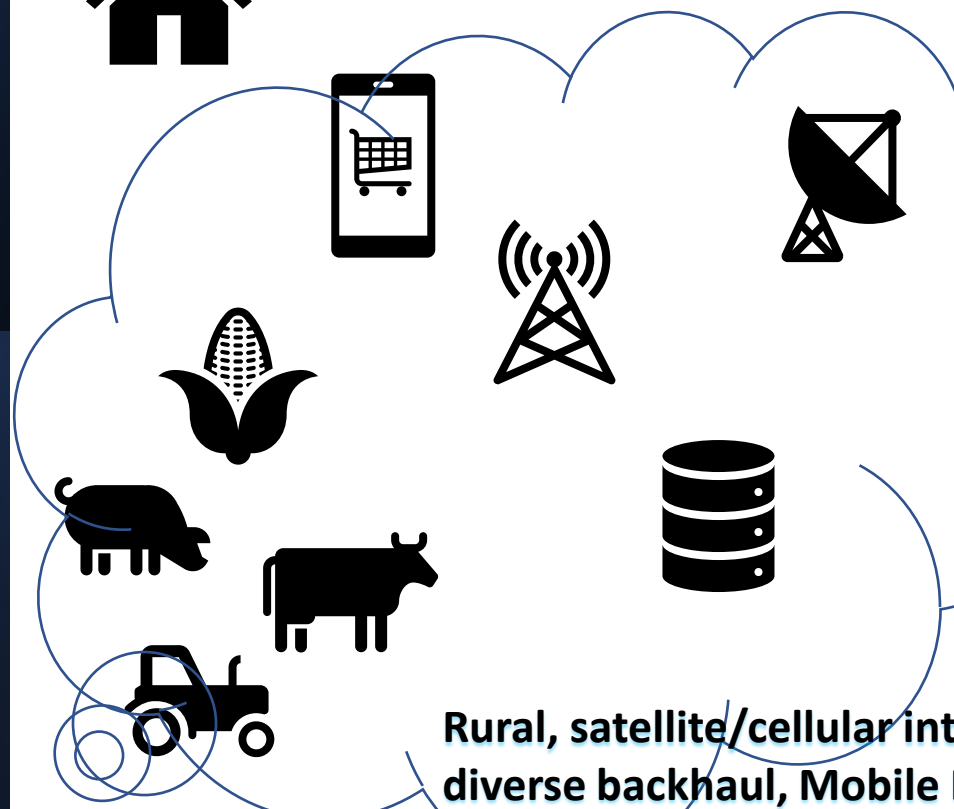
Convergence

Software-driven
Autonomous
Actuation-focused

Urban, dense
connections



LEO/MEO/GEO
Satellites, Cellular,
WiFi, LoRA/NB-IoT



High-speed, low-latency
networks, Cloud Computing



Rural, satellite/cellular integration,
diverse backhaul, Mobile Edge computing, remote sensing



Mobile
Broadband

Wide-area
Coverage

Connectivity
Fabric

No more
wires

Radar/
Active
Sensing

Natural
Phenomena
Monitoring/
Passive
Sensing

Power
Transfer

Land/Water/S
pace

5G/Cellular

WiFi

Sensing

Other Uses

Spectrum (RF/non-RF)

(300 MHz - 6 GHz, 6 -15 GHz, > 20 GHz)



Resilience

Resilient NextG Systems

Adaptability

End-to-End Security

Autonomy

Applications: Augmented Reality and others that merge physical/virtual

Algorithms: Spectrum sharing, Resource optimization and management

Device-to-Edge-to-Cloud

Hardware: RF and Mixed Signal Circuits, Antennas and Components



Ultra-Reliable Low-Latency Communications

- Human perception of latency: > 20 ms
- End-to-end communication latency today is impacted by many factors beyond speed-of-light
 - Application to network latency
 - Medium access latency
 - Content scanning/Deep Packet Inspection
 - Packet copying
 - Routing lookups
 - Photon \leftrightarrow electron translation latencies
- URLLC: < 20 ms round trip time
- Need guaranteed delay bounds (or with high probability)
- Jitter bounds are essential
- Not for human-human alone, but human-machine and machine-machine as well



Near Term

- Software-defined networking (SDN) ecosystems
- AI/ML for networking, spectrum sensing and access
- Enabling 6G and beyond systems (massive MIMO, mmWave)
- Mobile Edge computing
- Advanced wireless sensing, joint sensing/communication
- Free-space optical networks
- Large-scale MIMO
- Advanced duplexing
- Wireless measurements
- Long-distance high-BW links

Mid-term

- Fully programmable protocol stacks
- Ultra-low latency wireless links
- Ubiquitous wireless access
- Extremely low-power designs
- Zero-trust networking
- Meta-materials and intelligent surfaces
- “Security-by-design” and resilience
- On-demand spectrum sharing and access
- Widely tunable front ends.
- Energy efficient waveforms
- Intra-satellite communications
- Low-cost hybrid backhaul/fronthaul

Long-term

- Quantum networks
- THz networking (new radio approaches)
- “Self-driving” networks
- Repeatable and verifiable research
- Holographic calls
- Tactile Internet
- Flying networks

**Example
topics of
interest**



Getting ready for NextG

- Step away from the 5G roadmap
 - NextG is going to be radically different
 - Not just the way 2G was different from 1G, and 4G was different from 3G
 - Faster, Denser and Quicker – yes.
 - Convergent and unique as well
- Remember: what is now 5G started research around 2007 – 2009

Conclusion:

- Start work on these problems now
- Standards or product roadmaps happen much later
- Think broader

