2024 IEEE CQR Emerging Technology Reliability Roundtable - Lisbon, Portugal

Disruptive Impact of 6G To Global Technology, Humanity, & Reliability

David Lu

AT&T, Vice President, Network Systems (Retired)

May 22, 2024

Agenda

1. Disruptive Technologies Landscape
2. Foundation Technologies
3. Disruptive 6G & Beyond
4. 6G Path & Reliability Considerations
5. Open Dialog

Disruptive Technologies Landscape

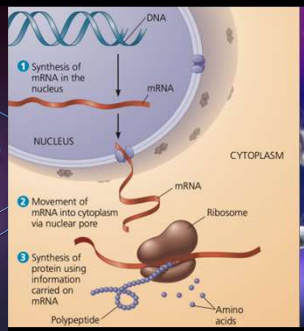
The tremendous change driven by innovation and disruptive technologies are revolutionizing the way we live, learn, and interact…

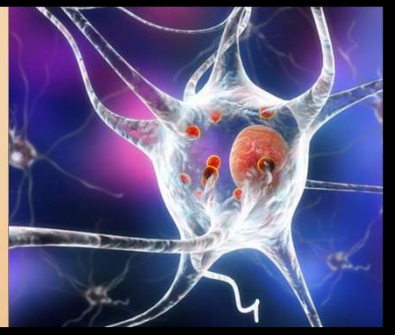
David Lu. April 16, 2024

Generative AI

Quantum Computing & Communication

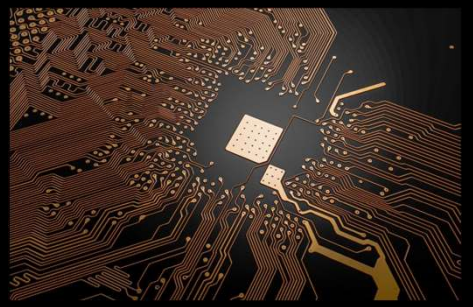
Blockchain





Degenerative genetics & medicine

LEO Satellite
& 6G



CPU to GPU
Can Nanometer go to Picometer?

Foundational Technologies Landscape

SOFTWARE-DEFINED EVERYTHING & REVOLUTION

A World Is Colliding & Converging with Foundation Technologies for Generative AI

Configure	Monitor	Modernize	Analyze	Innovate
Nano Technology, GPU, Sensors, Quantum Computing, Fiber (400/800G), Access 1G-20G, Spectrum, Towers, Small Cells, 5G/5GA/6G, WiFi6 & WiFi7, LEO Satellite	Explosive Network Traffic, Video (4K/8K), Video Net Traffic 129 ZB (Global)* VR/AR Apps Brain Computer Interface Comm-Sensing Net Integration Trade Rules Geopolitics Global Supply Chain	Software Super-Powered by Cloud/Hyper DB, Network Slicing, Open API, SaaS & NaaS, Open Source, SDN/VNF, Generative AI Hyper-Auto, Scale Ecosystem, SW Controlled Security, etc.	Business & Operation Automation Data Analytics & Insights User Centric Integration Green Field App Legacy Exit	Explosion of New Use Cases & Ideas about Consumer and Enterprise - Smart Cities, Smart Streets Smart Houses Smart Health, Smart Cars, And Drones, etc.

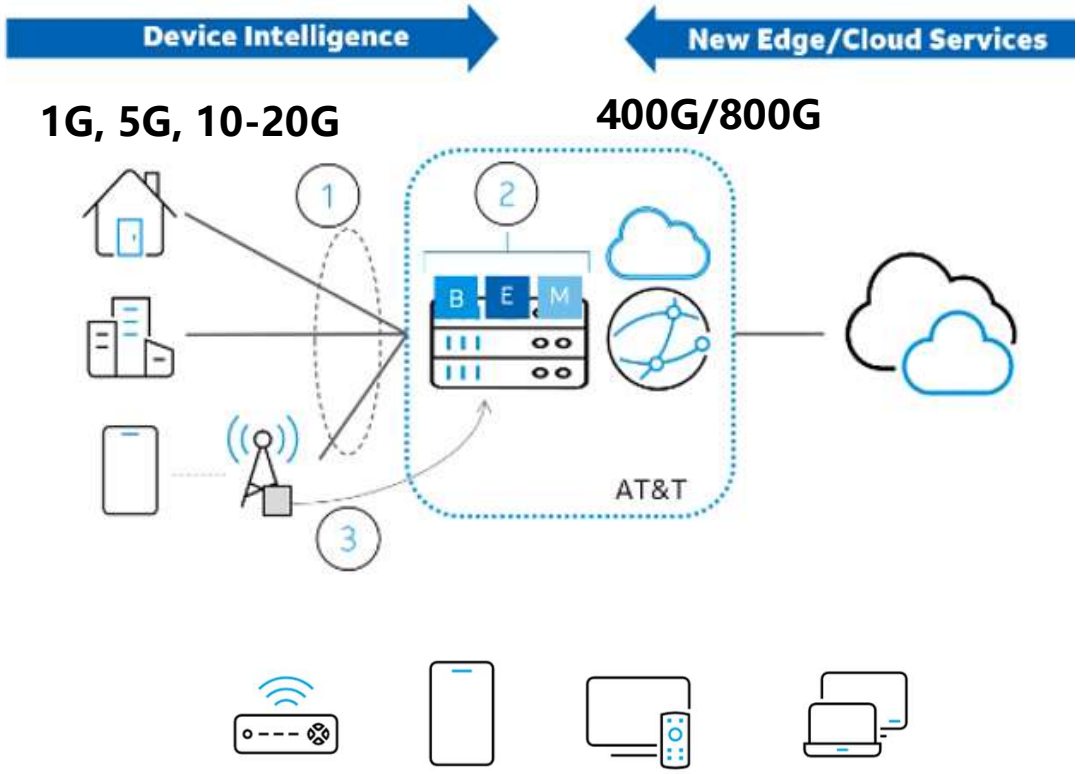
*Source "The Worldwide IDC Global DataSphere Forecast, 2023-2027"

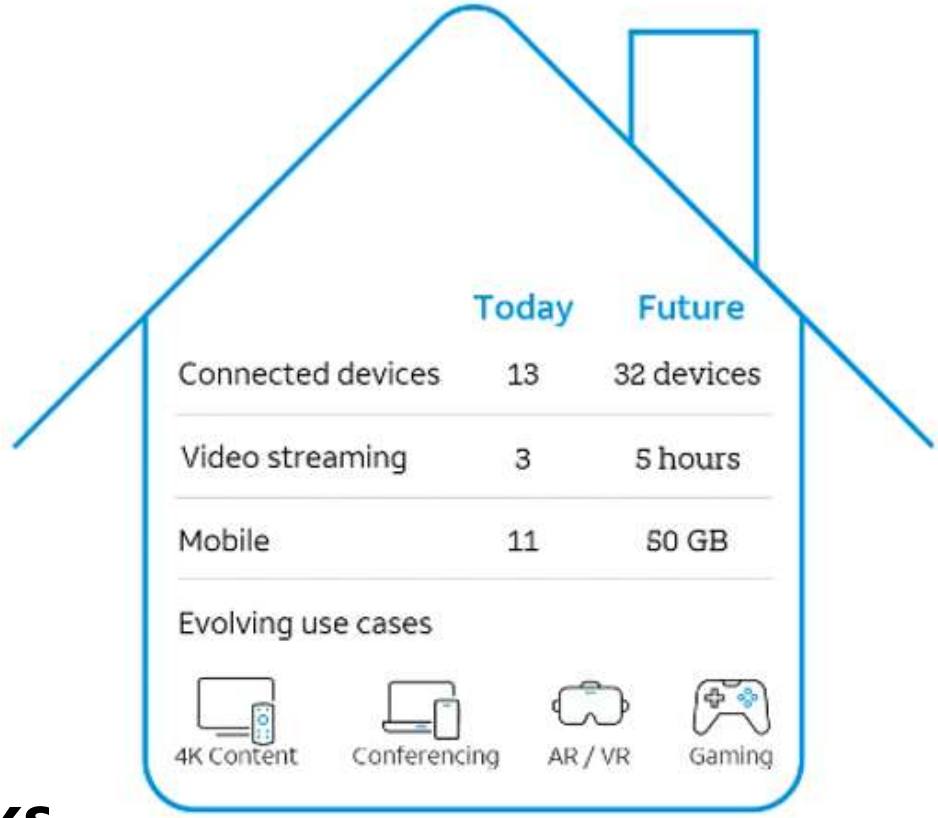
Examples of Emerging Technologies Evolution

SDN, 5G, Drone, and LEO Satellite

Foundation for Generative & Massive AI

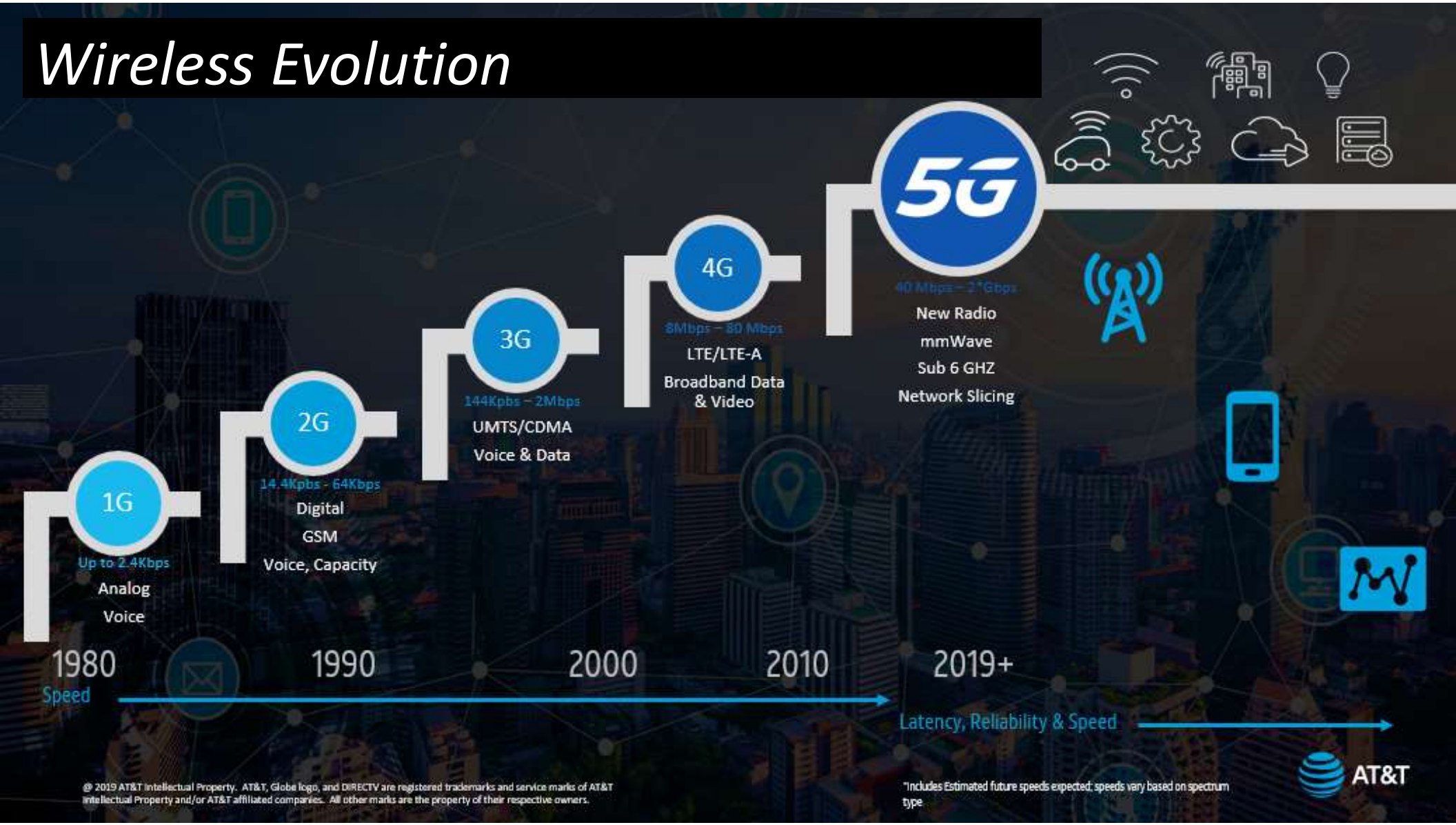
Converged Fiber and Wireless Network Yields Significant Benefits





SDN Driven Fiber and RAN Networks

Wireless Evolution



*Includes Estimated future speeds expected; speeds vary based on spectrum type

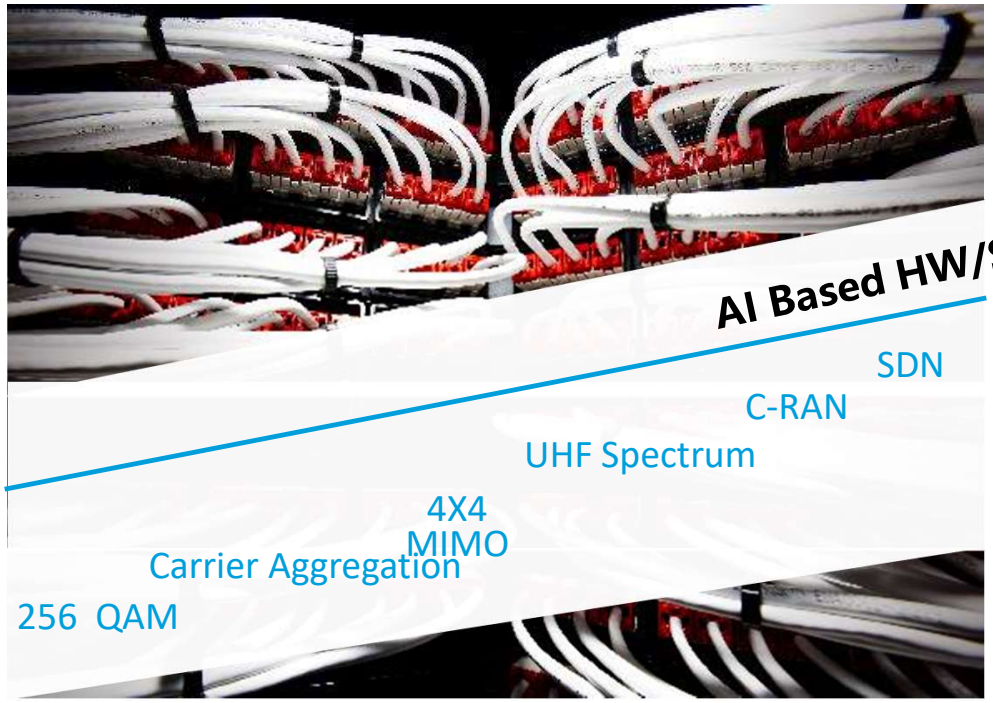
AT&T


THE 5G PATH
Promises ultimately to give us ultra reliability, better capacity and coverage, lower latency, and massive device connectivity.
MASSIVE DEVICE CONNECTIVITY
ULTRA LOW LATENCY
ULTRA RELIABILITY
BETTER CAPACITY & ULTRA HIGH SPEEDS
DATA-DRIVEN INSIGHTS

Software-driven (AI) Wireless Technology Evolution

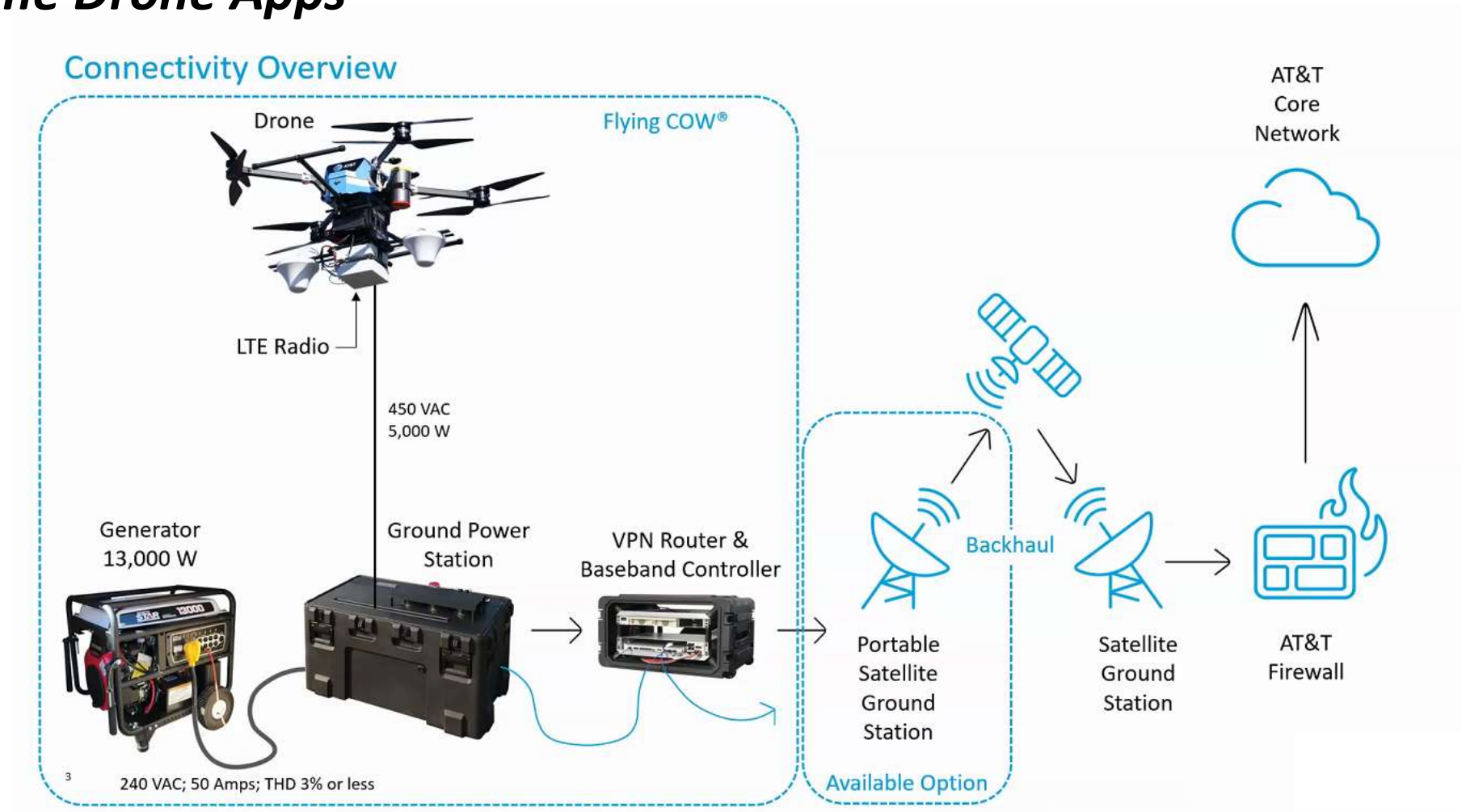
TODAY

FUTURE



THE FUTURE IS SOFTWARE-DRIVEN (AI) RADIO

Some Drone Apps



Low Earth Orbit (LEO) Satellites

Satellites <**500KM** above earth to provide Internet/Cell Access that is faster and higher capacity than geostationary satellites **36,000KM** above earth
Note: Starlink deployed 5,438 LEO satellites in space already.

Always in motion relative to ground and not over a fix location requiring many LEO satellites to provide coverage. (hundreds, thousands, tens of thousands)

Pros

- ✓ Available in rural areas
- ✓ Faster than dial-up
- ✓ Innovation is continually improving service
- ✓ Growing number of providers

STARLINK amazon | project kuiper BOEING OneWeb TELESAT

Cons

- ✓ Data Limits (varies by carrier)
- ✓ High Latency (varies by carrier)
- ✓ Geographical limitations (can't service deep canyons or heavily wooded areas)
- ✓ Complex ground stations to handle frequent handoffs between LEO Satellites
- ✓ Space traffic & debris
- ✓ Light pollution obstructing astronomers
- ✓ Bandwidth limits for large dense urban area

SpaceX massive scalability launches each rocket with 40 LEO satellites into orbit each week. Deployed 5,438 satellites by February 2024.

Disruptive 6G and Beyond

Accelerating Technology Innovation

IEEE/Industry Projected 6G Requirements

1 Extreme high data rate & capacity

- Peak data rate > 100 Gbps exploiting new spectrum bands
- >100x capacity for next decade

6 Extreme coverage

- Gbps coverage everywhere
- New coverage areas: sky (10000m), sea (200NM), space ...

5 Extreme low energy & cost

- Affordable mmW/THz NW & devices
- Devices free from battery charging

Characteristics	5G	6G
Individual data rate	1 Gbps	100 Gbps
DL data rate	20 Gbps	> 1 Tbps
U-plane latency	0.5 ms	< 0.1 ms
C-plane latency	10 ms	< 1 ms
Mobility	Up to 500 km/hr	Up to 1000 km/hr
DL spectral efficiency	30 bps/Hz	100 bps/Hz
Operating frequency	3 – 300 GHz	Up to 1 THz

2 Extreme low latency

- E2E very low latency < 1 ms
- Always low latency

3 Extreme high reliability

- Guaranteed QoS for wide range of use cases (up to 99.99999% reliability)
- Secure, private, safe, resilient ...

4 Extreme massive connectivity

- Massive connected devices (10M/km^2)
- Sensing capabilities & high-precision positioning (cm-order)

AI Enabled 6G Technology Outlook – Food for Thoughts

- Making use of free spectrum or new spectrum & improve the spectrum efficiency.
- Very high data transfer speeds & ultra-low latency network functions.
- Greater support for machine-to-machine (M2M) connections & use of new IP?
- Taking advantage of mesh networking & public/private clouds.
- Integration of terrestrial and satellite communication, especially LEO satellite.
- A focus on energy efficiency.
- Greater network reliability & security.
- The use of AI and ML for optimal connectivity (e.g., millimeter wavelength)

Key to 6G success are the use cases & adoption rates

Disruptive & Emerging Technology Use Cases

Connected Cars and Driverless Cars, 5G Slicing & On-Demand Network Capacity, Carrier Aggregations, Millimeter Wavelength for Fix Wireless in Dense Urban Areas, New Spectrum and Free Spectrum, New Energy Model, **Satellite Integration**, **WiFi Integration**, **Sensor Network Integration**, New IP, Mesh Network, New Reliability Model, AI Driven New Architecture

Smart City, Smart Home, & Smart Health Care, Driver-Less Cars & Low Altitude Drone App, Neural Networking using Deep Learning Analytics, and cybersecurity.

The Future is Here - Emerging Technology Use Cases !

Massive connectivity, higher speeds and lower latency will create opportunities with many new use cases and transform how data and content is consumed

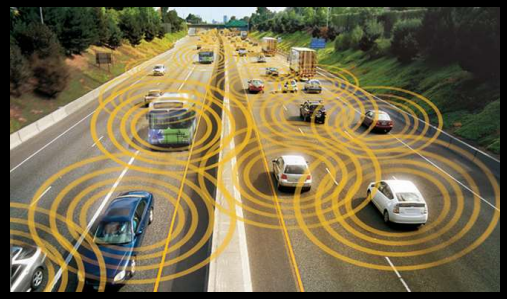
Smart cities

Smart homes

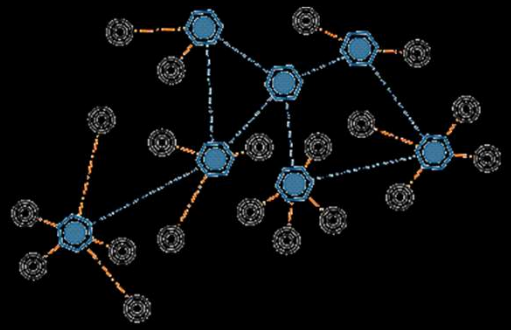
Connected hospitals

Smart grids

Industrial automation



Vehicle2X & connected



Wireless sensor networks

Smart Cities

Building & Construction

Smart solutions will transform buildings

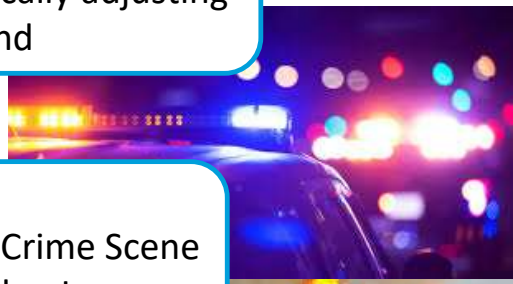
- Energy-efficient
- Sustainable
- Building Management Automation

Energy Sourcing, Management and Deployment

- Smart grids
- Next-generation energy transmission
- Distribution networks automatically adjusting to changes in supply and demand

Smart Water and Waste Management

- Leakage Detection
- Disease Detection in Wastewater
- Predictive Maintenance Planning
- Just-in-time waste collection



- Police Response Site Maps
- Video Image & Analytics on Crime Scene
- Fire fighter Site Map and Video Image
- Video AI for Earlier Warning

Public Safety & First Responder Apps

Smart City -Driverless Cars

Self-Driving Semi Trucks

- Operate 24 hours/day
- Drive consistent mileage rate
- Safer
- More fuel efficient

Zero-Occupant Delivery Vehicles

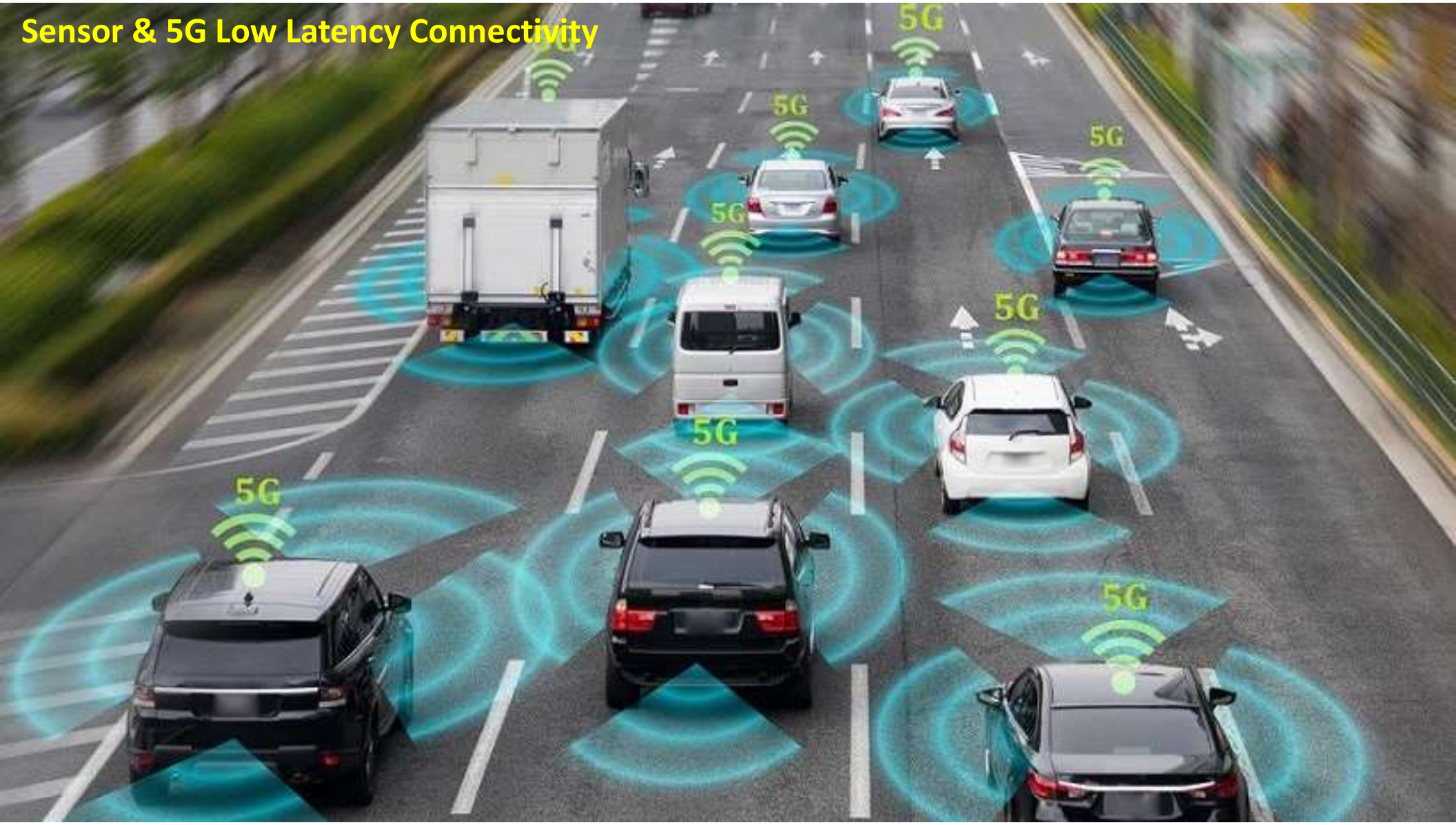
- Lower vehicle cost
- Improved customer experience

Sleeping in Self-Driving Cars

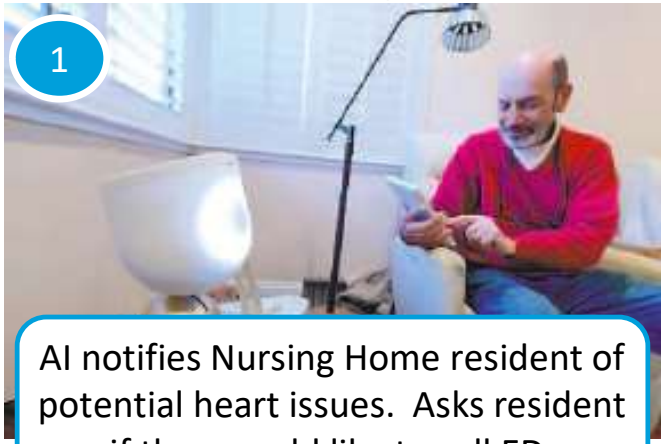
- Goodbye single night hotel stays on road trips
- Less air travel for shorter trips

Autonomous Buses

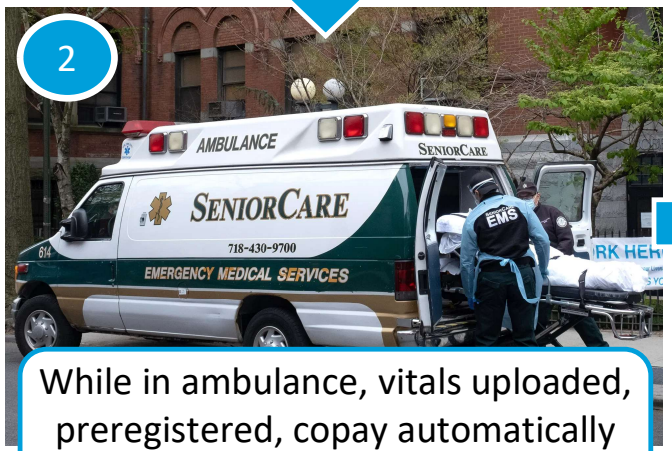
- Improved quality
- Reduced operating costs
- Increased frequency of transit service


Sensor & 5G Low Latency Connectivity
5G
5G
5G
5G
5G
5G
5G
5G

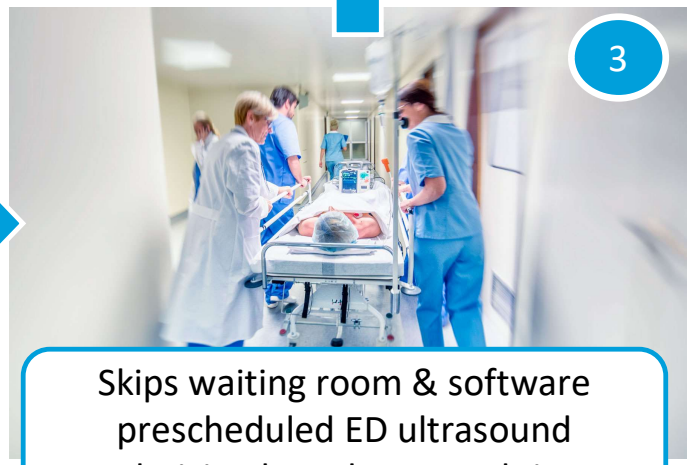
Smart Medical Emergency



AI notifies Nursing Home resident of potential heart issues. Asks resident if they would like to call ED.



While in ambulance, vitals uploaded, preregistered, copay automatically deducted from virtual wallet.

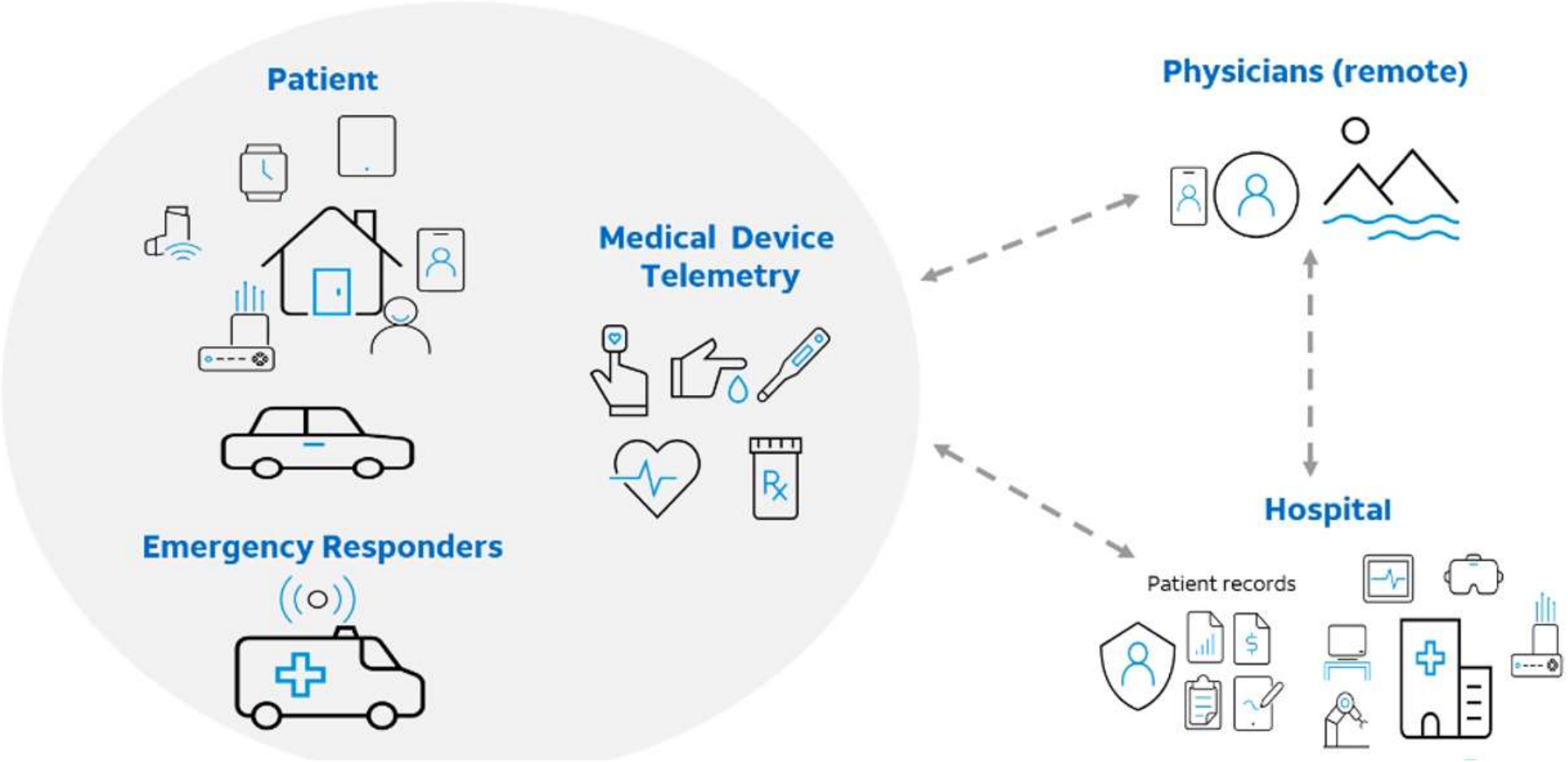


Skips waiting room & software prescheduled ED ultrasound technician based on travel time.

Board Certified Physician delivers difficult news.

At same time, virtual natural language processing documents conversation, codes encounter, submits for reimbursement, and prompts Physician to place orders previously placed for patients with similar presentations.

Healthcare Anywhere Ecosystem

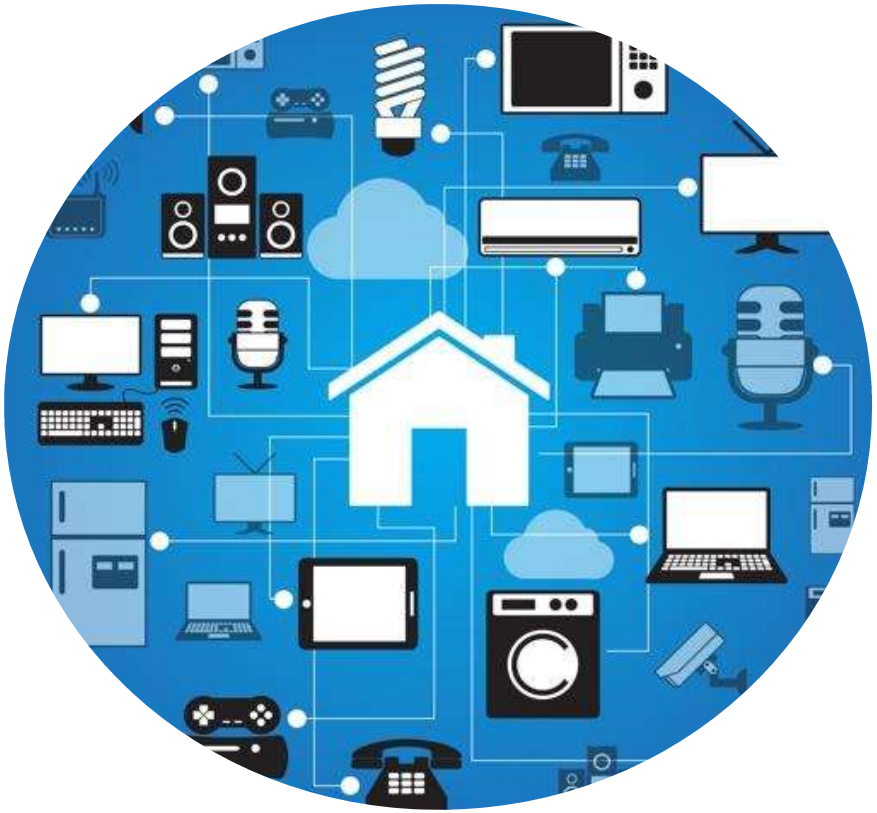


The Enormous Social & Human Impact of 6G!

- ✓ How do Massive Scale & Extreme Latency requirements impact future reliability, hence human dependency on 6G?
- ✓ How would 6G enabled AI apps or AI enabled 6G impact human productivity and future jobs?
- ✓ What kind of technology breakthrough will we witness with 6G?
- ✓ What can 6G do to change the learning and innovation model?
- ✓ What guiderail do we need in global standards and regulations to safe guide the future development of AI and 6G, i.e., security, safety, and env?

NOTE: There is no perfect "dream" answer, but these will help us to continuously to improve and innovate!

6G & Reliability Considerations



Does anyone have a crystal ball of the future?

Not really, but we could venture to explore…

Three key characteristics of the AI enabled 6G:

Extensive Use of AI, including generative AI, GPU based hyper cloud, massive cloud-based DB, etc.

ETE Serviceability ensured by self healing and adaptive capabilities. Element reliability become table stake!

Speed of continuous improvement will accelerate via nontraditional collaborators & intent driven prog!

Note: The pace of the change will accelerate, and the winners will be the leaders of the change, rather than follow the change.

AI enabled 6G technologies and innovation will bring:

- ✓ New Ideas – explosive innovations.
- ✓ Openness – despite the geo-political challenges.
- ✓ Speed – from idea to innovation to product (from decades to days).
- ✓ Performance – massive scale and reliability.
- ✓ Omnipresence – ultra fast network connectivity everywhere.
- ✓ Security – zero-tolerance.
- ✓ Unlimited innovation opportunity for all.

6G Path to Success – Recommendations

- Increase investment in digital transformation for major enterprises and industry.
- Promote foundry like innovation culture and investment model to scale **new apps**.
- Build resilient/hyper-scale cloud and communication network with geo-location diversity.
- Support multiple supplier model and diversified electricity source for key infrastructure.
- Implement autonomous and adaptive network control and management with self-healing using Generative AI – inherent to 6G.
- Expand the use of free spectrum & enhance spectrum efficiency.
- Establish government and global regulations for Generative AI, low air economy, DLV.
- Develop next generation talents with “prompt engineer” and data modeler as catalysts.
- Develop the knowhow on virtual ecosystem integration.

“Creativity is just connecting things.” – Steve Jobs

Challenges for Reliability, Safety, and Security in 6G Era

- AI as double-edge sword, not only focus on what AI can do, but also what we must avoid it to do (the unintended consequences)?
- As the ecosystem becomes smarter and more complexed, what will be a trustworthy reliability model for the 6G world?
- As breakthrough 6G technologies being developed, what needs to be part of these new technologies from reliability and security perspective?
- 6G network will need to have more integration with the sensing networks (same to WiFi, satellite networks). How do we address the reliability/security across the two different networks and their interactions?
- As 6G network moves into a more M-M and mesh network design, what kind of network resilience considerations must be factored in the 6G network architecture?
- From industry lessons learned, we must establish robust reliability & security testing use case & automation to ensure the ecosystem delivers the promised **CQRS**!

Note: **CQRS** = Capability, Quality, Reliability and Security

Open Dialogue