A world map with a blue background and green shading over the continents. The shading is darker in North America, Europe, and Australia, and lighter in South America, Africa, and Asia. The map is centered on the Atlantic Ocean.

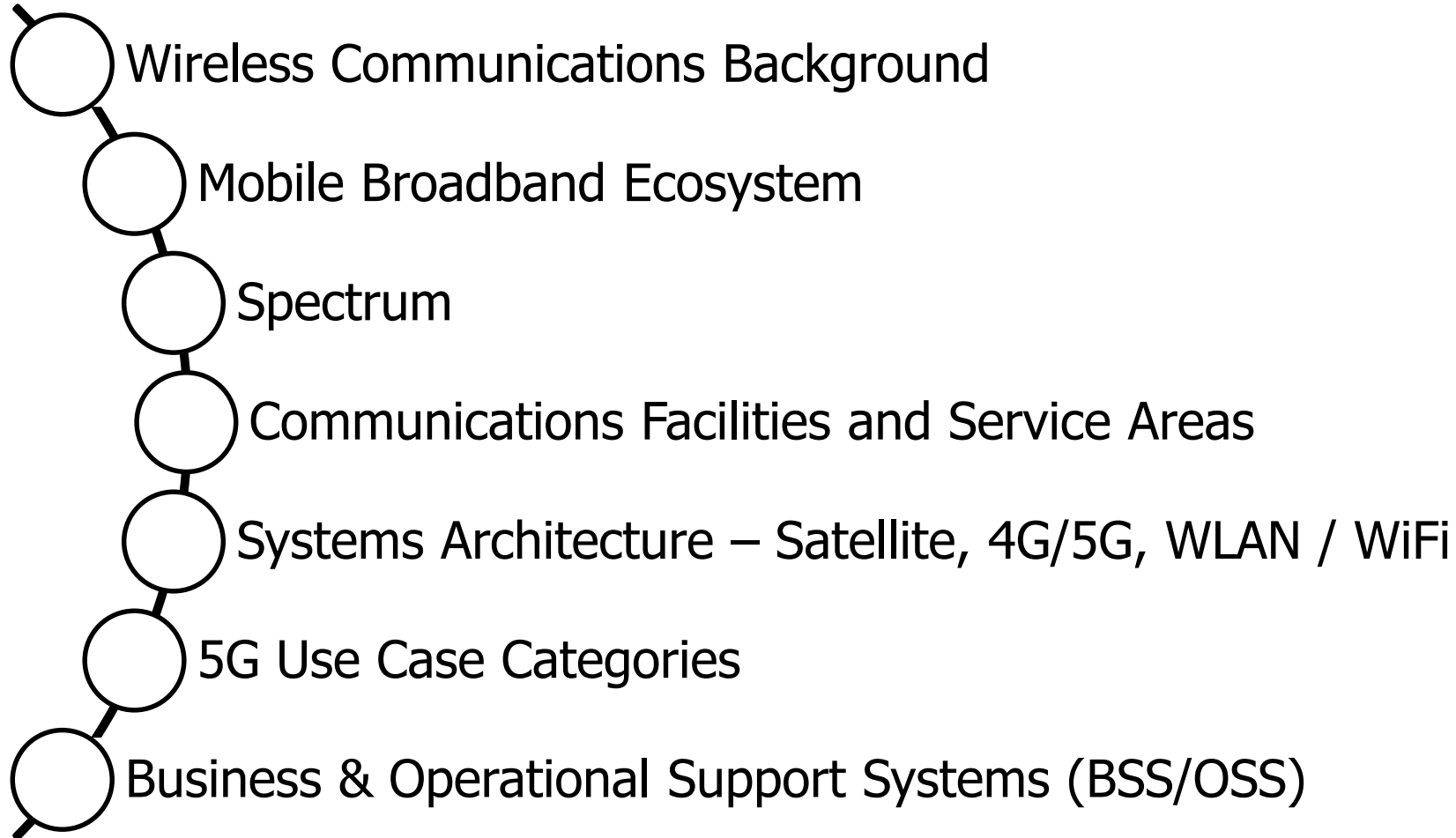
IEEE 5G Education

Mobile Ecosystem Overview

July 28th, 2018

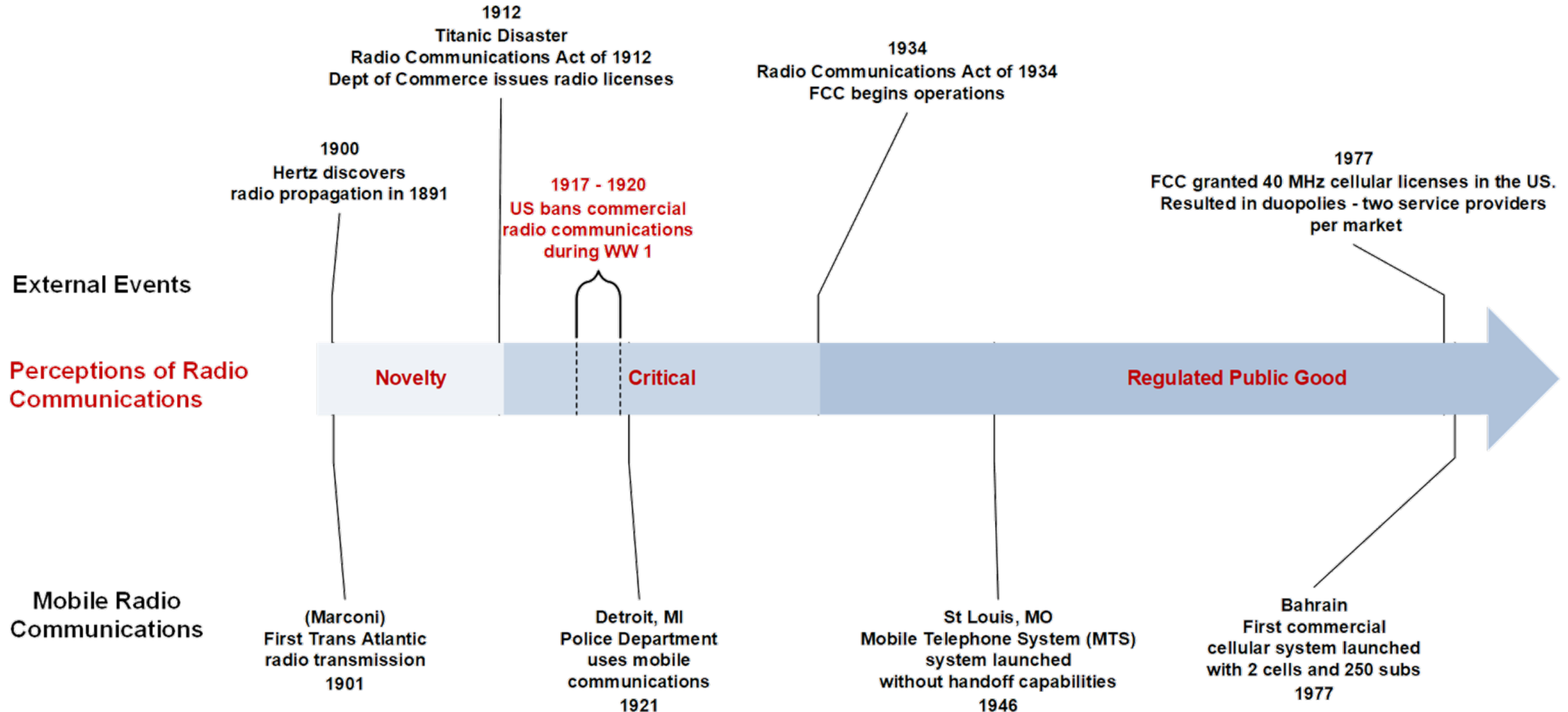
Narendra Mangra, GlobeNet

Mobile Ecosystem Overview

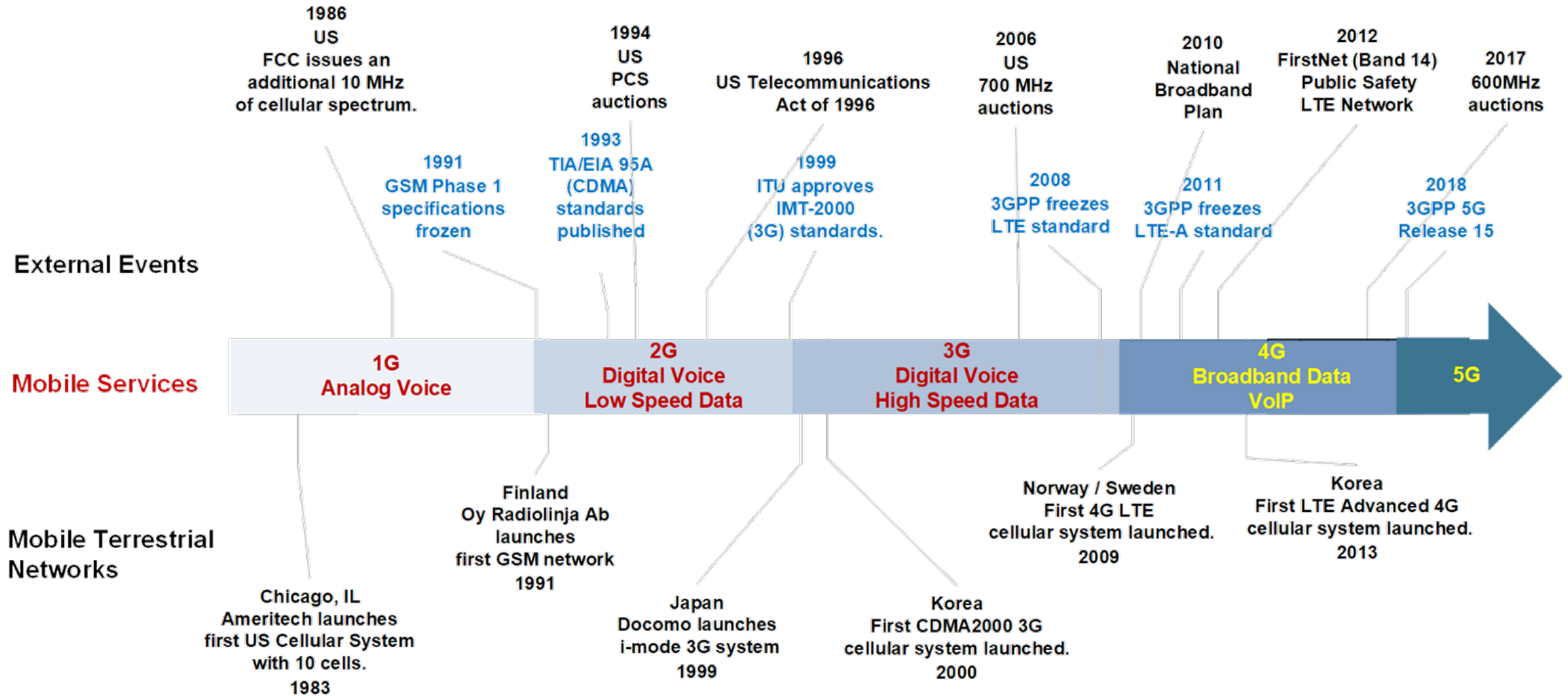


Wireless Communications Background

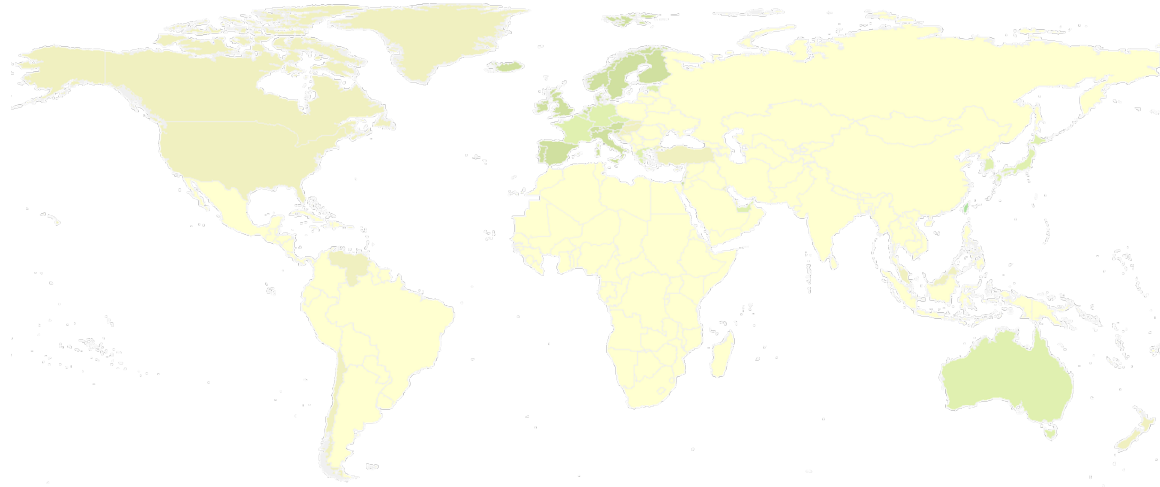
Changing perceptions of radio communications



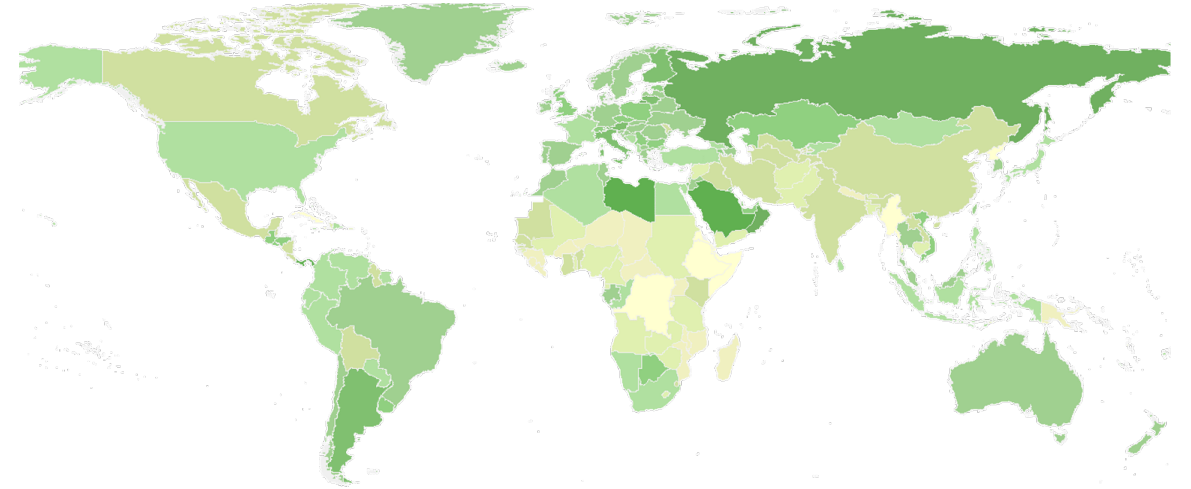
1G to 5G Mobile Communications



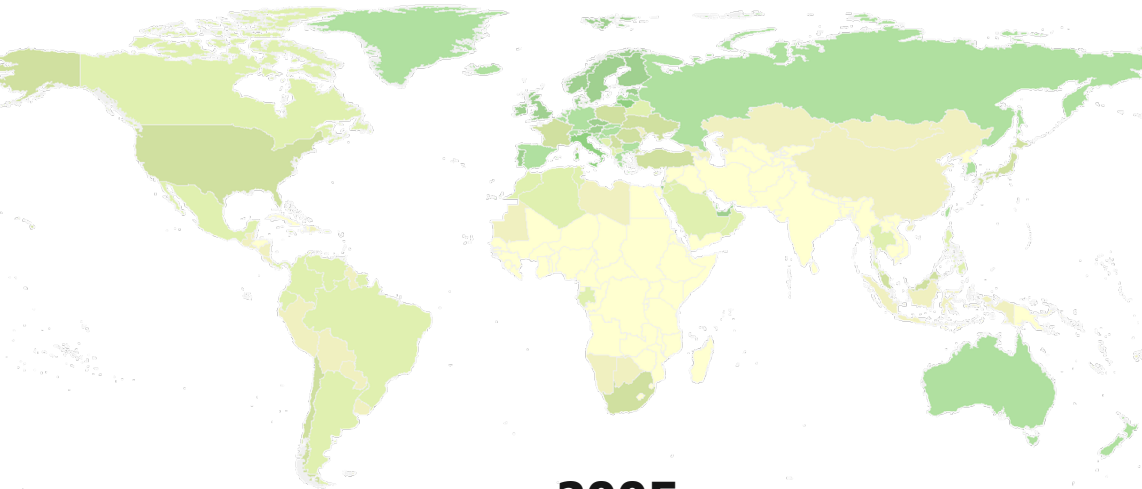
Global Mobile Wireless Penetration Rates



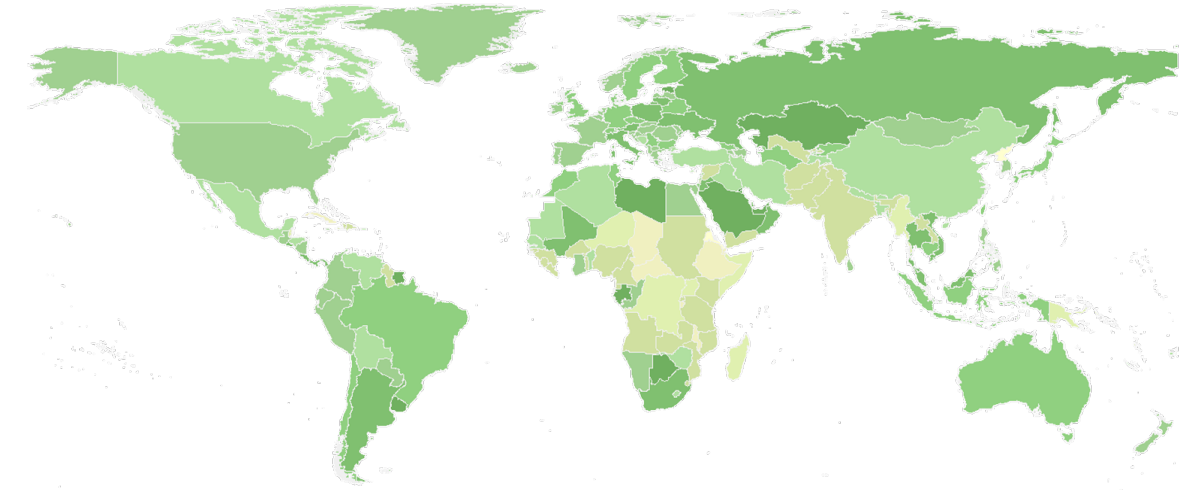
2000



2010



2005



2015

Mobile Broadband Ecosystem

Mobile Broadband Ecosystem Description

Mobile Ecosystem

Companies may belong to a mobile ecosystem may span several industries, e.g. mobile network operators in the wireless broadband access ecosystem that participate in several industries such as smart cities, connected vehicles, connected health, smart grids, etc

Companies in a business ecosystem may

- Coevolve capabilities around a new innovation:
- Work cooperatively and competitively to support new products, and satisfy customer needs,
- Incorporate the next round of innovations

Industries

Group of firms providing close substitutes for each other

Industry boundaries

- Defining the boundaries is a matter of choice
- Separate from defining a strategy or where the firm wants to compete

Mobile Broadband Ecosystem Sectors

Mobile Broadband Sectors

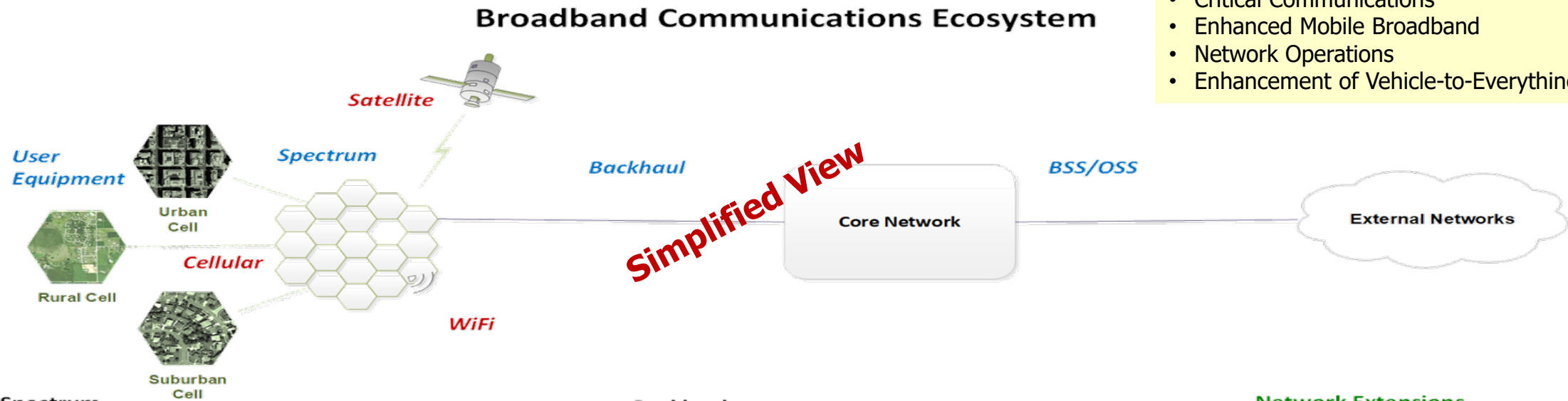
- Academia, e.g. new research
- Device Manufacturers, e.g. handset manufacturers
- Application Developers, e.g. App Store Developers
- Operating System, e.g. iOS, Android
- Spectrum Access / Regulatory Agencies, e.g. FCC, incumbents
- Industry Groups / Standard Bodies, e.g. 3GPP, IEEE
- Communication Facilities, e.g. tower companies
- Backhaul Providers, e.g. fiber companies, cable companies,
- Communications Infrastructure, e.g. equipment vendors
- Communications Support Systems, e.g. business & operation support companies

Adjacent Industries

- Smart Homes
- Smart Cities
- Public Safety Communications
- Connected Vehicles / Telematics
- Connected Health / Telehealth
- Mobile Money / Fintech
- Internet of Things (IoT) / Machine to Machine (M2M) Communications
- Electricity / Smart Grid

End to End Mobility Overview

- 5G Enhancements**
- Massive Machine Type Communications (MTC)
 - Critical Communications
 - Enhanced Mobile Broadband
 - Network Operations
 - Enhancement of Vehicle-to-Everything



Spectrum

- 5G Global Harmonized Spectrum
- Country / Operator Spectrum

Devices

- Human Interface Devices: Mobile Phones
- MTC / IoT Sensors

Radio Access

- Cellular: 5G NR, 4G LTE, V2V
- WLAN: 802.11 (WiFi), DSRC
- Mobile Satellite Systems

Facilities

- Cells: Macro, Small (Micro, Pico, Femto)
- Structures: Towers, Buildings, Street Furniture

Backhaul

- Fiber
- Microwave, including 5G Fixed Wireless

Core Network

- Network Slicing
- Technology / Link Aggregation
- Traffic / Congestion Management, e.g. SDN
- Policy Control
- Communications Interoperability

BSS/OSS

- Data Analytics
- Business / Technical Operations, e.g. SLAs,
- Domestic / International Roaming Support (Data / Financial Exchanges)

Network Extensions

- Roaming
- Smart Cities Platforms
- Connected Vehicles
- Public Safety Communications
- MTC / IoT
- Connected Health
- Mobile Money
- Smart Buildings
- Smart Grids

Spectrum

Spectrum affects existing service providers and potential entrants

- **Existing Service Providers:** network deployment, capacity expansion
- **New entrants:** market entry into a geographic area.

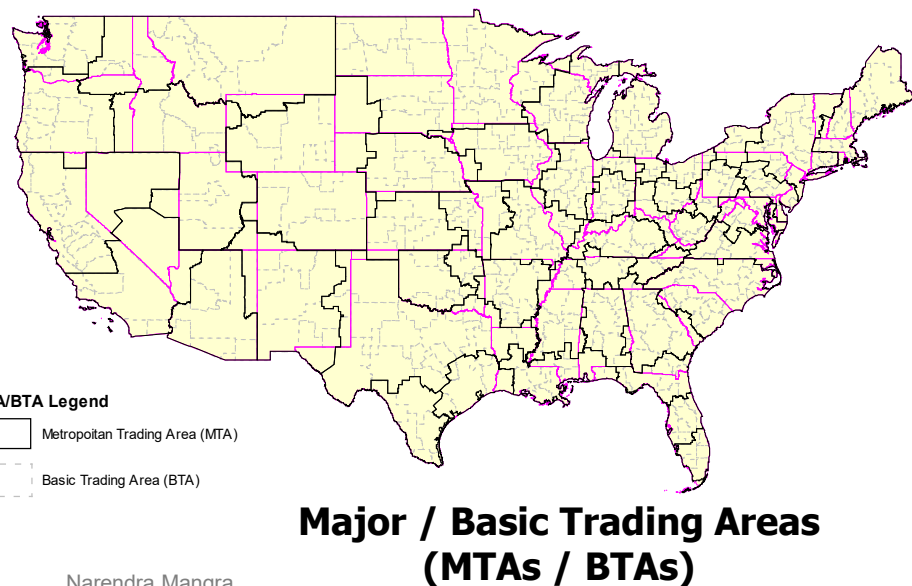
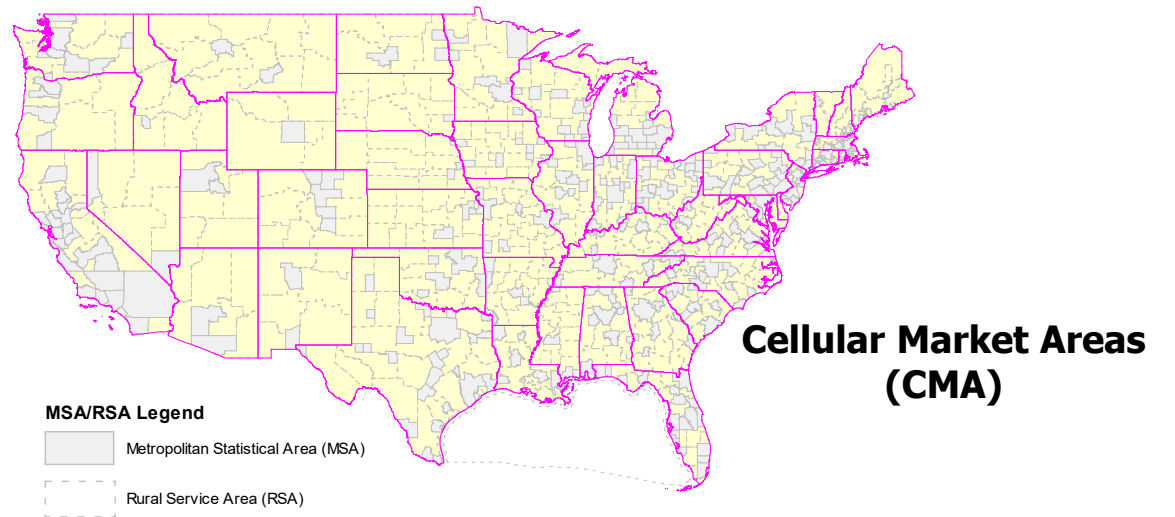
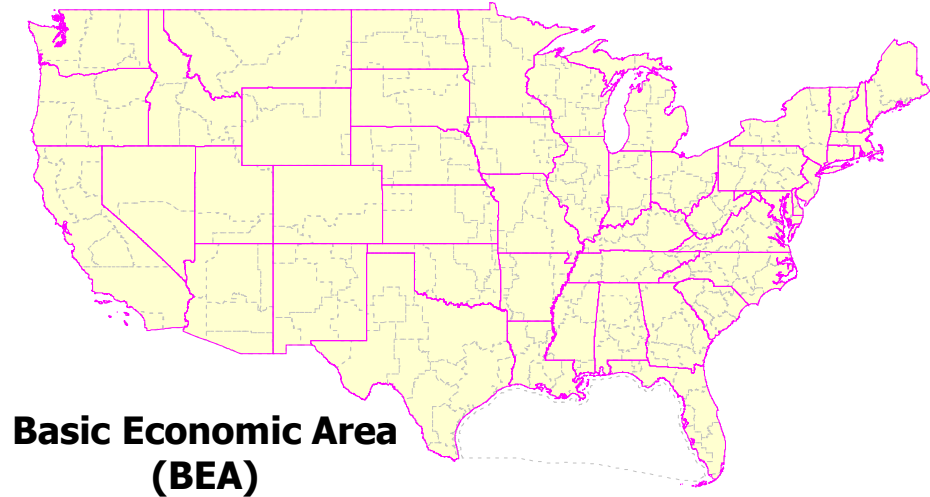
Mobile spectrum bands vary in their propagation characteristics

- **Low Band Spectrum** (<1 GHz): better suited for network deployment over long distances, penetrating buildings and urban canyons
- **Mid Band Spectrum** (between 1 GHz and 6 GHz): better suited for a balance of coverage & capacity for rural, remote and underserved areas.
- **High Band Spectrum** (> 6GHz): high capacity usage especially in urban areas

US Mobile terrestrial spectrum

- **Existing:** 700 MHz, 850 MHz (cellular), 1900 (PCS), 1700 / 2100 MHz (AWS), 2300 MHz (WCS), 3600 (BRS)
- **Recent:** 600 MHz, 3.5 GHz (CBRS shared spectrum)
- **Upcoming** (est Nov 2018): Auction 101 (28 GHz), Auction 102 (24 GHz)

US Geographical Licensing Areas

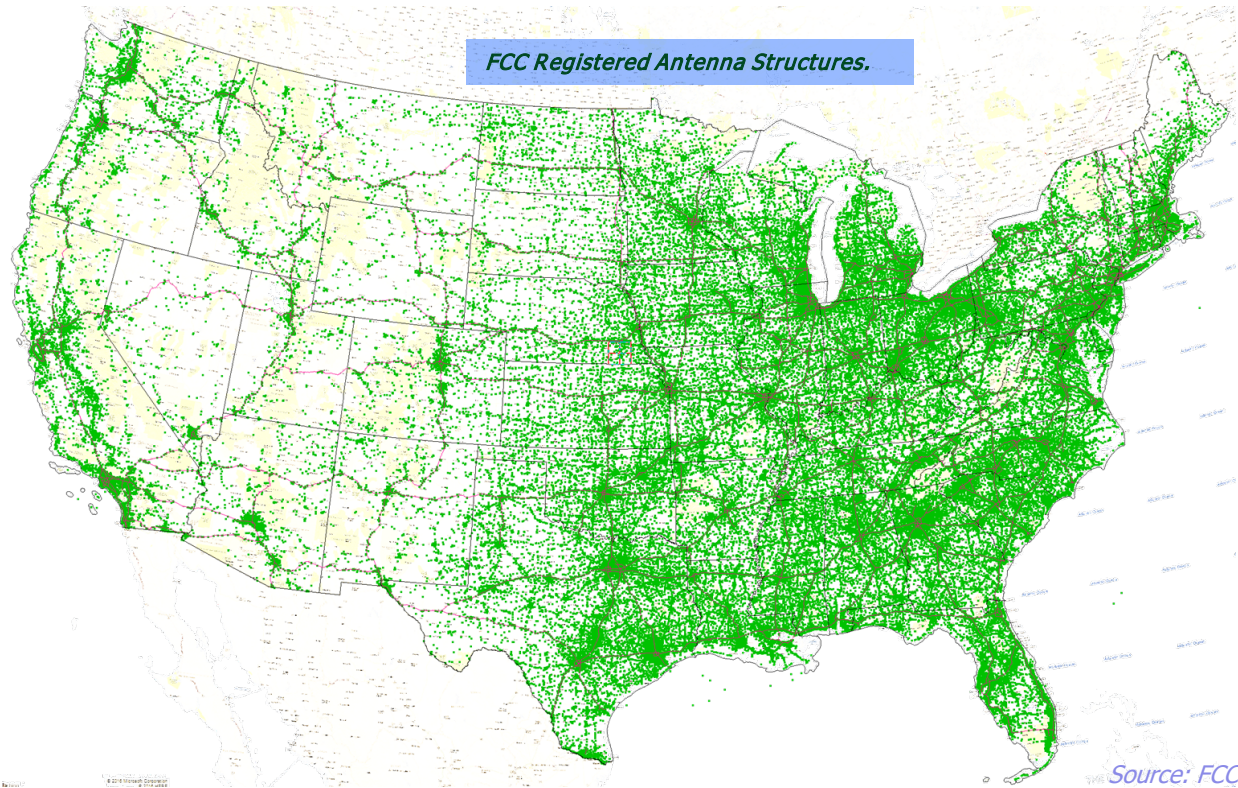


Spectrum licenses are typically based on different groupings of contiguous counties. Frequencies impact the number of cell sites required.

Selected Licensing Areas

- MTA/BTA – PCS
- CMA / MSA/RSA – Cellular, 700 MHz
- EA – AWS, 700 MHz
- PEA – 600 MHz
- REAG – AWS, 700 MHz

US Communications Facilities and Mobile Service



Nationwide Service Providers	Median Download Speed (Mbps)
Crowdsourced	9.5 - 15.7
Stationary / Drive Testing	7.6 - 16.7

Average US Monthly Voice Usage:
 2016: 722 MoU
 2015: 760 MoU
 2014: 671 MoU

Average US Monthly Data Usage:
 2016: 3.9 GB
 2015: 2.9 GB
 2014: 1.4 GB

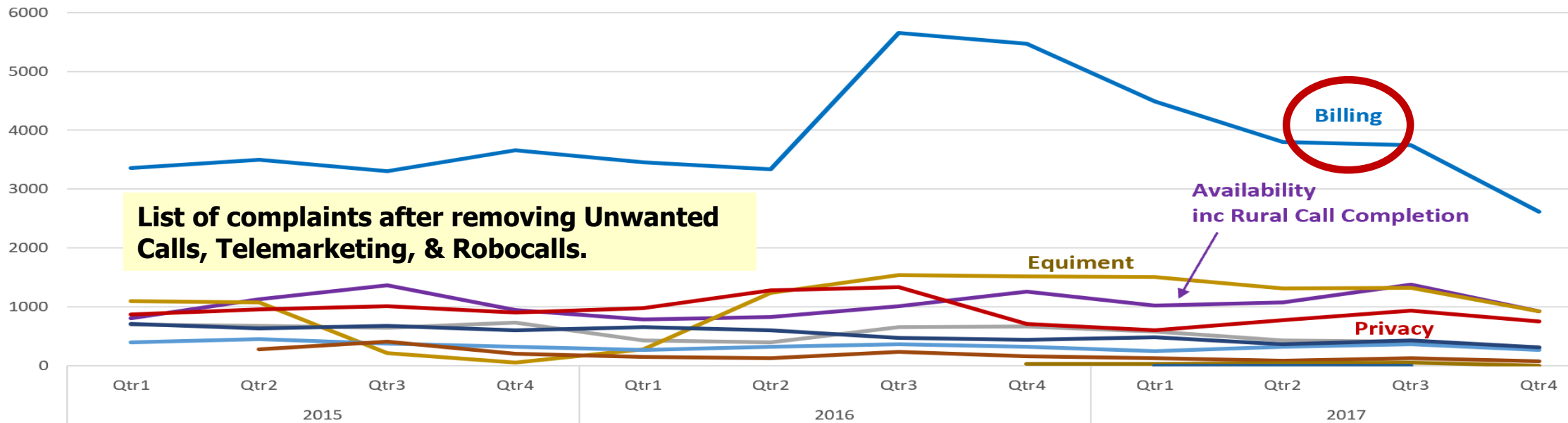
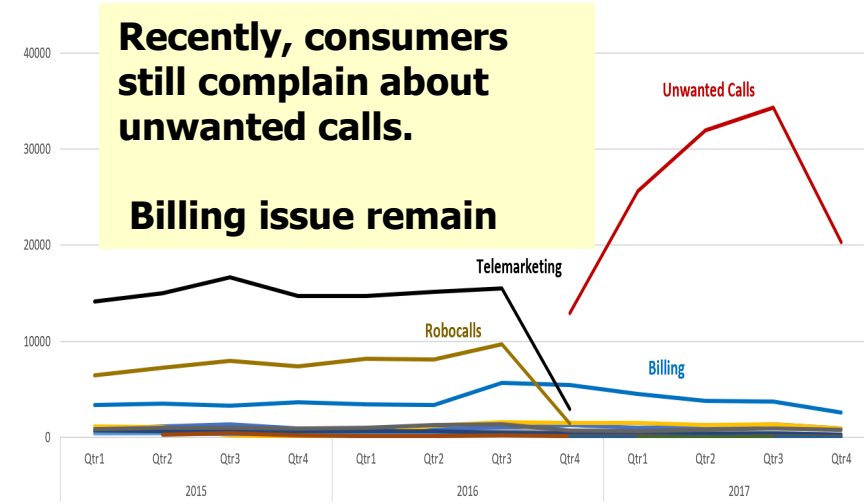
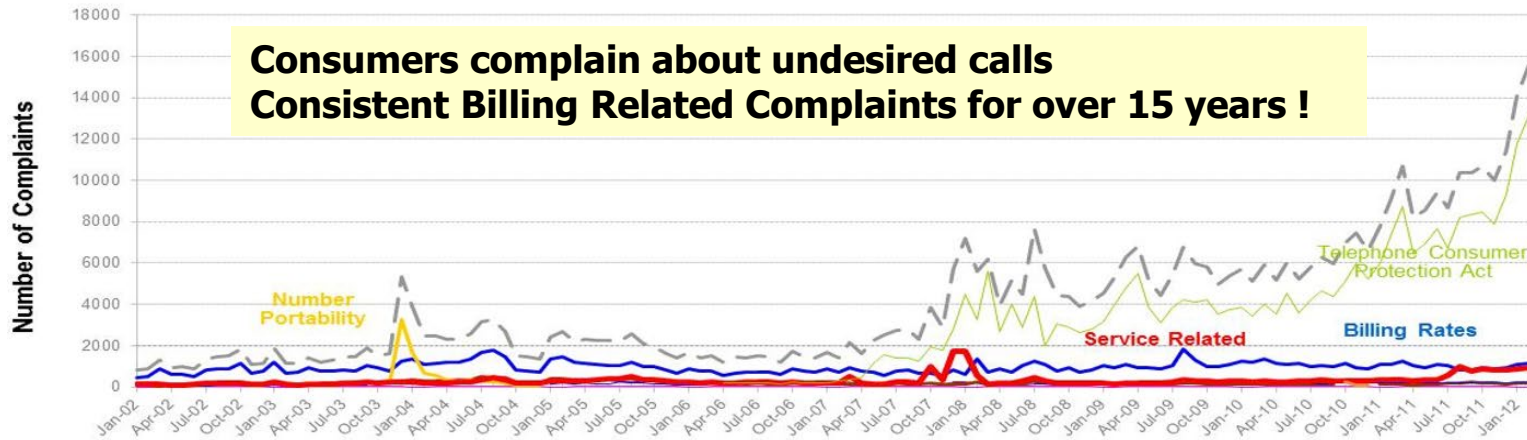
LTE service is available in most of the US population centers.
Rural Areas & Local Roadways may lack coverage!

Number of Service Providers	Population Covered (%)	US Road Miles Covered (%)	% US Square Miles Covered (%)
1 or more	99.7	92.6	72.7
2 or more	99.0	83.6	60.0
3 or more	96.6	69.4	44.3
4 or more	88.5	45.4	22.9

Wireless service provider services vary due factors such as:

- **Spectrum Availability** - primary or secondary markets
- **Addressable Market** - population density, vehicular traffic, critical areas, etc
- **Technology** – satellite and terrestrial fixed / mobile technologies
- **Physical Characteristics** – signal propagation, clutter, etc
- **Leasing & Zoning** – zoning rules differ among jurisdictions.
- **Construction** – Structural, NEPA, SHPO, etc
- **Regulatory** – FCC, FAA

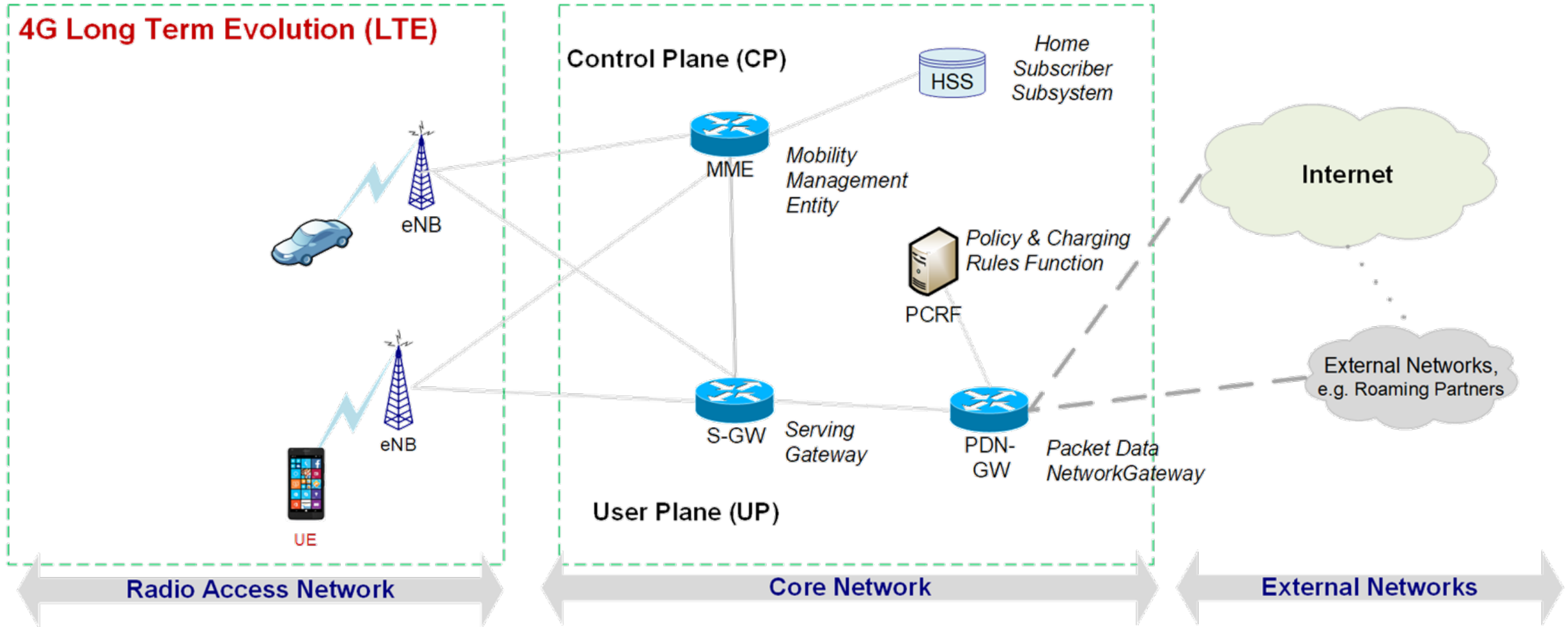
Consumer Complaints



Source: FCC

System Architectures

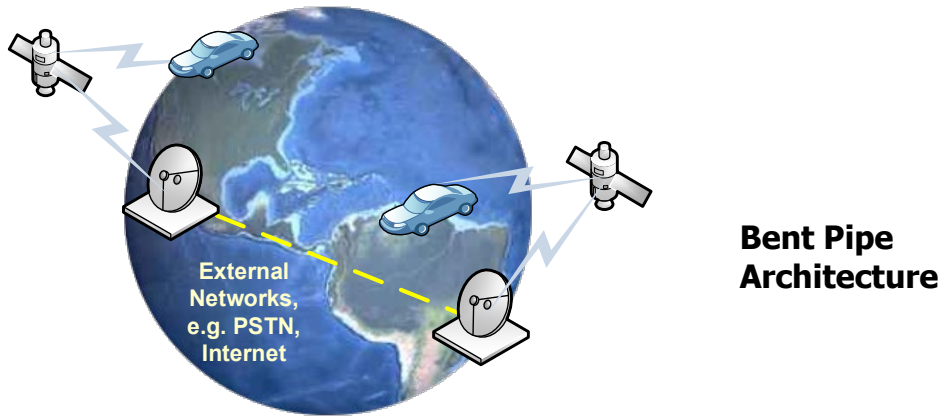
4G Long Term Evolution (LTE)



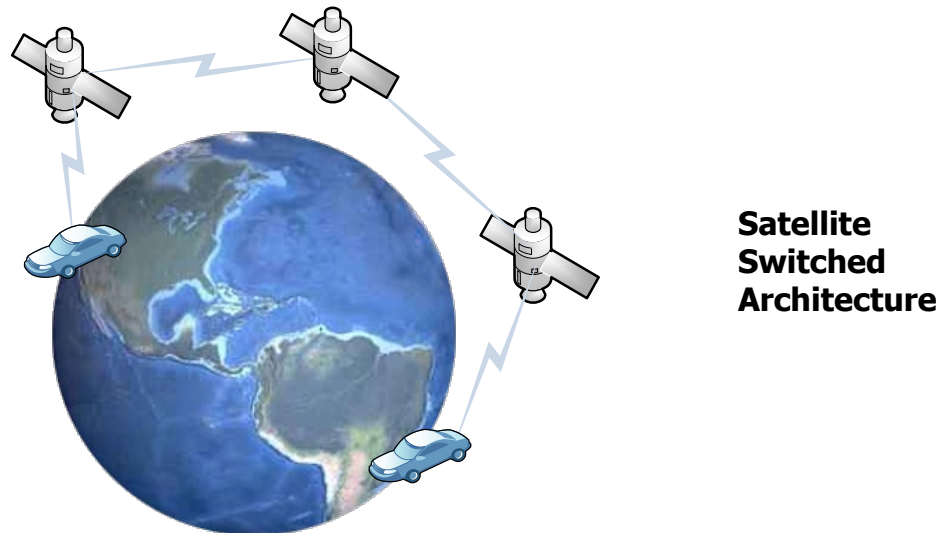
Source: 3GPP TS36.300

Satellite and WLAN Systems

Mobile Satellite Systems Architecture

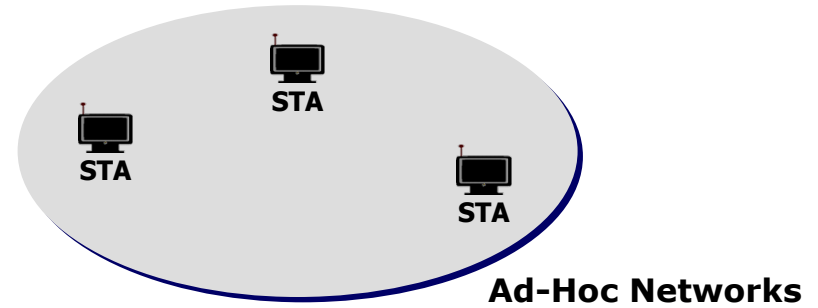


Bent Pipe Architecture



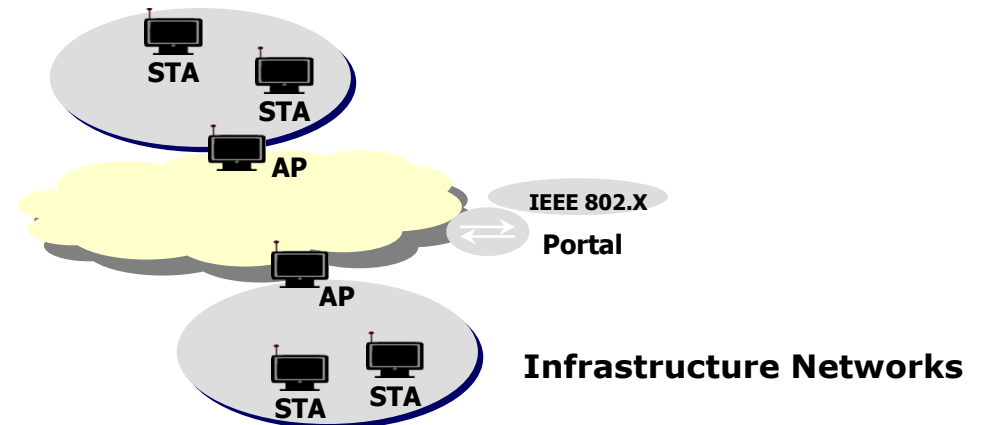
Satellite Switched Architecture

WLAN Network Architecture



Stations communicate directly with each other.

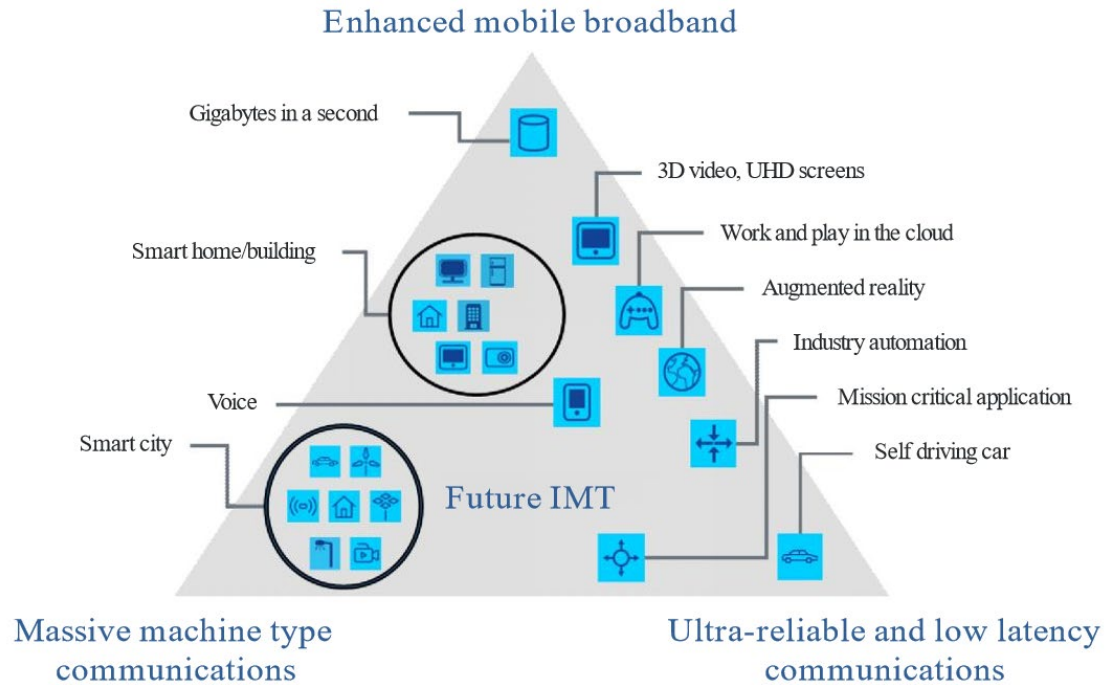
Meshed Networks contains low mobility nodes and may include routers



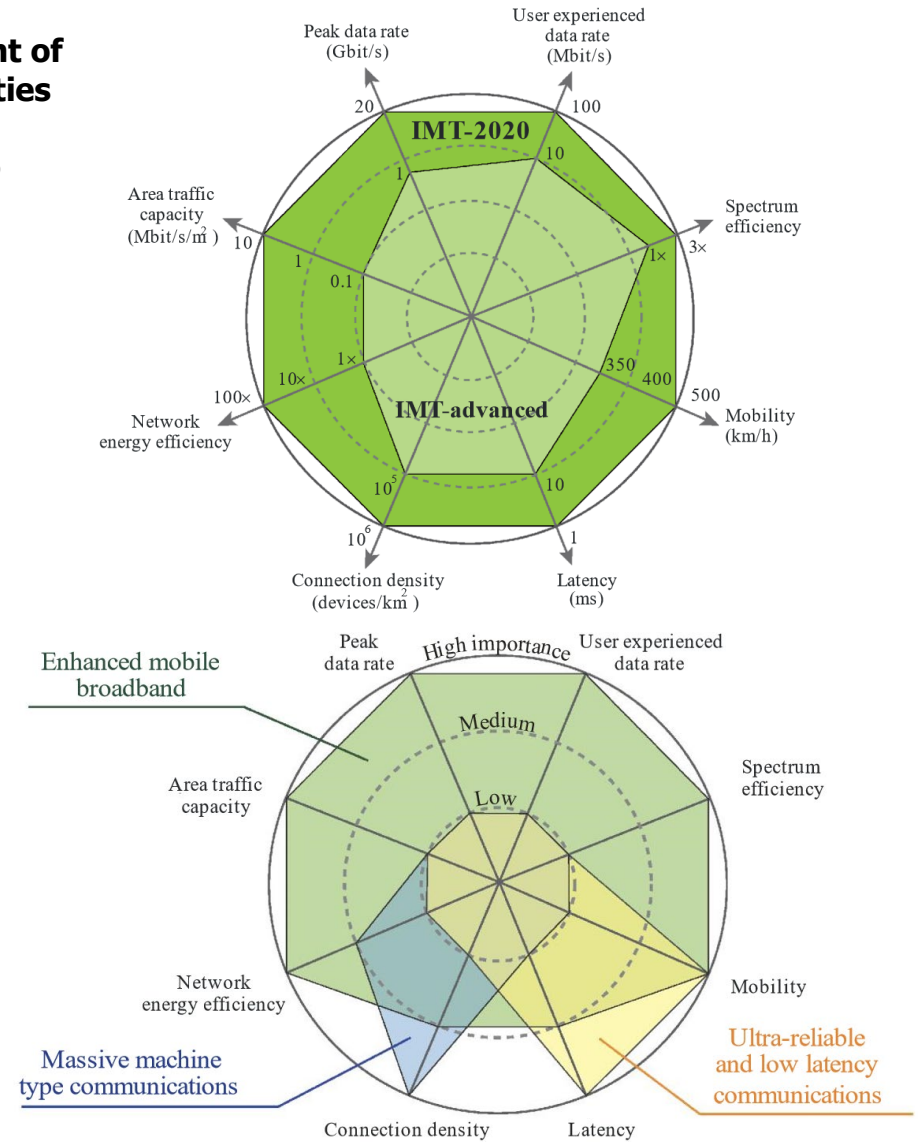
Stations communicate with each other through an access point (AP).

5G Vision

Usage scenarios of IMT for 2020 and beyond

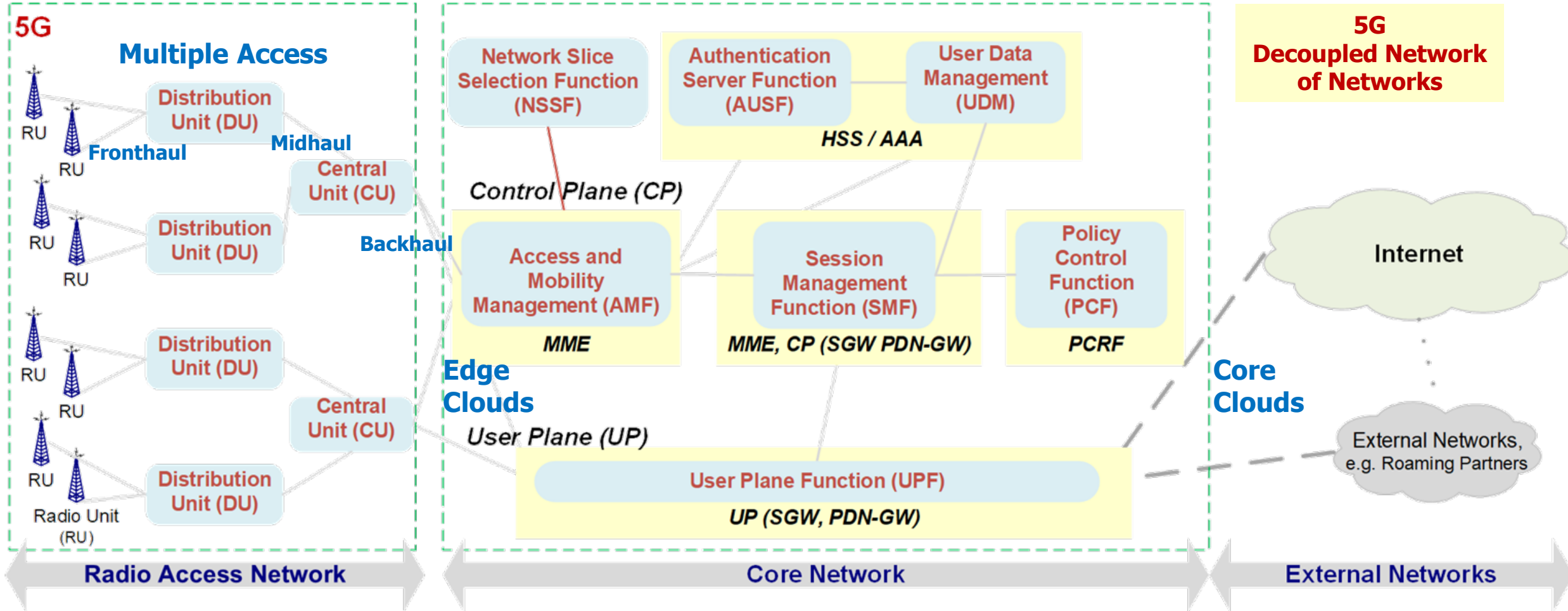


Enhancement of key capabilities from IMT-Advanced to IMT-2020



Source: ITU M.2083 : IMT Vision - "Framework and overall objectives of the future development of IMT for 2020 and beyond", Sep 2015

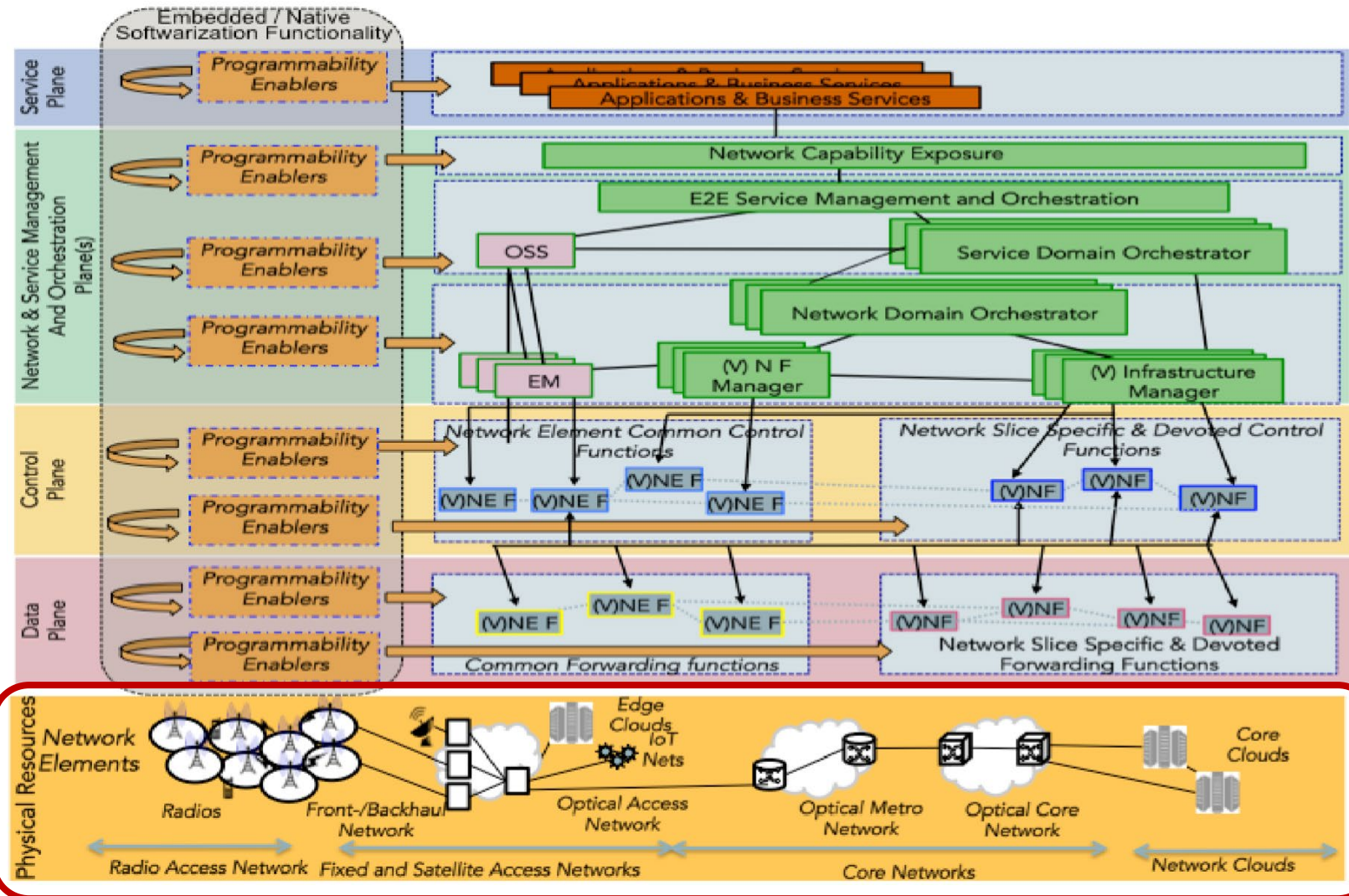
5G Network Architecture



5G accommodates NR, LTE, and non-3GPP systems such as satellite and WLAN access

Sources: 3GPP TS 23.501, ITU GSTR-TN5G

Network Element Softwarization & Programmability Viewpoint



Network Softwarization and Enablers:

- Network Function Virtualization (NFV)
- Software-Defined Networking (SDN)
- Service Function Chaining
- Network Slicing and Network Virtualization

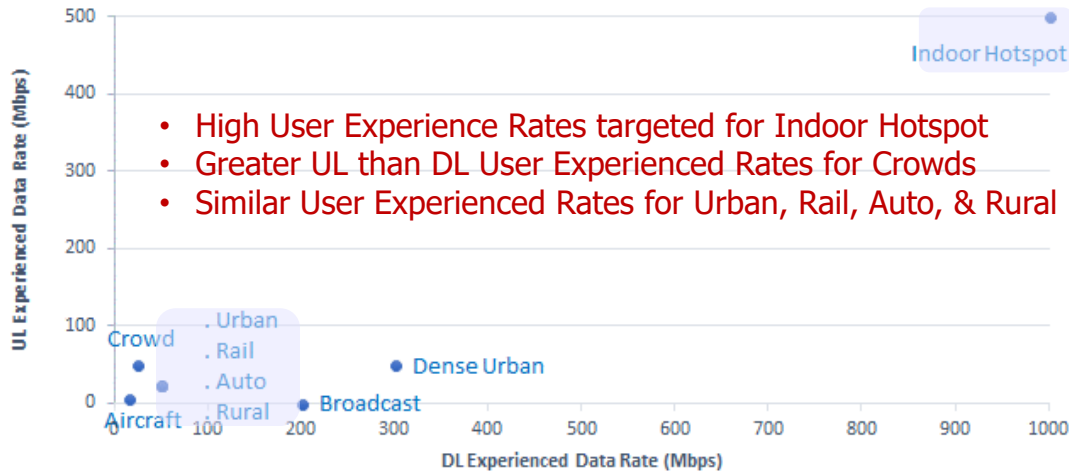
Transition from today's "network of entities" towards a "network of functions".

Source: View on 5G Architecture v 2.0, 5GPPP Architecture Working Group, Dec 2017

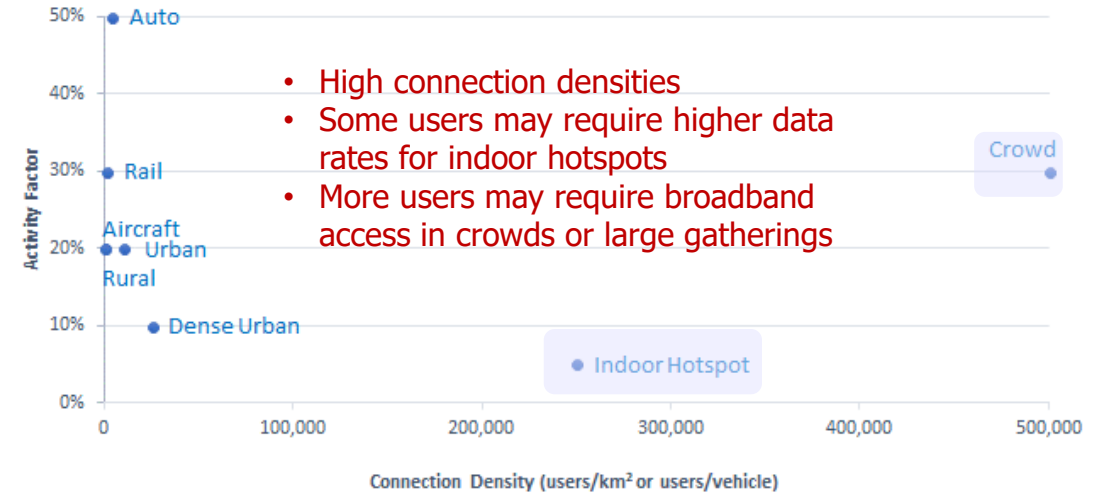
5G Use Case Categories

Enhanced Mobile Broadband (eMBB) Use Case Categories

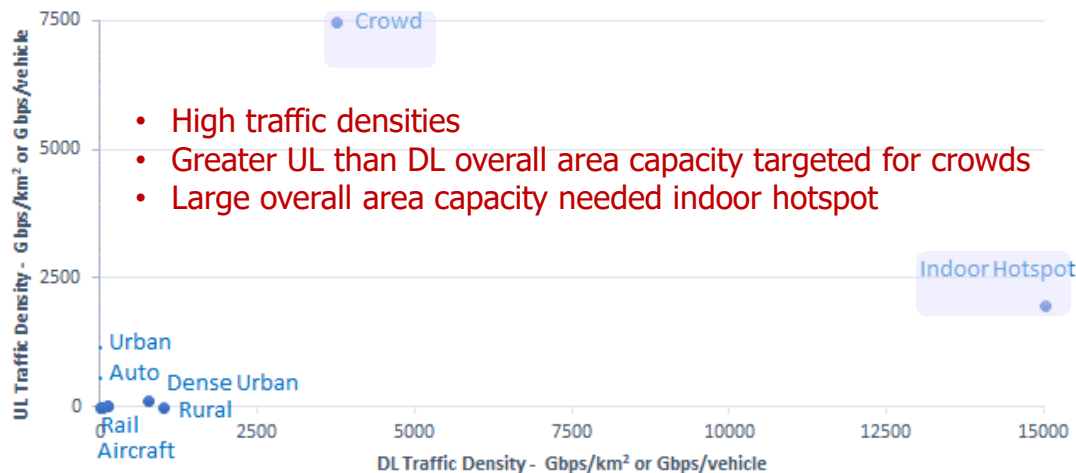
User Experienced Data Rate (Mbps)



Connection Density (users/km² or users/vehicle)



Traffic Density (Gbps/km² or Gbps/vehicle)



5G Drivers: High data rate, low latency, traffic density, connection density, varying levels of mobility

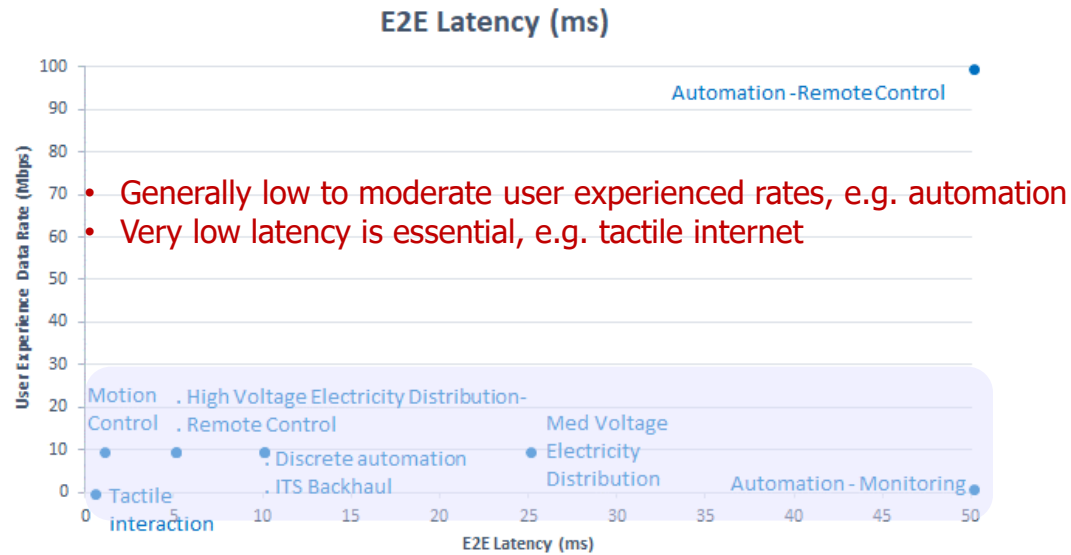
5G Deployments: Indoor/Outdoor Local and Wide Area Connectivity

Fixed Mobile Convergence: combined use of fixed broadband access, e.g. fiber, and 5G access network.

Femtocell Deployment: seamless user experience over radio access and Femtocell access using fixed broadband networks.

Source: 3GPP TS 22.261

Critical Communications Use Case Categories

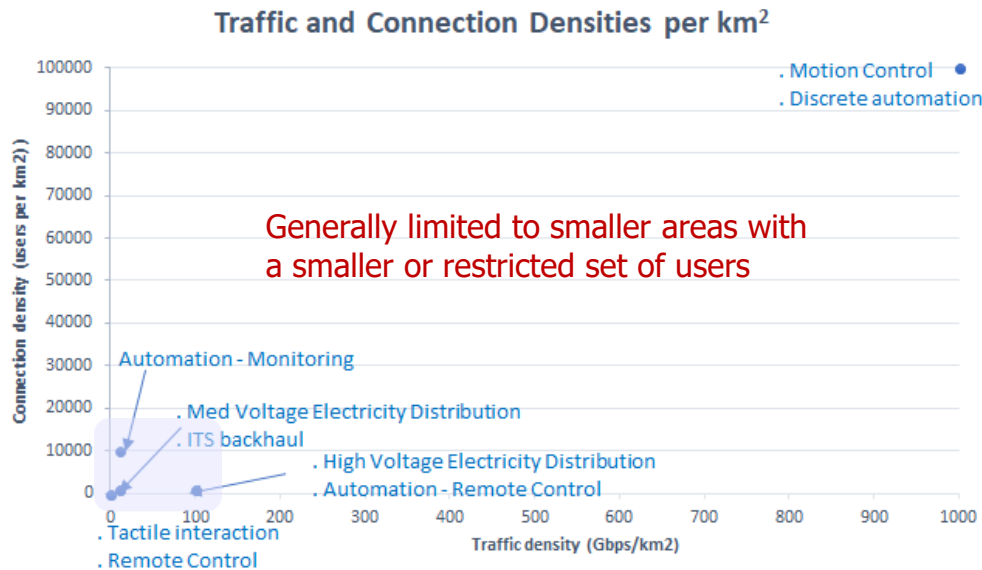


Other Considerations

- Availability, e.g. deployables
- Reliability, e.g. industrial control, drone connectivity
- Positioning Accuracy, e.g. connected vehicles

5G Drivers: Low latency, reliability, traffic density, position accuracy

Mission Critical Services: critical communications that may require a higher communications priority, e.g. first responders, disasters.



Source: 3GPP TS 22.261

Massive IoT & eV2X Use Case Categories

Massive Internet of Things (MIoT)

- **5G Drivers:** Communications efficiency, traffic density, communications density, position accuracy
- **Operational:** network servers/applications and devices support to identify and reach each other, IoT security
- **Connectivity:** Direct 3GPP connection (e.g., a sensors), indirect 3GPP connection (e.g., a smart wearable communicating via a smart phone), direct device connection (e.g., a biometric devices that communicate directly with other biometric devices).
- **Resource Efficiency:** include bulk provisioning, resource efficient access, optimization for device originated data transfer, and mobility management efficiencies for stationary or limited mobility devices.

eV2X

- **5G Drivers:** High data rate, low latency, reliability, traffic density, connection density, varying levels of mobility, high position accuracy
- **Vehicles Platooning:** All the vehicles (may be autonomous) in the platoon receive periodic data from the leading vehicle.
- **Advanced Driving:** enables semi-automated or fully-automated driving. Vehicles and/or RSU shares data obtained from its local sensors with vehicles in proximity,.
- **Extended Sensors:** enables data exchanges from local sensors or live video data among vehicles, RSUs, devices of pedestrians and V2X application servers.
- **Remote Driving:** enables a remote driver or a V2X application to operate a remote vehicle.

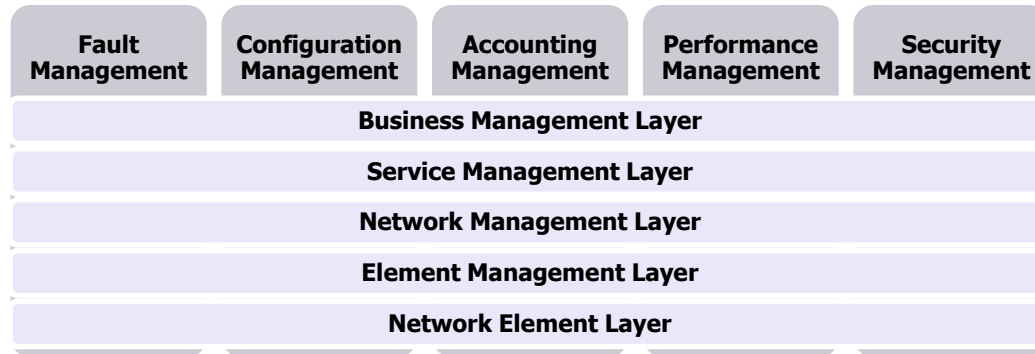
Source: 3GPP

Source: 3GPP TS 22.261

Business & Operational Support Systems (BSS/OSS)

Business and Operations Support Systems (BSS/OSS)

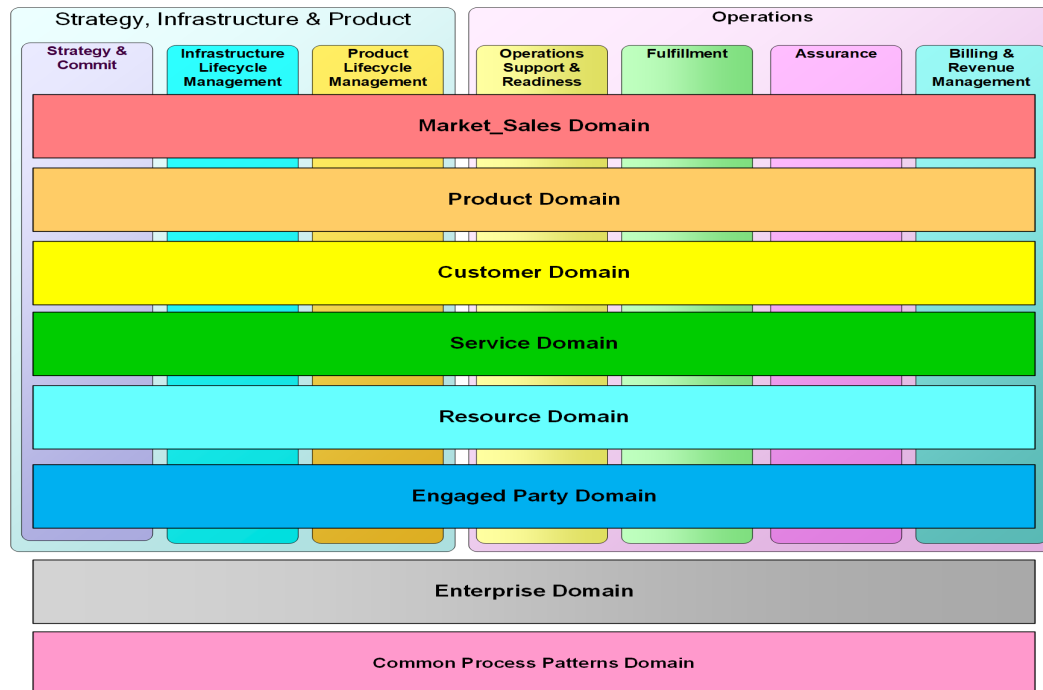
OSS



Source: ITU

Business Process Framework

"eTOM"



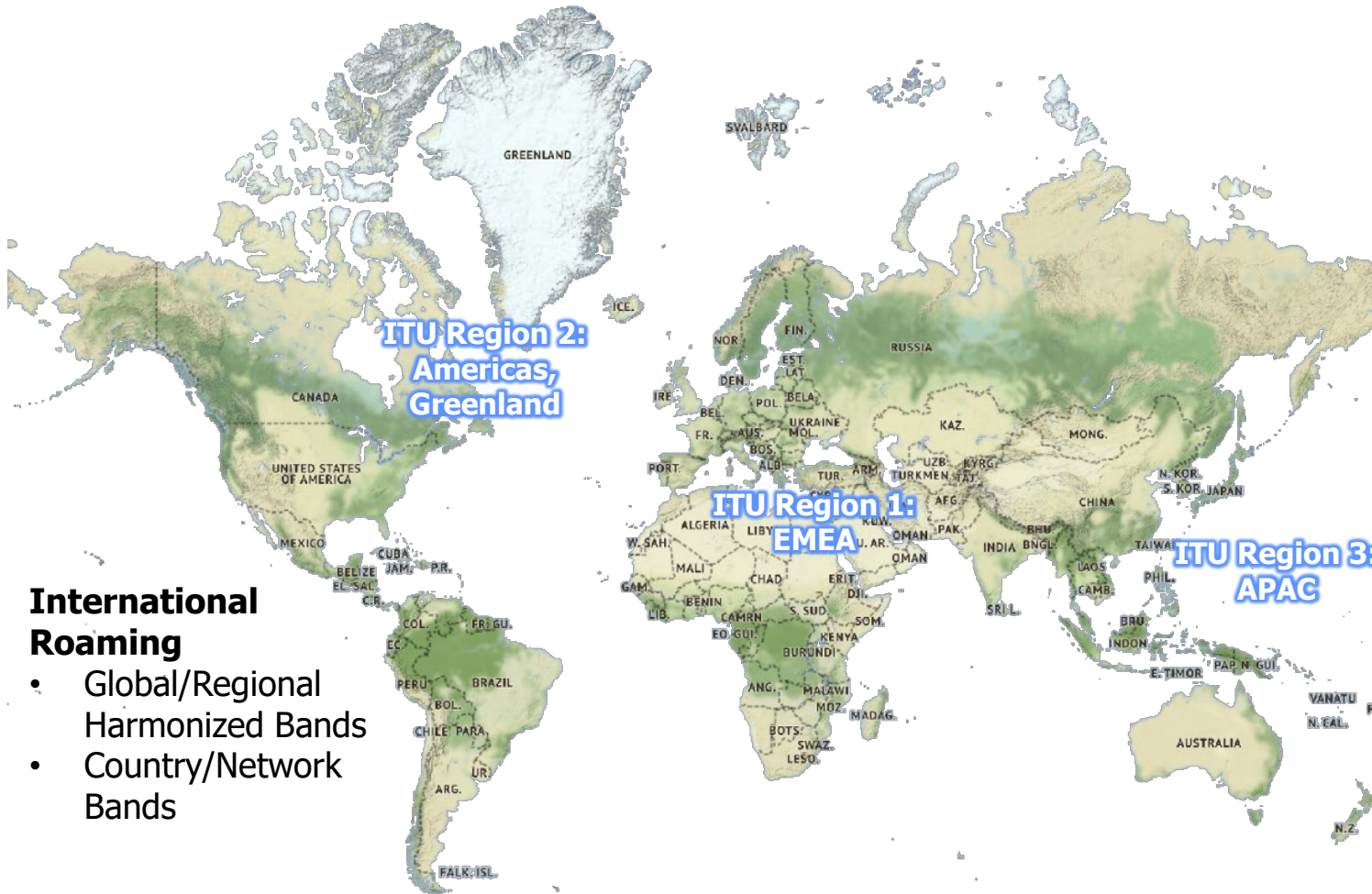
Source: TM Forum

Next Generation BSS/OSS

- Seamless Customer Experience
- Dynamic Real Time OSS
- Application Programming Interface (API) Development
- Network evolution (SDN / NFV, 5G, IOT)

Additional details may be found at ETSI, MEF, and TM Forum

Domestic and International Roaming



International Roaming

- Global/Regional Harmonized Bands
- Country/Network Bands

Mobile Subscriber Devices:

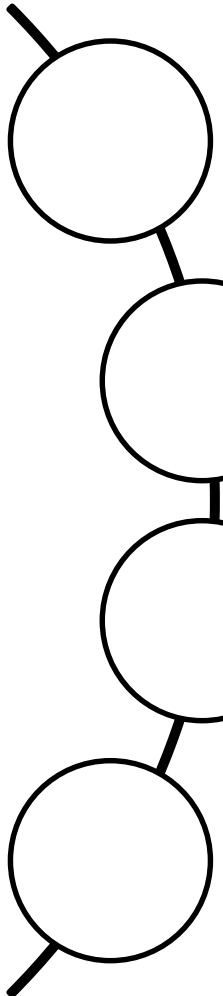
- Service Areas
- Mobile Technologies
- Device Capabilities (UE Categories)
- Spectrum Bands (US and international)

Service Providers

- Roaming Agreements
 - One-way
 - Bilateral
 - Roaming Hubs
- Financial Exchanges
- Data Exchanges

Sources: QGIS, Open Street Map/ Stamen Terrain, ITU,

Summary & Conclusion

- 
- 5G may be viewed as a decoupled network of networks. Opportunities for new business models.
 - 5G may be deployed in several spectrum bands subject to regulatory and service provider considerations, i.e. low, mid, and high band spectrum.
 - End to end system deployment requires different skillsets and different technologies, e.g. spectrum, RAN, Transport, Core, BSS/OSS, site deployments, etc
 - Network slicing, NFV, SDN, and APIs may create new business models and applications.

Q & A

IEEE 5G Education

<https://5g.ieee.org/education>