

Broadband Communications Industry and Path to 5G

2019 Winter Session for Young Professionals

IEEE Future Networks Education

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Topics



Industry Structure



Mobile and Fixed Broadband
Infrastructure



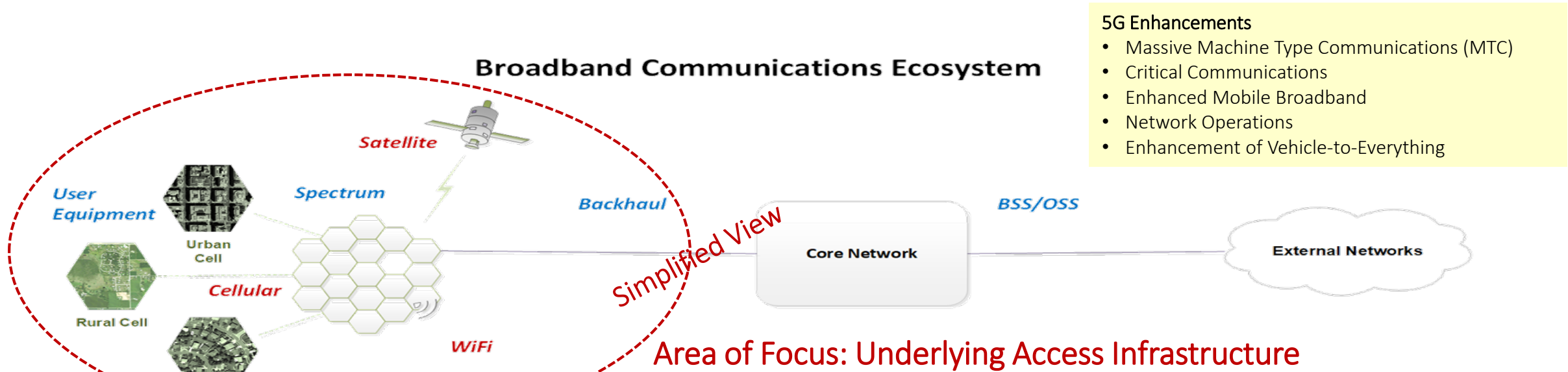
Path to 5G



Adjacent Industries

Wireless Mobility Ecosystem Area of Focus

Wireless Mobility Ecosystem Overview (Simplified View)



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

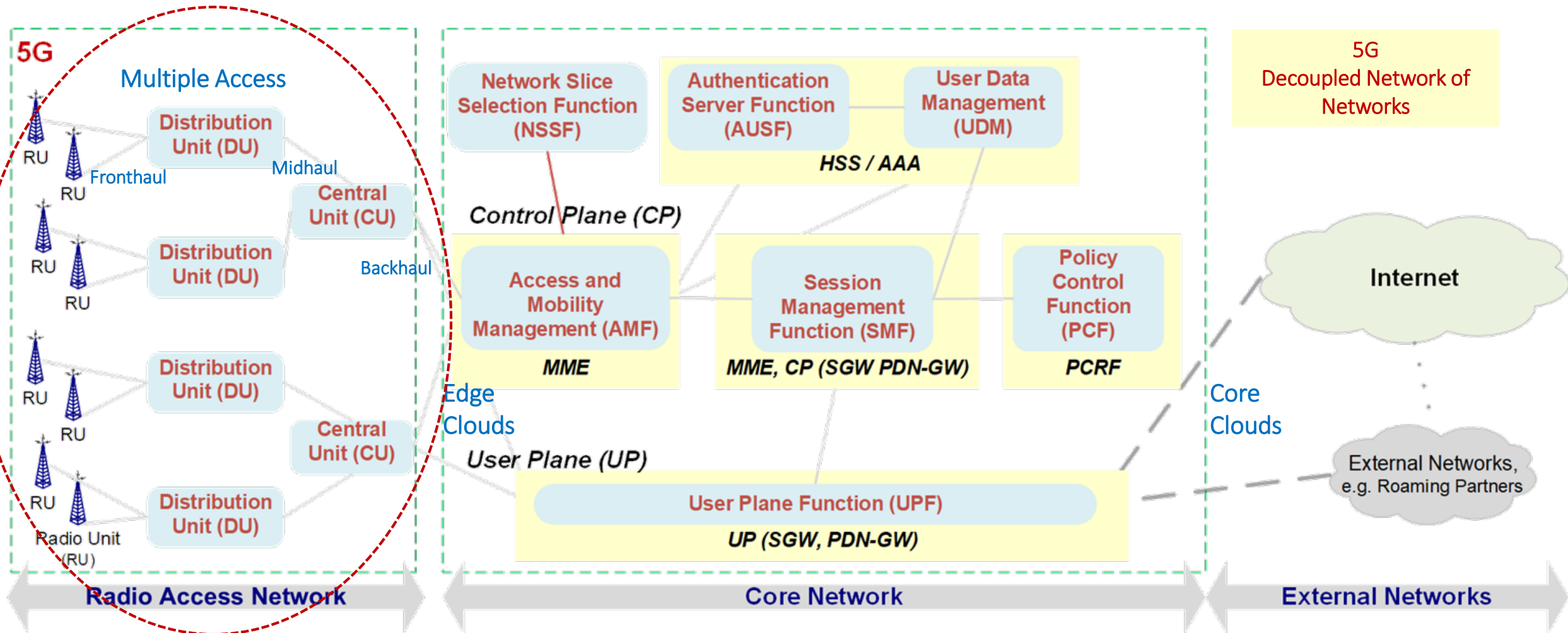
BSS/OSS

- 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

5G Network Architecture



Area of Focus: Underlying Access Infrastructure

5G is a system of systems

- 5G NR, LTE, and non-3GPP systems (e.g. satellite, WLAN access)

Sources: 3GPP TS 23.501, ITU GSTR-TN5G

Industry Structure Primer

Industry Boundaries

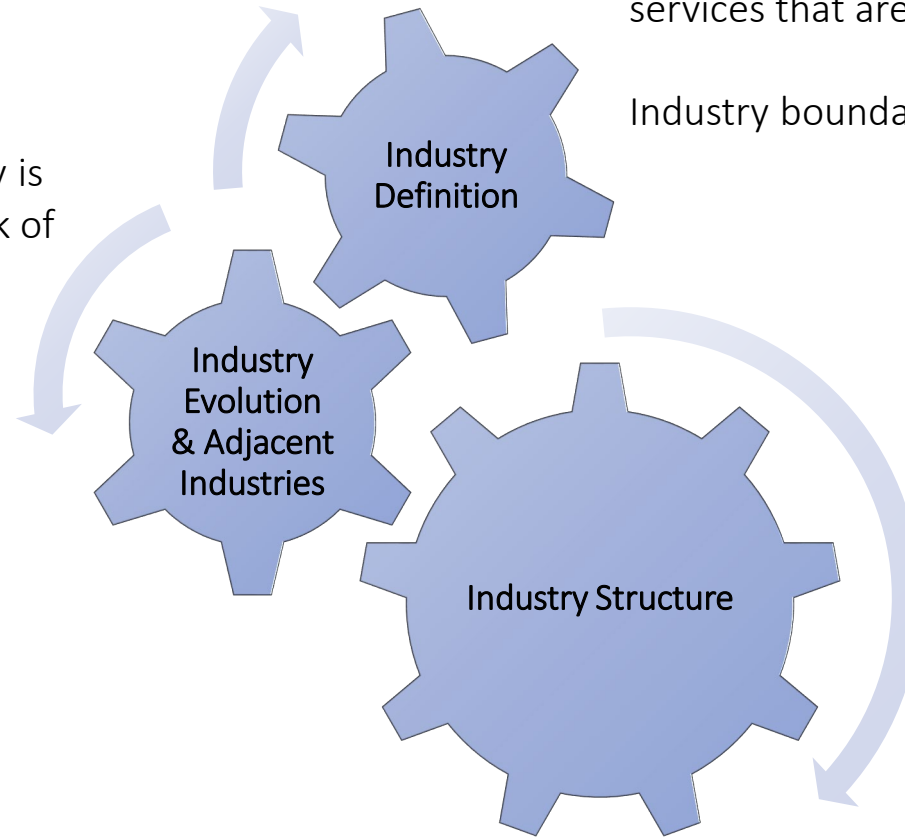
Industry → group of firms providing products or services that are close substitutes for each other.

Industry boundaries → a matter of choice.

Mobile broadband industry is evolving towards a network of networks with 5G.

Adjacent industries may also experience change, e.g.

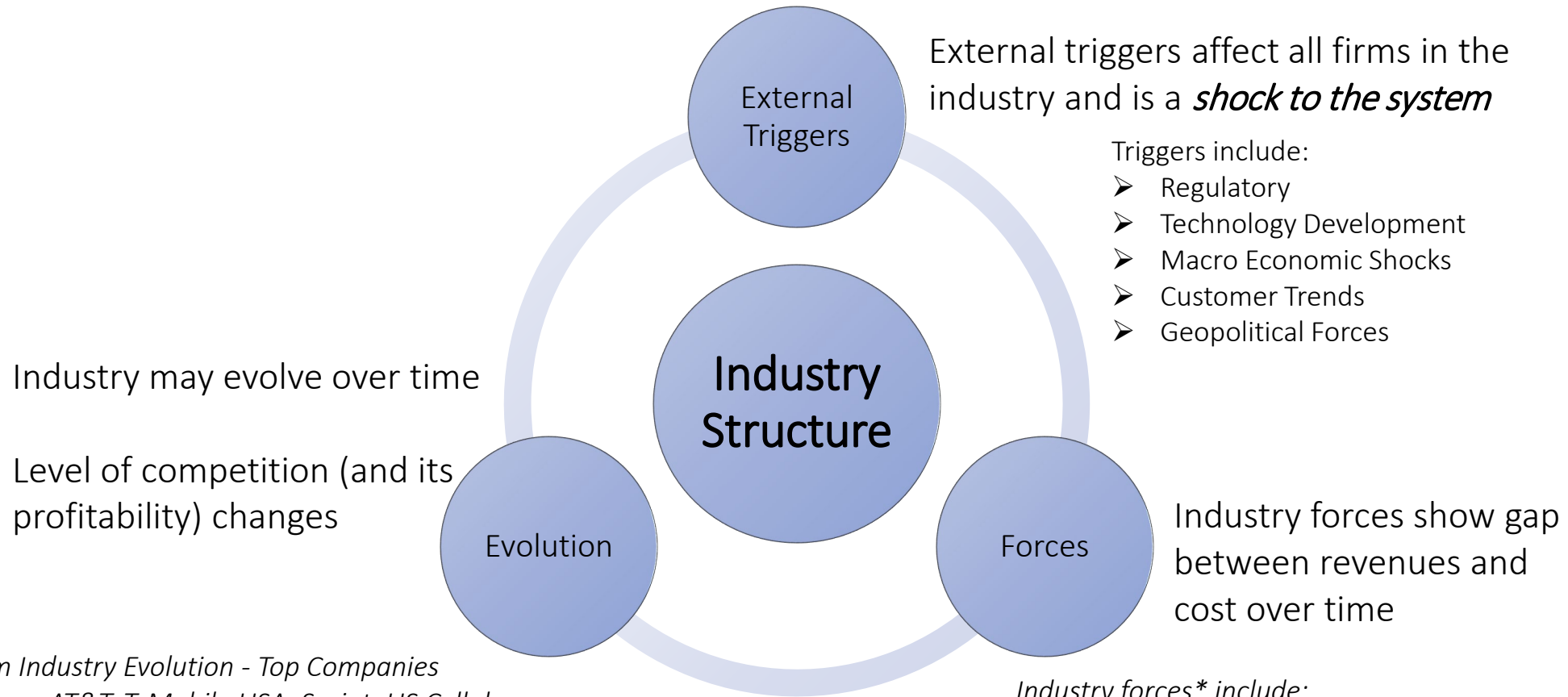
- Connected Vehicles
- Connected Health
- Smart Grid
- Mobile Money



Industry Structure Analysis

- used to assess the attractiveness of the industry
- Used to help develop a strategy or where a firm wants to compete

Evolving Industry Structure



Mobile Telecom Industry Evolution - Top Companies

- **2015:** Verizon, AT&T, T-Mobile USA, Sprint, US Cellular
- **2005:** Cingular, Verizon, Sprint, T-Mobile USA, Alltel
- **1995:** McCaw Cellular, GTE/Contel, BellSouth, Southwestern Bell, & Bell Atlantic

Industry forces* include:

- Threat of New Entrants
- Threat of Substitutes
- Bargaining Power of Suppliers
- Bargaining Power of Customers
- Intensity of Competitive Rivalry

* Porter's Five Forces

Mobile and Fixed Broadband Industries



Form 477 data is currently the most accurate data that is publicly available



Form 477 data is self reported and is generally considered to be inaccurate
- data may understate or overstate deployments



Accuracy may be improved by synthesizing additional data sources



Rulemaking to consider improvements in the Form 477 data collection process

Ref - *Modernizing the FCC Form 477 Data Program*, Further Notice of Proposed Rulemaking, FCC Docket 11-10

General Note on FCC Form 477 Data Source

Mobile Broadband Infrastructure

4G LTE US Mobile Network Deployment – Dec 2017



LTE deployment tends to focus on the larger population centers.

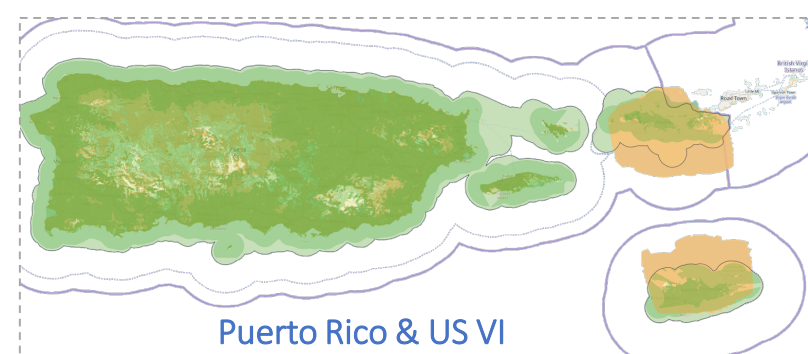
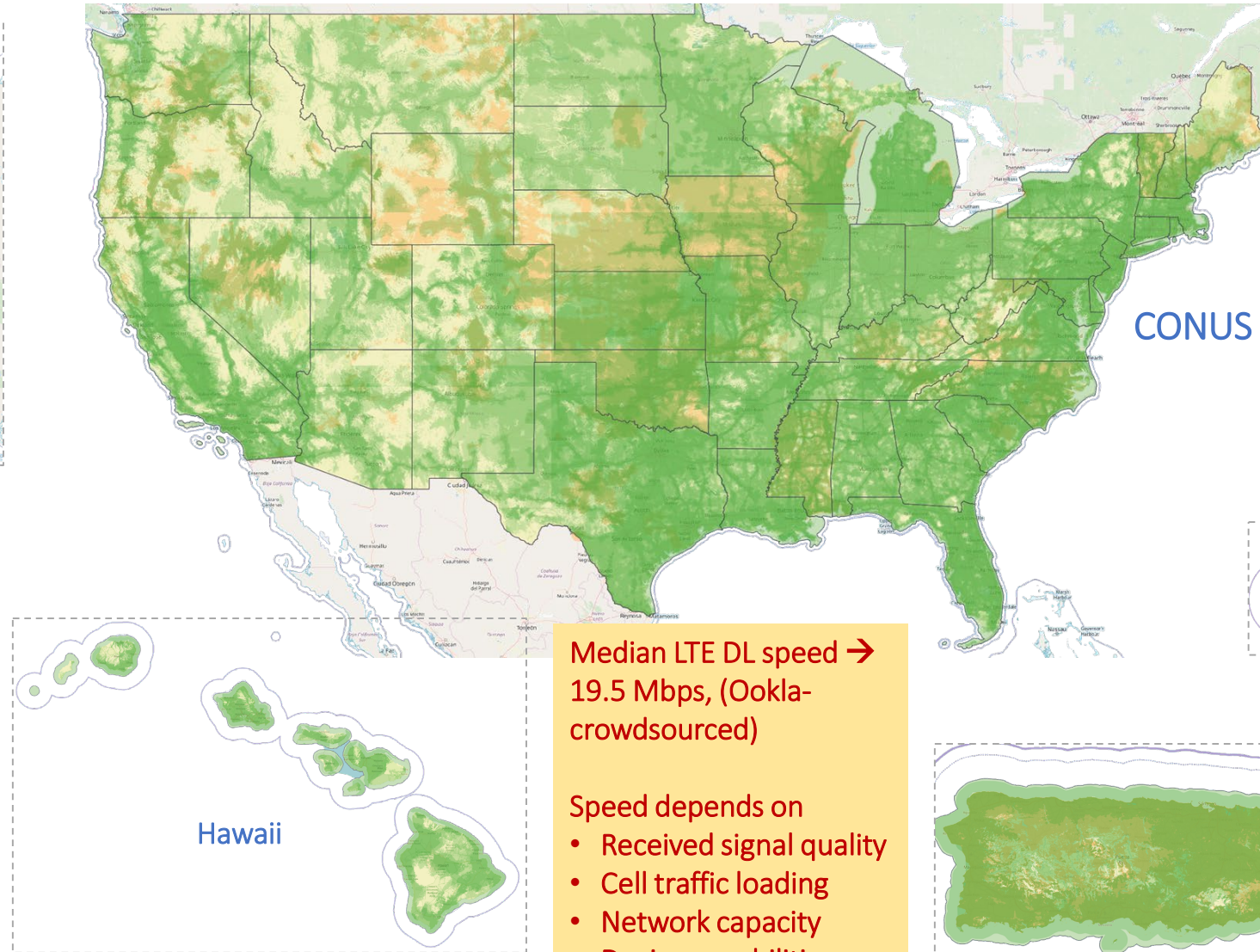
Approx service area from *at least four service providers*

- ❖ **Population:** 92% (97% non-rural / 67% rural) of population
- ❖ **Roadways:** 54 % of road miles
- ❖ **Area:** 30 % of total US land area

■ **Nationwide Providers**
■ **Non-Nationwide Providers**

Dark green indicates overlapping nationwide provider service area

Combined LTE service areas shown.



Median LTE DL speed → 19.5 Mbps, (Ookla-crowdsourced)

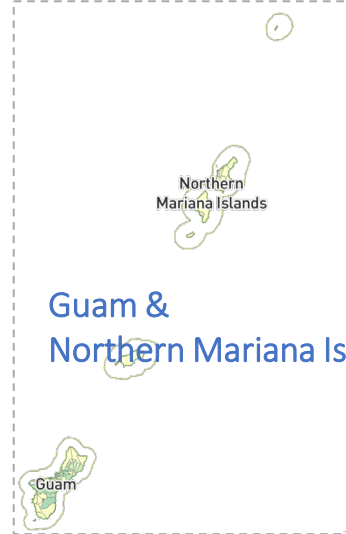
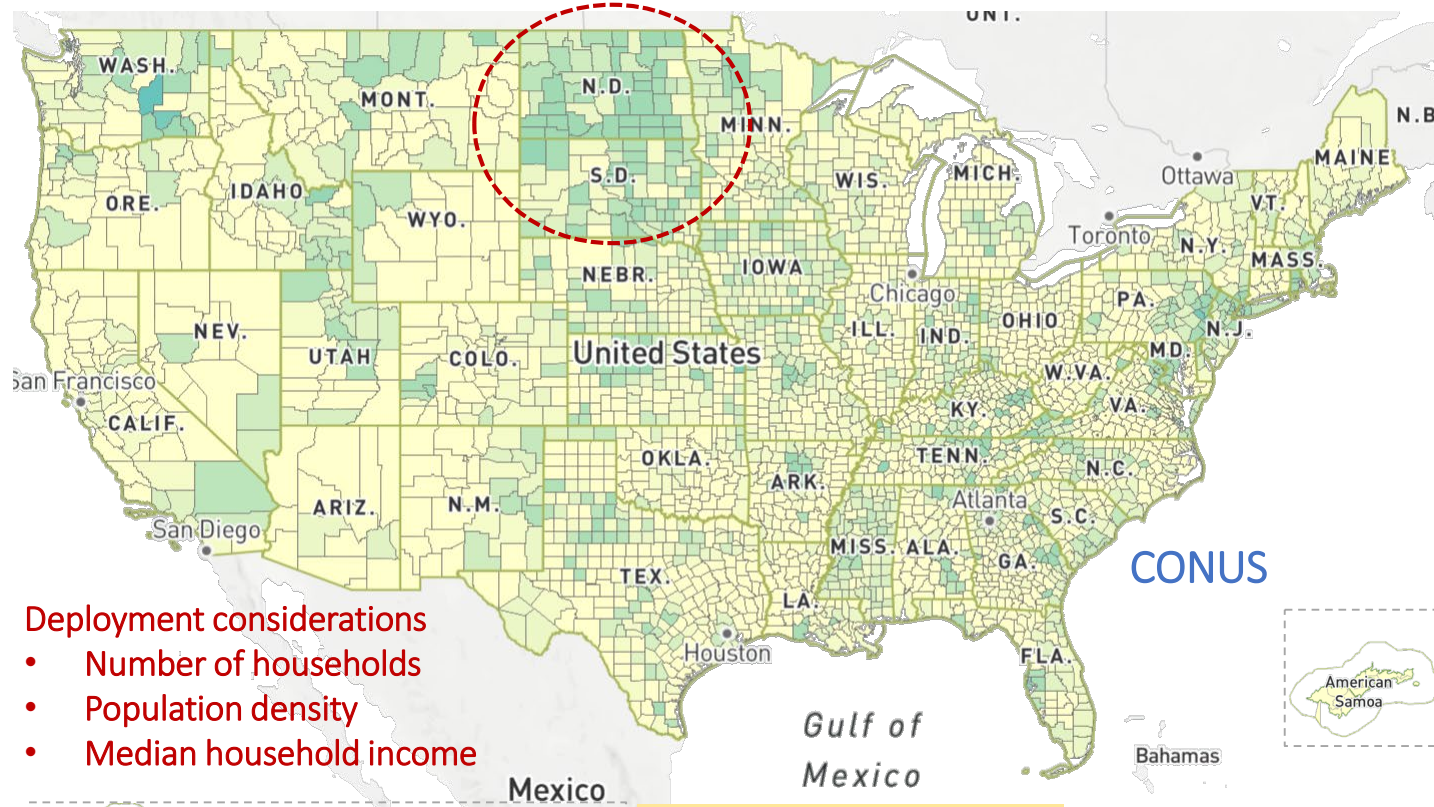
Speed depends on

- Received signal quality
- Cell traffic loading
- Network capacity
- Device capabilities
- Network Policies

Source: LTE maps generated from Dec 2017 FCC Form 477 data

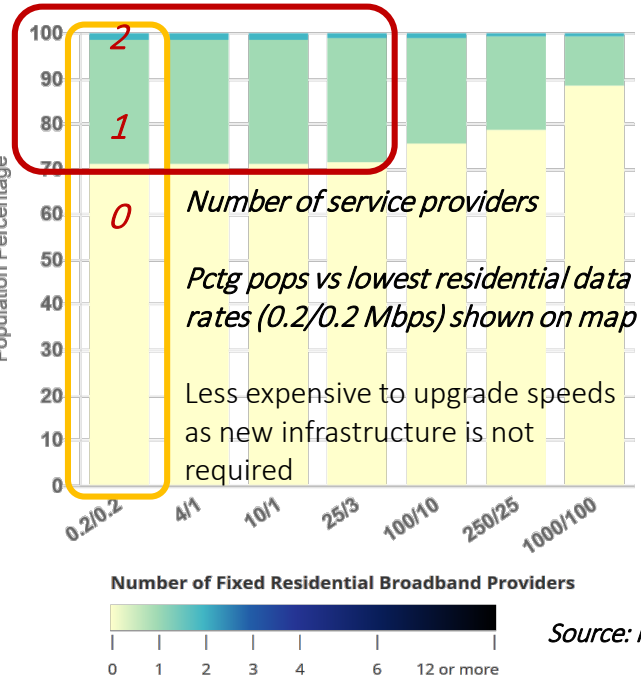
Fixed Terrestrial Broadband Infrastructure

US Fixed Broadband Deployment (Fiber) – Jun 2017



- Deployment considerations**
- Number of households
 - Population density
 - Median household income

Data Rates
 Median speed of 73 Mbps (approx. 60% of subscribers experience greater speeds.)
Max advertised DL speed
 between 100 to 150 Mbps
Latency
 •Typically 12 to 20 ms

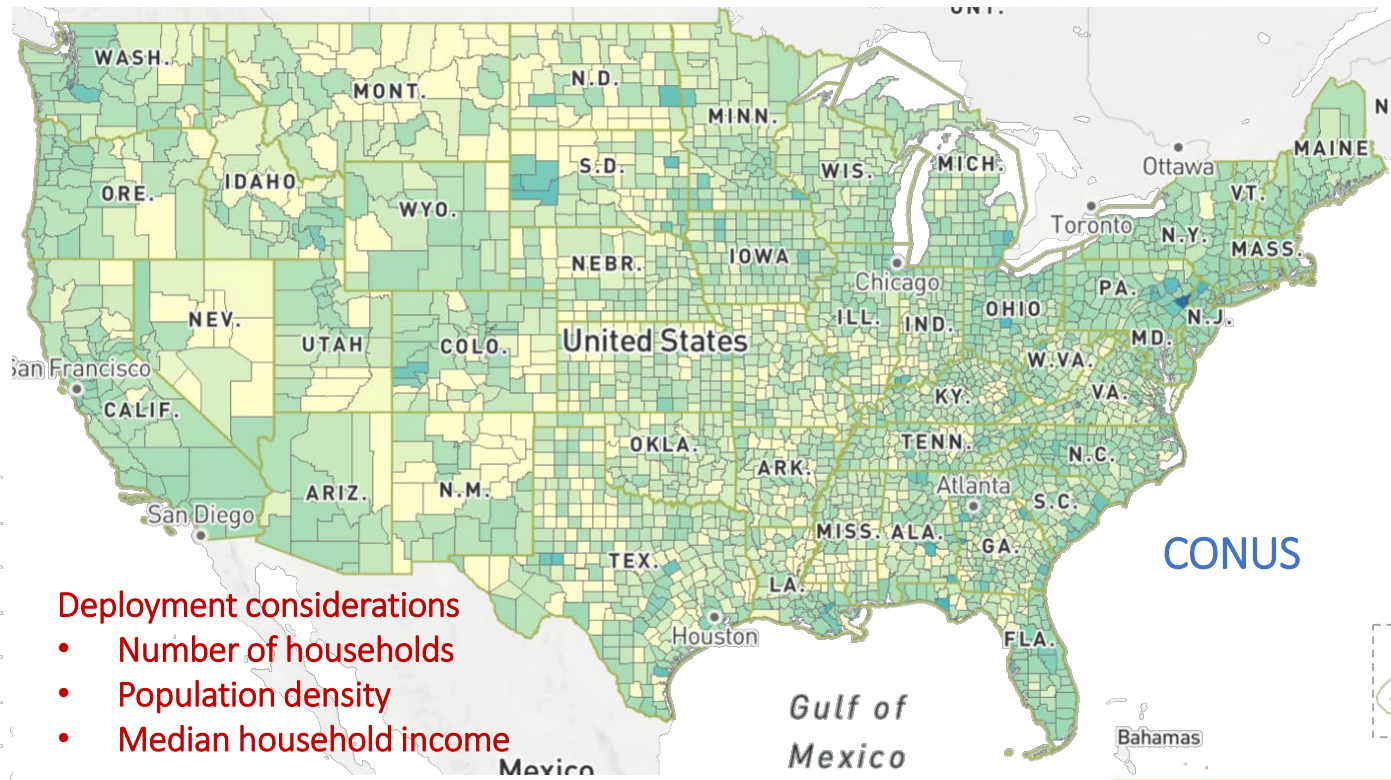


Number of service providers

Pctg pops vs lowest residential data rates (0.2/0.2 Mbps) shown on map

Less expensive to upgrade speeds as new infrastructure is not required

US Fixed Broadband Deployment (DOCSIS/Cable) – Jun 2017



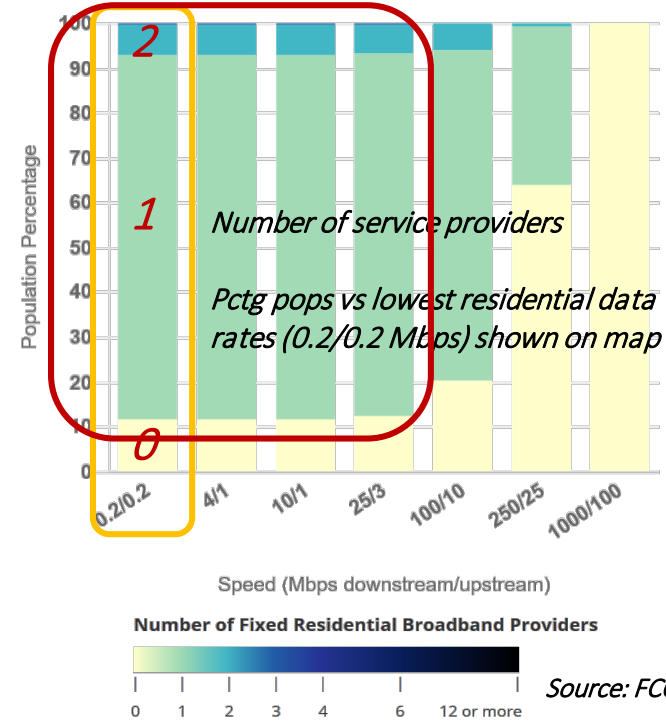
- Deployment considerations**
- Number of households
 - Population density
 - Median household income

Data Rates
 Median speed of 97 Mbps
 (approx. 80% of subscribers experience greater speeds.)

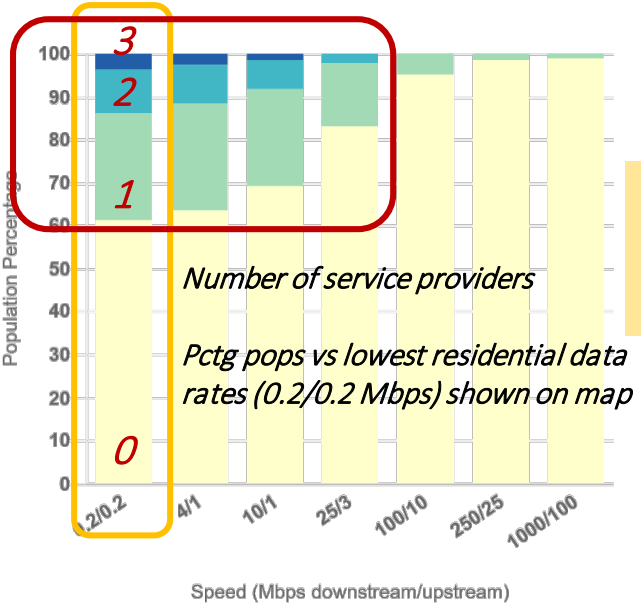
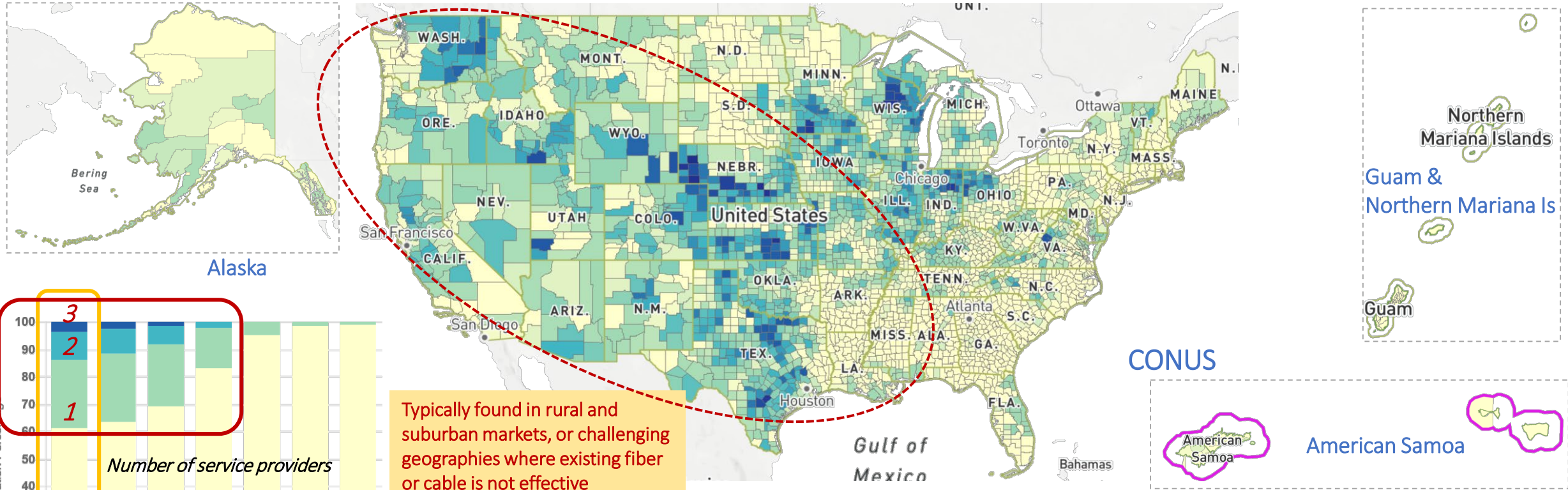
Max advertised DL speed
 between 100 to 200 Mbps

Latency
 • Typically 15 to 34 ms

- DOCSIS 3.1 → potential for speeds of up to 10 Gbps
- DOCSIS 3.0 (typical) → up to 900 Mbps.



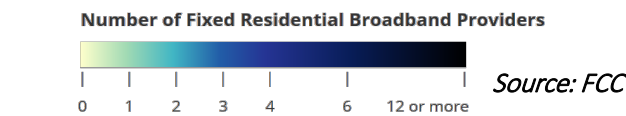
US Fixed Broadband Deployment (Fixed Wireless) – Jun 2017



Typically found in rural and suburban markets, or challenging geographies where existing fiber or cable is not effective

Data Rates
Typically 5 to 50 Mbps but may reach 1Gbps

Fixed wireless uses licensed, unlicensed, or shared access spectrum



Satellite Network Deployment

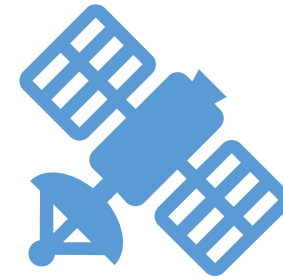
Satellite Orbits



Geostationary Orbit (GSO)

Satellite Service

Geostationary satellites (GSO) → approx 22,300 miles above the earth (appear to be fixed above a particular point on the Earth)



Non-Geostationary Orbit (NGSO)

Satellite Service

New high-throughput, lower-latency (< 100ms RTT) broadband services expected from NGSOs to serve remote or rural areas

- **Medium earth orbits (MEO)** → approx 6,000 to 12,000 miles above the earth (orbits the earth in 5 to 12 hours)
- **Low-earth orbits (LEO)** → approx 100 to 300 miles above the earth (orbits the earth in 90 minutes).

Fixed Satellite Service (FSS)

Fixed Satellite Service (FSS)

- Satellite communications with earth stations that are located at fixed points on earth. Services include:
 - Wholesale transponder services
 - Managed services (also known as enterprise services)
 - Consumer broadband services
 - Mobile services such as Earth Stations in Motion (ESIMs) that operate within the FSS spectrum. (Mobile earth stations operate in MSS spectrum).
 - ESIMs are Earth Stations on Vessels (ESV), Vehicle-Mounted Earth Stations (VMEs), and Earth Stations Aboard Aircraft (ESAAs)
 - Includes maritime enterprise VSAT services and broadband connectivity for cruise ships, in-flight entertainment and WiFi services for commercial airlines
 - ESIMs are able to transmit and receive very high data rate broadband communications while in motion, e.g. ships, vehicles, trains, and aircraft

FSS (US providers)

- Intelsat, SES, Eutelsat, Telesat Canada, Echostar, and ViaSat
 - End users include government organizations, commercial entities, and individual clients.

Mobile Satellite Service (MSS)

Mobile Satellite Service (MSS)

- *Satellite communications with* mobile earth stations located on land, on sea, or on airplanes
- MSS data services are more limited than FSS mobile data services due to the bandwidth allocated for service
- Services include voice, low-speed data, and tracking services for aircraft and ships, remote services

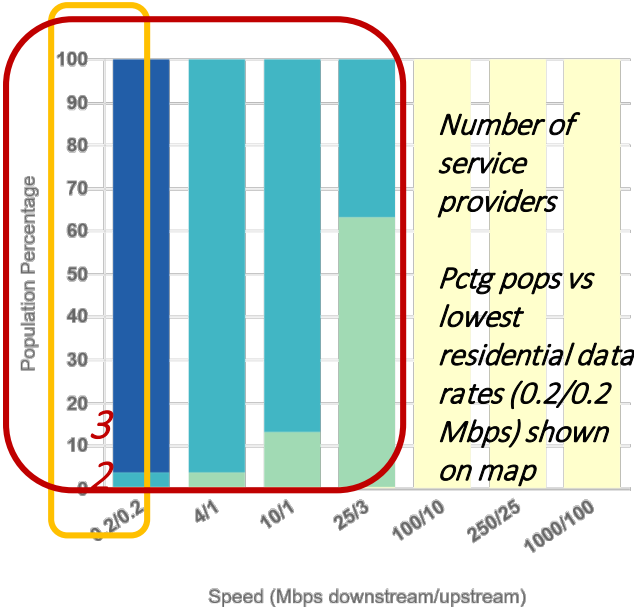
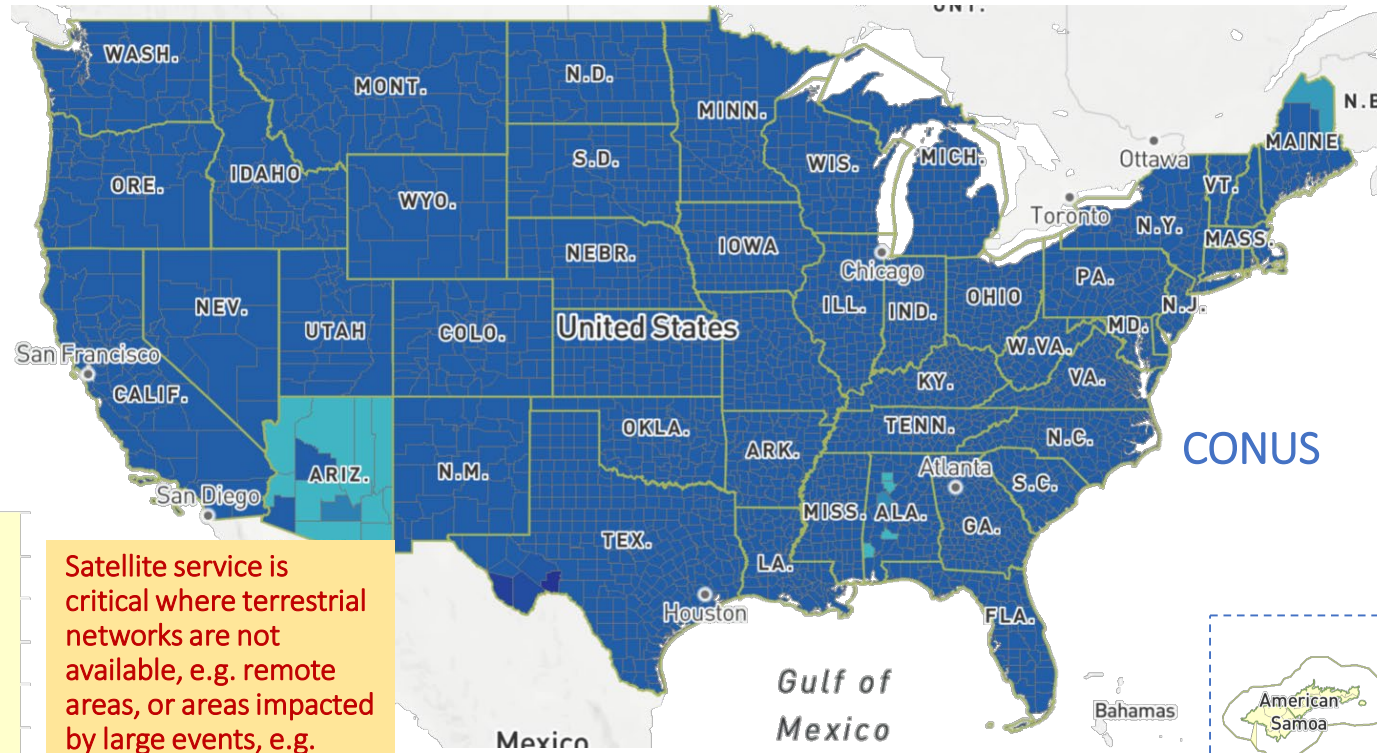
GSO Based Services

- Inmarsat - voice, video, and data communications services
- Ligado - IoT

LEO Based Services

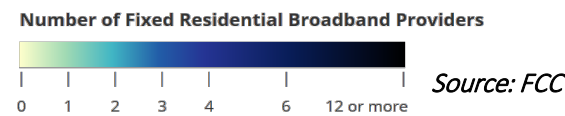
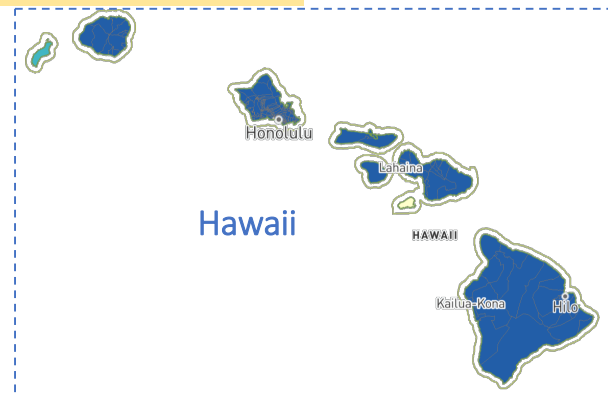
- Iridium - low-latency mobile voice, data, and IoT
- Globalstar - voice, data, IoT low-latency services
- ORBCOMM - IoT

US Fixed Broadband Deployment (FSS) – Jun 2017



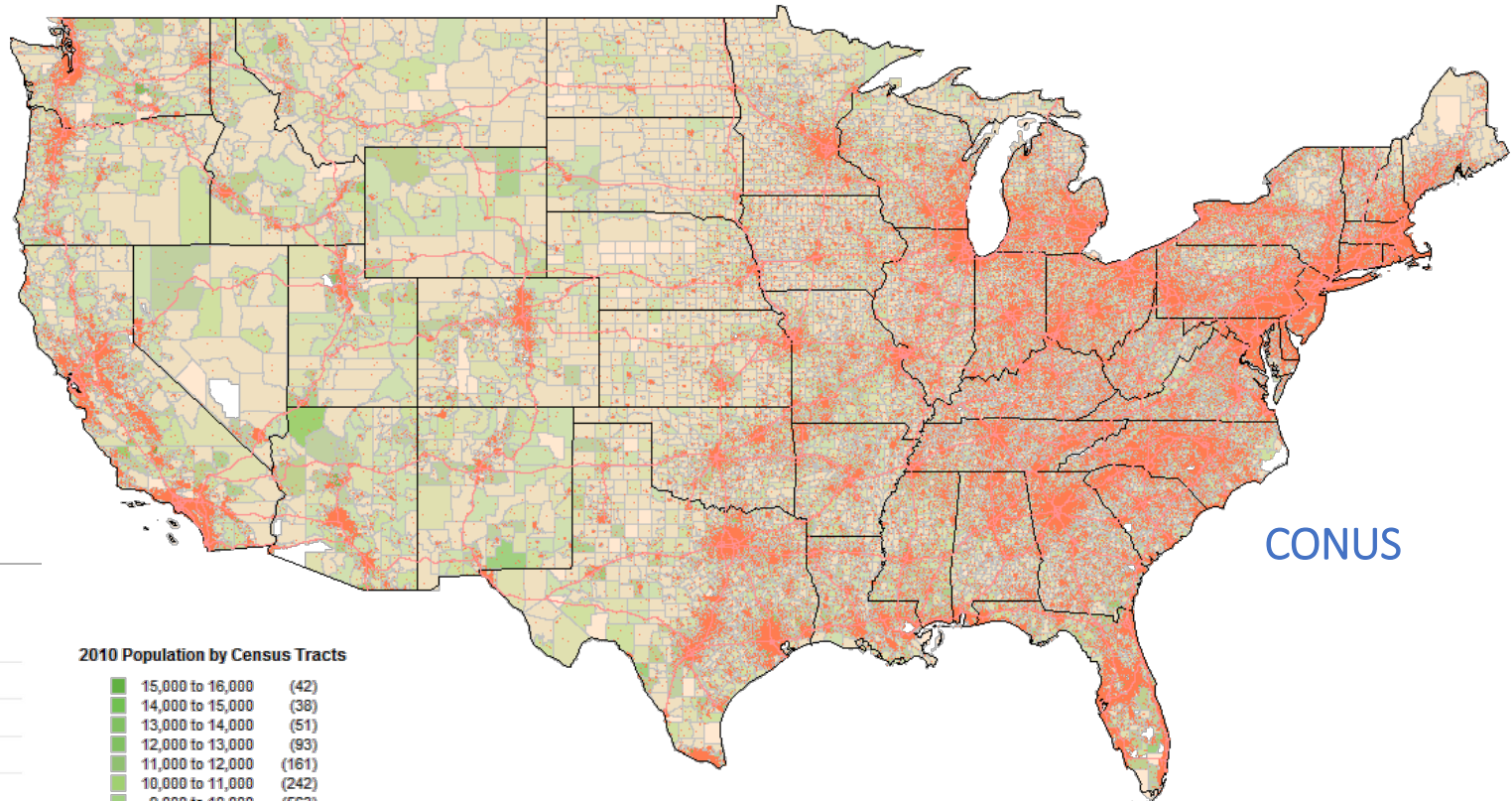
Satellite service is critical where terrestrial networks are not available, e.g. remote areas, or areas impacted by large events, e.g. natural disasters

Data Rates
At least 25Mbps/3 Mbps (SIA)
Satellite capacity may limit the number simultaneous users

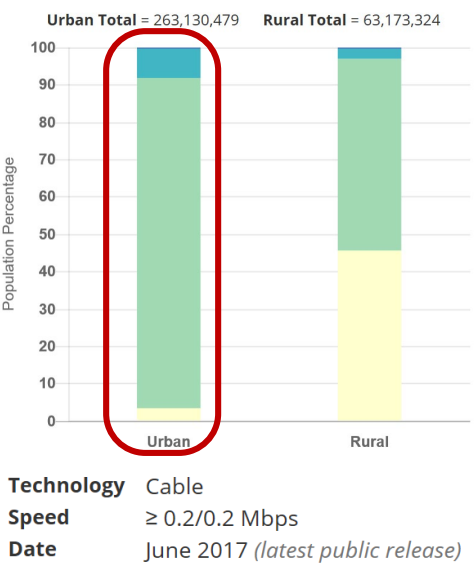
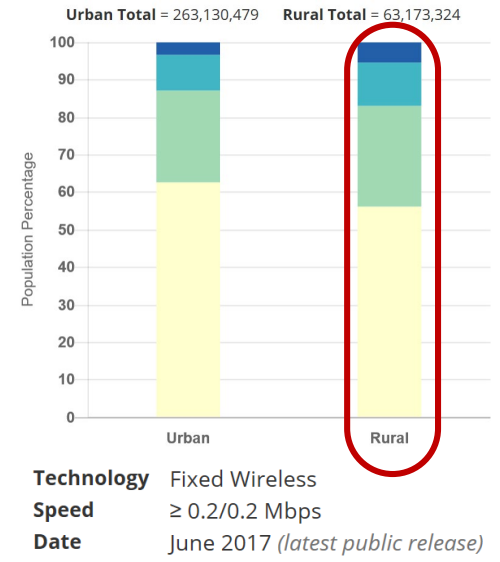
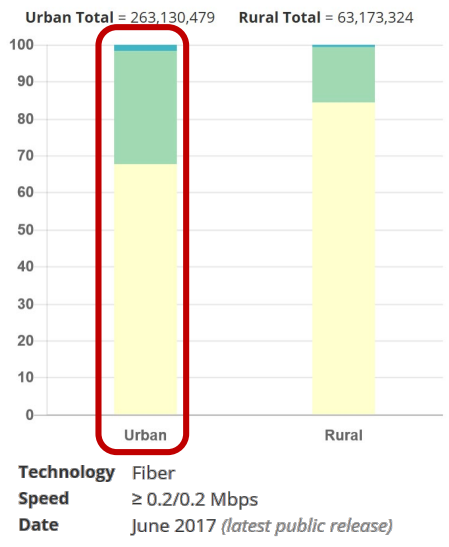


Urban and Rural Services

Urban and Rural Services



CONUS



2010 Population by Census Tracts

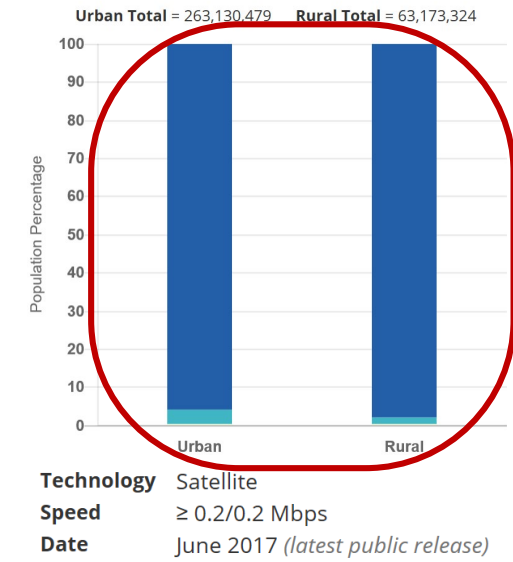
15,000 to 16,000	(42)
14,000 to 15,000	(38)
13,000 to 14,000	(51)
12,000 to 13,000	(93)
11,000 to 12,000	(161)
10,000 to 11,000	(242)
9,000 to 10,000	(563)
8,000 to 9,000	(1277)
7,000 to 8,000	(3165)
6,000 to 7,000	(6296)
5,000 to 6,000	(10264)
4,000 to 5,000	(14643)
3,000 to 4,000	(16551)
2,000 to 3,000	(13298)
1,000 to 2,000	(5874)
1 to 1,000	(790)
all others	(654)

2010 Population Density per Census Tract
1 Dot = 1,000

- Rural area → population density of 100 people or less per square mile
- 56 million people or (18% of the U.S. population)
- 3 million square miles, or (84% of the geographic area)

Mobile LTE Service: 92% (97% non-rural / 67% rural) of population

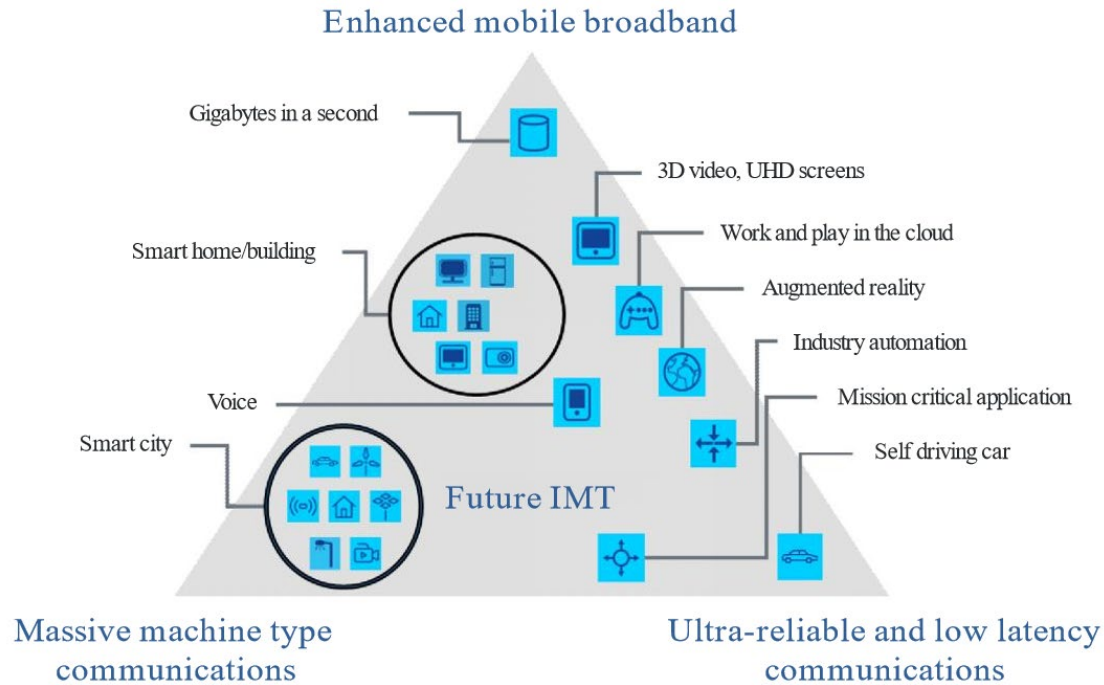
Population density varies across the US and drives the cost for geographical licensing areas



Path to 5G

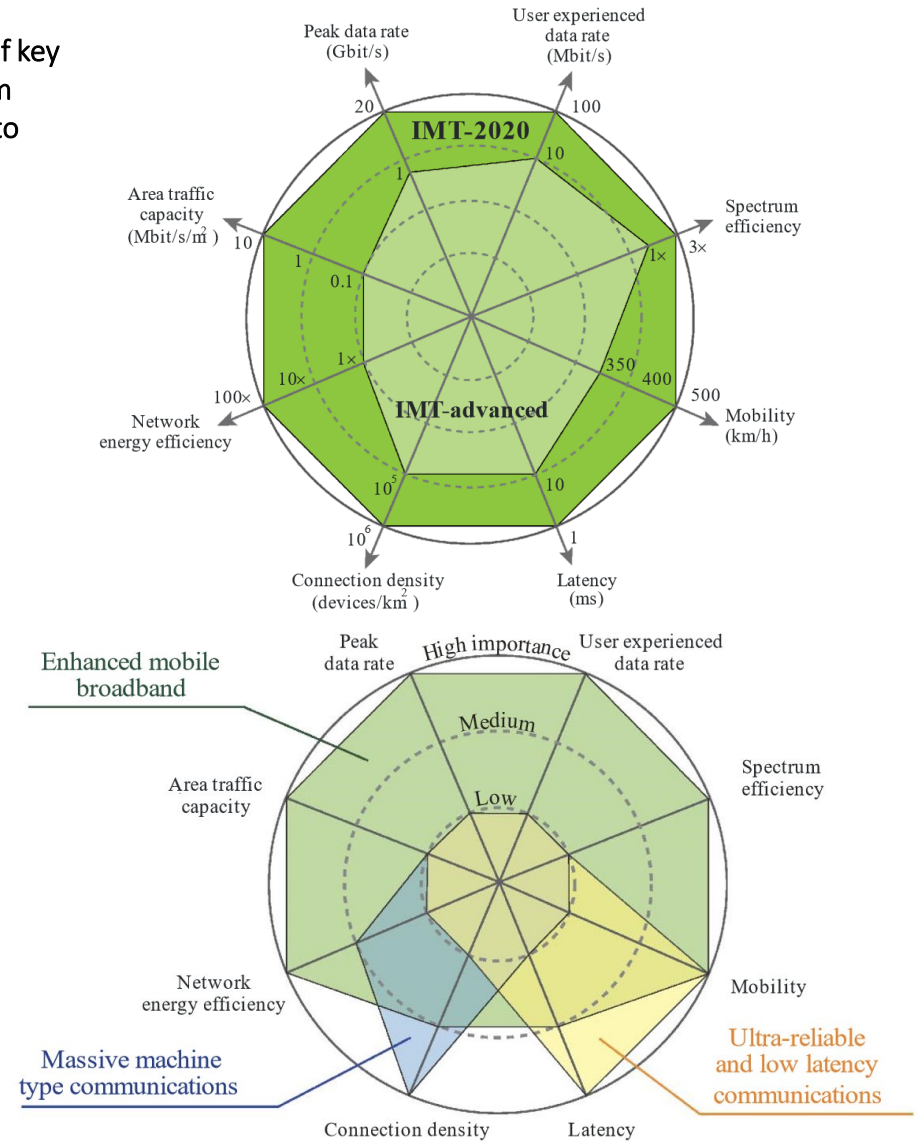
5G Vision

Usage scenarios of IMT for 2020 and beyond



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

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



Market & Technological Barriers

Profits and Market Attractiveness impact Industry Structure

- High profits encourage entry into the market and stimulate competition
 - Lower market concentration in high population density areas, e.g. urban areas with greater demand and greater cost efficiencies (per-user mobile wireless network deployment costs)
- Low profits discourage entry,
 - Higher market concentration in low population density areas, e.g. rural areas that may not be able to support multiple service provider deployments
 - Sustained losses may trigger market exit

Access to spectrum

- International & regional spectrum harmonization, e.g. for next generation satellite networks

High deployment costs, e.g. geography

- Additional fiber investment needed for support small cells and network densification. Low population densities, e.g. rural areas

Efficiencies of scale and scope

- Access to sites for network deployments
- Service upgrades in less competitive rural markets (smaller companies with lower profit margins & limited capital)

Wireless Services and 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

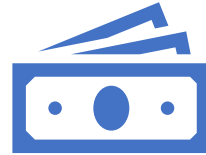
- **Existing Spectrum:** 700 MHz, 850 MHz (cellular), 1900 (PCS), 1700 / 2100 MHz (AWS), 2300 MHz (WCS), 3600 (BRS)
- **Recent Auctions:** Auction 101 (28 GHz) closed in Jan 2019 @ \$702 M, 600 MHz
- **Ongoing/ Upcoming:** Auction 102: Spectrum Frontiers - 24 GHz yielded **over \$1.5 B** as of March 27 !!!, Auction 103: Spectrum Frontiers – Upper 37 GHz, 39 GHz, and 47 GHz, 3.5 GHz (CBRS shared spectrum)
- **C Band spectrum discussions ongoing**

Fixed Broadband Sectors



Technologies - Fixed technologies that differ in function, speed, and cost of deployment

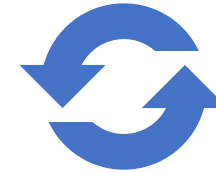
- Fiber to the end user
- Cable broadband services
- Digital subscriber lines (DSL)
- Fixed wireless
- Satellite



Investments and Threat of Competition

Continued investment in fixed networks for service quality and availability:

- Internal competition (other fixed Internet service providers)
- Potential external market entry (inter-modal competitors)



Threat of Substitutes

2018 Broadband Deployment Report - mobile services are not “currently full substitutes for fixed services.”

- Current difference include:
 - Mobile data caps
 - Pricing models
 - Speed variation
 - Network reliability
- However, 5G and Low Earth Orbit (LEO) wireless services will be targeting residential broadband

Multi-Modal Terrestrial Service and Path to 5G

Hybrid fiber/coaxial (HFC) – combination of fiber and legacy copper wire or coaxial cable.

- 5G deployment considerations
 - Combination of existing fiber backhaul and 5G fixed wireless for the last-mile connections.
 - Some fixed carriers may also rely on satellite backhaul.

FTTC (Fiber-to-the-curb) – combination of fiber and legacy copper wire

- 5G deployment considerations
 - Combination of existing fiber backhaul and 5G fixed wireless for the last-mile connections.
 - Some fixed carriers may also rely on satellite backhaul.

Converged wireline and wireless networks

- 5G and LEO wireless services will be targeting residential broadband in the future, e.g. 5G fixed wireless applications
- Cable operators are entering the mobile wireless market, e.g. Spectrum Mobile, Xfinity Wireless

Broadband Forum Fixed Mobile Convergence (FMC) specifications in progress. It includes:

- SD-407 for FMC architecture and requirements to 5G core
- SD-406 for End-to-End Network Slicing

Satellite Service and Path to 5G



Latency requirements for maximum one way end-to-end latency



Satellite Services.

Inter-satellite connectivity to other satellite service providers for data backhaul or satellite mission extension capabilities



Technological Developments.

Increased use of LEO and Middle Earth Orbit (MEO) satellite systems.



New satellite launch technologies, e.g. reusable hardware and vehicles designed to launch smaller satellites



Next generation high throughput satellite systems e.g. spot beams for higher power transmission and spectrum reuse

Proposed 5G specifications for future releases:

- **GEO** based satellite: **285 ms** end-to-end latency (inc 5ms network delay)
- **MEO** based satellite: **95 ms** end-to-end latency (inc 5ms network delay)
- **LEO** based satellite: **35 ms** end-to-end latency (inc 5ms network delay)

Source: 3GPP TR 22.822 - Study on using Satellite Access in 5G

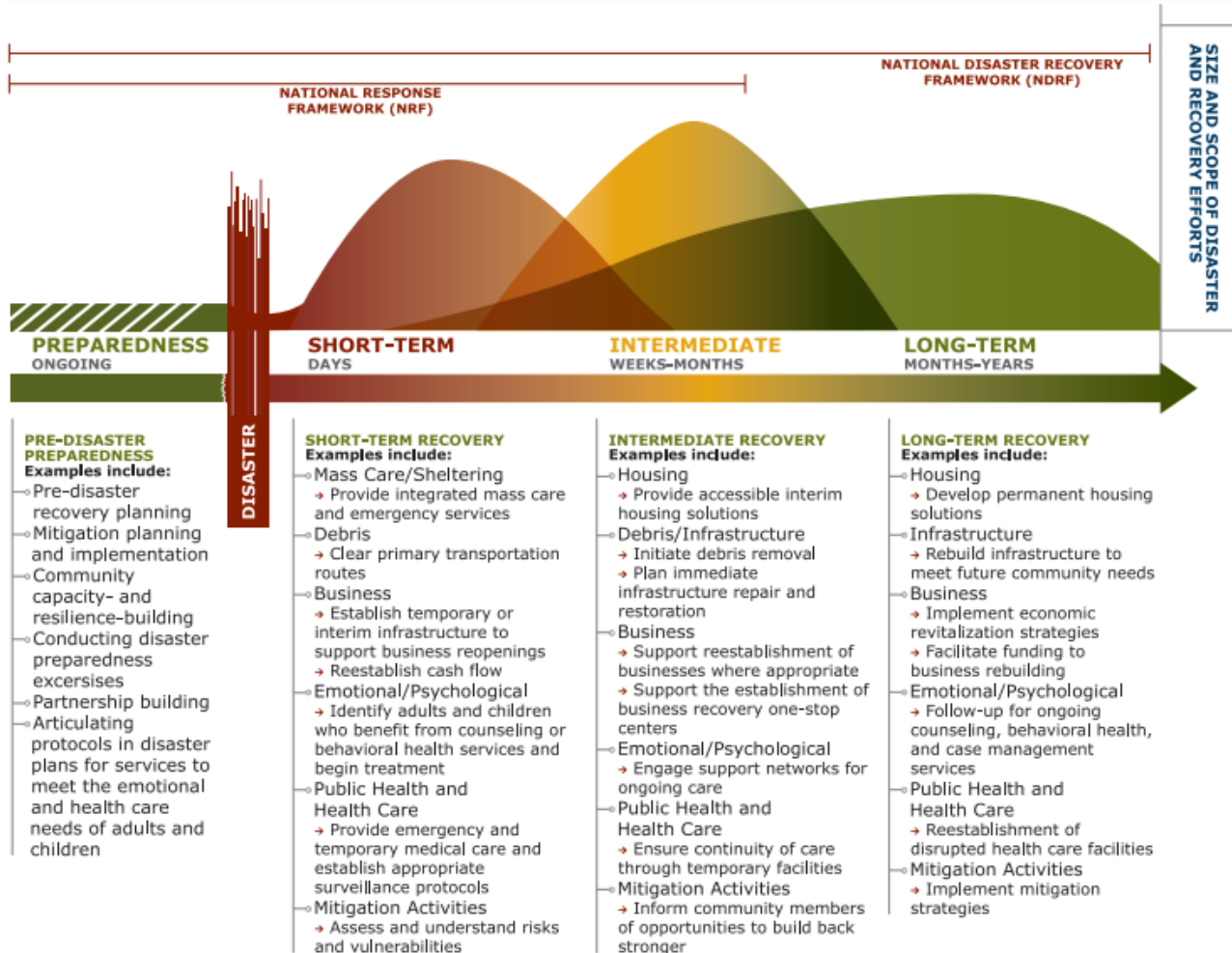
Satellite Market (New/Proposed Systems)

New /
Proposed
Systems

- **Audacy:** NGSO FSS system - inter-satellite (ISS) data relay network for continuous high-speed communications between other NGSO satellites and gateway earth stations
- **Kepler:** NGSO LEO system - global IoT connectivity
- **LeoSat:** NGSO LEO - broadband services for enterprise-to-enterprise communications, Internet and 5G/4G cellular backhaul, video content delivery, oil field services and operations, and maritime communications
- **O3b Limited:** NGSO system - broadband Internet access
- **OneWeb:** NGSO FSS system - high-speed, affordable broadband connectivity
- **Space Norway AS (Space Norway):** NGSO FSS system - broadband Internet access to currently unserved and underserved Arctic areas.
- **SpaceX:** NGSO Satellite System *–includes ISS* links for seamless network management and continuity of service to enable spectrum sharing with other systems
- **Telesat Canada:** NGSO LEO - broadband services

Adjacent Industries

Public Safety Sector



Permanent, Temporary and Deployable Communications

- Communication form factors and specialized capabilities to support:
 - Emergency preparedness
 - Emergency response – ref National Response Framework (NRF), FEMA National Incident Management System (NIMS)
 - Disaster Recovery and Continuity of Operations – ref National Disaster Response Framework (NDRF)

Source: National Disaster Recovery Framework, FEMA, Sep 2011,

Transportation



Roadway – includes primary, secondary, and arterial roads.

eV2X features include vehicles platooning, advanced driving, extended sensors, and remote driving.

Advanced Traveler Information Systems, Road Weather, Intelligent Traffic Signal Systems, Reduced Speed/Work Zone Warning (RSWZ), Incident & Emergency Management, Commercial Vehicle Applications, Agency Data Applications, Pedestrian & Bicycle, Pedestrian in Crosswalk Warning (PCW) and Bicycle



Railway – includes heavy and light commuter rail, freight lines.

Bulk Transfer of CCTV archives from train to ground, multimedia from ground to train, and massive Inter-carriage data transfer

Train control services, maintenance services, and railway specific services (e.g. Railway Emergency Call, location-based addressing),

Other services (e.g. providing train crews or train drivers with information of train operation and interworking with the existing railway communication systems)



Waterway – includes ferries, cargo ships, small vessels.

Satellite and airborne base stations may be used to provide service for ship-to-shore, ship-to-ship, and intra-ship communications.

Network connection and service continuity, vessel identification, multi-access and seamless mobility, warning notification and emergency request.



Airway – includes airports, and personal air transportation systems, e.g. urban air mobility (UAM)

High Altitude Platforms (HAPs) including Unmanned Aircraft Systems (UAS) and tethered UAS, Lighter than Air UAS and Heavier than Air UAS

Healthcare, Utilities, and Agricultural Sectors



Healthcare

Continuum of Care support – Includes trauma centers, specialized and general hospitals, emergency medical transport, outpatient monitoring, etc

Infrastructure needed to support applications such as:

- MIIoT - devices, sensors,
- URLLC –remote surgery, telemedicine, tactile internet
- Broadband Services –AR/VR, live streaming, e.g. during emergency medical transportation,



Smart Grid

Communications infrastructure, e.g. WiFi mesh, cellular, microwave, etc

- Advanced metering infrastructure (AMI)
- Time-based rate programs, e.g. Time of Use, Critical Peak Pricing
- Consumer System Devices, e.g. Home Area Network
- Direct load control, e.g. shifting electricity usage to non-peak times
- Distribution automation systems, e.g. isolating faults, reduce energy loss from the distribution system
- Plug-in electric and hybrid electric vehicle charging stations, e.g. performance evaluation, charging patterns



Smart Agriculture

Solutions includes satellite and terrestrial LPWA networks, IoT, and connected tractors for:

- Information and Monitoring Services, e.g. best practices, market information
- Food Supply Chain Visibility, e.g. inspections, logistics
- Mobile Financial Services, e.g. mobile money, rural development

Summary

Industry Structural analysis

- Need to understand external forces as they affect all companies in the industry

Fixed and Mobile Inter-modal Competition

- Competition to increase between mobile and fixed broadband services.
- Industry landscape may change as market boundaries shift, e.g. cable providers offering mobile services, mobile providers offering fixed broadband services

New Satellite Services and Architectures

- Satellite system architecture will need to adjust to meet demand for high throughput low latency services
- New entrants are expected in the satellite services industry to meet demand.

Path to 5G

- Existing fixed broadband services, such as HFC and FTTC, may be augmented by a combination of fiber and fixed wireless connection to the end user.
- Adjacent industries will benefit from the 5G enhanced mobile broadband services, ultra reliable low latency communications, massive IoT, and network operations enhancements
- Deployment of smart cities are expected to benefit from 5G satellite integration and fixed mobile convergence



2019 Winter Session

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