Session #6: Rural Broadband Technology Landscape

18 July 2024

Bridging the Digital Divide with Fixed Wireless Access (FWA) and Non-Terrestrial Networks (NTN)

by

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NOKIA

North American Representative Use Cases

Multi-Sensory XR

Fixed Wireless Access

ITS/Connected Vehicles

Smart Factory

Low Power Wide Area (LPWA)

Personalized User Experiences

Robots

Digital Twins

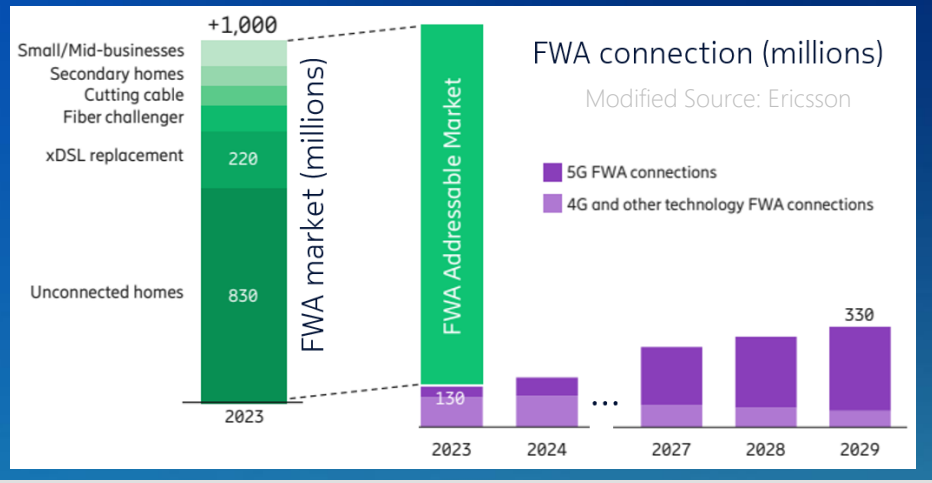
Short Range Massive Sensors (Ambient IoT)

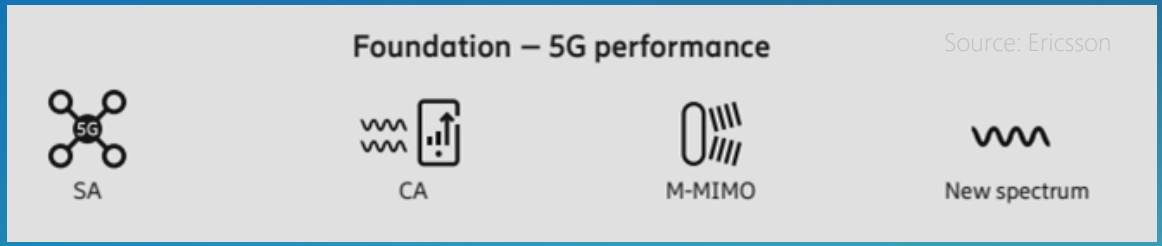
3GPP SA1 Workshop presentations: https://www.3gpp.org/ftp/workshop/2024-05-08_3GPP_Stage1_IMT2030_UC_WS/Docs

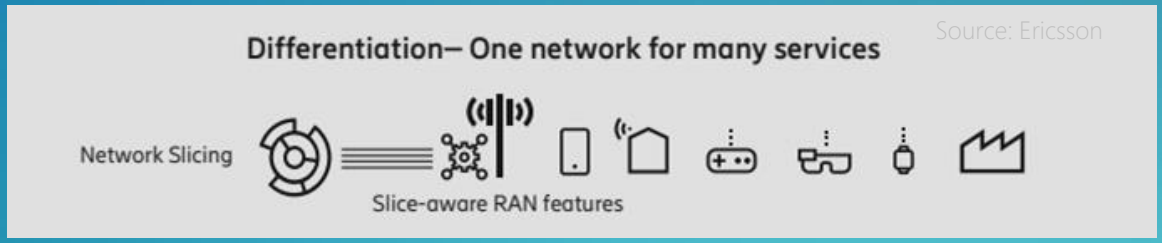
FWA – A growing Market segment

- **330M subscribers by 2029 (130M in 2024)**
- **50% FWA svc providers offer 5G**
- **1/3 of 6G NW traffic – FWA users 10-20x MBB**
- **$75B in 5G service provider revenues by 2029**
  - Creating Global Economies of Scale
- **Sub-7 days 'time to service' (fast flexibility)**
  i. Quick On-line coverage determination for residence address
  ii. If yes, then order ($30 - $50 mo.). CPE arrives in 2 days
  iii. User self installs and picks Location (no truck rolls, self-opt.)
  (IL Suburb examples: 100-300 Mbps DL, 8-20 Mbps UL)
- **3GPP (5G & 6G) offers future-proof FWA platform**
  - **Leverages: 5G SA, CA, 5G/6G spectrum**
    FWA-specific enhancements (e.g., 8TX, MIMO)
    Government incentives to close digital divide

CPE: larger form factor, stationary, ext. power supply, opt. location





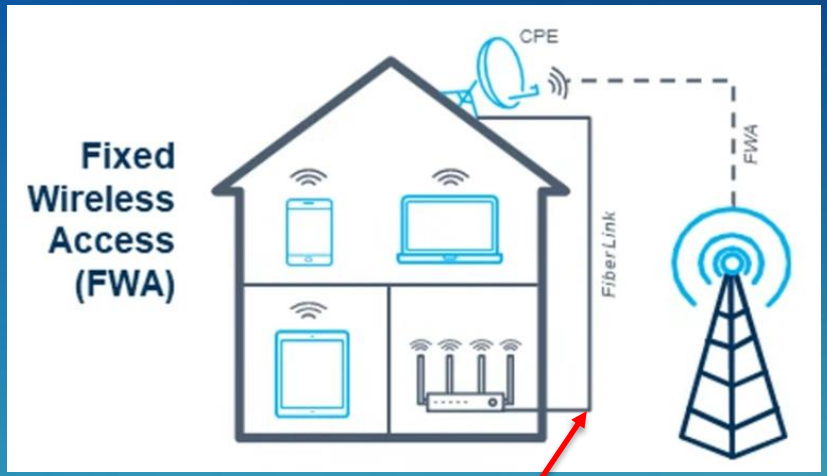


FWA – 5G and 6G Use Cases

- **FWA use cases:**
  - **Efficient, Secure, and Scalable alternative to wired connections**
  - **Rural/Suburban residential indoor CPEs, Urban/mmWave outdoor CPEs**
    - Rural/Suburban more benign channel loss vs. Urban deployments
  - **Locations with geo constraints (e.g., no/poor fixed line service areas)**
    - **FWA with Fiber enables flexible cost-effective operator service tool kit**
    - Temporary setups – e.g., use FWA while waiting for Fiber deployment
    - Fiber not always cheapest alternative (if available) vs. FWA for last mile.
  - **Fixed internet connection for integrating new business sites (esp. outdoor CPE)**
  - **Take adv. of underused mmWave spectrum, esp. in Sub/Rural areas.**
    -- Higher BS antennas = more LOS opportunities which enables mmWave. --
  - **Secure Backup (failover) for fiber optic - copper business, Gov. entity connections**
  - FWA competition **enables cheaper unbundled Broadband Internet -or- promotes sticky Cell phone/Mobile service (less churn)**
    - **One Fiber/Cable broadband operator in a geographical area without competition will inevitably gouge customers. Large customer dissatisfaction is a factor in some FWA sales.**

TMO investing ~$1B in Fiber

AT&T investing $5B in FWA



Split CPE architecture option
- RF-Ant outdoor/Modem (&WiFi) indoor
- power over fiber (PoF) connection

Indoor unsplit CPE architecture
(typical for suburban/rural)

FWA Performance

NOTE: FWA exploits mmWave spectrum especially Suburban/Rural deployments given typical BS antenna heights of 35m above average terrain levels creating more LOS opportunities via 'optimally' located outdoor arrays

Freq	Mean DL	Mean UL	Edge DL	Edge UL
2.0 GHz (5G)	66 Mbps	>30 Mbps	24 Mbps	>4 Mbps
3.5 GHz (5G)	60 Mbps	30 Mbps	20 Mbps	4 Mbps
7.0 GHz (6G)	250 Mbps	100 Mbps	50 Mbps	2 Mbps
13.0 GHz (6G)	175 Mbps	85 Mbps	15 Mbps	0.5 Mbps
28 GHz-SU (5G)	335 Mbps	110 Mbps	50 Mbps	50 Mbps
28 GHz-MU (5G/6G)	550 Mbps	275 Mbps	75 Mbps	115 Mbps

Further UL improvement
~ 2.5x UL Cell Edge increase
- Optimized UL PC
- Opt. BS Advanced Rcvr

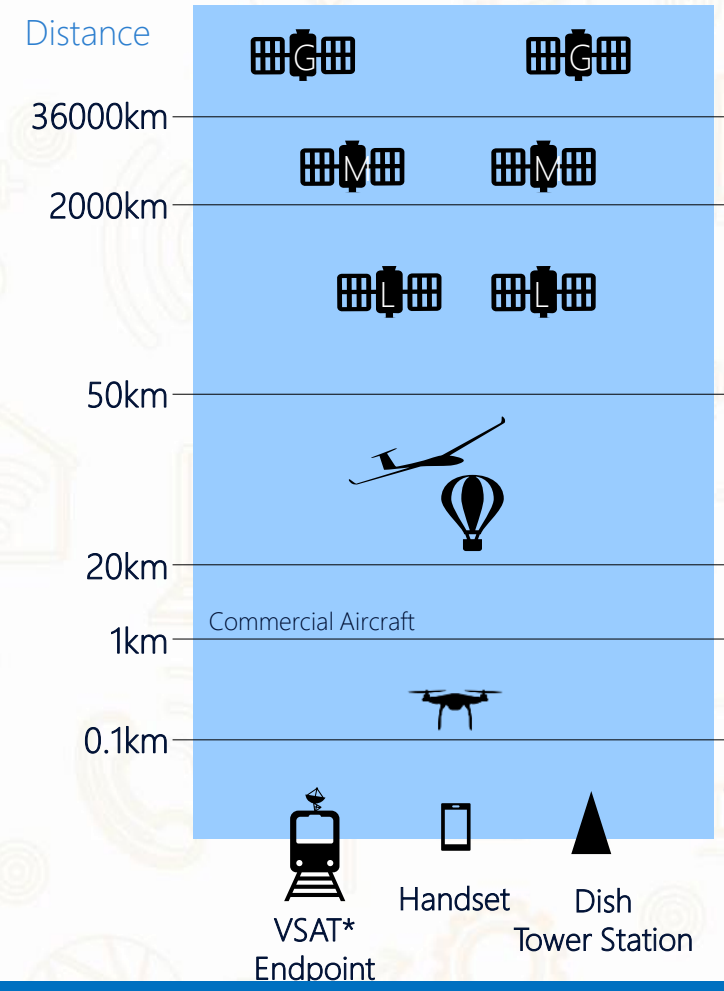
100% Outdoor CPEs
T-put reflects NLOS & Shadowing via TR 38.901 model

- 2.0GHz: 100MHz, 500m ISD (BS: 192AE → 32TRX * CPE: 4RX/4TX
- 3.5GHz: 100MHz, 500m ISD (BS: 256AE → 64TRX * CPE: 4RX/4TX
- 7 GHz: 200MHz, 500m ISD (BS:1024AE → 256TRX * CPE:16RX/16TX
- 13 GHz: 200MHz, 500m ISD (BS:1024AE → 256TRX * CPE:16RX/8TX
- 28GHz: 800MHz, 100m ISD (BS: 512AE → 8TRX CPE: 32AE, 2-panels)

* Wideband ZF-GoB Type I CSI

- TDD split in all cases: DL: 0.6, UL: 0.2
- 38.901 with 50/50 high loss / low loss penetration model
- 3.5/7/13 GHz: 80% indoor, 20% outdoor
- 28GHz: 100% outdoor
- 10 CPEs per cell in all cases; Full Buffer Traffic

LEO and HAPS are primarily driving the disruption in non-terrestrial networks leading to aggressive deployment plans



GEO	Geostationary Satellites Fixed point over earth
MEO	Medium Earth Orbit
LEO	Low Earth Orbit Satellites 90-120min period over point on earth
HAPS	High Altitude Platform Stations Roughly at same point in sky 200km diameter coverage
GPL	Ground to Plane
LAPS	Low Altitude Platform Stations Unmanned Aerial Vehicles for package delivery, inspections
Ground	

** VSAT = very small aperture terminal*

HAPS for rural, disasters, remote IIoT, extra urban capacity; LEO for underserved global internet/IoT coverage; UAV's for package deliveries, inspections etc.

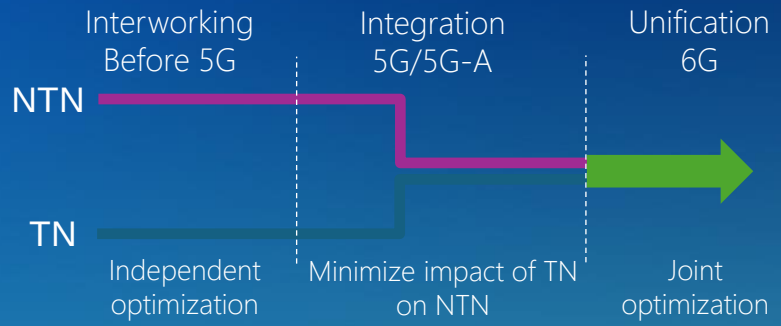
The New Space Economy

The new Space Economy (LEO)

- Launch cost reduced
- Satellite cost reduced
- Launch intervals reduced
- Number of satellites per launch increased
- End-to-end latency reduced
- Throughput increased
- NTN can reuse TN spectrum with beaming

Convergence between Terrestrial and Non-Terrestrial Networks

- Ubiquity, continuity and resiliency
- 3GPP Standard protocol



Rise of coherent space-optics

For both

- Satellite-to-satellite

- Ground-to-satellite

Non-Terrestrial Networks gives rise to a plethora of new use cases

Ubiquitous connectivity

Remote ~fixed connectivity
(VSAT*)

~200 B$/year by 2030
Satellite-broadband service revenue
vs. Terrestrial BB: 750 B$/year
Source: Analysis Mason 2022

Mobile expansion
(100% coverage)

Upscaling IoT connectivity
(e.g., asset tracking, agriculture)

Network backup
(disaster recovery)

Defense applications
(e.g., **secure comms**)

Space-compatible cloud
and Wide-Area Networks

Security applications
(e.g., satellite-based Quantum Key Distribution)

* VSAT = Very Small Aperture Terminal (mounted devices with directional antenna's)

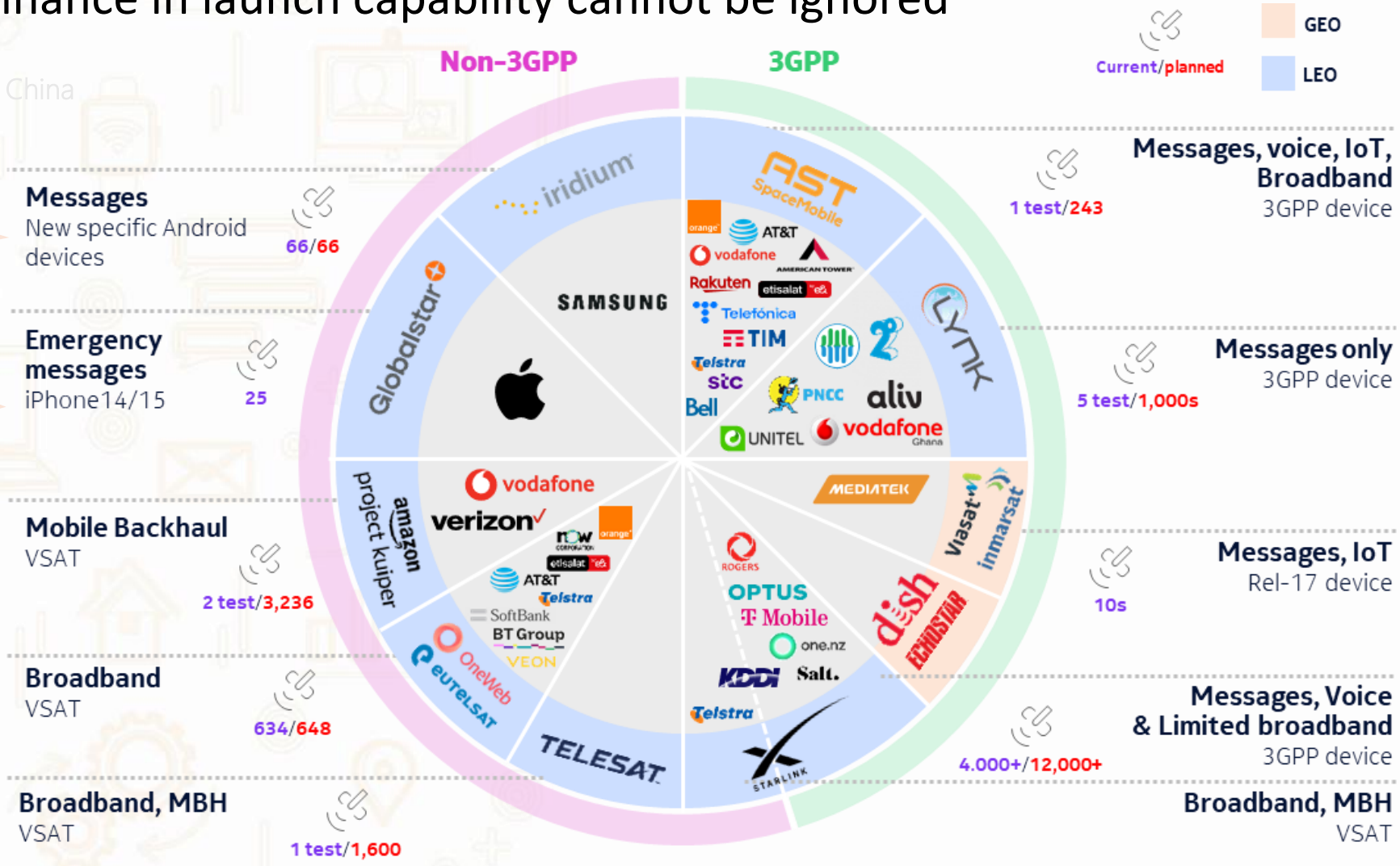
NTN partnership and investment momentum is high

SpaceX dominance in launch capability cannot be ignored

Note: overview excl. China

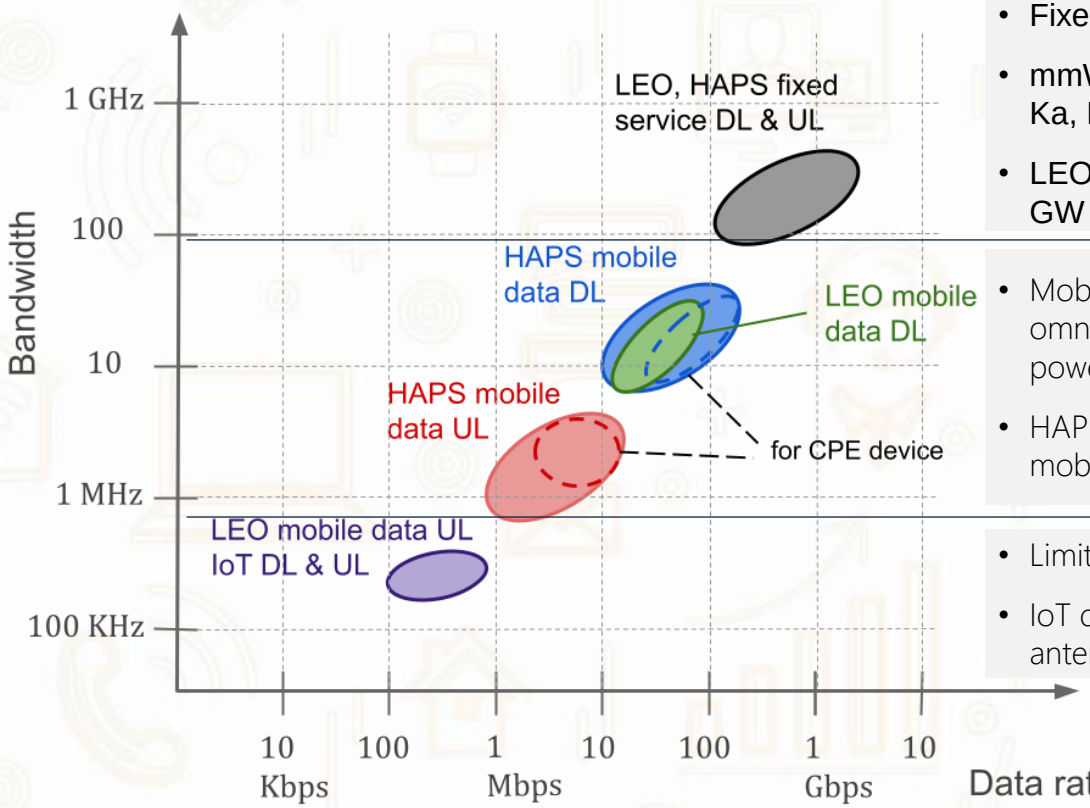
9 Nov 2023
Qualcomm ends D2D deal with Iridium

15 Nov 2023
iPhone14 users get another year of free satellite SOS access



NTN standalone service is ideal for low population density fixed services and providing coverage for low data rate use cases

NTN Service Potential



Key characteristics

- Fixed Wireless Service with 43dBi Antenna gain
- mmWave spectrum, e.g. 39, 47 GHz for HAPS; Ka, Ku for LEO
- LEO/HAPS feeder link with a larger antenna at GW

- Mobile service is provided to handheld devices (e.g., omni-directional antenna and 23 dBm transmit power).
- HAPS mobile service uses 2.1 GHz band while LEO mobile service uses S band and L band

- Limited by NR UE power and antenna gain
- IoT devices: 23 dBm transmit power, omni-directional antenna (0 dBi)

Addressable use cases

Rural Consumer and Enterprise Broadband Service

Mobile backhaul for terrestrial networks

Emergency connectivity (temporary networks)

Mobile coverage and resiliency use cases

Global IoT network

NTN achievable data rates dependent on deployment model, terminal power, bandwidth, antenna gains, and capacity constraints influencing use case addressability

Automotive NTN use cases

NTN e-call

- What if emergency calls (eCall) stop working when you are out of network coverage ?
- Narrowband data rates

Software Updates

- Fleet monitoring, diagnostics, maps and SW updates.
- Wideband Data Rates

1

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Car Sharing

- Remote unlocking of shared cars is only working if network coverage is available
- Narrowband data rates

2

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Entertainment

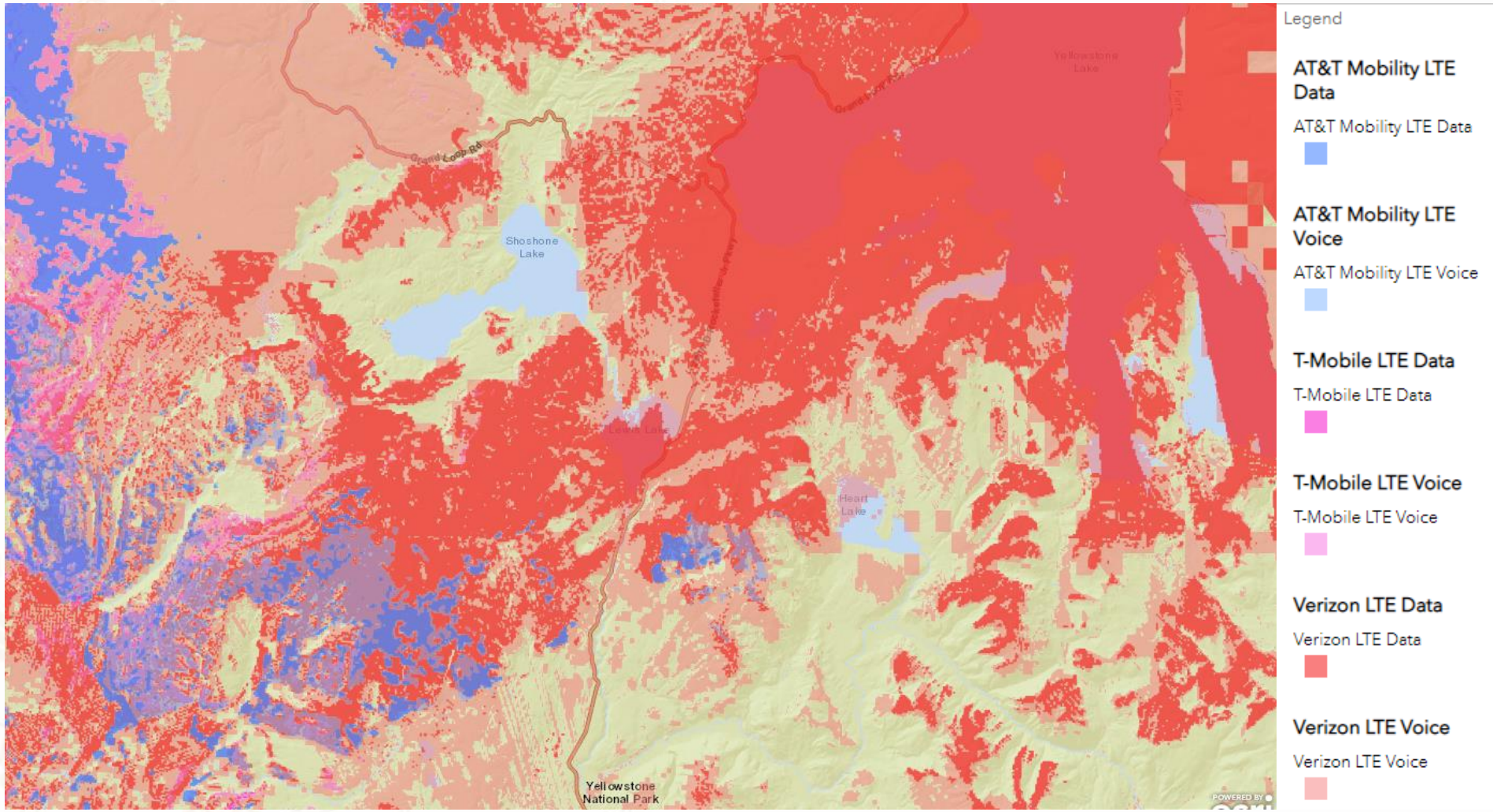
- On Demand video, Gaming
- Broadband Data Rates

Safety Related Traffic Information (SRTI)

- Road hazard warning (e.g. black ice) is only working if network coverage is available to receive sensor data from vehicles and warn/informa other vehicles.
- Narrowband Data Rates

Challenge: Ubiquitous 4G/5G Connectivity

An example: 4G Coverage as of May 15, 2021, US area of Yellowstone National Park



Source: US FCC: https://fcc.maps.arcgis.com/apps/webappviewer/index.html?id=6c1b2e73d9d749cdb7bc88a0d1bdd25b

NTN Comparison

	Pre rel 17	HAPS	LEO	GEO
Height	500-1400 km	20-50 km	600-1500 km	36000 km
Architectures	Transparent and regenerative	Regenerative and transparent	NR Rel 17 and 18: transparent	NR Rel 17 and 18: transparent
UE requirements	no extra requirements	no extra requirements	3GPP NTN require at least release 17 implementation	3GPP NTN require at least release 17 implementation
Spectrum	Can reuse terrestrial spectrum in agreement with operator.	Can reuse terrestrial spectrum in agreement with operator.	S, L band in release 17. Ka band in release 18.	S, L band in release 17. Ka band in release 18.
Typical Throughputs (median, normalized to 30 MHz)	Handheld: • Messaging only VSAT 100-200 Mbps (400 MHz).	Handheld: • 42 Mbps DL • 18 Mbps UL VSAT 100-200 Mbps (400 MHz).	Handheld: • 20 Mbps DL • 200-500 kbps UL VSAT 100-200 Mbps (400 MHz).	Handheld only low throughput IoT devices. VSAT 100-200 Mbps (400 MHz).

Disclaimer: Information on the table is not considering satellite antenna and custom SW enhancements for pre Rel-17
Pre Rel-17 numbers: https://transhumanica.com/asts

Summary

Global Coverage

- NTN will augment terrestrial network (TN) and broadband networks in areas of low traffic densities; provide global IoT coverage and used for public safety and other applications.
- Cost, power and energy efficiency, improving coverage for both UL and DL

Market Trends

- Many partner space-device-ground collaborations are being created
- Due to market saturation, consolidation is expected
- NTN investment momentum is high

Fixed Wireless Access

- Economical, Secure, and Scalable alternative to wired connections
- Good DL data rates, UL rates sufficient
- Locations with geo constraints (e.g., no/poor fixed line service). Includes Fiber economic drop off with population density

Ground Stations, Feeder Link, ISL

- Essential components of End-to-End NTN network

3GPP is Key

- NTN, TN Architecture compliant with 3GPP
- FWA compliant with 3GPP (incl enhancements)

UE/CPE Requirements

- Commercial or Specialized UE, CPE, and IoT devices
- Improve UL LB for LEO/HAPS and FWA

- NTNs will remain largely complementary to terrestrial based networks for broadband services and is also well positioned to address areas of low traffic densities and low data rate IoT use cases
- FWA a popular and growing market segment due to high date rates, flexibility and economics

Thank You

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