5G:
Why Do You Care?

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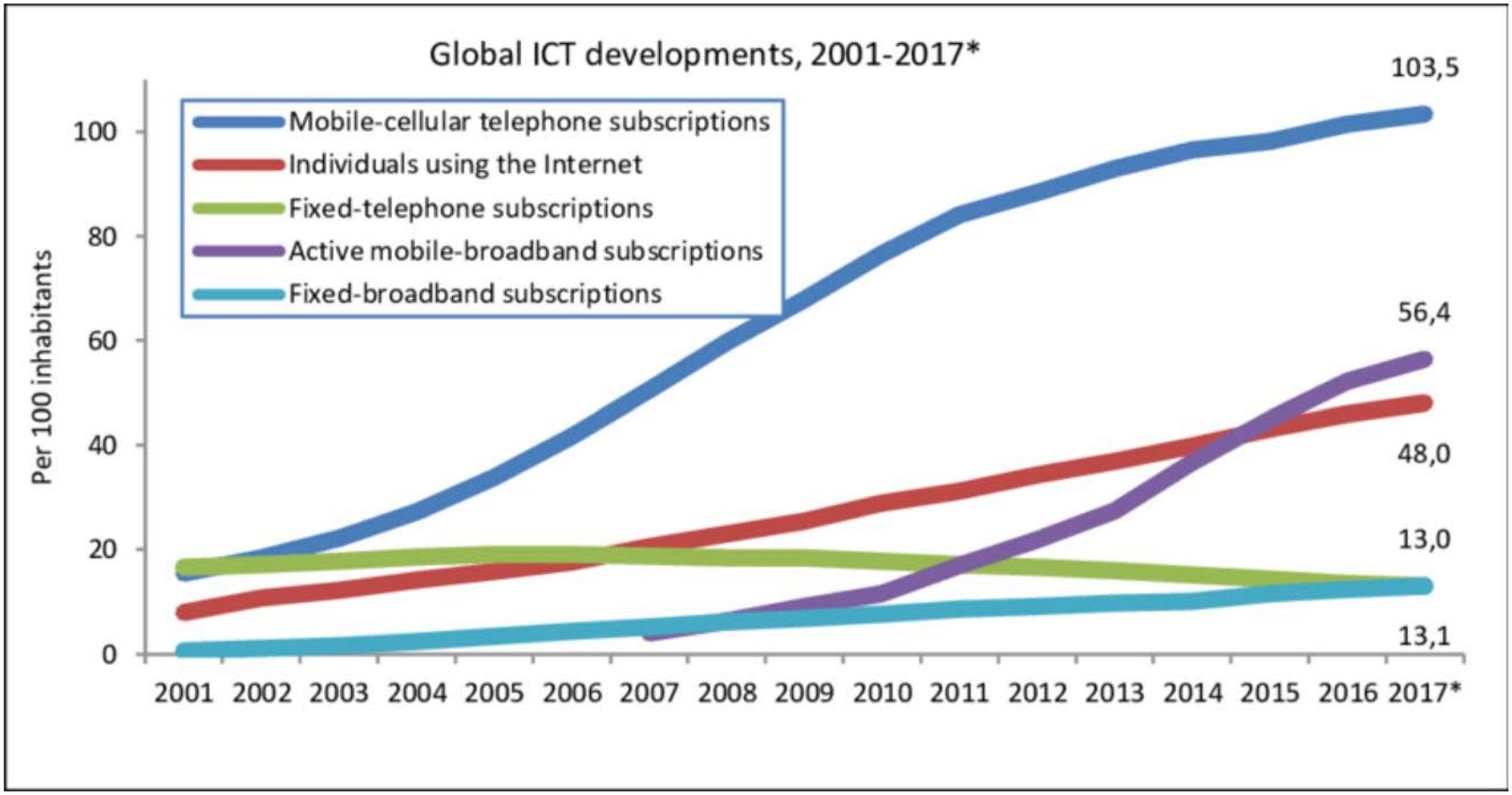
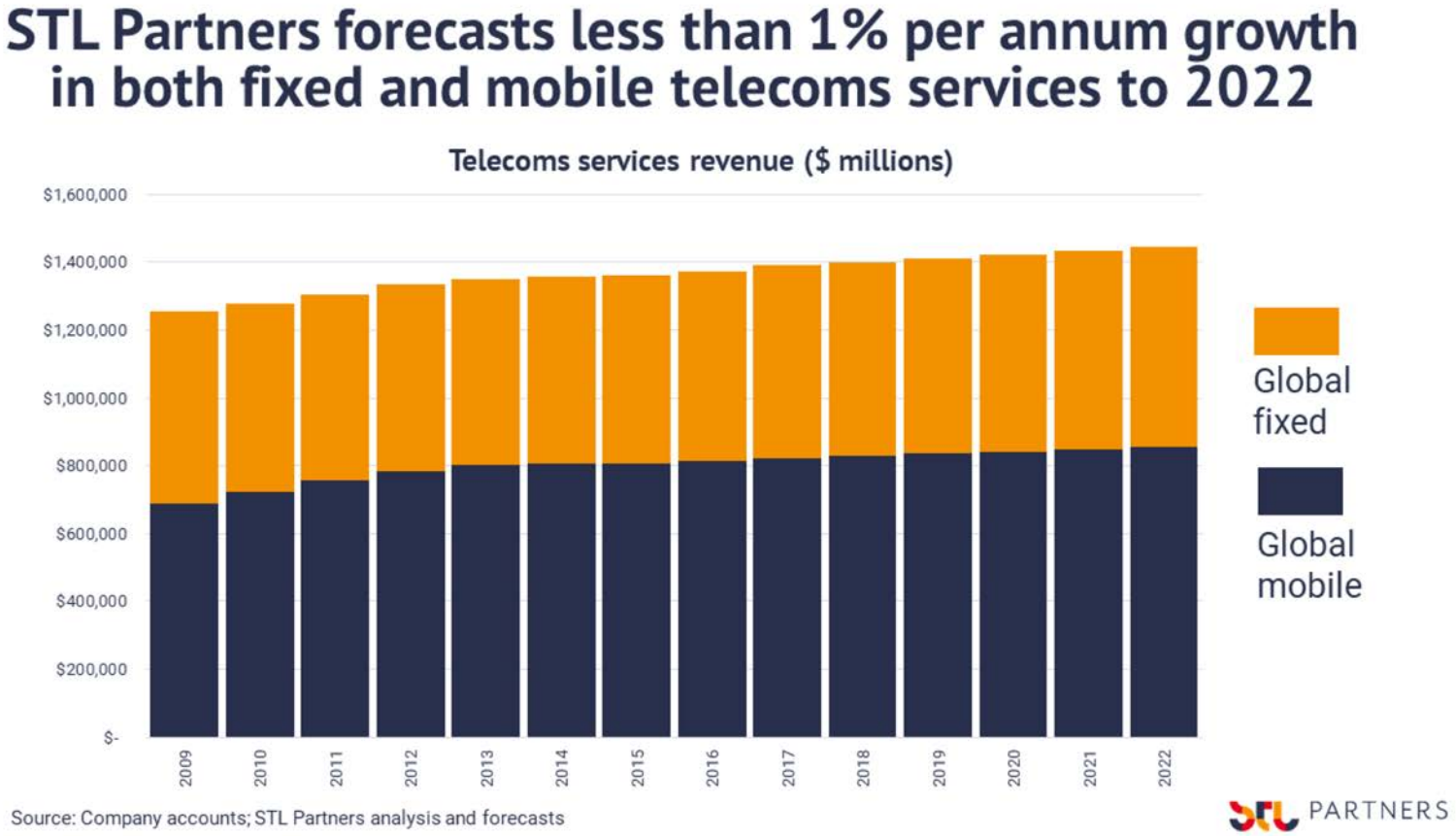
Mobile Drives Global Subscriptions



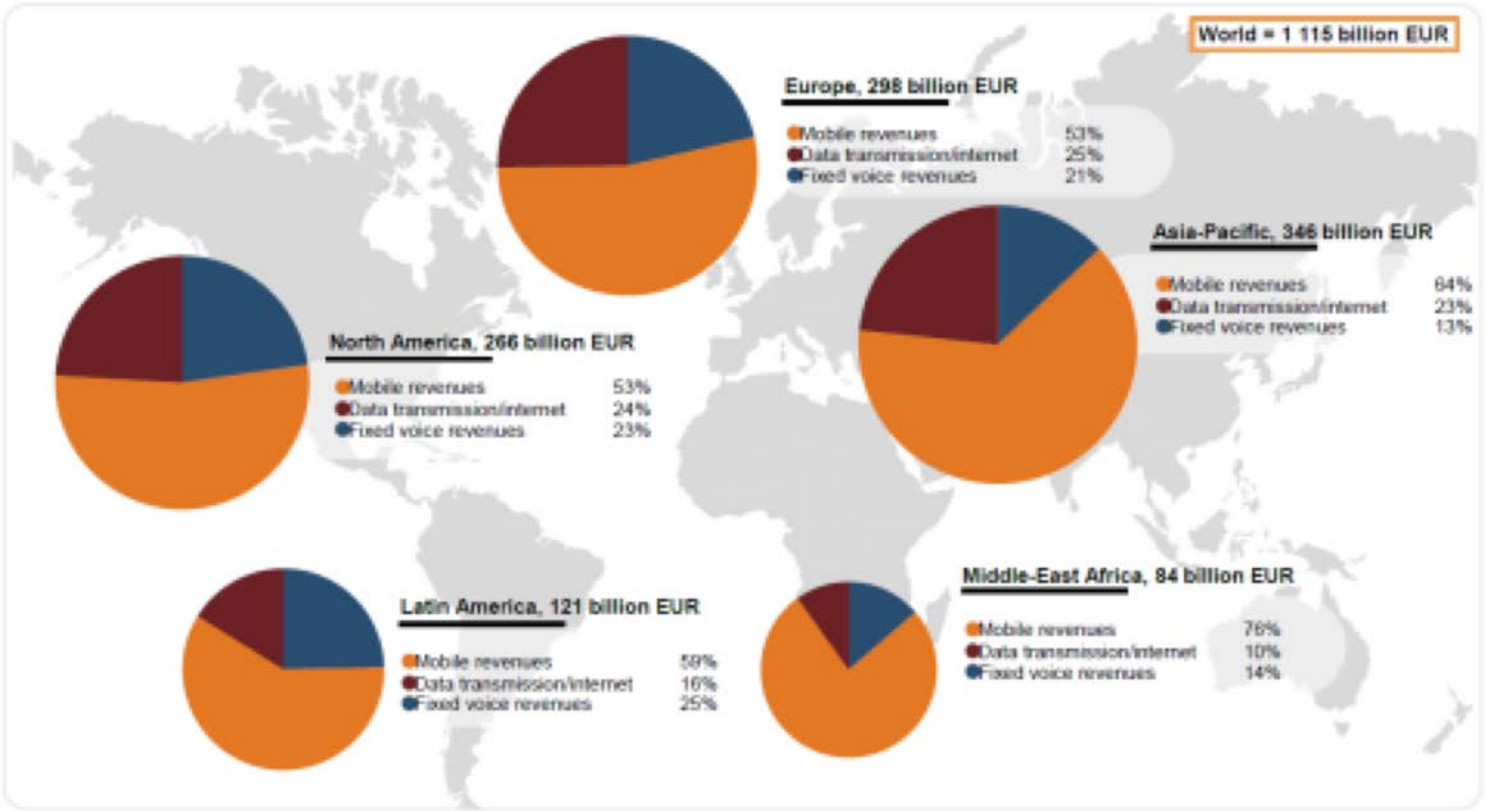
source: ITU

Mobile Drives Revenue Globally

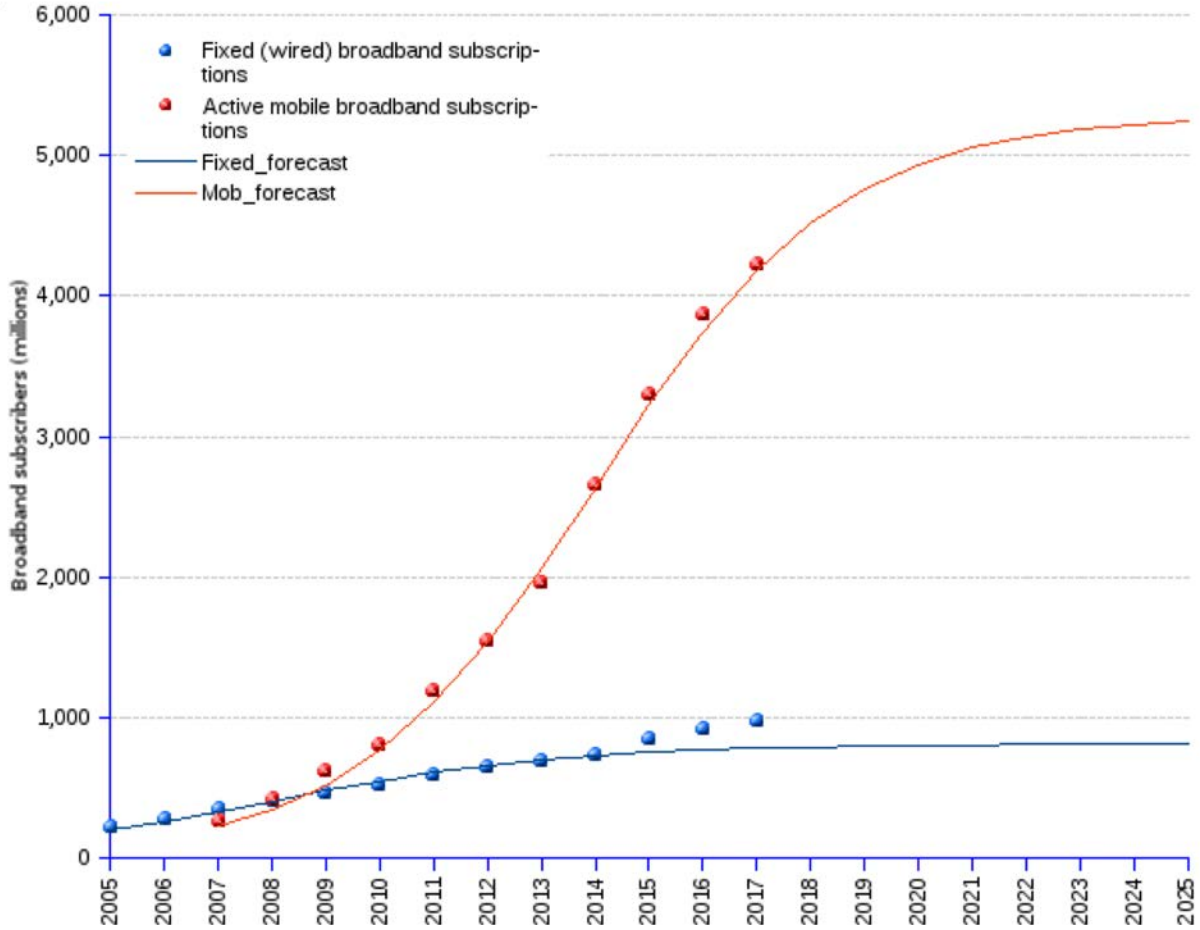


source: STL Partners

Mobile Drives Revenue in Asia, Pacific

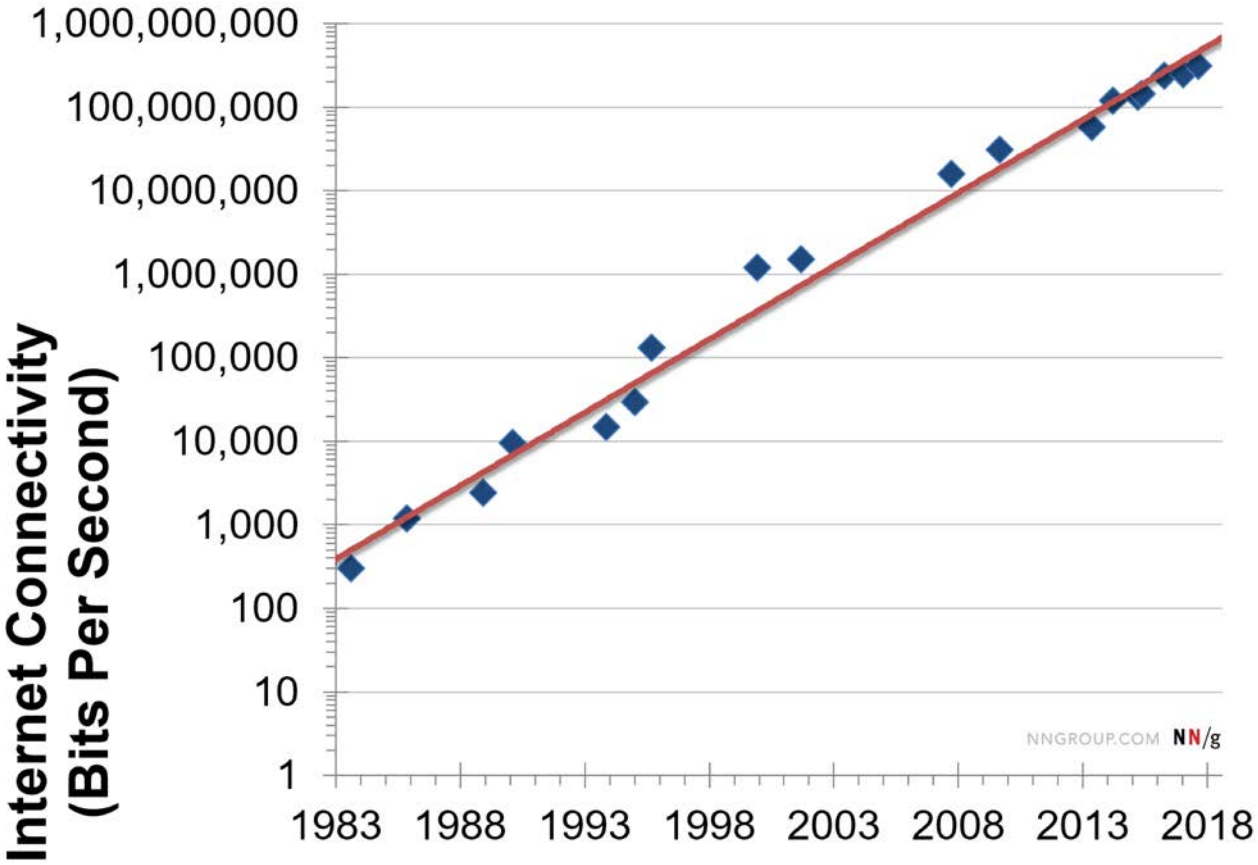


Mobile Data Drives Subscription Growth



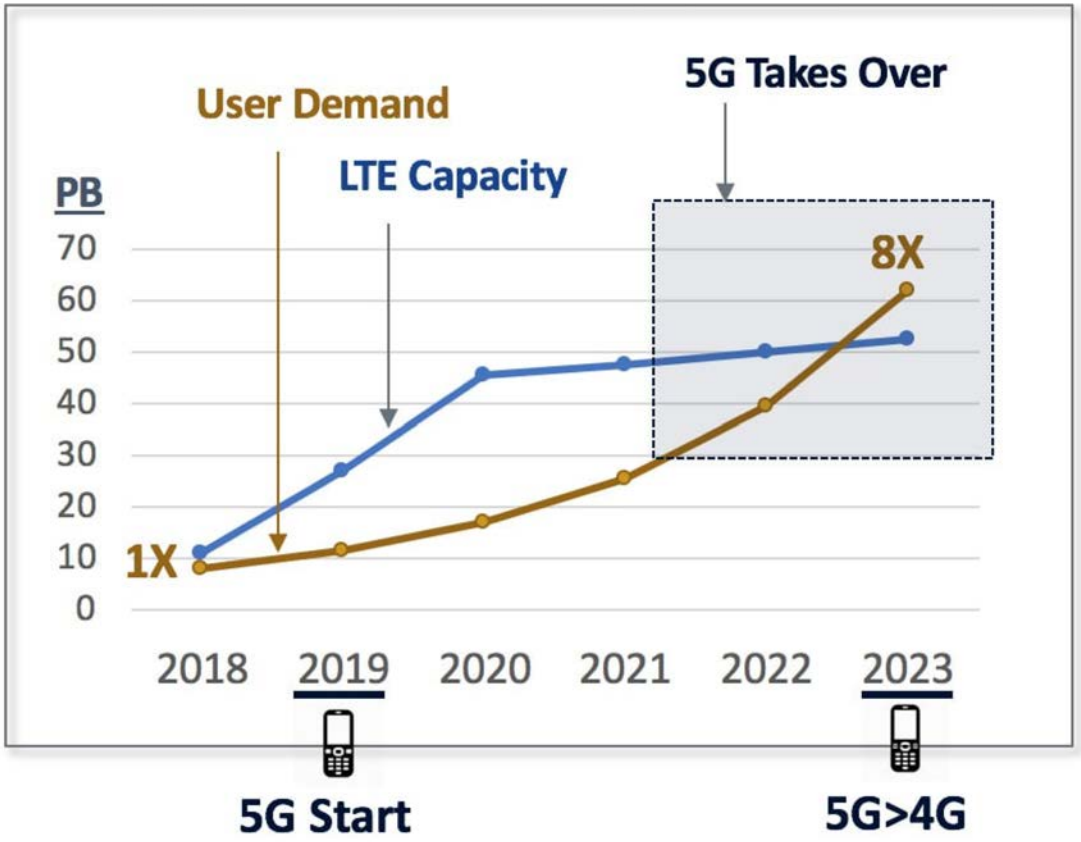
source: ITU

Capacity Demand Grows 50% Per Year



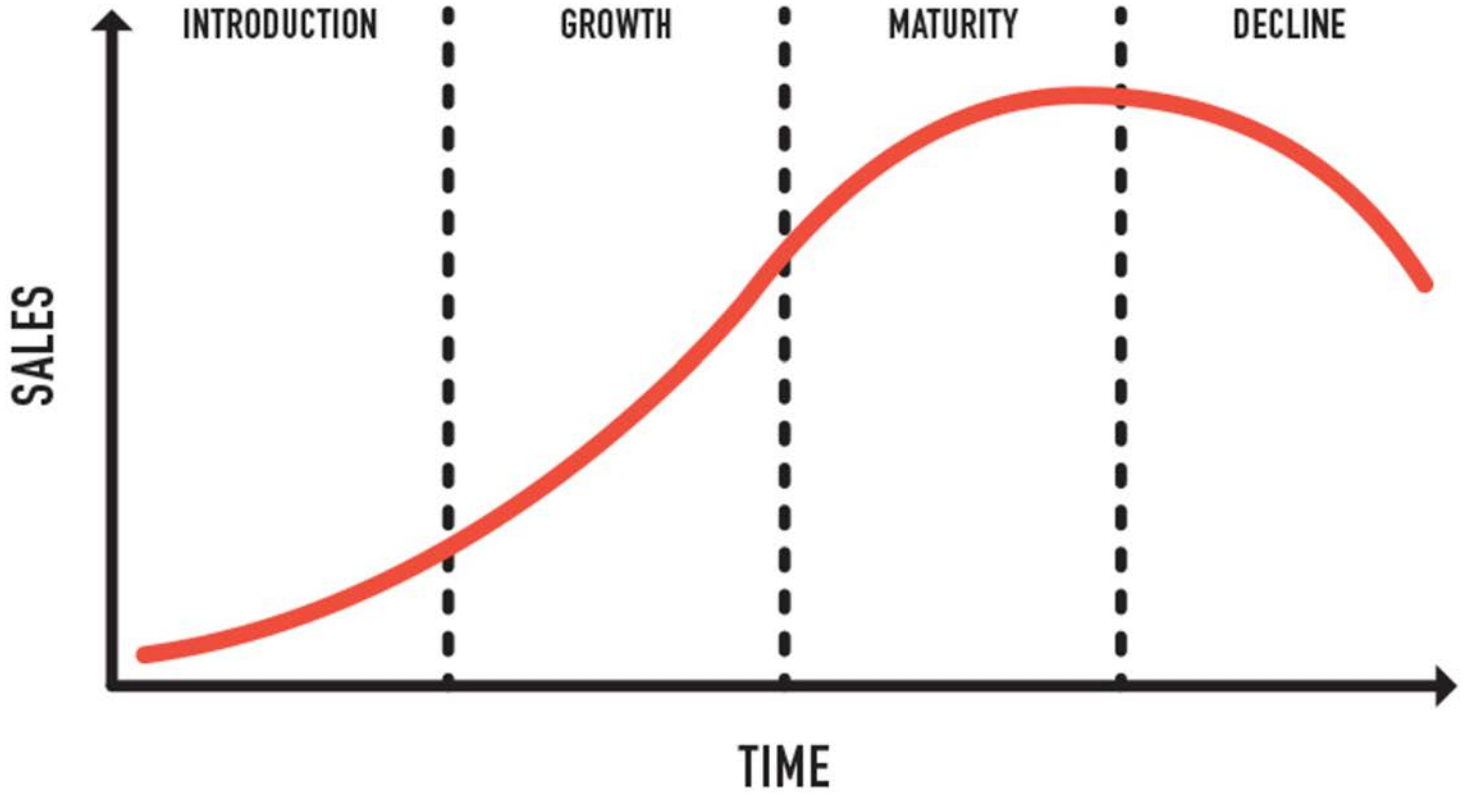
source: Nielsen Norman Group

4G Capacity Growth Cannot Keep Up

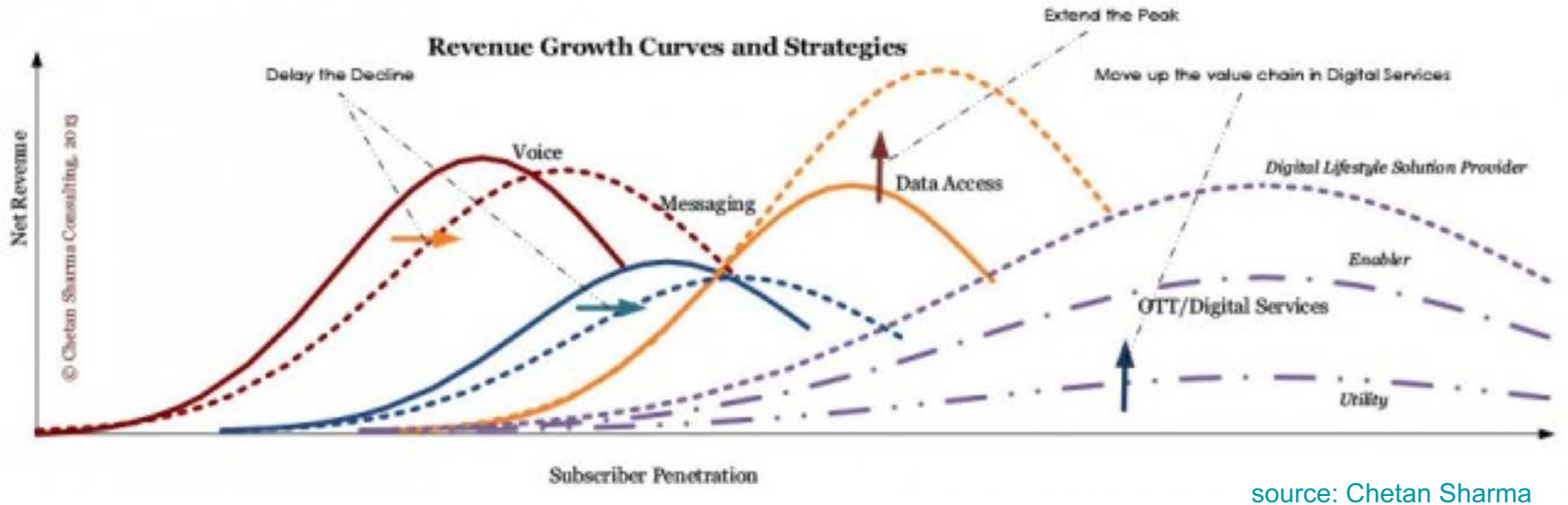


source: Nokia

All Products Have a Life Cycle

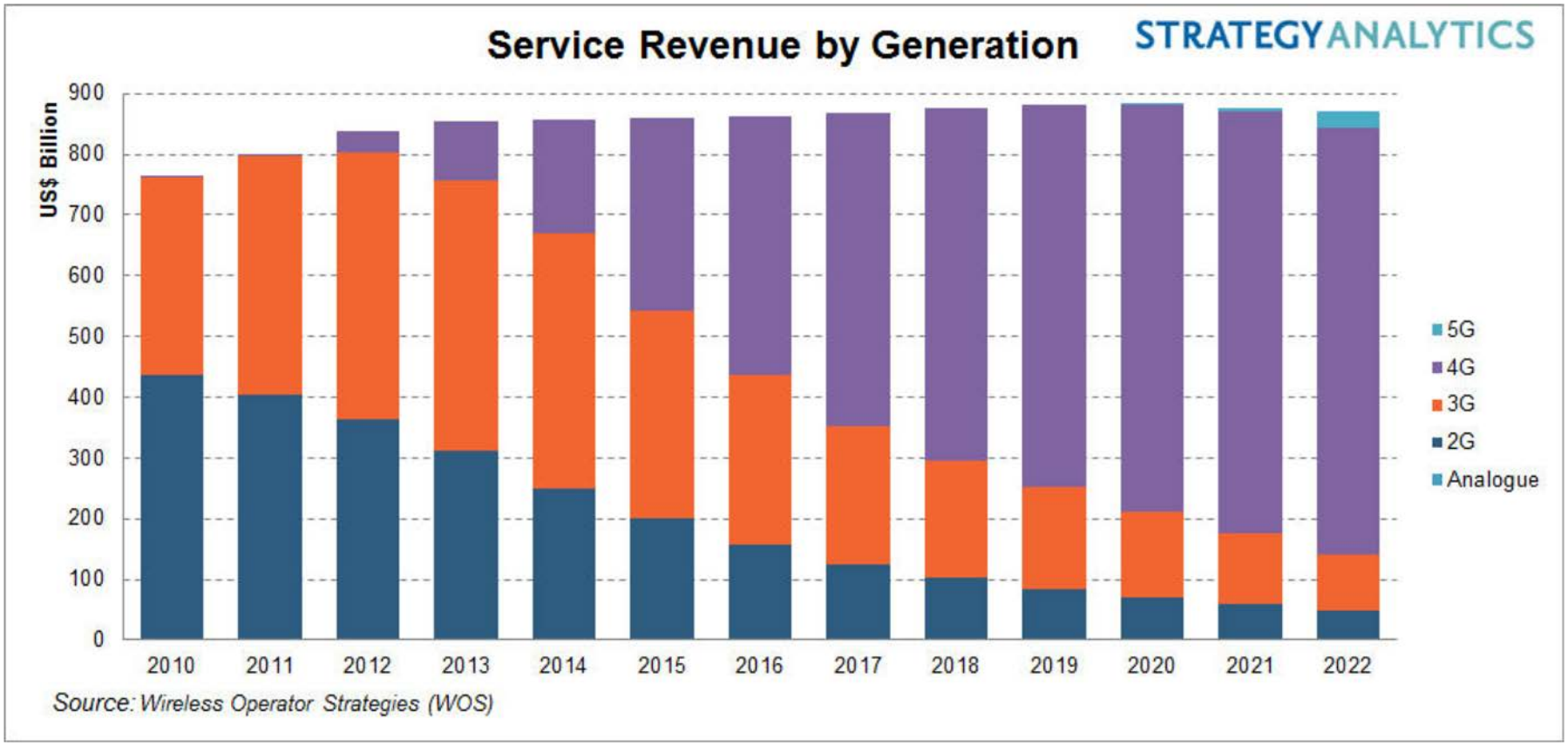


Mobile Products have Life Cycles

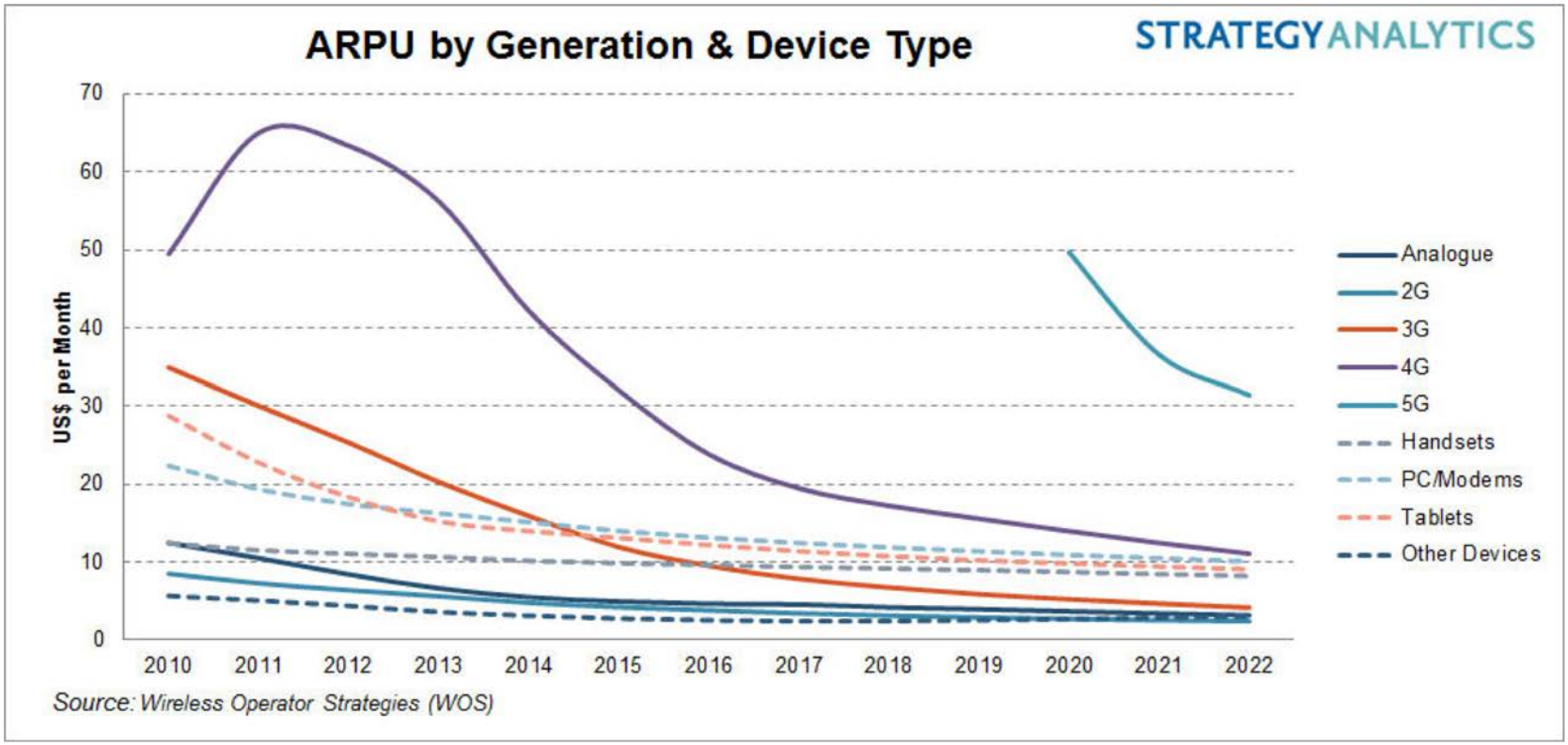


source: Chetan Sharma

Mobile Generations Have Life Cycles



Higher Average Revenue Per User?



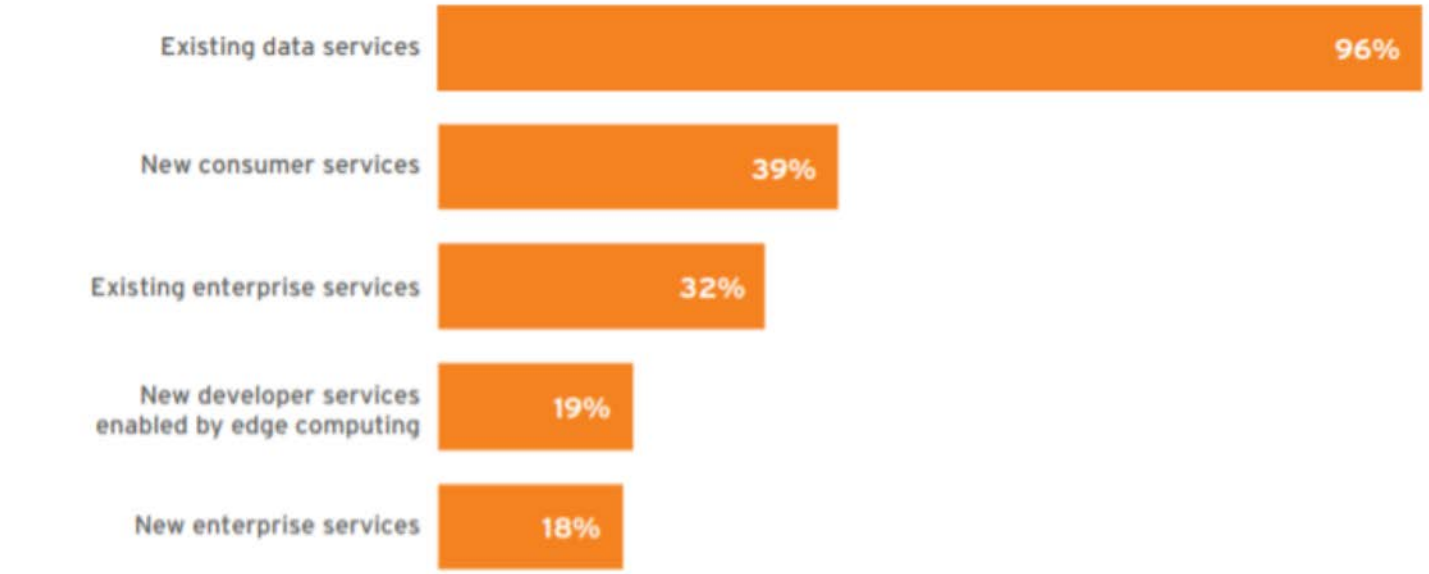
source: Strategy Analytics

Evolution or Revolution?

Evolution: Most of the value is simply adding capacity 4G cannot supply

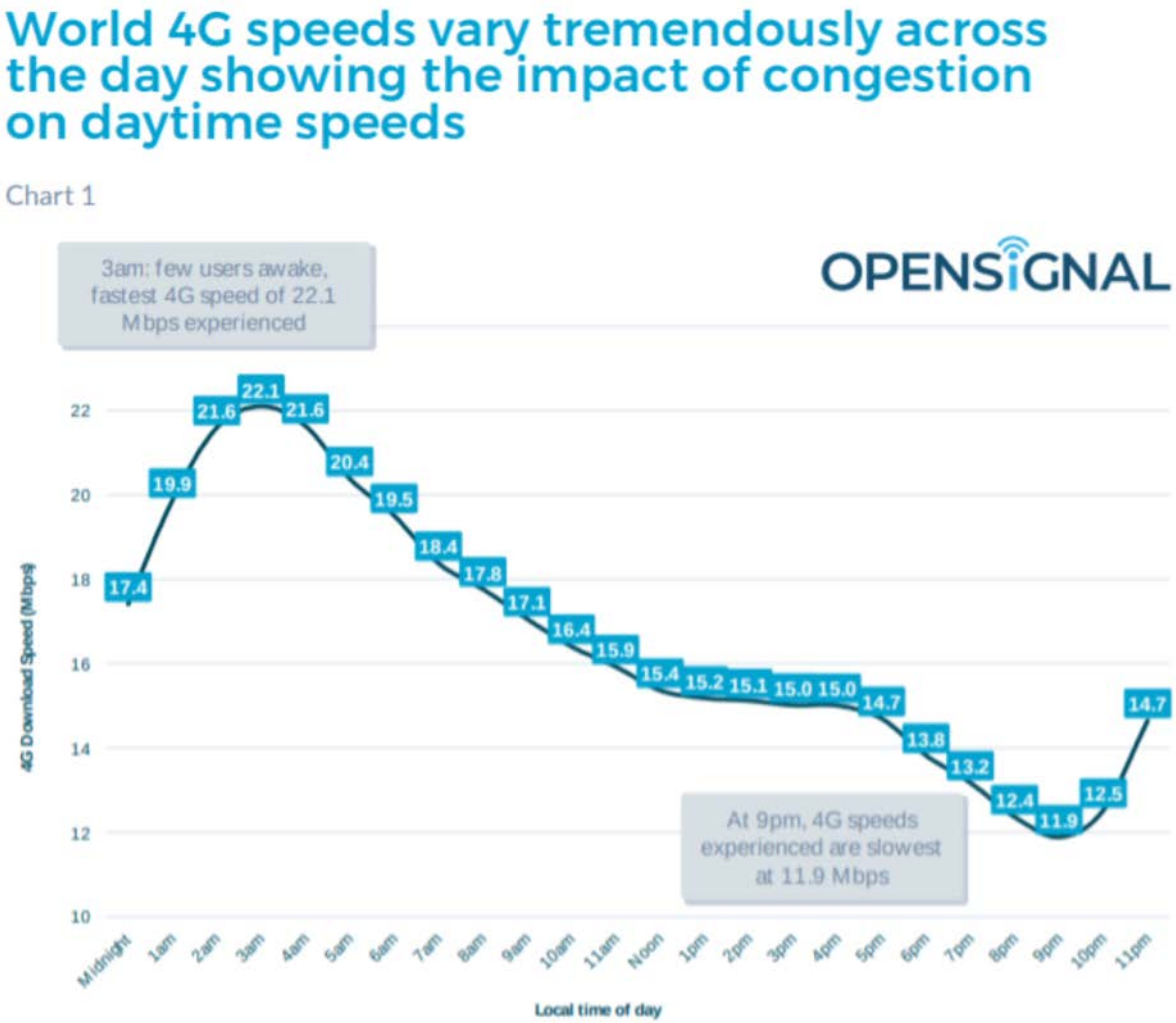
Figure 4: 5G services expected by 2021

Source: 451 Research, custom research commissioned by Vertiv, 2019 (n=105)



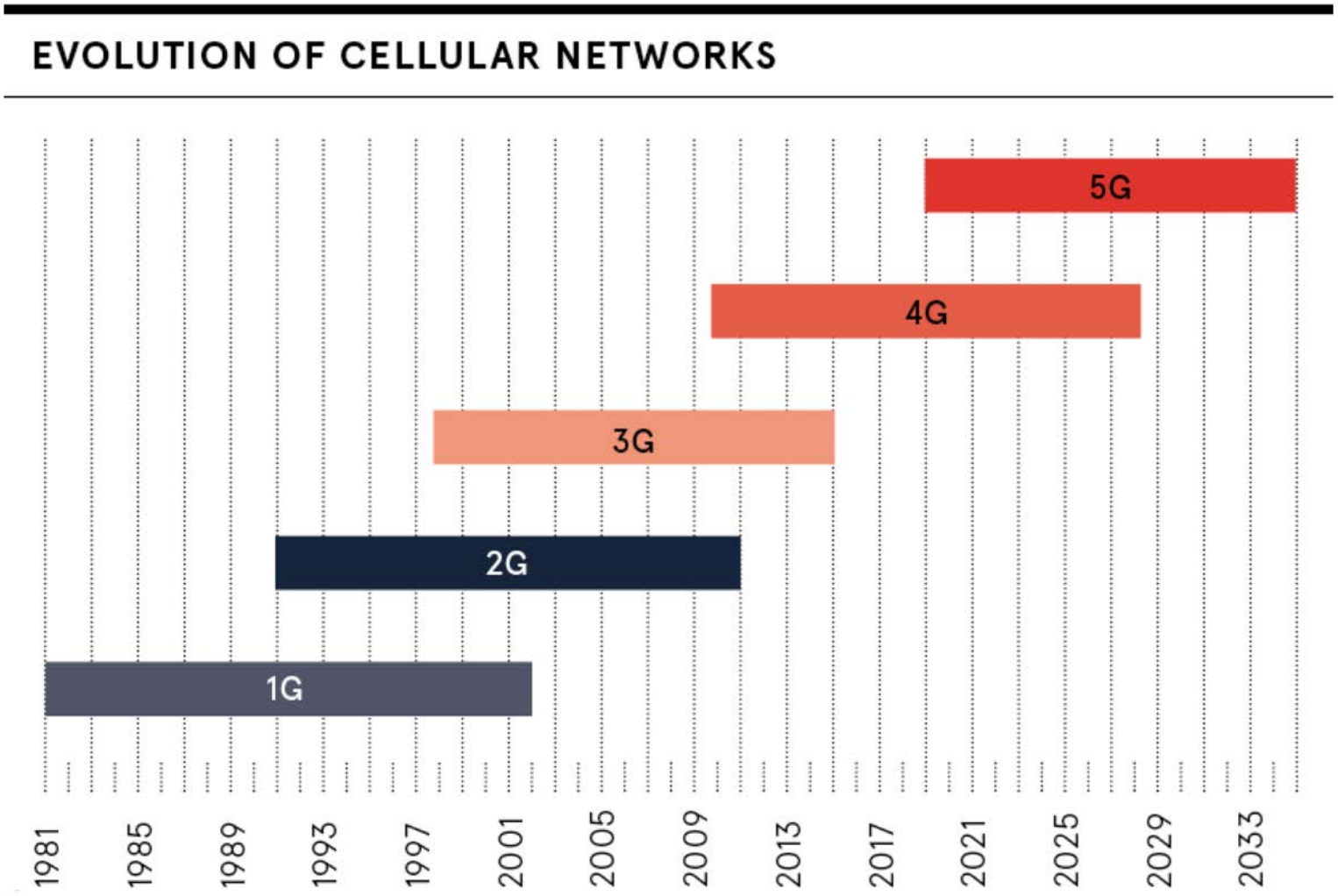
source: 451 Research

4G Congestion

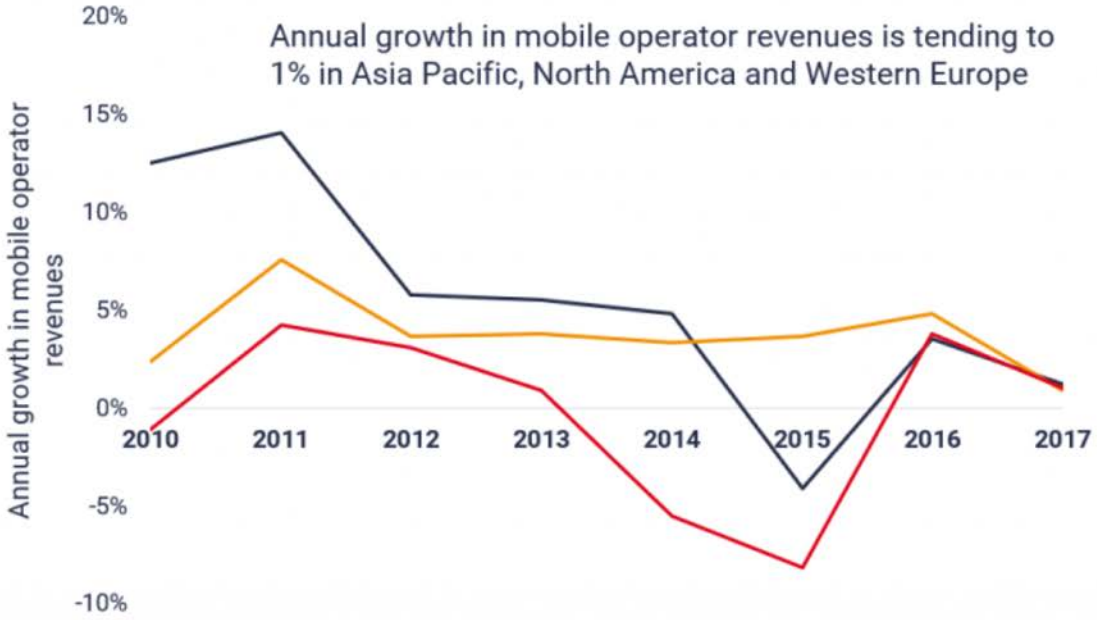


source: Opensignal

5G is Coming, on Schedule



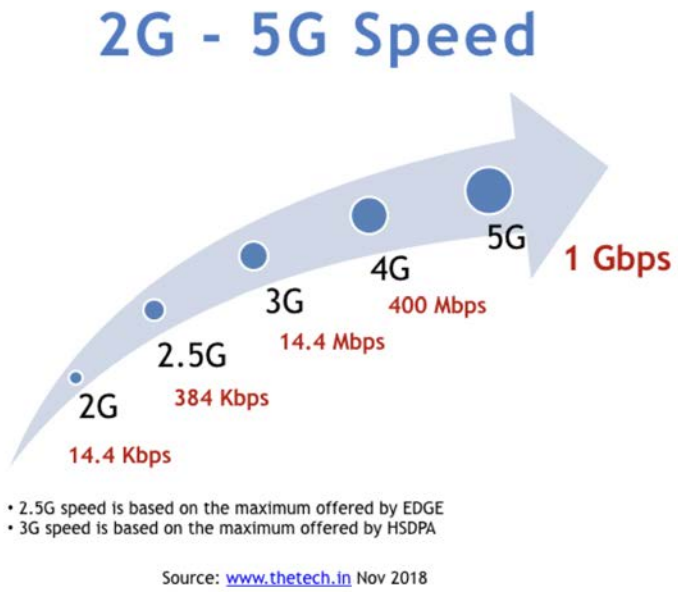
4G Revenue Upside Limited



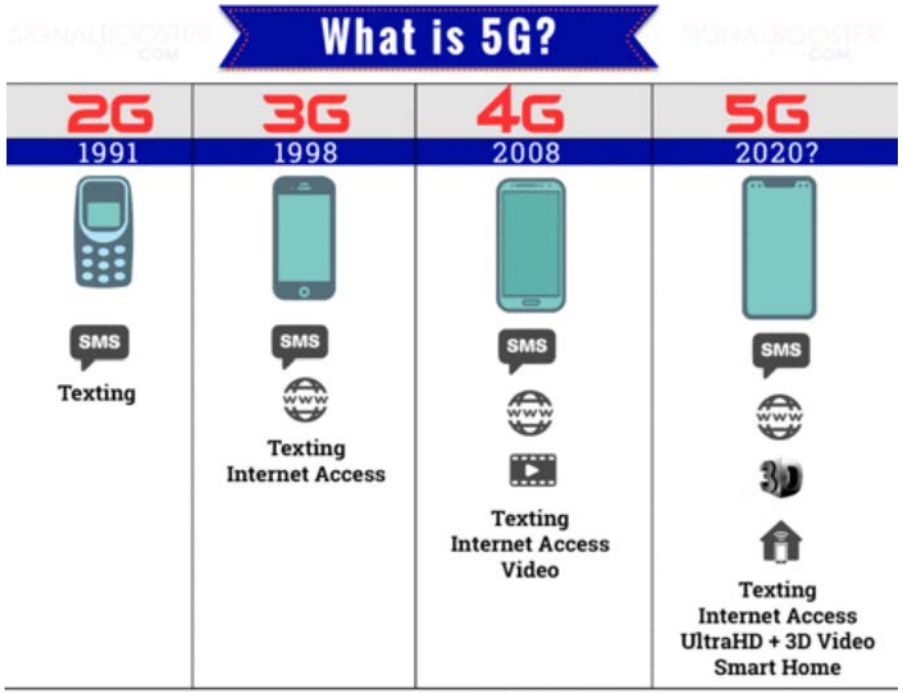
Region	Compound annual rate of change (mobile revenues)	
	8 year (2009-17)	4 year (2013-17)
Asia Pacific	5%	1%
North America	4%	3%
Western Europe	0%	-2%

source: STL Partners

Performance Demands Keep Increasing



source: Tech In



source: Signal Booster

5G Builds on 4G

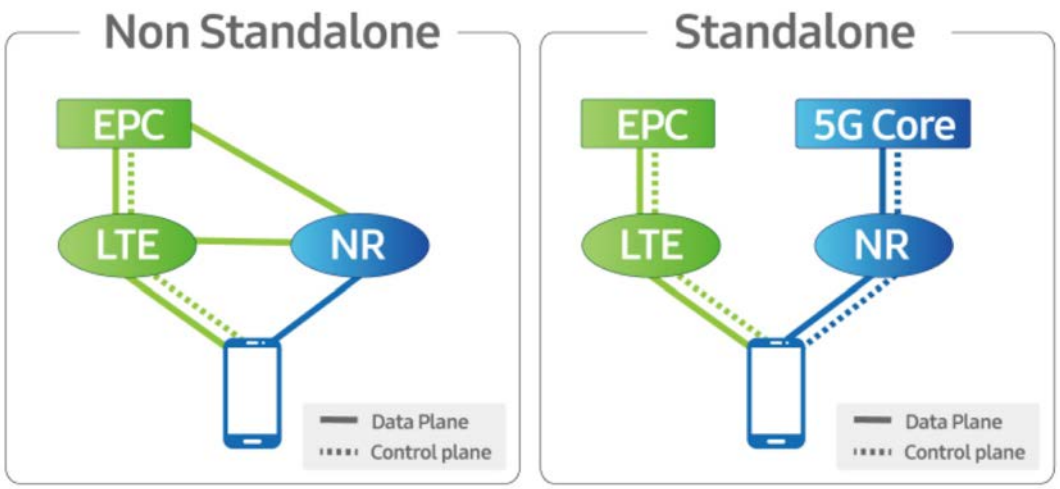
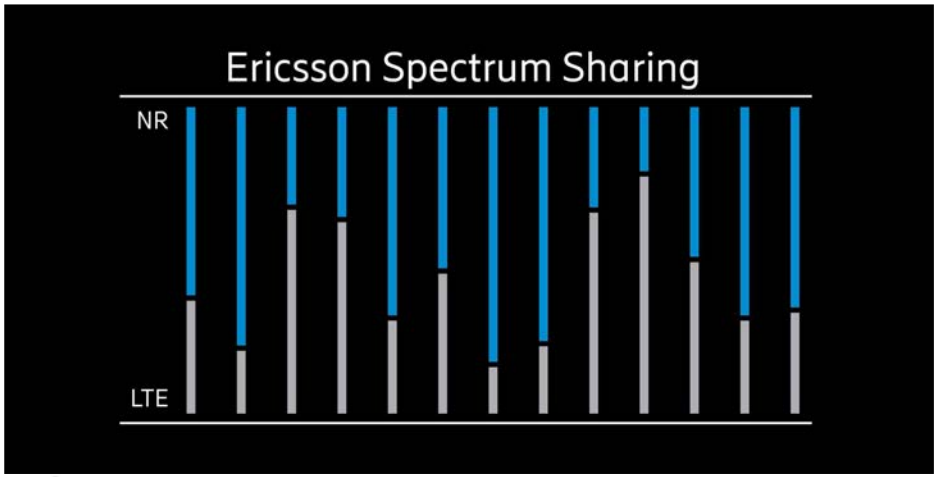


Figure 11 : How NSA and SA work

source: Test and Verification



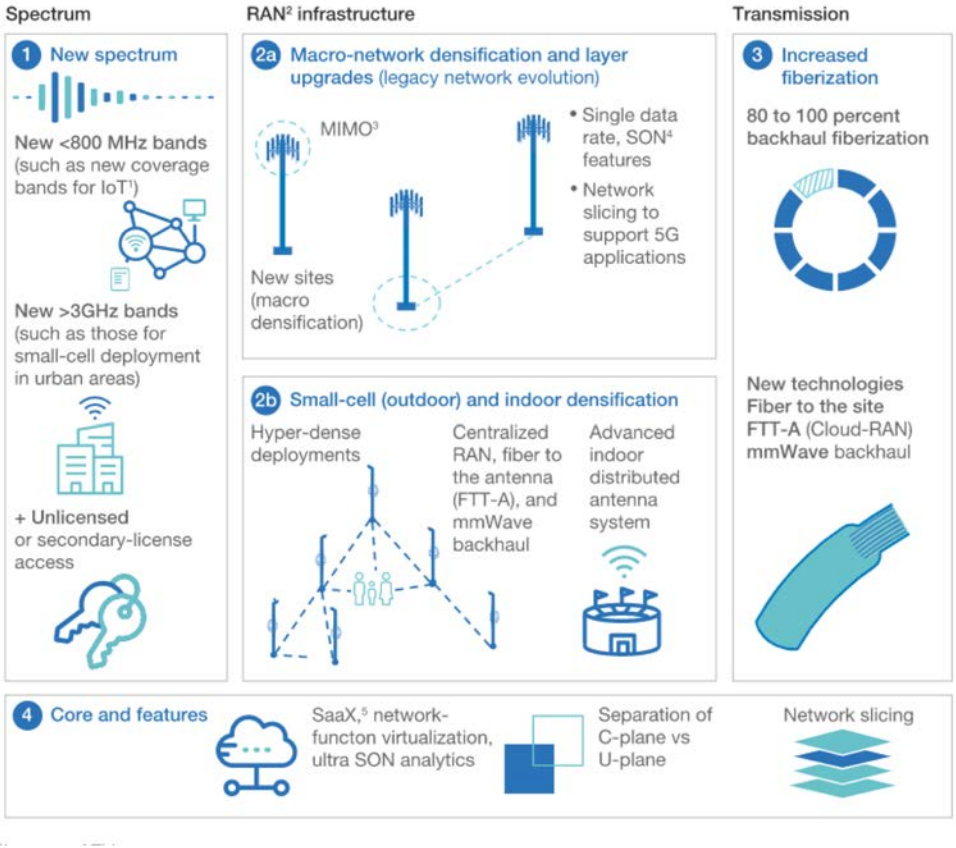
source: Ericsson

So 5G is Evolutionary

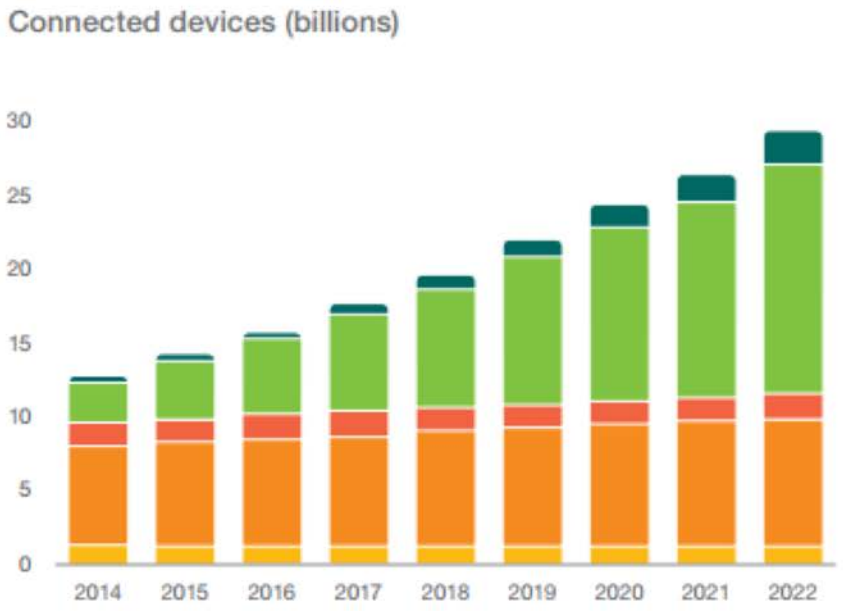
- Lower cost per bit
- Capacity 4G cannot supply
- Builds on 4G
  - dynamic spectrum sharing
  - 5G air interface with 4G evolved packet core
  - macrocell sites reused
  - 4G small cell sites reused
- Builds on Wi-Fi offload
- Millimeter wave for capacity reinforcement in urban areas
- Uses 4G packet core before transition to 5G core (virtualized)

5G Also is Revolutionary

- Computers talking to computers
- Enterprise drives revenue growth
- Millimeter wave
- Fixed network substitution
- Network slicing
- Internet of Things
- Edge computing for latency, transport cost use cases
- Virtual and customized networks



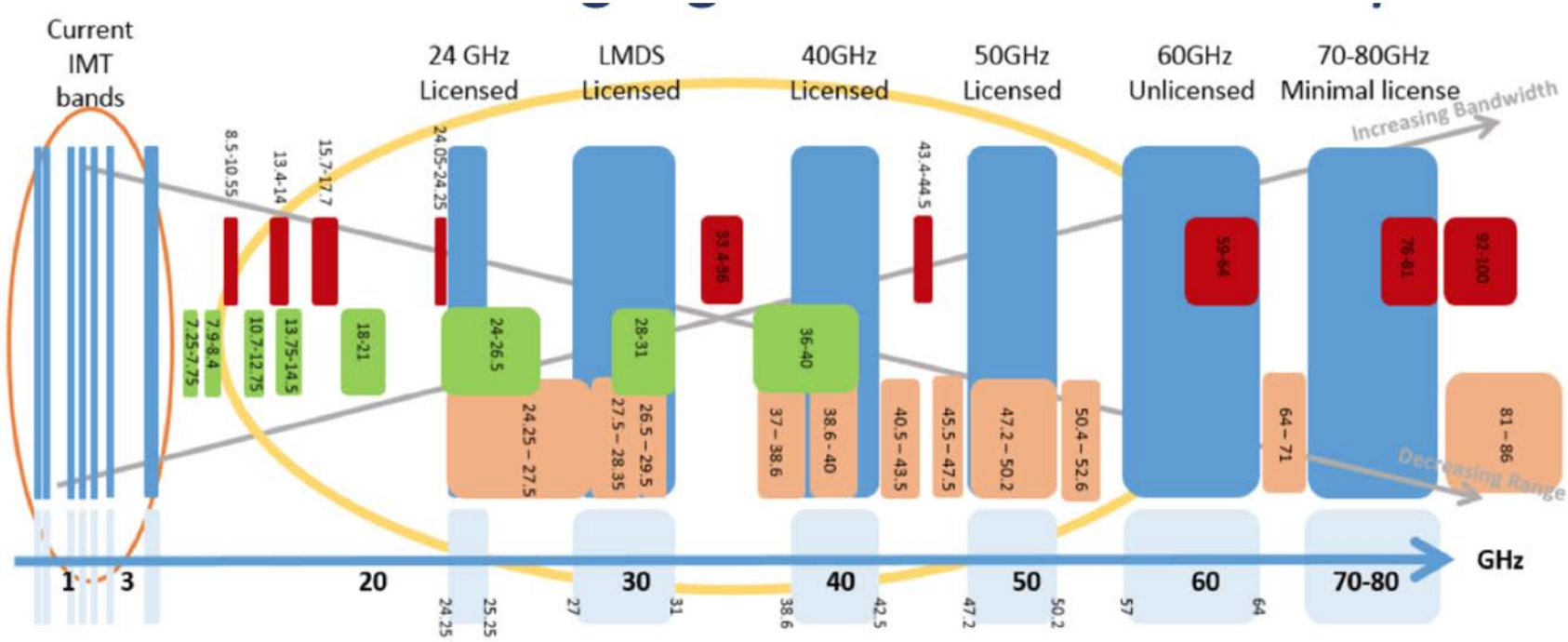
Growth from “Non-Human” Users...



	2016	2022	CAGR
Wide-area IoT	0.4	2.1	30%
Short-range IoT	5.2	15.5	20%
PC/laptop/tablet	1.6	1.7	0%
Mobile phones	7.3	8.6	3%
Fixed phones	1.4	1.3	0%
	16 billion	29 billion	

source: Ericsson

From Scarcity to Abundance



source: Anokiwave orange FCC release, red/green already license to other uses. Blue shows potential mobile spectrum

Capacity Scarcity Has Been the Norm

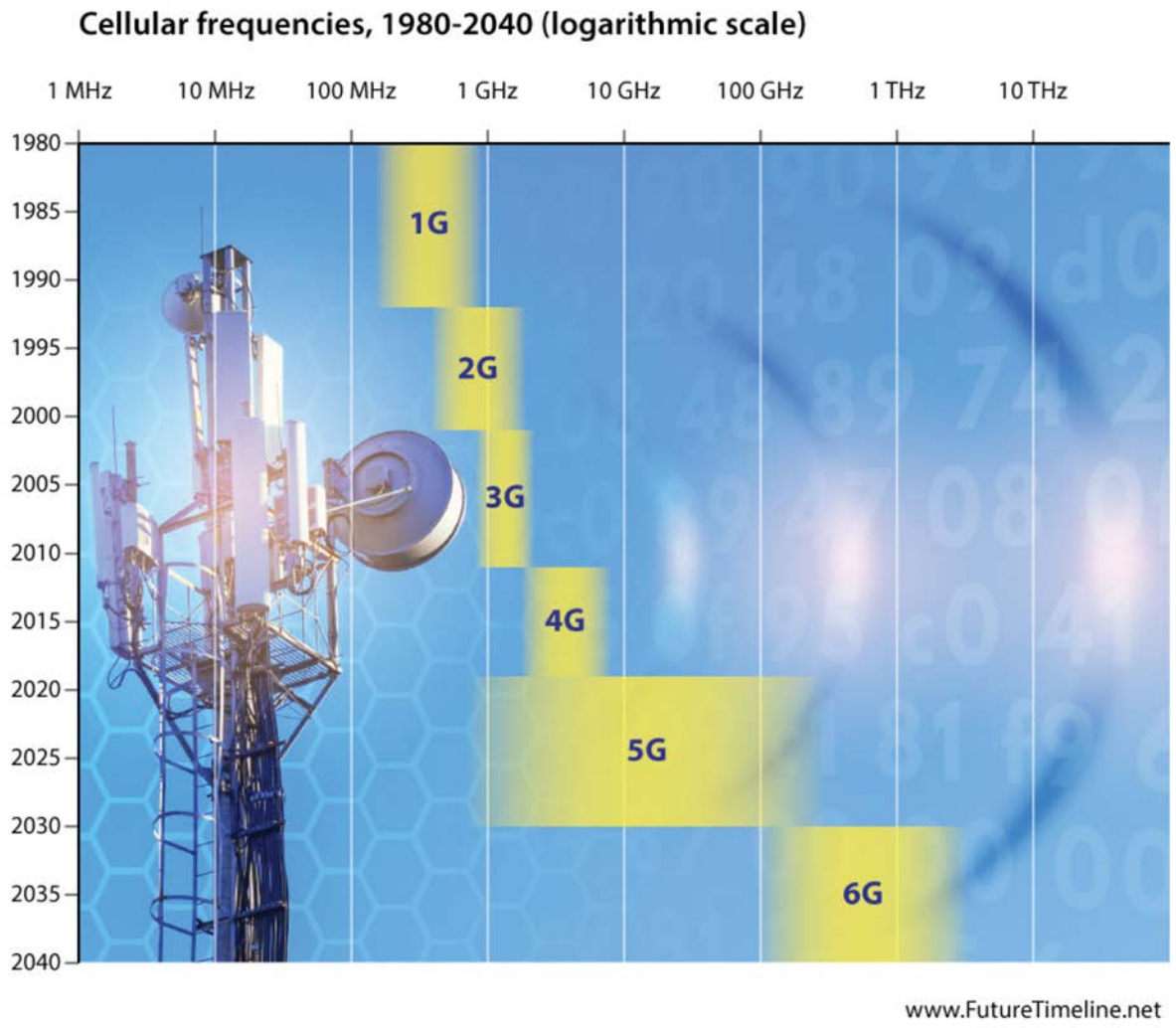
CTIA
The Wireless Association®

	USA	Japan	Germany	U.K.	France	Italy	Canada	Spain	S. Korea	Mexico
Subscribers#	302.9M	117.1M	107.4M	79.9M	63.2M	90.0M	24.6M	56.0M	50.8M	91.0M
Average Consumers' Minutes of Use per Month**	793	141	133	204	231	153	373	150	303	191
Average Revenue per Minute – A Measure of the Effective Price per Voice Minute**	$0.04	$0.23	$0.11	$0.10	$0.13	$0.11	$0.10	$0.16	$0.08	$0.05
Efficient Use of Spectrum -- Subscribers Served per MHz of Spectrum Allocated	739,579	337,351	174,634	213,067	168,461	240,000	90,992	134,940	188,030	350,000
Spectrum Assigned for Commercial Wireless Use	409.5 MHz*	347 MHz	615 MHz	375 MHz	375 MHz	375 MHz	270 MHz	415 MHz	270 MHz	260 MHz
Potentially Usable Spectrum/In the Pipeline***	50 MHz	400 MHz	Recently auctioned 350 MHz	310 MHz	250 MHz	250 MHz	up to 200 MHz	270 MHz	120 MHz	150 MHz

*Figure includes AWS-1, 700 MHz spectrum not yet in use and 55.5 MHz of spectrum at 2.5 GHz. #Regulatory and company websites.

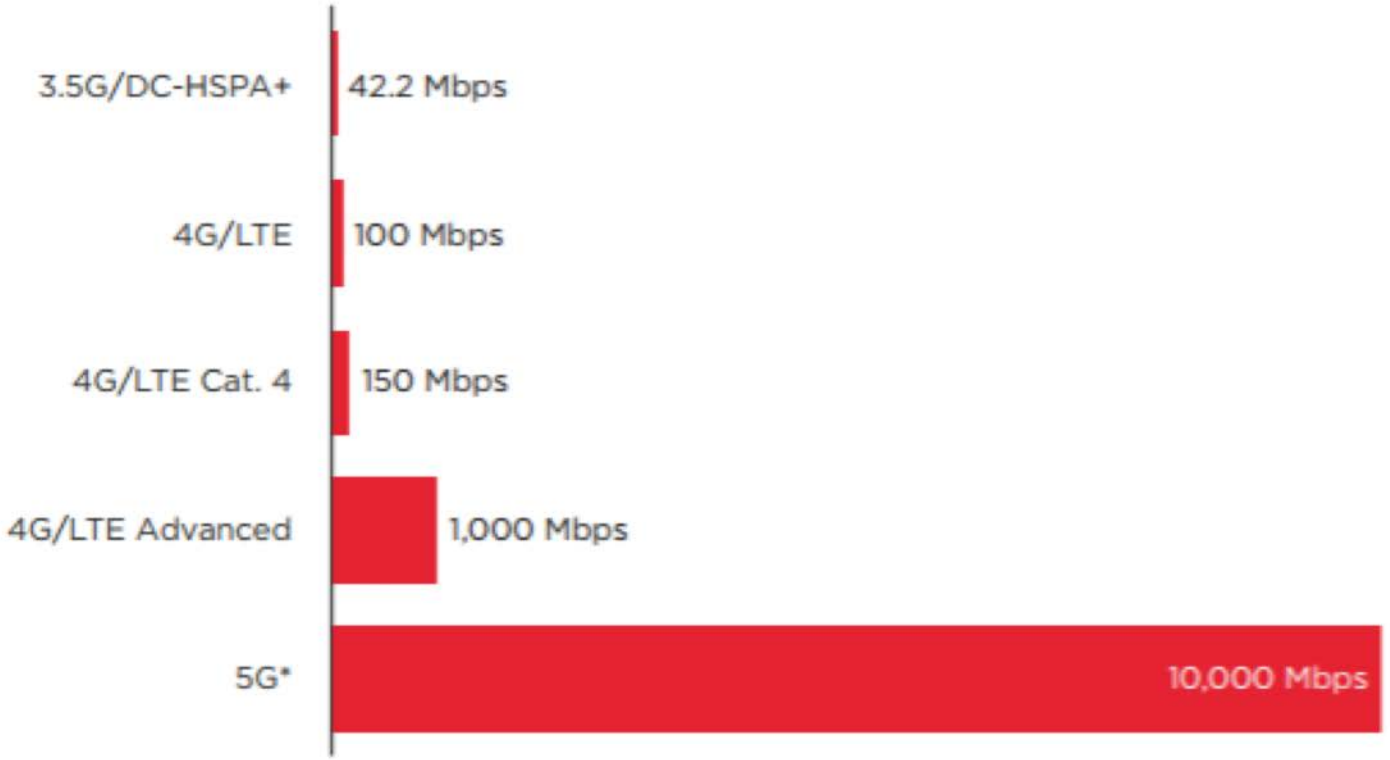
** *Glen* Campbell, et al., "Global Wireless Matrix 1Q11," Bank of America Merrill Lynch, May 1, 2011, at Tables 1-2. ***Regulatory and company websites and press reports.

Millimeter Wave Frequencies are the Future



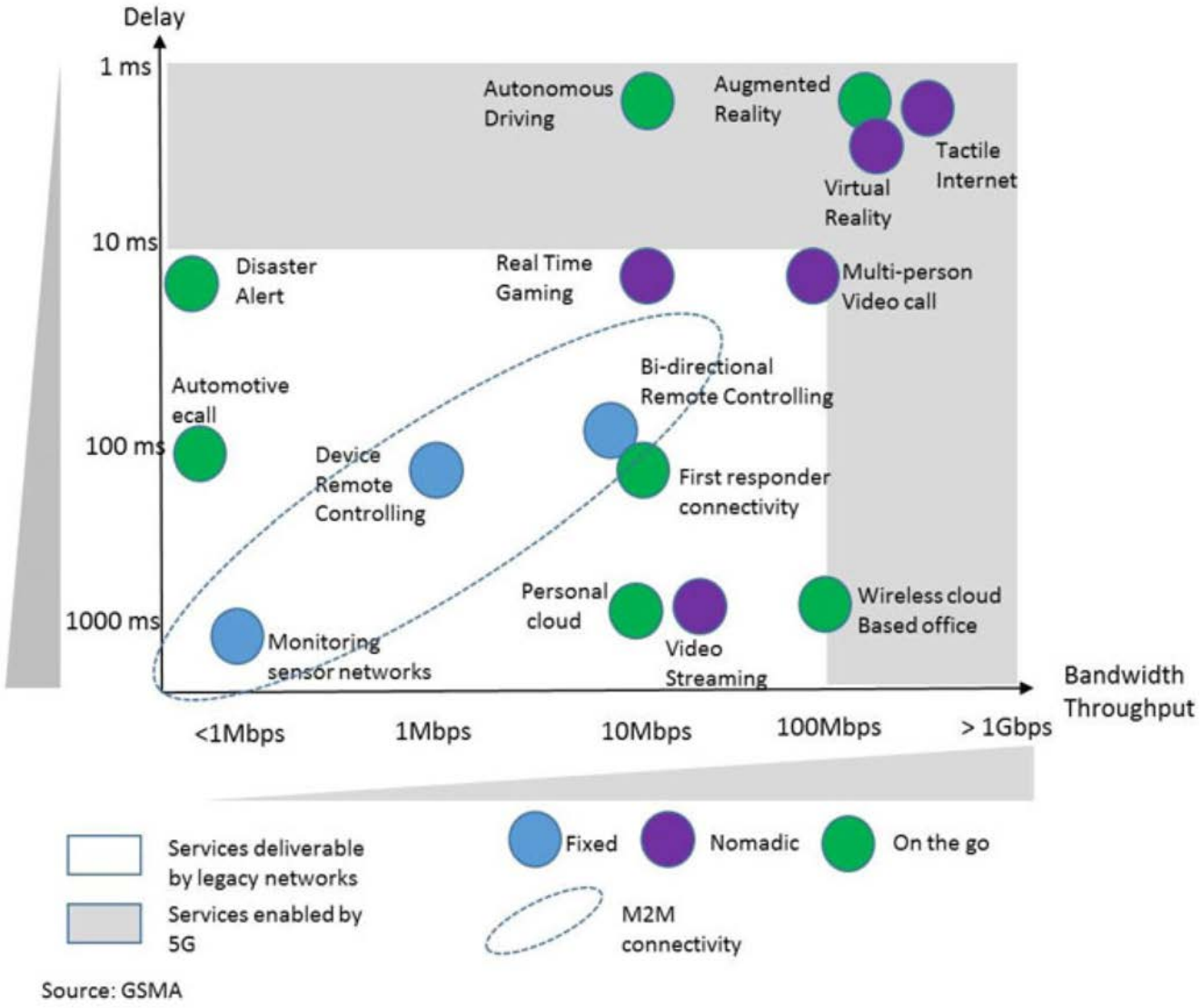
source: FutureTimeline.net

Orders of Magnitude Difference



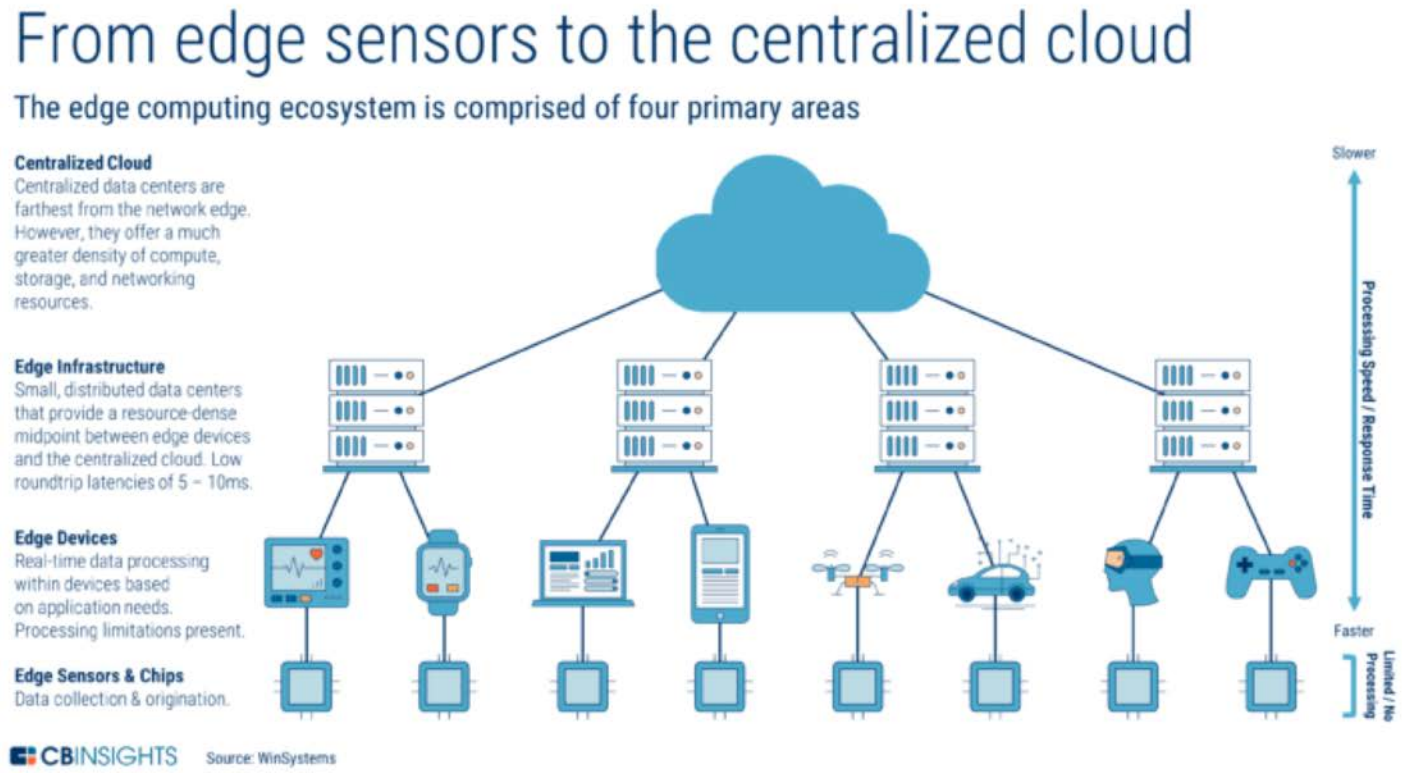
source: gsmaintelligence.com

Latency Advantages Drive Most New Use Cases



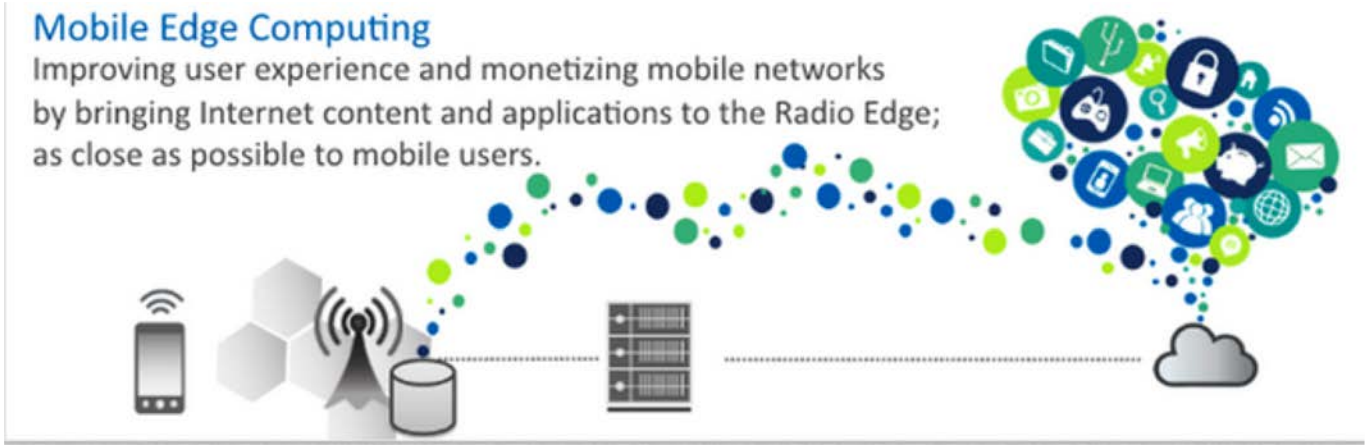
source: GSMA

Low Latency Means Edge

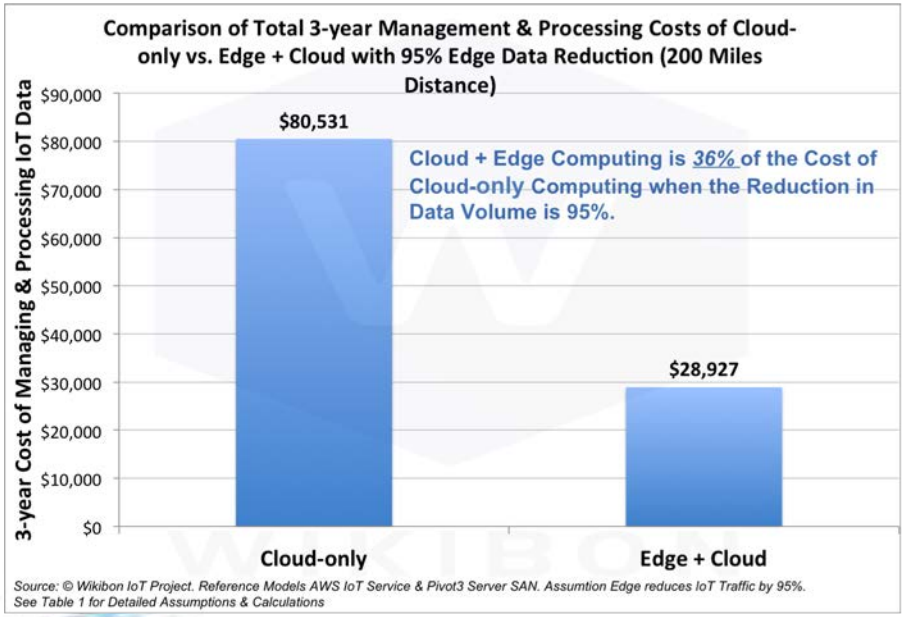


source: CB Insights

5G and Mobile Edge Computing



Both latency and bandwidth cost are use cases for mobile edge computing



source: Wikibon

5G Shift to Enterprise

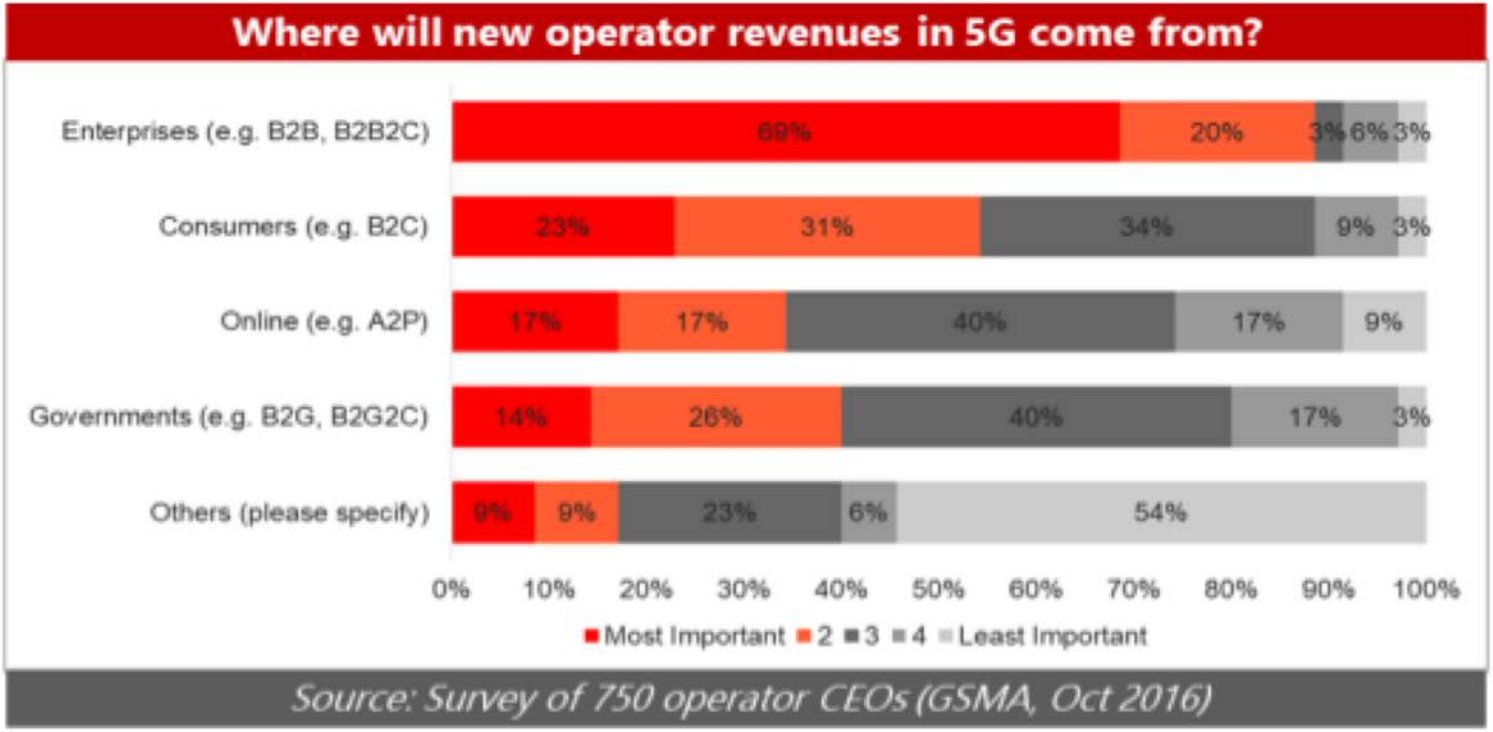


Figure 1: New incremental revenue opportunities in 5G to come from the enterprise segment

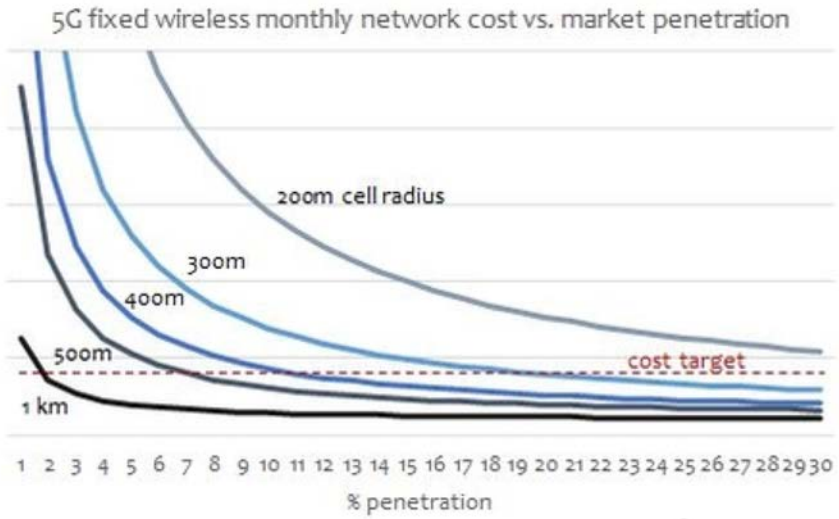
source: GSMA

Why 5G Fixed?

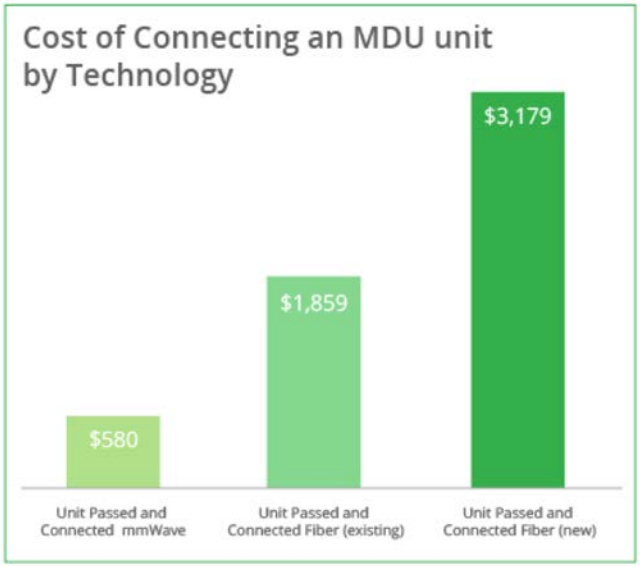
	MAIN TECHNOLOGY	HOMES AND BUSINESSES PASSED (MILLION)	FIXED BROADBAND CUSTOMERS (MILLION)*
Comcast	Cable	57.2	25.9
Charter	Cable	49.8	23.9
AT&T	FTTH/xDSL	>60	15.7
Verizon	FTTH/xDSL	14.6	7.0

* Includes business customers (the vast majority of customers are residential though). Q4 2017 figures.
Source: company data and GSMA Intelligence

source: GSMA Intelligence



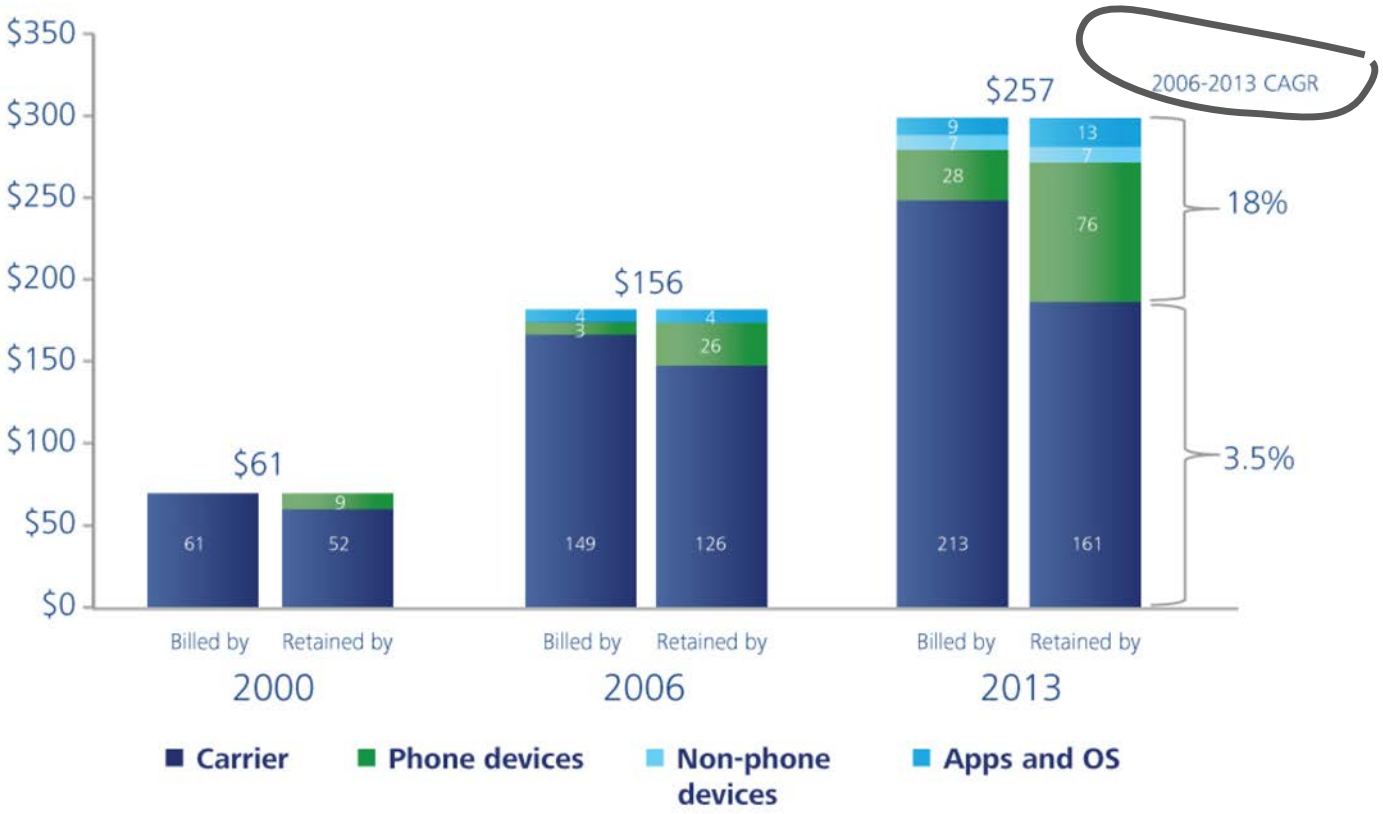
source: Mobile Experts



source: Siklu

Share of Value in 5G Era?

Figure 10. Payment and retention of customer spend
(wireless industry total in $ billion)



Sources: 2000 annual reports for AT&T, Verizon, Sprint, T-Mobile, USCC; 2006 annual reports for AT&T, Verizon, Sprint, T-Mobile, Alltel, USCC, Motorola, Apple, Google, Microsoft, Nokia, Research in Motion; 2013 annual reports for AT&T, Verizon, Sprint, T-Mobile, USCC, Apple, Google, Microsoft, Nokia, Research in Motion; Deloitte analysis.

source: Deloitte University Press

Graphic: Deloitte University Press | DUPress.com

Network Slicing

Network slicing creates end-to-end virtualized networks differentiated by speed, reliability, latency, energy consumption, security, geography, edge or cloud computing, charging, identity.

One Size Fits All

Wholesale	Retail	Network
MVNO: pay for what you use	Best effort access only	Shared access

New Things You Can Do

Wholesale

End to end:

- Quality of service
- Class of service
- MVNO capacity
- Access VNO

Retail

End to end:

- QoS
- CoS
- Substitution
- On-demand

Network

On-demand

- Geography
- Speed
- Latency
- Reliability
- Security

Business Model Impact

Wholesale

Customized product with higher revenue and value

Retail

Product differentiation

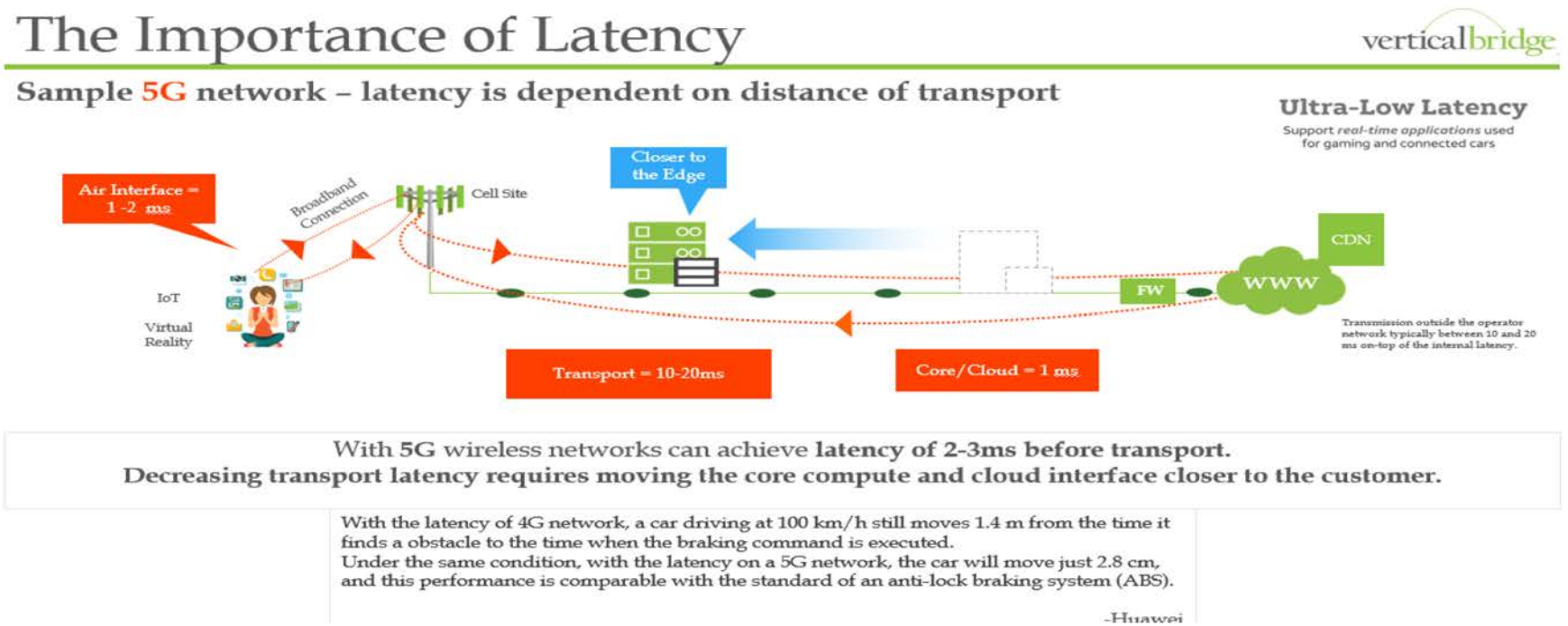
- Speed tiers
- QoS tiers
- CoS tiers

Network

Customized networks

- IoT
- Ultra-low latency
- Video, gaming

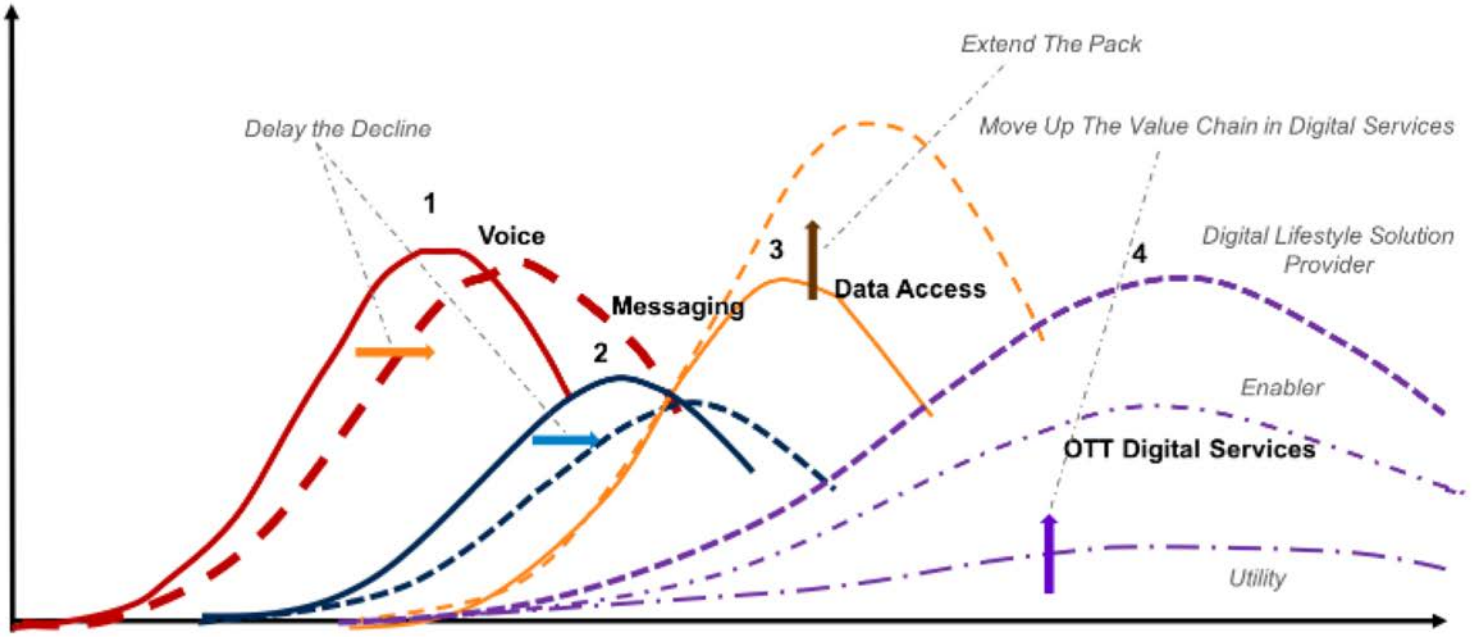
Edge Computing Value: Latency, Bandwidth Cost



4G link latency 50 ms to 70 ms
5G link latency 1 ms to 2 ms

source: DataBank

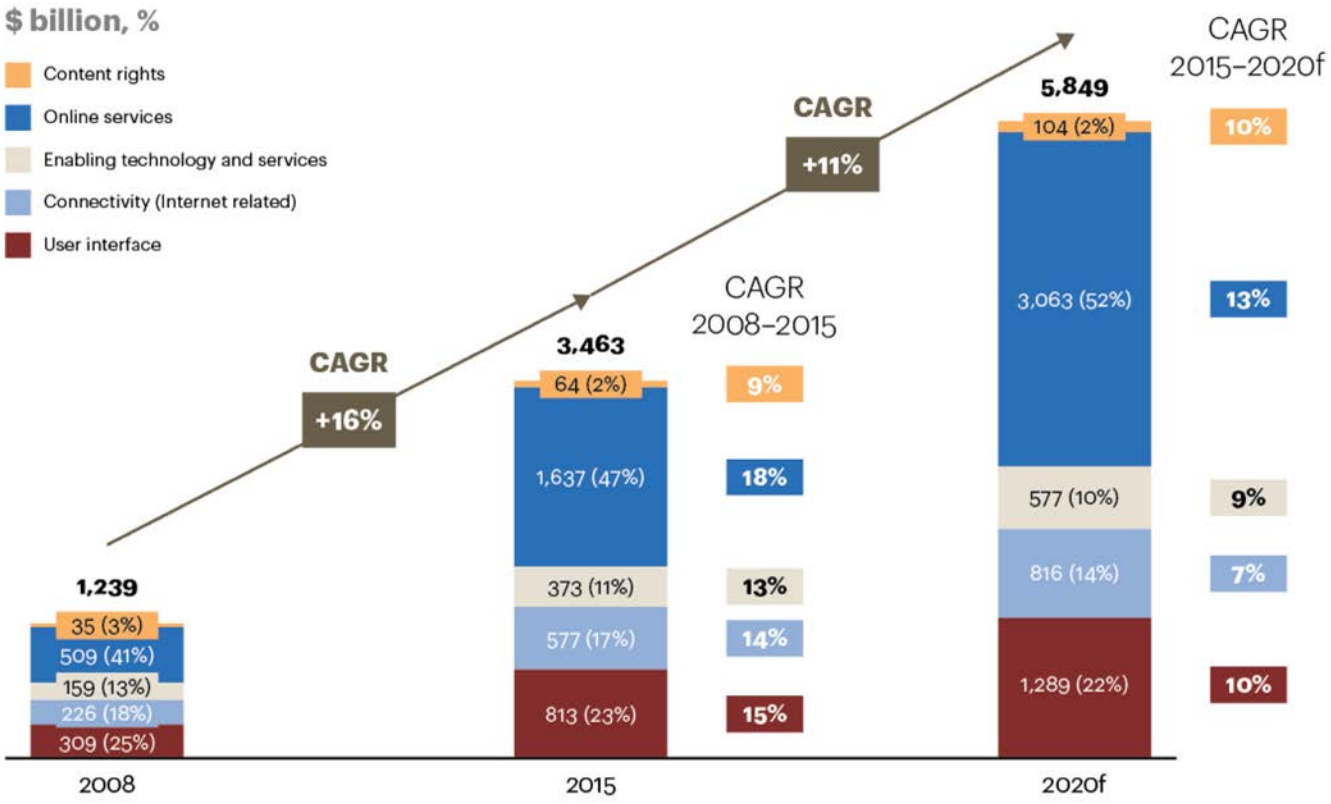
Replace Half of Revenue Every 10 Years



source: Turk Telecom

“Access” CAGR Drops 50% in 5 Years

Internet value chain size and growth by segment



Note: Includes restatements of 2008 data to 2015 structure to enable comparability.
Source: A.T. Kearney analysis

source: AT Kearney

Many Related Advances...

Virtualized Core (NFV, SDN)
Virtualized Edge (Slicing)
Small Cells (Backhaul dominates cost)
Use “any spectrum” (below 2 GHz, Millimeter)
Aggregate licensed and unlicensed spectrum
Millimeter wave capacity
Substitute for fixed network
Designed for new use cases (IoT)

Key Attributes

- 1-10Gbps connections
- 1 millisecond end-to-end delay (latency)
- 1000x bandwidth per unit area
- 10-100x number of connected devices
- 99.999% availability
- 90% reduction in network energy usage
- Up to 10-year battery life
- M2M device support

Battery Life, Cost are Key for Many IoT Apps

LPWA Solution

	SIGFOX	LoRa	NB-LTE	LTE-M	EC-GSM
Range (outdoor)	<13km	<11km	<15km	<11km	<15km
MCL	106dB	157dB	164dB	156dB	164dB
Spectrum	Unlicensed	Unlicensed	Licensed	Licensed	Licensed
Bandwidth	100Hz	<500Hz	180kHz	1.4MHz	200kHz
Data Rate	<100bps	<10kbps	<150kbps	<1Mbps	10kbps
Battery Life	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs
Cost of Device	~2 USD	~2 USD	<5 USD	<5 USD	<5 USD
Timeline	Today	Today	2016-17	2016-17	2016-17

	Devices and Bearer Scale	Control Plane Signaling	Data Plane Throughput	Mobility	Latency
Smart Meters	Massive (milions)	Low (2–10 t/ hr.)	Low	None	High Tolerance
Non Consumer Video	Moderate (10+ thousands)	High (2–10 t/hr.)	High	None	Low Tolerance
Connected Car	High (milions)	High (500-1000 t/hr.)	High	Frequent	Moderate Tolerance
Smartphone Users	High (milions)	Moderate (200-500 t/hr.)	Moderate	Frequent	Moderate Tolerance

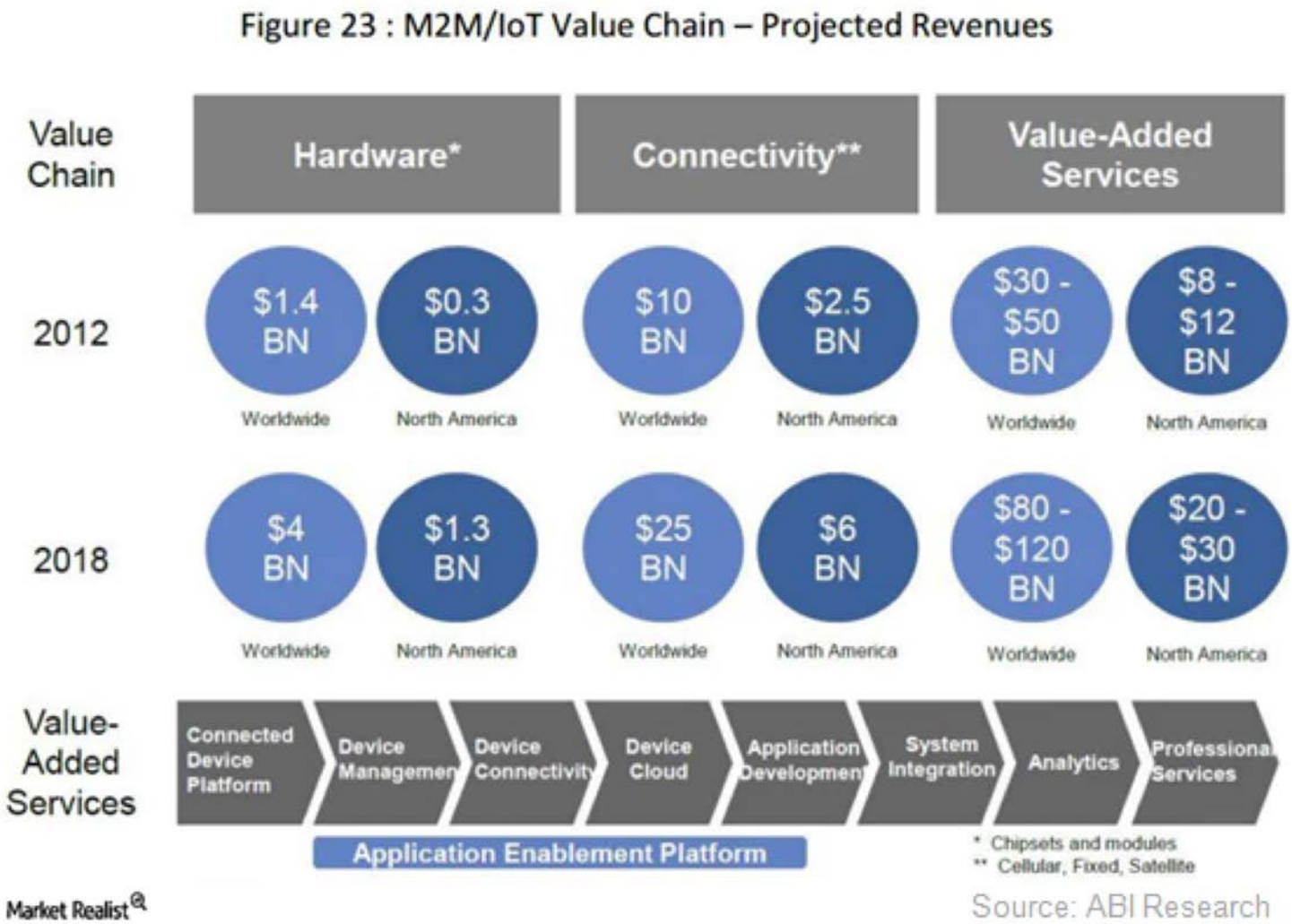
Table 1. Network Behavior of Three Examples of IoT Services and Smartphone Users

- unattended operation
- low device cost
- low access cost
- long battery life
- low bandwidth
- low latency

Spectrum Sharing

- Citizens Broadband Radio Service
- TV White Spaces
- Licensed Assisted Access
- Licensed Shared Access

Most of the Upside is Apps



source: ABI Research

PACIFIC
TELECOMMUNICATIONS
COUNCIL

THANK YOU