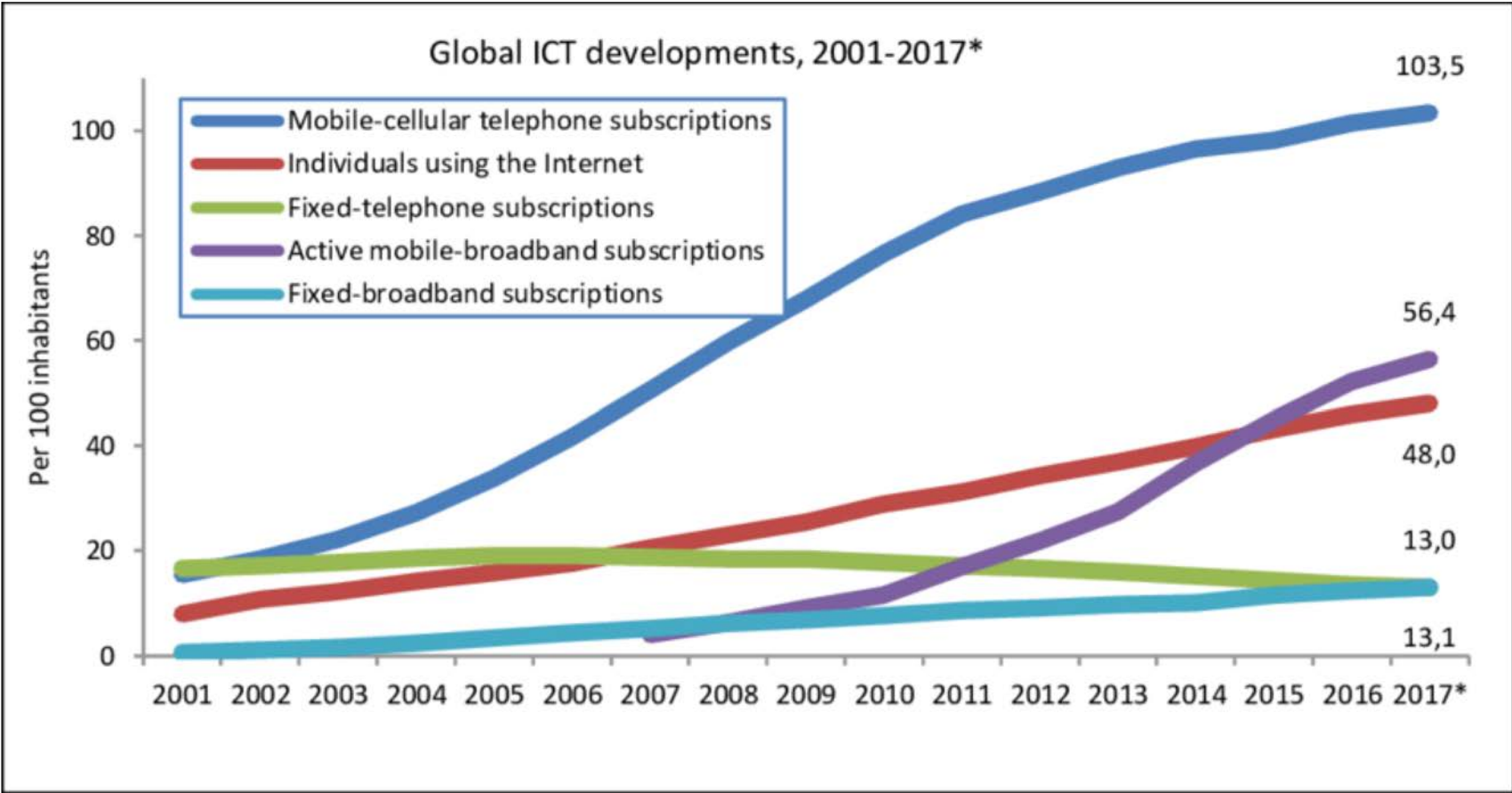


5G: Why Do You Care?

Gary Kim
IP Carrier
gary@fatpipes.biz



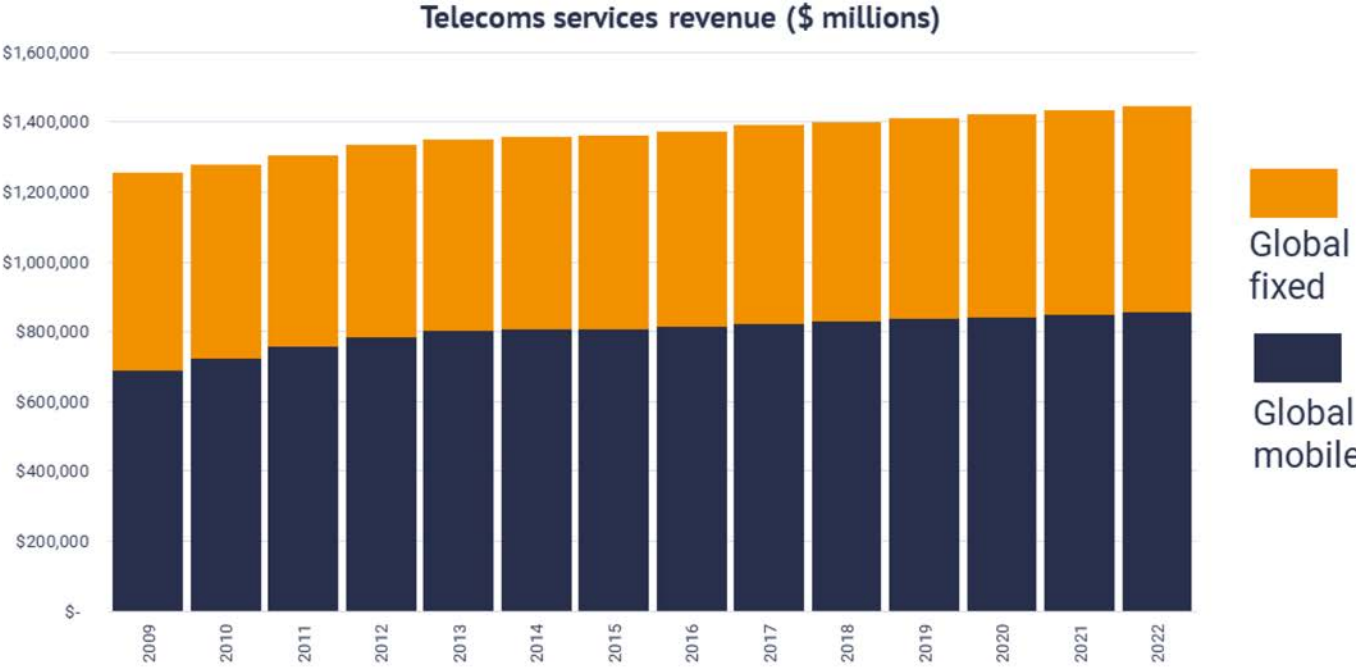
Mobile Drives Global Subscriptions



[source: ITU](#)

Mobile Drives Revenue Globally

STL Partners forecasts less than 1% per annum growth in both fixed and mobile telecoms services to 2022



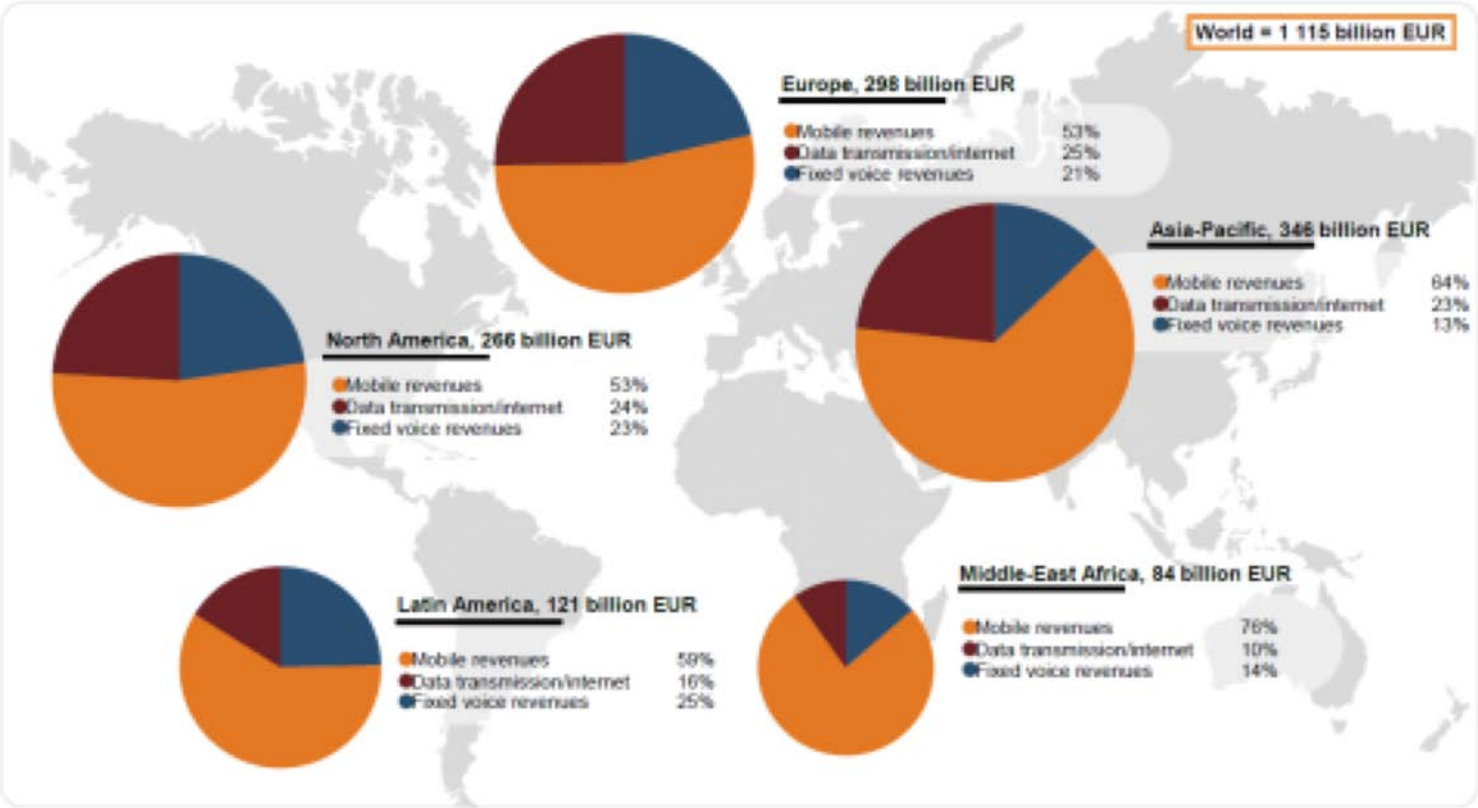
Source: Company accounts; STL Partners analysis and forecasts



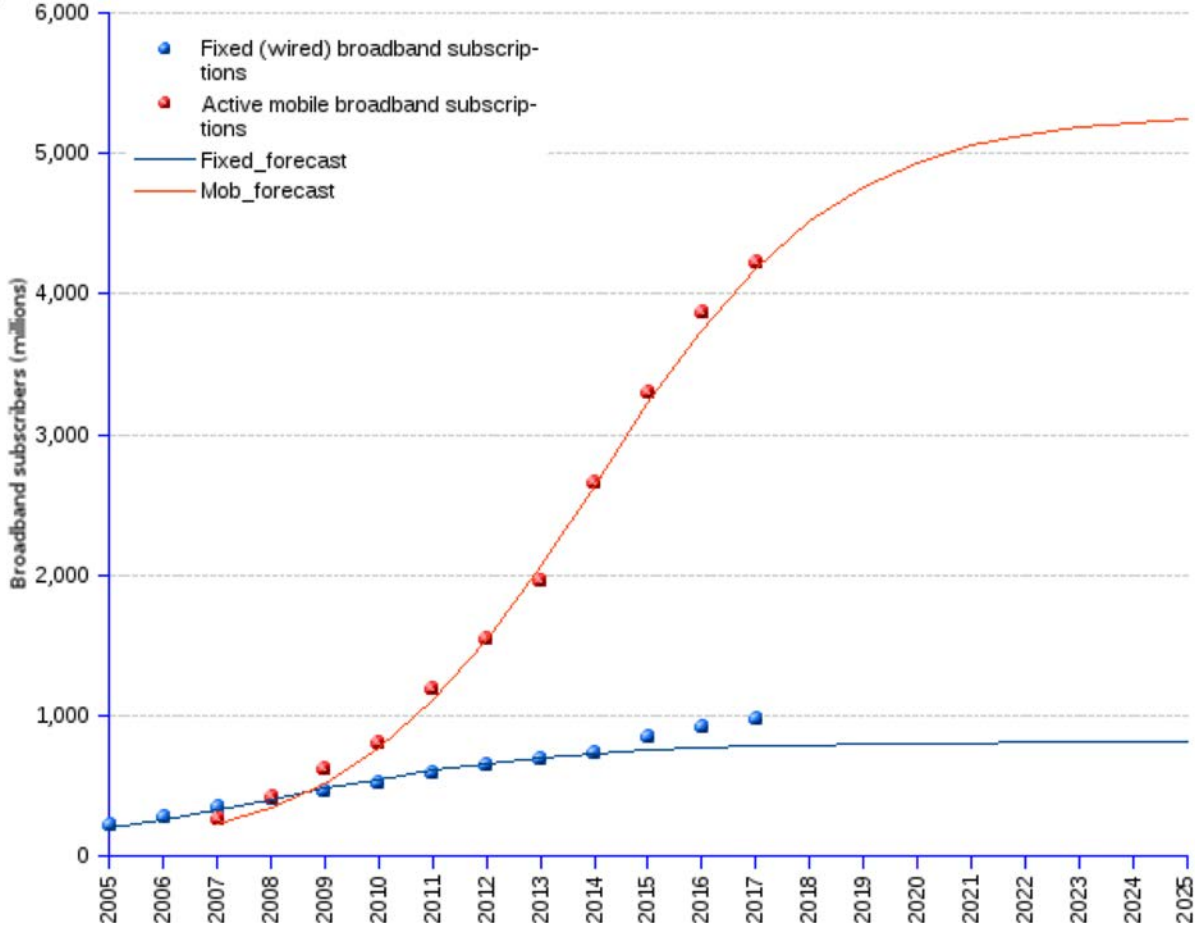
[source: STL Partners](#)



Mobile Drives Revenue in Asia, Pacific

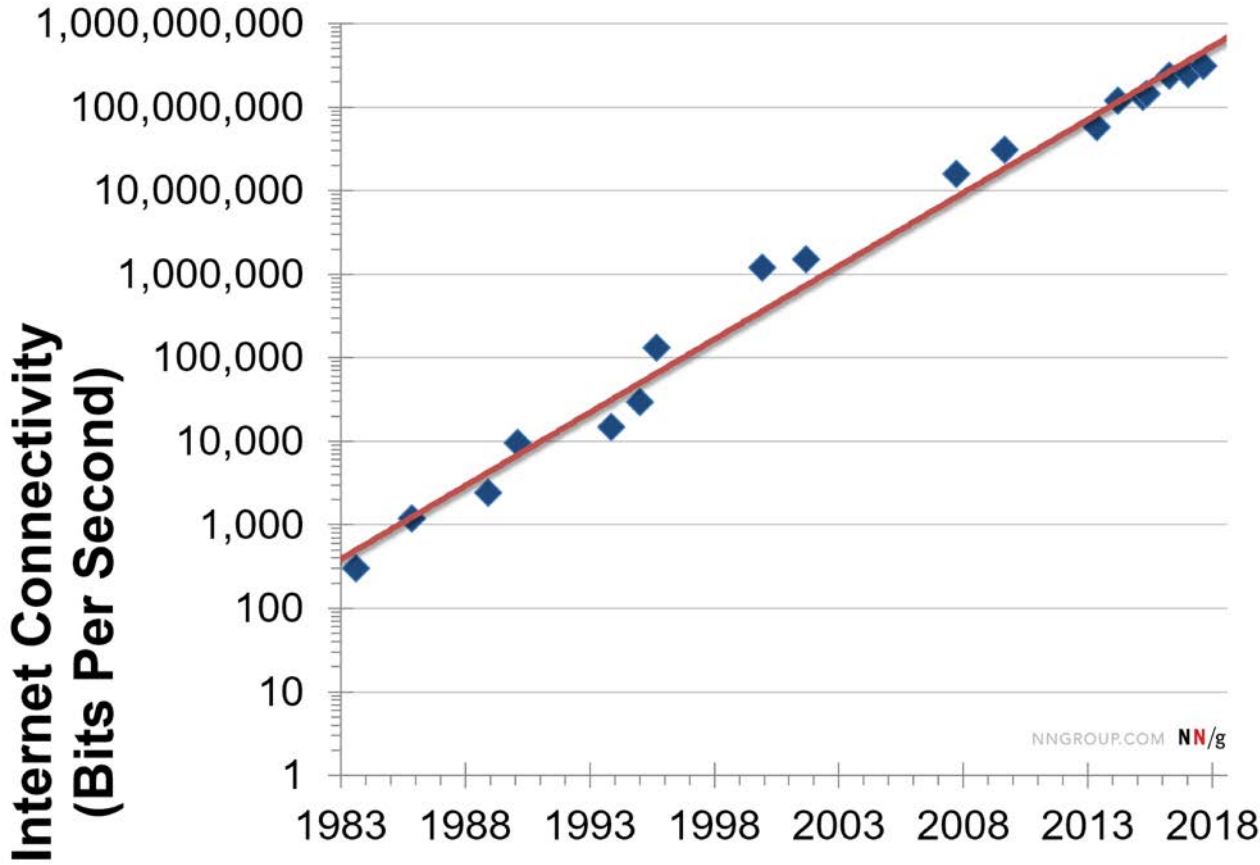


Mobile Data Drives Subscription Growth



source: ITU

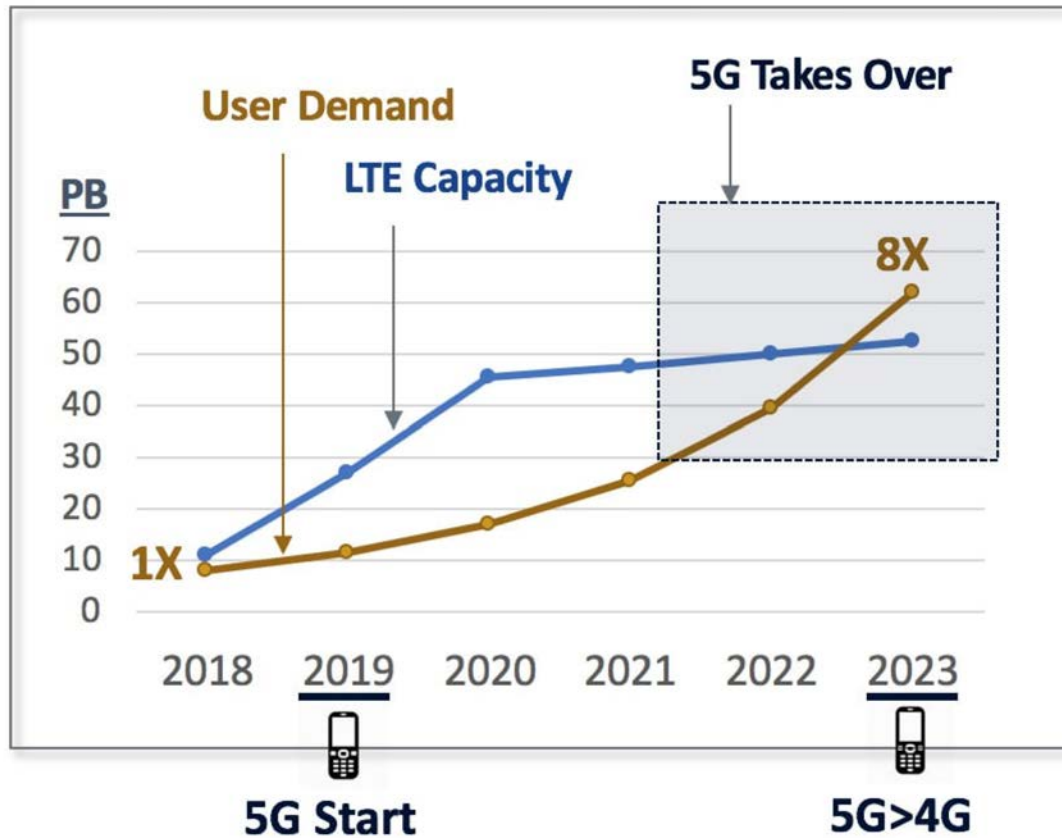
Capacity Demand Grows 50% Per Year



[source: Nielsen Norman Group](#)

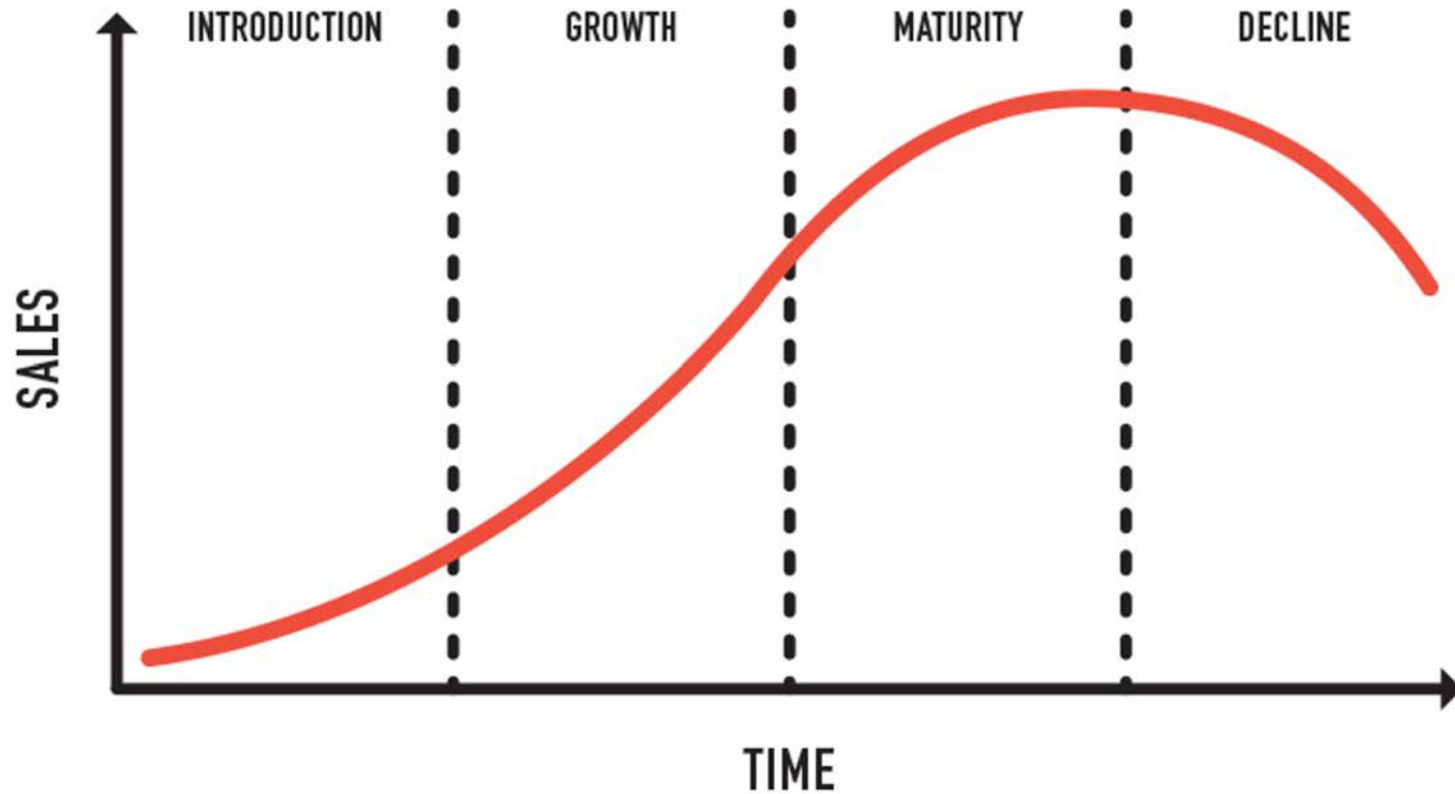


4G Capacity Growth Cannot Keep Up

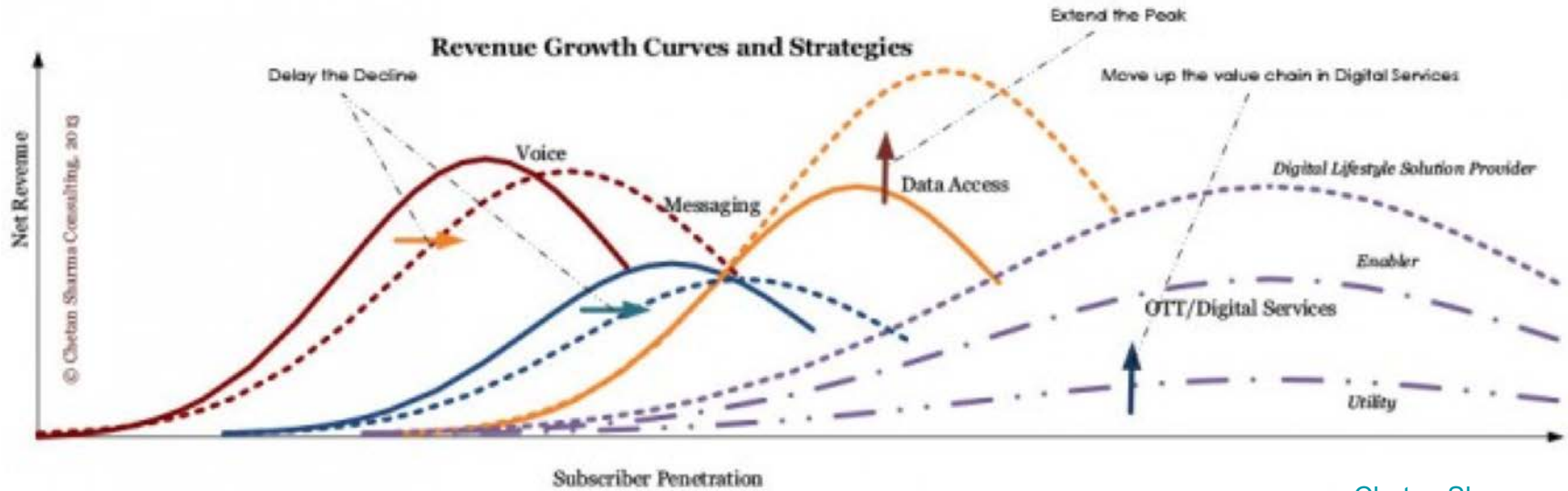


source: Nokia

All Products Have a Life Cycle



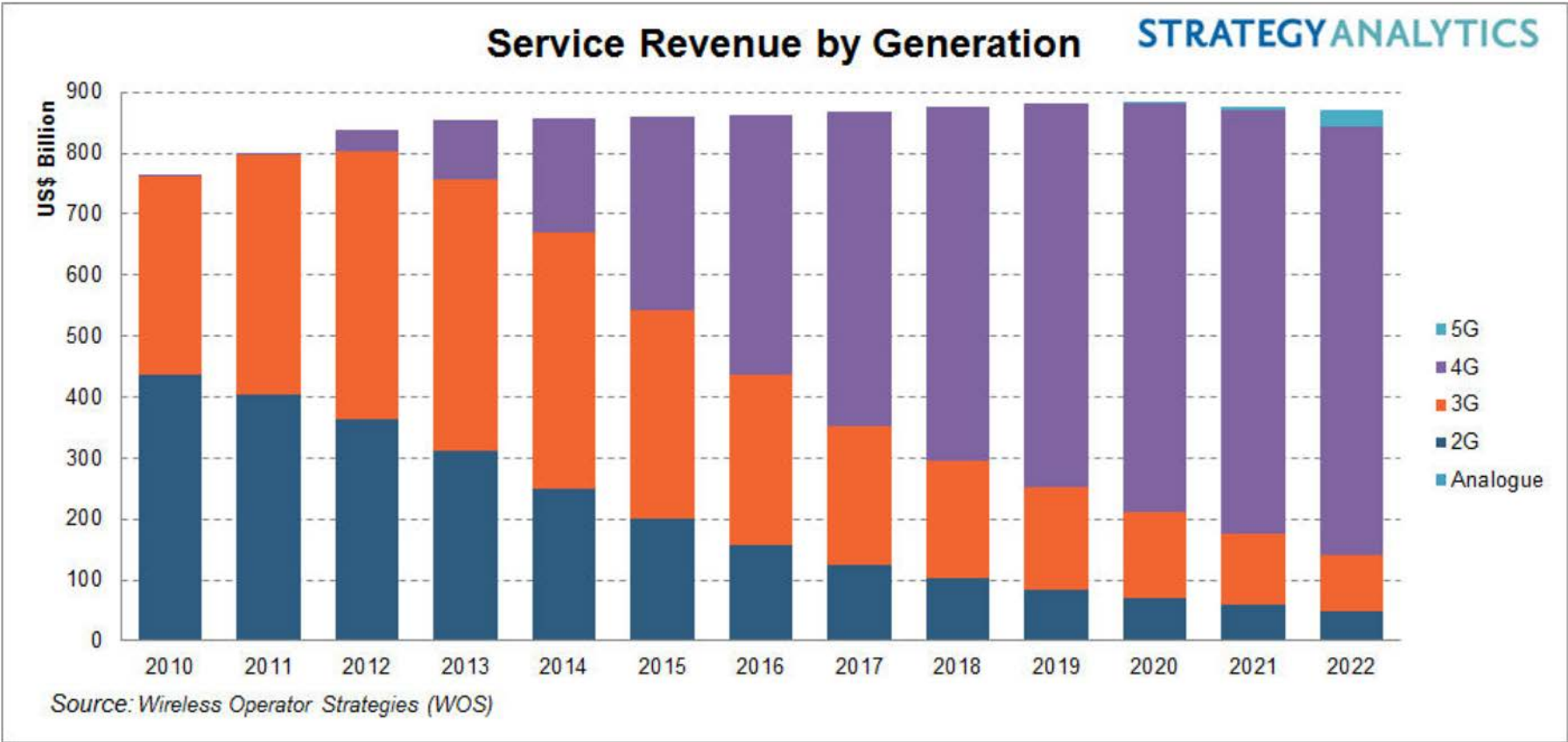
Mobile Products have Life Cycles



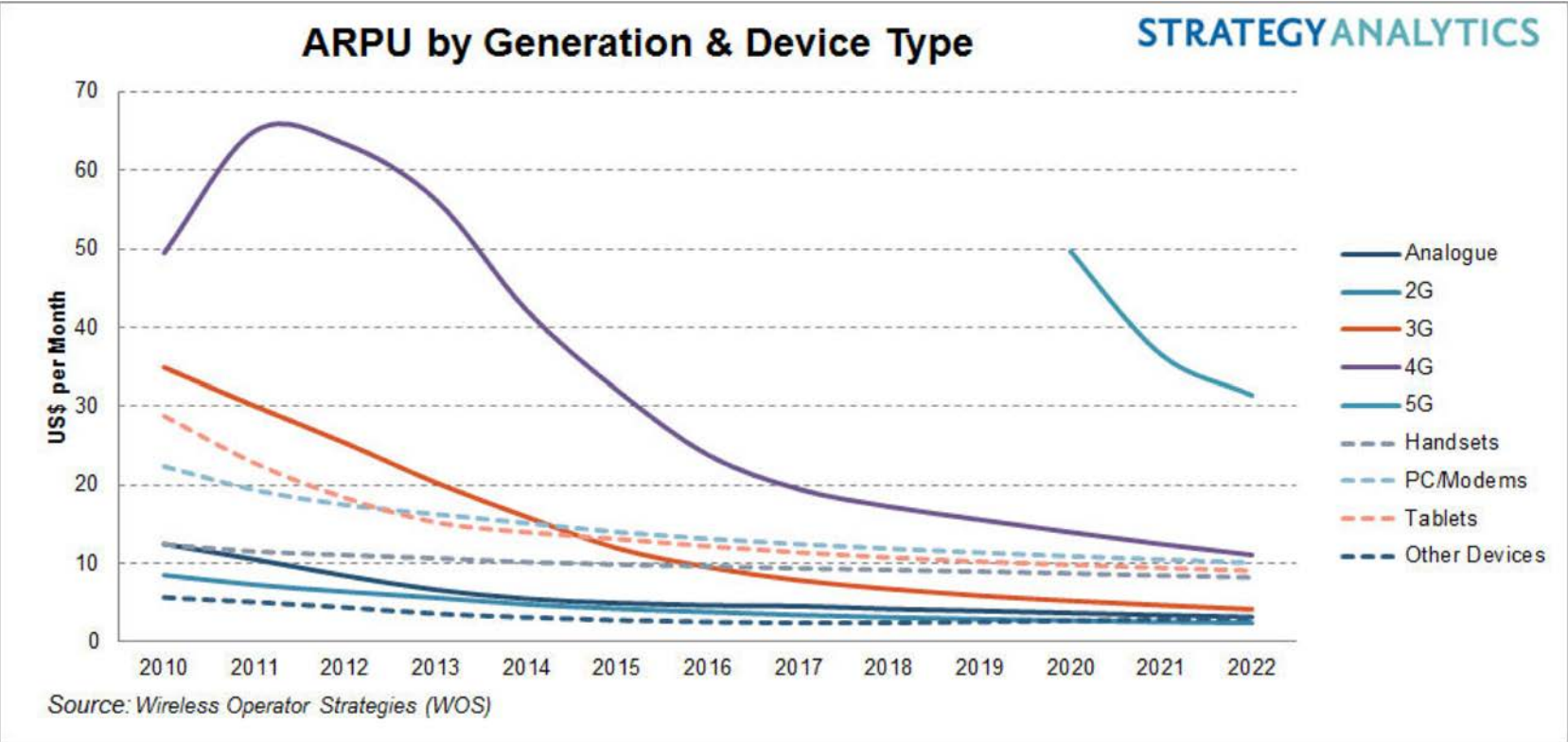
source: [Chetan Sharma](#)



Mobile Generations Have Life Cycles



Higher Average Revenue Per User?



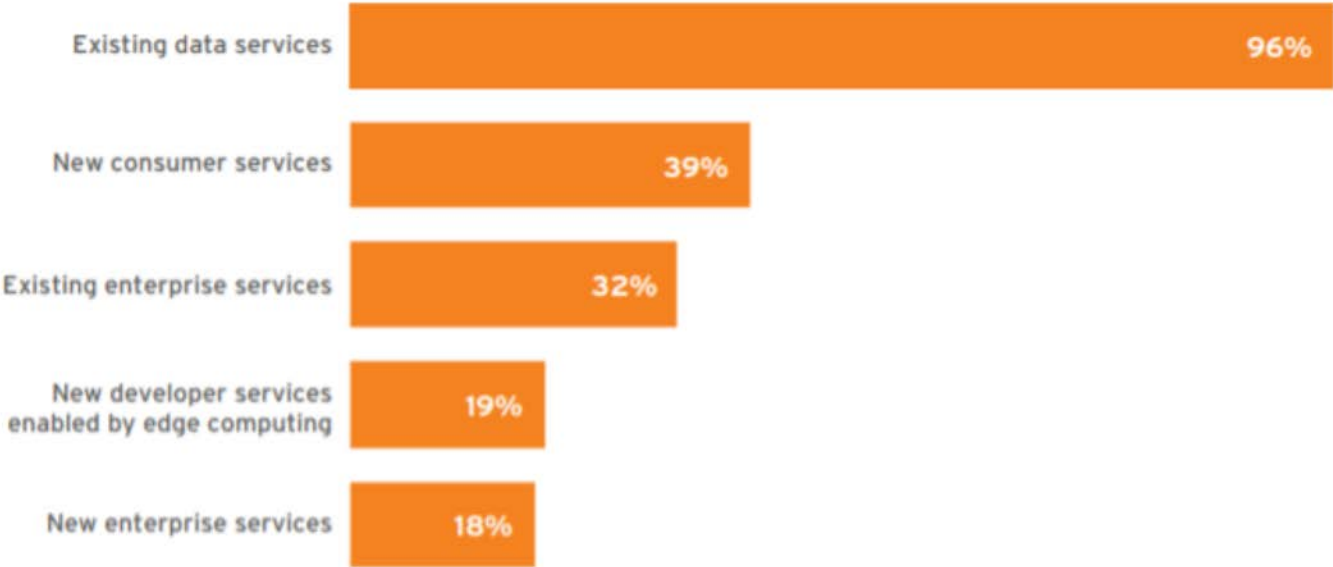
[source: Strategy Analytics](#)



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)



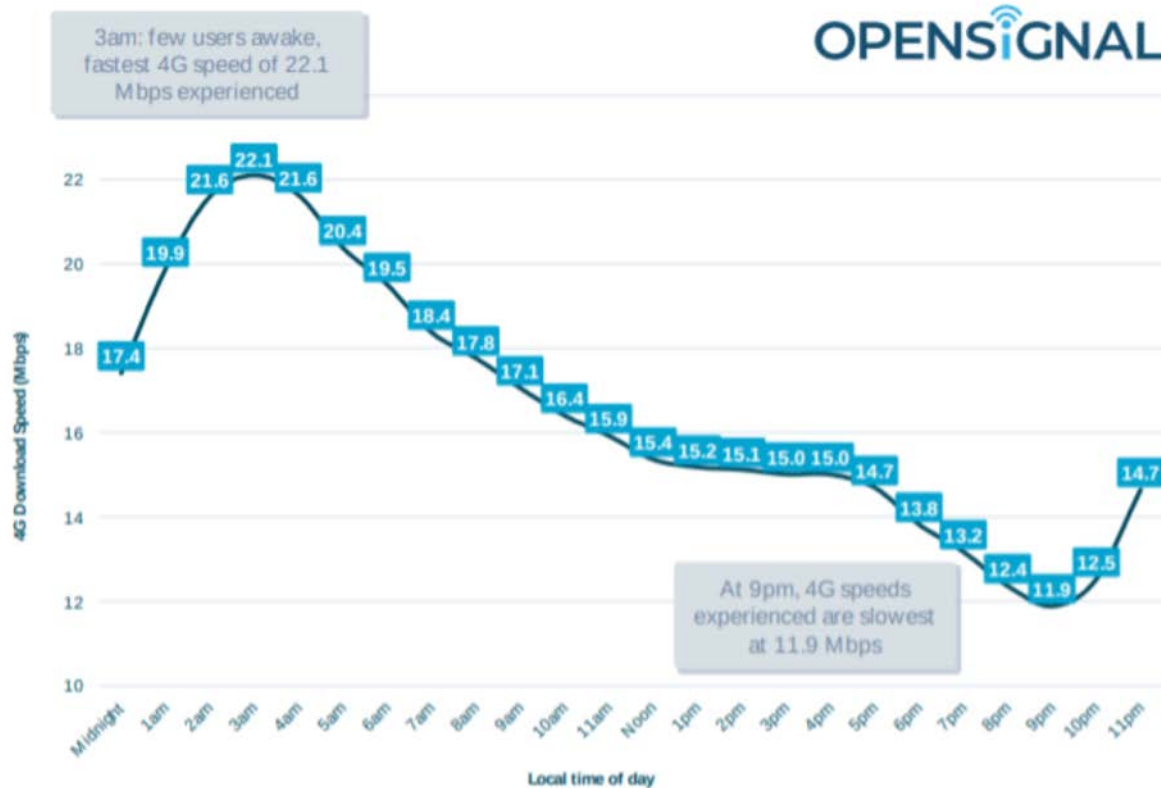
[source: 451 Research](#)



4G Congestion

World 4G speeds vary tremendously across the day showing the impact of congestion on daytime speeds

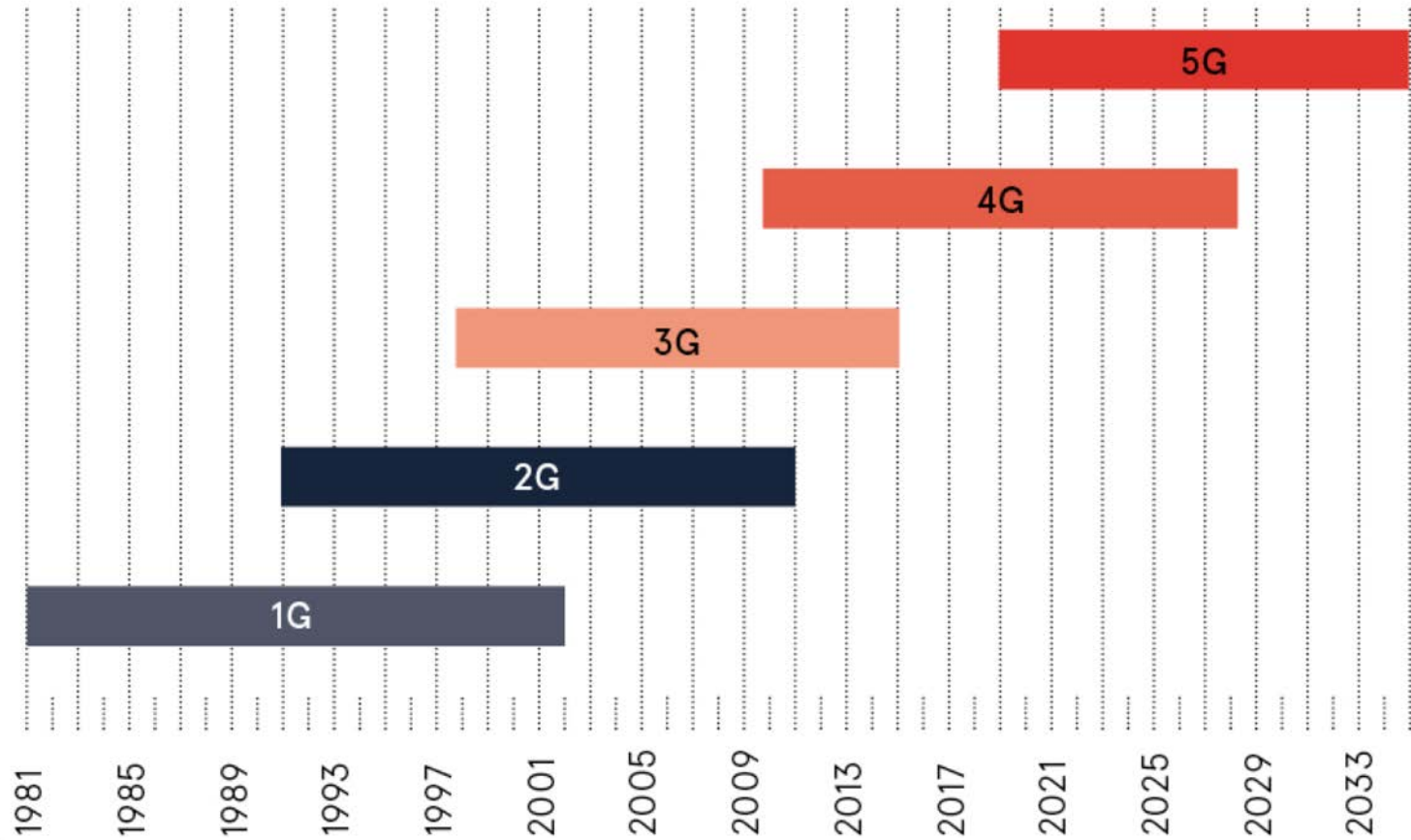
Chart 1



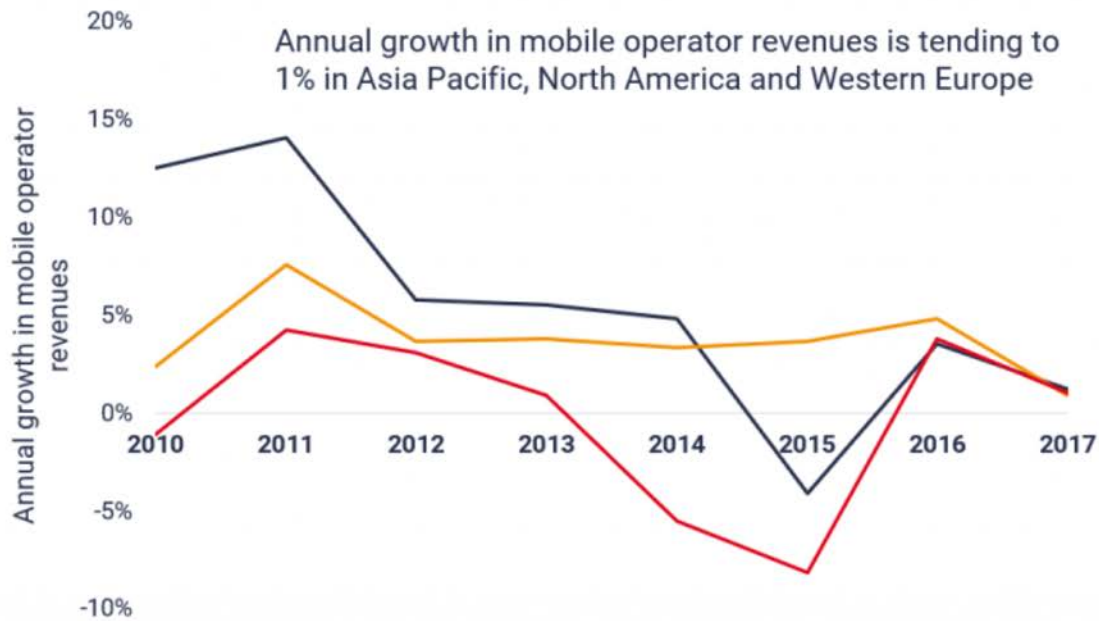
source: Opensignal

5G is Coming, on Schedule

EVOLUTION OF CELLULAR NETWORKS



4G Revenue Upside Limited

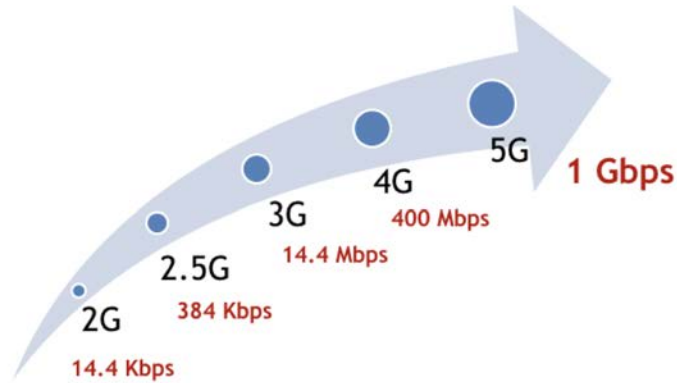


Region	Compound annual rate of change (mobile revenues)	
	8 year (2009-17)	4 year (2013-17)
Asia Pacific	5%	1%
North America	4%	3%
Western Europe	0%	-2%

[source: STL Partners](#)

Performance Demands Keep Increasing

2G - 5G Speed



- 2.5G speed is based on the maximum offered by EDGE
- 3G speed is based on the maximum offered by HSDPA

Source: www.thetech.in Nov 2018

[source: Tech In](http://www.thetech.in)

What is 5G?			
2G	3G	4G	5G
1991	1998	2008	2020?
Texting	Texting Internet Access	Texting Internet Access Video	Texting Internet Access UltraHD + 3D Video Smart Home

[source: Signal Booster](http://www.signalbooster.com)

5G Builds on 4G

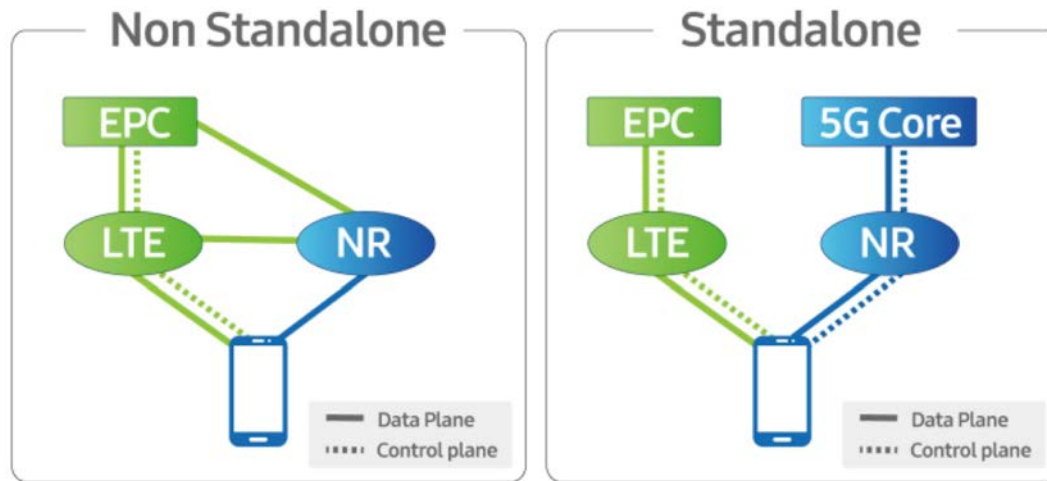
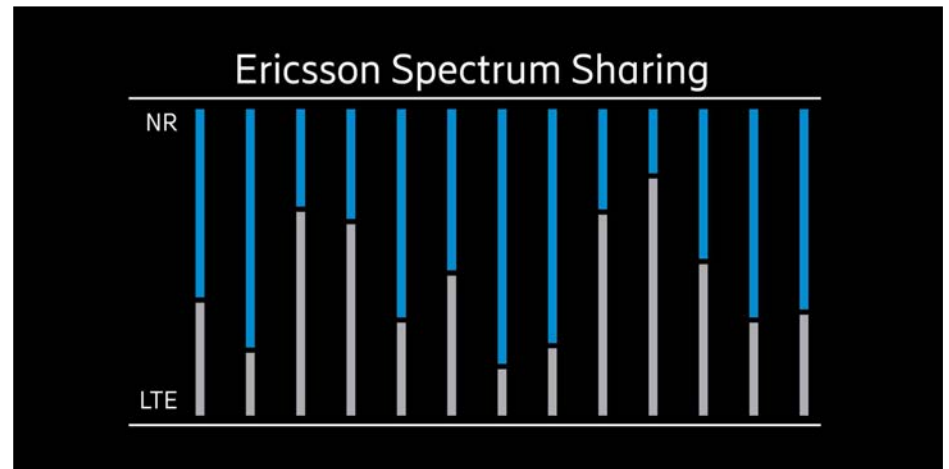


Figure 11 : How NSA and SA work

[source: Test and Verification](#)



[source: Ericsson](#)

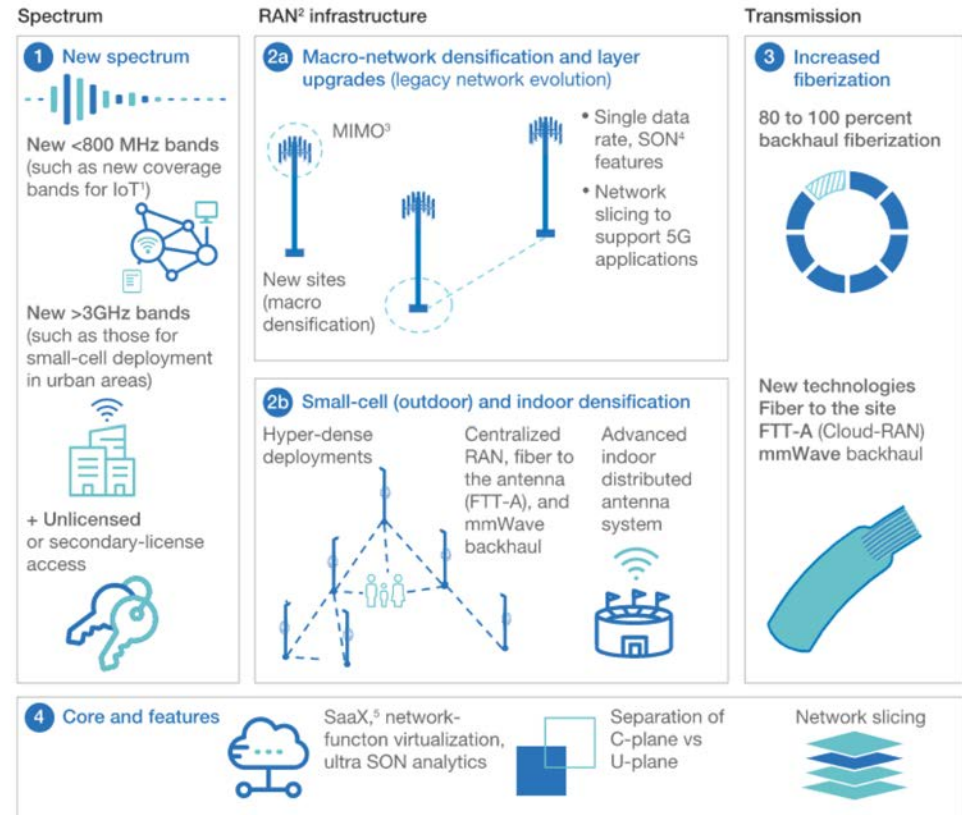
So 5G is Evolutionary

- 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)



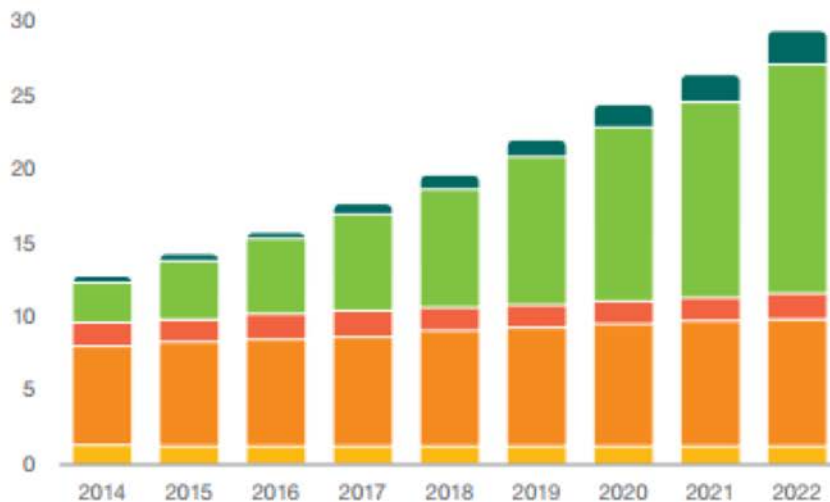
5G Also is Revolutionary

- 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...

Connected devices (billions)

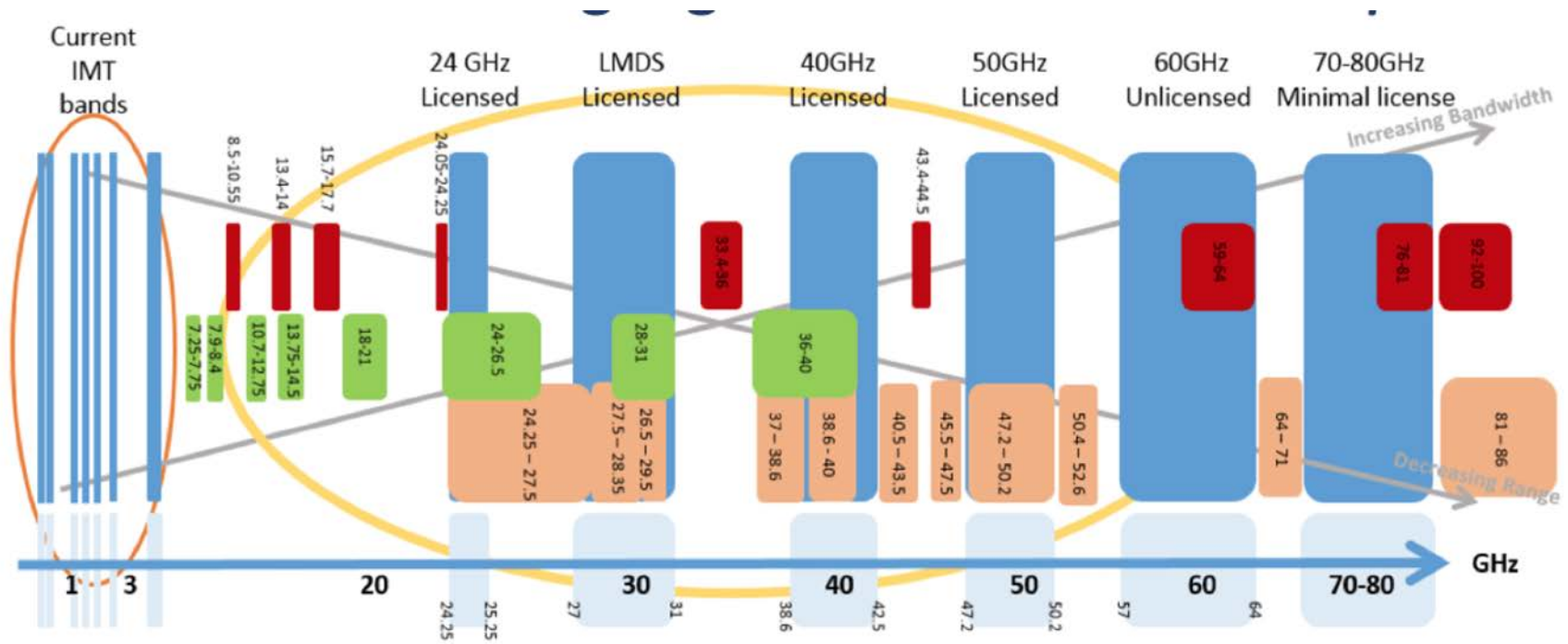


	2016	2022	CAGR
Wide-area IoT	0.4	2.1	30%
Short-range IoT	5.2	15.5	20%
PC/laptop/tablet	1.6	1.7	0%
Mobile phones	7.3	8.6	3%
Fixed phones	1.4	1.3	0%
	16 billion	29 billion	

[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



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

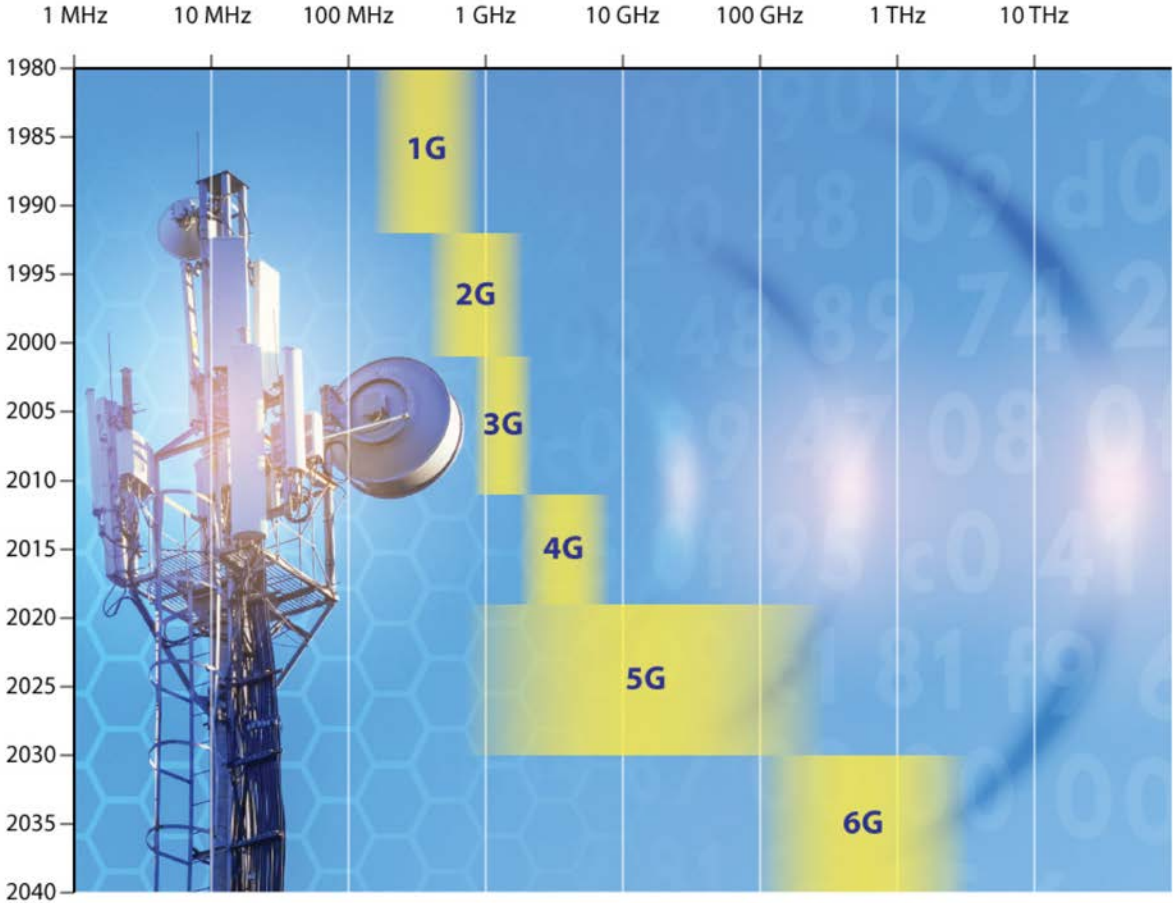
*Figure includes AWS-1, 700 MHz spectrum not yet in use and 55.5 MHz of spectrum at 2.5 GHz. #Regulatory and company websites.

** 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

Cellular frequencies, 1980-2040 (logarithmic scale)



www.FutureTimeline.net

source: FutureTimeline.net

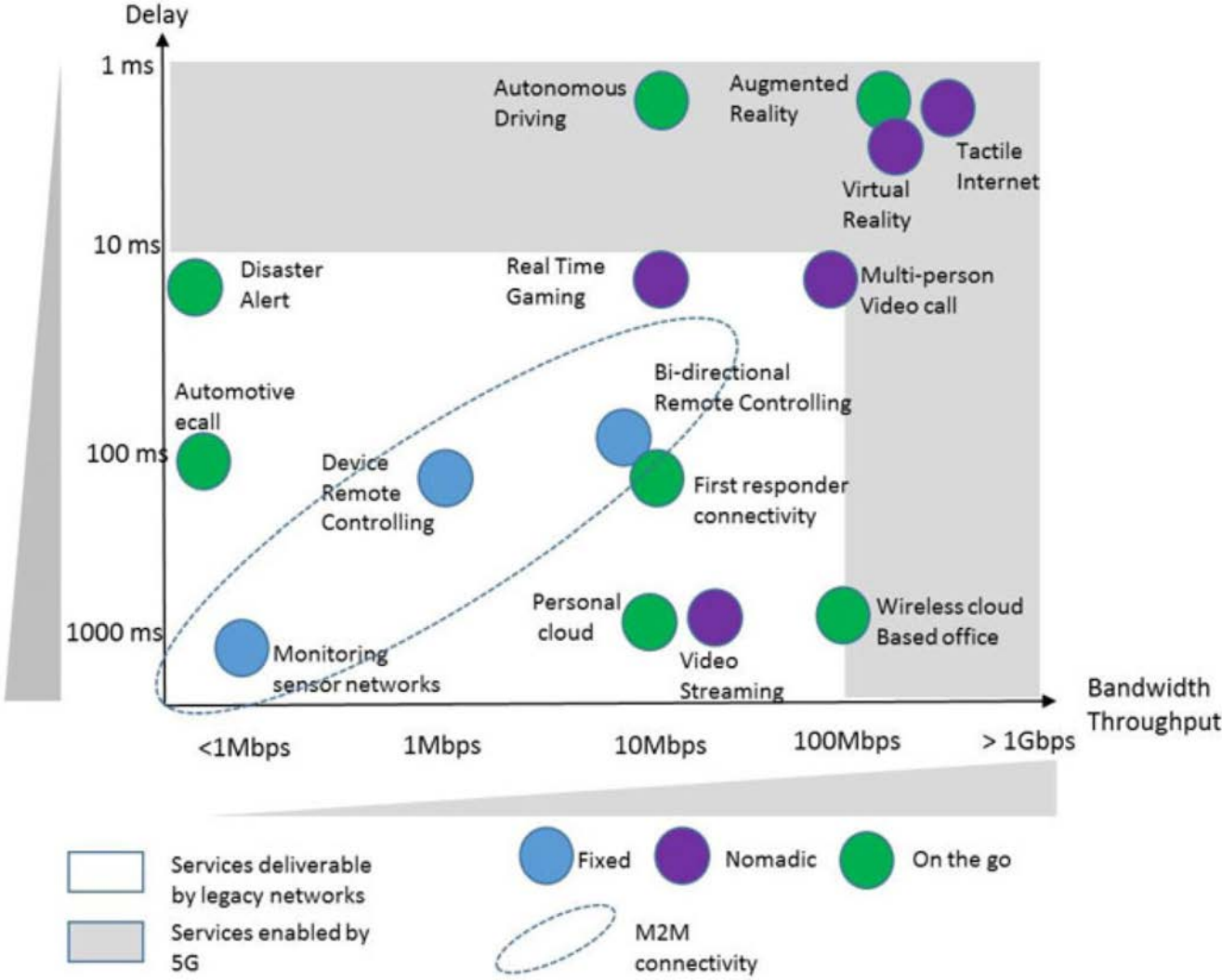
Orders of Magnitude Difference



[source: gsmaintelligence.com](http://gsmaintelligence.com)



Latency Advantages Drive Most New Use Cases



Source: GSMA

Low Latency Means Edge

From edge sensors to the centralized cloud

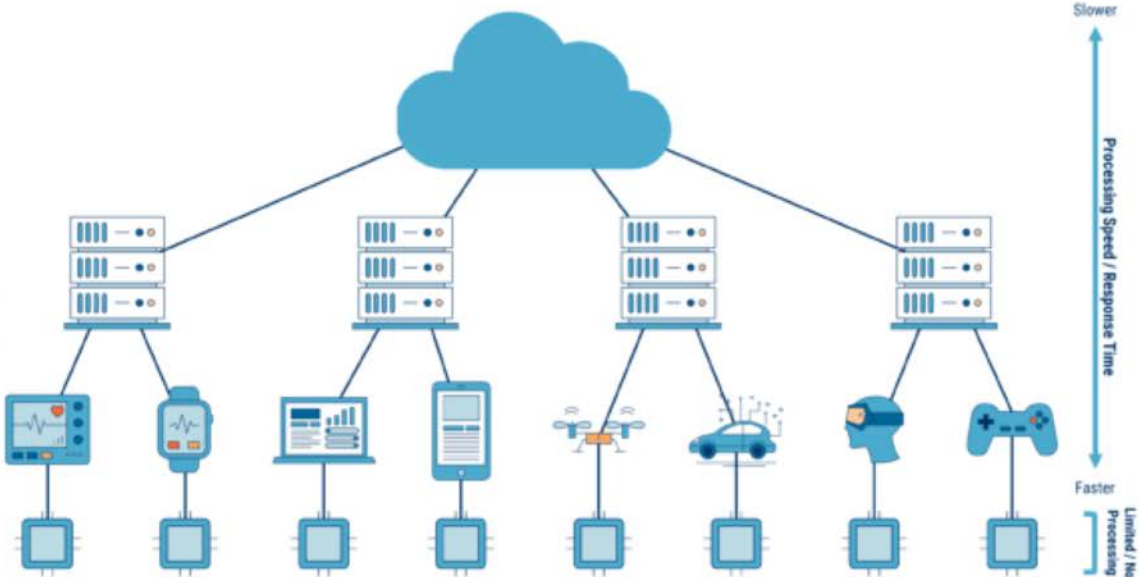
The edge computing ecosystem is comprised of four primary areas

Centralized Cloud
Centralized data centers are farthest from the network edge. However, they offer a much greater density of compute, storage, and networking resources.

Edge Infrastructure
Small, distributed data centers that provide a resource-dense midpoint between edge devices and the centralized cloud. Low roundtrip latencies of 5 - 10ms.

Edge Devices
Real-time data processing within devices based on application needs. Processing limitations present.

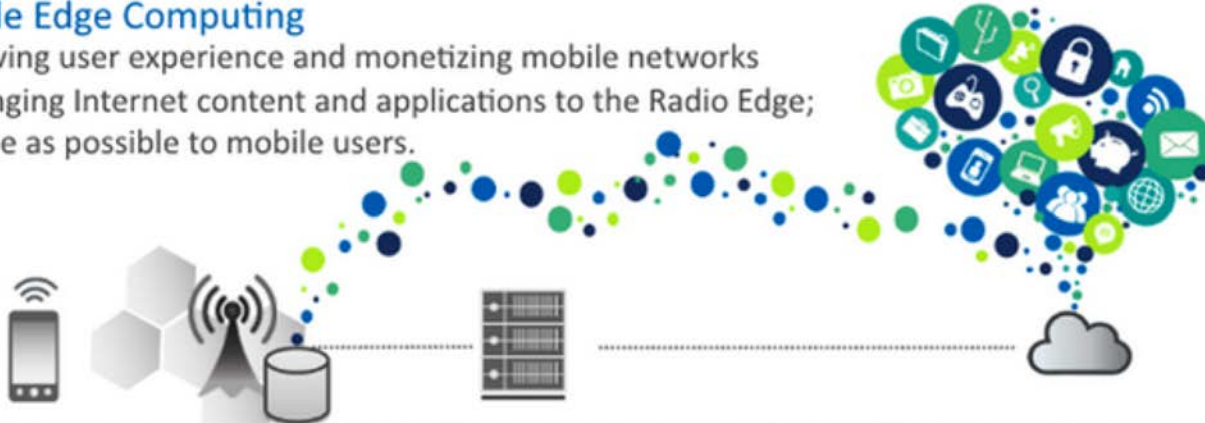
Edge Sensors & Chips
Data collection & origination.



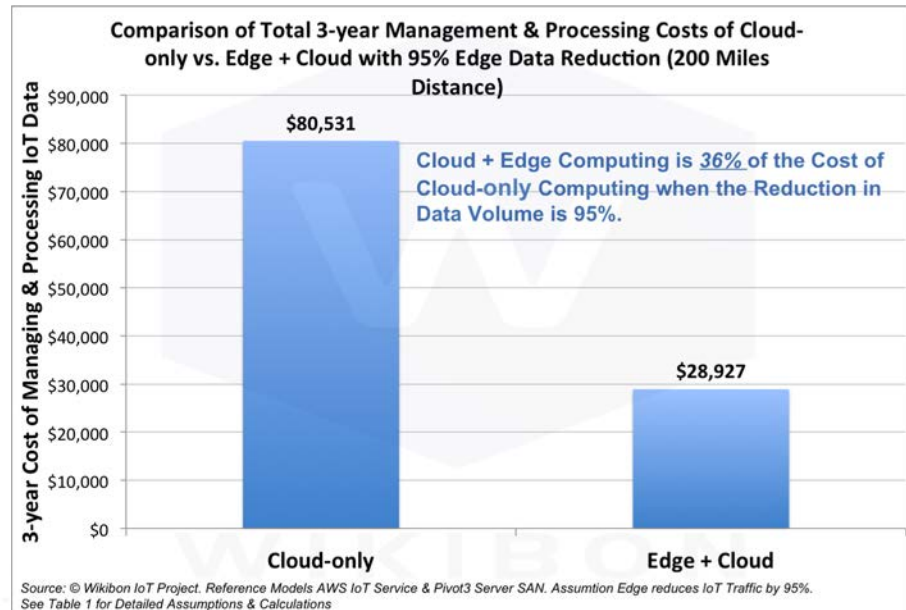
5G and Mobile Edge Computing

Mobile Edge Computing

Improving user experience and monetizing mobile networks by bringing Internet content and applications to the Radio Edge; as close as possible to mobile users.



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



5G Shift to Enterprise

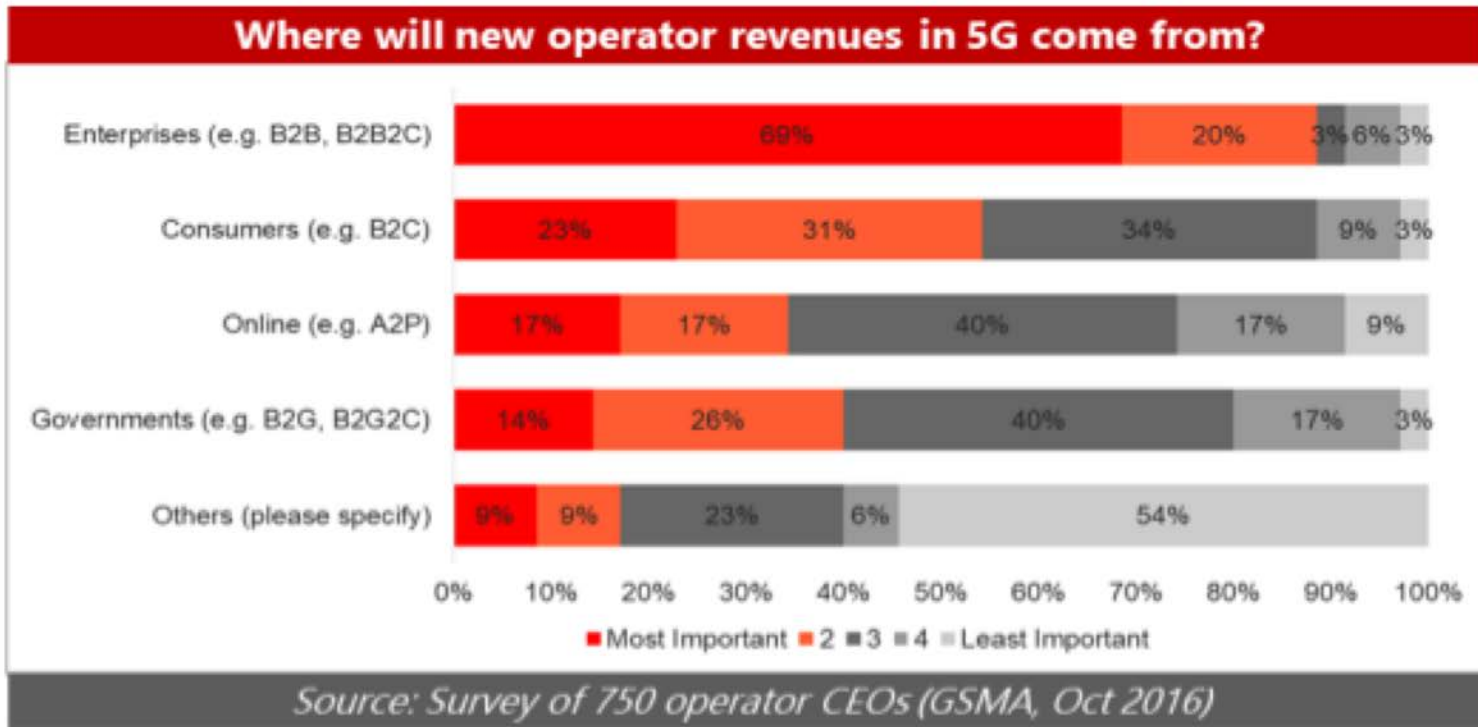


Figure 1: New incremental revenue opportunities in 5G to come from the enterprise segment

[source: GSMA](#)



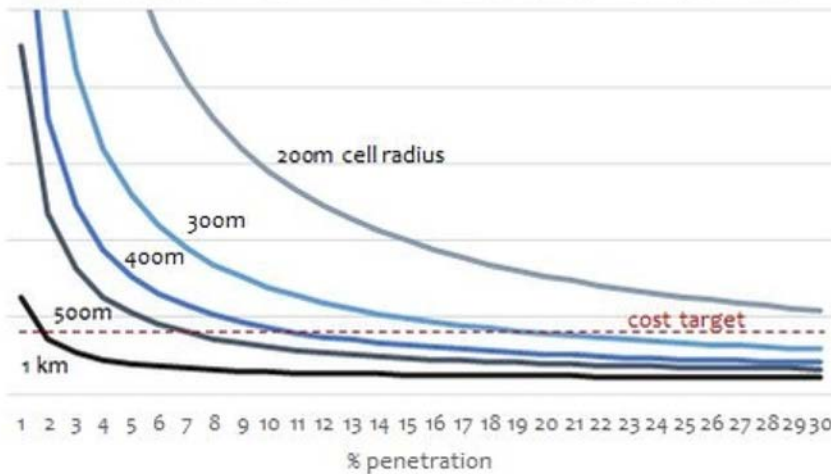
Why 5G Fixed?

	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

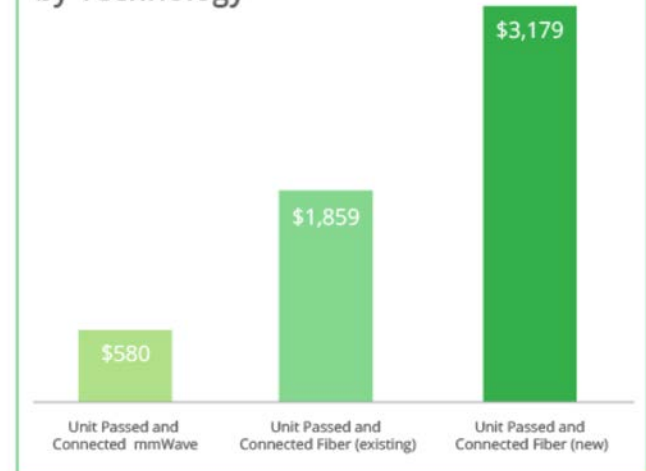
[source: GSMA Intelligence](#)

5G fixed wireless monthly network cost vs. market penetration



[source: Mobile Experts](#)

Cost of Connecting an MDU unit by Technology

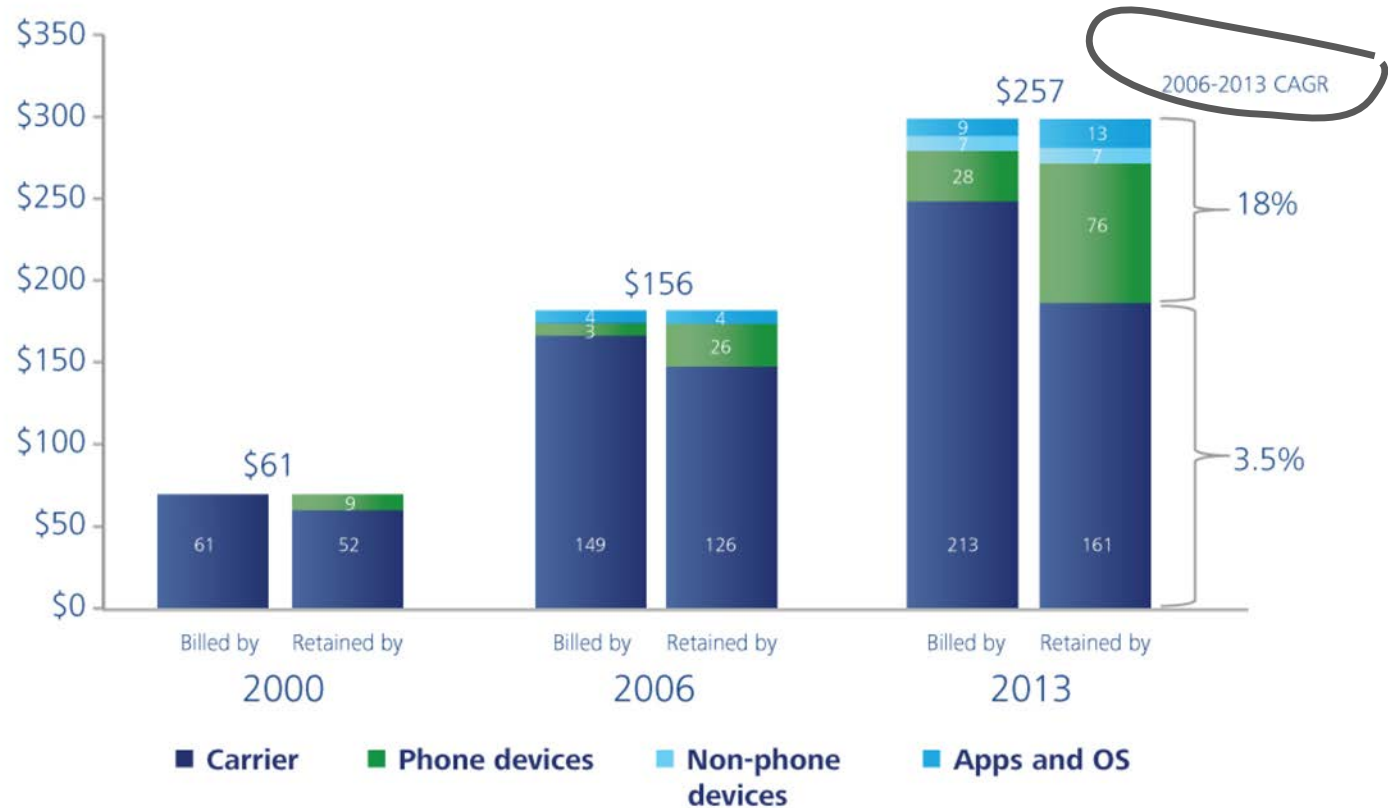


Source: White paper: 5G Fixed Wireless Gigabit Services Today- An Industry Overview

[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](#)

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

Retail

Network

End to end:

End to end:

On-demand

Quality of service

QoS

Geography

Class of service

CoS

Speed

MVNO capacity

Substitution

Latency

Access VNO

On-demand

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



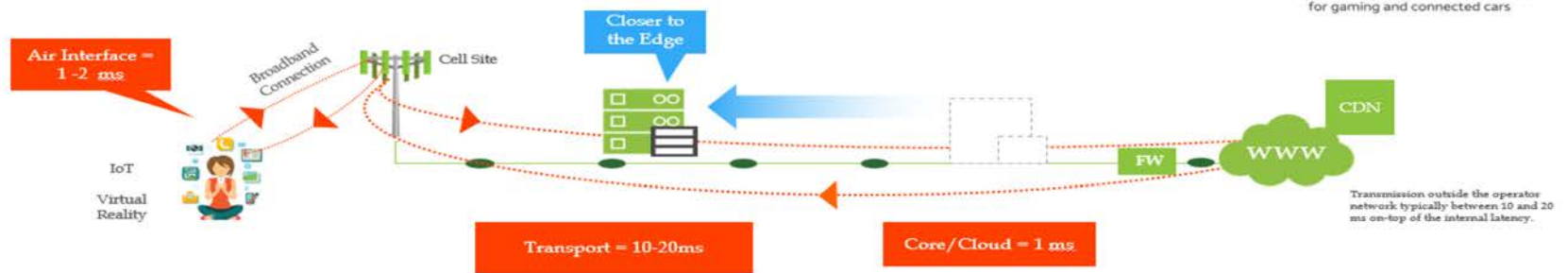
Edge Computing Value: Latency, Bandwidth Cost

The Importance of Latency



Sample 5G network - latency is dependent on distance of transport

Ultra-Low Latency
Support real-time applications used for gaming and connected cars



With 5G wireless networks can achieve latency of 2-3ms before transport.
Decreasing transport latency requires moving the core compute and cloud interface closer to the customer.

With the latency of 4G network, a car driving at 100 km/h still moves 1.4 m from the time it finds an obstacle to the time when the braking command is executed. Under the same condition, with the latency on a 5G network, the car will move just 2.8 cm, and this performance is comparable with the standard of an anti-lock braking system (ABS).

-Huawei

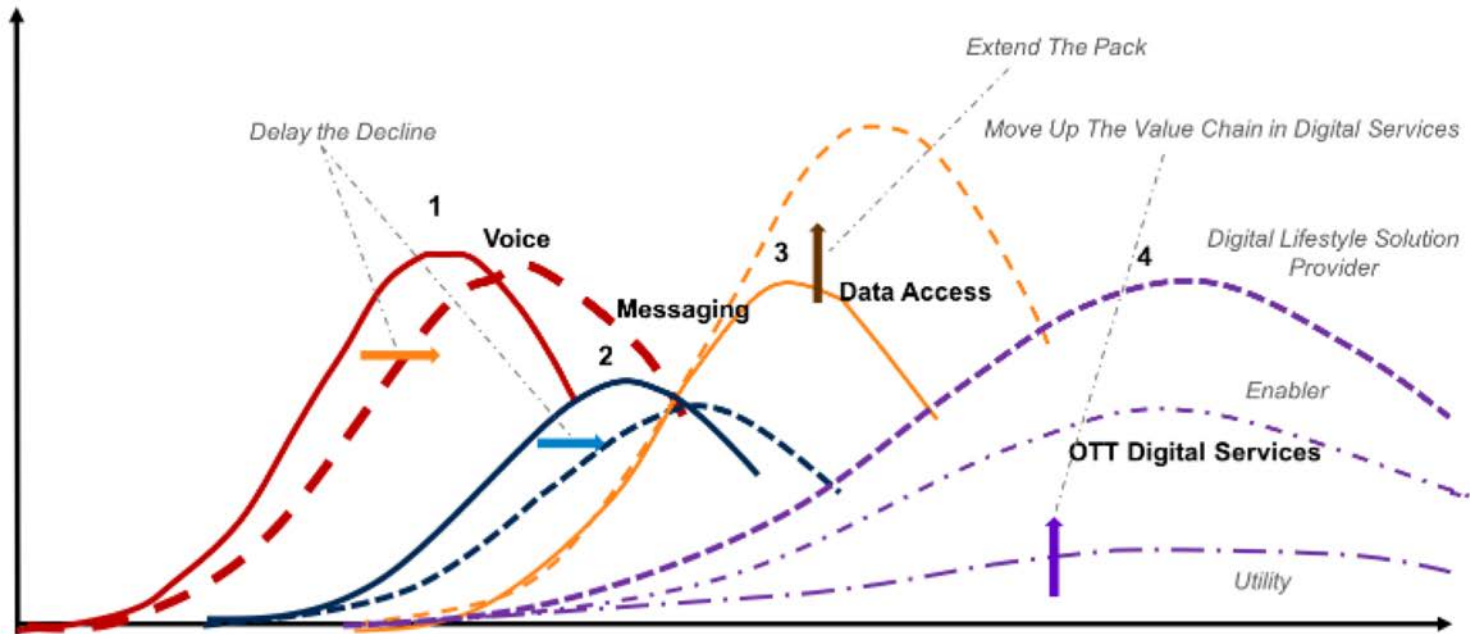
4G link latency 50 ms to 70 ms

5G link latency 1 ms to 2 ms

[source: DataBank](#)



Replace Half of Revenue Every 10 Years

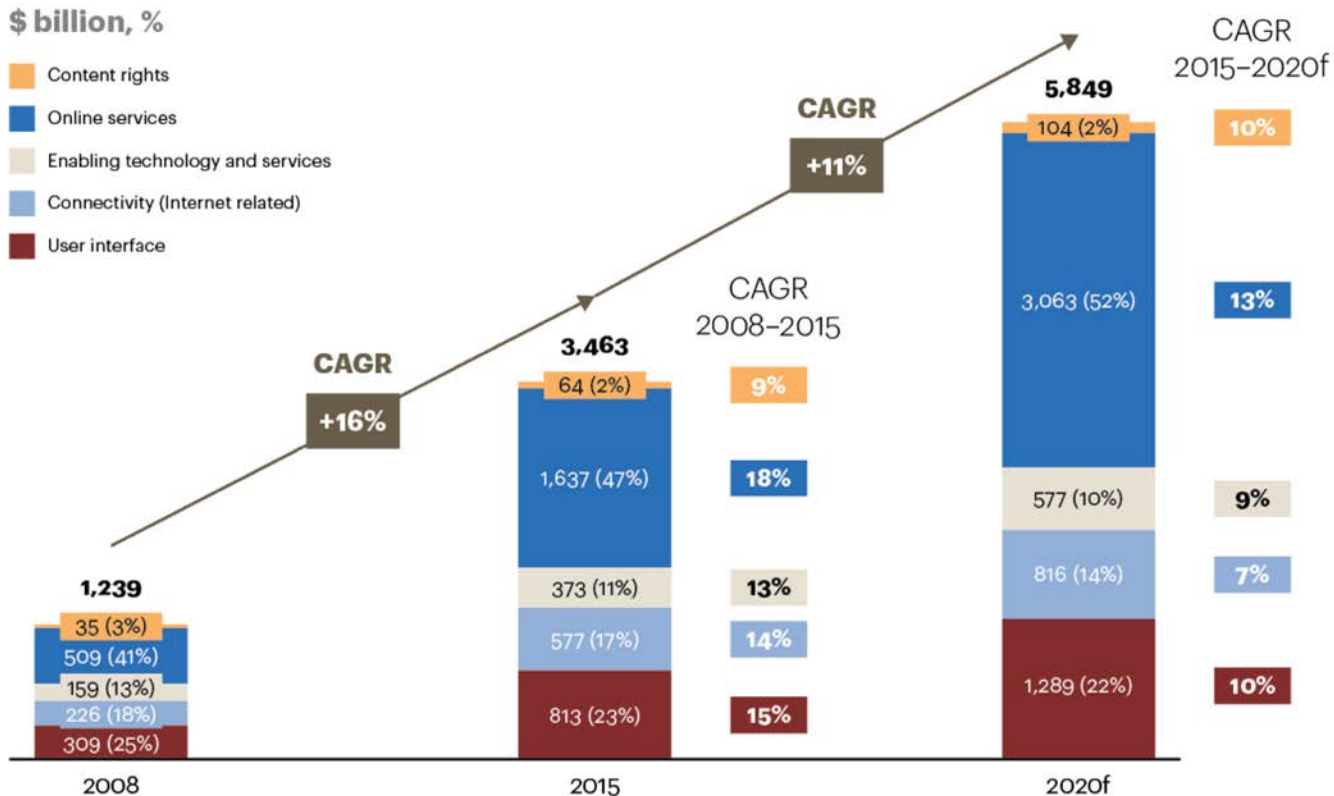


[source: Turk Telecom](#)



“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 (millions)	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 (millions)	High (500-1000 t/hr)	High	Frequent	Moderate Tolerance
Smartphone Users	High (millions)	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

Licensed spectrum

Exclusive use
Over 40 bands globally for LTE



Shared spectrum

New shared spectrum paradigms
Example: 2.3 GHz Europe / 3.5 GHz USA



Unlicensed spectrum

Shared use
Example: 2.4 GHz / 5 GHz / 60 GHz global

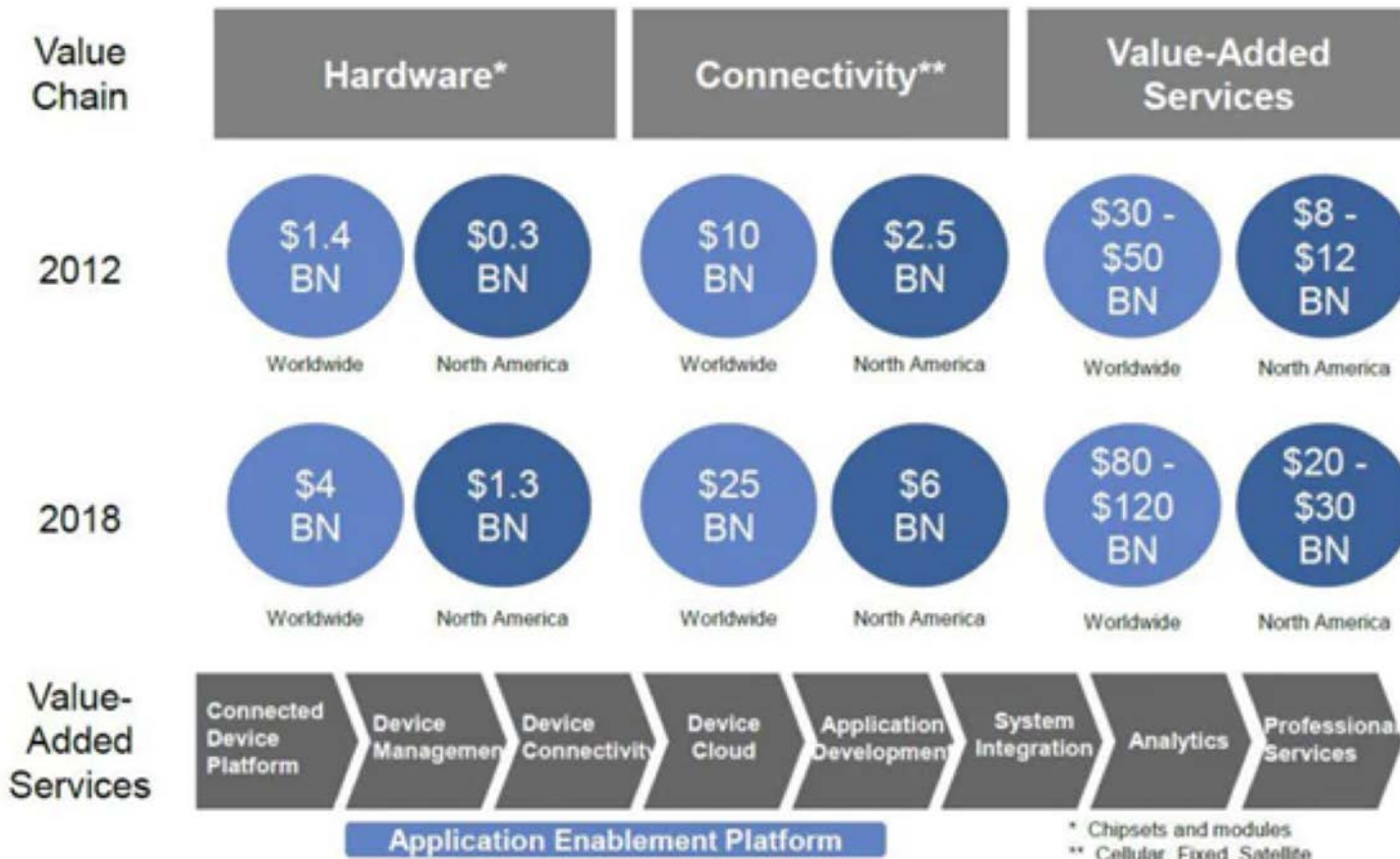


- Citizens Broadband Radio Service
- TV White Spaces
- Licensed Assisted Access
- Licensed Shared Access



Most of the Upside is Apps

Figure 23 : M2M/IoT Value Chain – Projected Revenues



* Chipsets and modules
 ** Cellular, Fixed, Satellite

Source: ABI Research

Market Realist®

[source: ABI Research](#)





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