5G:
Why Do You Care?

Gary Kim
IP Carrier
gary@fatpipes.biz

Mobile Drives Global Subscriptions

Global ICT developments, 2001-2017*

- Mobile-cellular telephone subscriptions
- Individuals using the Internet
- Fixed-telephone subscriptions
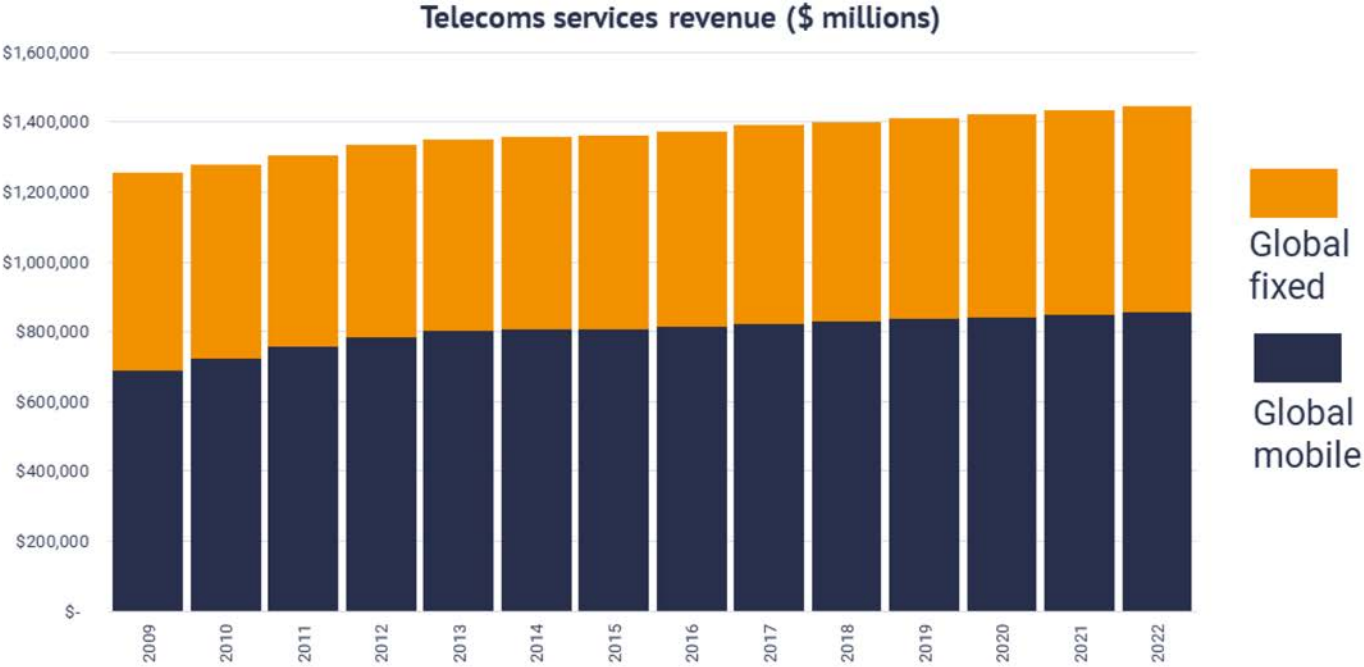- Active mobile-broadband subscriptions
- Fixed-broadband subscriptions
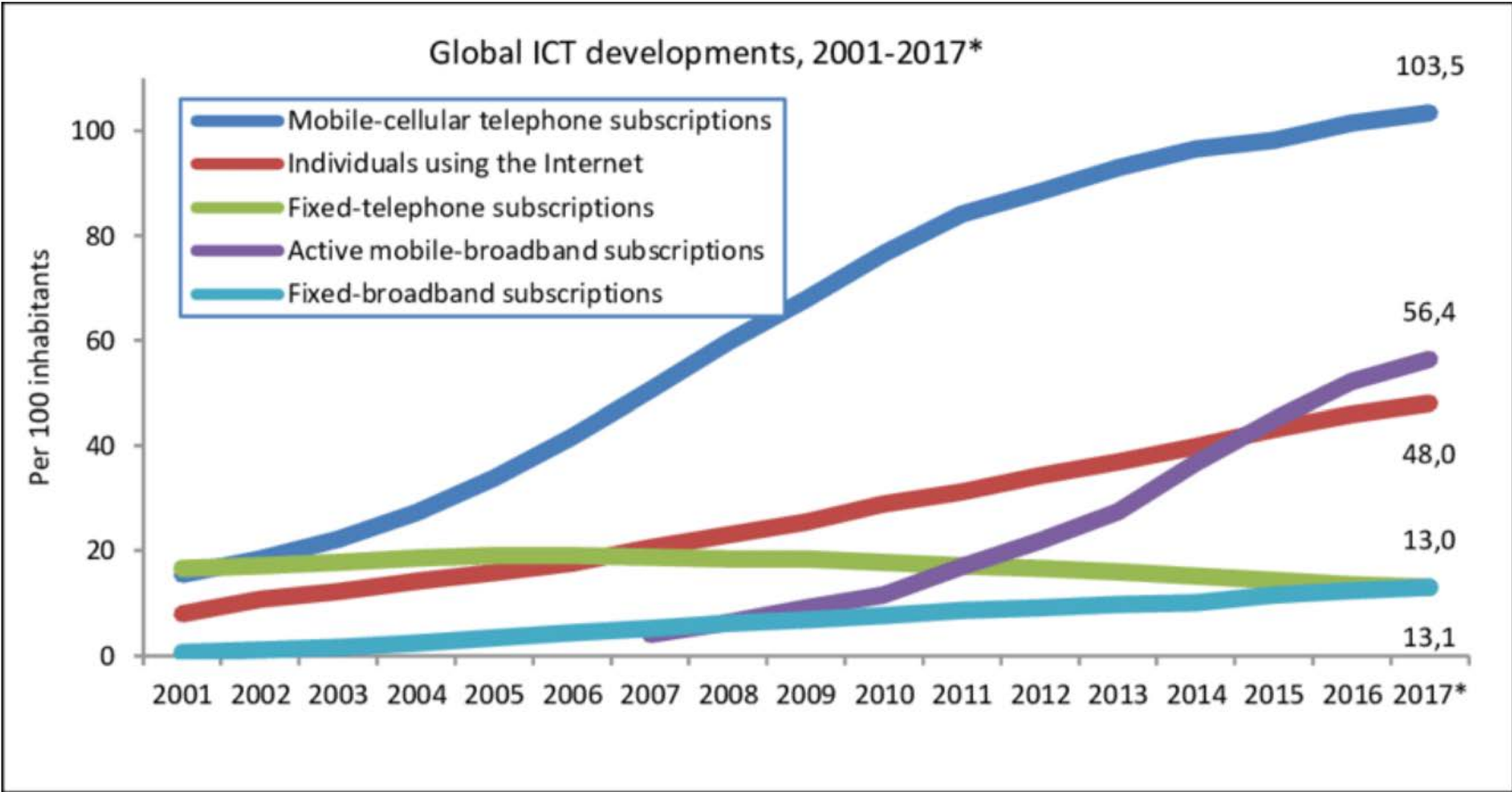
source: ITU

Mobile Drives Revenue Globally

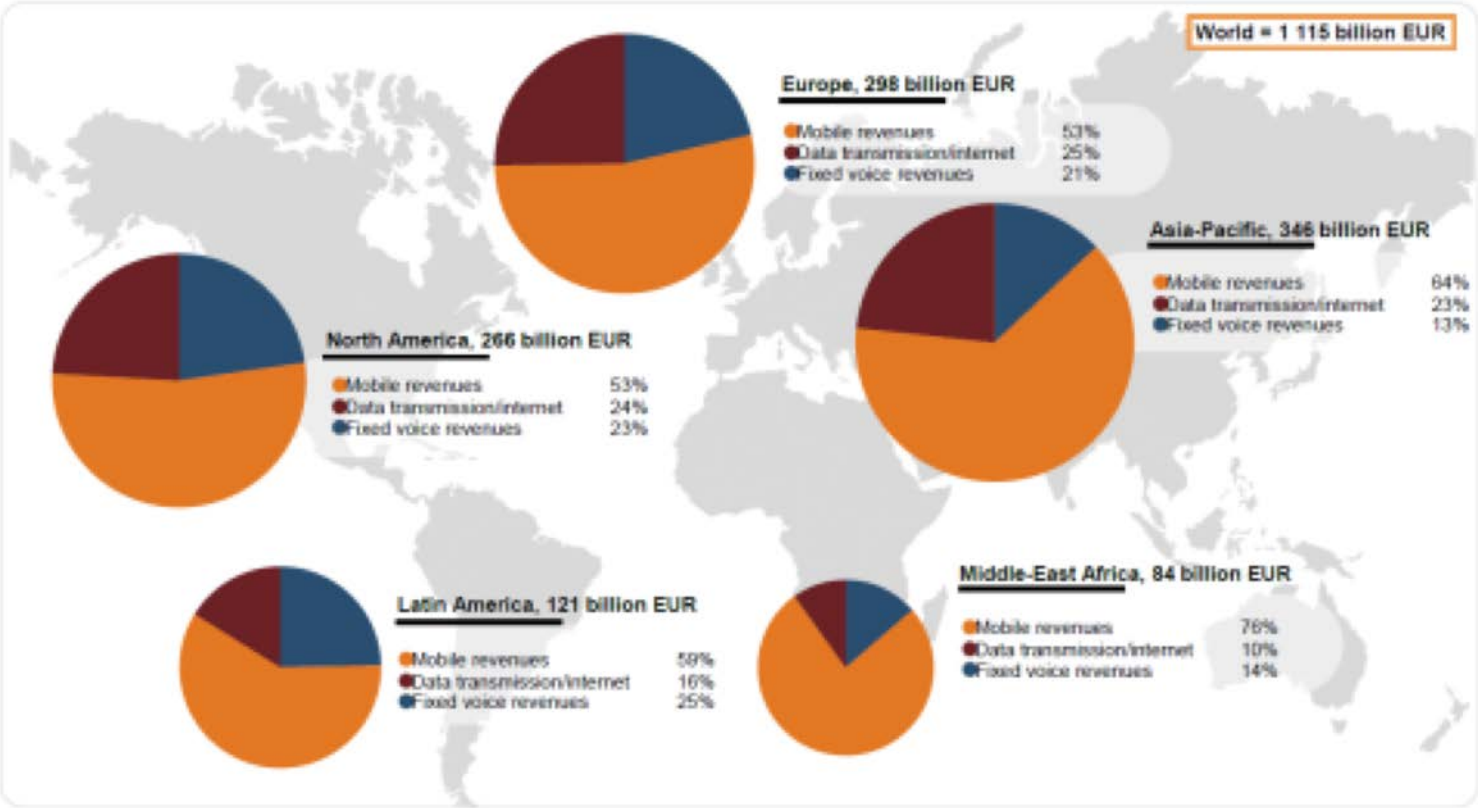**STL Partners forecasts less than 1% per annum growth in both fixed and mobile telecoms services to 2022**

Telecoms services revenue ($ millions)

Legend:
- Global fixed (orange)
- Global mobile (dark blue)

Source: Company accounts; STL Partners analysis and forecasts

STL PARTNERS
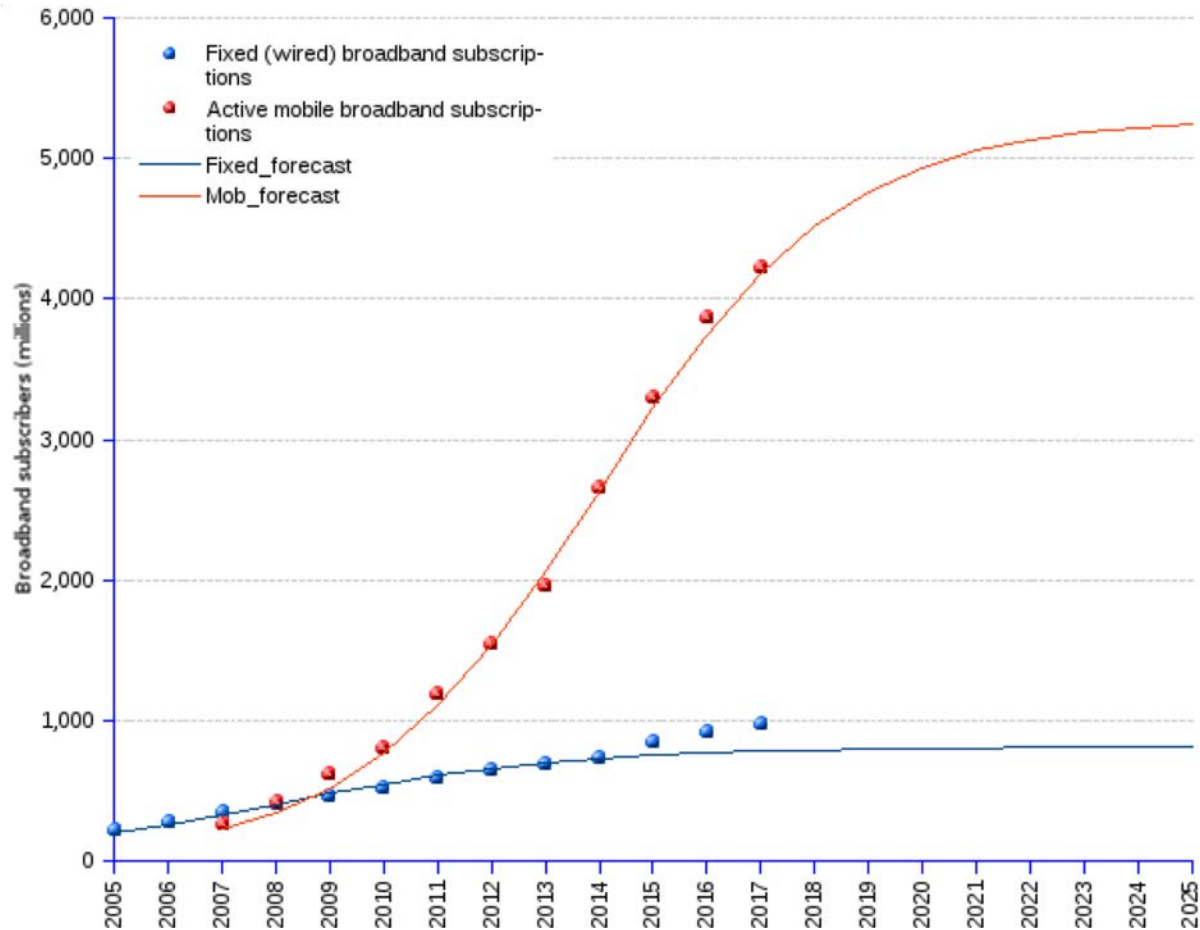
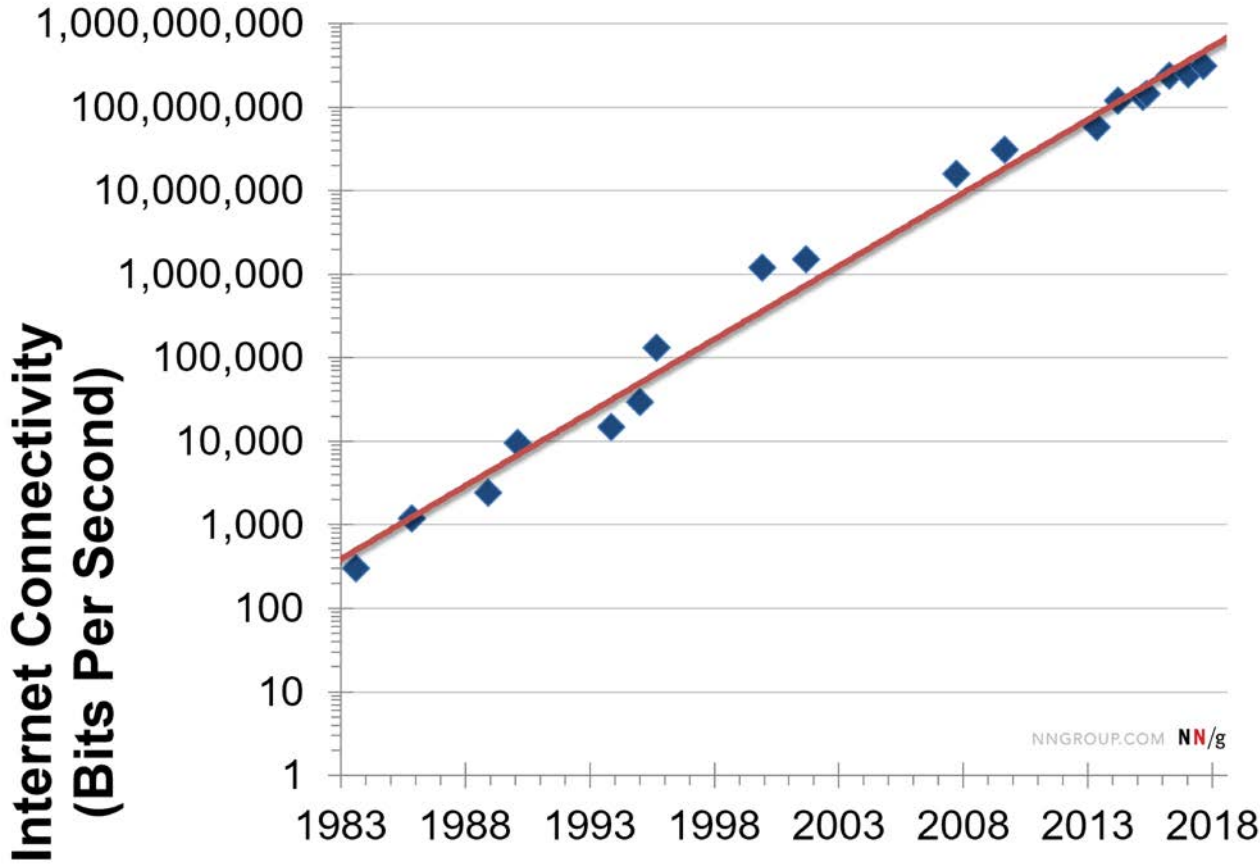source: STL Partners

Mobile Drives Revenue in Asia, Pacific

Mobile Data Drives Subscription Growth

source: ITU

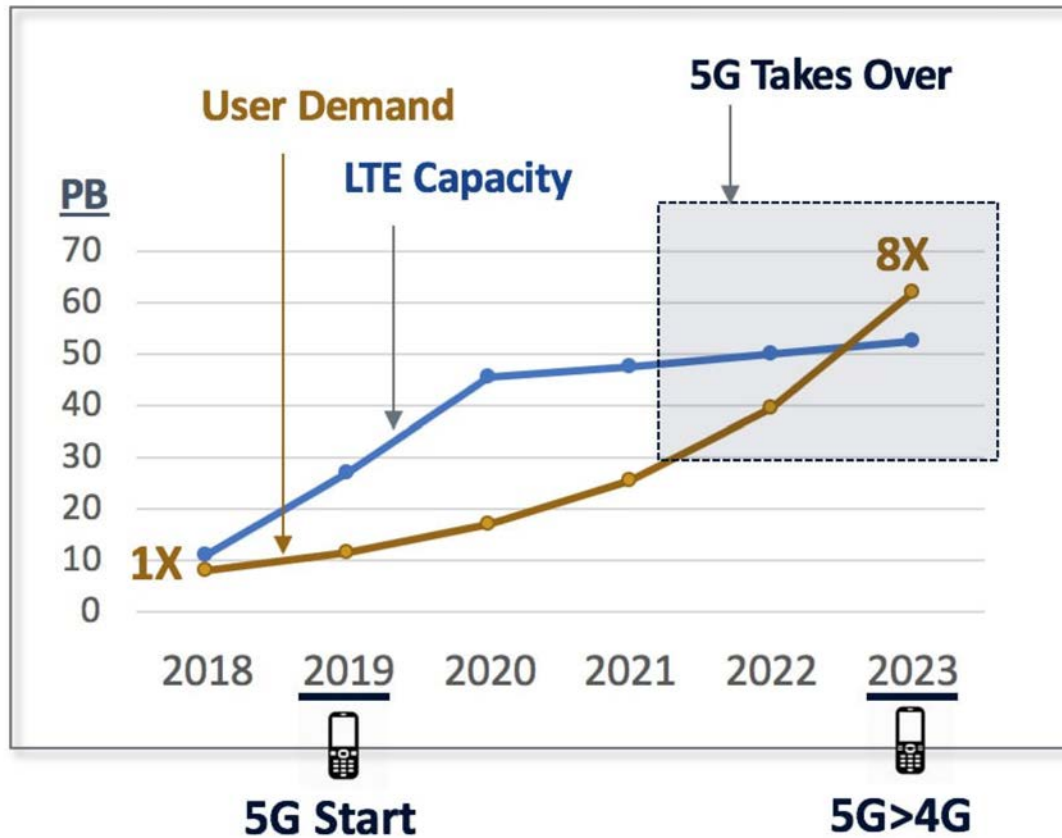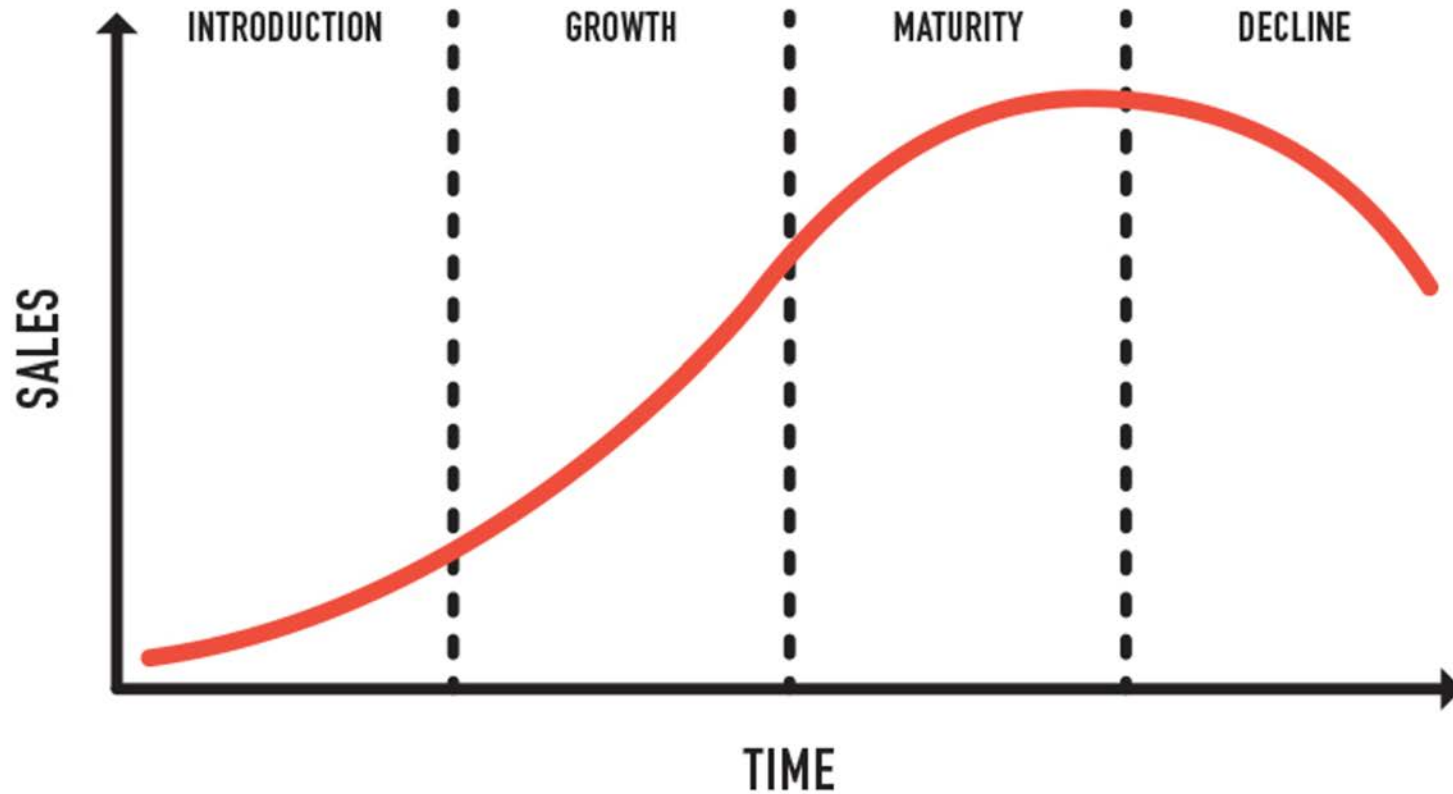# Capacity Demand Grows 50% Per Year

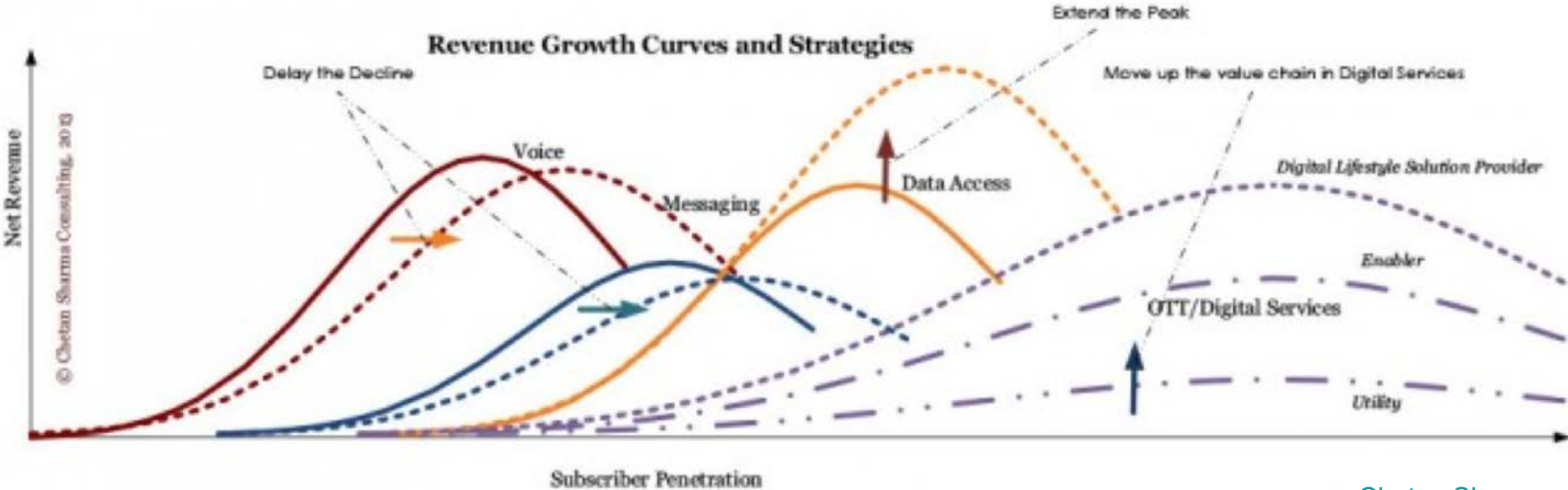source: Nielsen Norman Group

4G Capacity Growth Cannot Keep Up

source: Nokia

All Products Have a Life Cycle

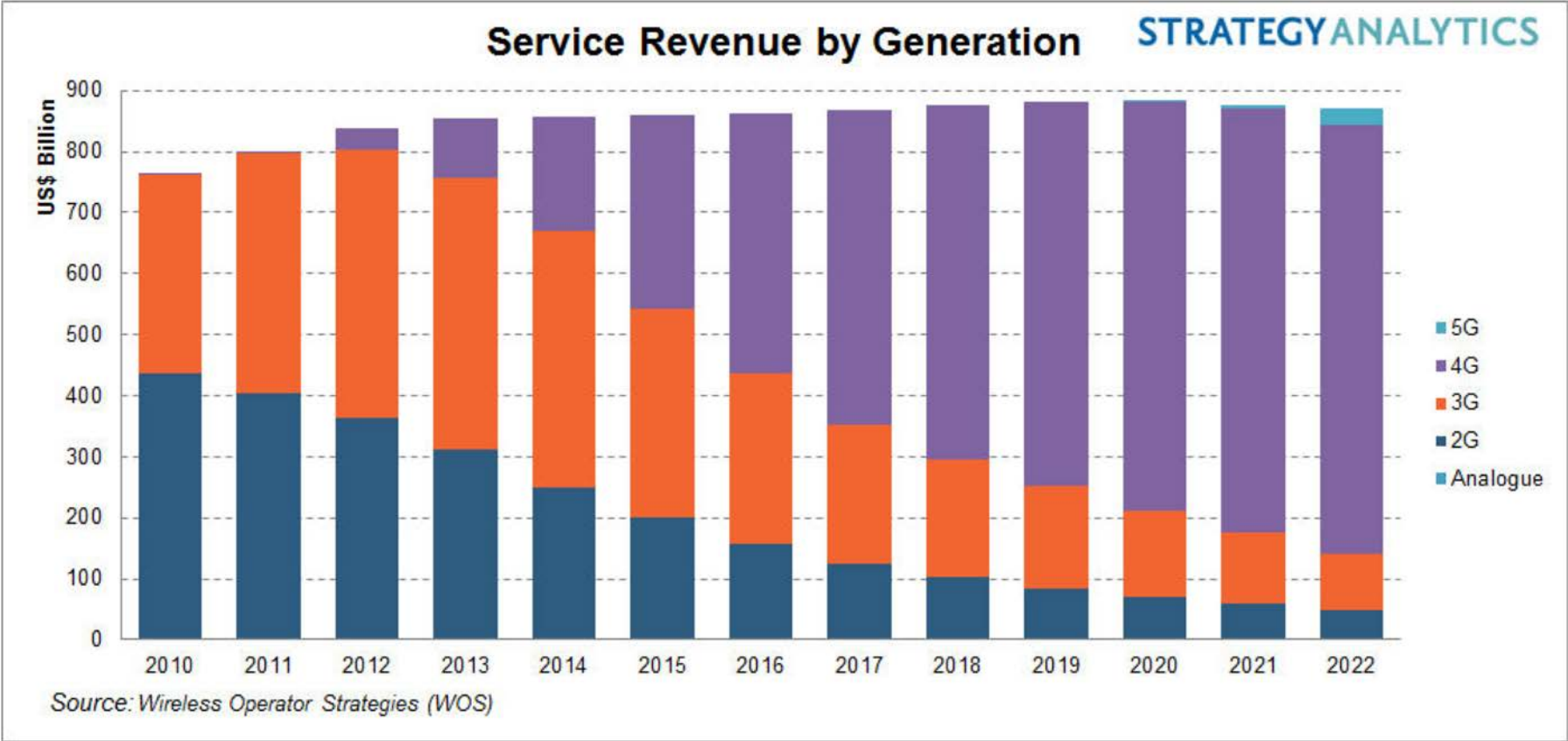# Mobile Products have Life Cycles

source: Chetan Sharma
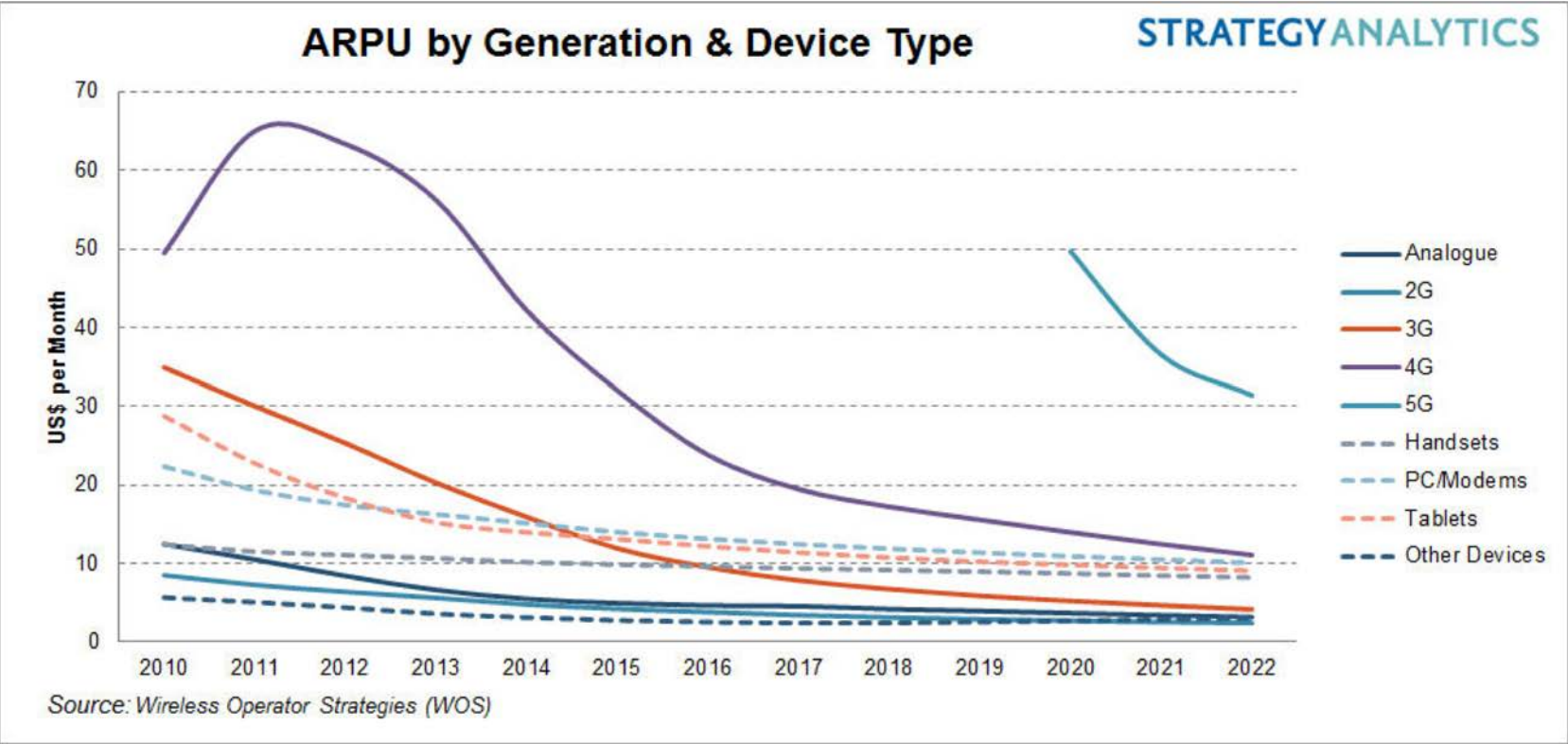
Mobile Generations Have Life Cycles

Service Revenue by Generation — STRATEGY ANALYTICS

Source: Wireless Operator Strategies (WOS)

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)

Service	Percentage
Existing data services	96%
New consumer services	39%
Existing enterprise services	32%
New developer services enabled by edge computing	19%
New enterprise services	18%
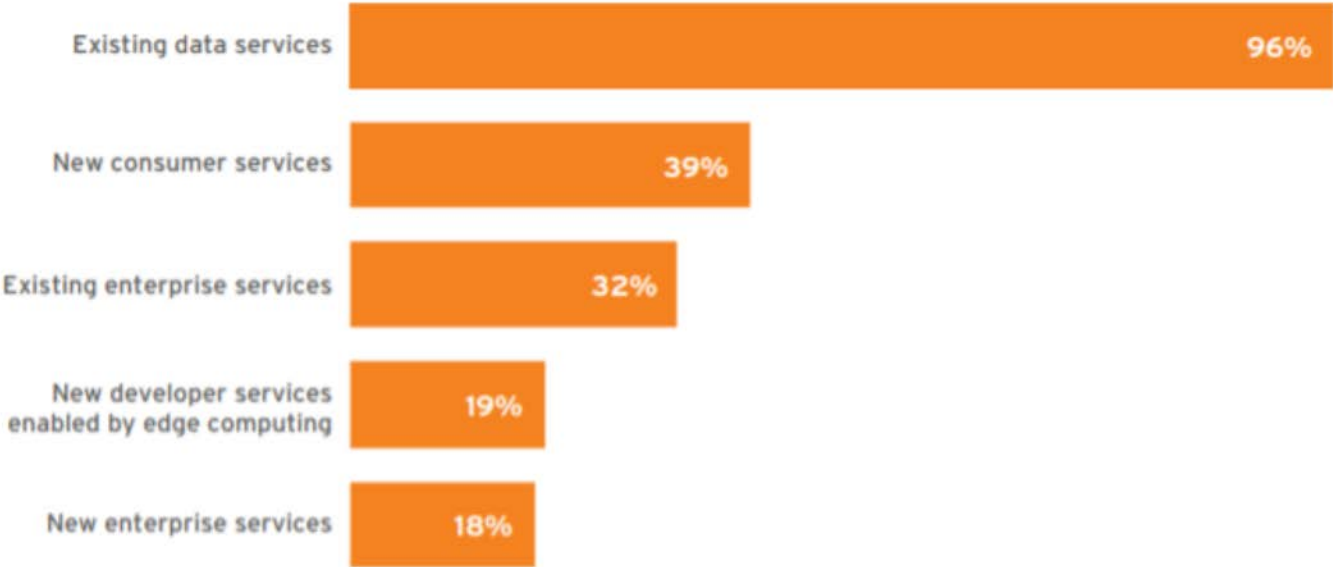
source: 451 Research

4G Congestion

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

Chart 1

3am: few users awake, fastest 4G speed of 22.1 Mbps experienced

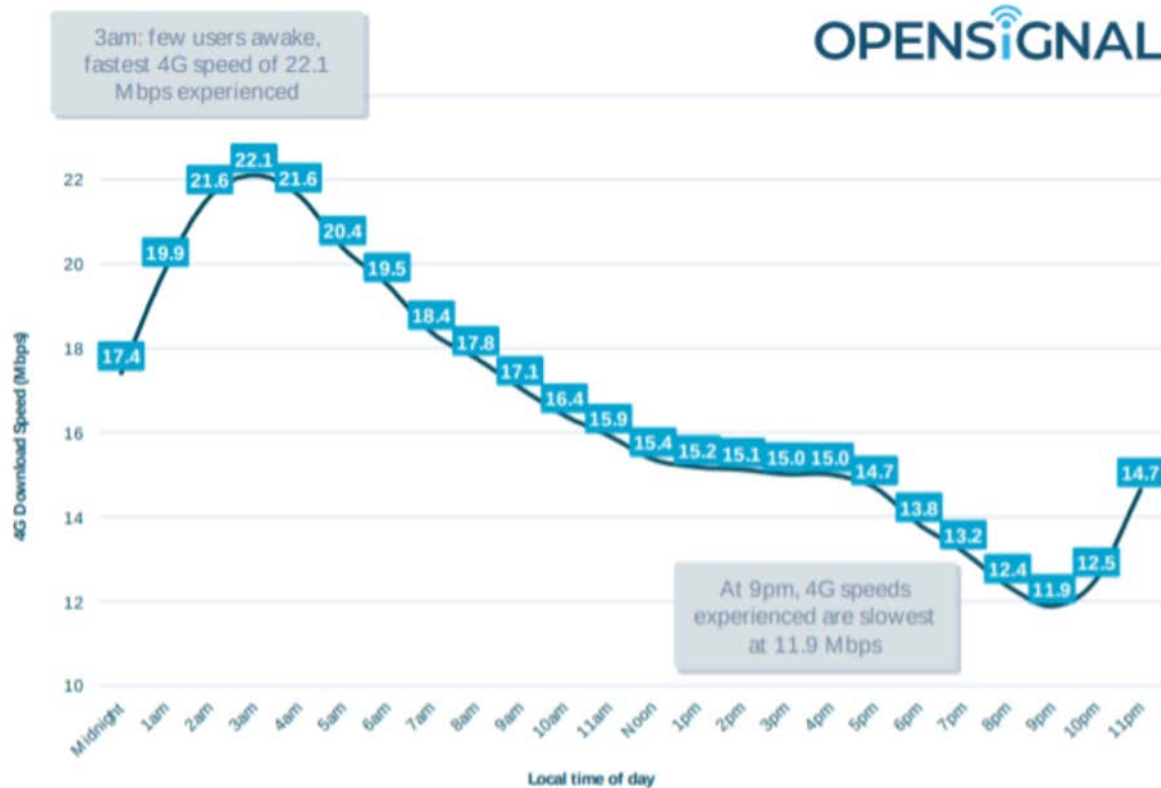OPENSIGNAL

At 9pm, 4G speeds experienced are slowest at 11.9 Mbps

4G Download Speed (Mbps)

Local time of day

5G is Coming, on Schedule

EVOLUTION OF CELLULAR NETWORKS
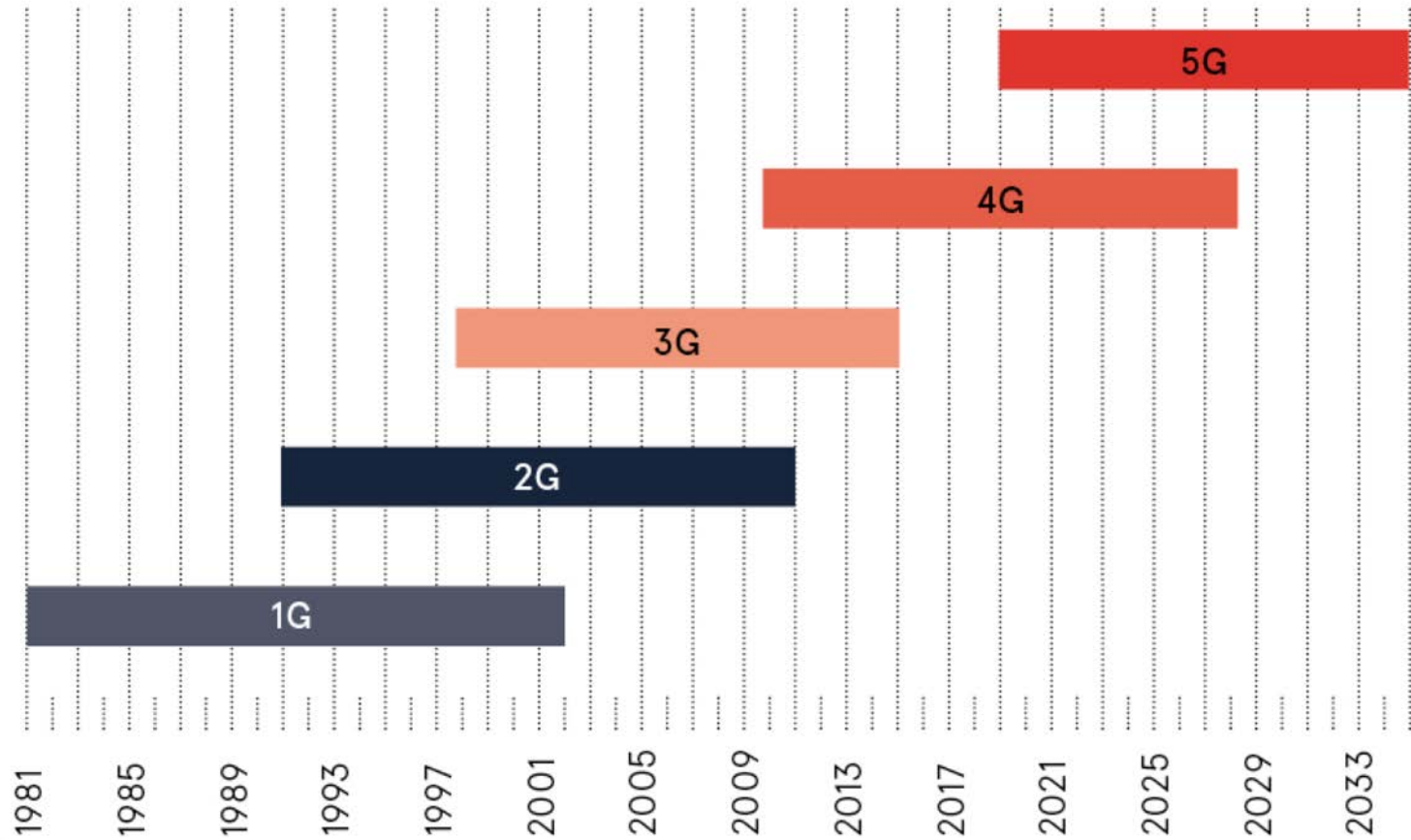
4G Revenue Upside Limited

Annual growth in mobile operator revenues is tending to 1% in Asia Pacific, North America and Western Europe
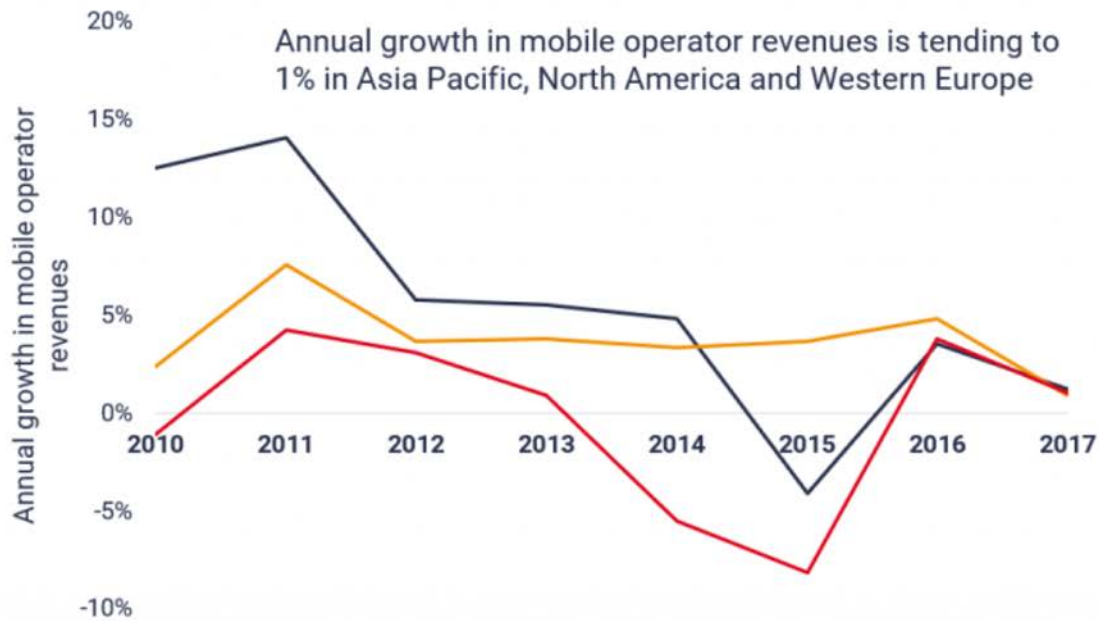
Region	Compound annual rate of change (mobile revenues)	
	8 year (2009-17)	4 year (2013-17)
Asia Pacific	5%	1%
North America	4%	3%
Western Europe	0%	-2%

source: STL Partners

Performance Demands Keep Increasing

source: Tech In

source: Signal Booster

5G Builds on 4G
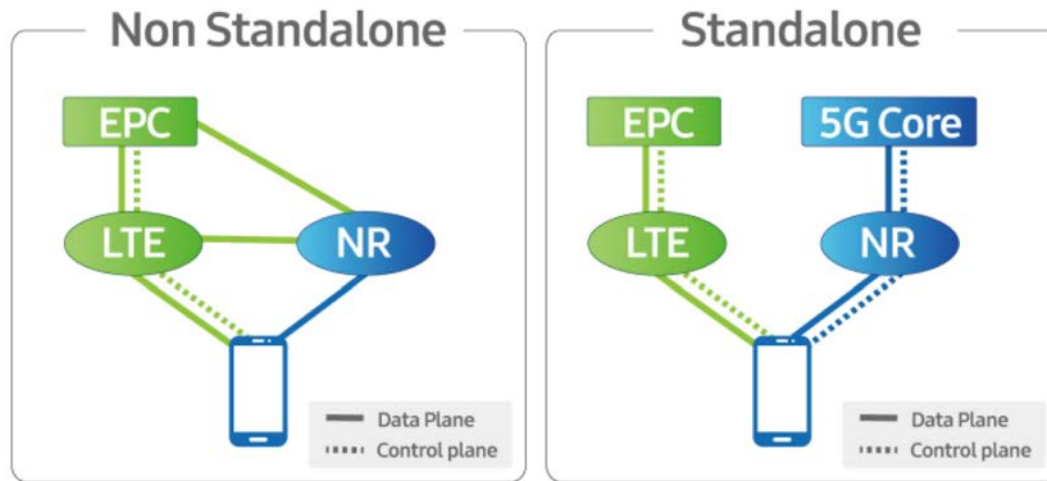
Figure 11 : How NSA and SA work

source: Test and Verification
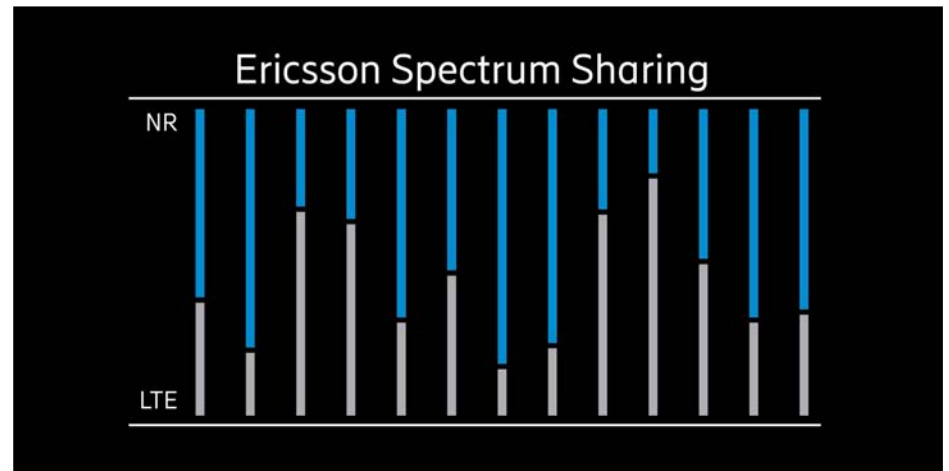
source: Ericsson

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

Spectrum

1 New spectrum

New <800 MHz bands (such as new coverage bands for IoT[1])

New >3GHz bands (such as those for small-cell deployment in urban areas)

+ Unlicensed or secondary-license access

RAN[2] infrastructure

2a Macro-network densification and layer upgrades (legacy network evolution)

MIMO[3]

New sites (macro densification)

- Single data rate, SON[4] features
- Network slicing to support 5G applications

2b Small-cell (outdoor) and indoor densification

Hyper-dense deployments

Centralized RAN, fiber to the antenna (FTT-A), and mmWave backhaul

Advanced indoor distributed antenna system

4 Core and features

SaaX,[5] network-functon virtualization, ultra SON analytics

Separation of C-plane vs U-plane

Network slicing

Transmission

3 Increased fiberization

80 to 100 percent backhaul fiberization

New technologies Fiber to the site FTT-A (Cloud-RAN) mmWave backhaul

Growth from "Non-Human" Users…

Connected devices (billions)
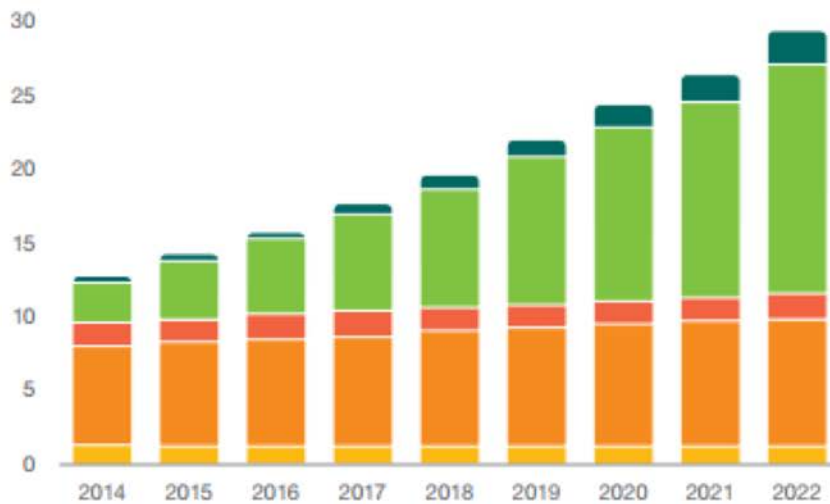
		2016	2022	CAGR
🌐	Wide-area IoT	0.4	2.1	30%
⌚	Short-range IoT	5.2	15.5	20%
💻	PC/laptop/tablet	1.6	1.7	0%
📱	Mobile phones	7.3	8.6	3%
☎	Fixed phones	1.4	1.3	0%
		16 billion	29 billion	

source: Ericsson

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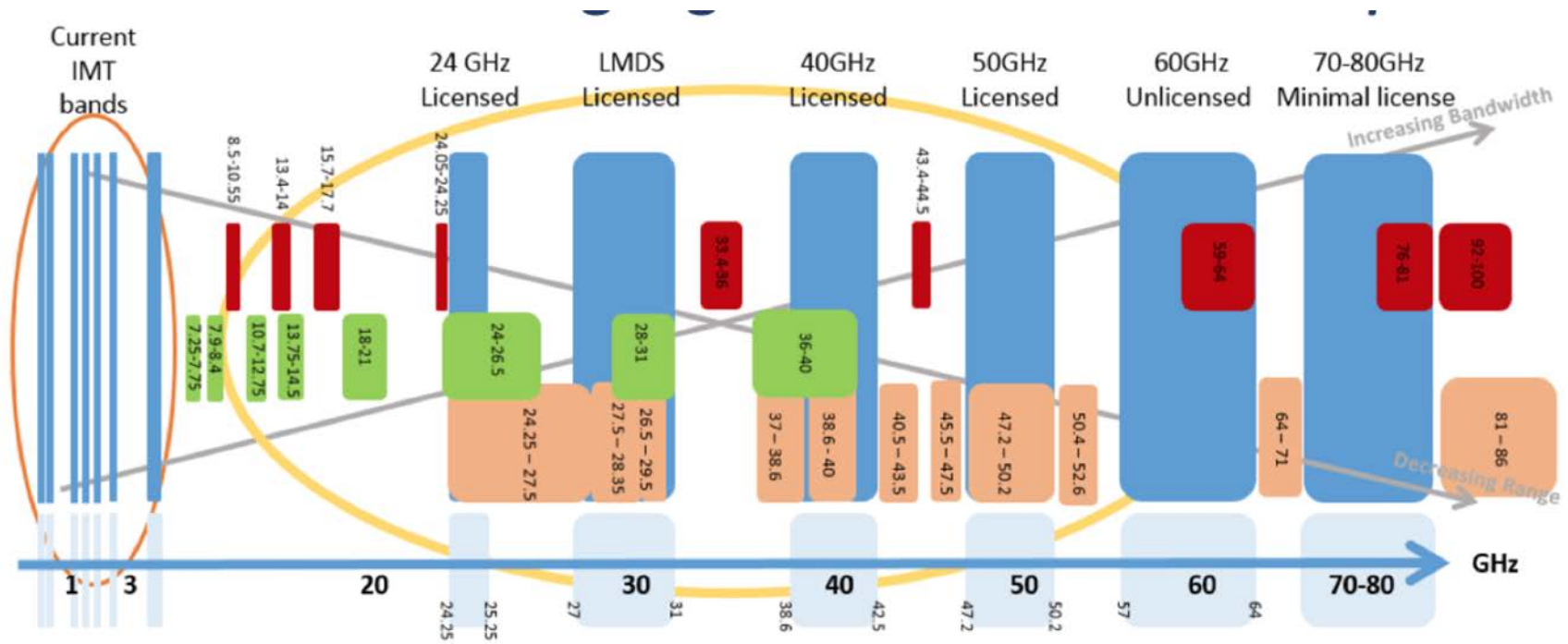
source: Anokiwave orange FCC release, red/green already license to other uses. Blue shows potential mobile spectrum

Capacity Scarcity Has Been the Norm

	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

Cellular frequencies, 1980-2040 (logarithmic scale)
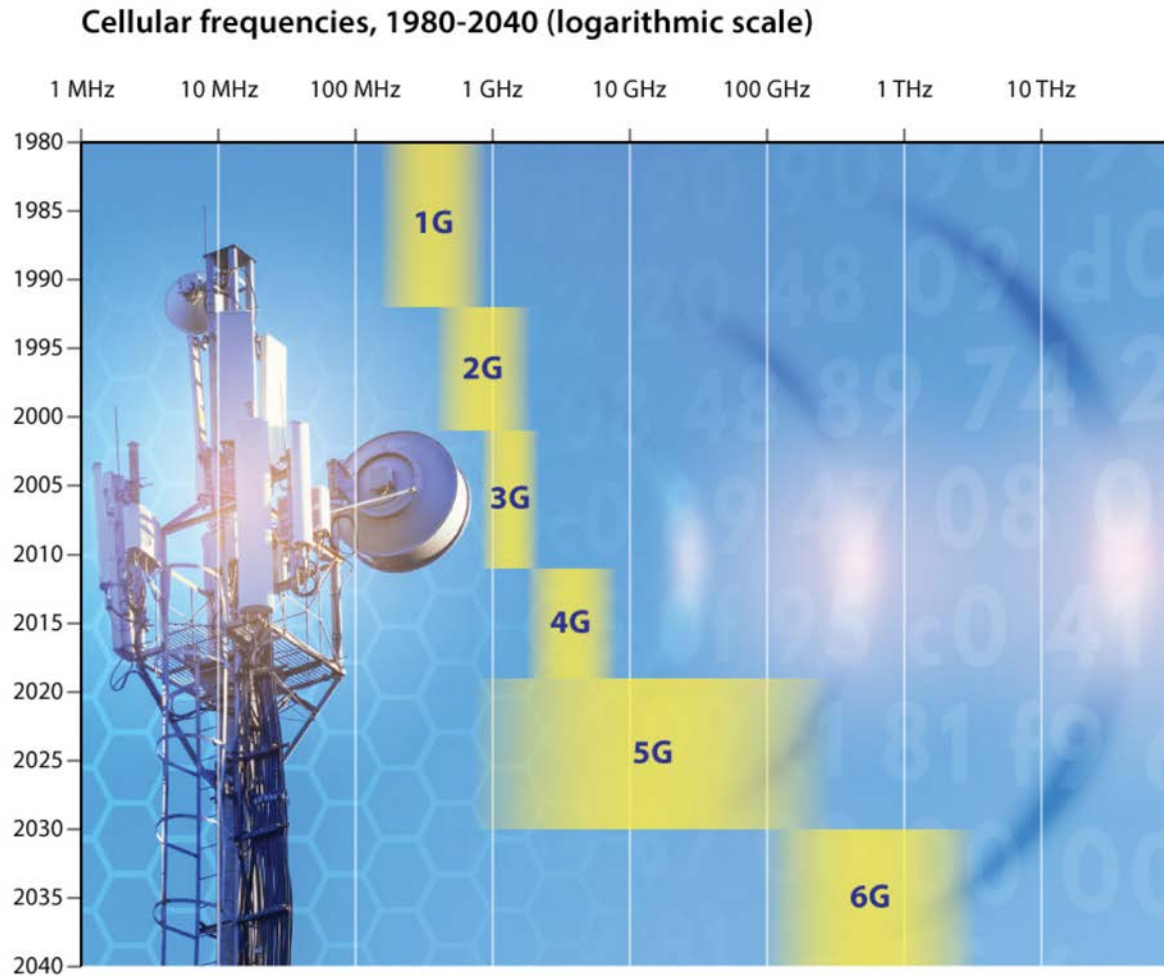
source: FutureTimeline.net

Orders of Magnitude Difference
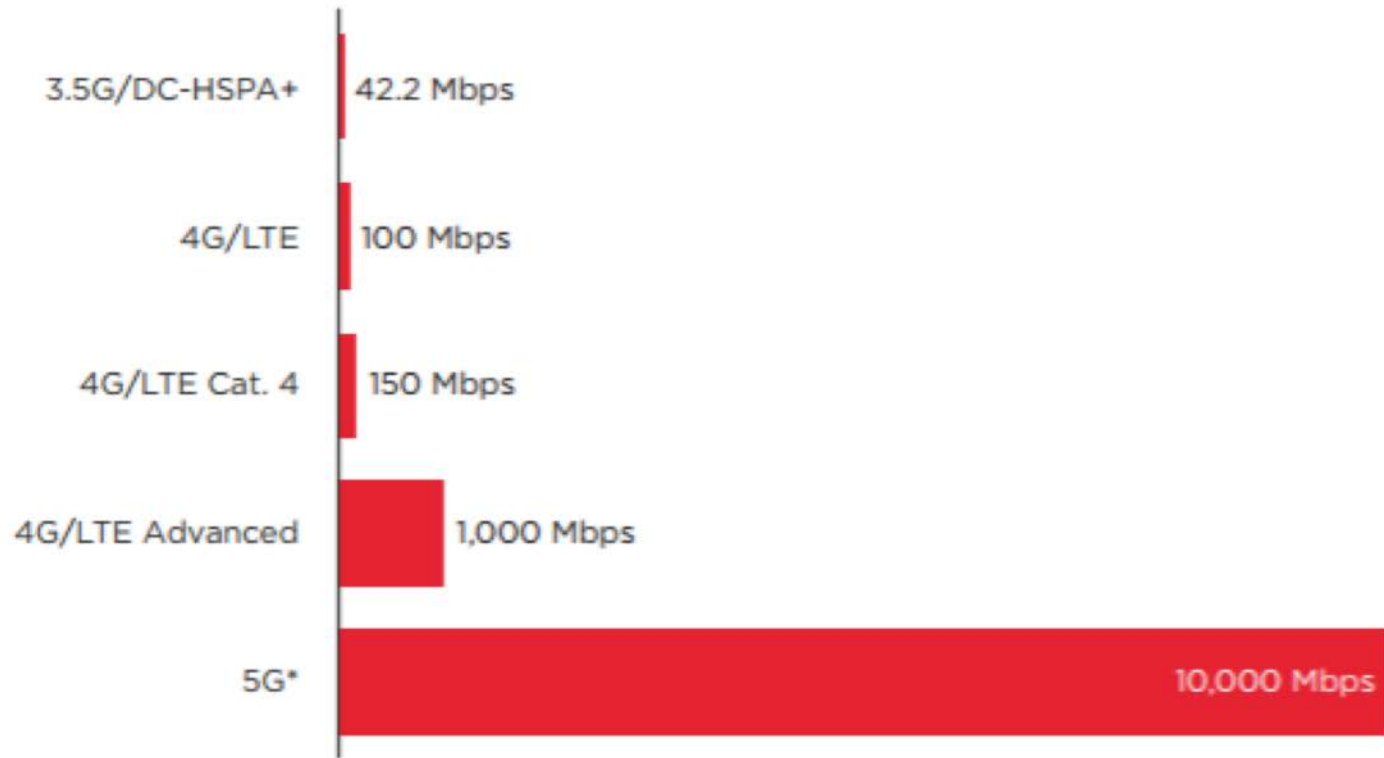
source: gsmaintelligence.com

Latency Advantages Drive Most New Use Cases
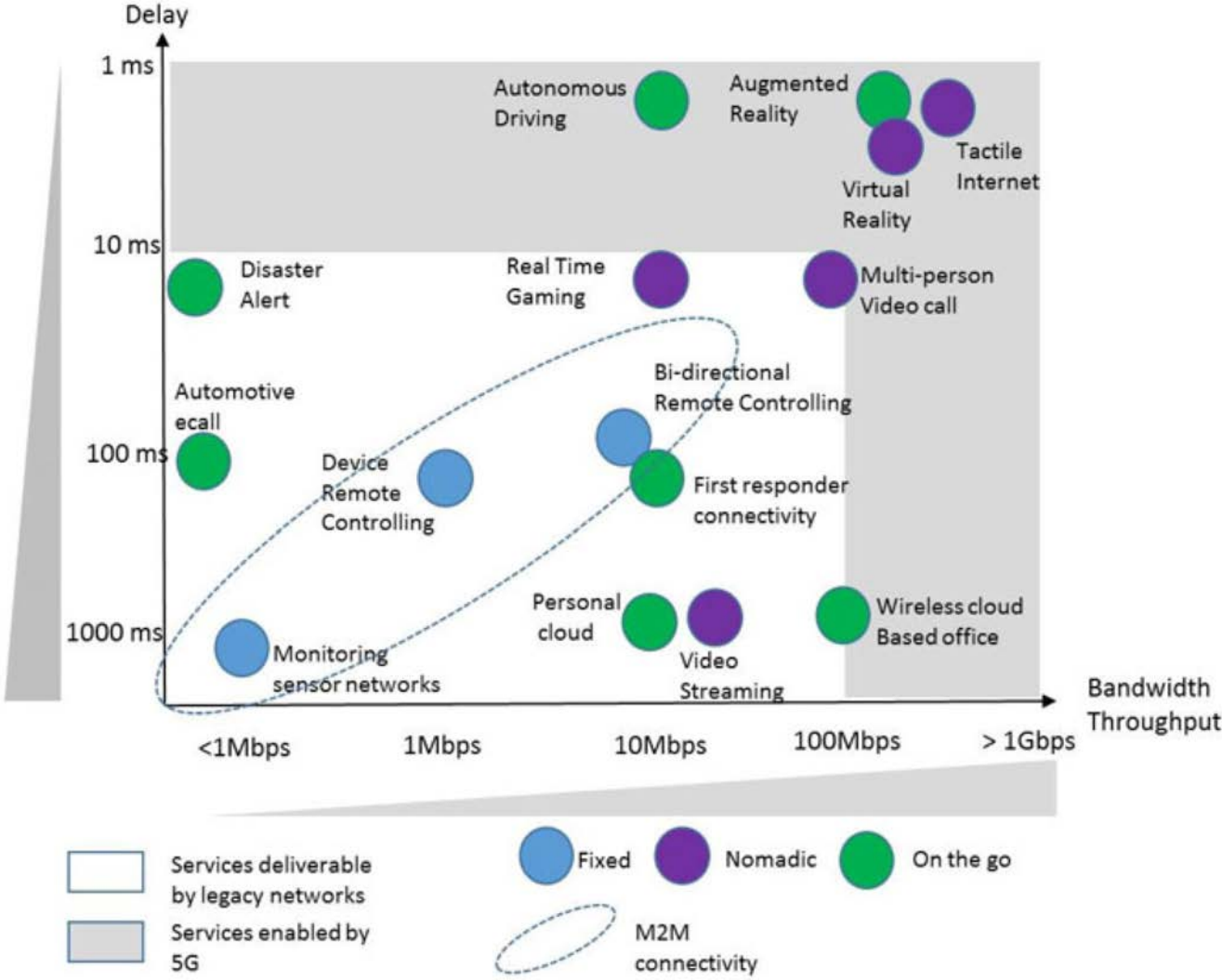
Source: GSMA

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.

CBINSIGHTS   Source: WinSystems

source: CB Insights
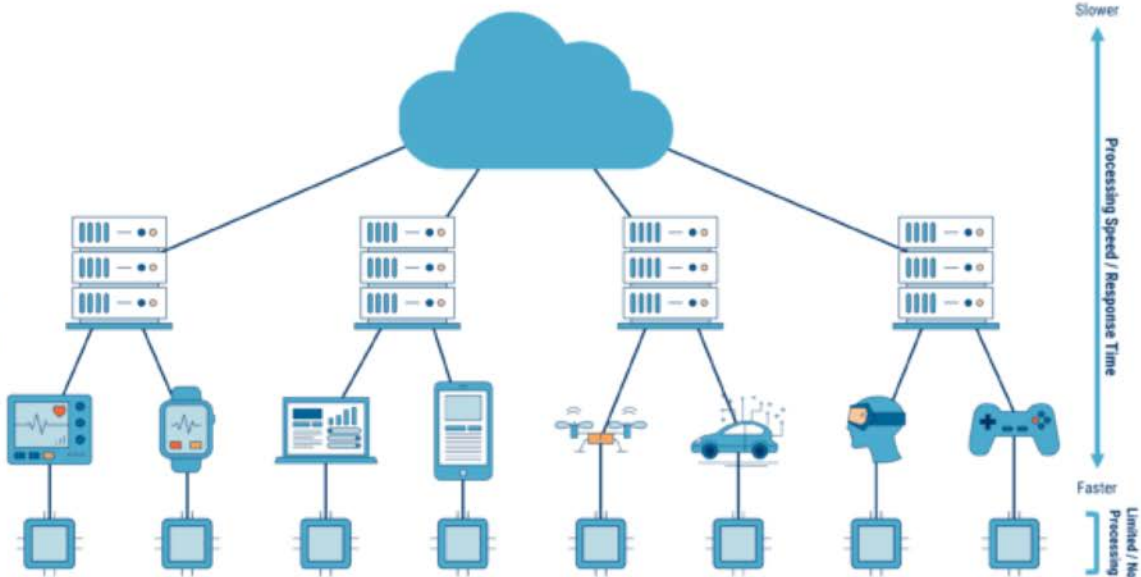
5G and Mobile Edge Computing

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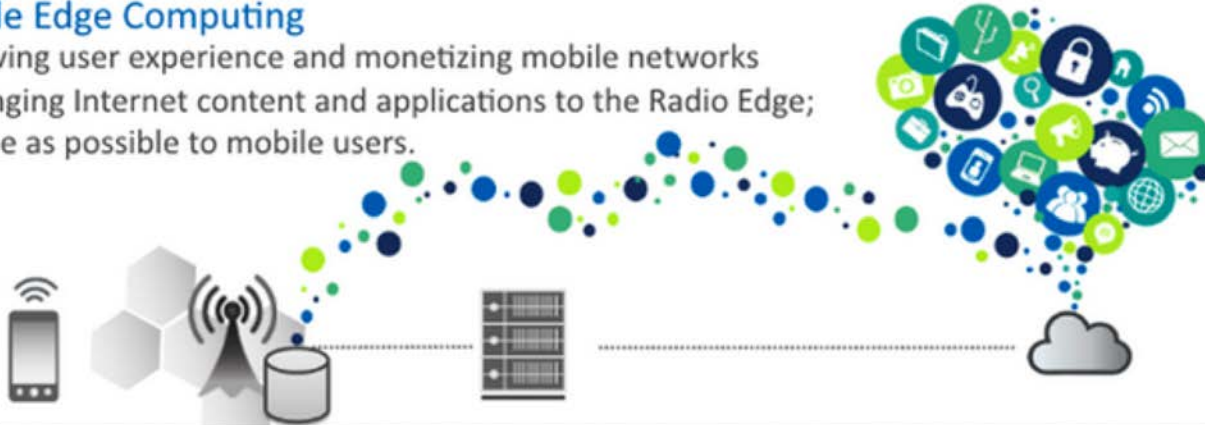
Both latency and bandwidth cost are use cases for mobile edge computing

Comparison of Total 3-year Management & Processing Costs of Cloud-only vs. Edge + Cloud with 95% Edge Data Reduction (200 Miles Distance)

Cloud + Edge Computing is _36%_ of the Cost of Cloud-only Computing when the Reduction in Data Volume is 95%.

$80,531 — Cloud-only

$28,927 — Edge + Cloud

3-year Cost of Managing & Processing IoT Data

Source: © Wikibon IoT Project. Reference Models AWS IoT Service & Pivot3 Server SAN. Assumtion Edge reduces IoT Traffic by 95%.
See Table 1 for Detailed Assumptions & Calculations

source: Wikibon

5G Shift to Enterprise

Where will new operator revenues in 5G come from?

	Most Important	2	3	4	Least Important
Enterprises (e.g. B2B, B2B2C)	69%	20%	3%	6%	3%
Consumers (e.g. B2C)	23%	31%	34%	9%	3%
Online (e.g. A2P)	17%	17%	40%	17%	9%
Governments (e.g. B2G, B2G2C)	14%	26%	40%	17%	3%
Others (please specify)	9%	9%	23%	6%	54%

Source: Survey of 750 operator CEOs (GSMA, Oct 2016)

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
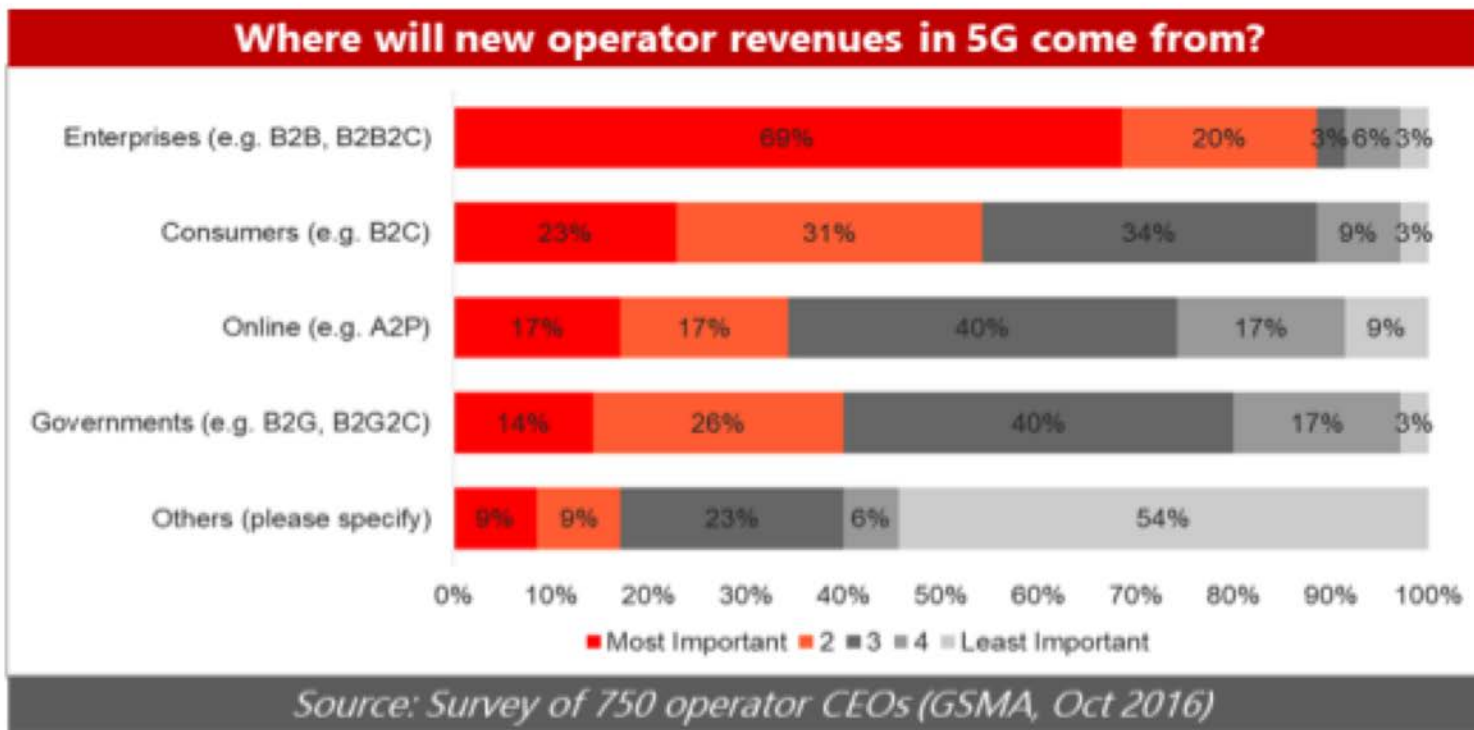
200m cell radius
300m
400m
500m
cost target
1 km

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
% penetration
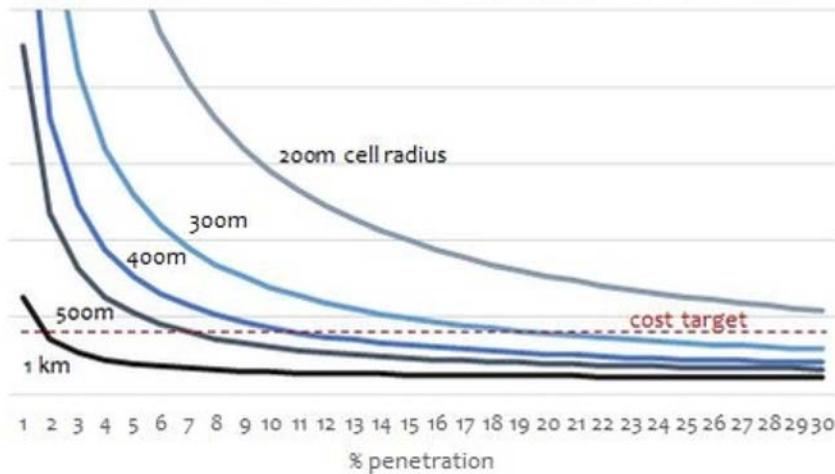
source: Mobile Experts

Cost of Connecting an MDU unit by Technology

$3,179
$1,859
$580

Unit Passed and Connected mmWave | Unit Passed and Connected Fiber (existing) | Unit Passed and Connected Fiber (new)
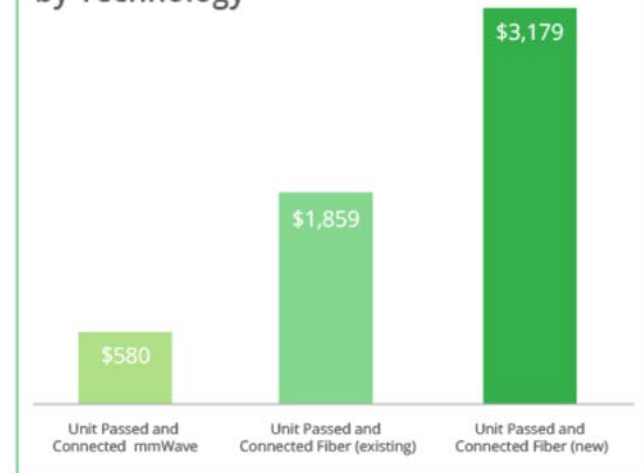
Source: White paper: 5G Fixed Wireless Gigabit Services Today- An Industry Overview

source: Siklu

Share of Value in 5G Era?

Figure 10. Payment and retention of customer spend

(wireless industry total in $ billion)

Legend: ■ Carrier ■ Phone devices ■ Non-phone devices ■ Apps and OS
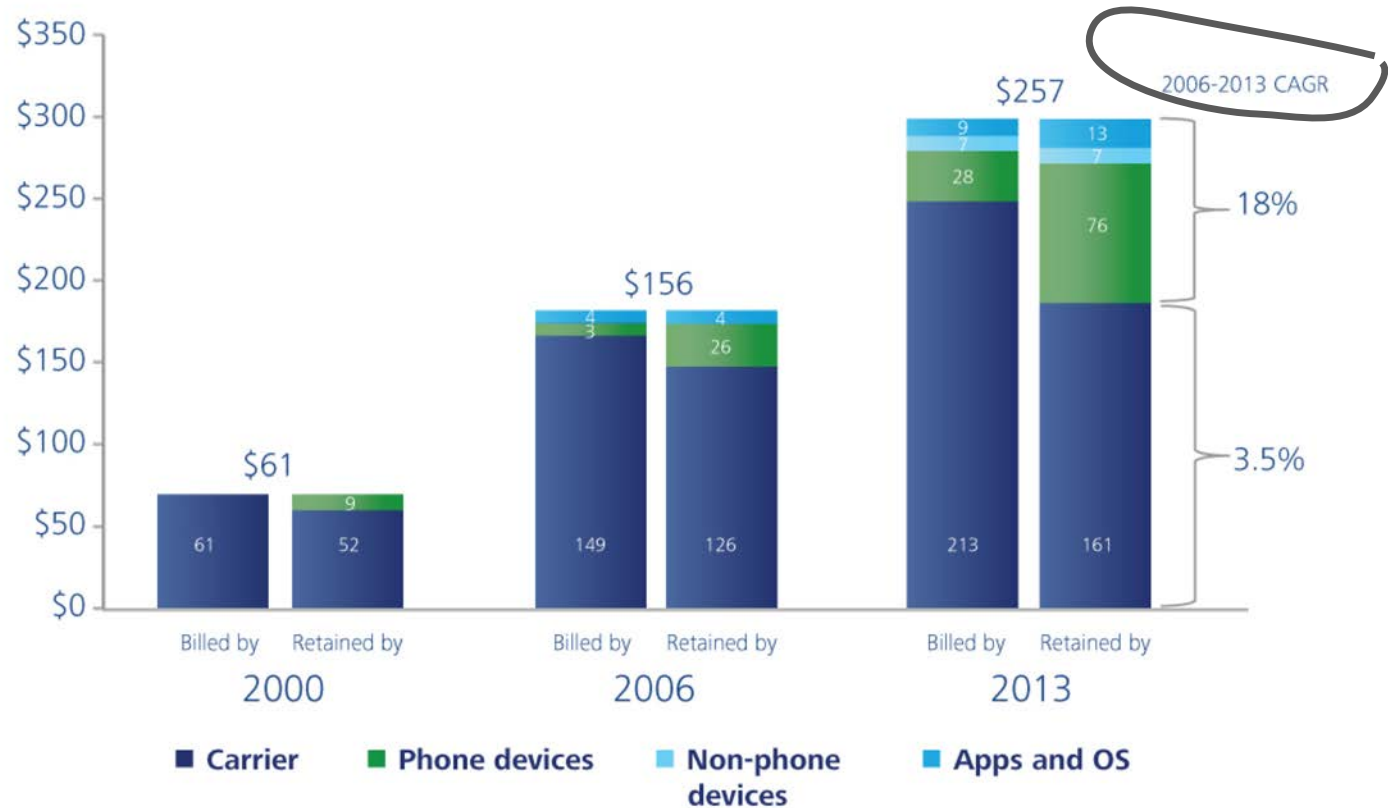
Sources: 2000 annual reports for AT&T, Verizon, Sprint, T-Mobile, USCC; 2006 annual reports for AT&T, Verizon, Sprint, T-Mobile, Alltel, USCC, Motorola, Apple, Google, Microsoft, Nokia, Research in Motion; 2013 annual reports for AT&T, Verizon, Sprint, T-Mobile, USCC, Apple, Google, Microsoft, Nokia, Research in Motion; Deloitte analysis.

source: Deloitte University Press

Graphic: Deloitte University Press | DUPress.com

Network Slicing

Network slicing creates <u>end-to-end virtualized networks</u> 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

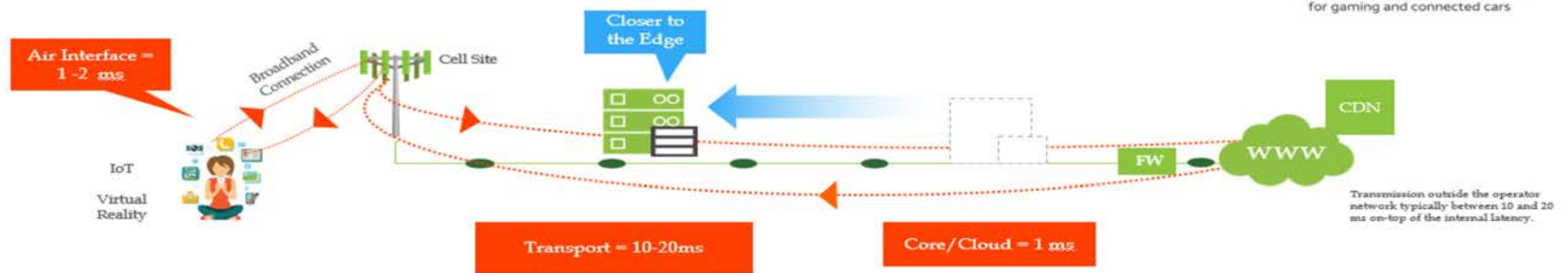IoT

Ultra-low latency

Video, gaming

Edge Computing Value: Latency, Bandwidth Cost

The Importance of Latency

verticalbridge

Sample **5G** network – latency is dependent on distance of transport

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

Air Interface = 1-2 ms

Broadband Connection

Cell Site

Closer to the Edge

IoT
Virtual Reality

CDN

WWW

FW

Transmission outside the operator network typically between 10 and 20 ms on-top of the internal latency.

Transport = 10-20ms

Core/Cloud = 1 ms

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 a 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).
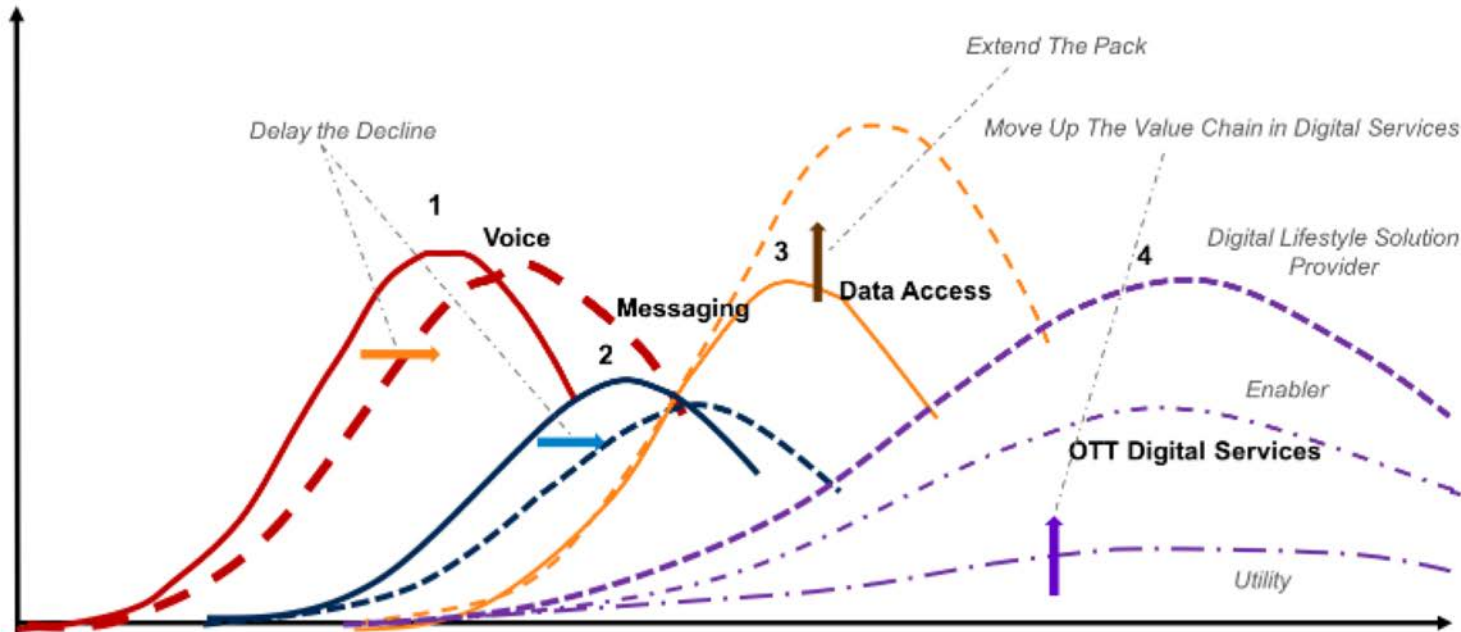
-Huawei

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

source: DataBank
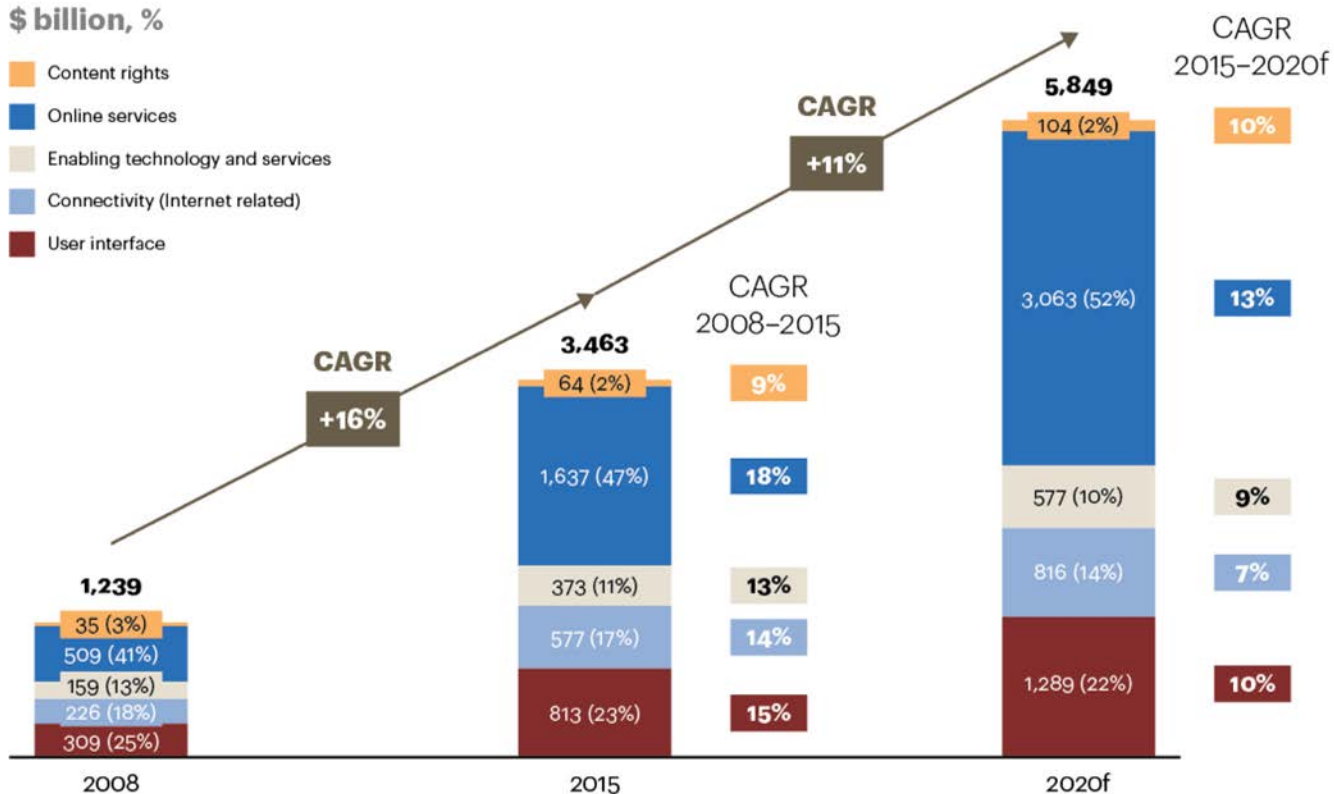
Replace Half of Revenue Every 10 Years

source: Turk Telecom

"Access" CAGR Drops 50% in 5 Years

Internet value chain size and growth by segment

$ billion, %

- Content rights
- Online services
- Enabling technology and services
- Connectivity (Internet related)
- User interface

CAGR +16%
CAGR +11%

2008 — 1,239
- 35 (3%)
- 509 (41%)
- 159 (13%)
- 226 (18%)
- 309 (25%)

2015 — 3,463
- 64 (2%)
- 1,637 (47%)
- 373 (11%)
- 577 (17%)
- 813 (23%)

2020f — 5,849
- 104 (2%)
- 3,063 (52%)
- 577 (10%)
- 816 (14%)
- 1,289 (22%)

CAGR 2008–2015
- 9%
- 18%
- 13%
- 14%
- 15%

CAGR 2015–2020f
- 10%
- 13%
- 9%
- 7%
- 10%

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
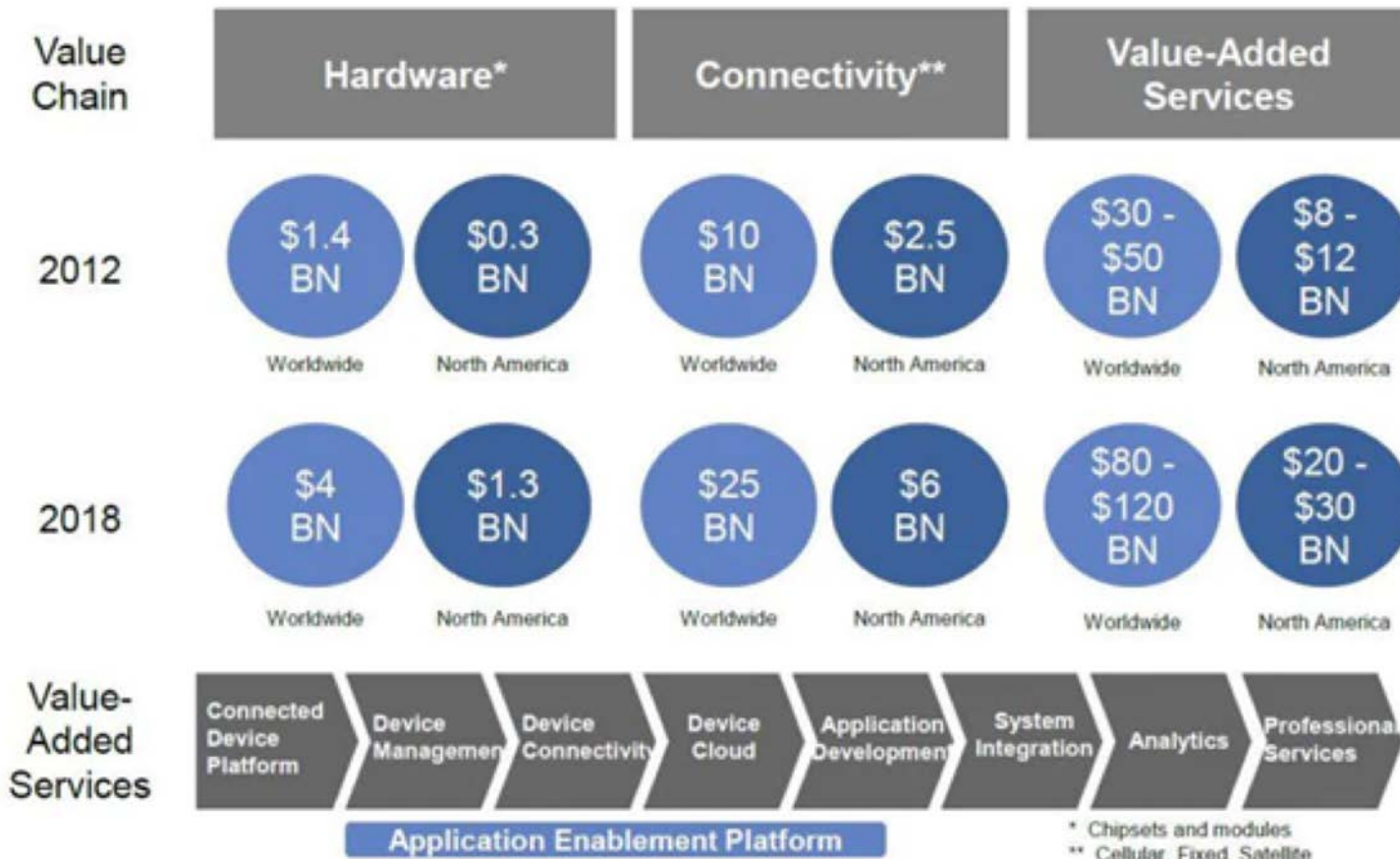Example: 2.4 GHz / 5 GHz / 60 GHz global

- 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

THANK YOU