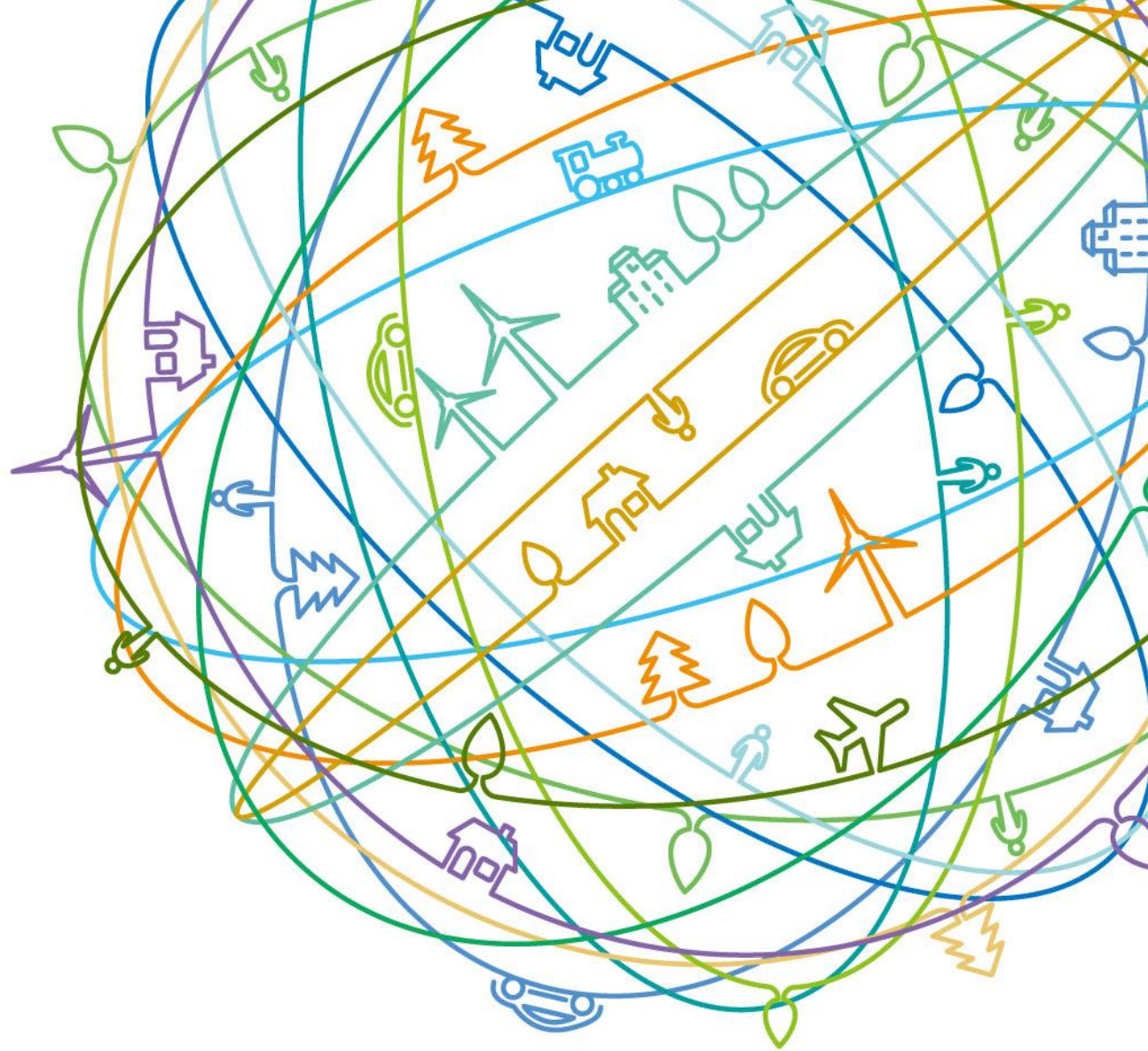


5G

Mérouane Debbah

Building a Better Connected World



HUAWEI TECHNOLOGIES CO., LTD.

www.huawei.com

Huawei

- *Huawei* is the official English transliteration of the firm's Chinese name 华为
- The origin etymology and character 华 means "flower" (as suggested from its logo). it can also mean "splendid" or "magnificent« or « China/Chinese »
- The character 为 means "action" or « achievement »
- Huawei literally means « China's achievement ».

Contents

Huawei Overview

Huawei in France

*Taux de change : USD1 = CNY 6.1958 (au 31 décembre 2014)

Huawei was founded in Shenzhen, China's Special Economic Zone

- 1987** Huawei, a private company, was founded by Ren Zhengfei and several other investors with an investment of US\$3,500. At that time, the company was a reseller of PBX switches of Hong Kong Hong Nian Company.
- 1993** Huawei developed C&C08 digital switches, which were primarily deployed in rural areas.
- 1997** Huawei started engaging global top consulting firms for management transformations.
- 1999** Huawei established its first international R&D center in Bangalore, India.
- 2005** Huawei became a preferred supplier for top carriers such as British Telecom and Vodafone. Revenue from Asia Pacific, the Americas, and EMEA exceeded domestic market for the first time.
- 2010** Huawei transformed itself from a CT company to an ICT company and established three BGs: Carrier BG, Enterprise BG, and Consumer BG.



Today, Huawei is a leading ICT company

Who is Huawei



- A leading global ICT solutions provider
- A Fortune Global 500 company, ranking 285 in 2014
- Interbrand Top 100 Best Global Brands

Employees



- 170,000+ employees worldwide
- 45% or 76,000+ employees engaged in R&D
- LinkedIn World's 100 Most InDemand Employers

Market Progress



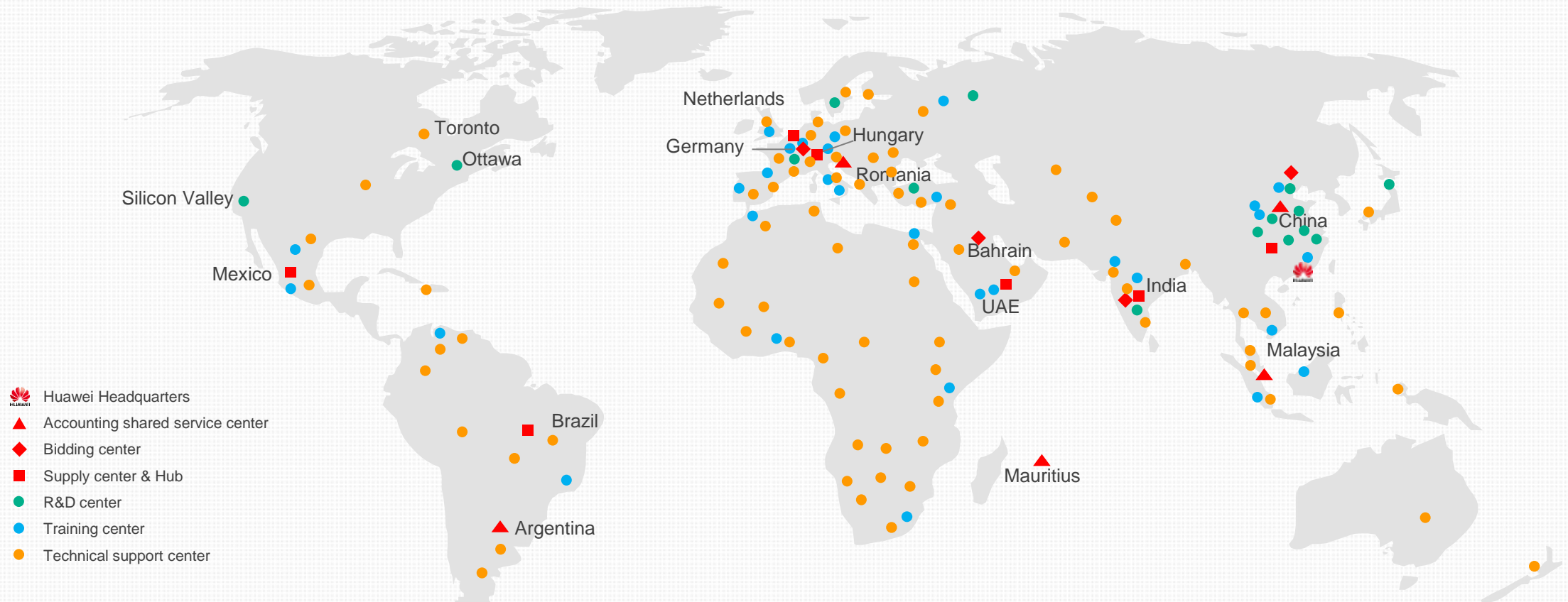
- US\$46.5B revenue in 2014
- Serving 1/3 of the world's population

Business Areas



- **Carrier** : 77% Huawei's revenue generated from the carrier network business is from world's top 50 carriers
- **Enterprise** : serving more than 100 global top 500 companies
- **Consumer** : raising the brand awareness to 65%

Globalized resource deployment and localized business operations



- Operations in **170+** countries and regions; **170,000+** employees comprised of **160+** nationalities worldwide ; **30,000+** non-Chinese employees with **75%+** localization rate.
- Huawei's global value chain allows fluid capability transfer across the globe, develops and retains talent in local countries, and creates jobs and economic opportunities.

Achieve win-win outcomes with global partners through open collaboration

Joint innovation

- Set up 28 joint innovation centers with carriers
- Cooperate with top universities in future technologies
- Collaborate with industry partners to develop joint solutions and strengthen cooperation on Industry 4.0 and IoT



Standards

- Member of 170+ standards organizations, 185 important positions



Channel

- Over 280 tier-1 channel partners globally



Financing

- Overseas financial institutions provide 78% of all debt financing



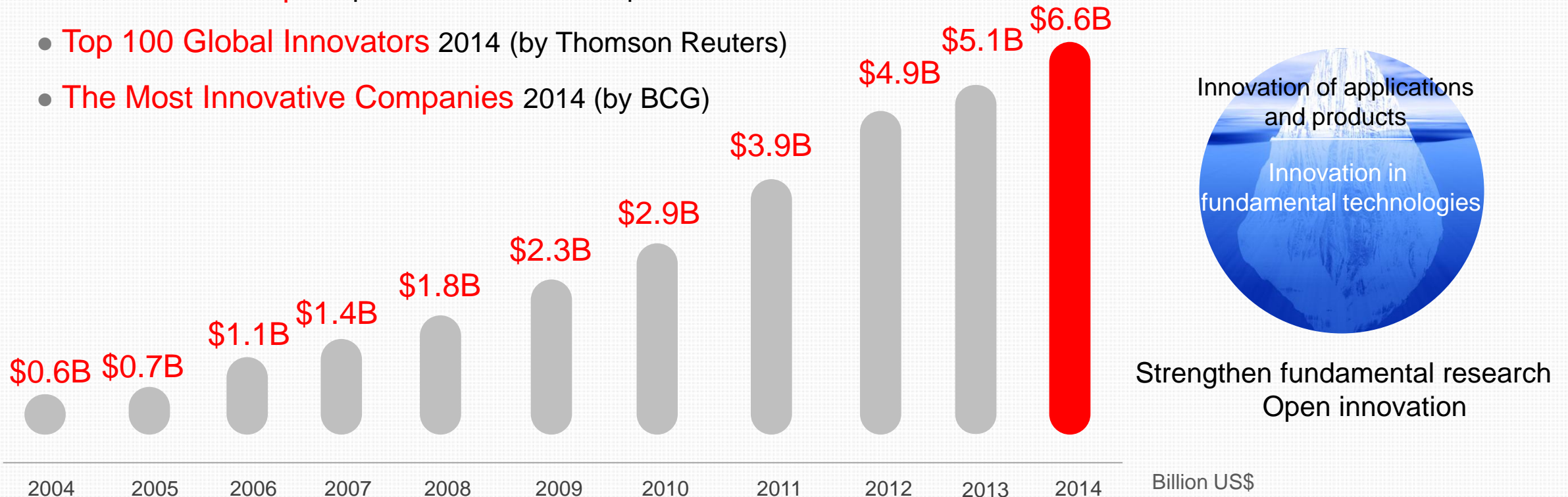
Suppliers

- Non-Chinese suppliers account for 82%, which are mainly from the US, Europe, Japan, and Korea



Long-term investment in innovation

- Continue to invest **over 10%** of revenue into R&D. Total R&D investment in the past decade amounted to **US\$30.7 billion**
- **No. 1** Chinese company with the largest number of patents in China; one of the **Top 50** patent holders in the US; one of the **Top 10** patent holders in Europe.
- **Top 100 Global Innovators** 2014 (by Thomson Reuters)
- **The Most Innovative Companies** 2014 (by BCG)



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*Taux de change : USD1 = CNY 6.1958 (au 31 décembre 2014)

A photograph showing Mr Ren Zhengfei on the left and Prime Minister Manuel Valls on the right, both looking down and smiling slightly. They are in a formal setting with ornate gold-colored wall decorations.

30 SEPTEMBRE 2014

HUAWEI 
iNFRANCE

INVESTMENT PLAN
2014-2018

Mr Ren Zhengfei in a meeting with Prime Minister Manuel Valls announced an investment plan for France over 5 years, providing 600 new hires and 1.5 billion euros.

Ren Zhengfei said « *Huawei enhances the competitive advantages of France in the digital economy and is committed to investing in France. Our investments have a significant impact on our overall innovation while sharpening the competitiveness of France in the new technologies and creating jobs for the French talent.* »

INVESTMENT PLAN 2014-2018



RECRUITMENT

- Hiring 600 people including 200 in R&D at the end of 2017
- Creating competence center in the field of French excellence



R&D

Increasing R D effort with 4 areas of expertise:

- Mathematics
- Design & Aesthetics
- Internet of Things
- Chipset



ECOSYSTEM

- Contribute to the development of French digital economy
- Increase cooperation with SMEs and start-ups



BUSINESS

- Carriers : 4G/LTE, FTTH and 5G
- Enterprise : Fusion range in the Cloud, storage....
- Device : Smartphones, wearable... (P8, Mate 7, Watch)

KEY FIGURES
IN FRANCE

1,5 billions € investment plan

For the period 2014-2018

+ 700 employees

600 recruitment including 200 in R&D from now until 2018

6 offices in France

Headquarter in Boulogne-Billancourt ; offices in Paris, Issy-les-Moulineaux, Bordeaux, Lille, Nantes and Sophia Antipolis

4 R&D centers

Mathematics, Design, Internet of Things and Chipset

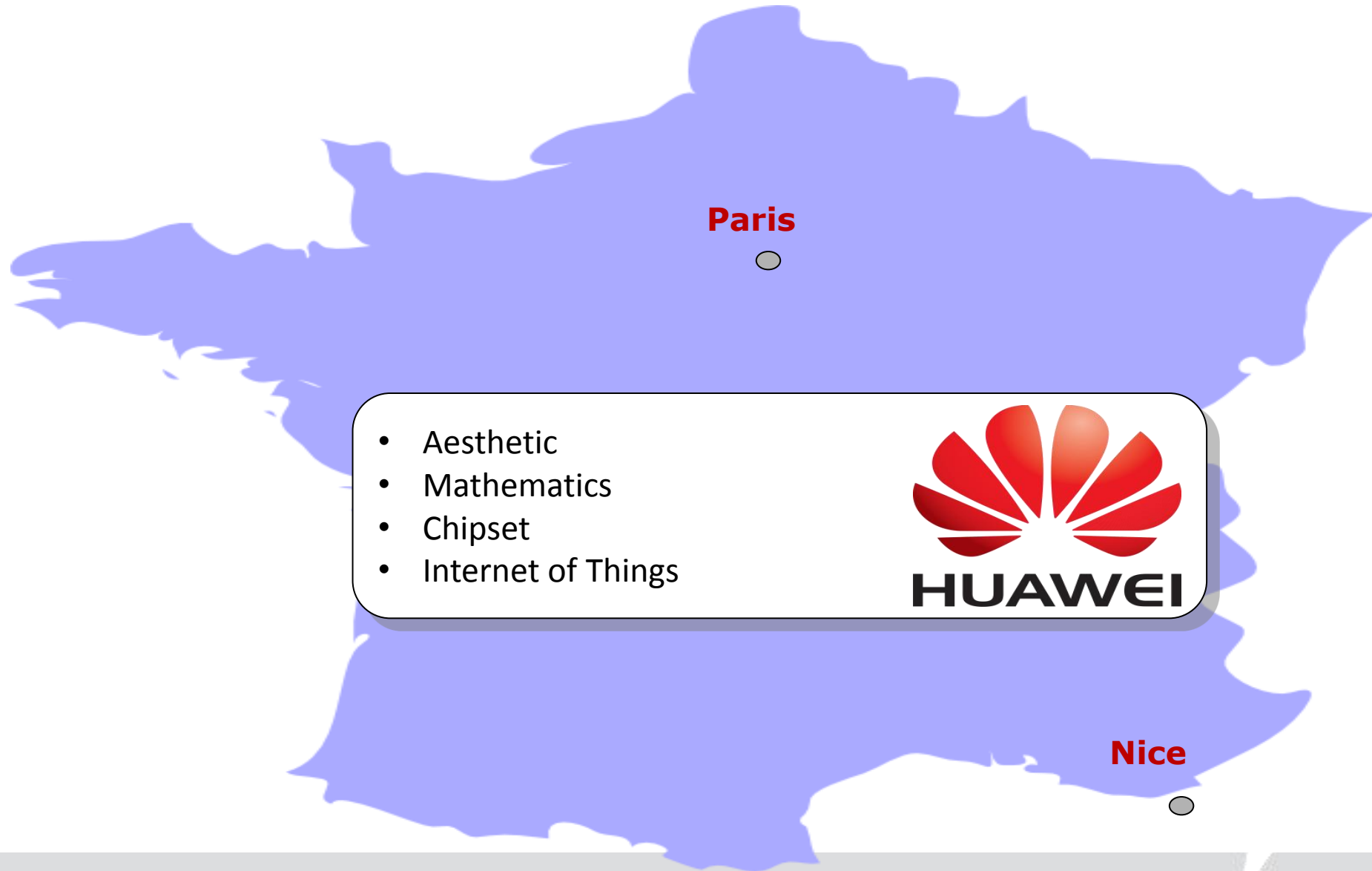
13 laureates startups

« IN-Pulse » contest (600 000 € allocation in 2014)

+240M \$ procurement in 2014

French suppliers (electronic, software, logistics...)

Huawei French Research Center



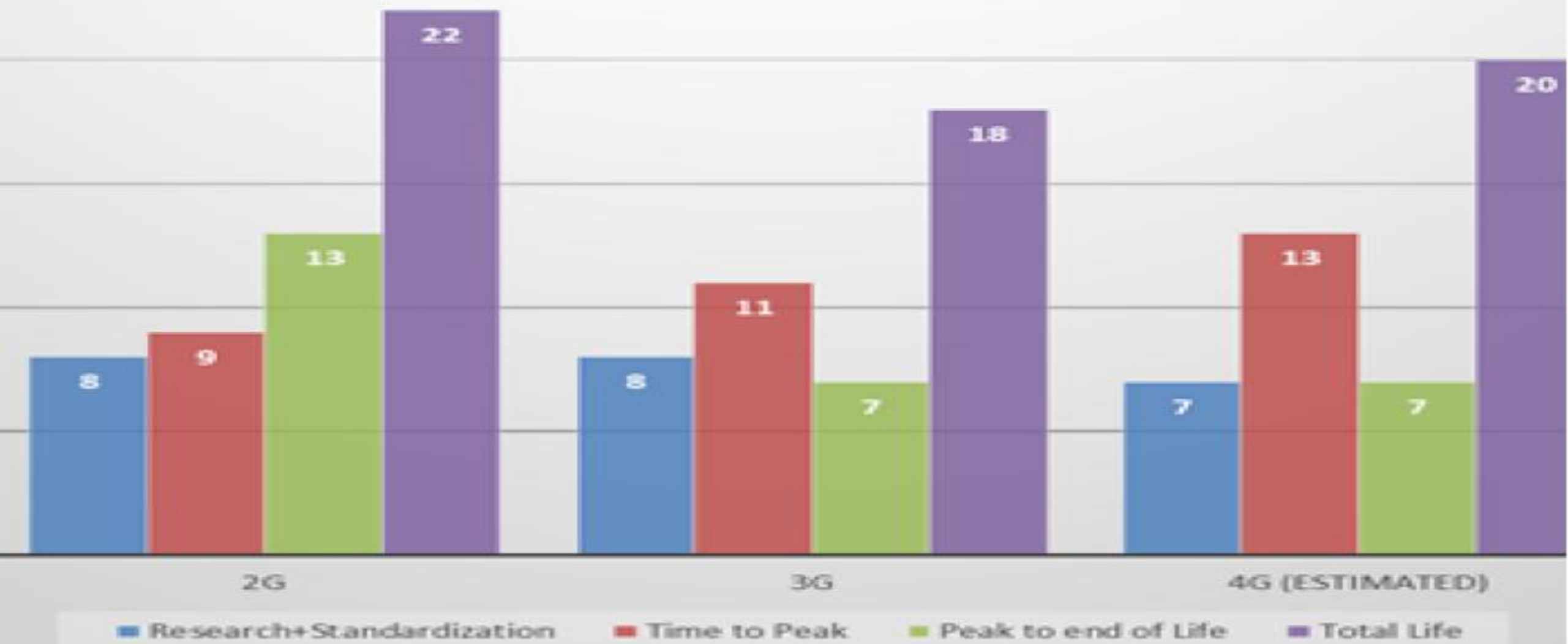
- Aesthetic
- Mathematics
- Chipset
- Internet of Things



5G-4G=1G

Mobile Network Technology Lifecycles (North America)

© Chetan Sharma Co



International 5G getting Momentum



ITU-R Visions Group

EU

- Framework Program 7, e.g. METIS and 5GNow projects
- 5G PPP in Horizon 2020



UK – 5G Innovation Centre (5GIC) at University of Surrey



US

- Intel Strategic Research Alliance (ISRA)
- NYU Wireless Research Center
- 4G Americas



China

- 863 Research Program
- Future Forum
- IMT-2020 (5G) Promotion Association



Japan – 2020 and Beyond Ad-Hoc Group under ARIB's Advanced Wireless Communications Study Committee, now transformed to 5G Promotion Forum



Korea – 5G Forum



Russia – 5GRUS by Russia's Icom-Invest

CJK White Paper

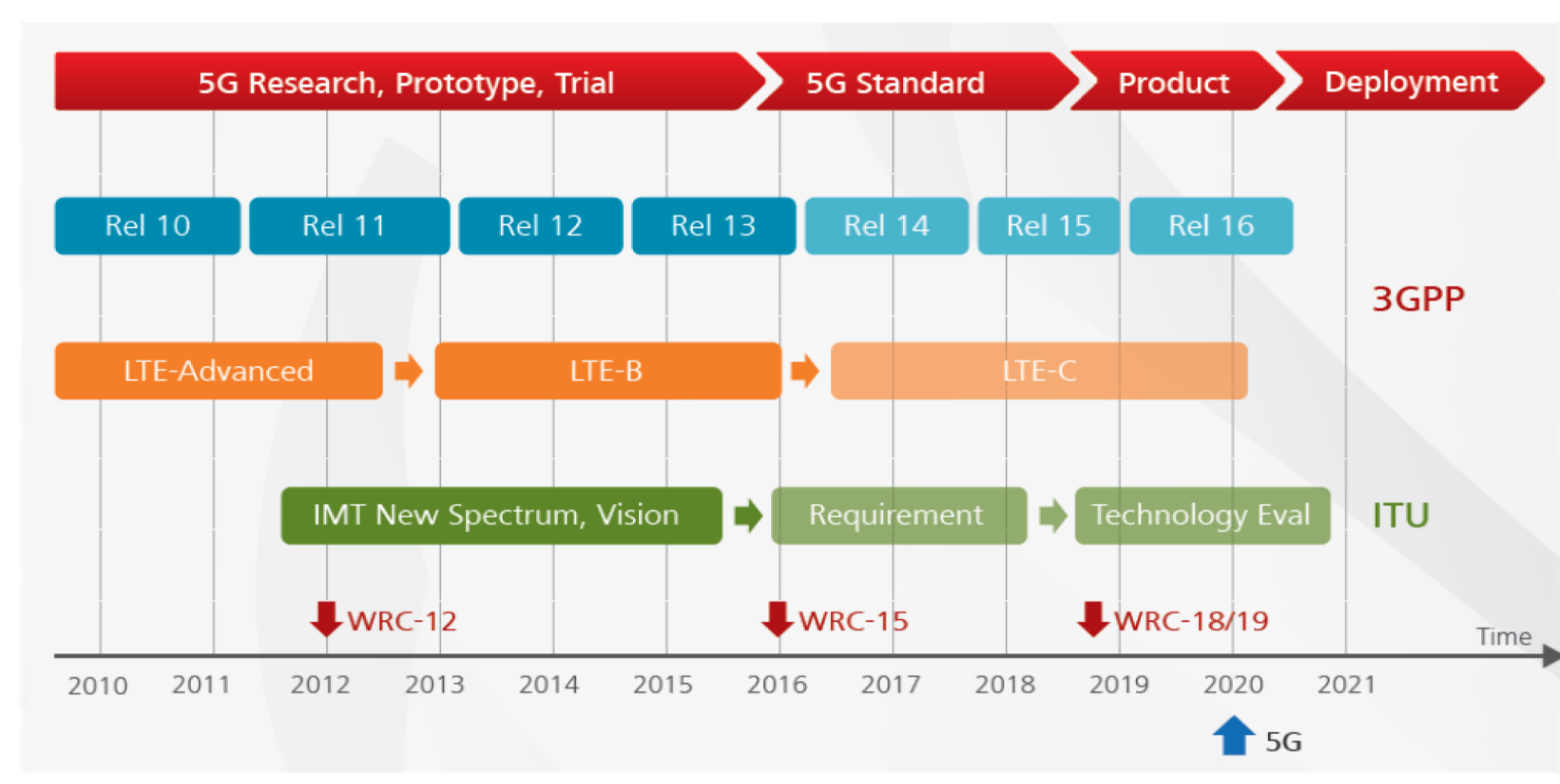


NGMN – White paper on future requirements

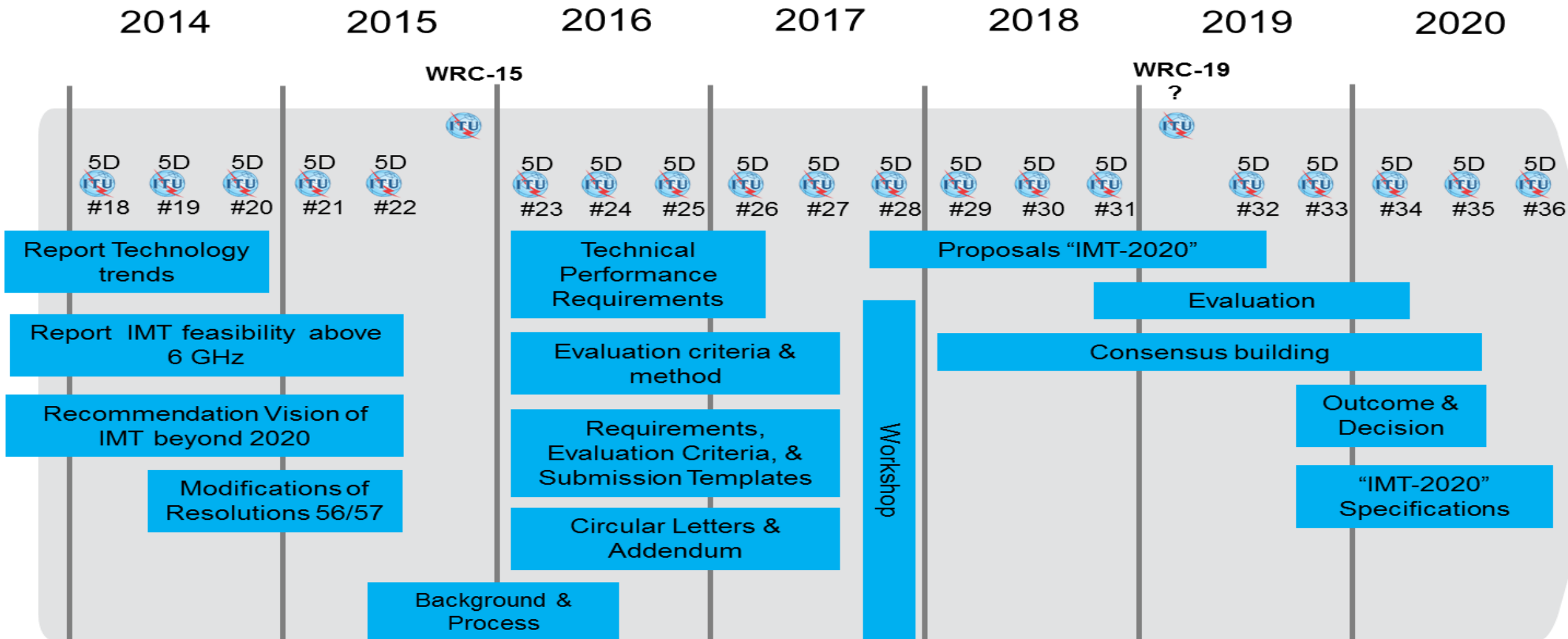
- Company internal research

Source: 5G Infrastructure Association.

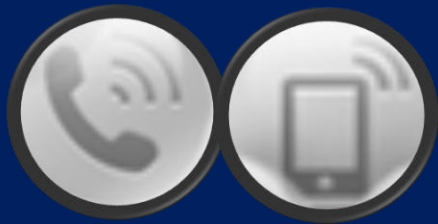
5G Timeline



Workplan for IMT-2020



5G From Mobile Internet to Connected World



Voice

Smartphone

3G 4G

Mobile Internet

(4 Billions@2020)

Mobile Internet replaced PC Internet



HD Video Surveillance



Augmented Reality



Wireless IP TV



High Speed Train



Meter & Sensor



Stadium



4K 3D HD TV



Smartphone



Voice



Shipping Logistic



Multi-User UHD Telepresence



Gaming



Wireless Cloud Office



Automatic Driving



Monitoring

5G

Connected World

(50-100Billions@2020)

90% objects are not connected

Example: movie projectors tomorrow (lasers)

→ 30-50 Mb/s for a single view transmission and Zero-Latency (adaptive) interaction client-server *

*) For luminance (brightness), chrominance (color), resolution, view point, etc. adaptation

Learning



2-8K → 30-50 Mb/s/view

<http://spectrum.ieee.org/consumer-electronics/audiovideo/lasers-coming-to-a-theater-near-you>

Example: The iCub robot platform (www.iit.it)

→ 5.000 sensors!



iit, Genova, Nov 2014



Computer vision



Force control

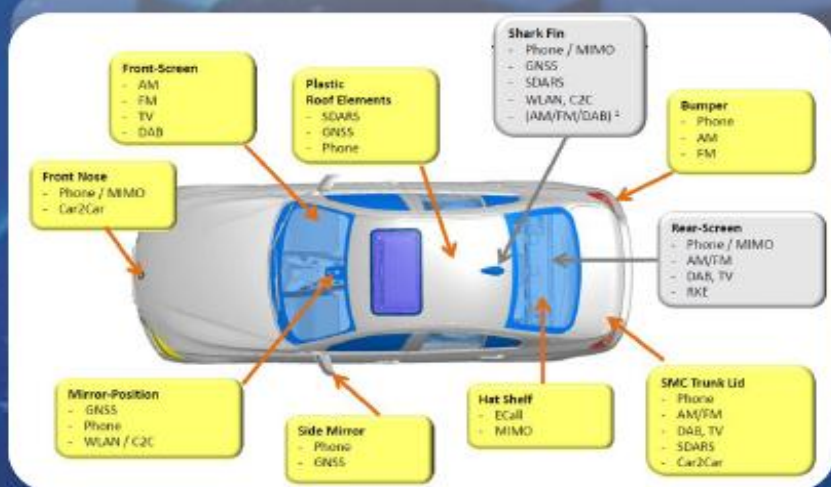
Sensor	Specs	Bandwidth
Cameras	2x, 640x480, 30fps, 8/24bit	147Mbit/s uncompressed
Microphones	2x, 44kHz, 16bit	1.4Mbit/s
F/T sensors	6x, 1kHz, 8bit	48kbit/s
Gyroscopes	12x, 100Hz, 16bit	19.2kbit/s
Tactile sensors	4000x, 50Hz, 8bit	1.6Mbit/s
Control commands	53DoF x 2-4 commands, 100Hz/1kHz, 16bit	3.3Mbit/s (worst case), 170kbit/s (typical)

→ Force control latency requirement = 1-5 ms

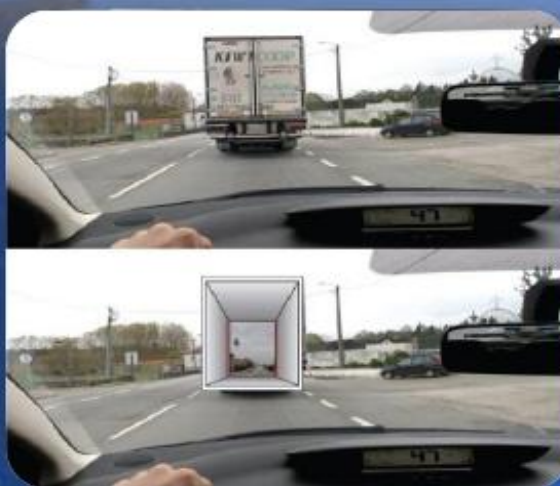
[G. Metta "Robotics-Derived Requirements for the Internet of Things in the 5G Context," IEEE MMTC E-Letter, Sept 2014]

Example: Future Car Communications

➔ New Antenna Concepts for MIMO, Integration of 11p and LTE/5G, Mobile Edge Computing



[Kathrein Automotive]



[Markus Dillinger, Huawei]

Communication requirements

- Better connection than smart phone
- Reliable for future advanced driver assistant systems (ADAS)
- High data volumes (**>200MB/s**) at low latencies for future cooperative automatic driving functions (V2V)
- Support performance up to maximum speed (**500km/h relative**)
- **Any network operator**, regardless vehicle occupants' contract (safety information)

5G Wireless Requirements For FEC

Human Centric Communications:

The user data rate: **10Gbps**

iPhone, iPad, iGlass, iWatch

The base station data rate: **1Tbps**

cloud computing blade

Machine Centric Communications:

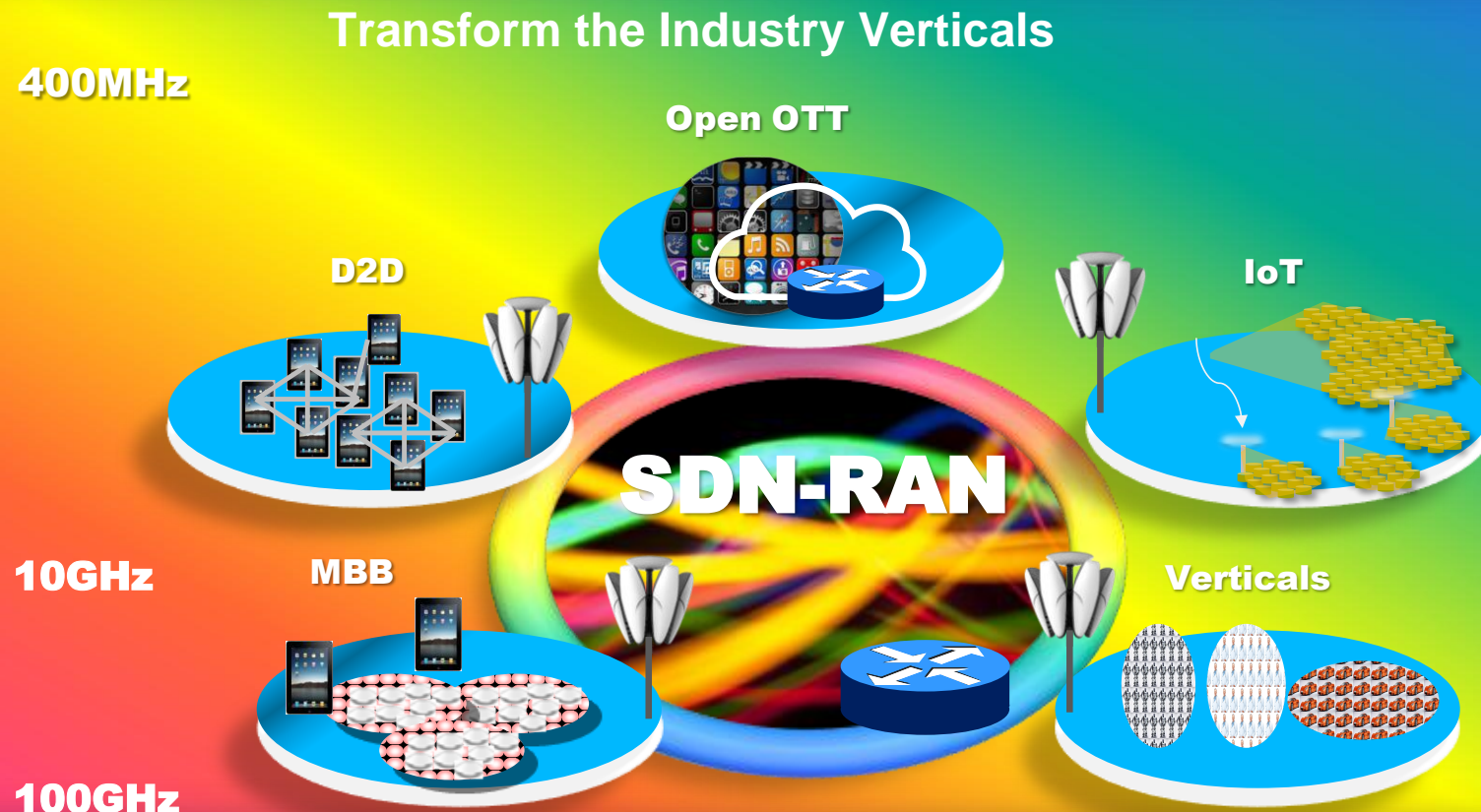
The sensor data size: **10~100Bytes**

meters, telemetric, RFID,

The industry control: **10^{-4} second latency**

Could-drive-car, factory control

5G (Beyond Smartphone)



Auto-drive



Medicare



Robots



Meters Sensors

Capacity

1000X
(Capacity/km²)

Speed

100X
(10Gbps)

Latency

Less than 1ms

Links


100x

Energy

1000X Reduce

How to address Capacity requirements ?

- In the context of 5G activities, a 1000x increase of capacity is targeted



Company	Spectrum	Spectral Efficiency	Base Station Densification	Total capacity increase
Nokia	10	10	10	1000
Huawei	4	16-30	10	640-1200
NTT DoCoMo	2.8	24	15	1000
Ericsson	4	2.5	100	1000
RWTH Aachen	3	5	66	1000

Source: 5G Summit Munich, 10-Feb-2014

- New dedicated licensed bands (e.g., spectrum under discussion towards WRC-15)
➔ **Issue: limited opportunities**
- Spectrum Sharing (e.g. Licensed Shared Access in 2.3-2.4 GHz in Europe)
- New mmWave spectrum (10/28-90 GHz, licensed/unlicensed)
- New rules for unlicensed Spectrum for WiFi (5 GHz) or TVWS

5G spectrum – Ofcom position

Ofcom on Monday identified four frequency bands in the 6 GHz-100 GHz range that it believes offer the best potential for use as 5G spectrum.

The U.K. regulator has suggested that the 10 GHz, 32 GHz, 40 GHz, and 66 GHz bands would be appropriate for use for next-generation mobile services (see table). The proposal is based on a combination of in-house analysis, a report by consultancy Quotient Associates, and responses to a consultation that Ofcom launched in January.

"We believe it is desirable to identify specific potential bands above 6 GHz to help focus an agenda item for the World Radio Communication Conference in 2019 (WRC-19) and to maximise the potential for international harmonisation of 5G spectrum," said Ofcom.

"We have therefore identified a preliminary set of bands in different parts of the 6 GHz-100 GHz range that we currently believe offer the best potential for use in the U.K. and harmonisation of 5G mobile services globally.

"This does not guarantee that these bands will be adopted in the future and we do not rule out consideration of other options" ahead of November's WRC-15 in Geneva, the watchdog said.

Summary of preliminary bands identified

Frequency range	6-20 GHz	20-40 GHz	40-60 GHz	60-100 GHz
Specific bands identified	10 GHz band 10.125-10.225 GHz / 10.475-10.575 GHz	32 GHz band 31.8-33.4 GHz	40 GHz band 40.5-43.5 GHz '45 GHz' band 45.5-48.9 GHz	66 GHz band 66-71 GHz
Potential bandwidth	2 x100 MHz	1.6 GHz	5.8 GHz total	5 GHz

Source: Ofcom, April 2015

Bande 2.6 GHz

uplink

WiFi	SFR	OF	BYT	Free	TDD
------	-----	----	-----	------	-----

downlink

TDD	SFR	OF	BYT	Free	radars
-----	-----	----	-----	------	--------

Largeur
(MHz)

15

20

15

20

Prix

150 M€

287 M€

228 M€

271 M€

Bande 800 MHz

TNT	BYT	SFR	OF
-----	-----	-----	----

Largeur
(MHz)

10

5+5

10

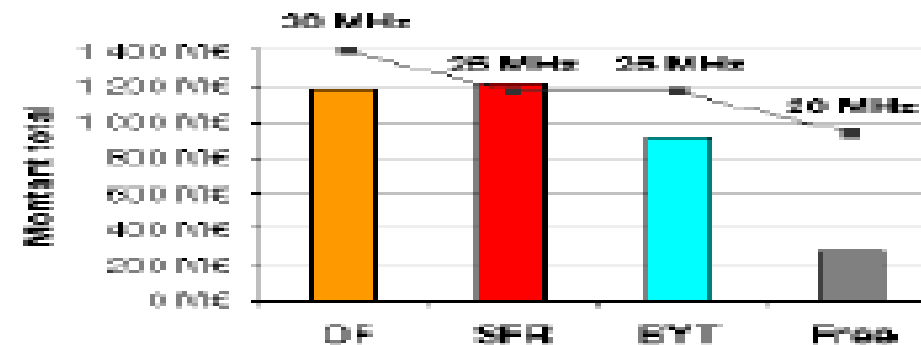
Prix

683 M€

1065 M€

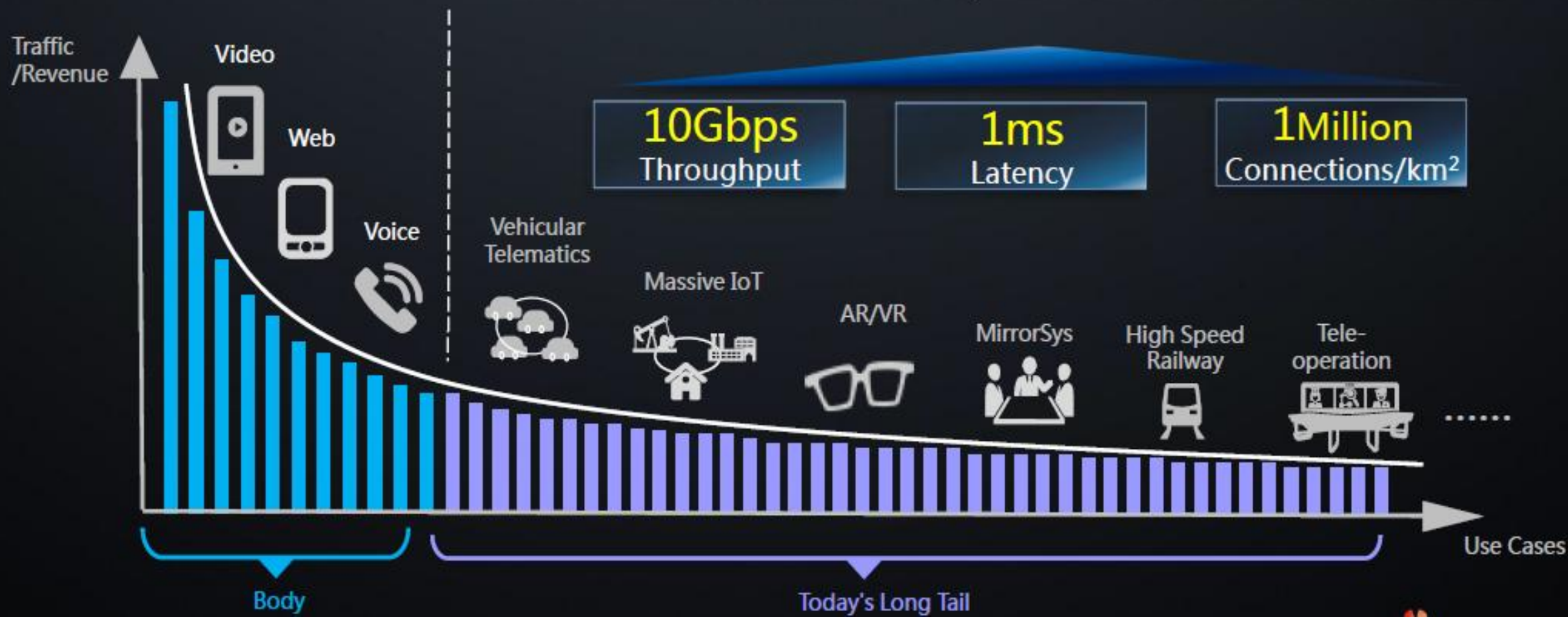
891 M€

Bilan enchères LTE
(somme 2.6 GHz et 800 MHz)



Today's Long Tail, Tomorrow's New Field

5G will enable **new applications**,
new business models, and **even new industries**



5G Will Carry Many Industries and Benefit Stakeholders

**Enhance
Mobile Internet**



**Empower
Internet of Things**



Consumers

- Ubiquitous consistent experience
- New services



Vertical Industries




- Easy access to the common infrastructure of 5G
- Real-time, on-demand service



Operators

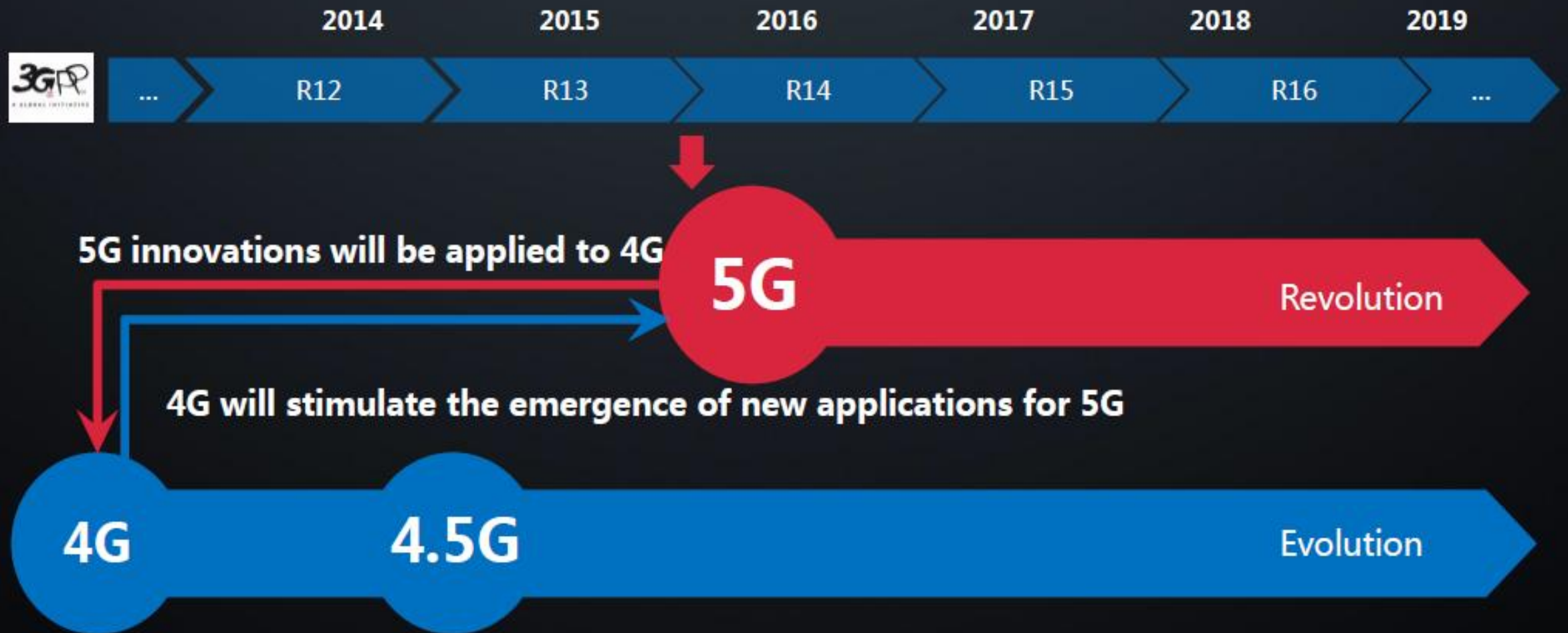
- Easy deployment and maintenance
- Network flexibility for multiple industries

Diversified Challenges and Gaps to Reach 5G

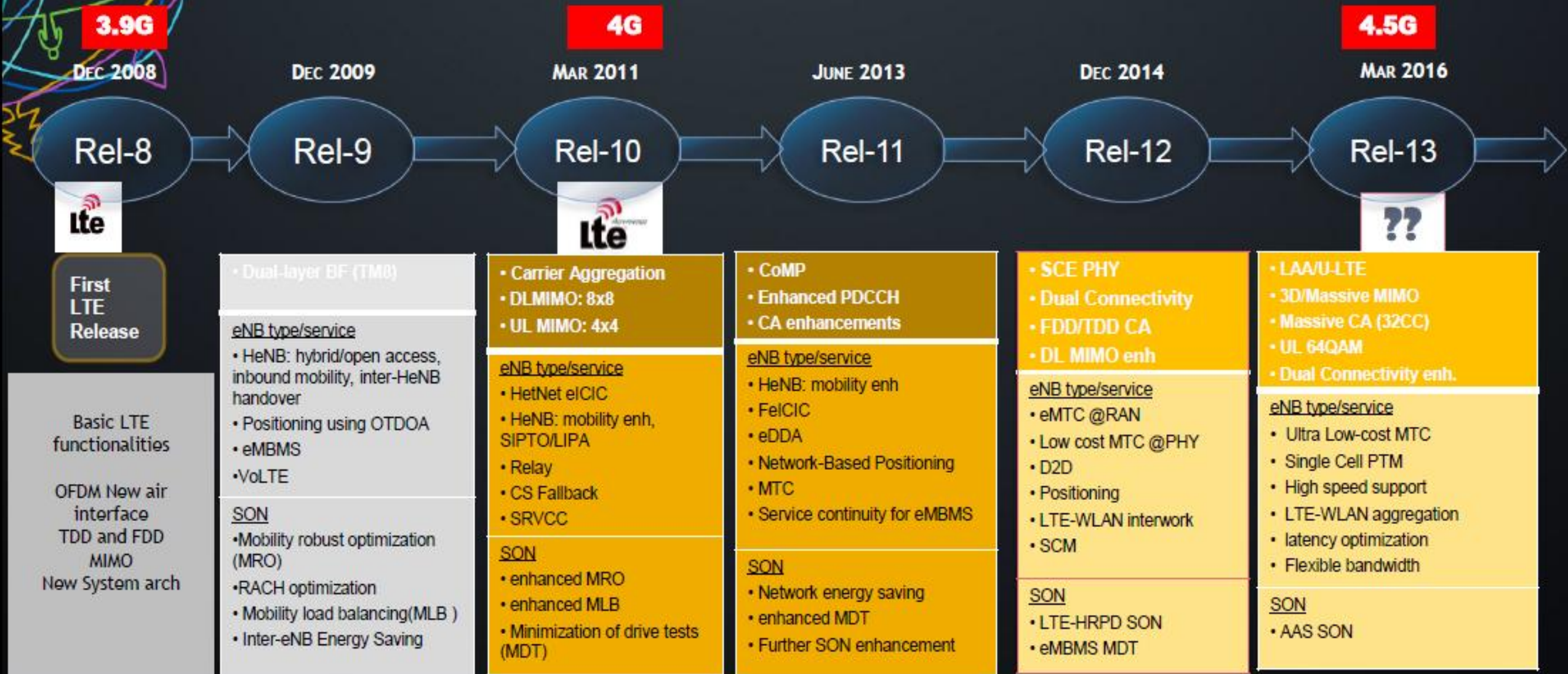
5G	Latency	Throughput	Connections	Mobility	Network Architecture
	1 ms E2E Latency 	10G bps Per Connection 	1,000K Connections Per km ² 	500 km/h High-speed Railway 	Slicing Ability Required 
GAP	30~50x	100x	100x	1.5x	NFV/SDN
LTE	30~50ms	100Mbps	10K	350Km/h	Inflexible



5G Innovations Will be Applied to 4G to Leverage 4G Investment



How did we get here to 4G and 4.5G => 5G



4.5G has some key radio features that will form the basis for a 5G system (Massive MIMO, LAA, enhanced MTC, Latency reduction..)

3GPP work areas in 4.5G leading to 5G

Flexible Spectrum Utilization

Physical layer small cell enhancements

U-LTE/LAA

Flexible Bandwidth

FDD/TDD CA

Massive CA

Flexible Duplex

Flexible Service Extension

FeMTC

Single Cell PTM

D2D/V2V

Positioning enh.

Latency Optimization

High Speed Scenario Support

Flexible Network

Enhanced Multiuser Transmissions

3D MIMO

Uplink Enhancement

Small Cell Enh.
/Dual Connectivity

LTE-WLAN Aggregation

Multi-RAT Joint Operation

A Global Unified Standard for 5G



Key Challenges for Reaching 5G

Spectrum



Aggregate All
Available Bands

New Architecture & Operation



One Physical Network
Multiple Industries

New Air Interface

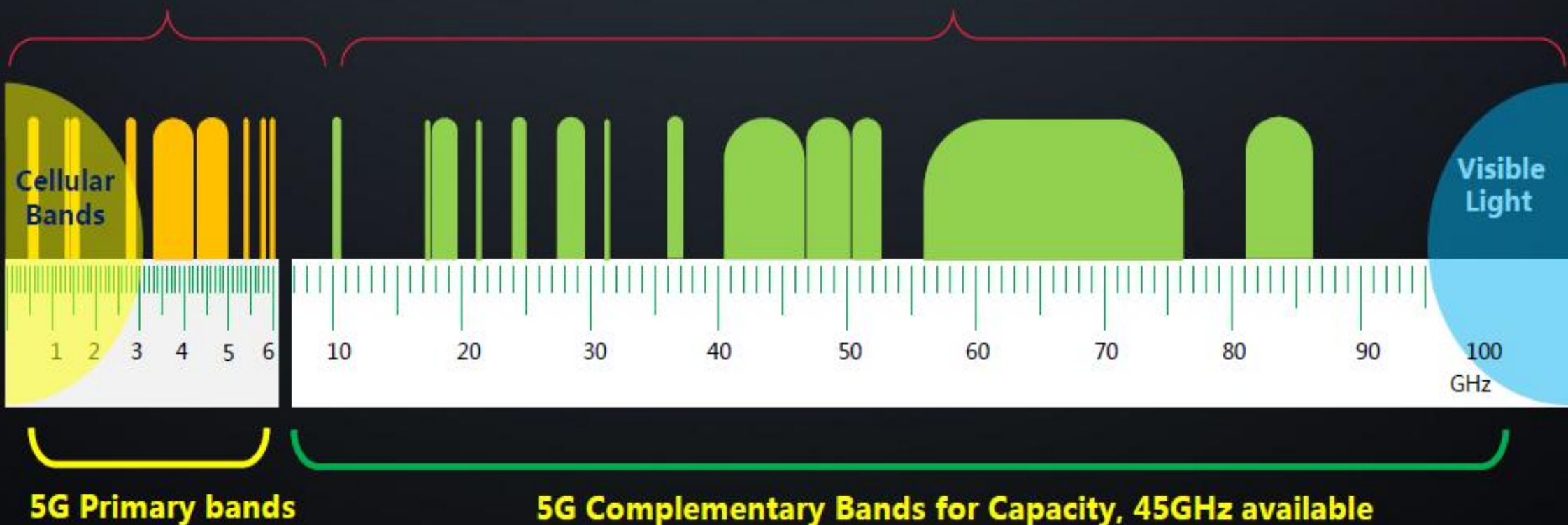


Flexibility &
Spectrum Efficiency

5G Will Aggregate Sub 6GHz and the Bands >6GHz

WRC15
Requirement >500MHz
for IMT-2020

WRC19
45GHz available
for future Cellular Access and Self-Backhaul



LAA is a stepping stone in 4.5G towards 5G

As secondary carriers, LTE carriers at unlicensed bands are integrated to LTE carriers

Non-Standalone

Licensed LTE

U-LTE

Primary Carrier

Secondary Carrier



Licensed LTE

U-LTE

Primary Carrier

Secondary Carrier



Carrier Aggregation into LTE networks

Coverage
& Capacity
Guarantee

Mobility
and service
continuity

QoS
Guarantee

Unified
OAM, RRM,
Billing

Controlled by Operator Networks

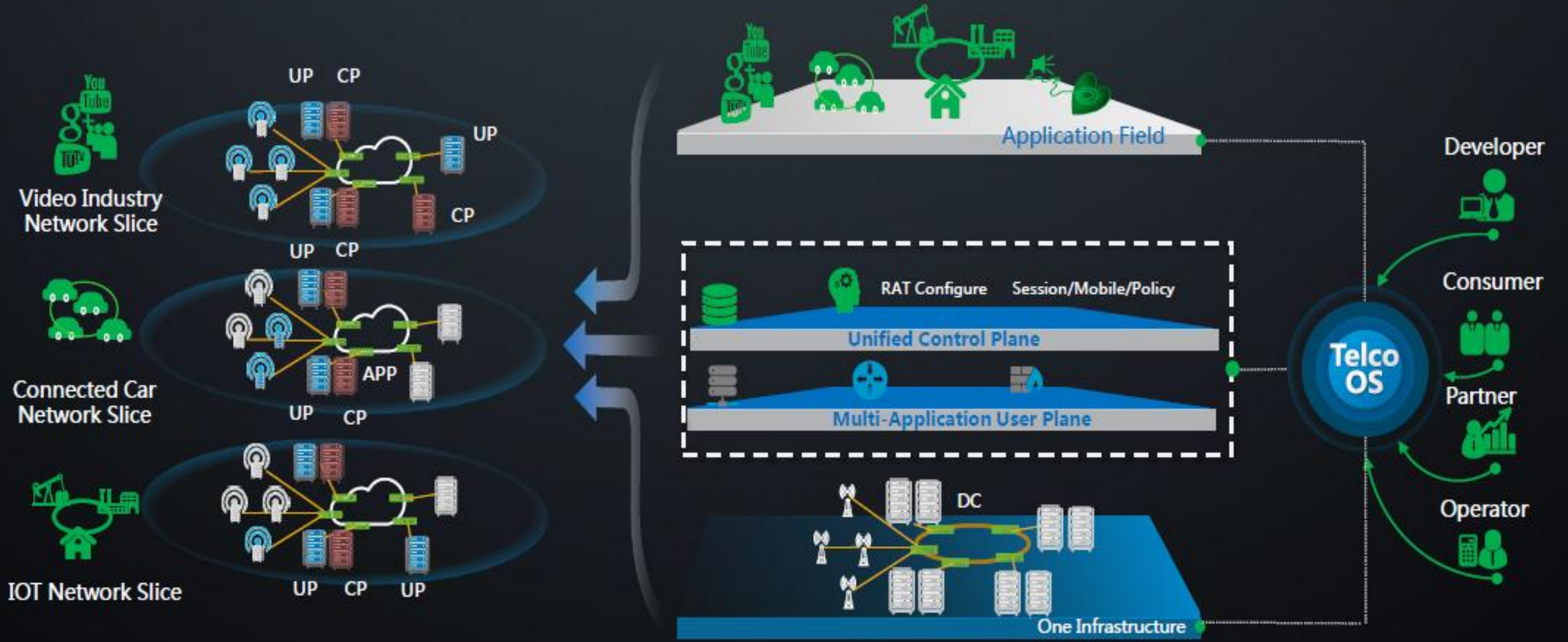
Standalone

U-LTE



Without Licensed LTE,
U-LTE will lose these
advantages

A New Architecture & Operation

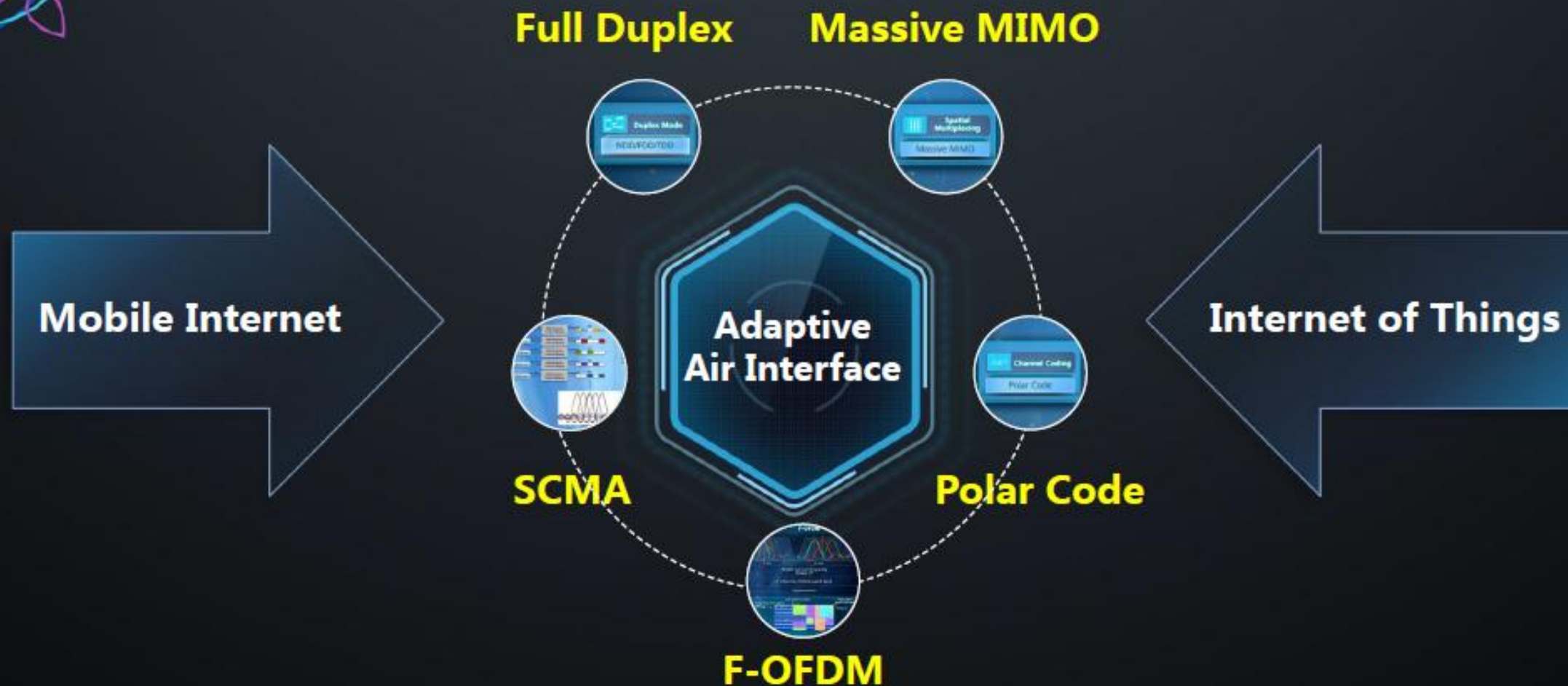


Industry defined network slicing

Service oriented cloud-formation

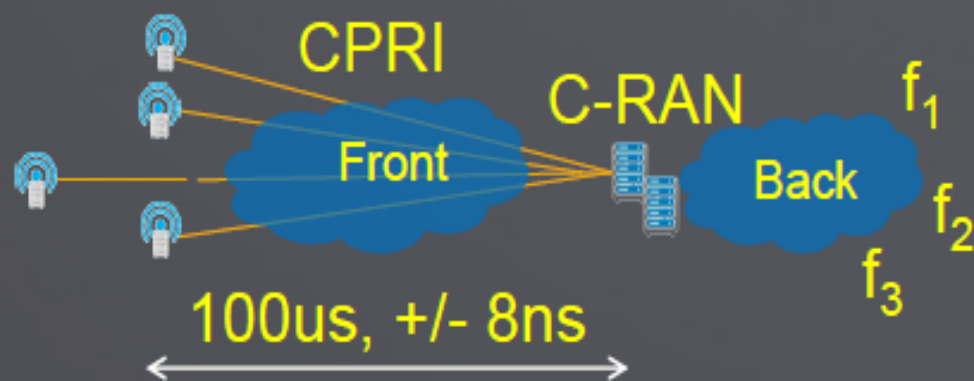
Internet architectural operation

New Air Interface

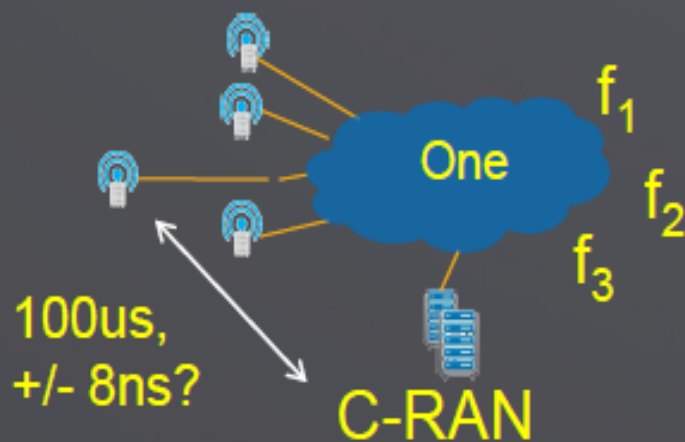


One air interface fits **many** applications with high **flexibility**,
at least a **3x** spectrum efficiency improvement

Consolidated Front haul & Backhaul – one Fixed Networks

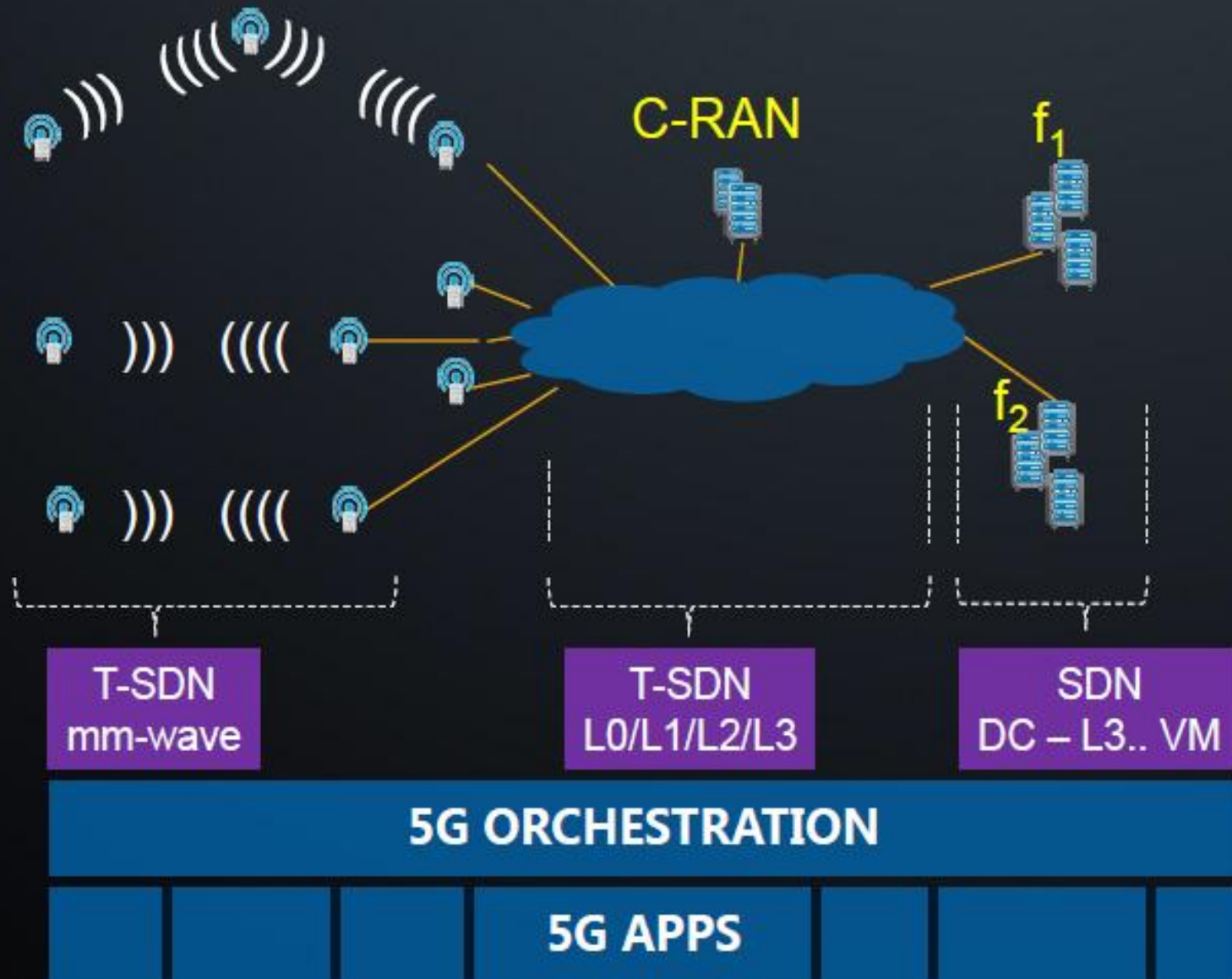


- Cloud/C-RAN virtualizes all 5G compute resources
- C-RAN requires ultra low delay/jitter 'front-haul'
- One option is use of dedicated fiber per antenna site
- Allows C-RAN to send I/Q samples at ultra low delay/jitter



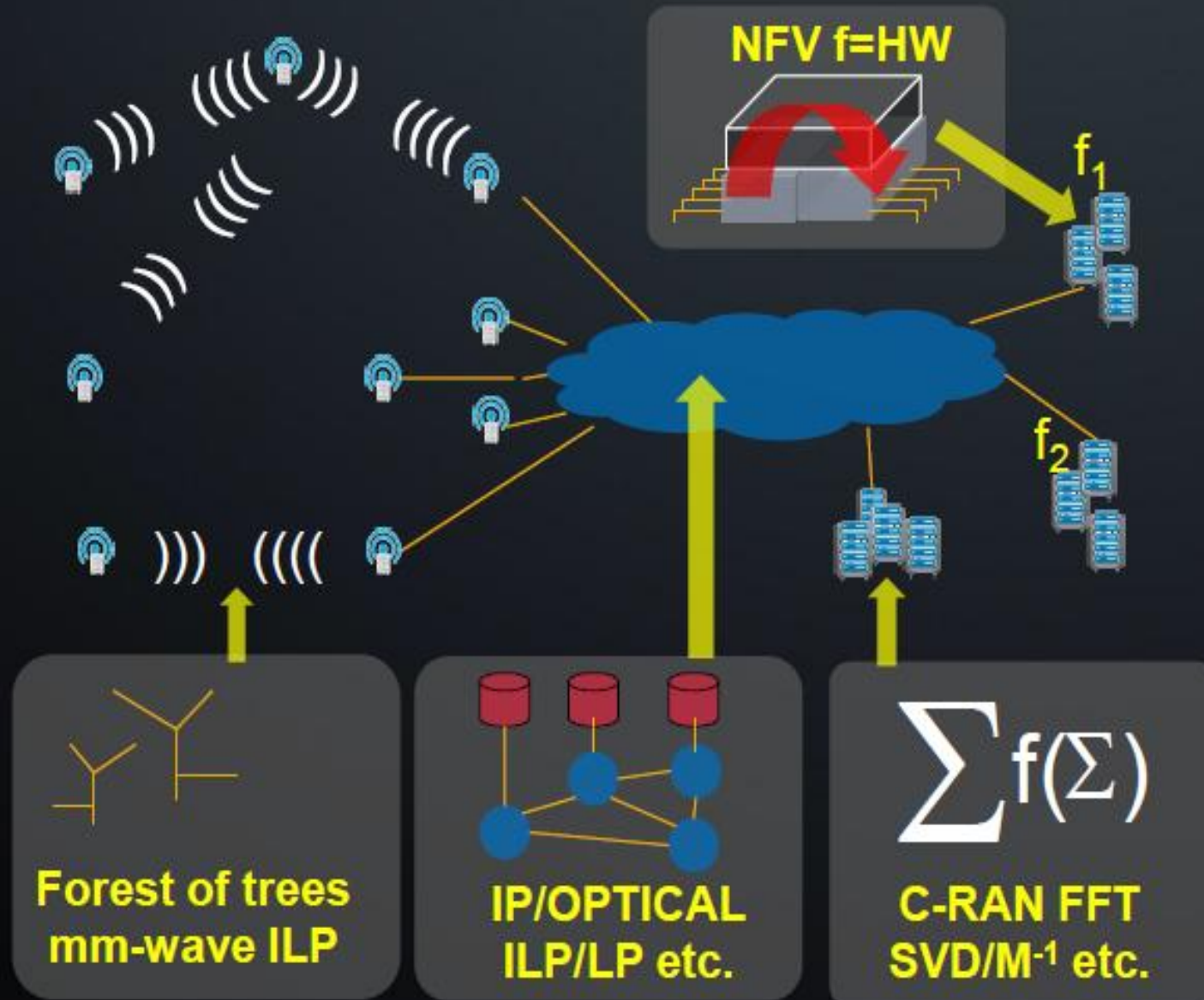
- C-RAN communicates with antenna sites and other 5G components over same network.
- Network now has to support ultra low delay/jitter and provide extremely precise clocking.
- Work starting in IEEE but needs CPRI / division changes

SDN/Transport-SDN for back-haul/front-haul/DC/DCI



- Multiple SDN/TSDN controllers
- Allocate B/W connectivity
- Reconfigure optical network
- Reconfigure IP network
- Reconfigure microwave network
- Reconfigure DC network
- Allocate DC resources for EPC
- Allocate resources for C-RAN
- Consolidated view for services.

Optimized NFV/SDN for EPC/TE/C-RAN etc.



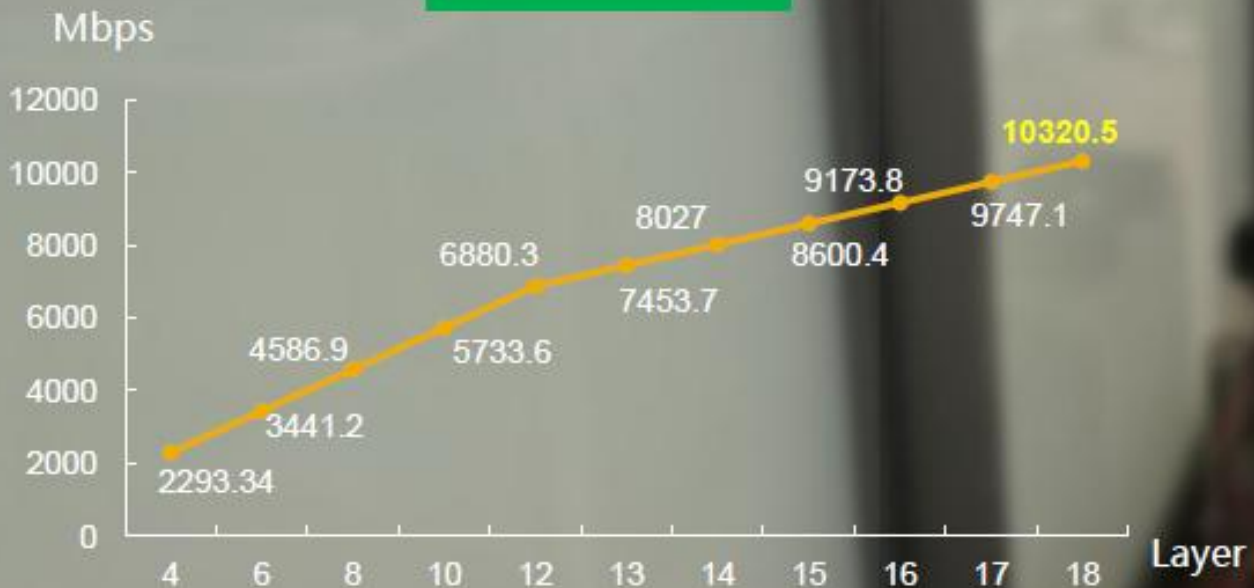
- **Hybrid CPU/FPGA (Intel 2017)**
- **Allow massive parallel programming**
- **Can do LP/ILP/Convex/FFT etc in HW/Software hybrid**
- **High performance $f()=DPI$**
- **High performance packet forwarding**
- **Problem – very hard to program**

Huawei 5G Low Band Test Bed

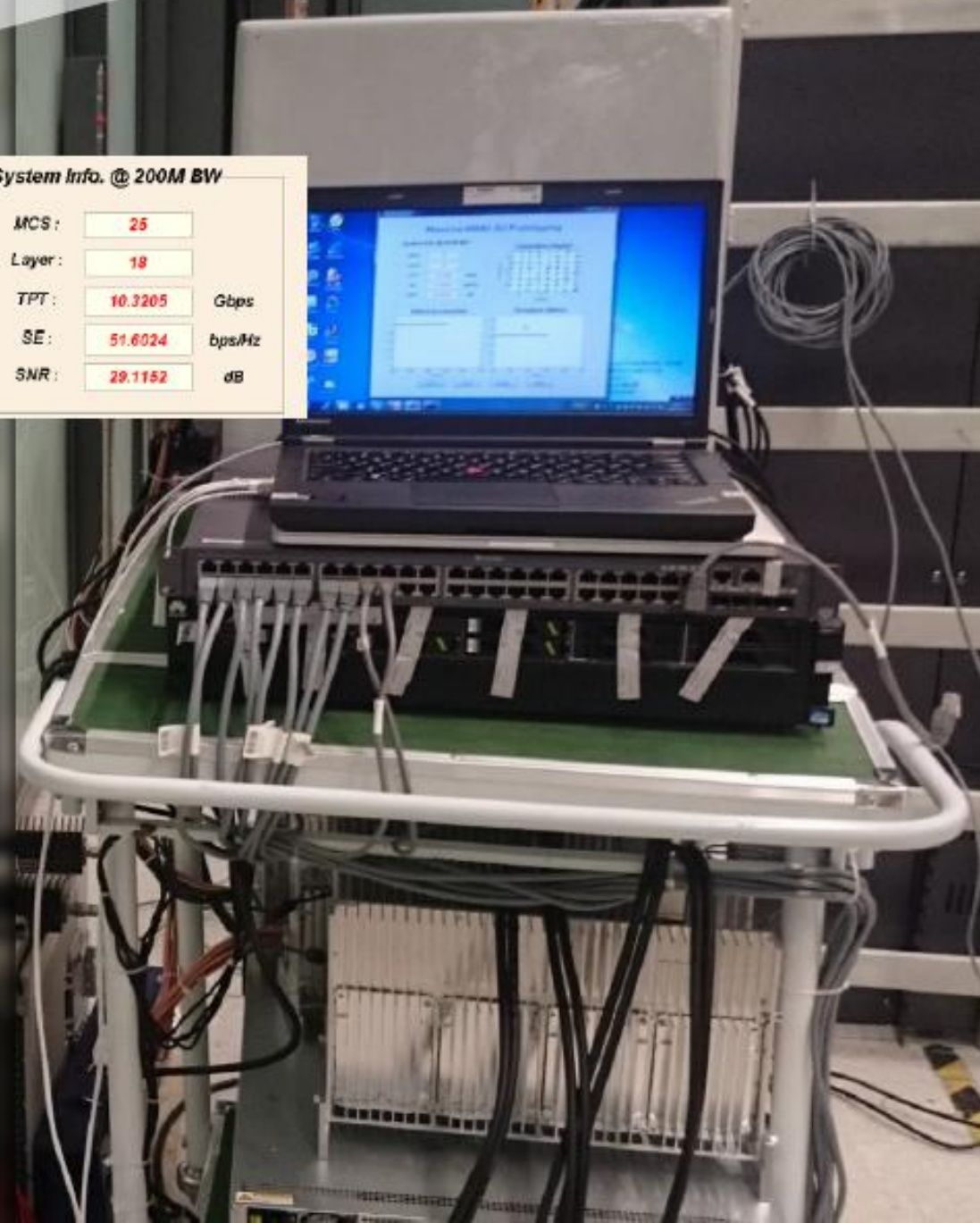
Cell Throughput@ Sub6G

10 · 32 Gbps

200MHz BW



System Info. @ 200M BW			
MCS :	25		
Layer :	18		
TPT :	10.3205	Gbps	
SE :	51.6024	bps/MHz	
SNR :	29.1152	dB	



Huawei 5G High Band Test Bed

Breaks World Record

115

20

Gbps

9.6GHz BW

Thank you
www.huawei.com

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