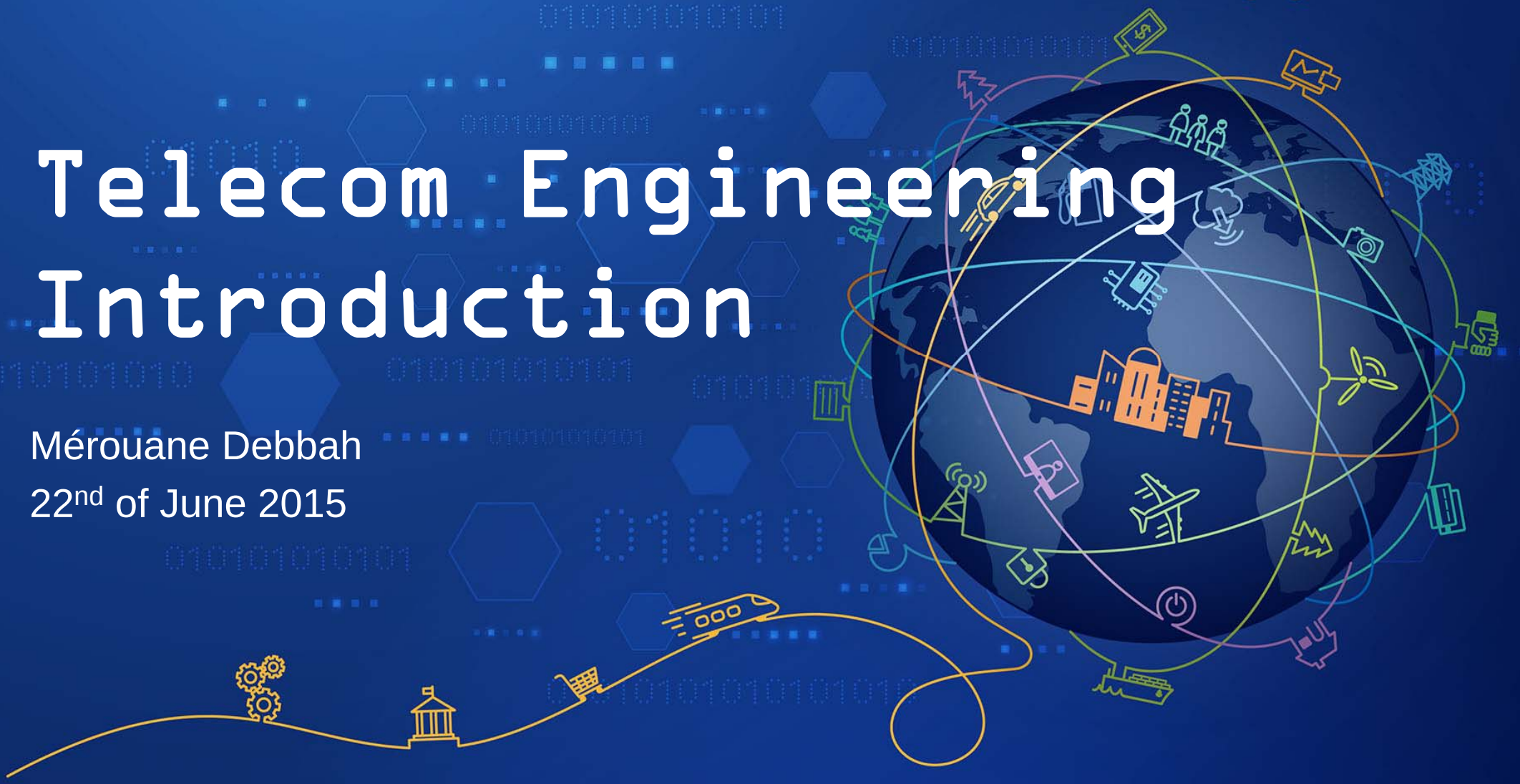
Telecom Engineering Introduction

Mérouane Debbah

22nd of June 2015



Contents

*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.


Shenzhen in the early 1980s


Shenzhen after three decades

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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%

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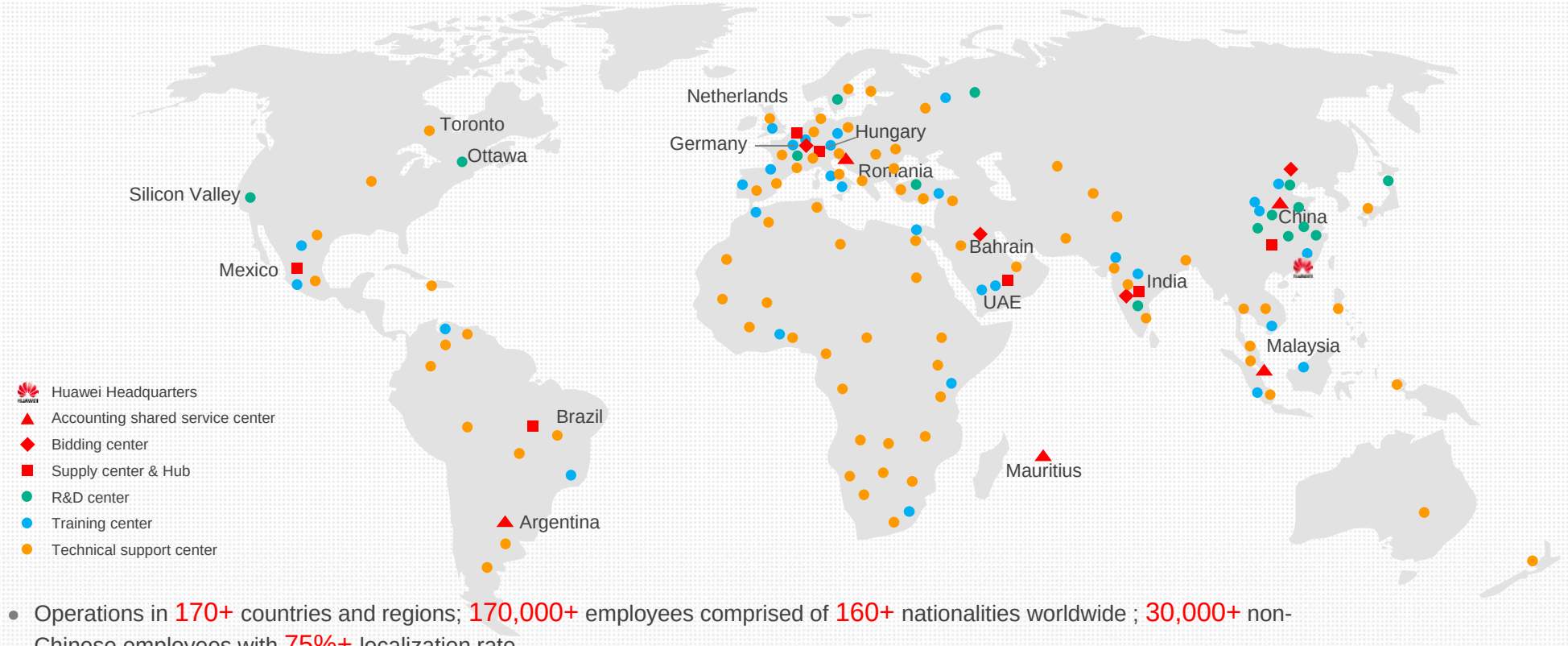
Globalized resource deployment and localized business operations



- 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.

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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

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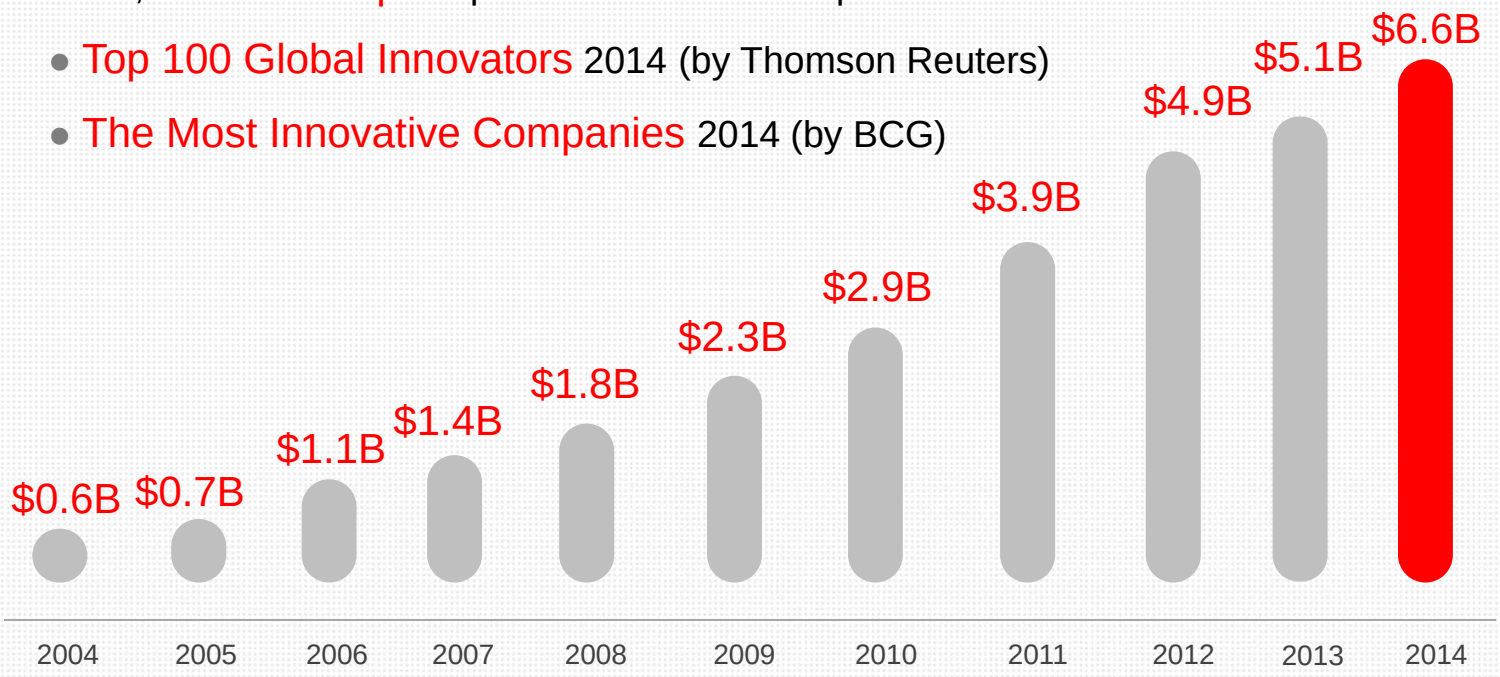
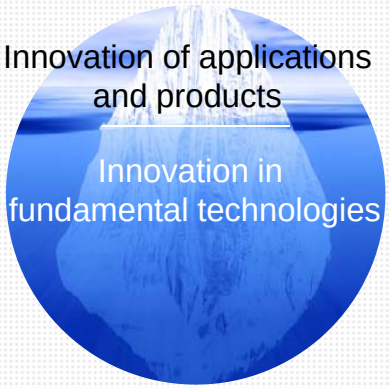
Long-term investment in innovation

- 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)





Strengthen fundamental research
Open innovation

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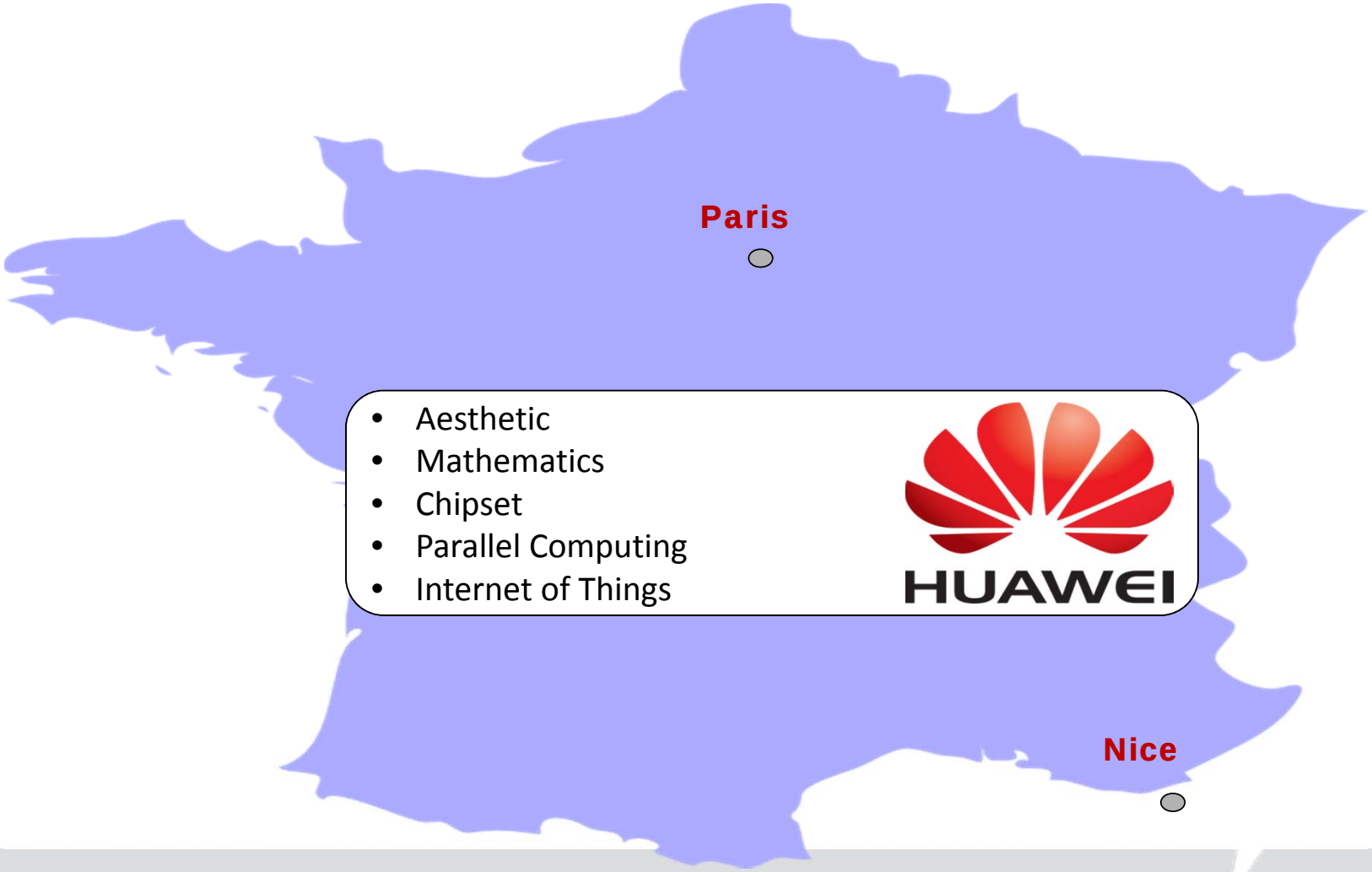
Huawei French Research Center



- Aesthetic
- Mathematics
- Chipset
- Parallel Computing
- Internet of Things

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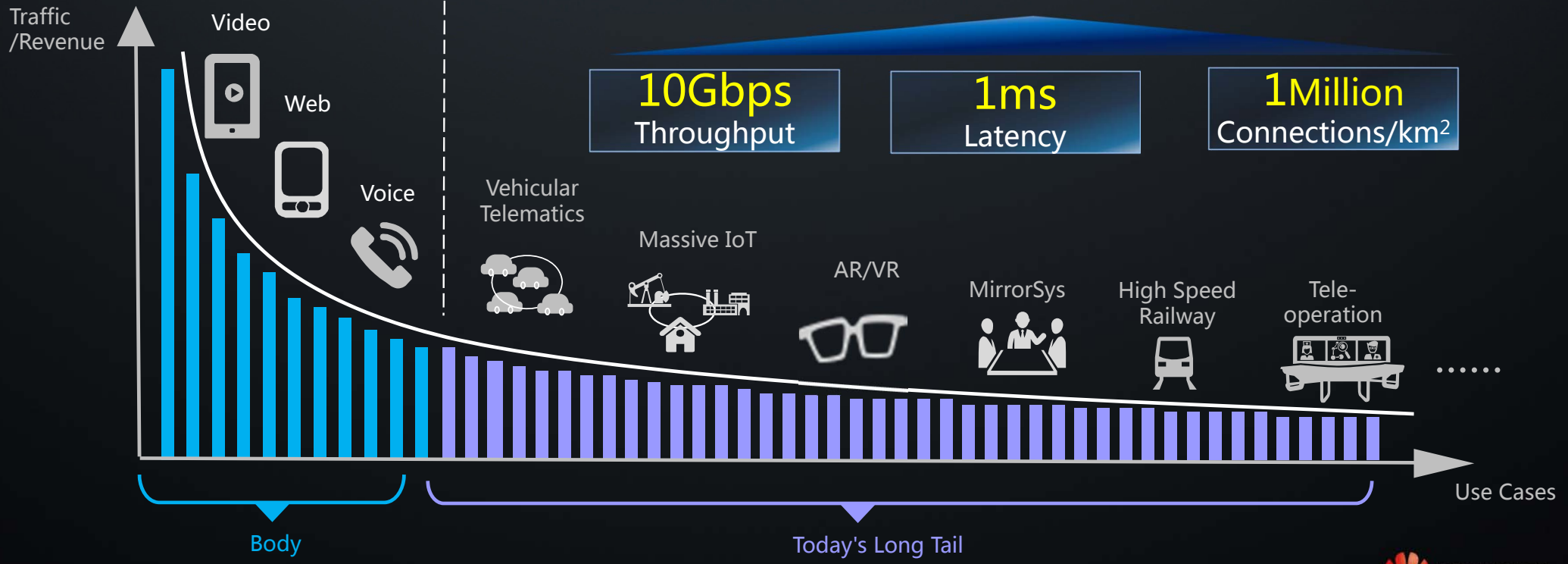
5G Vision

Today's Long Tail, Tomorrow's New Field

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



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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
- "Millions of" per AT&T

Operators

- Easy deployment and maintenance
- Network flexibility for multiple industries

Diversified Challenges and Gaps to Reach 5G

	Latency	Throughput	Connections	Mobility	Network Architecture
5G	1 ms E2E Latency	10Gbps Per Connection	1,000K Connections Per km²	500km/h High-speed Railway	Slicing Ability Required
GAP	30~50x	100x	100x	1.5x	NFV/SDN
LTE	30~50ms	100Mbps	10K	350Km/h	Inflexible

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*

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

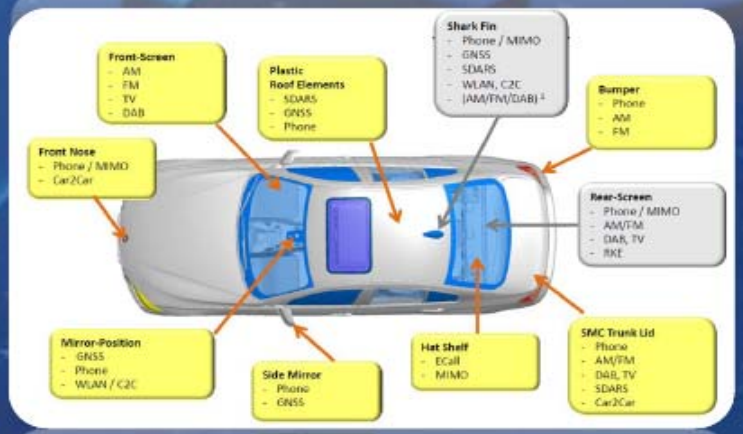
Sensor	Specs	Bandwidth
Cameras	2x, 640x480, 30fps, 8/24bit	147Mbit/s uncompressed
Microphones	2x, 44kHz, 16bit	1.4Mbit/s
F/T sensors	6x, 1kHz, 8bit	48kbit/s
Gyroscopes	12x, 100Hz, 16bit	19.2kbit/s
Tactile sensors	4000x, 50Hz, 8bit	1.6Mbit/s
Control commands	53DoF x 2-4 commands, 100Hz/1kHz, 16bit	3.3Mbit/s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

➔ *Force control latency requirement = 1-5 ms*

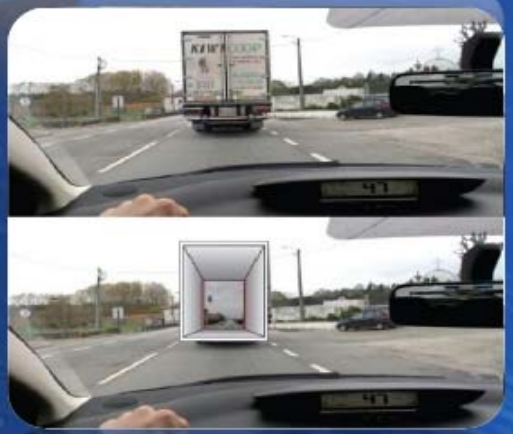
[G. Metta "Robotics-Derived Requirements for the Internet of Things in the 5G Context," IEEE MMTC E-Letter, Sept 2014]

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 ....

Human Centric Visual Communications with Future Media

Power Consumption Barrier at Device

1 Device 1 Day → 1 Hour 5G video call

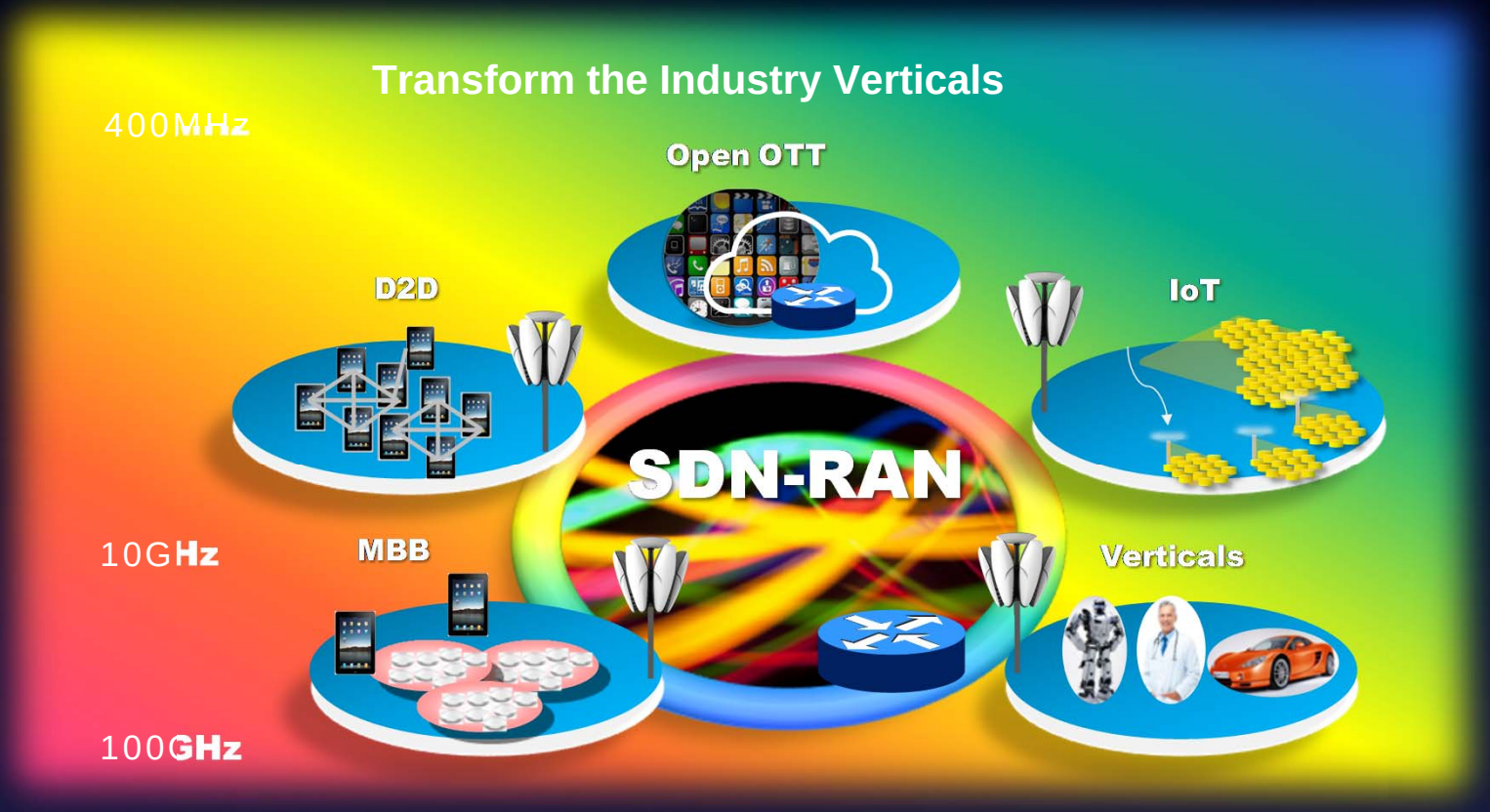
10Gbps → 3600×10^{10} bits/Hour

1 Device → **10 Watts/Hour** video call

Today LDPC FEC Decoder: 10^{-9}J/bit

→Require 100 times simplified encoding/decoding techniques, *yet approach Shannon Limit*

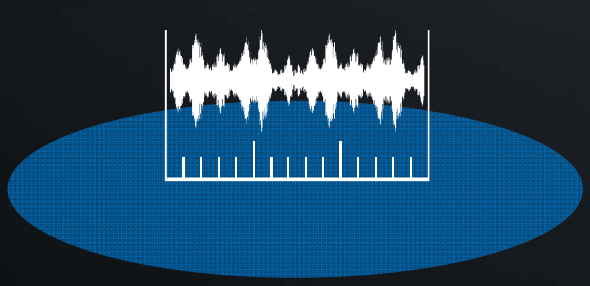
5G (Beyond Smartphone)



Capacity	Speed	Latency	Links	Energy
1000X （Capacity/km^2)	100X （10Gbps)	Less than 1ms	100x	1000X Reduce

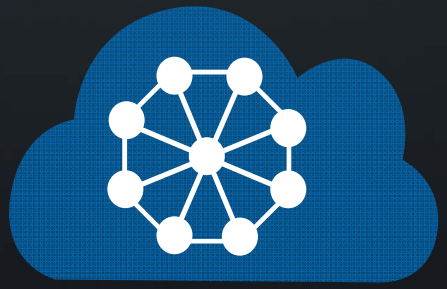
Key Concerns for Reaching 5G

Spectrum



Aggregate All
Available Bands

New Architecture & Operation

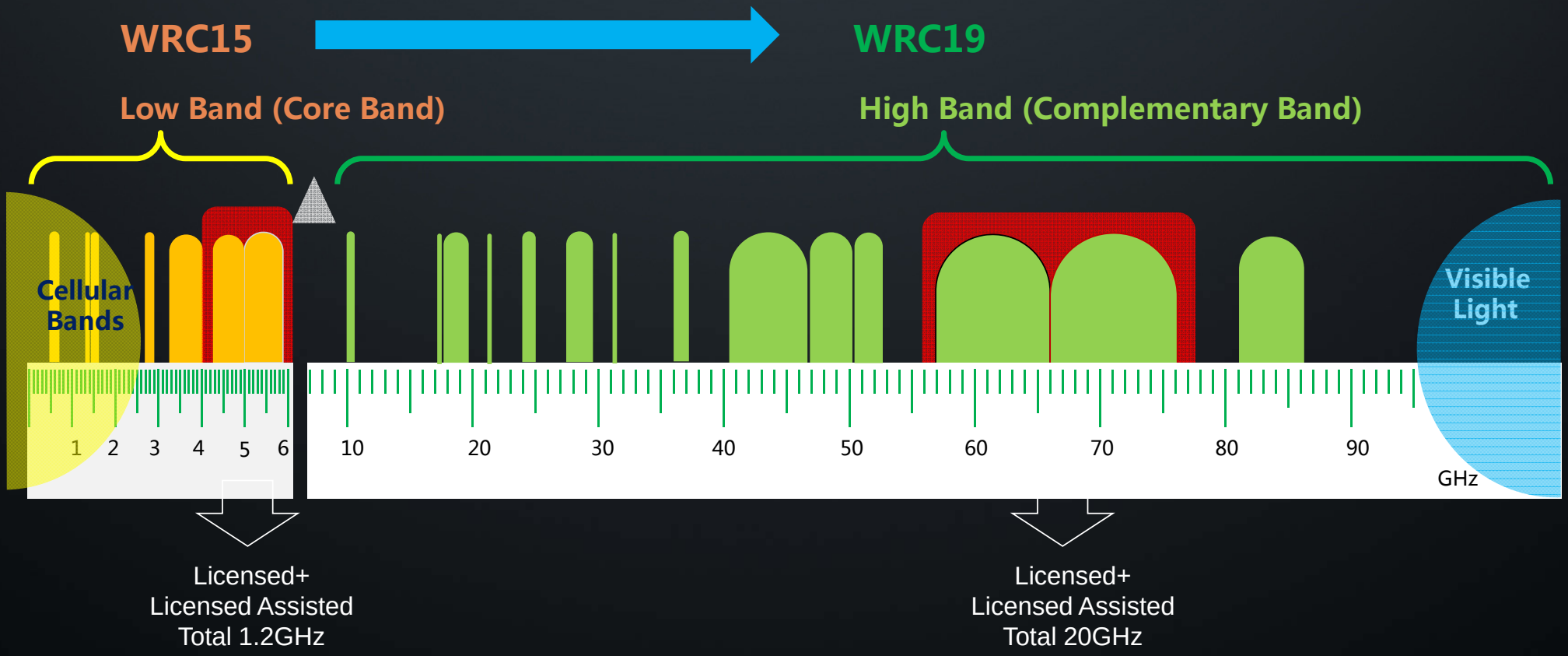


One Physical Network
Multiple Industries

New Air Interface

Flexibility &
Spectrum Efficiency

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



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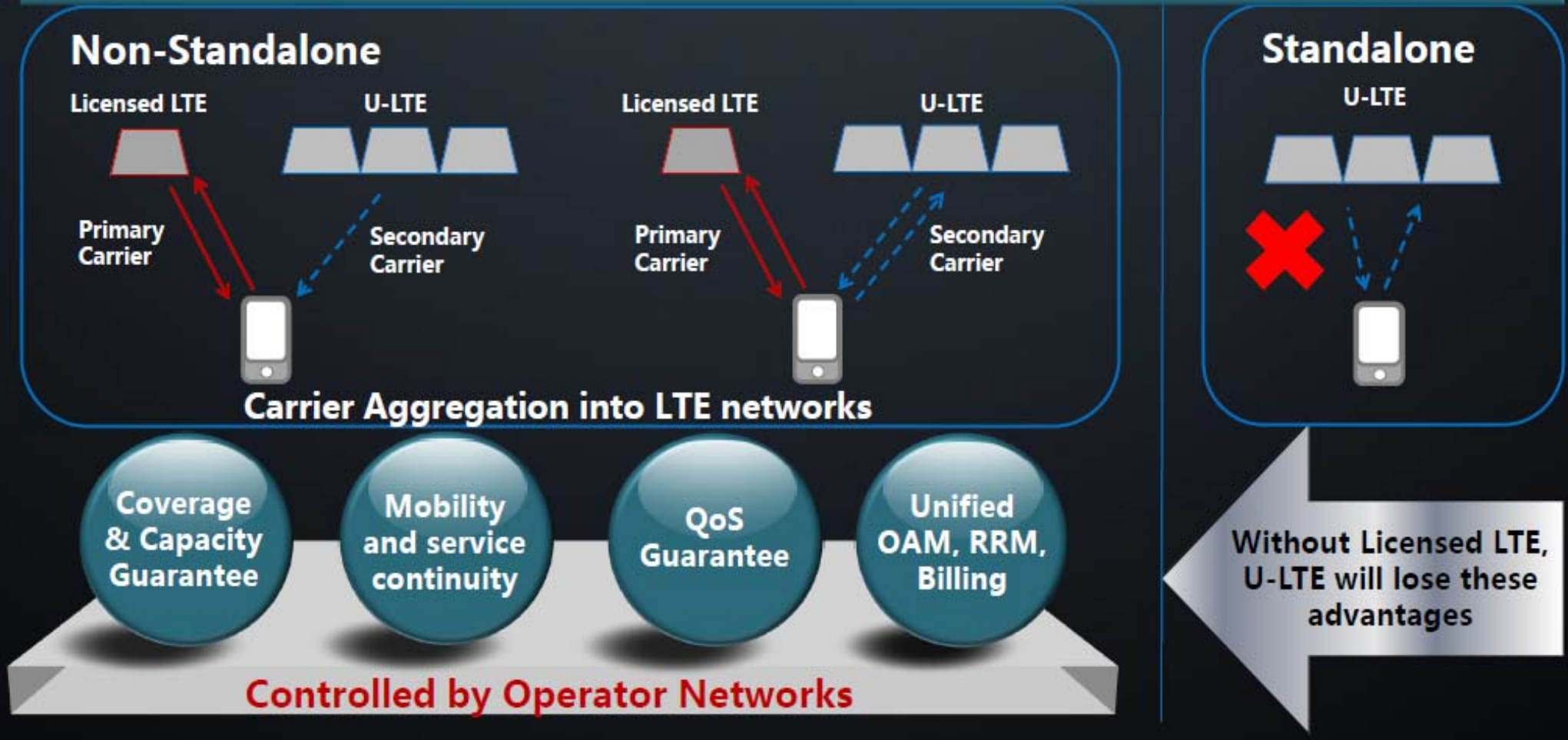
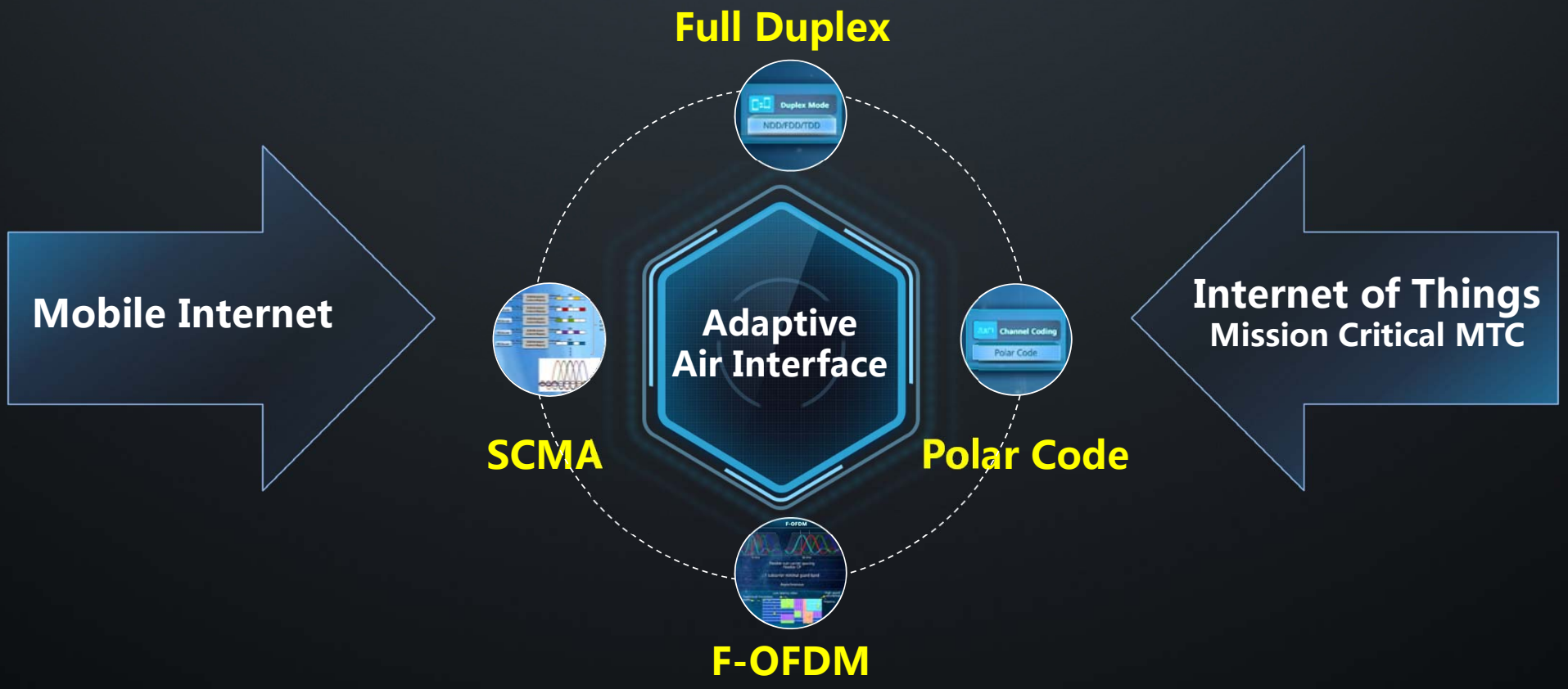
LAA is a stepping stone in 4.5G towards 5G

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



New Air Interface (Huawei Innovations)



One air interface fits **many** applications with high **flexibility,**

at least a **3x** intrinsic spectrum efficiency improvement

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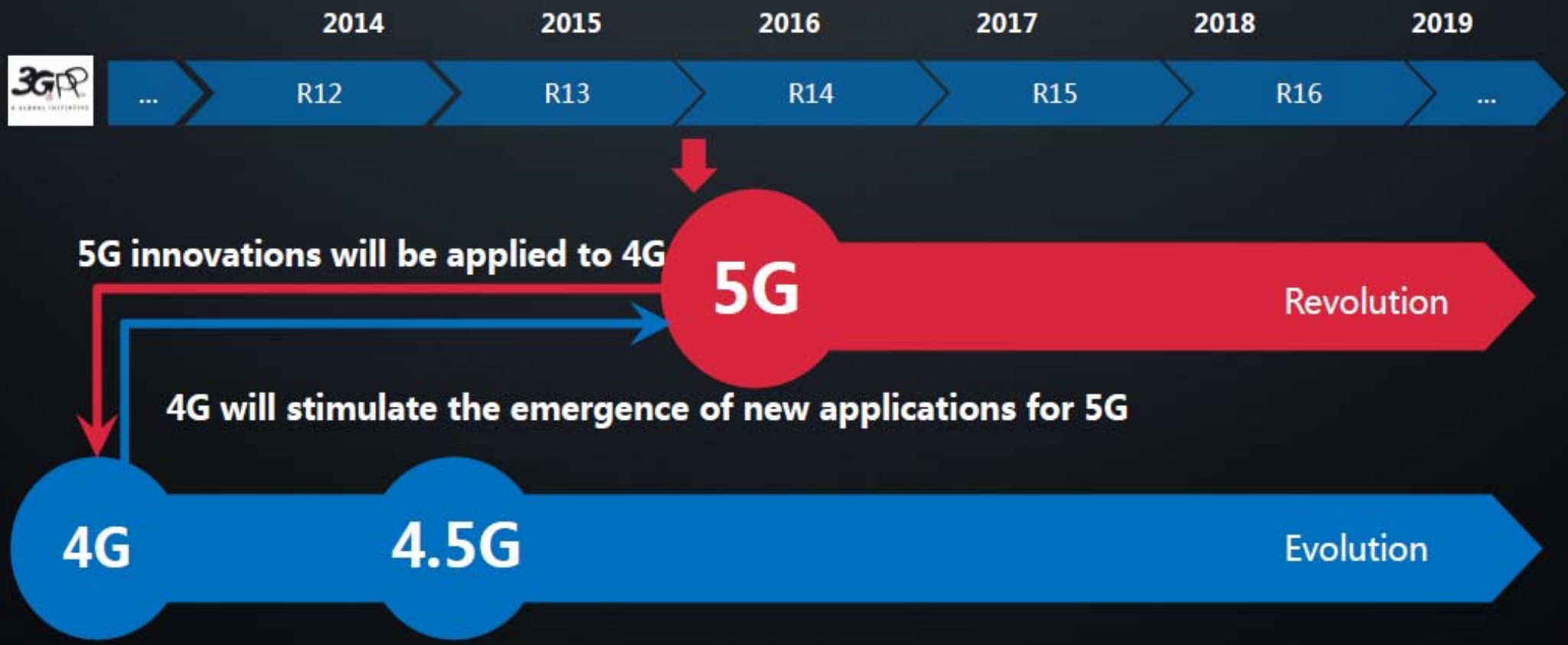
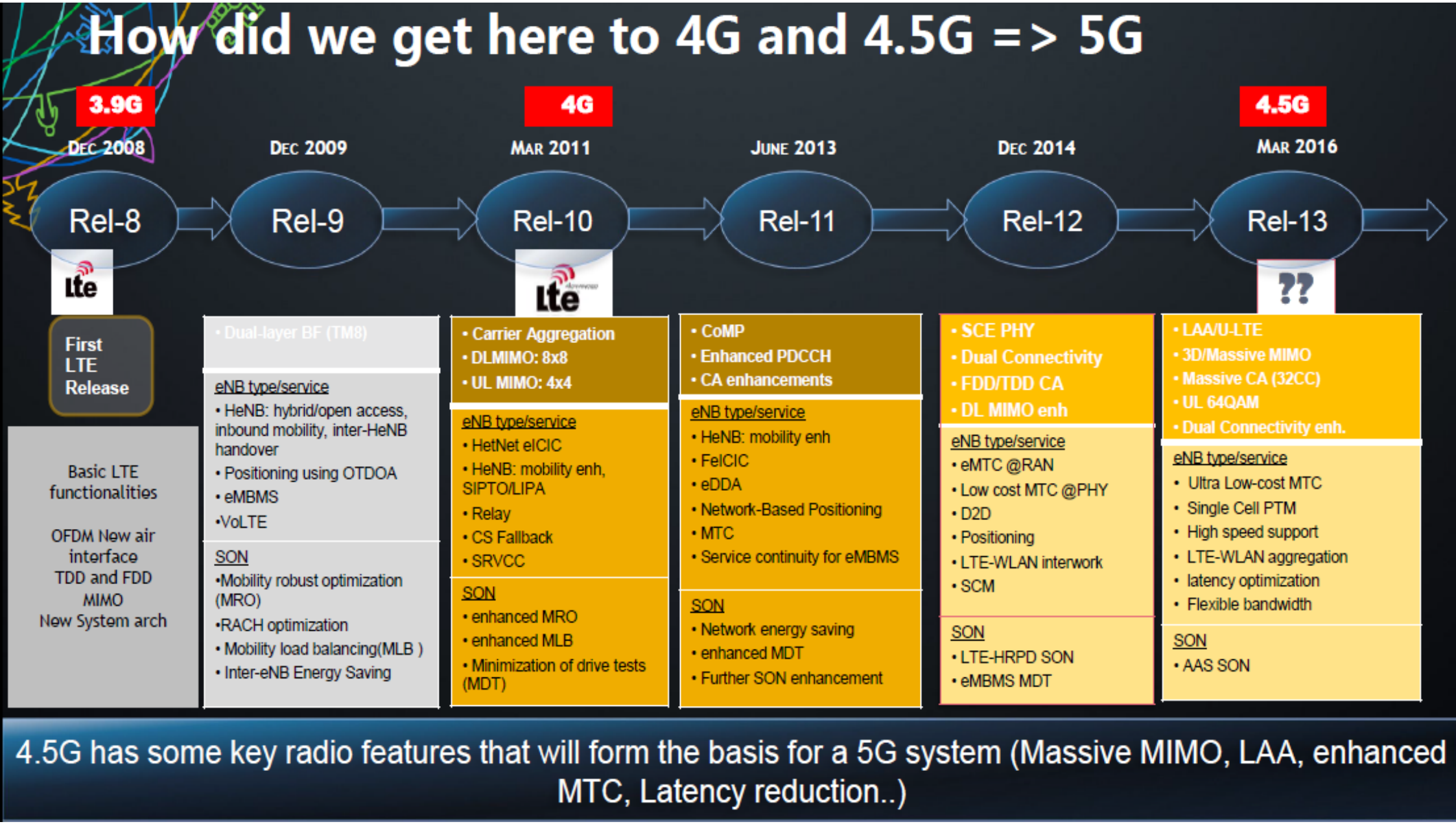
5G Innovations Will be Applied to 4G to Leverage 4G Investment

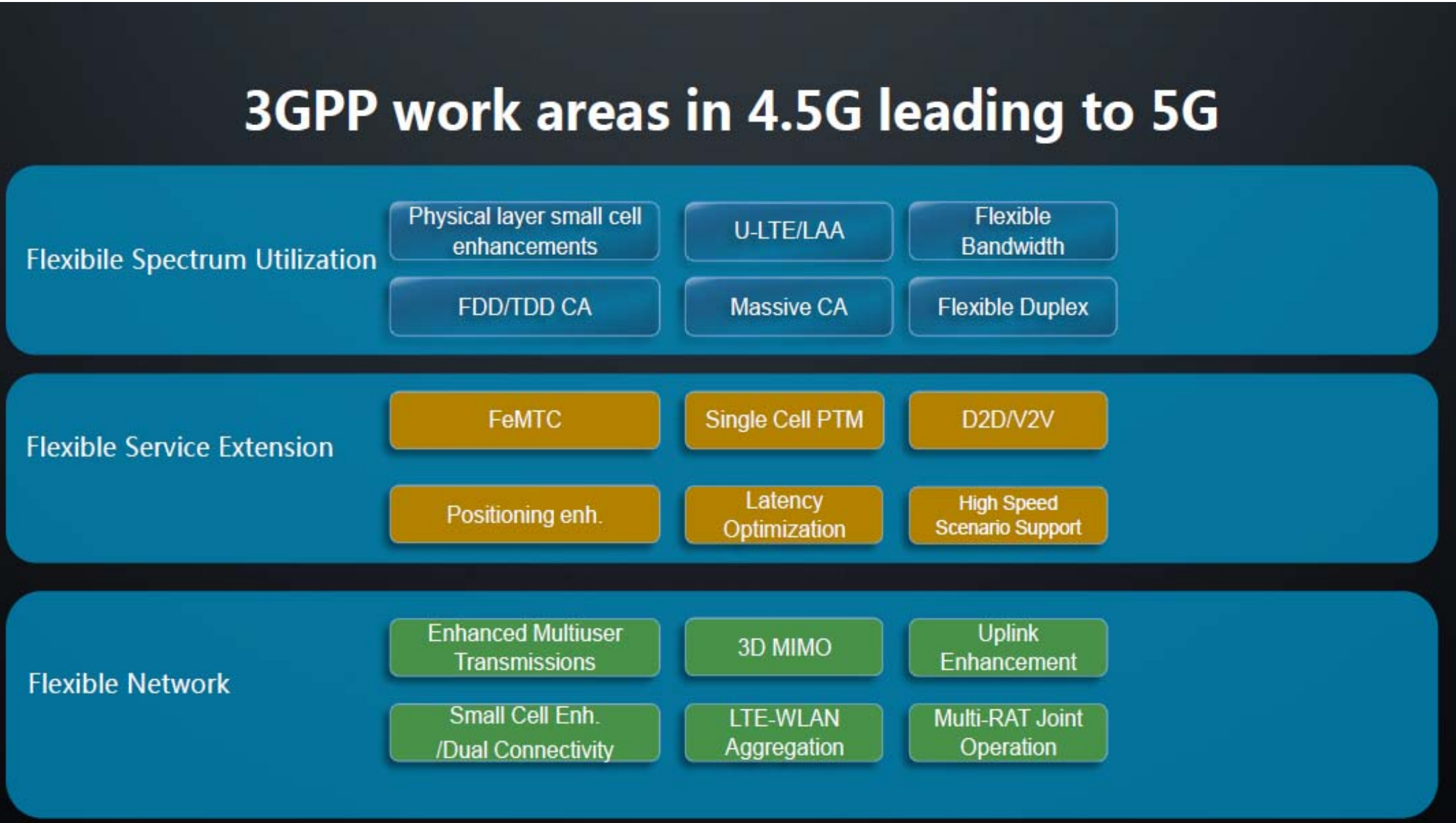


How did we get here to 4G and 4.5G => 5G

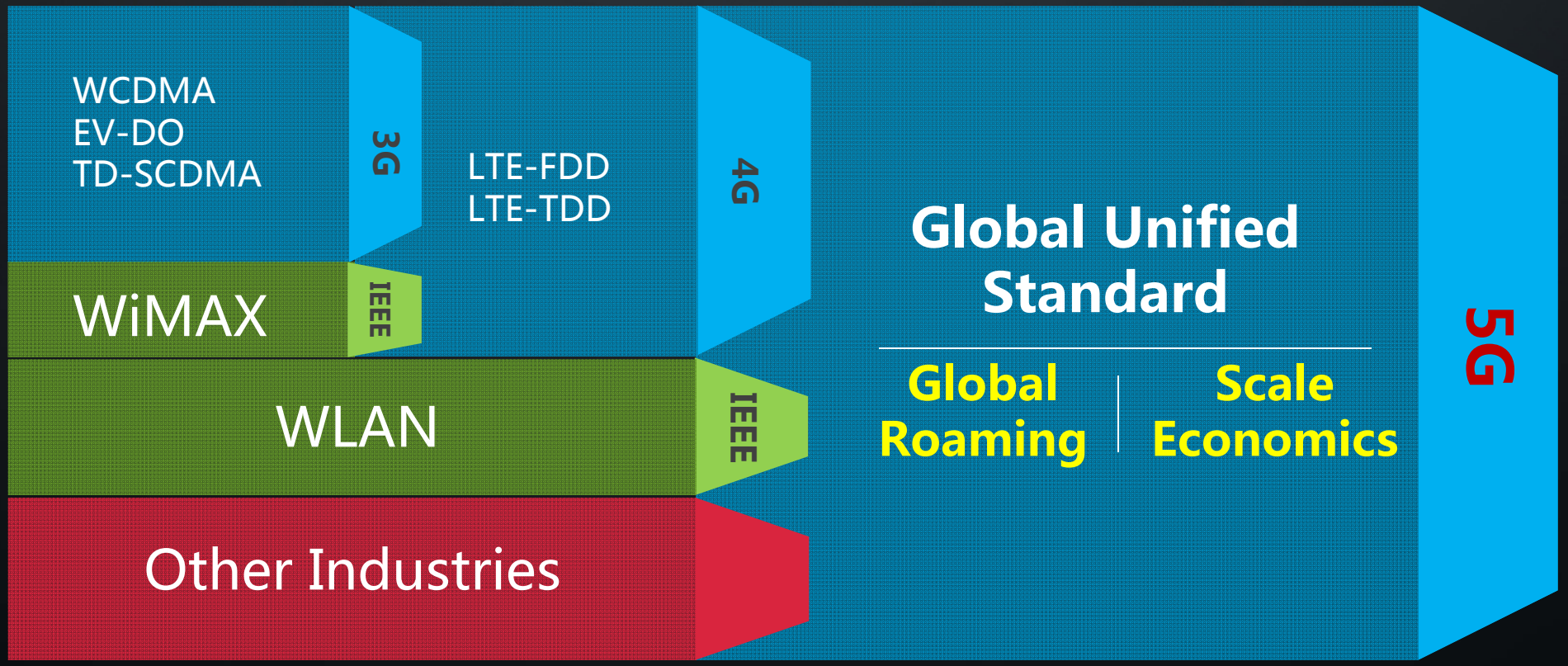


4.5G has some key radio features that will form the basis for a 5G system (Massive MIMO, LAA, enhanced MTC, Latency reduction..)

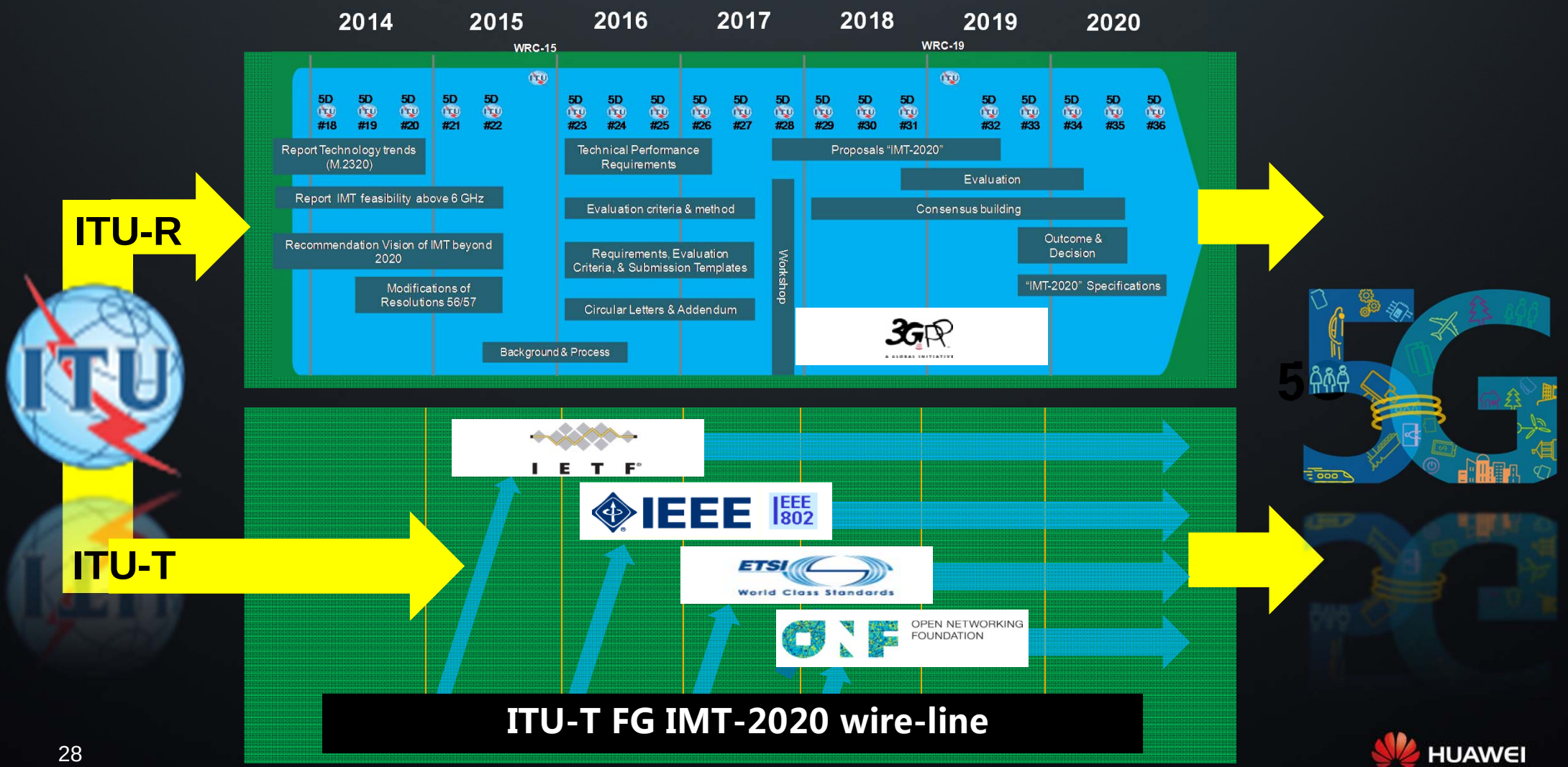
3GPP work areas in 4.5G leading to 5G



A Global Unified Standard for 5G



A New Initiative to Align the 5G Networks



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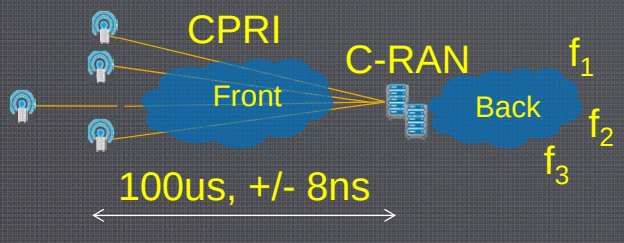
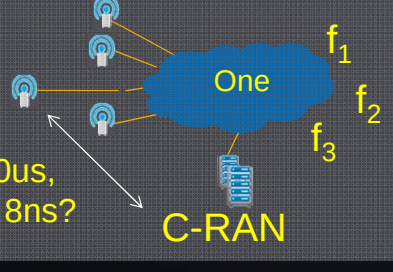
Consolidated Front haul & Backhaul – *one* Fixed Networks

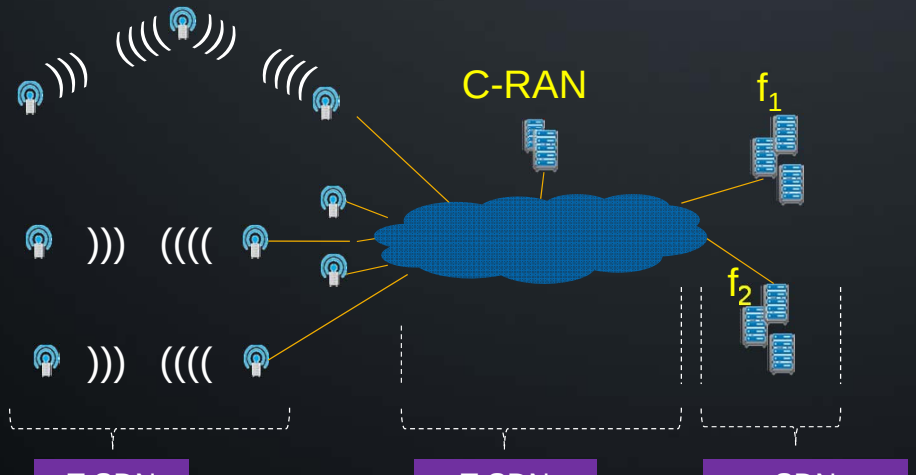


- Cloud/C-RAN virtualizes all 5G compute resources
- C-RAN requires ultra low delay/jitter 'front-haul'
- One option is use of dedicated fiber per antenna site
- Allows C-RAN to send I/Q samples at ultra low delay/jitter



- 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



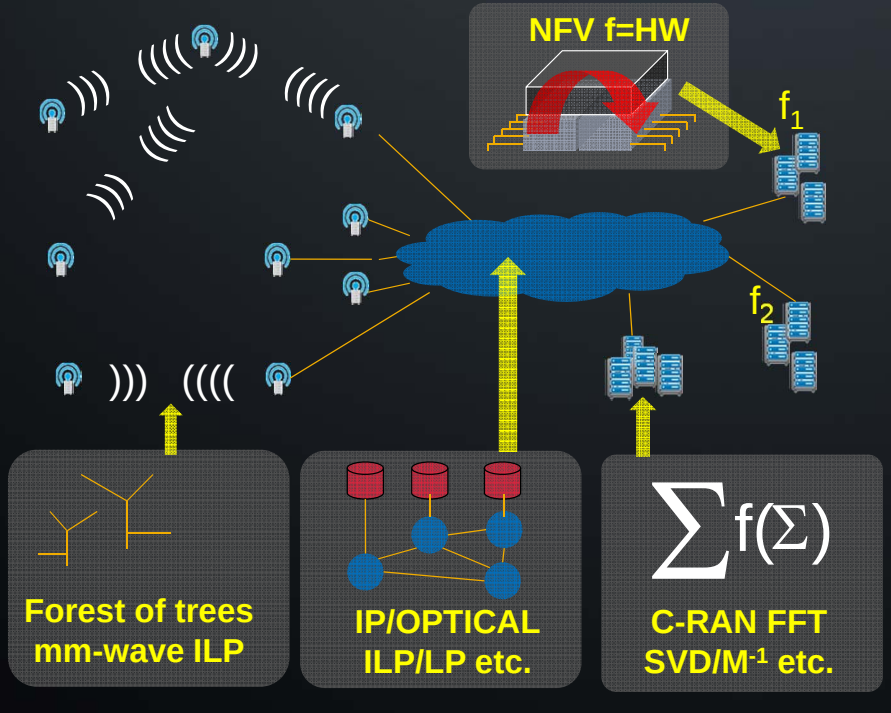
- **Multiple SDN/TSDN controllers**
- **Allocate B/W connectivity**

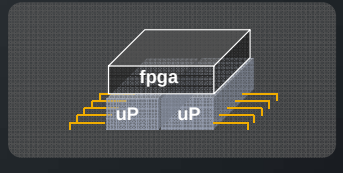
- **Reconfigure optical network**
- **Reconfigure IP network**
- **Reconfigure microwave network**
- **Reconfigure DC network**

- **Allocate DC resources for EPC**
- **Allocate resources for C-RAN**

- **Consolidated view for services.**

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

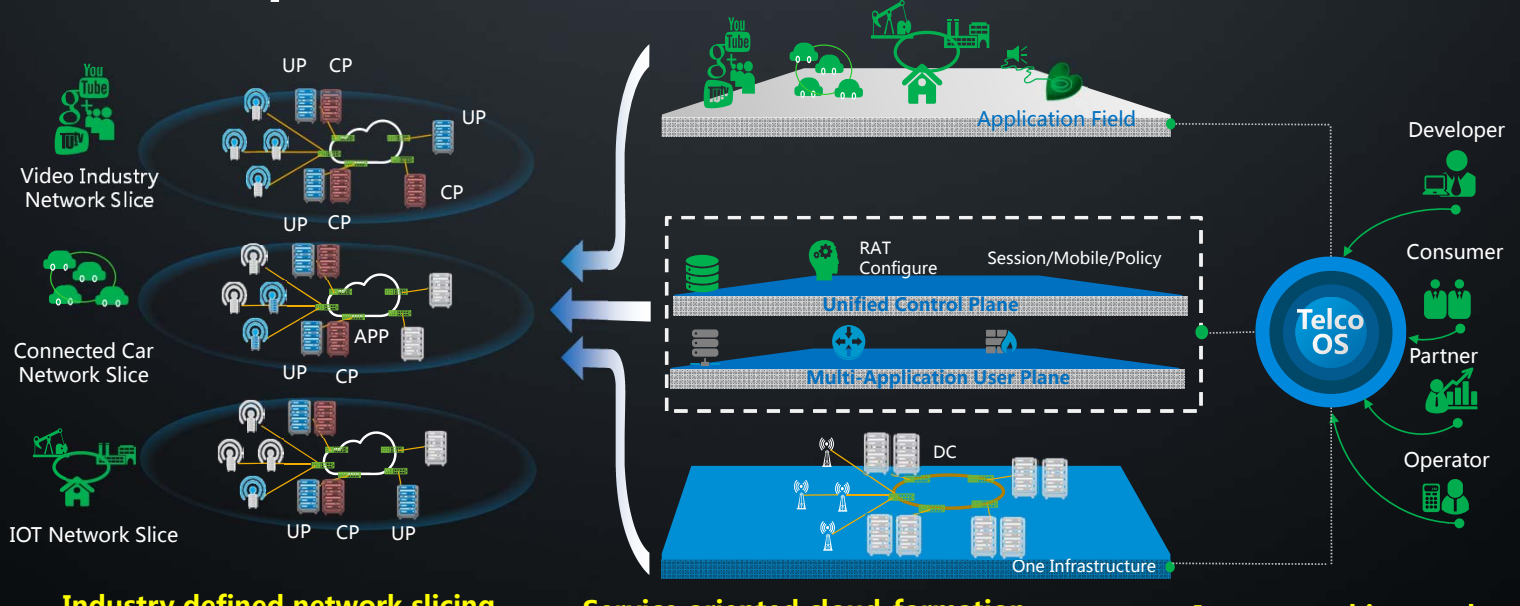




- Hybrid CPU/FPGA (Intel 2017)
- Allow massive parallel programming
- Can do LP/ILP/Convex/FFT etc in HW/Software hybrid
- High performance f()=DPI
- High performance packet forwarding
- Problem – very hard to program

RESULT

Result = A New Consolidated Architecture & Operation for 5G top to bottom.



Industry defined network slicing
Consolidated network
High efficiency/High B/W air I/F

Service oriented cloud-formation
Accelerated and virtualized
key functions w.o custom H/W

Internet architectural operation/orchestration

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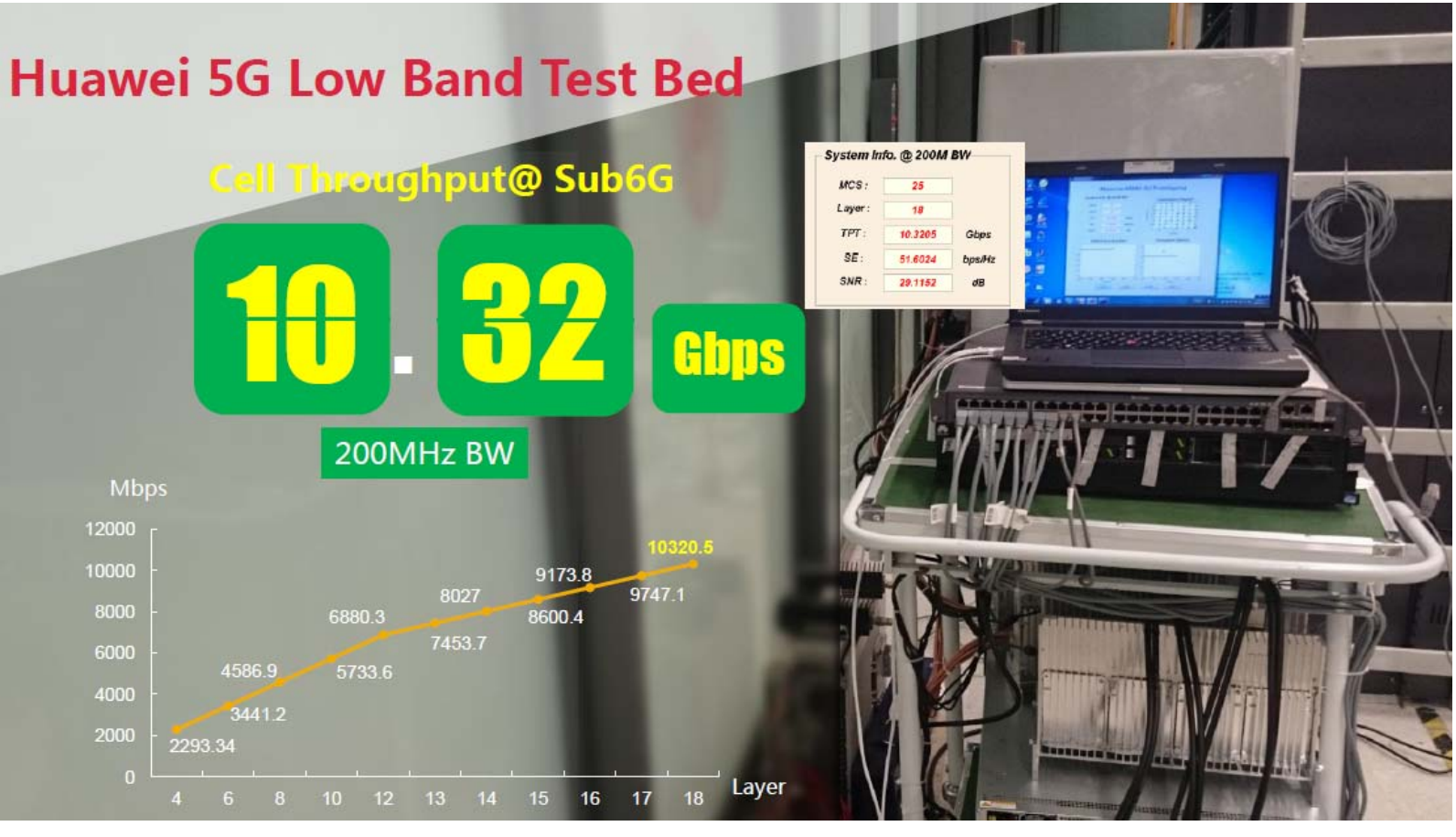
Huawei 5G Low Band Test Bed
Cell Throughput@ Sub6G
10.32 Gbps
200MHz BW
System Info. @ 200M BW
MCS : 25
Layer : 18
TPT : 10.3205 Gbps
SE : 51.6024 bps/Hz
SNR : 29.1152 dB
Mbps
12000
10000
8000
6000
4000
2000
0
2293.34
3441.2
4586.9
5733.6
6880.3
7453.7
8027
8600.4
9173.8
9747.1
10320.5
4
6
8
10
12
13
14
15
16
17
18
Layer


Huawei 5G High Band Test Bed
115Gbps
Wireless Transmission System
Breaks World Record
115.20
Gbps
9.6GHz BW

What about fixed access technologies?

Spectral Efficiency for fixed and Wireless Technologies