“5G Ready, Multi-wave” Microwave Backhaul Solutions and Spectrum Consideration

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HUAWEI

Multi-wave

Contents

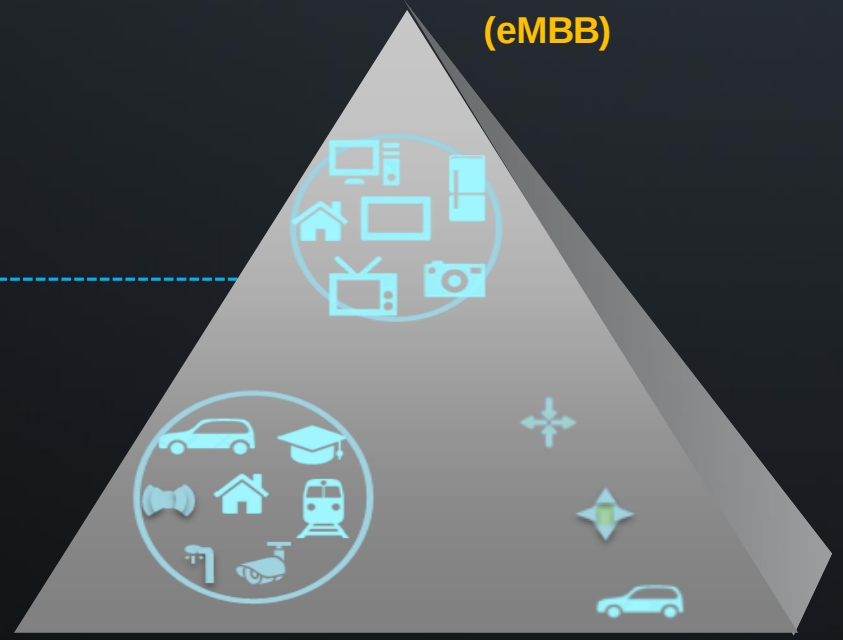
5G : 2 Drivers+3 usage scenarios + massive use case

2 Drivers

3 usage Scenarios

Connecting People

Connecting Things



Leading Operators Progress

		eMBB			uRLLC				mMTC
Carriers	Trial/Commercialization	AR/VR	UHD	Other (Multi-View,…)	Auto Driving	Smart Electrify net	Industrial Connection	Ohthers	NB-IoT
NTT DOCOMO	2020		✓						✓
DT	2019	✓		✓	✓	✓	✓	✓	✓
VDF	2019		✓	✓	✓		✓		✓
CMCC	2020	✓	✓						✓
AT&T	2017Q4		✓						
Verizon	2017Q4		✓						
SKT	2018Q1	✓	✓	✓					
KT	2018Q1	✓	✓	✓				✓	✓

✓ firstly commercialized Use Case

*Source: ITU-R M.2083-0, “IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond”, Sept. 2015.

Mobile backhaul hold the key to 5G： MW still the mainstream

What is the biggest challenge in implementing 5G?

489 survey takers responded to this question

Backwards compatibility with 4G, 3G and even some 2G networks	15.13% [74]
Ensuring 5G networks are secure	7.98% [39]
Future-proofing the network for the next ten years	8.59% [42]
Meeting challenging and diverse performance targets	13.70% [67]
Too many consortiums trying to influence the standards process	19.02% [93]
Upgrading backhaul to support the enormous amount of traffic coming to 5G	31.70% [155]
Other (Let us know in the comments section below.)	3.89% [19]

- Poll by Light Reading, to 500+ operator customers

5G
Mobile Backhaul

- **31.7%** Mobile Operators : Upgrading backhaul, is the biggest challenge in implementing 5G.
- **65%** cell sites are backhauled by Microwave.
  (* From huawei Research institution 2016)
- Y2020,5G kick off : Normally 1-2 years ahead, operators prepare bearer network for RAN side.
- NOW, 2017 : Time to Think about the Mobile Backhaul Network .

5G Wireless Bandwidth : Max to 10G/site

Backhaul Provisioning for N cells = max (N x busy time mean, Peak)

By NGMN definition for single site

Site type	LTE / LTE-A	5G Low band (Initial stage)
Spectrum	20MHz	3.4G～3.5G：200MHz
Configuration	**3** cells, 4T4R	**3** cells，64T64R
Spectrum Efficiency	Peak：15bit/Hz ，Average：2.5bit/Hz	Peak：50bit/Hz，Average：10bit/Hz
Others Factors	10% overhead，20 % X2 traffic（LTE-A） 1:3 TDD Up/down	10% overhead, 20% Xn traffic 1:3TDD Up/down
Cell average rate	2.5bit/Hz * 20M * 1.1 * 1.2 * 0.75 * 3=148.5M	10bit/Hz * 200M * 1.1 * 1.2 * 0.75=1.98G
Cell peak Rate	15bit/Hz * 20M * 1.1 * 0.75 * 3 = **742.5M**	50bit/Hz * 200M * 1.1 * 0.75=**8.24G**
Site Average Rate	3*148.5M + 3*1.98G = **6.39G**	

Peak 5G site / 5G + 4G site last mile throughput requirement : **8.98G**

Average 5G site last mile throughput requirement : **5.94G**

Average 5G+4G site last mile throughput requirement : **6.39G**

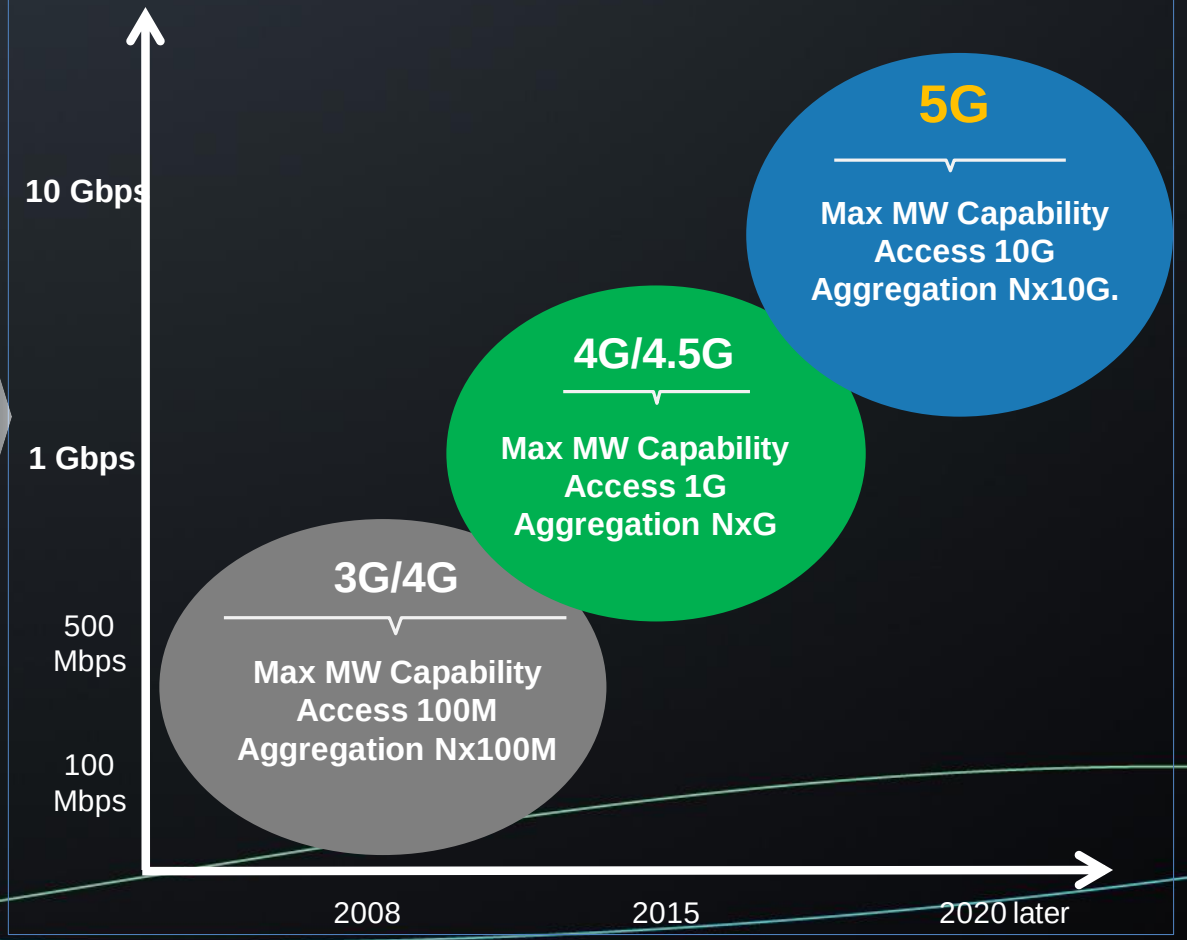
Network Bandwidth Forecast

300M~2G/site Capacity Will Be Main stream to Y2020

- In real network , 200M spectrum is hard to obtain, considering **100M spectrum**, throughput would be **4.12G**
- Considering real deployment, 5G will be deployed in urban city in initial stage while LTE network will upgrade continually.

Bandwidth Anticipated	2017	2020	2023
75% of sites	**150M bps** LTE 20M 2T2R	**300~600M bps** LTE 40M 2T2R/4T4R	**1~2G bps** LTE 40~100M 4T4R/8T8R
25% of Sites	**300M bps** LTE 40M 2T2R	**0.8~1G bps** LTE 40~60M 4T4R/8T8R	**4~5G bps** LTE 40~100M 4T4R/8T8R 5G 100M 64T/64R
<5% Sites	**1G bps** LTE 40~60M 4T4R/8T8R	**2~4G bps** LTE 40M 4T4R 5G 100M 64T/64R	**10~20G bps** 5G 100M 64T/64R 5G 800M 64T/64R

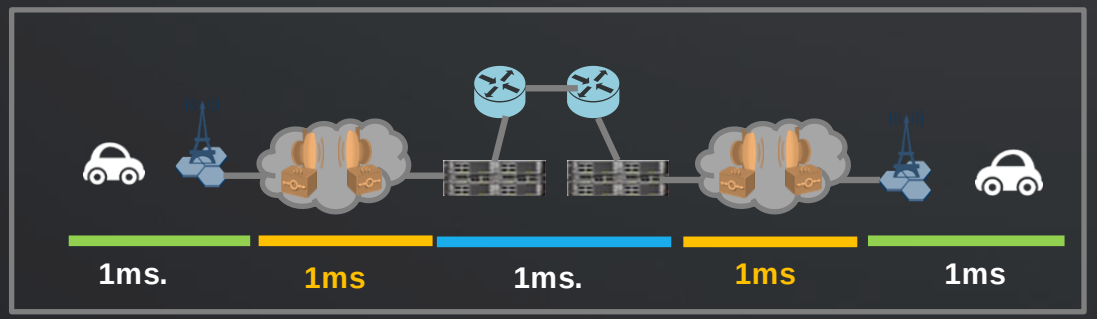
MW Should Have 10G+ Capacity Evolution Ability



Latency Challenge by 5G Service and Network Architecture

Latency Requirements for 5G Use Case

2G/3G/4G Cellular	4.5G V2X 3GPP TR 23.785	5G eV2X 3GPP TR 22.886
Intelligent Communication	Safe Driving	Automated Driving
		
< 50ms	< 20ms	< 5ms

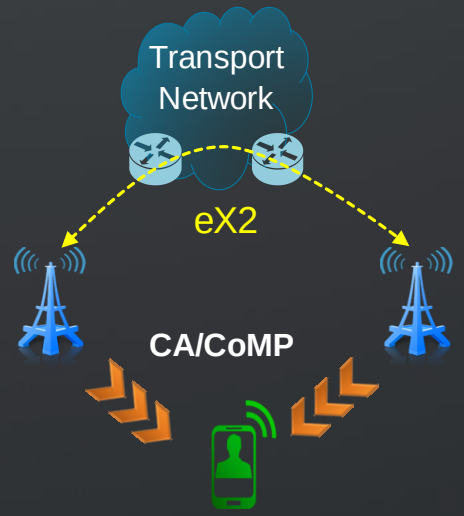


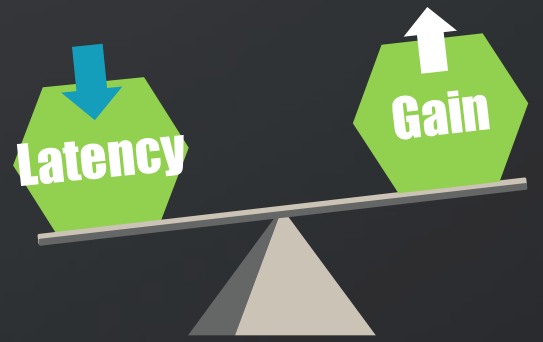
E2E latency requirement for transport section is **2ms,** which leading less equipment level latency

Latency Requirements for CA/CoMP

<100us latency for 100% Gain
<4ms latency for 40~80% Gain
>8ms latency for 0% Gain (TBD)

Disclaimer: Latency requirement for 5G wireless features may vary based on actual technical development.

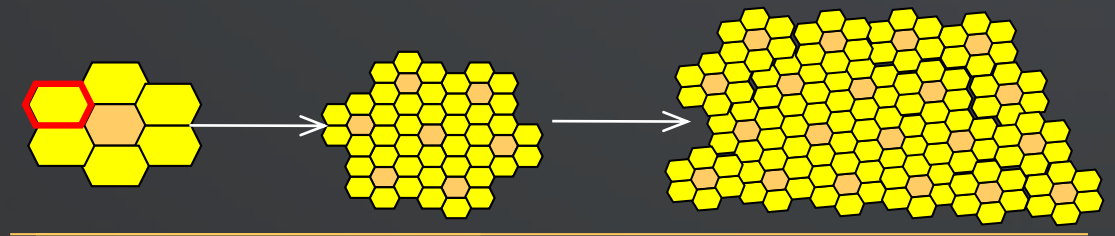




For higher wireless gain, latency of eX2 forwarding **<4ms,** which leading less network level latency

OAM Challenge: Multiple sites and Services in 5G era

Increasing Site Density



1X 3X 10X

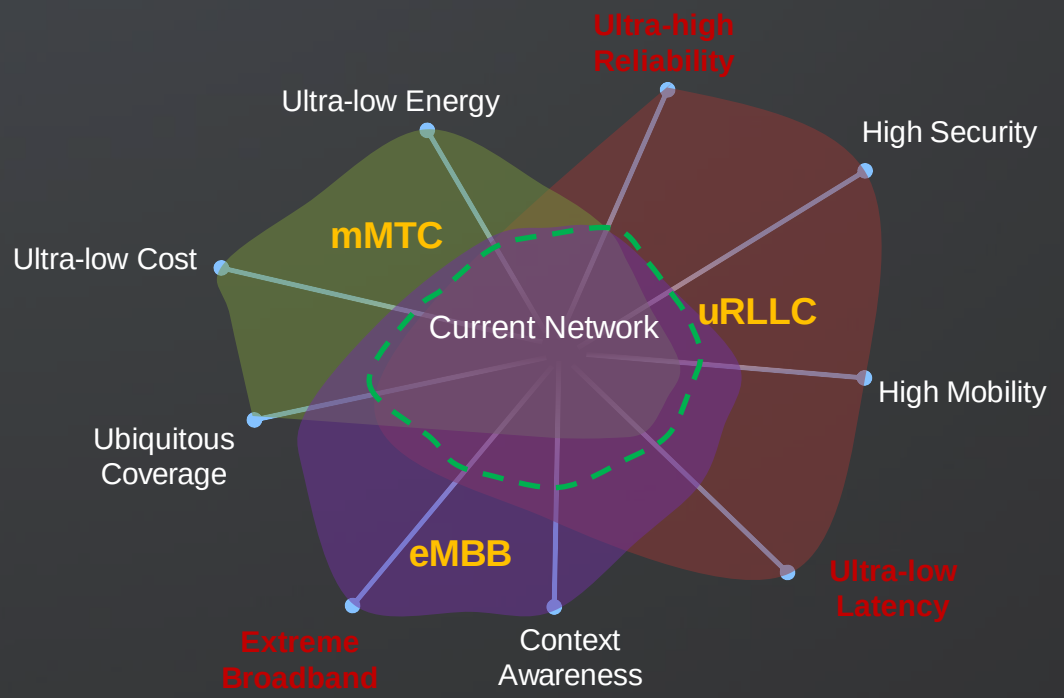
How to Match High Density Sites Scenario

?

How to Manage Such A Great Network

?

Different Services



Different Service Different SLA

Key 5G Microwave Requirements of Leading Operators

vodafone

SDN Ready

Urban Macro Sites

Dis<2km, 1~10Gbps, E-band mainly

Rural Macro Sites

Dis<2-7km, 1.5-4Gbps, BCA* upgrade

Countryside Macro Sites

Dis>7km, 1Gbps, traditional band bundling

*VHA: A **low latency** transmission network underpins the architecture !*

***BCA:** band carrier aggregation

orange™

4.5G-5G Smooth Evolution

SDN Ready

Hot pot Urban & Aggr Macro Sites

1-2Gbps
E-band & BCA*

Urban Macro Sites

500Mbps-1Gbps
112MHz channel

Rural Macro Sites

250-500Mpbs
28MHz@2048 or 4096QAM

*Orange: What are the mobility limits to reach the latency targets of **1-10ms** for applications?*

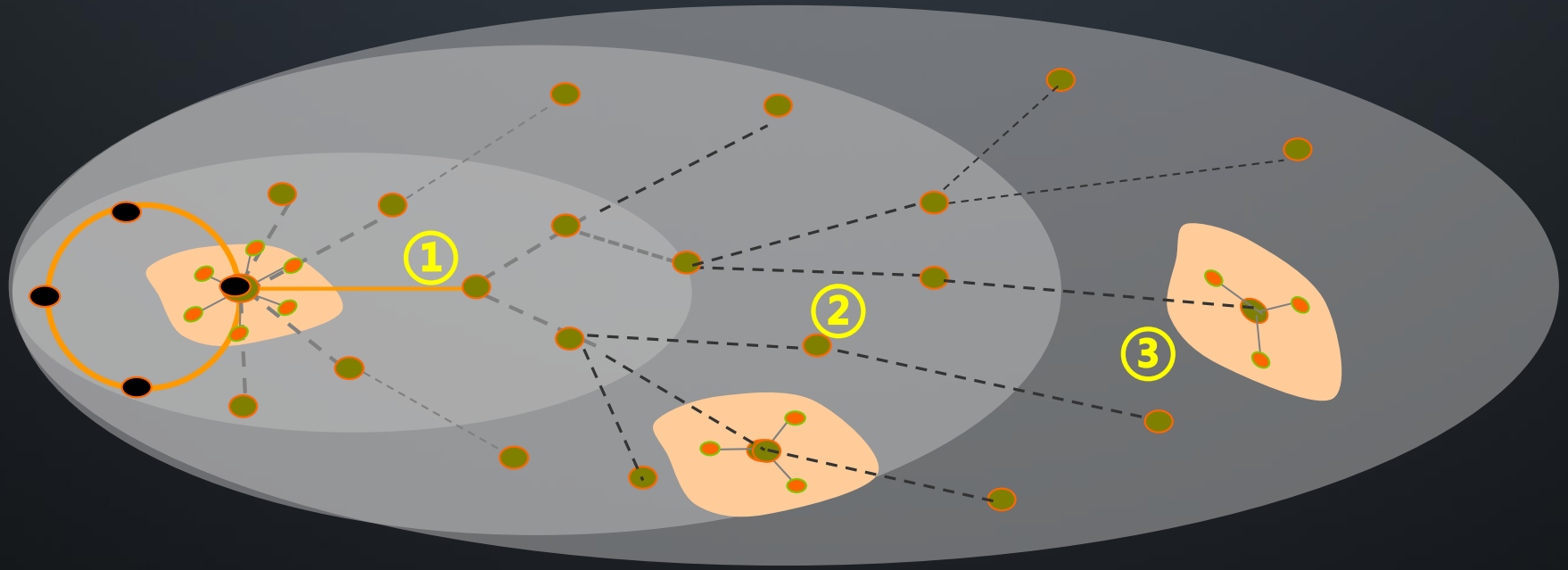
Telefónica

SDN Mandatory

"10 GE interface be ready for all microwave equipment"

Contents

How Microwave Bandwidth Evolution Towards 5G



① Hotspot Sites

- High capacity
- Link distance < 2km
- Limited tower space

② Urban Sites

- Middle capacity
- 2km < Link distance < 7km

③ Rural Sites

- Low capacity
- Link distance >7km

Hotspot Sites Bandwidth Evolution with CA/E-band

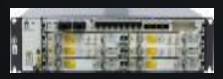
3G / 4G

500Mbps

Frequency 1

- 28M XPIC 1+0
- 56M 1+0

IP MW



4.5G

1Gbps

Frequency 1

Frequency 2

- 28M XPIC 2+0
- 56M XPIC 1+0
- 112M 1+0

IP MW

Adding ODU / IF
(28/56M)

Frequency **Must**

Frequency **Optional**

Without E-band Spectrum

With E-band Spectrum

5G

2Gbps

Frequency 1

Frequency 2

Frequency 3

Frequency 4

- 28M XPIC 4+0
- 56M XPIC 2+0
- 112M XPIC 1+0

IP MW

Adding ODU / IF
(28/56/112M)

>2Gbps

Spectrum ?!

- *28M XPIC 8+0*
- *56M XPIC 4+0*
- *112M XPIC 2+0*

E-band

Swap with E-band

CA Helps Bandwidth Evolution Smoothly And Less Tower space

Carrier Aggregation (CA) : smooth upgrade from 1+0 to 4+0/8+0

Single polarization expansion

Dual polarization expansion

More than **75%** outdoor units saving

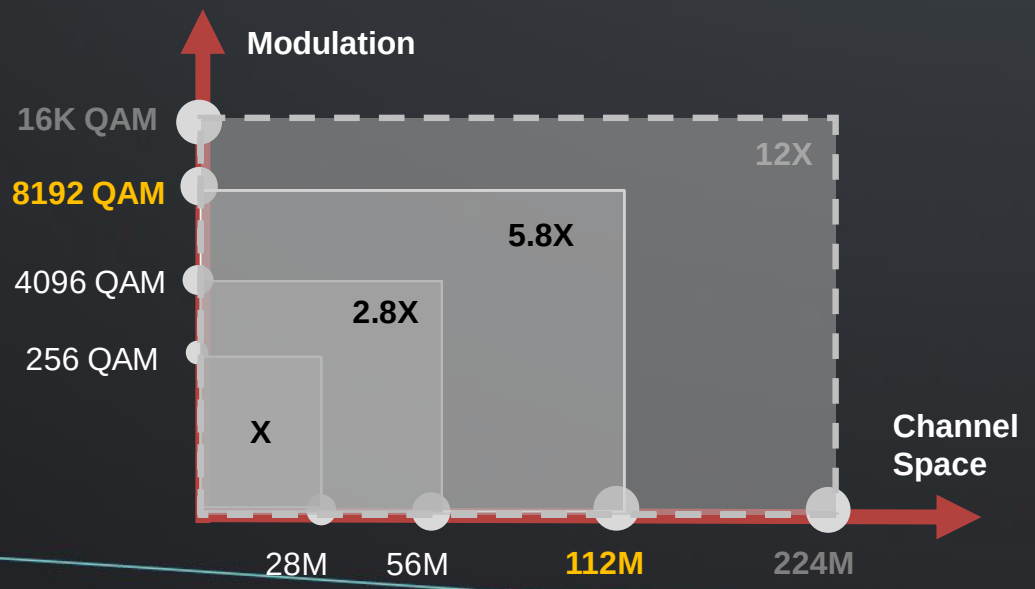
- "0" tower delivering when expansion
- 30% tower spacing saving
- 8+0 is make sense

2018Q3 ready

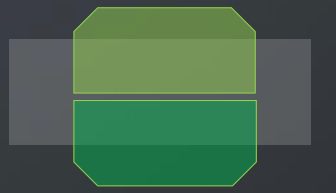
New Spectrums Provide xG ~ 10G+ bps Bandwidth Evolution

>5 times bandwidth increasing by upgrade to 8K QAM and 112M CS

Traditional band

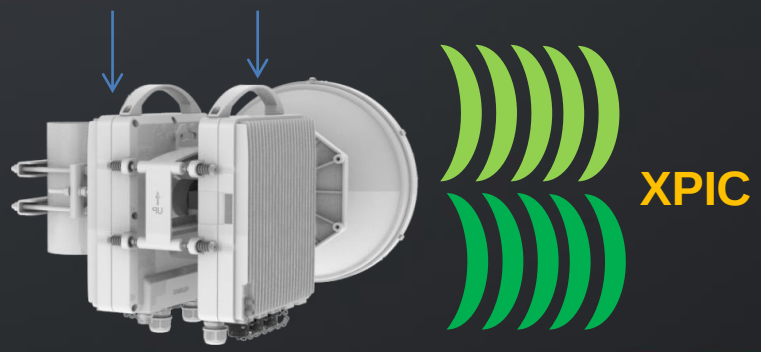


Upgrade E-band to XPIC for 20Gbps capacity



E-band

2* 10G E-band Equipment



Industry 1st 20Gbps Microwave link

2018Q1 ready

2017Q3 ready

Urban Sites Bandwidth Evolution with CA/SDB

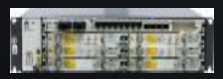
3G / 4G

300Mbps

Frequency 1

- 28M XPIC 1+0
- 56M 1+0

IP MW



4.5G

800~1Gbps

Frequency 1

Frequency 2

- 28M XPIC 2+0
- 56M XPIC 1+0
- 112M 1+0

IP MW

Adding ODU / IF (28/56M)

Without E-band Spectrum

5G

2Gbps

Frequency 1

Frequency 2

Frequency 3

Frequency 4

- 28M XPIC 4+0
- 56M XPIC 2+0
- 112M XPIC 1+0

IP MW

Adding ODU / IF (28/56/112M)

With E-band Spectrum

>2Gbps

SDB

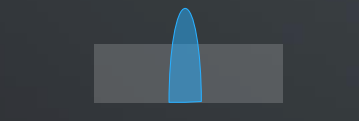
Adding E-band

Frequency — Must

Frequency — Optional

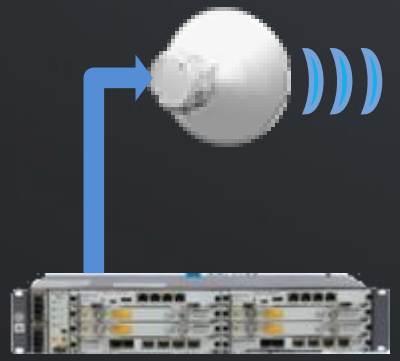
Evolution to SDB For 10Gbps@10km Ability

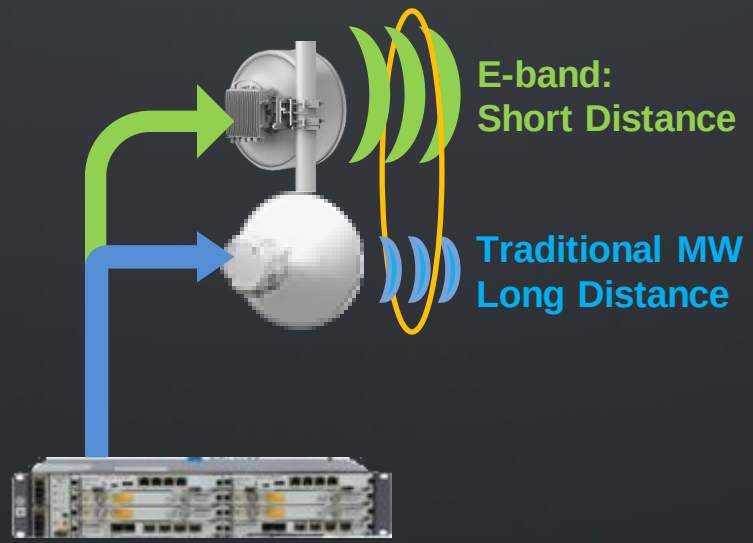
IP MW Evolution to SDB Solution by Adding E-band Link for 10Gbps Capacity

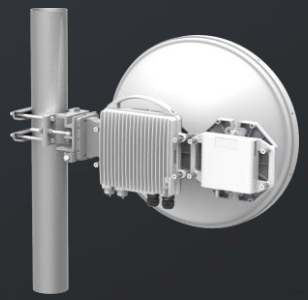


Traditional Band

Traditional Band+ E-band







Dual-band antenna

10Gbps@10km 5Gbps@20km
for SDB Relay Solution

50% tower spacing saving

Rural Sites Bandwidth Evolution with XPIC/CA

3G / 4G

150Mbps

Frequency 1

- 28M 1+0

IP MW

4.5G

500Mbps

Frequency 1

- 28M XPIC 1+0
- 56M 1+0

IP MW

Adding ODU / IF (28M)

5G

1Gbps

Frequency 1

Frequency 2

- 28M XPIC 2+0
- 56M XPIC 1+0
- 112M 1+0

IP MW

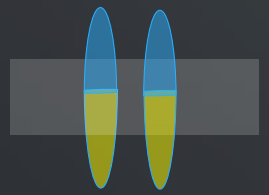
Adding ODU / IF (28/56M)

Frequency **Must**

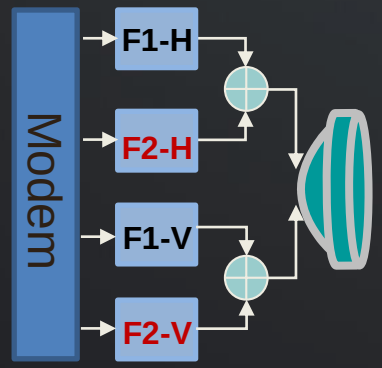
Frequency **Optional**

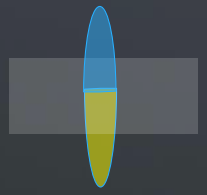
Spectrum Limitation? MIMO for Spectrum Cost Saving

Same Bandwidths Half Frequency by MIMO

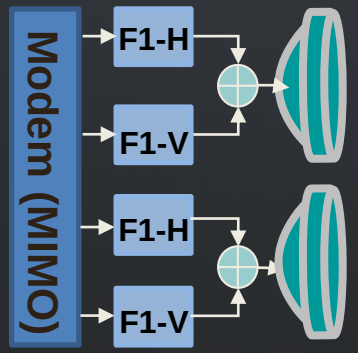


1G = 2x 28M XPIC

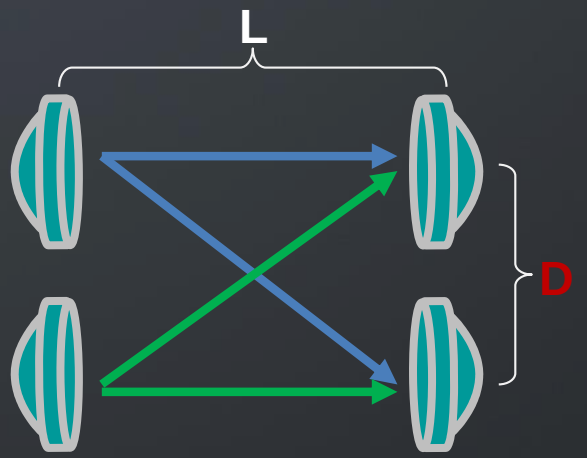




1G = 1x 28M MIMO



HW Innovation to Make MIMO Easy Deployment in Real Network



$$D = \sqrt{\frac{L \bullet c_0}{N \bullet f_{MW}}}$$

c_0 = free space light speed

N = number of TX or RX

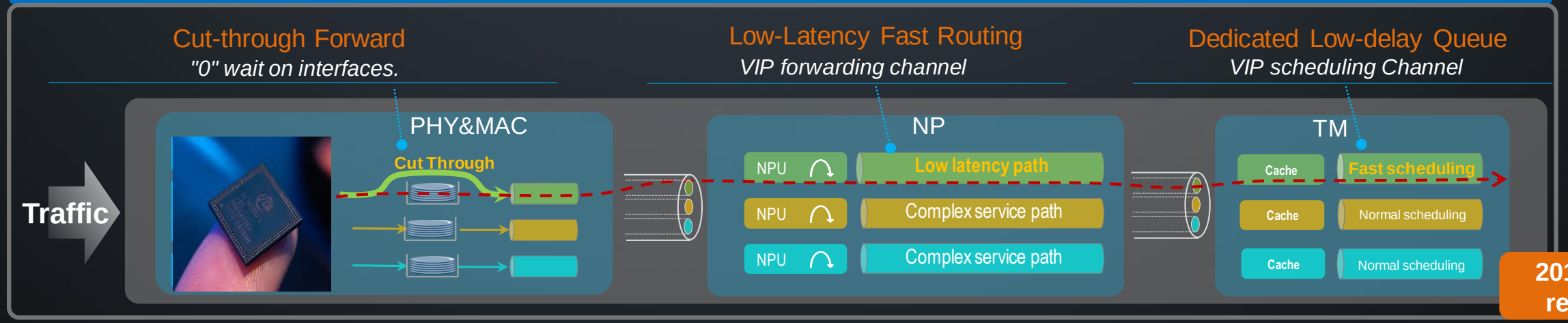
f_{MW} = channel frequency

With HW dedicated pre-coding algorithm,
D is expected to be less than **3M**
when distance no more than **10KM** for 6~42G

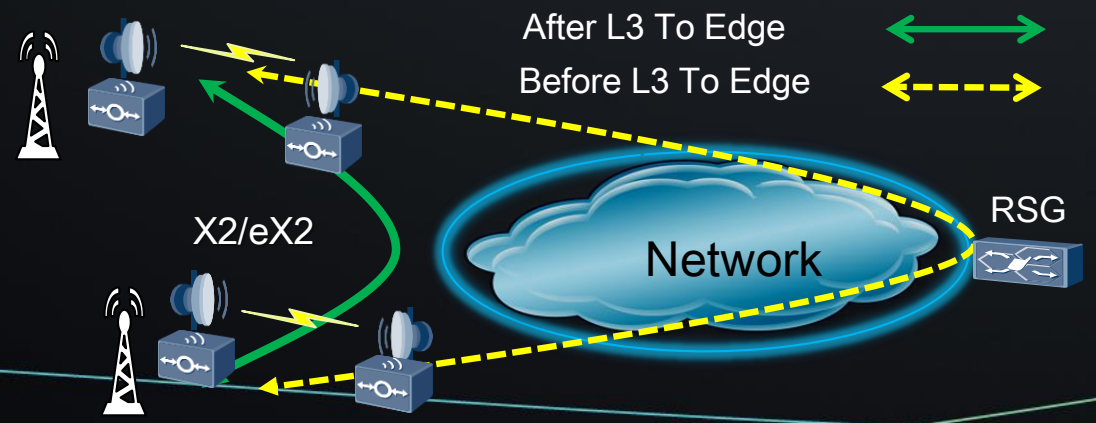
Future Innovation

Optimize Latency in Device Level and Network Level

Huawei HISILICON Asic: **shorten 50%** forward latency, **50us/hop for traditional band (56M CS)**



L3 Microwave, Shorten the Transport Path of Sensitive Service, **E2E 1~2ms**

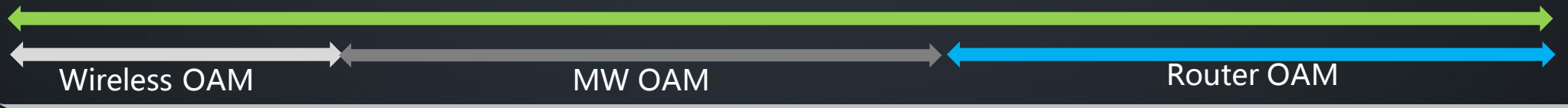


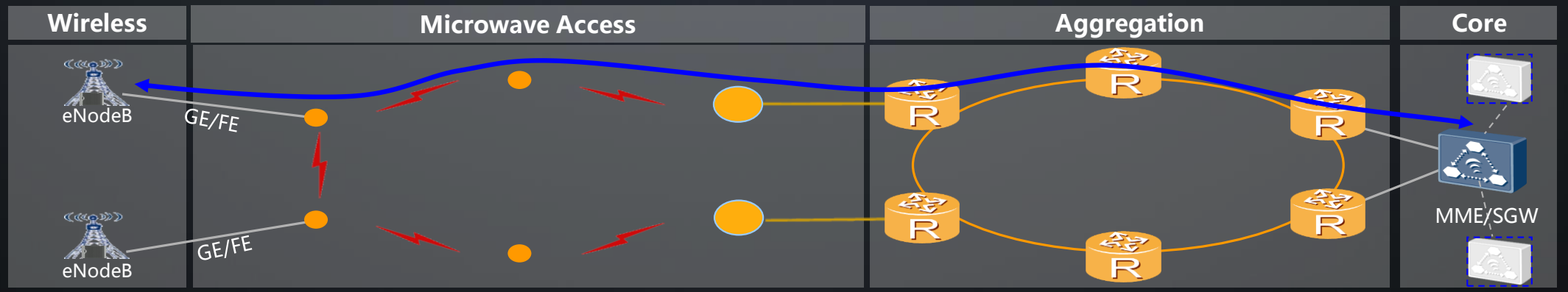
- **Save** BW of uplink **15~30%**
- **Reduce** X2/eX2 Traffic Latency **80%**,
- **Increase** CA/CoMP gain **> 80%**

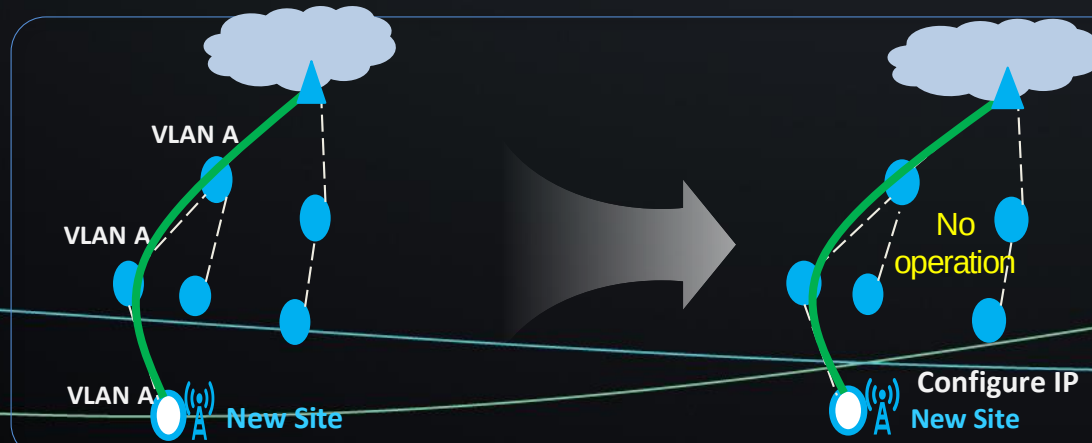
L3 Microwave enable Flex OAM

①

- E2E "PING" for L3 network helps to make fast troubleshooting and easy OAM



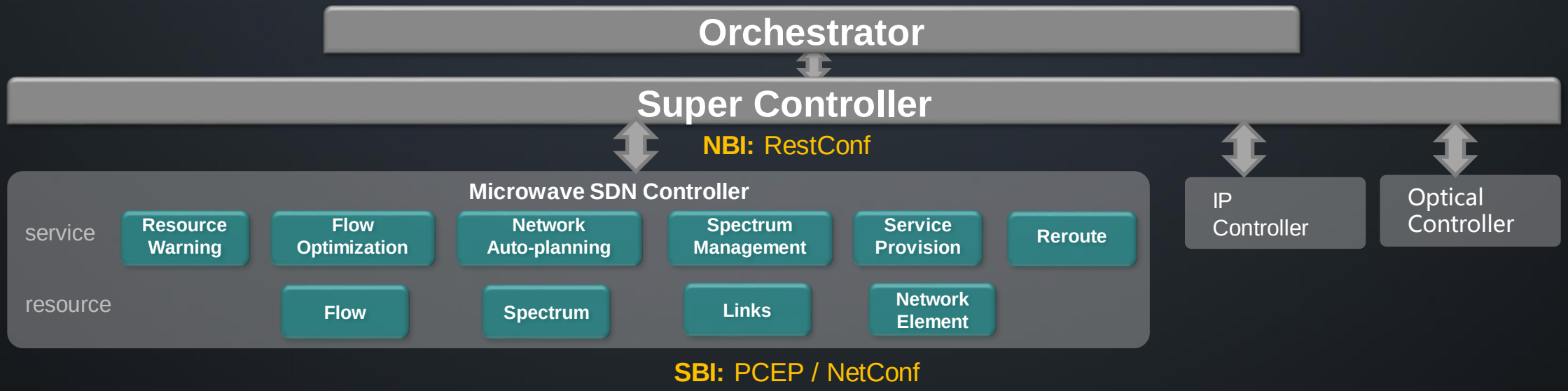




②

- No need complex VLAN configuration when sites change and new site coming
- Service automatic dispatched

Flexible OAM : SDN Architecture & Application



Service Provisioning

- Fast Service Provisioning （L3/L2）

Latency Management

- Optimize link latency
- Enable Network slicing

Open

- Multi-vender coordination
- NBI : Restconf　SBI : PCEP/Netconf

Network Optimization

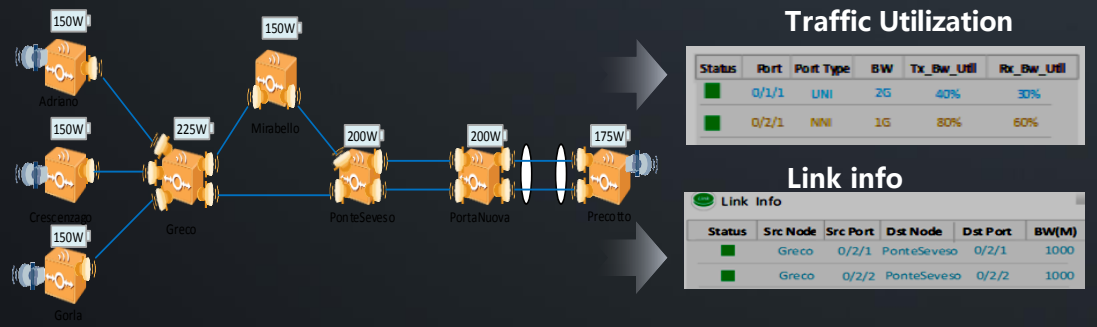
- Traffic optimization
- Re-routing
- Power consumption management
- Spectrum management

Network Resource Management

- Network resource visualization
- Large-scale network management

Flexible OAM : SDN Typical Use Cases

Service & Network Auto-Discovery



Traffic Utilization

Status	Port	Port Type	BW	Tx_Bw_Util	Rx_Bw_Util
	0/1/1	UNI	2G	40%	30%
	0/2/1	NNI	1G	80%	60%

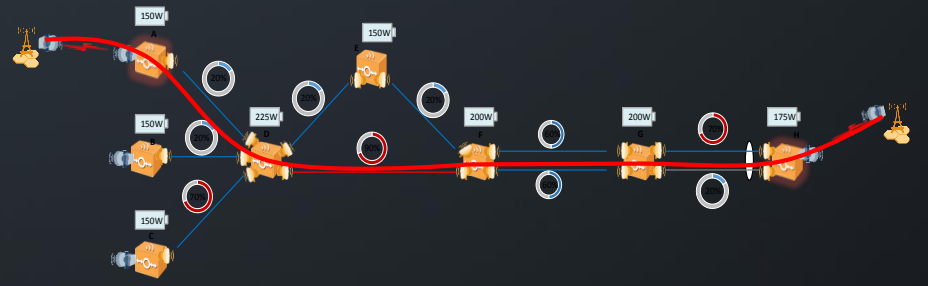
Link info

Link Info

Status	Src Node	Src Port	Dst Node	Dst Port	BW(M)
	Greco	0/2/1	PonteSeveso	0/2/1	1000
	Greco	0/2/2	PonteSeveso	0/2/2	1000

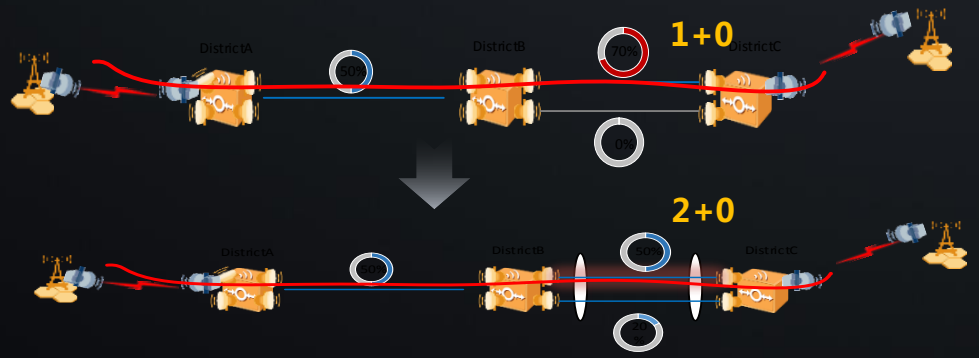
- GUI display **node**, **link**, **port traffic** and **node power consumption** and **service information** through minute level periodical query operation

Service Configuration



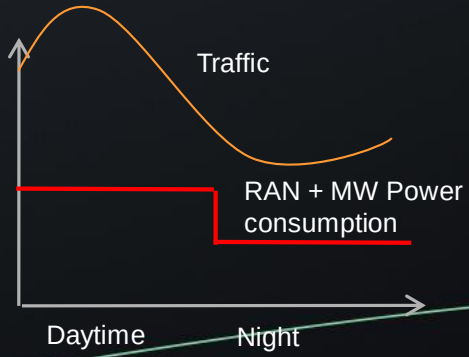
- Service deployment automatically by select the **source/sink node** and port, including service name, type, bandwidth

Network Configuration



- When upgrade link from 1+0 to 2+0, or 1+0 to SDB, all network configuration is automatically. No need complex NE configuration.

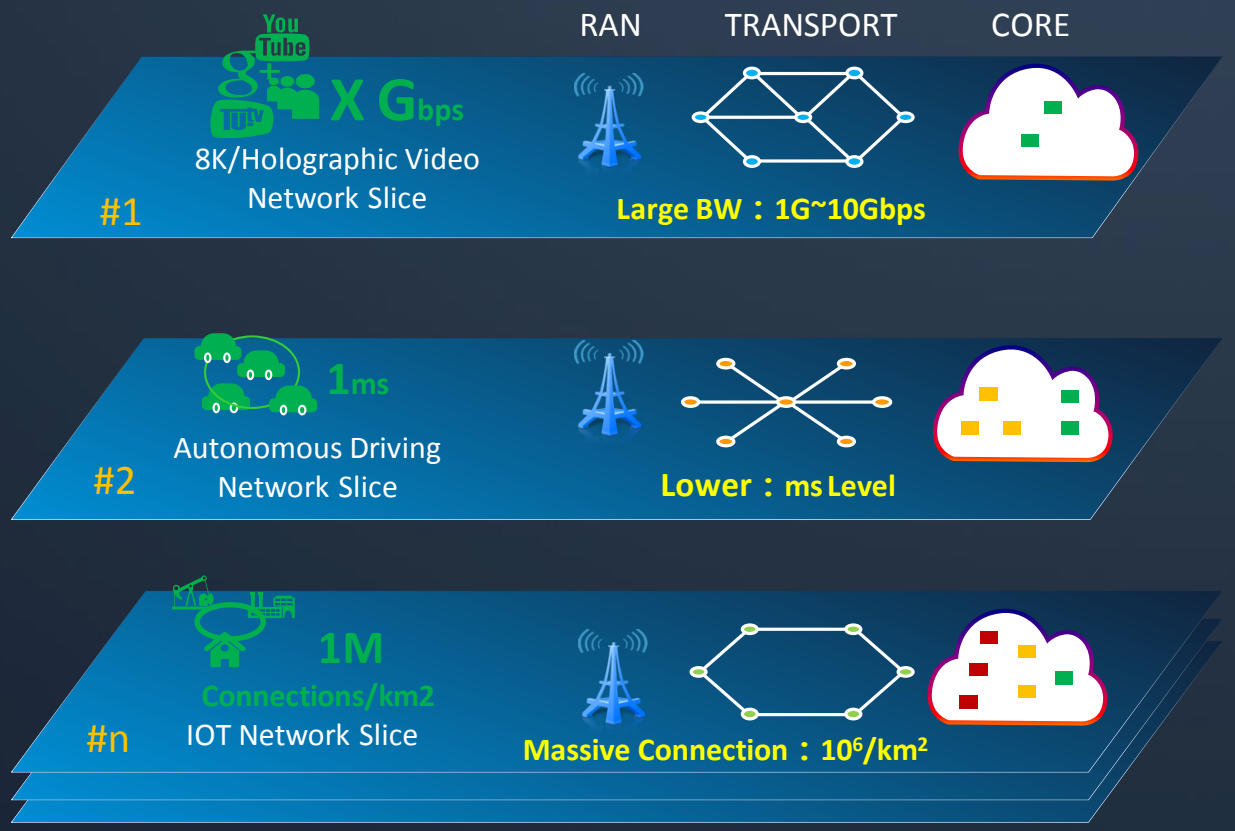
Power Management



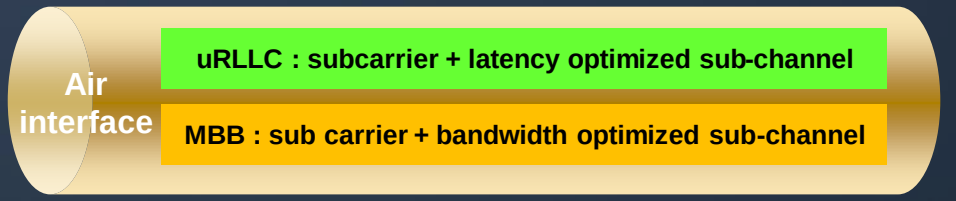
- Off-peak time: RAN controller turns off the BTS and sends notification to MW controller. MW controller change relative MW links to “standby”.

Flexible OAM: Microwave for 5G Network slicing

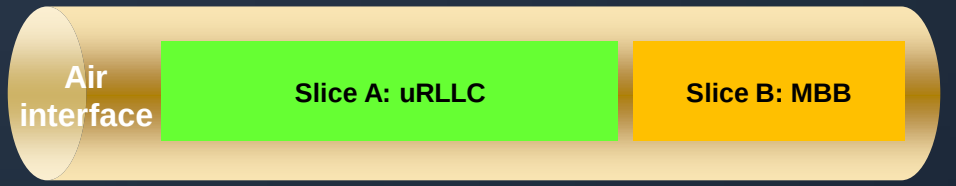
E2E Network Slicing Concept



How Microwave Join as Part of Slicing:



1. Sub-carrier: by CA technology, one air interface provide isolated carrier
2. Sub-channel: by dedicated low latency optimize algorithm, one carrier provide isolated channel with different SLA



Divide air interface to different time slots for different service, guarantee different SLA and isolated

Future

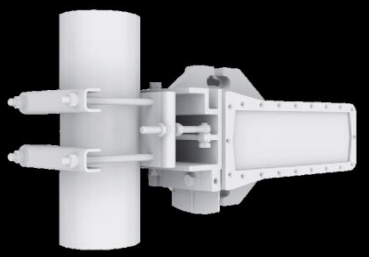
And Some More… Site Densification Solution

Site Densification: Tower to Street Level

- Street level deployment lead to new **Environment Adaptation** challenges for Microwave, such as **easy site deployment, NLOS, Landscape harmony.**

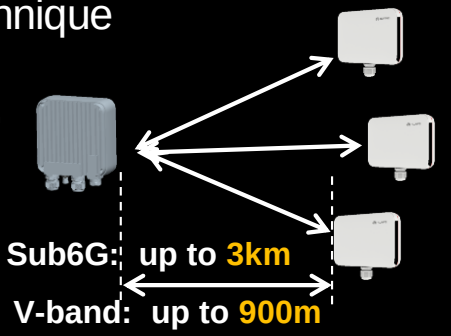
Low Installation Stablility on Easy site

- Anti-shaking by wide beam Ant
- @2017 E-band Ant 3dB width rise from ~1° to 4 °

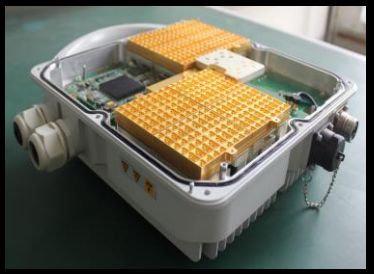


Street Level transmission barrier

NLOS by beamforming technique
@2017 Sub6G PMP
@2018 V-band PMP (TBD)
@2020 E-band



Sub6G / v-band PMP

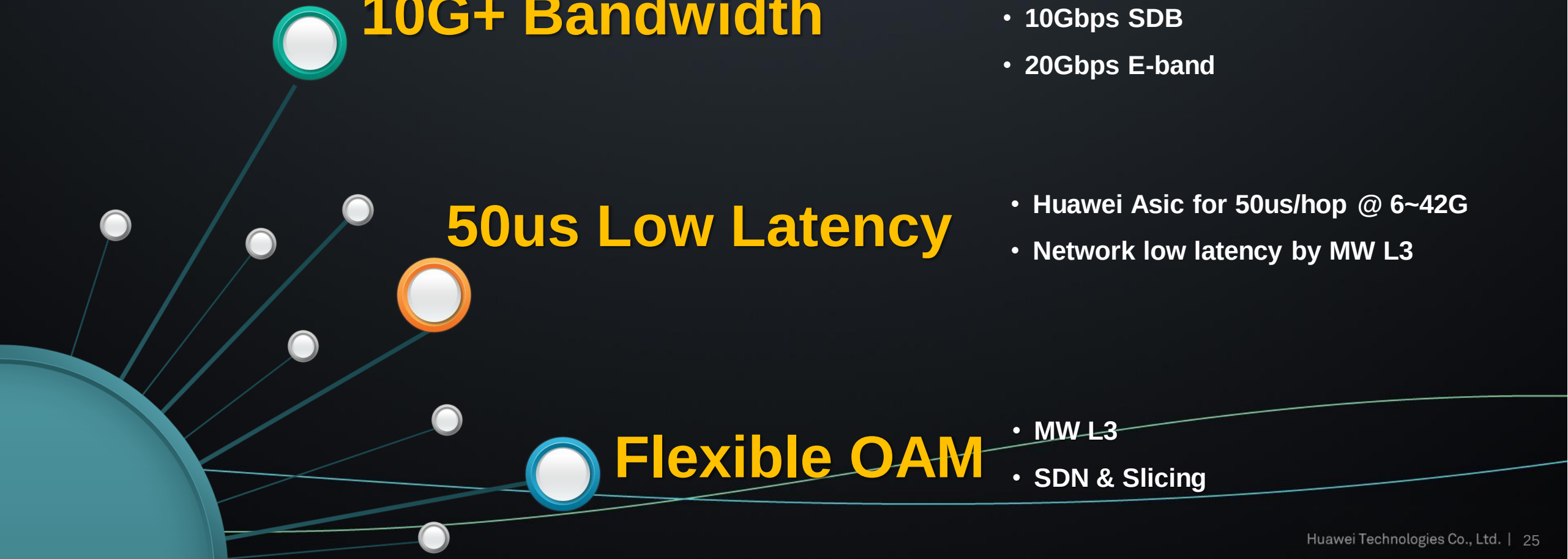


E-band beam-forming

Landscape harmony by law

- Cylinder/Disguised outline

Huawei Multi-wave, Ready for 5G:



10G+ Bandwidth

- xGbps IP MW by CA
- 10Gbps SDB
- 20Gbps E-band

50us Low Latency

- Huawei Asic for 50us/hop @ 6~42G
- Network low latency by MW L3

Flexible OAM

- MW L3
- SDN & Slicing

5G Backhaul Strategy Highlights

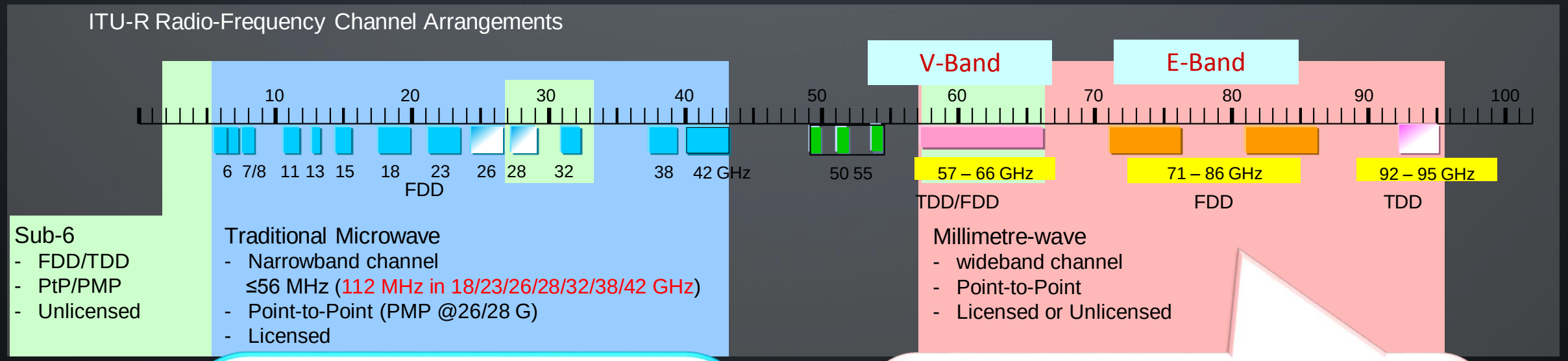
- **Overall RAN trends when going to 5G:**
  - **Fiber penetration from core to edge to accommodate capacity demands and high reliability (no weather impact)**
  - **Wireless backhaul being push at the periphery**
  - **Site densification**
  - **Capacity demands**
  - **New mmWave bands for 5G radio interface**

- **Microwave systems trends for 5G:**
  - **Increase channel bandwidth:**
    - Traditional microwave bands
      - Band & Carrier aggregation (i.e. 18 or 23GHz + E-band)
      - 112/224MHz bandwidth
    - **Go to millimeter-wave:**
      - **E-band (10 Gbit/s per carrier NOW)**
      - D-Band (141 to 174.8 GHz)

1. **Fiber to be the first backhaul priority for 5G macro sites**
2. **Microwave Systems being a relevant option in challenge of fiber availability**
3. **New self-backhauling option (on-going 3GPP R15 works)**

Contents

Frequency Spectrum – Macro backhaul and aggregation



Improve spectrum efficiency
- 4096/8192 QAM
- 4x4 MIMO

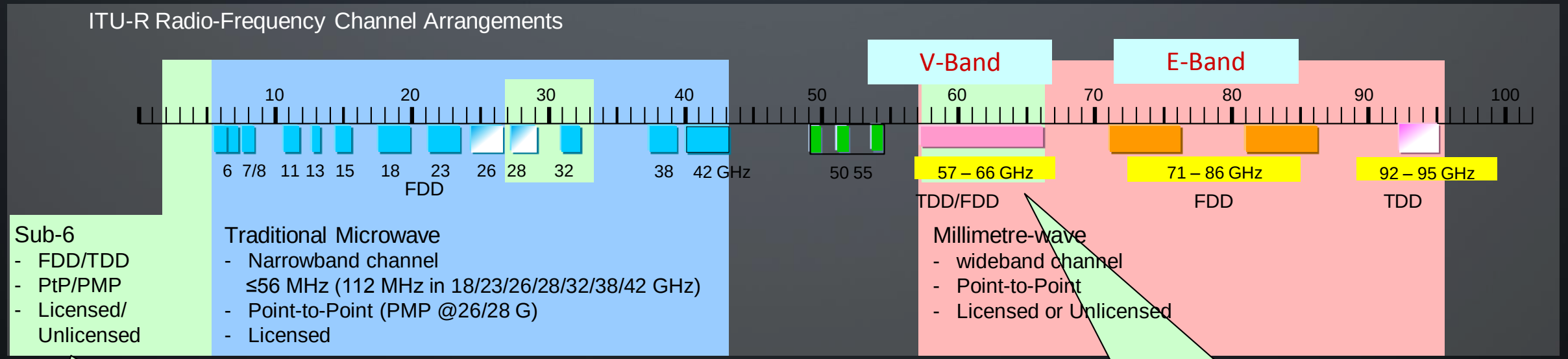
Increase capacity
- 112 MHz channel
- Channel Aggregation

Reduce TCO
- High power efficiency GaN PA
- Tunable Diplexers

E-band becomes mainstream

Increase capacity (10/20/40 Gbit/s) and hop length (up to 5 km)
- 256 QAM / 2GHz
- XPIC and MIMO
- High System gain
- Phased array antennas

Frequency Spectrum – Small Cells backhaul/fronthaul



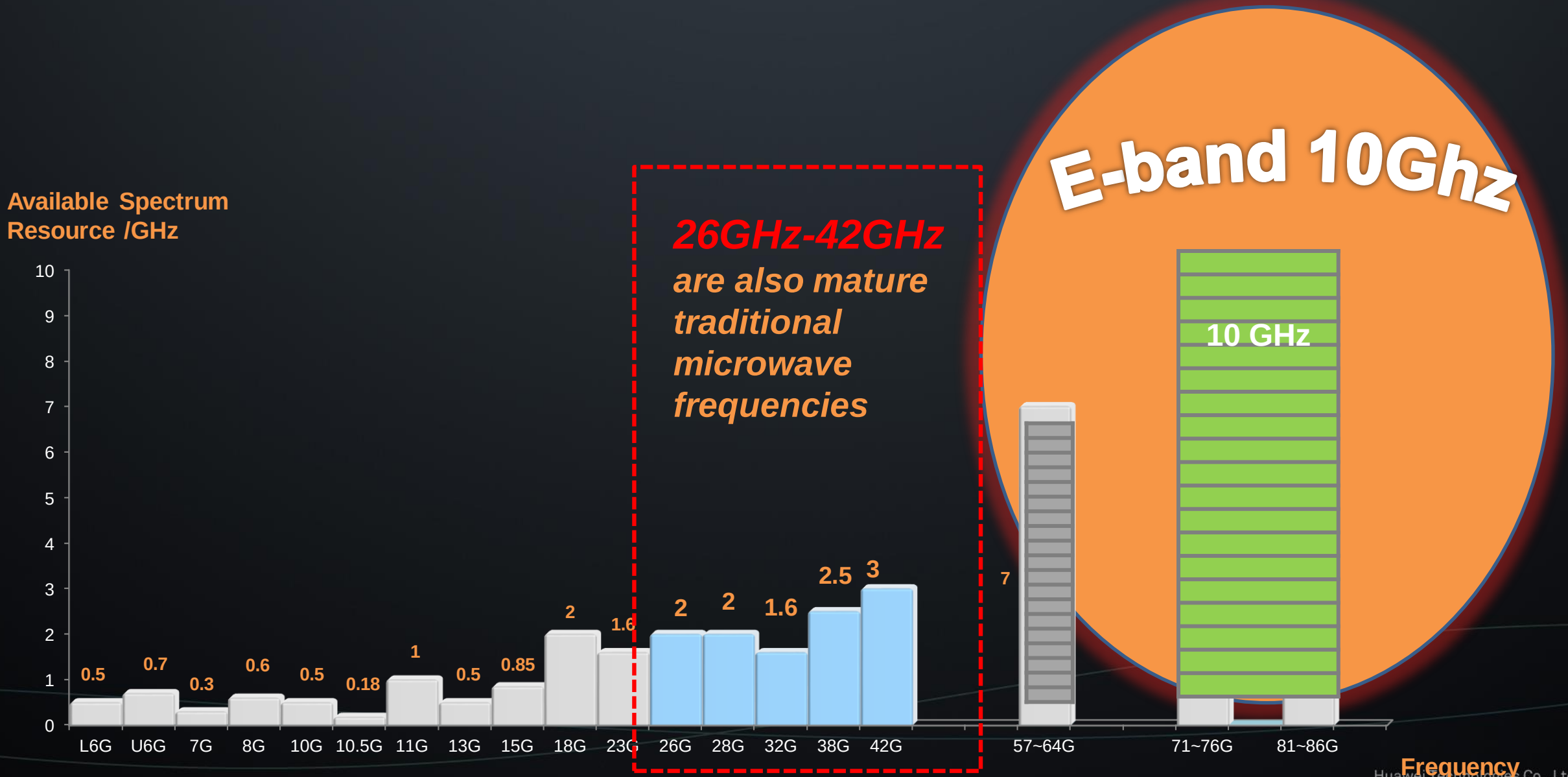
Sub-6GHz

- 2.6, 3.5 GHz licensed
- 5 GHz unlicensed
- Limitation in throughput and latency performance

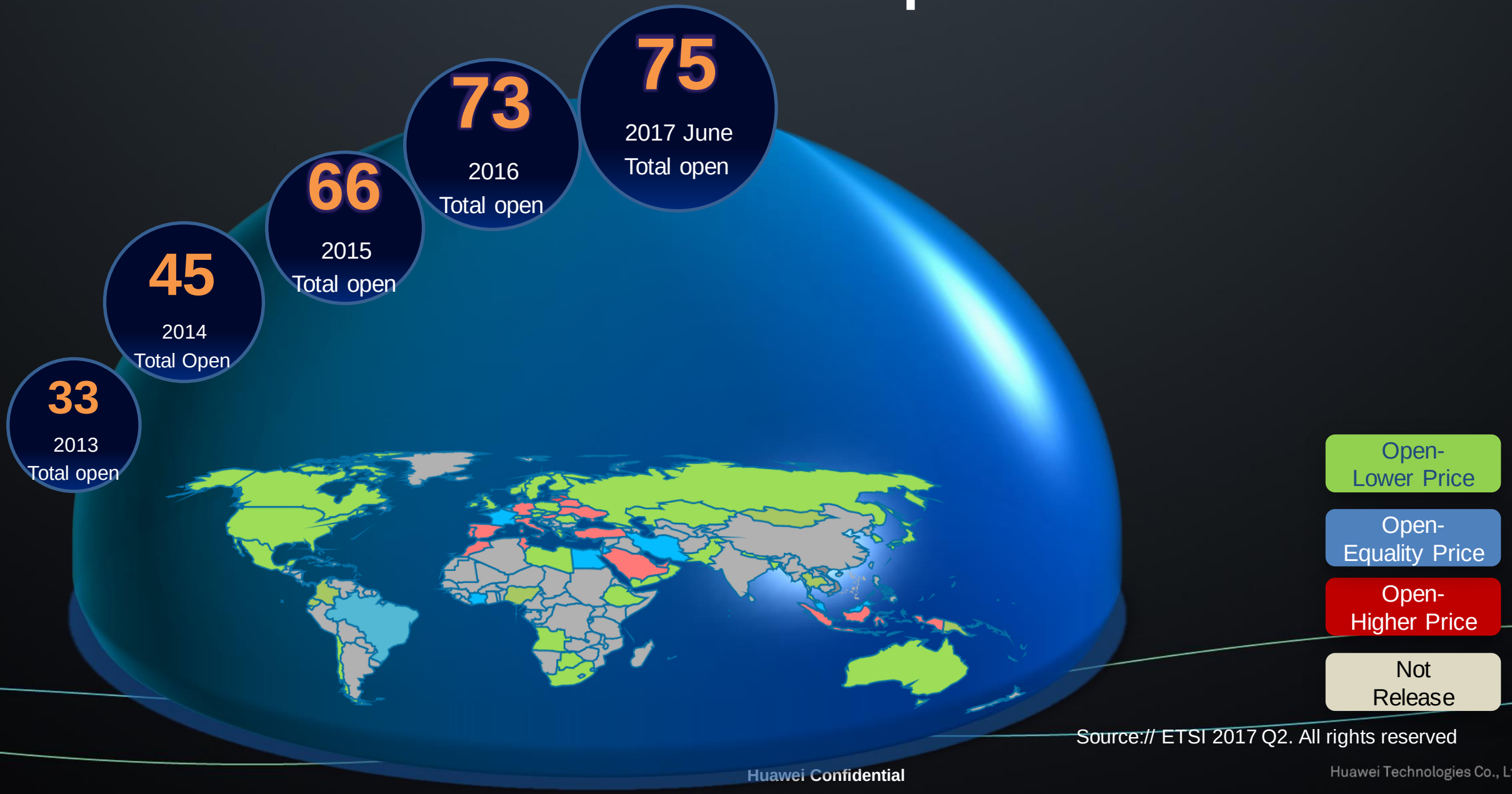
V-band

- Unlicensed and uncoordinated
- Extension to 66 GHz
- Ideal for TDD
- Full Duplex possible

Microwave Also Need New Bands to Support 5G



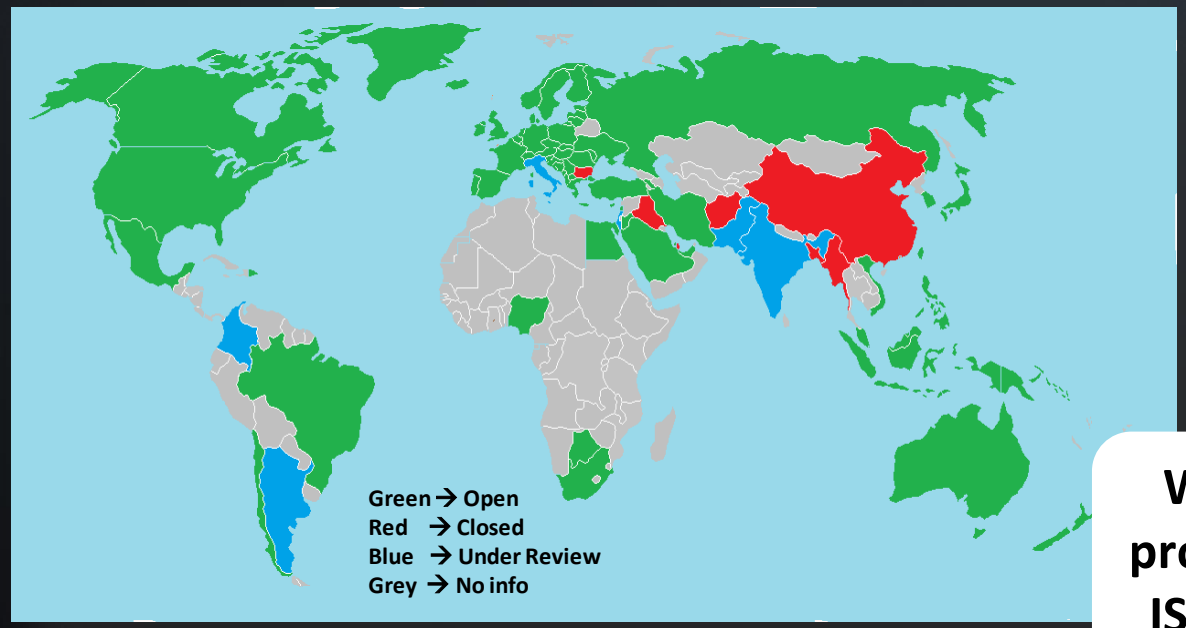
More and More Countries To Open E-Band



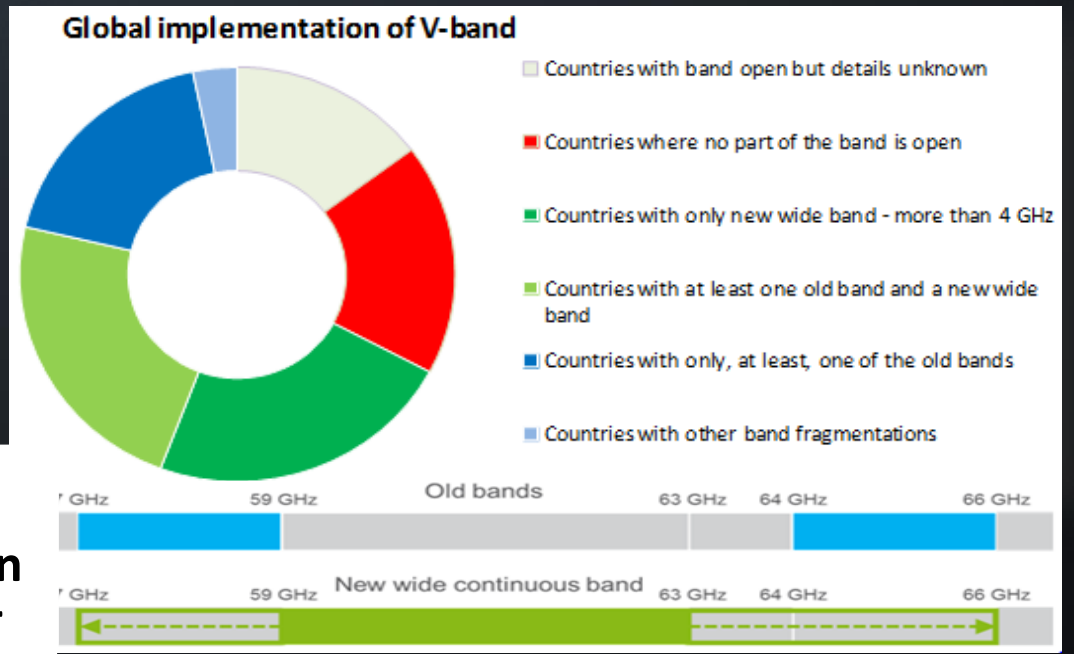
Source:// ETSI 2017 Q2.

E-band and V-band licensing worldwide

E-band



V-band



Work in progress in ISG mWT

E-BAND LICENSES				
	Individual Licensing	Light Licensing	Block Assignment	License Exempt
Current	✗	✗	✗	✗
Desired	✗	✗		

V-BAND LICENSES				
	Individual Licensing	Light Licensing	Block Assignment	License Exempt
Current	✗	✗	✗	✗
Desired		✗	✗	✗

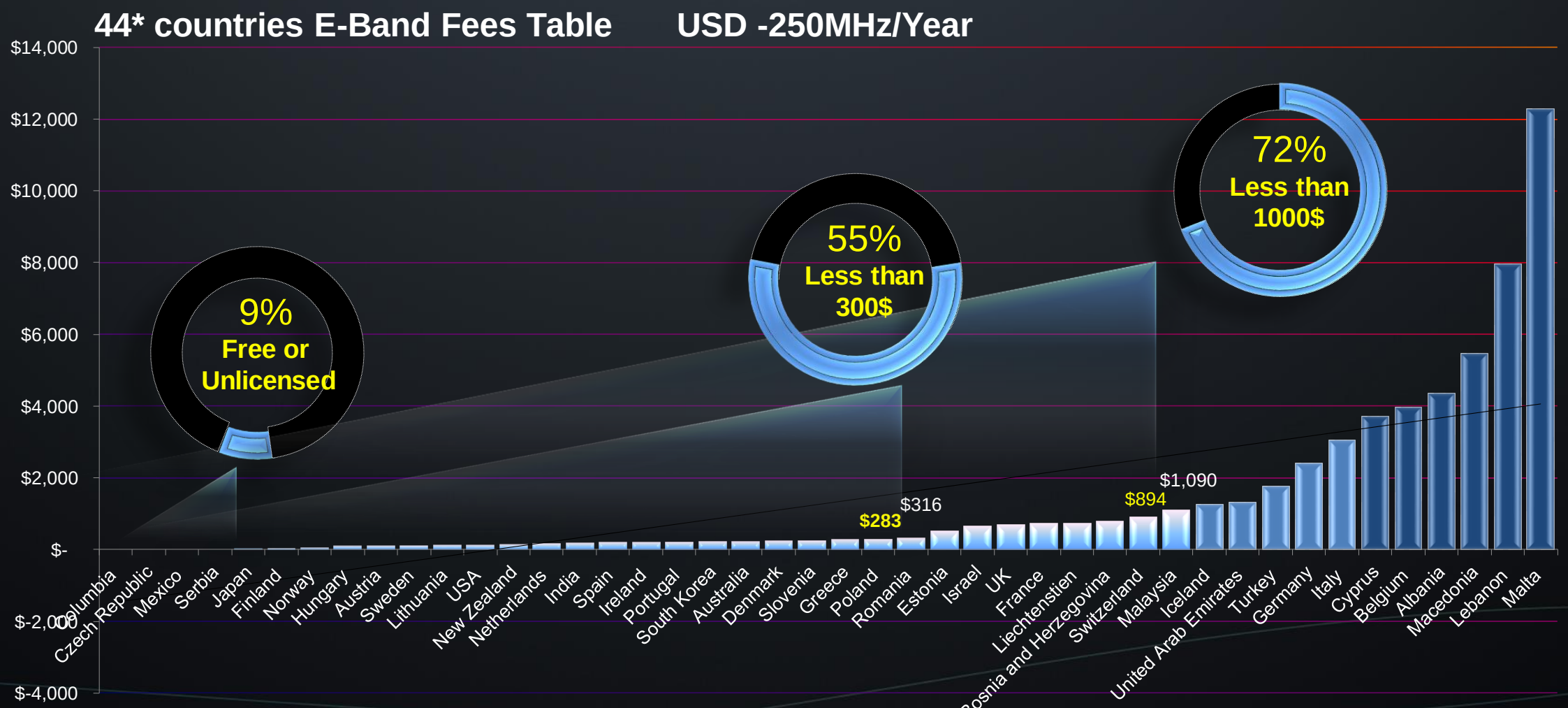
E-Band Regimes Analysis and Summary

Regimes Type	Key info.	Typical Band	Scenarios	Management	Interference administration	Price	exclusive
Per link	conventional link-by-link coordination	ALL	PTP	Government	Government	cheap.	Yes
Block assignment & auction	through licensing (renewable, but not permanent) or through public auction (permanent).	32 /28 GHz 31 GHz(USA)	PTP PMP	Government	Government	higher	Yes
Shared licensing	1.share a block of spectrum with one or more participants 2. a first-come, first-served basis	ALL	PTP	Government	Operators themselves	Lower	NO
Lightly licensing	1.a combination of license-exempt use and protection of users of spectrum; 2. first come first served	E-Band, D-Band 10.5G	PTP PMP	Operators	Operators themselves	Very Little	NO
Unlicensed	No licensing requirements; therefore, reduced administrative burden	2.4 /, 5.8 GHz, E/V-Band	WIFI, PTP	Operators or individual	not guarantee	free	No

Regimes Distribution Of 72 Counties

Source：http://www.etsi.org/images/files/ETSIWhitePapers/etsi_wp9_e_band_and_v_band_survey_database.zip.

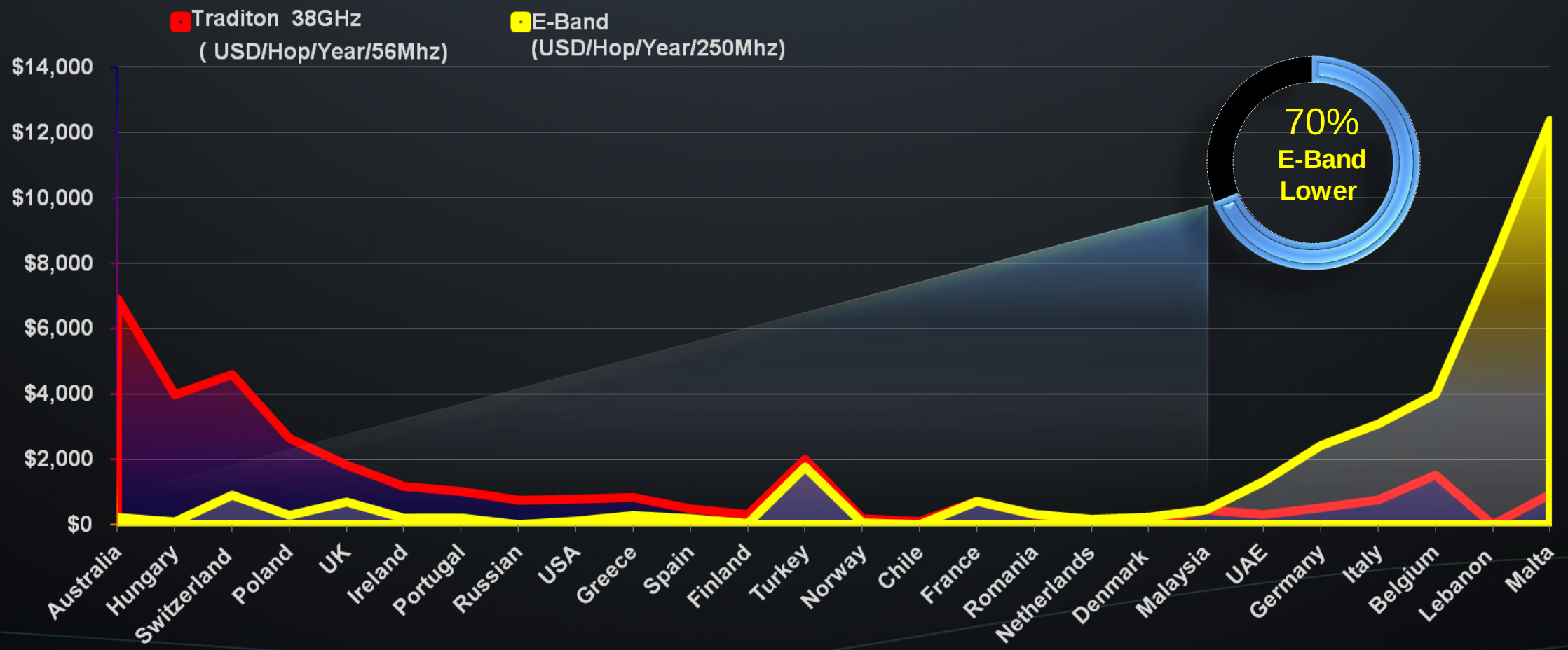
Lower Licensing fee is Trend



Notes: *The fee Regulation of other 22 countries are still under collection
Source: etsi_wp9_e_band_and_v_band_survey_20150629

E-Band fee, Most countries is lower than Traditional

The license fee comparison of 26* Countries between E-Band and Traditional



Notes: *The traditional license fee Regulation of other 18 countries are still under collection

Source: etsi_wp9_e_band_and_v_band_survey_20150629, DATABASE_mWT_10062015_released.xlsx

Win-Win E-band License Strategy Achieved In Hungary

E-band and traditional MW links share the same per-MHz license fee

17000EURO

1000 EURO

6 hops Before 2014

Almost no E-band links deployed

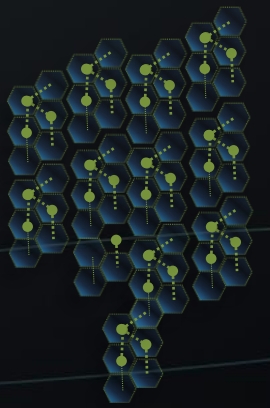
Thousands of E-band links to expand network capacity

2012
1 Hop

2013
5 Hop

2014
200 Hop

2015
3000 Hop

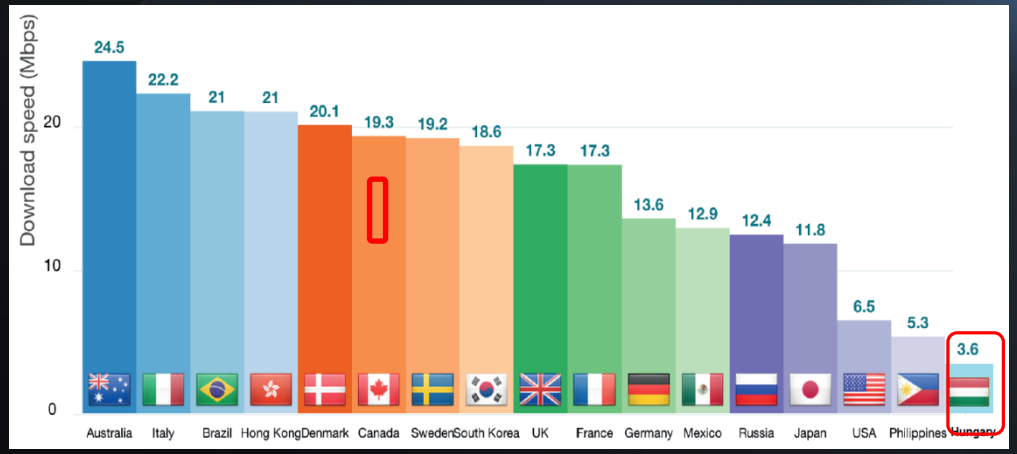


Hungary LTE Speed Increase Dramatically

	Feb 2014	May. 2015
Download Speed	3.6Mbps	25Mbps
Global Rank.	>No. 20	No.6

Feb 2014

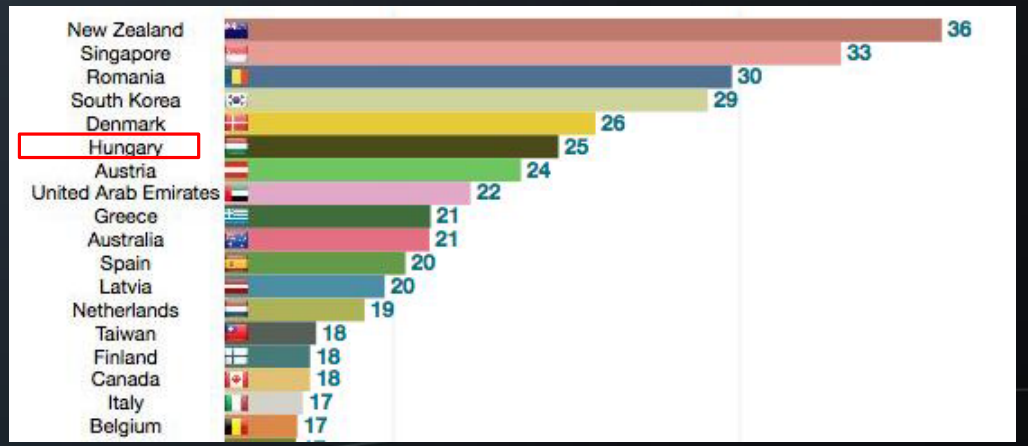
Global LTE Download Speed Comparison



Source: *https://opensignal.com/reports/state-of-lte-q1-2014/*

May. 2015

Global LTE Download Speed Comparison



Source: *http://opensignal.com/reports/2015/02/state-of-lte-q1-2015/*

Positioning Highlights and Strategy for mmWave Bands (Group 30)

Bands	Bandwidth	ITU Status	Current Use	Targeted Use	Strategy Implementation
26GHz (e.g. Australia, China, Region 1)	3.25GHz	Part of WRC-19 AI 1.13	• Microwave Systems in some Europe countries e.g. Bulgaria, Germany, Spain, Sweden, etc. • Satellite usage (limited)	• 1st priority for 5G services (large spectrum capacity to accommodate 1GHz / operator in most of cases); Europe Parliament decision for 5G services • Under standardization (3GPP R15)	• On-going ETSI ISG mWT study for sharing vs. cleaning strategies analysis (official results by 09-2017) • Difficulties to co-exist Microwave Systems & 5G services ➔ Most likely migration of legacy MW to other bands (e.g. 23GHz or other bands) in order to gradually free 26GHz band for 5G services ~2022 (CEPT SE19 and ECC PT1) • Need ITU study for satellite & 5G
28GHz (e.g. Japan, Korea, North America)	1.0GHz		• Microwave Systems (in USA acquisition of MW services providers controlling 28GHz by Tier-1 MNOs) • Satellite usage (limited)	• USA: FCC decision for 5G services • Canada: Public consultation for 5G during H2-2017 • Under standardization (3GPP R15)	Need migration of microwave systems
32GHz (Region 1)	1.6GHz	Part of WRC-19 AI 1.13	Limited usage by satellite and Microwave	• 2nd priority for 5G services • Under standardization (3GPP R15)	• 2nd priority for 5G services (~2 times less capacity than 26GHz and 42GHz bands) • Gradual migration of 32GHz for 5G? • Need ITU study for satellite & 5G

Positioning Highlights and Strategy for mmWave Bands (Group 40)

Bands	Bandwidth	ITU Status	Current Use	Targeted Use	Strategy Implementation
39GHz (e.g. Australia, Japan, Korea, North America)	3.5GHz	**Part of WRC-19 AI 1.13**	• Microwave systems usage • Satellite usage • In USA 39GHz being owned by several US regional players (on-going acquisitions by USA MNOs)	• In USA FCC decision to use 39GHz for 5G • Canada: Public consultation for 5G during H2-2017 • **Under standardization (3GPP R15)**	◦ Gradual migration of microwave systems ◦ Need ITU study for satellite & 5G
42GHz (e.g. China, Europe, Middle East)	3.0GHz	**Part of WRC-19 AI 1.13**	• Few microwave links • Satellite usage (limited)	• Europe Parliament activities kick-off for 5G services during H1-2017 • Most likely 3GPP R16 (TBC)	• **On-going ETSI ISG mWT study for sharing vs. cleaning strategies analysis** (official results by 09-2017); similar work as 26GHz (however migration should be easier than for 26GHz band as there are less legacy systems using 42GHz) • To move satellite services to other bands (e.g. below 40GHz) • Need ITU study for satellite & 5G

ETSI ISG mWT & ECC Studies on 26GHz & 42GHz for 5G and Fixed Services

Q2-2017: Kick-off **ETSI ISG mWT** study on 26GHz & 42GHz.
Feasibility Study for sharing of **26GHz and 42GHz** between 5G and fixed services (microwave).

Q3-2017: ETSI ISG mWT final report publication and guidance (presentation of technical arguments about sharing or segmentation of the 26 GHz and 42GHz between IMT access and MW backhauling).

ETSI ISG mWT results being communicated to ECC PT1 (IMT) for co-existence study on 26GHz and 42GHz.

ETSI ISG mWT results being communicated to ECC SE19 (FS) for co-existence study on 26GHz and 42GHz.

Follow up based on ETSI ISG mWT study results for migration scenario definition

Take Away for mmWave Bands Use

- **5G Services:**
  - 5G services can take advantages of mmWave bands for addressing new needs e.g. Home Broadband access
  - Standardization is on-going from both ITU-R and 3GPP for 5G (3GPP R15 considering 3 types of mmWave bands for 5G NR)
  - Candidate mmWave bands for 5G include 26/28/32/39/42GHz and V-band

- **For mobile backhauling 3 options are expected for coming 5G rollout; they are fiber, microwave systems (incl. mmWave bands e.g. E-band) and self-backhauling**

- **Industry guidance for the best usage of mmWave bands e.g.:**
  - On-going 26GHz and 42GHz sharing study by ETSI ISG mWT; results by 09-2017
  - ECC PT1 and ECC SE/SWE19 works to evaluate a gradual migration of microwave systems on 26/42GHz to other bands; early results by end of 2017 and final output in 2018
  - ETSI ISG mWT study on E-band and V-band usage; report on 10-2016

Thank You.