Evolution of Fixed Services for wireless backhaul of IMT 2020 / 5G

- **Wireless Backhaul for IMT 2020 / 5G - Overview and introduction**
  by Renato Lombardi, Huawei
- **Wireless X-Haul Requirements**
  by Nader Zein, NEC
- **Microwave and millimeter-wave technology overview and evolution**
  by Mario Frecassetti, Nokia
- **Operator's view on frequency use related challenges for microwave and millimeter-wave in IMT 2020/ 5G backhaul/X-Haul**
  by Paolo Agabio, Vodafone
- **Panel discussion:**
  Economics on deployment and operational aspects of microwave and millimeter-wave technology in IMT 2020 / 5G mobile backhaul/X-Haul network

Microwave and millimeter-wave technology overview and evolution Introduction

- To cope with future 5G transport network requirements, two main points should be considered including their impact on solution TCO :

  1. Availability of suitable "Spectrum" → New Bands are needed
     - Specific spectrum for different use cases
     - New mmW Bands to address forthcoming 5G use cases
  2. Capacity & Spectral efficiency (spectrum is a scarce resource)
     - Channel size & Modulation schemes (bit/s/Hz)
     - XPIC, BCA, LoS-MIMO, OAM
     - Geographical spectral efficiency: Dense reuse of channels

- Overview of current technology capabilities
  - Capacity
  - Latency
  - SDN

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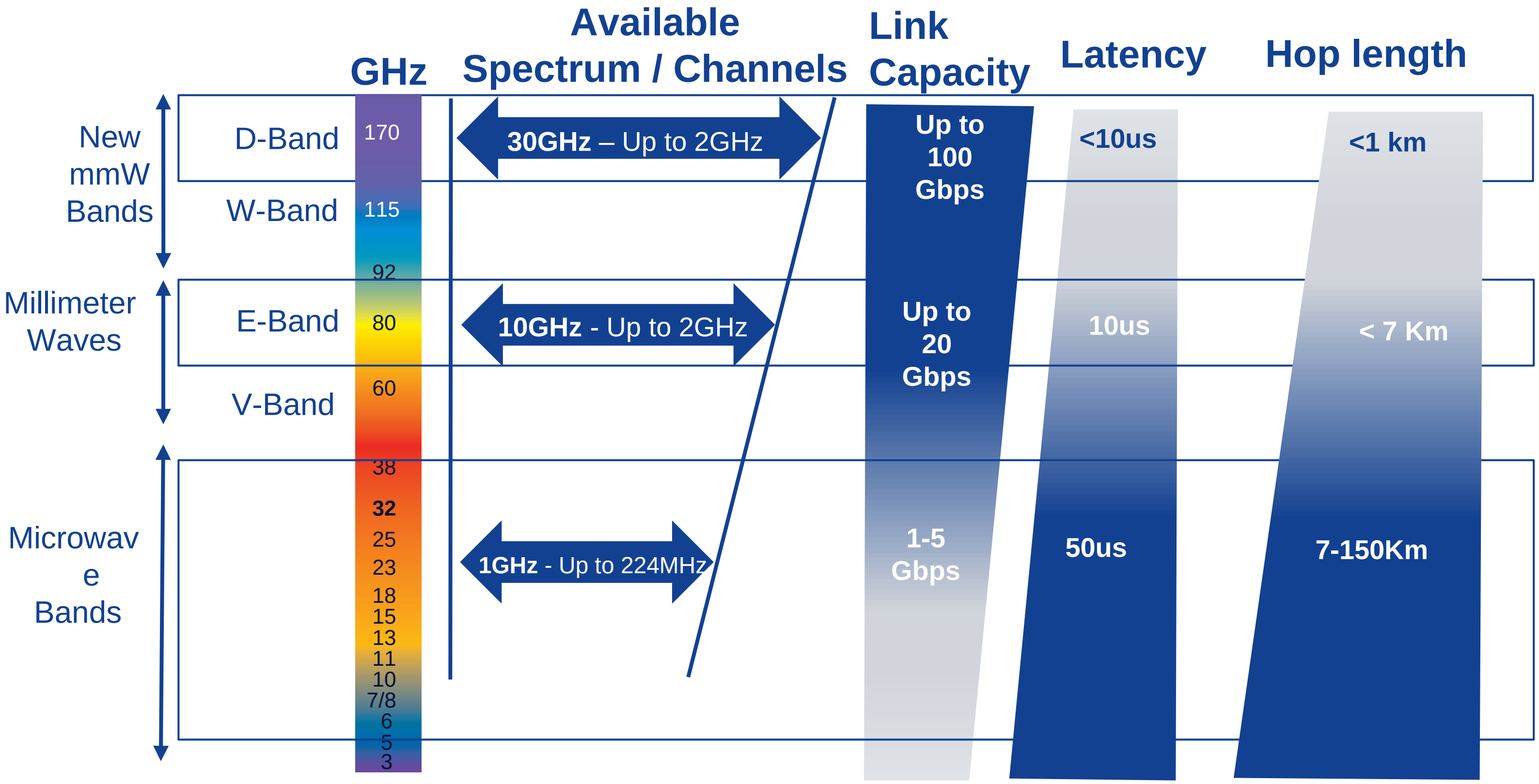
New mmW Bands to address forthcoming 5G use cases



5G Access Sites Configurations and Network Segments

	RURAL	SUB-URBAN	URBAN	DENSE URBAN
Transmission Distance	>7 km	<7 km	<3 km	<1 km
Capacity – Initial phase	<1 Gbps	<2 Gbps	<5 Gbps	
Capacity – Mature phase	<2 Gbps	<5 Gbps	<10 Gbps	≥25 Gbps
Site distribution by segment	>40%	>25%	>30%	5%
	Wireless Backhaul			Fiber
Wireless BH distribution	>90%	>70%	>30%	0%
	Backhaul			IAB
Longer hops and high rain region require lower bands	MW + BCA (low+mid bands) 6 to 23 GHz 18 to 42 GHz	BCA (E-Band + Traditional MW) 15/18 GHz + 80 GHz 18/23 GHz + 80 GHz	E-Band W/D-Band	V/D-Band (mesh)

Small Cells at street level for densification

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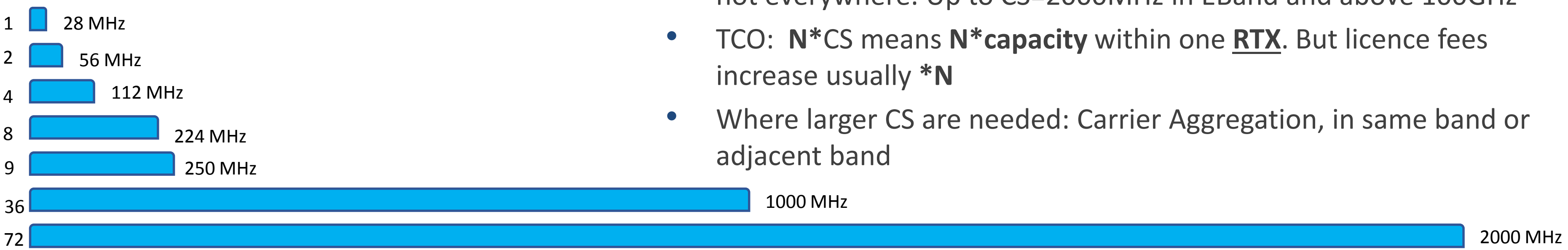
Capacity & Spectral efficiency

Larger channels → not anymore a technology limit

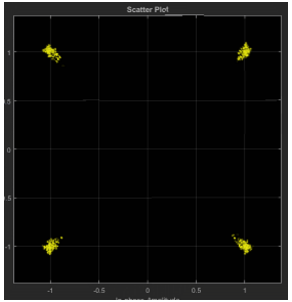
- In MW bands recent regulatory limit shifted up to CS=224MHz, but not everywhere. Up to CS=2000MHz in EBand and above 100GHz
- TCO: **N***CS means **N*capacity** within one **<u>RTX</u>**. But licence fees increase usually ***N**
- Where larger CS are needed: Carrier Aggregation, in same band or adjacent band



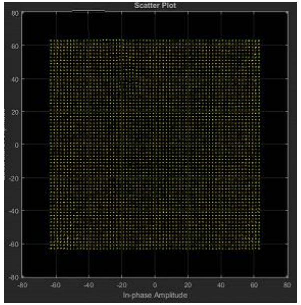
Higher Modulation schemes → Reached the reasonable top

- 4096QAM (and more) → Channel spectral efficiency reached substantially the top
- After 1024QAM spectral efficiency gain is less than 10% ever step
- Adaptive Modulation introduced everywhere
- Penalty on System Gain to be considered
- TCO: High modulations RTX at the same cost

QPSK (2b/s/Hz)

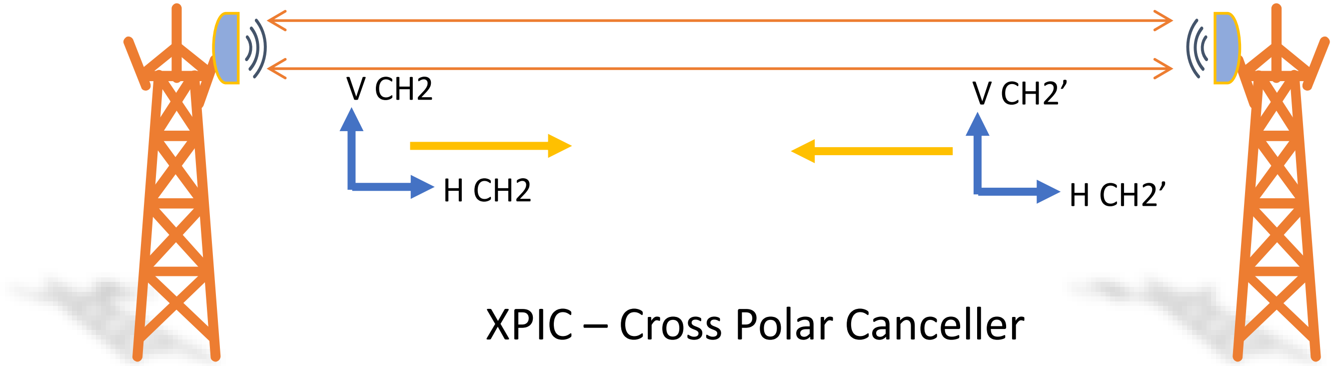


4096QAM (12b/s/Hz)



Capacity & Spectral efficiency

- Frequency Reuse (XPIC) → well known technique doubling the spectral efficiency
  - Well known approach
  - Spectral efficiency *2
  - TCO: Need two RTXs and one antenna per site. TCO's advantage is reached only if license fees are reduced for second polarization



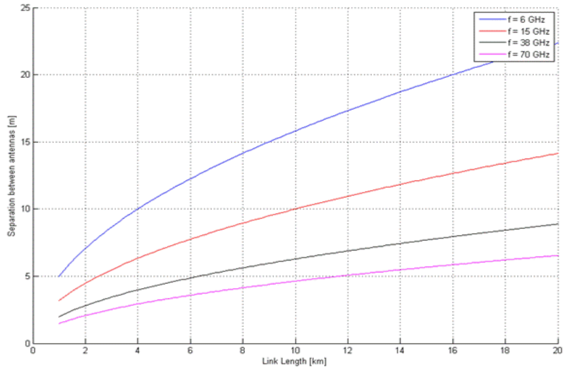
XPIC – Cross Polar Canceller

Capacity & Spectral efficiency

- LoS-MIMO → Line of Sight Multi-Input Multi-Output
  - Exploiting link geometry deployment two different signals in the same channel can be transmitted. 4x4 LoS-MIMO is obtained with LoS-MIMO 2x2 plus XPIC
  - LoS MIMO needs optimal antennas separation.

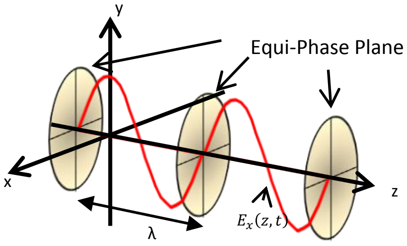
    Under optimal conditions, spectral efficiency close to x4 improvement, lower performance in case of suboptimal conditions
  - Not yet massively deployed
  - TCO: RTX cost per bit is the same (4 RTX). Spectrum fees approach will play a role in LoS-MIMO future success

FDD – LoS-MIMO 4X4

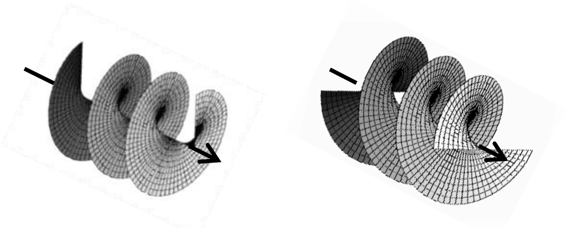


Optimal antennas separation

Capacity & Spectral efficiency



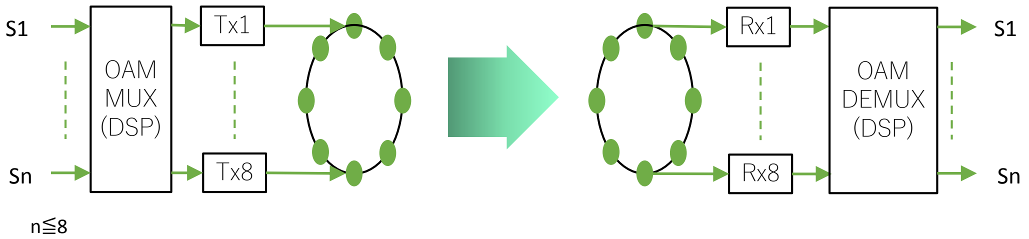
Equi-Phase Plane of Plane wave



Equi-Phase Plane of OAM Signal

OAM → Orbital Angular Momentum

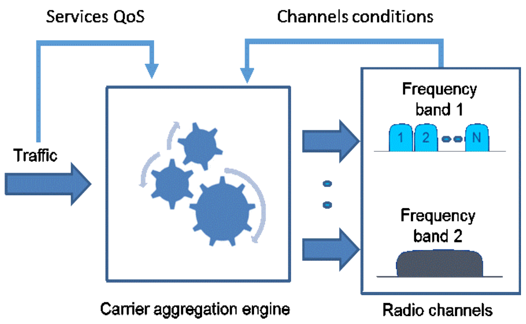
- Using different antennas, multiple OAM signals with different spiral phase front (mode) can be transmitted. OAM modes are orthogonal of each other
- OAM promises then to be able to transmit N different signals in a single channel and single polarization
- Today, experimental results with 16 streams. No commercial product on the market
- TCO: Spectrum fees approach will play a role in its future success

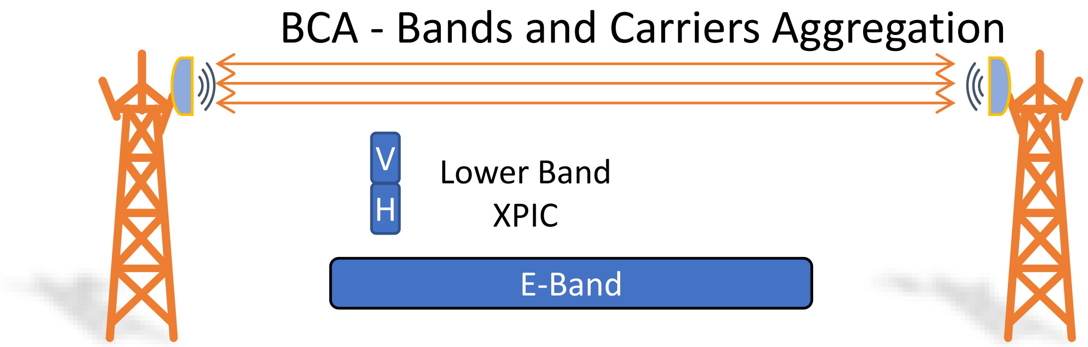


Capacity & Spectral efficiency

Bands & Carriers Aggregation (BCA)

- BCA joins different channels that may be even in different bands, providing a single big capacity pipe. Lower band will provide capacity pipe’s segment with high availability, while higher band the best effort capacity pipe segment. Packets may be adaptively re-routed among different channels according to their priority and channels condition
- One of the most valuable approach is 15/18/23 GHz with E-Band where dual band antennas are available:
  - Links up to 7-10Km are feasible. Capacity may even exceed 10Gbps
  - High spectral efficiency obtained because E-Band can reach longer links than in traditional approach.
- BCA among two MW bands is another variant when distance becomes more challenging i.e.: rural application



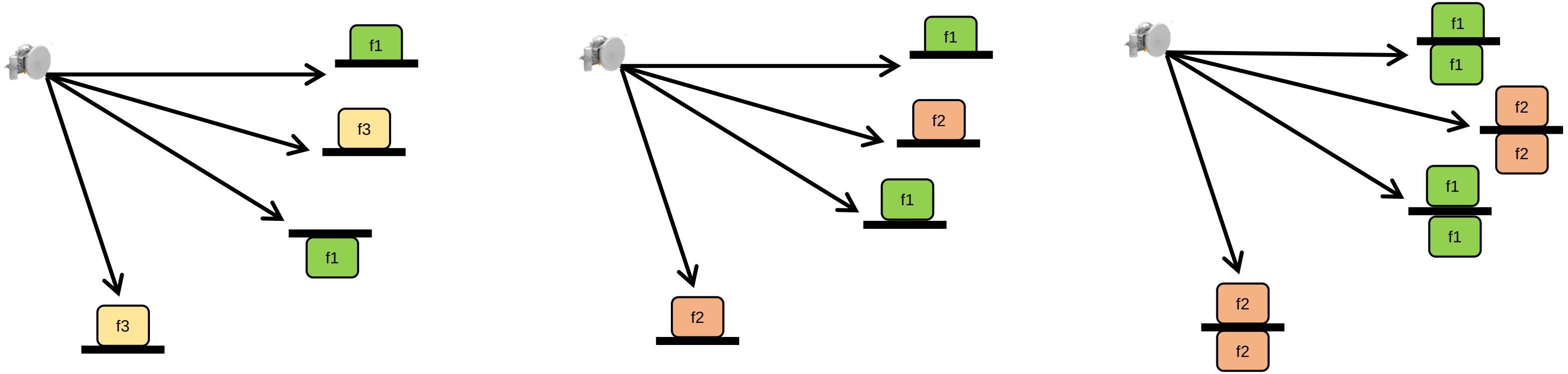


Capacity & Spectral efficiency

- Geographical spectral efficiency: Dense reuse of channels
  - To better exploit the scarce resource (spectrum) it is advisable to increase not only the single channel spectral efficiency but also the channel reusability in a given area, guaranteeing the “interference free operation”
  - Nodal configuration is the key point to understand the concept
    - Better antenna class are introduced (e.g. ETSI Class 4), reducing a lot the minimum angle between two links using the same/adjacent channels (angle discrimination)
    - Cross polar (XPIC) can here help in reducing angle discrimination
    - Co-Channel Interference Canceller (CCIC) further improve the re-use of channels with very narrow angle discrimination
    - TCO: Investments and efforts to be spectral efficient should be rewarded through adequate policy fees (discount/license per node/area)

Capacity & Spectral efficiency

Geographical spectral efficiency: Dense reuse of channels



Today to avoid interference:

- Ch1 reused but with different polarization
- Ch3 must be used because too close to Ch1

Class 4 antenna enable:

- Ch1s can be used with same polarization
- Ch2 can be used instead of Ch3

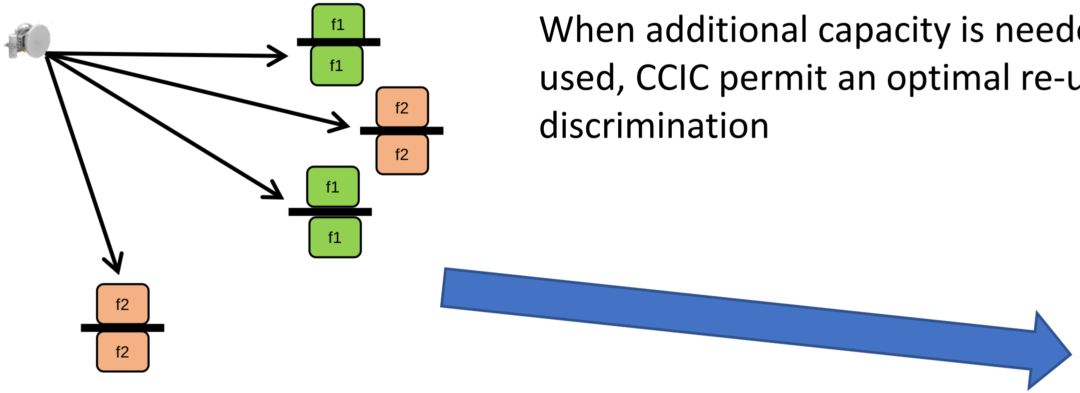
Increase nodal capacity is now easy at **<u>no additional spectrum (*)</u>** with XPIC

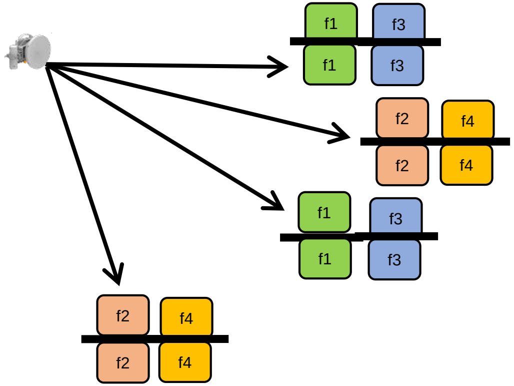
(*) In this region no other operator can use the H spectrum, so no additional spectrum is consumed

Capacity & Spectral efficiency

Geographical spectral efficiency: Dense reuse of channels

When additional capacity is needed and then additional channels shall be used, CCIC permit an optimal re-use of channels with very narrow angle discrimination





- License fees made to incentivize **"geographical spectral efficiency"** thanks to higher channel re-usability (more directive or smart antennas, interference cancellation)

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Overview of current technology capabilities

- Possible “basic” solutions to address the different scenarios
- Capacity and latency already capable to address 5G Phase 1

Backhaul Technology	Configuration (indicative)	Backhaul Capacity (typical)	Backhaul Latency One-Way (typical)	5G “Phase 1”	Cell Type	Area
6-15GHz	4+0 56MHz or 2+0 XPIC 56MHz	2 Gbps	<250us	<2 Gbps	Macro-cell	Rural
18-42GHz	BCA MW 56MHz + E-band 500MHz	3.7 Gbps	<250us	<3 Gbps	Macro-cell	Sub-Urban/ Semi-Rural
V-band (PtP 60GHz)	200MHz	1 Gbps	<500us	<5 Gbps	Small-cell	Dense Urban/ Urban
E-band (70/80GHz)	500MHz-2GHz	3-10 Gbps	<50-100us		Macro-cell	

Overview of future technology capabilities - Capacity

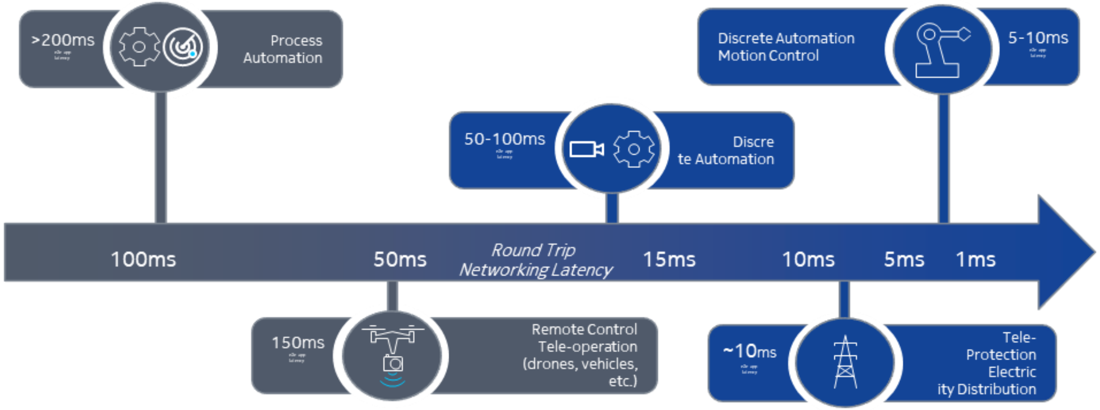
- Evolution to enhance performance combining latest capabilities
- Microwave (MW) and mmWave evolution represented

MW Backhaul Technology	56 MHz BW	112 MHz BW	224 MHz BW	+XPIC	+ LoS 2x2 MIMO	+ BCA (with higher MW Band)	+ BCA (with mmW Band)
6-15GHz	0.5 Gbps	1 Gbps		2 Gbps		3-4 Gbps	
18-42GHz	0.5 Gbps	1 Gbps	2 Gbps	2-4 Gbps	4-8 Gbps		4-10 Gbps

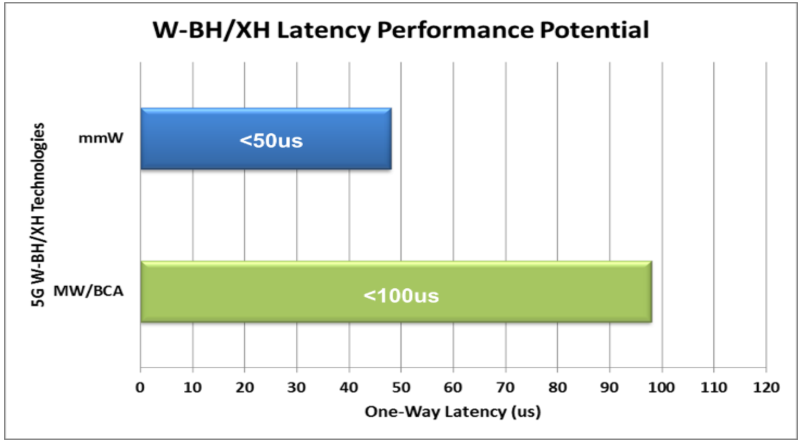
mmW Backhaul Technology	500 MHz BW	2 GHz BW	4 GHz BW	+XPIC	+LOS 2x2 MIMO/OAM
V-band (60GHz)		>4 Gbps			
E-band (70/80GHz)	3.2 Gbps	12.8 Gbps		25.6 Gbps	51.2 Gbps
W-band (100GHz)	3.2 Gbps	12.8 Gbps	25.6 Gbps	51.2 Gbps	102.4 Gbps
D-band (150GHz)	3.2 Gbps	12.8 Gbps	25.6 Gbps	51.2 Gbps	102.4 Gbps

Overview of future technology capabilities - Latency

- Target end to end latency:
  - eMBB use cases (max ~10ms RTT)
  - URLLC use cases (max ~1ms RTT)



- MW latency can go down to 100us per hop, mmW is able to reach down to 10us (but always less than 50us)
- Fundamental for network slicing evolution



SDN use cases for mobile backhaul

SDN Evolution

Manage

Network and service discovery

Smart fault management

Analytics

FCAPS

Automate

Service automation (L2 and L3)

Automated SW upgrade

Service migration

Zero-touch commissioning/audit

Self-healing

Optimize

Efficient power consumption

Traffic re-routing

Interference handling

Network slicing

Enable demanding 5G services

- Dynamic path selection
- SLA monitoring

Conclusions

- Specific spectrum for different use cases and new mmW Bands to address 5G use cases are needed
- Pursuing solutions for increasing the spectral efficiency of single Channel and Geographical Spectral efficiency are a must that should be rewarded

We believe that only a coordinated approach involving all stakeholders will enable this view

- Manufacturers → to invest in innovation
- Operators → to adopt more spectral efficient approaches
- Regulators → to reward spectral efficient approaches, enabling innovation as well