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# **Microwave and Millimetre-wave for 5G Transport**

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## Executive Summary

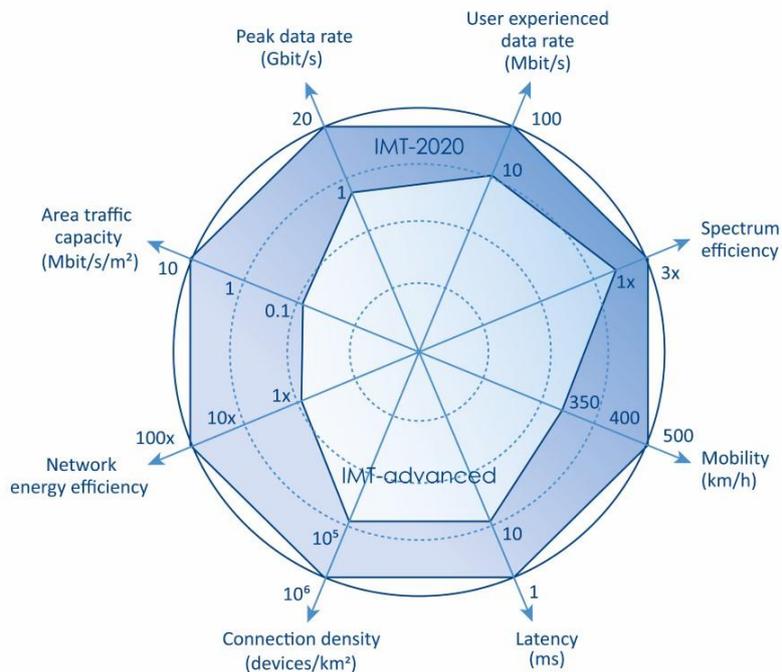
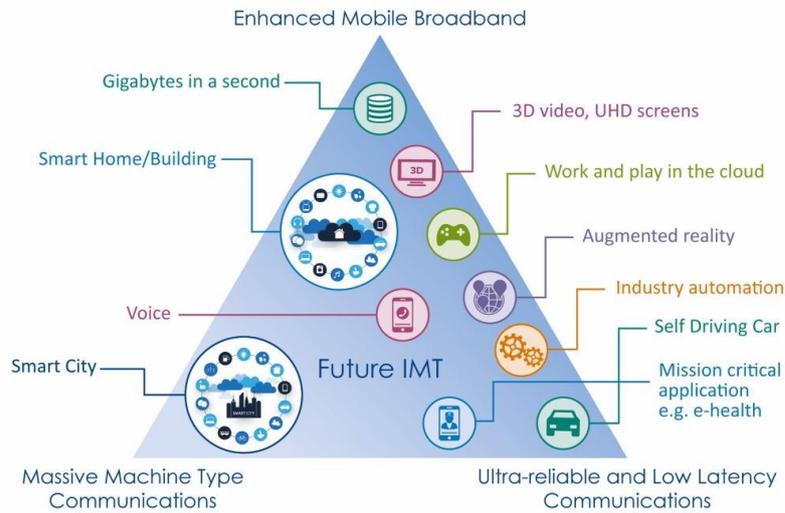
For over 20 years, microwave has been the primary solution for the rapid and cost-effective roll-out of mobile backhaul infrastructure with over 50% of mobile sites worldwide today connected via Microwave (MW) or Millimetre Wave (mmW) radio links, up to over 90% in some networks. The evolution from 4G towards 5G presents significant challenges to all transport technologies and wireless ones make no exception.

The purpose of this paper is to show how **MW and mmW technologies are able to fulfil all 5G requirements**, both at transport and at network (end to end) level.



# Overview of 5G Requirements

Many sources describe and analyse the services and related requirements that define a 5G network, including most notably ITU-R [Recommendation ITU-R M.2083-0].



**Figure 1 – ITU Definitions for 5G Services**

We can distinguish among requirements most directly affecting:

- Transport capacity: throughput
- Network planning: traffic per area, that translates into site density (and MW/mmW link density)



- Networking: Latency, slicing, agility (SDN etc.)
- Areas not directly impacting MW/mmW transport: number of connected devices, mobility etc.

## 5G Mobile Transport Capacity Requirements

In order to determine the transport requirements across the network, we start from the capacity requirements of typical macro sites, and later combine this information with the network topology to get the transport requirements of the MW/mmW links in different segments of the network (tail links, aggregation links).

Four representative types of mobile base station site can be identified, as described in Table 1:

Site Type	Mobile spectrum and type	Cell type	Backhaul Capacity
Dense Urban	<ul style="list-style-type: none"> <li>• LTE up to 50 MHz</li> <li>• 5G 200 MHz 16L MIMO ~4GHz</li> <li>• 5G ≥ 400 MHz 16L MIMO ~30GHz</li> </ul>	Macro-cell: ~4GHz <i>and</i> ~30GHz Small-cell: ~4GHz <i>or</i> ~30GHz	>10 Gbps
Urban	<ul style="list-style-type: none"> <li>• LTE up to 50 MHz</li> <li>• 5G 100 MHz 8L MIMO ~4GHz</li> <li>• 5G 200 MHz 8L MIMO ~30GHz</li> </ul>	Macro-cell: ~4GHz Small-cell: ~4GHz <i>or</i> ~30GHz	<10 Gbps
Sub Urban	<ul style="list-style-type: none"> <li>• LTE up to 50 MHz</li> <li>• 5G 100 MHz 8L MIMO ~4GHz</li> </ul>	Macro-cell	<4 Gbps
Rural	<ul style="list-style-type: none"> <li>• LTE up to 50 MHz</li> <li>• 5G 50 MHz 4L MIMO ~2GHz</li> <li>• 5G 20 MHz 4L MIMO ~700MHz</li> </ul>	Macro-cell	<2 Gbps

**Table 1 – Types of mobile site**

Moreover the evolution of mmW technologies and the availability of new spectrum will allow supporting front-haul applications, with capacities ranging from 10 Gbps to 100 Gbps.



## Microwave and mmW Transport Characteristics

The engineering of a MW or mmW link involves finding the optimal combination of link length, capacity, frequency band and availability.

### MW and mmW Spectrum Overview

In the course of several decades increased transport capacity requirements and greater and greater site density have promoted the use of ever higher frequency bands (see Figure 2).

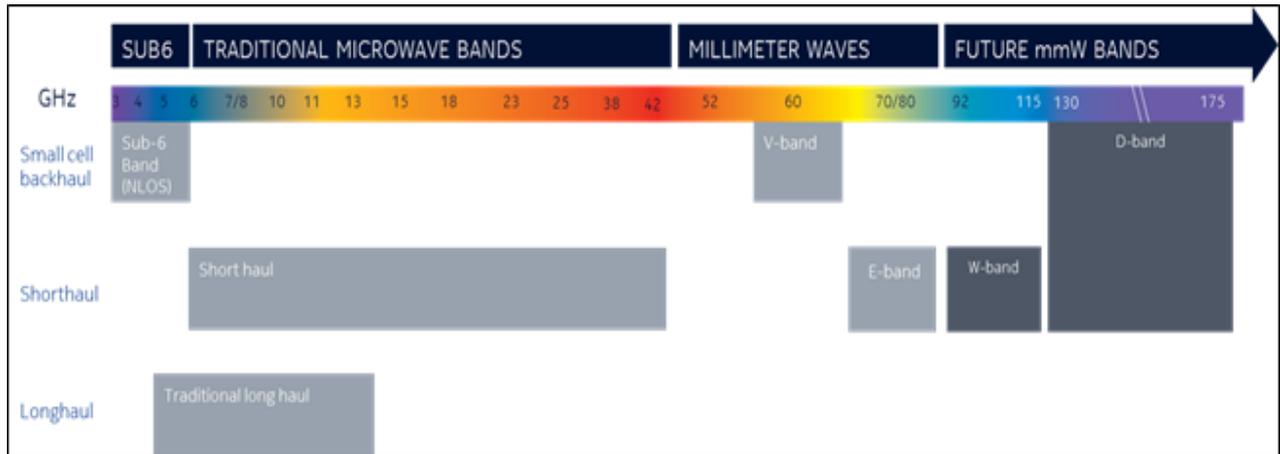
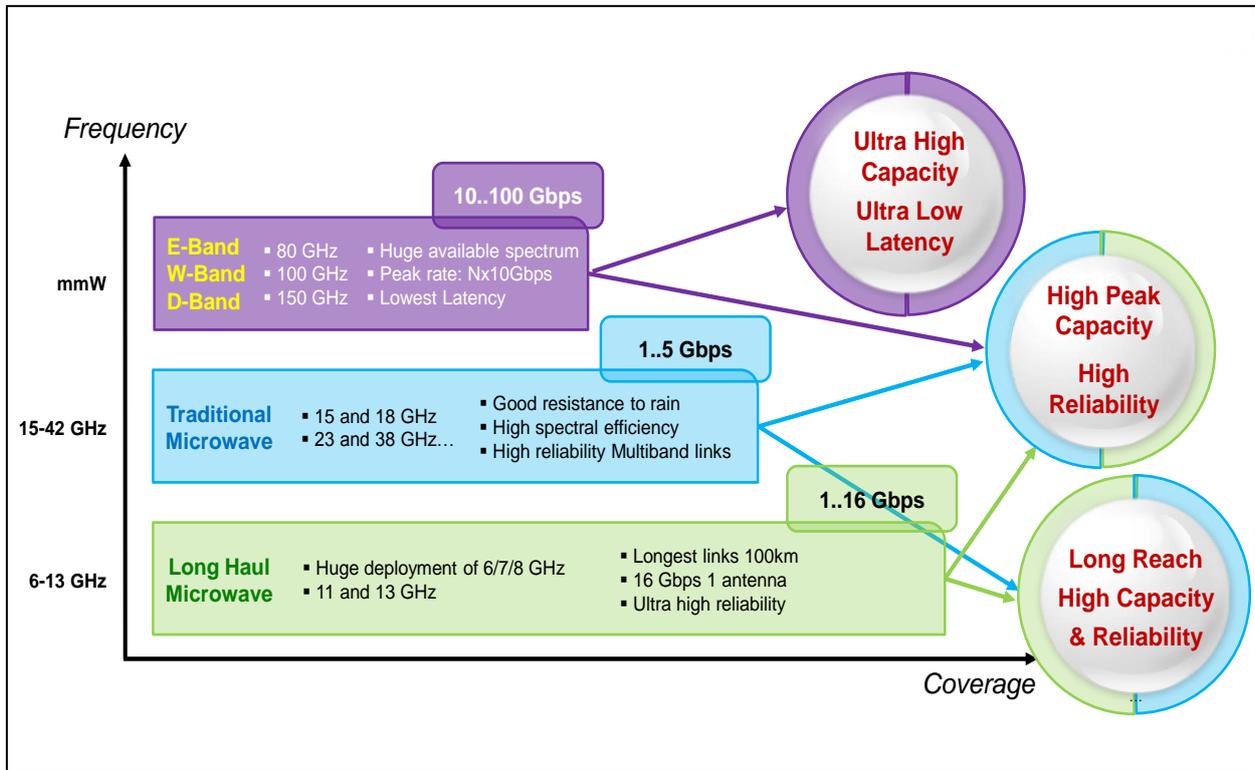


Figure 2 – MW and mmW spectrum

The physics of radio waves propagation determine the relation among capacity, availability and link length.

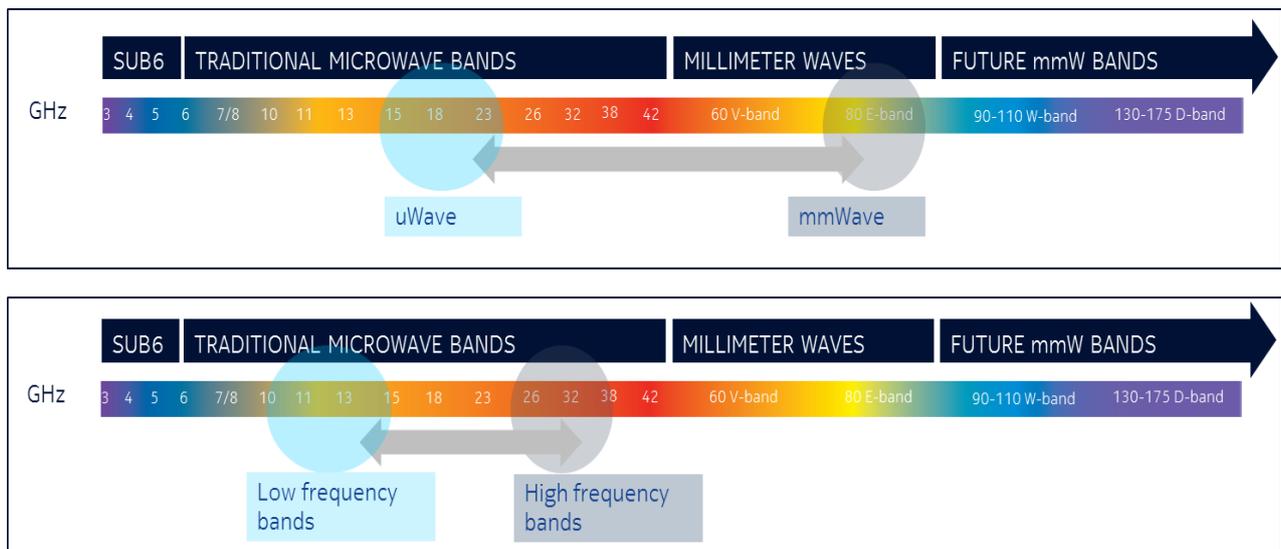
Since the available spectrum is proportional to the centre frequency, the highest frequencies are also those that carry the most capacity, but also cover the comparatively shortest link lengths.



**Figure 3 – Interdependence among frequency, capacity and availability**

As a rule of thumb, frequencies below 13 GHz can be considered mostly unaffected by the intensity of rainfall and frequencies above are more and more influenced by the attenuation caused by rain, so that as a general principle higher frequencies are used for shorter links, as described in Figure 3.

BCA (multi-band aggregation), the combination of different frequency bands on the same radio link, allows combining the best of both worlds in terms of capacity, availability and link length, as depicted in Figure 4.



**Figure 4 – Multi-band aggregation examples**



## MW and mmW Transport Network Topology

The penetration of fibre to the edge of the network and the densification of sites have two main effects:

- Shortening of chains of cascaded radio links, approaching the limit of one radio link to the fibre
- Increase of the number of links originating from a hub site in a star-like topology

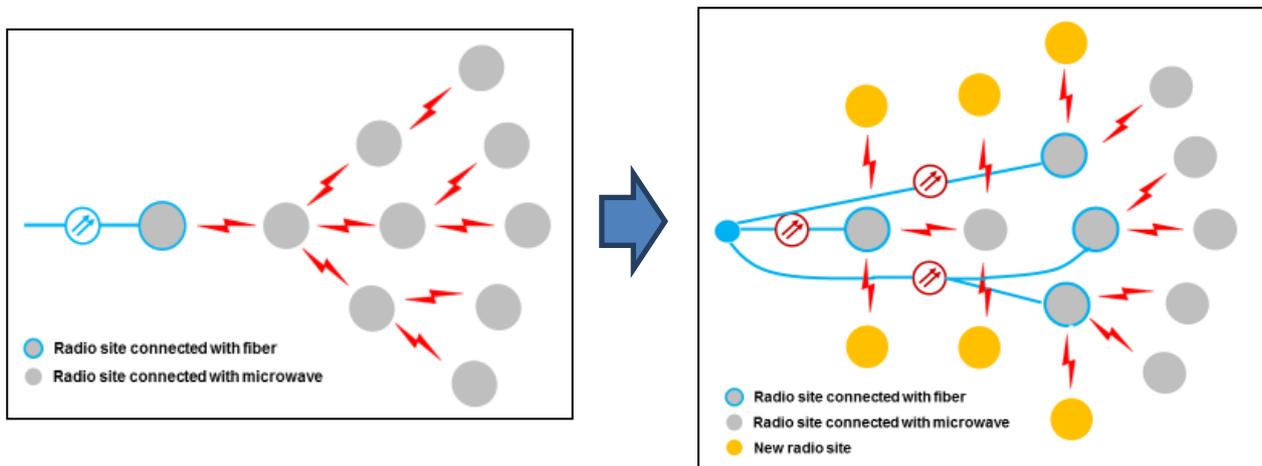


Figure 5 – Topology evolution in the macro cell backhaul network

The tree topology of typical MW/mmW networks means we have to distinguish between tail links, connecting just one terminal mobile site, and aggregation links, which carry the traffic of different terminal sites.

A meshed topology can be used as well; in this case radio links are the fastest and most efficient way to assure the secondary connection, covering the requirements related to network slicing, per path and per service, and performing link protection with media differentiation over the shortest/fastest path between adjacent sites.

In general, these considerations lead us to define different network segments:

- **Dense Urban and Urban scenarios:** where previously the network was based on a hub-and-spoke kind of topology, there is a strong increase in fibre Points of Presence (PoP), from which a star topology of high capacity tail links originate; the fan-out of such hubs tends to be high. The depth of the MW/mmW network tends to become 1...1.5 hops from the fibre PoP.
- **Sub-urban scenarios:** the trend is the same, but here the MW/mmW network depth is going towards an average of 1.5...2 hops from the fibre PoP.
- **Rural scenarios:** here the variance will be greater due to the widely different geographical conditions, but it is expected that the average network depth should tend towards 2.5 hops from the fibre PoP.
- **Mixed scenarios:** in some places, it may happen that a small cluster of urban or suburban sites are situated at a certain distance from the fibre PoP, so that the MW/mmW link length for the aggregation link towards the PoP is not directly related to the cell radius.



## MW and mmW Spectrum Availability

The availability of MW/mmW spectrum depends on both technological and regulatory factors.

**Technology** is available and under development to make full use of existing (6-86 GHz) and future (90-300 GHz) spectrum: E-band (80 GHz) has been commercially deployed for several years, W-band (100 GHz) and D-band (150 GHz) are the most promising upcoming bands, with trials already deployed for more than one year.

Wider channels (112MHz, even 224MHz where possible) in traditional frequency bands and raw availability of spectrum (10GHz in E-band, 18GHz in W-band and 30GHz in D-band) provide the main resources to expand the capacity of MW and mmW radio systems.

Apart from technological factors, the spectrum **regulation and licensing**, which is different country-by-country, is the key aspect:

- MW/mmW bands are not everywhere available to operators, including those that are considered “traditional” in most of the world (especially above 23 GHz)
- Lower frequency bands have been regulated many decades ago, based on transmission capacity and availability targets born in the TDM era, before features like adaptive modulation were even available. This complicates in some cases the regulation, planning and pricing of the MW/mmW backhaul network
- Techniques like XPIC (Cross Polar Interference Cancellation) and Line of Sight MIMO that address link spectrum efficiency should be made more attractive from license point of view
- Higher directivity antennas and new techniques for active interference cancellation should be encouraged with licensing schemes that incentivize geographical spectrum efficiency by a higher degree of channel reusability



## 5G Networking Requirements

One of the most important requirements for the next generation network is to generate new revenues and reduce TCO. Among the means to reach that goal there are:

- Enabling and deploying new types of services (mMTC, uRLLC) in addition to traditional voice and eMBB, on one common transmission network
- Enabling to deploy and manage those services (and new ones not yet foreseen) in a time that is orders of magnitude quicker than today
- Automating as many processes as possible (configuration, troubleshooting, multi-layer optimization, resilience etc.)

The aspects of MW/mmW technology impacted by the above requirements can be summarized as follows:

- Ultra-low and deterministic transmission latency (a few tens of  $\mu\text{s}$ ) and jitter. This mainly impacts the design of the data interfaces, the packet processing engines and the radio modem and air interface design
- Ultra-high precision network-wide, packet-based time and phase synchronization
- Support for SDN and advanced packet networking (L2/L3, L3 VPN, segment routing etc.)
- Support for multiple 10G interfaces and nodal capabilities due to increasing network density

All of the networking requirements are addressed in MW/mmW, leveraging what is developed for every other network segment.



## Summary

MW/mmW technology is able to fulfil the challenge of 5G capacity and distance in all scenarios, as synthetically depicted in Figure 6.

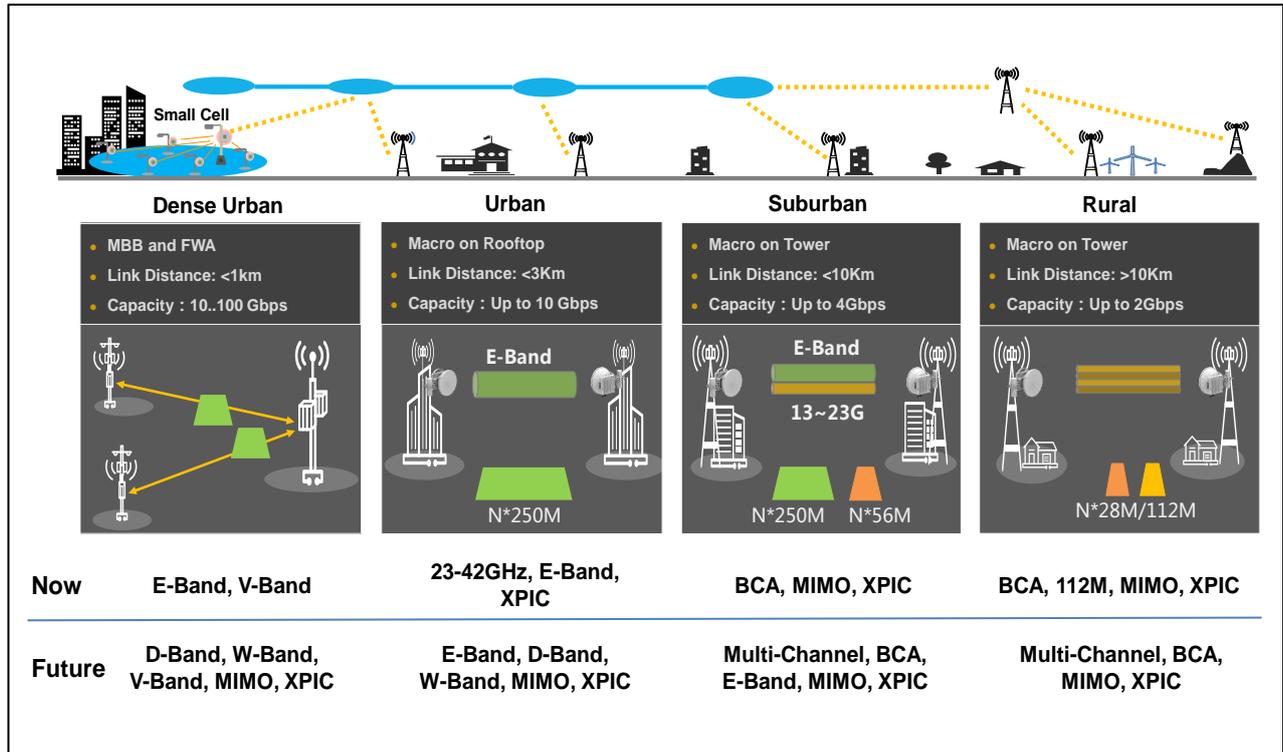


Figure 6 – Microwave technology per network segment

Even if fibre penetration is increased, a very significant share of mobile and fixed access sites will still require a MW/mmW connection to the fibre infrastructure.

The MW/mmW industry is developing the solution along several dimensions:

- 1. Spectrum resources:**
  - Expanding to new bands: the E, W, D-bands offer in total about 50GHz of new unused spectrum
  - Increasing spectrum efficiency: MIMO, higher modulations, interference cancelling
  - Working in close cooperation with standard bodies and all stakeholders to promote new, efficient and effective spectrum regulation and licensing
- 2. Transmission technology:**
  - Ultra-low, deterministic and guaranteed transmission delay
  - New packet forwarding technologies
  - Ultra-high precision time/phase packet-based synchronization
- 3. Operational agility and efficiency:**
  - Development and deployment of SDN across the whole network
  - Support for current and future packet transmission protocols



## ETSI ISG mWT activity on MW and mmW industry

Within ETSI a specific Industry Specification Group (ISG) on millimetre Wave Transmission (mWT) has been established since January 2015. The group has the task of providing a platform and opportunity for companies and organizations involved in the microwave and millimetre-wave transmission industry, to exchange technical information in order to prepare White Papers and presentations to increase the level of confidence by the operators worldwide in the use of traditional microwave and millimeter-waves.

This white paper is one of many technical deliverables produced by ISG mWT about the different aspects of technology, applications, spectrum management, regulation and licensing, which can be found on the dedicated ETSI web site: [www.etsi.org/mwt](http://www.etsi.org/mwt).



## Acronyms

BCA	Band and Carrier Aggregation
eMBB	enhanced Mobile BroadBand
ISG	Industry Specification Group
MIMO	Multiple Input Multiple Output
mmW	millimetreWave
mMTC	massive Machine Type Communications
MW	MicroWave
mWT	millimetre Wave Transmission
PoP	Point of Presence
SDN	Software Defined Networking
TDM	Time Division Multiplexing
uRLLC	Ultra-Reliable and Low Latency Communications
VPN	Virtual Private Network
XPIC	Cross Polar Interference Cancellation





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