Make 5G Backhaul Feasible Everywhere

Contributed by Huawei
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01 5G Networks are Here, and Need Transmission

As the world just seemed to get used of the 4G LTE networks, which coincided with the universal diffusion of the modern Smartphone, we have now 5G technologies already being tested in the field, and due to start early deployment in 2019 already, with worldwide deployments widely expected from 2020 on.

As it always happens with new technologies, the very first deployments occur in high-density, high-revenue urban scenarios in the main cities, under very controlled circumstances, and without great concern for cost – the main goal is to demonstrate their performances, and – of course – to be “first”.

But, as network designers and planners know very well, while frantically working behind the scenes, in order to make this magic happen network-wide, all of the required transmission infrastructure needs to be readied in advance.

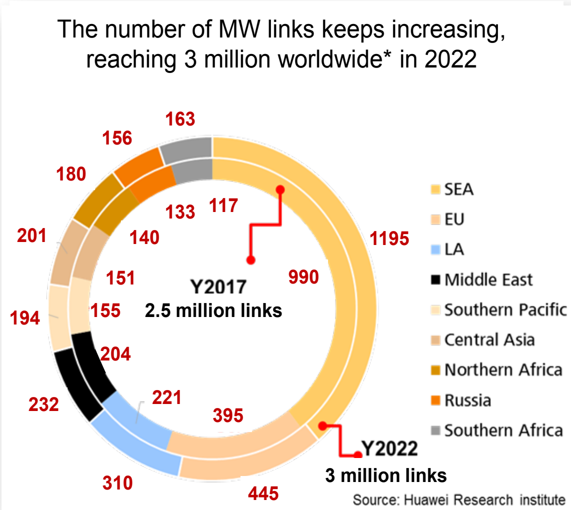
Fiber infrastructure is being expanded as much and as fast as possible, microwave transmission networks are being upgraded and modernized as we speak, the innovation pipeline is full of bold new developments.

However, the extent to which all these new exciting solutions can be deployed to reach all of humanity remains a challenge for many reasons, and this whitepaper aims at illustrating why and how 5G Microwave solutions are an integral part of the solution to these incredible challenges.

02 The Role of Wireless Transmission in 5G

Paraphrasing an old adage, all networks are the same, but each one is different from the others.

The relative share of fiber-based vs. wireless transport (microwave)-based backhaul links can vary widely, based on the geographical region, an area within a region (e.g. a big city downtown vs. a mountainous, rural area), or even the role of the Operator (e.g. incumbent with vast fiber resources, vs. a competing MNO with limited or even no affordable access to fiber).



Overall, it is estimated by the industry's estimate is that the number of wireless transmission links will increase worldwide in the next years.

This could sound contradictory to the mainstream understanding that fiber is the only way to support 5G, but there are several reasons why this is happening, including:

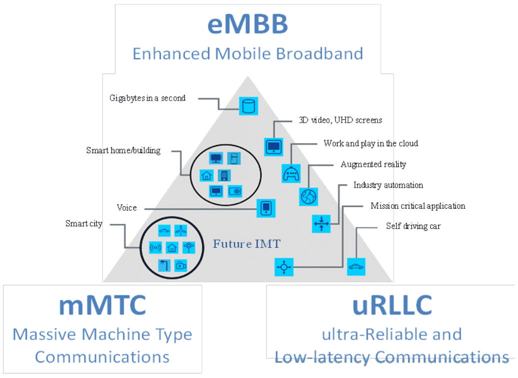
- The number and the density of macro and micro mobile sites is going to increase overall, to support the higher traffic capacity.
- There is an optimal balance between fiber penetration and wireless backhaul, which depends on the local market conditions. Carefully planning the amount of fiber PoPs, from which several more sites can be reached via wireless transmission, allows for very significant TCO savings.
- In most rural areas, the balance is strongly tipped in favor of wireless connectivity.

The network structure is also changing: whereas a tree-like topology of microwave links was the standard topology in most areas, now we see an increase of "star" topologies: as more fiber points of presence (PoP) are deployed farther in the periphery of the network, the microwave trees are shortened, in the limit reducing to a star of single-depth links emanating from the PoP itself.

03 What it Means to Make it Feasible…

To make 5G backhaul over microwave feasible, the challenges 5G networks bring to the transmission network must be overcome.

Transmission Capacity and Latency



eMBB is arguably the advanced 5G service that will impose the highest strain on the transmission network from the raw transmission capacity point of view. We are talking here of end-user speeds in the Gb/s range.

uRLLC, on the other hand, in addition to ultra-reliability, also requires transmission delays down to the millisecond range, which can be as much as one order of magnitude improvement, compared to today's typical 3G/4G networks.

Whereas latency in a transmission network is mostly affected by the physics of electromagnetic propagation, capacity has always to be traded off against electromagnetic spectrum availability and transmission distance. The main factors determining the wireless backhaul engineering are:

- Availability and cost of microwave spectrum – both as a total resource, and as maximum allowed size of a single transmission channel.
- Required link availability (usually between 99.995% and 99.999%), taking into consideration the effects of multipath and rain attenuation.

In addition to the transmission performance requirements, 5G microwave solutions address all the aspects of a mobile site engineering:

- Supporting all types of site: rooftop, pole, tower, with or without the availability of an indoor space or even an outdoor shelter ("fully-outdoor", or "zero-footprint" sites)
- Minimizing the visual and mechanical impact: multi-transceiver radio units, multi-band antennas, allowing incredibly compact solutions of e.g. 8 bearers on 2 frequency bands on a single antenna, with minimal weight, wind load and visual impact.
- Allowing ultra-dense hubs in fiber PoPs, connecting many peripheral sites thanks to very low interference millimeter-wave links and active interference cancellation systems.

Networking and Automation

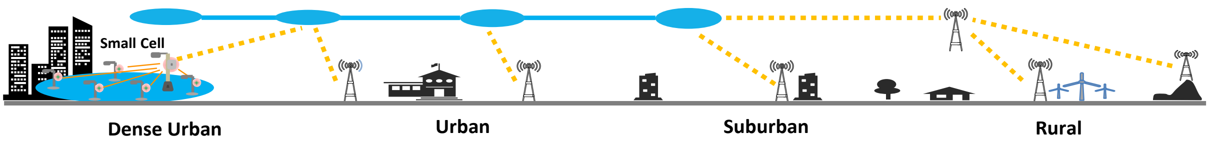
Future networks require to support and ever higher number of ever more sophisticated and diverse services, and this will require unprecedented levels of operational speed, efficiency and automation.

Even if most of these requirements are not specific to microwave transmission, they need to be supported in each and every network layer and segment, otherwise they will never be deployable end-to-end.

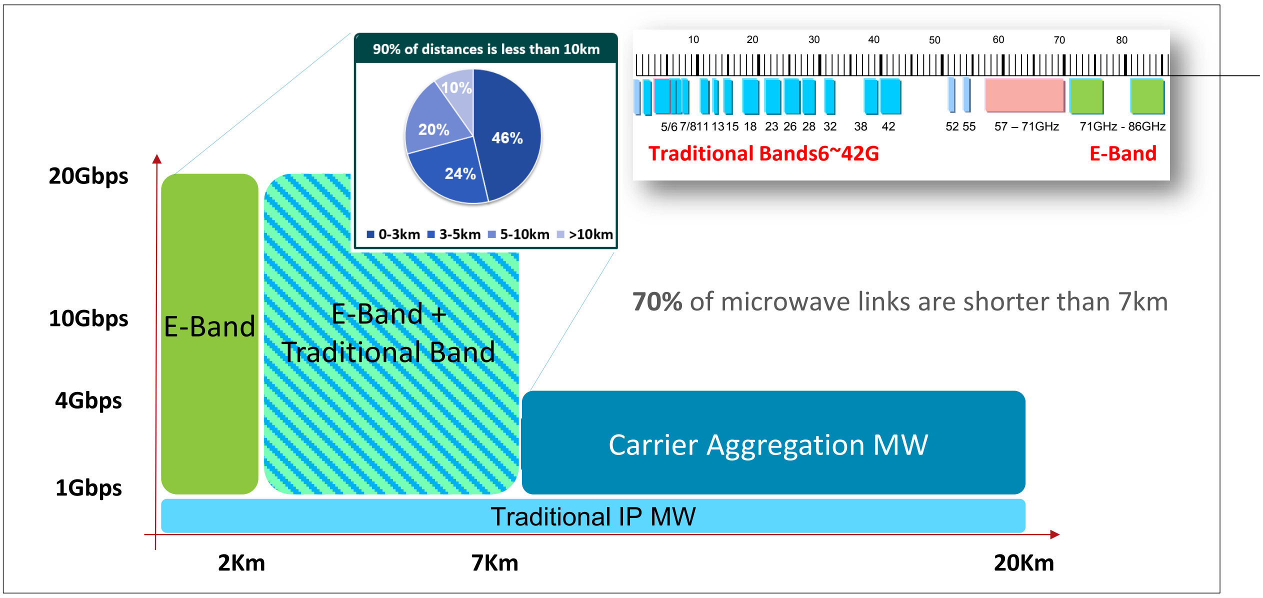
1. **Network slicing.** This is the ability to support multiple virtual networks, with vastly differing requirements, on one common physical infrastructure.
2. **Network Automation.** Only a truly programmable network will be able to adapt and support new services (both in the sense of new instances of known services, and services of new type that are not known today) with the required speed.
3. **High Precision Synchronization.** The efficiency of the air interface critically depends on an ever higher frequency and time/phase network

04 What it Takes to Bring it Everywhere...

As mentioned before, when planning any transmission network, we need to take into account the required capacity, link availability and link length at the same time



In the case of wireless transmission, due to the effects of multipath propagation (dominant at lower frequencies, say below 11GHz) and rain attenuation (dominant at higher frequencies, say above 13GHz), the choice of the operating frequency band is also a basic consideration.



The picture above illustrates the relationship among transmission frequency, link length and transmission capacity (at customary link availability for a conservative European rain intensity) attainable with the current generation of 5G Microwave systems.

Counting that about 70% of microwave links are reachable with E-band or dual-band solutions (E-band + lower band), we can see that the mobile site backhaul capacity target of up to 20Gb/s is easily attainable in all dense urban, urban and suburban scenarios.

When considering the macro mobile site typical configurations, where a cluster of 5G rural sites is not expected to require more than an aggregated capacity of 2 to 4Gb/s, it is clear how microwave transmission systems fully cover the 5G network deployment in any area.

05 Key Elements of 5G Microwave

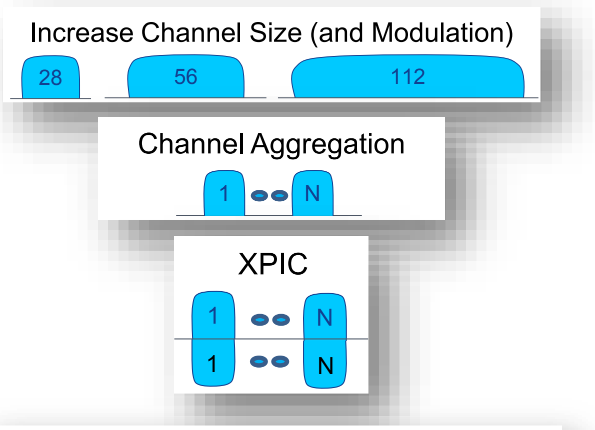
Let’s now have an overview of the technical solutions that a modern 5G Microwave system can offer, to address all the points mentioned in the previous chapters.

5.1 Capacity and Range

5.1.1 Single-band solutions

Considering a microwave link in any given band, there are several possibilities:

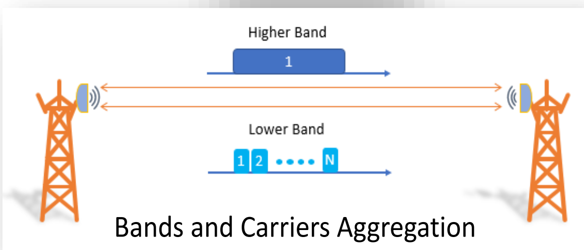
1. Increase the size of each individual channel
2. Bundle together more than one channel (channel aggregation), in one or more hardware units
3. Use both polarizations (horizontal and vertical) for each used channel



5.1.2 Multi-band solutions

Combining transmission of one or more channels in more than one (usually two) frequency bands, we can get the most from each:

- Ultra-high capacity from the higher band
- High availability from the lower band



Most of these techniques are not really new by themselves, but they are of renewed interest, among other reasons, because:

- New RF hardware and new modem designs allow for very large channels (110-112 MHz in many bands)
- E-band (80 GHz), with its very large channels (multiples of 250 MHz) provides very high capacity and low latency
- New self-aligning antennas will allow to ease the installation and maintain the correct alignment, which is especially important at very high frequencies
- Multi-transceiver and multi-channel (per transceiver) units allow to use up to 4 channels with just one hardware unit
- Multi-band antennas allow to combine the multi-channel, multi-band RF bearers on a single antenna unit, minimizing the required tower space and installation and rental cost

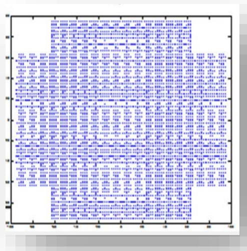
5.2 Efficiency and Density

As the required performances of the transmission network increase more and more, efficiency becomes a primary concern.

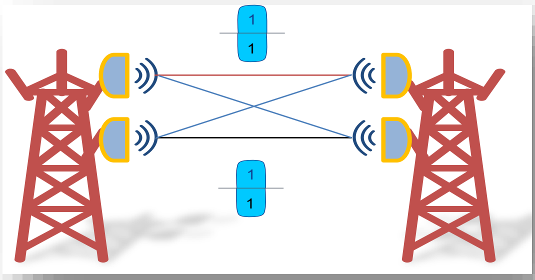
5.2.1 Spectral Efficiency

1. Increase the modulation: currently the top modulation supported is 8196 QAM
2. Deploy Line-of-sight MIMO, obtaining a maximum theoretical 4x efficiency gain

8K QAM



Line-of-Sight MIMO



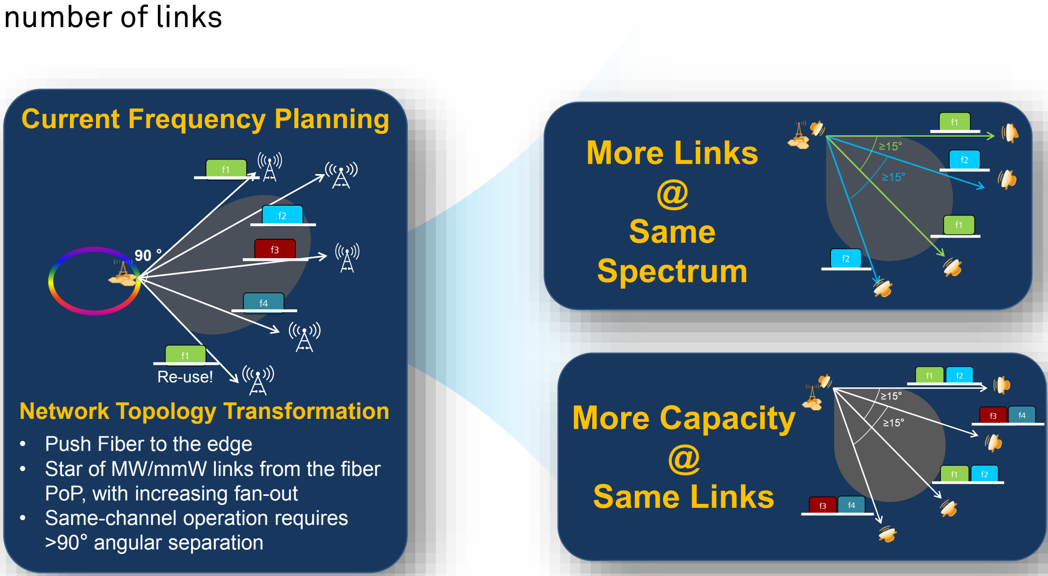
5.2.2 Spatial/Spectral efficiency

As we noted earlier, there is a tendency for the microwave network topology to evolve more and more towards dense stars of links, originating in a common hub, which is a fiber PoP.

With the current technologies, as a rule of thumb a channel may be re-used in a hub if the angle between the two links exceeds 90°.

Active interference-cancelling algorithms are being investigated, which will allow to:

1. Re-use the same channel at a smaller angle than 90° (theoretically down to about 20°), increasing the number of links from that hub
2. Double the spectrum available to the existing links, while not changing the total number of links



5.3 Networking and Automation

Modern 5G microwave equipment include very sophisticated L2, L2.5 (MPLS) and L3 functionalities. These will be extended as time passes to even more, including support for IPv6 and Segment Routing.

All these features, though, currently find a hard limitation by being very complex to manage and troubleshoot, and by not being easily deployed across manufacturer and technology boundaries.

With the advent of cloud-based new unified management, control, analytics and optimization solutions, those limitations can be overcome. The maturing of SDN-based network management and operation brings all this in the realm of actual feasibility.

The main highlights of the new paradigm are:

1. Flexible and efficient OAM
   - MW topology and performance monitoring
   - Automatic troubleshooting
   - Automatic software upgrade
   - One-touch link upgrade configuration
2. Fast service provisioning
   - Unified and simplified portal
   - Microwave synergy with other technologies, fast service provisioning
3. Automatic decision-making, new services
   - Automatic spectrum and service design
   - (Multi-) Point to Multi-Point automatic rerouting for small cell
   - Interference analysis and capacity expansion
   - E2E network slicing
   - Lowest latency routing calculation

06 Some Considerations about Transmission Spectrum

Background

Even as 5G access spectrum is being auctioned country by country, attracting all of the media attention, a lot of action is happening also in the less glamorous area of backhaul spectrum.

The huge required increment in transmission capacity requires to find and use vast amounts of new spectrum, the underlying trends will sound familiar:

- Move to higher frequencies than before: E-band (80GHz) is now widely deployed, D-band (150GHz) is now standardized and the components are being developed, W-band (90GHz) is also a future candidate, as are frequencies above 170GHz
- Use wider channels than before, when a 28MHz channel was “big”: start using 112MHz channels now, 224MHz in the future, wherever possible, and use both polarizations
- (This is actually “new” to backhaul) 5G access spectrum is now claiming sizeable portions of previously uncontested backhaul spectrum (26 and 42 GHz in Europe, 28 and 39 GHz in US, Korea and Japan, potentially even other bands), potentially requiring moving any existing backhaul links operating in those frequencies

The role of Regulation and Licensing

Spectrum allocation regulation is of course a key element in determining if, how well and how fast new spectrum can be allocated for backhaul, and if and how effectively existing spectrum can be reallocated.

The whole Industry is working hard since years to make sure that backhaul is allowed to support the advanced features and applications of 5G, in time for when the actual networks will be deployed.

Microwave backhaul is such an important part of the 5G picture in so many countries and networks, that this aspect is actually a critical point to be kept under control, even if far less glamorous than all regarding 5G access.

07 Conclusions and Outlook

5G networks are not only going to revolutionize the way telecommunication networks are built and operated, but it will change the way of life of all the people who will be reached by it.

A very wide proportion of humanity lives in challenging areas of the world, be it for the environmental, economic or geographical conditions.

5G Microwave backhaul represents a fundamental tool to be able to extend the advantages of 5G networks to all areas of the world.

The technological advancement is taking care of the technical challenges to increase the capacity, reach and efficiency of 5G Microwave backhaul, and the Industry as a whole is working closely with all the stakeholders and the Spectrum Standards and Regulation Authorities to unleash the full potential of 5G.

Huawei has always been deeply and strongly involved both in pushing the technological advancement, with its vast portfolio of innovative products, and is investing heavily in participating and promoting all initiatives at international level in all matters Standardization and Regulation.

08 Acronyms and Abbreviations

Acronym or Abbreviation	Full Name
CCIC	Co-Channel Interference Canceller
E2E	End-to-End
eMBB	Enhanced Mobile Broadband
MIMO	Multiple Input, Multiple Output
MNO	Mobile Network Operator
MPLS	Multi-Protocol Label Switching
MW	Microwave
OAM	Operation and Maintenance
PoP	Point of Presence
QAM	Quadrature Amplitude Modulation
SDB	Super Dual Band
SDN	Software Defined Networking
TCO	Total Cost of Ownership
uRLLC	Ultra-Reliable and Low Latency Communication
XPIC	Cross-Polar Interference Canceller

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