MICROWAVE BACKHAUL FOR LTE AND BEYOND

WITH THE ALCATEL-LUCENT 9500 MICROWAVE PACKET RADIO

APPLICATION NOTE

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INTRODUCTION

Mobile subscribers are demanding high-speed, reliable and seamless access to mobile data services, a growing applications ecosystem, and mobile video. Mobile Network Operators (MNOs) are taking different network evolution paths to address this demand, but at some point all evolution paths will involve a Long Term Evolution (LTE) Radio Access Network (RAN) complemented with small cells. This evolution to a heterogeneous network of LTE and small cells requires that a flexible backhaul network is in place to support increasing RAN capacity demands resulting from continuous LTE innovation and new heterogeneous network topologies. And at the same time, it is important to minimize the network’s Total Cost of Ownership (TCO).

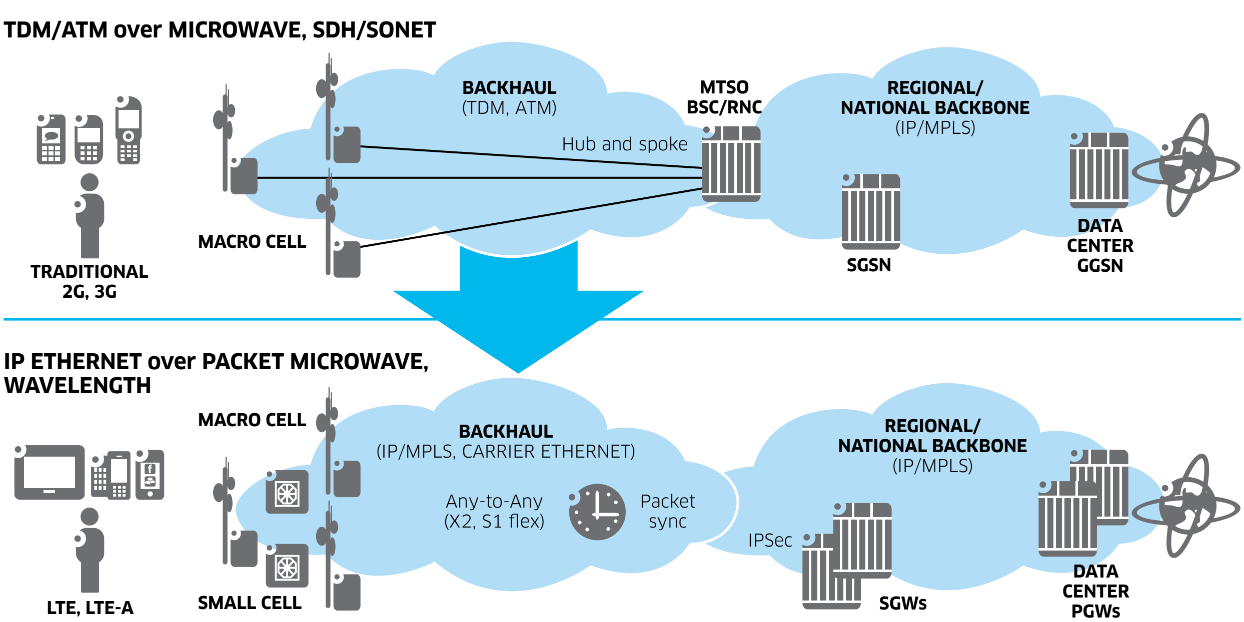
This paper describes the role of microwave in supporting the RAN evolution to LTE, small cells and beyond. The LTE architectural requirements for backhaul networks are reviewed, followed by a discussion of microwave deployment economics to support LTE backhaul, and an outline of how Alcatel-Lucent’s industry-leading packet microwave portfolio economically addresses RAN backhaul requirements for LTE and beyond.

LTE ARCHITECTURAL REQUIREMENTS

The introduction of LTE has changed the way mobile operators architect their backhaul network — the network segment that interconnects LTE evolved Node B (eNB) base stations and Service Gateways (S-GWs). As defined by 3GPP, the LTE backhaul architecture is based on an all-IP packet infrastructure. However, options also exist for carrying traditional 2G/TDM and 3G services over the same converged backhaul network. This converged backhaul option might not be used for an initial LTE deployment; operators can overlay traditional backhaul networks to support LTE initially, and subsequently move to a converged 2G, 3G and LTE network later when business priorities permit.

Figure 1 shows the key architecture changes introduced by LTE.

Figure 1. Evolving from a traditional 2G/3G RAN architecture to an LTE RAN architecture



Backhaul requirements for LTE and beyond

To reduce network cost, the LTE architecture eliminates the role of the traditional Base Station Controller (BSC) or Radio Node Controller (RNC). These network functions have been moved to more intelligent LTE eNBs and S-GWs. However, to support this reallocation of functions, the LTE architecture leverages the any-to-any communication service foundation that is inherent in packet-based services (for example, E-LAN, IP and IP VPN services) for some of its communication interfaces.

The LTE X2 interface supports communication between eNBs for the purposes of handover, SON, and LTE Advanced features. LTE Advanced features to control interference and increase capacity require close cooperation among cell sites using the most direct network communication path. E-LAN and IP services can be used to efficiently support the LTE X2 interface as they can support the most optimal direct communication between eNBs, saving on backhaul bandwidth, and minimizing communication delay.

eNBs need to communicate with a pool of S-GWs for the purposes of reliability and scale over the LTE S1 interface. Again E-LAN and IP-based services can be leveraged to efficiently support this requirement.

Delivering RAN synchronization over the backhaul network also changes when moving to LTE. New synchronization techniques such as Synchronous Ethernet and IEEE 1588v2 Precision Time Protocol (PTP) are required to deliver synchronization over LTE packet backhaul networks. The need for IEEE 1588v2 phase, or time-of-day, synchronization is also increasing to support:

- LTE-TDD RAN spectrum
- Enhanced Multimedia Broadcast Multicast Service (eMBMS)
- Flexible deployment of small cells in areas where satellite-based synchronization reception is difficult to achieve.
- LTE-Advanced multi-cell coordination to increase spectral efficiency

LTE has also been architected to support Voice over LTE (VoLTE). VoLTE support enables new MNO service innovation while also offering superior voice quality and RAN spectral efficiencies. However, VoLTE support places strict IP packet latency requirements on the LTE backhaul communication path between the eNB and S-GW.

Addressing LTE backhaul requirements also requires advanced Quality of Service (QoS) capabilities to ensure that the end subscriber’s Quality of Experience (QoE) is consistent with MNO service plans, while also ensuring that the mobile network is reliable and continues to operate over network-impacting events such as fiber cuts and weather impairments to microwave links.

The 3GPP LTE-Advanced initiative has as one of its key goals the ability to provide faster mobile connections, including peak rates of up to 1 Gb/s in the downstream direction, by leveraging advanced technologies such as Carrier Aggregation, Coordinated MultiPoint operation, and enhanced interference control.

LTE Category 4 user devices offer an enhanced user experience supporting peak downlink speeds up to 150 Mb/s and peak uplink speeds up to 50 Mb/s. To support these speeds, LTE-Advanced Carrier Aggregation-capable systems operate in more flexible spectrum allocations than are used today. LTE-Advanced Category 6 user devices will push these speeds even higher, supporting up to 300 Mb/s downlink and 100 Mb/s uplink speeds. Category 6 devices are expected to enter commercial availability between 2014 and 2015.

Supporting these types of bandwidths is causing concern for mobile operators as they analyze the impact to their backhaul networks. Many of these operators have extensively deployed and/or are planning to deploy wireless transmission/microwave to support the deployment of small cells, macro cells, cell site aggregation and long-haul transport, and these operators want to be sure that their wireless transmission systems can scale to meet LTE-Advanced capacity demands.

LTE BACKHAUL AND MICROWAVE

It is well known that the optimal transmission medium to meet LTE backhaul capacity needs is fiber. However, it is difficult to deploy fiber to all cell sites, or deploy fiber fast enough to meet RAN coverage and/or capacity needs. Microwave transmission options are an economical alternative to fiber, an option that also can be rapidly deployed ahead of fiber availability, and subsequently be redeployed when fiber options are available. It’s instructive to compare a microwave versus fiber backhaul option in terms of performance, LTE bandwidth capacity needs, and cost to deploy.

Performance

LTE backhaul requires Service Level Agreement (SLA) performance criteria for availability, packet delay, packet delay variation, and packet loss. SLA performance factors such as packet delay and packet delay variation are especially important to support VoLTE services and IEEE 1588v2 PTP packet synchronization. Fiber-based backhaul can typically be designed to easily meet LTE SLA requirements. The same can also be said for an LTE backhaul network using Line-of-Sight (LoS) microwave, since LoS microwave links offer similar latency characteristics to fiber.

From a microwave link perspective, MNOs typically require 99.999% availability — approximately 5 minutes of down time per year. To achieve this level of availability over fiber, a BTP (for example, an AAV) is required to make a significant network investment — an investment that might not justify a backhaul services Return on Investment (ROI), making microwave the only backhaul alternative to the MNO.

Capacity

From a theoretical point of view, fiber is almost unlimited in the capacity it can support. Techniques exist to scale microwave capacity without sacrificing RF performance. Increasingly, these are techniques that can only be utilized by packet microwave systems.

Cost to deploy

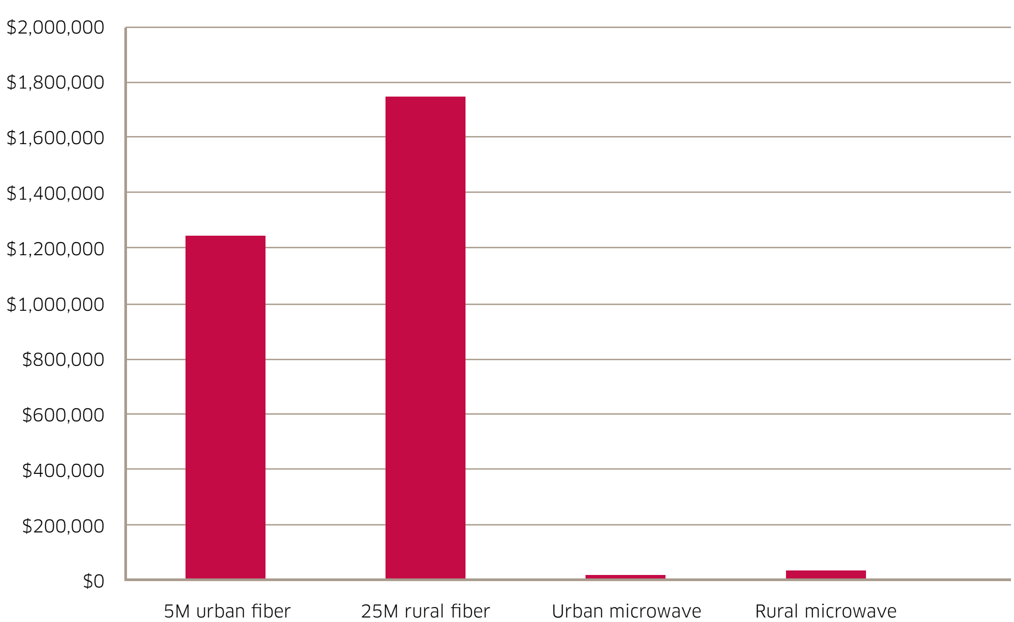
Sky Light Research specifies that the 7/8 GHz frequency bands support the majority of deployed microwave channels globally. Typically, this frequency is used for backhaul between aggregation hub sites, or for rural areas to achieve longer reach. The approximate distance for a 7/8 GHz microwave link at 99.999 percent ("Five 9s") availability is 25 miles, or 40 kilometers. In North America, the primary frequency band is 6 GHz, with similar propagation characteristics to 7/8 GHz.[1]

The lack of fiber is a common issue for rural cell site deployments and is frequently an issue for urban cell site deployments as well. Many times operators are forced to place a cell site in urban locations where fiber does not exist. There may also be cases where a Backhaul Transport Provider (BTP) such as an Alternative Access Vendor (AAV) may have fiber, but the cost to lease an Ethernet backhaul circuit is not cost effective for the MNO. These fiber deployment challenges are addressed by microwave backhaul alternatives.

In an urban environment, the most widely deployed frequency is 23 GHz. To maintain the standard 99.999 percent availability at this high frequency often means that the link distance is less than 5 miles or 8 kilometers. Typically these systems are unprotected, resulting in a lower link cost.

In the United States, the Department of Transportation monitors the fiber installation costs in various states, and the fiber installation alone can be over $250,000 per mile.[2] This high cost, along with the delays due to permits and construction make fiber an unrealistic expectation for many cell sites. The following figure compares microwave versus fiber deployment economics for the preceding rural and urban backhaul examples.

Figure 2. Fiber versus microwave relative costs for an urban 5-mile link and a rural 25-mile link

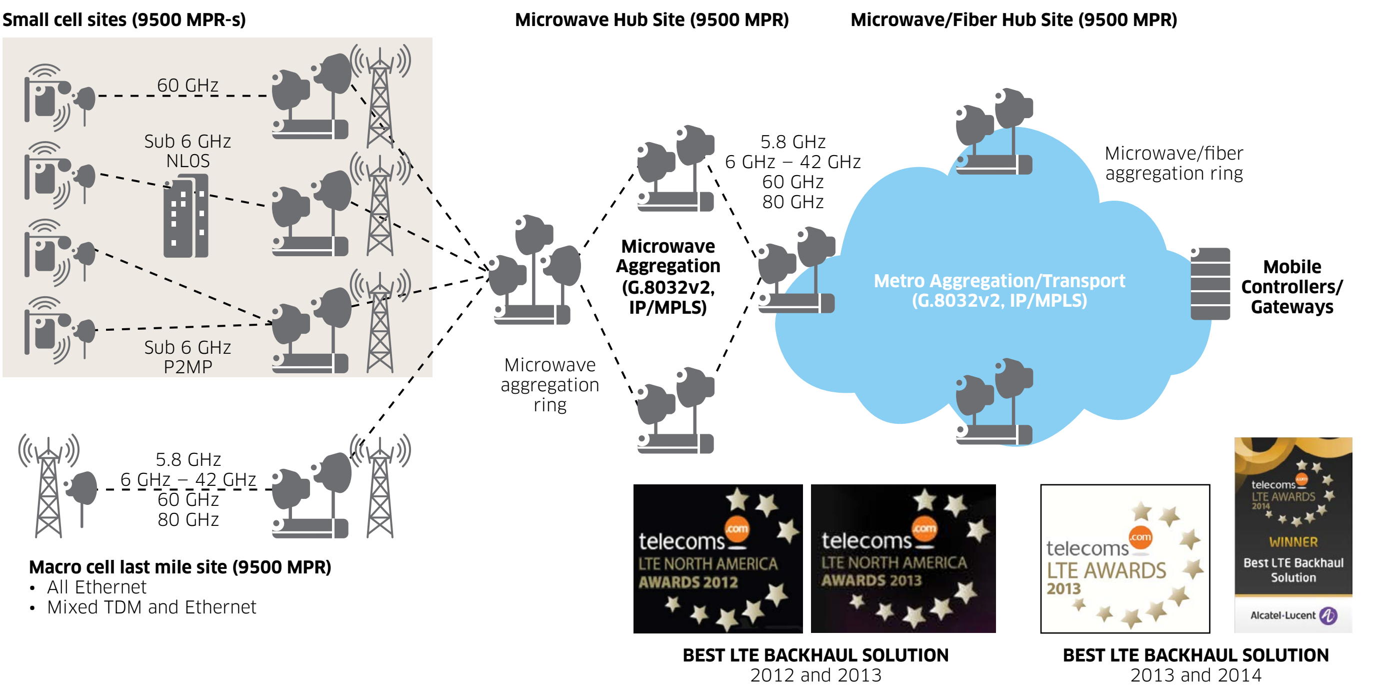


1 Sky Light Research, "Microwave Market Summary & Executive Analysis," 4Q 2012
2 U. S. Department of Transportation Research and Innovative Technology Administration (RITA), "Fiber Optic Cable Installation Costs", DOT web site, July 3, 2013

ALCATEL-LUCENT 9500 MPR AND LTE BACKHAUL

The Alcatel-Lucent Microwave Packet Radio (MPR) holds the leadership position for packet microwave globally, and is a key component in Alcatel-Lucent's award winning end-to-end mobile backhaul solution. A key reason for this success is that the 9500 MPR was initially designed with LTE backhaul and beyond requirements in mind, and delivers an end-to-end wireless transmission portfolio to optimally address all cell site geographies and site constraints. The 9500 MPR combines the technical foundation of a packet system with the economical effectiveness of microwave, delivering ease of deployment and low TCO advantages.

Figure 3. Alcatel-Lucent 9500 MPR industry-leading, award-winning, end-to-end portfolio



The strengths of packet microwave are reinforced by research from Infonetics Research indicating that over 90 percent of all 2013 backhaul equipment spend was on IP/Ethernet equipment, and 53 percent of this spend was on microwave-based systems.[3] However, not all microwave systems are created equal.

Since its ground-breaking packet microwave short-haul introduction, the 9500 MPR has grown to be one of the most complete microwave end-to-end portfolios in the industry. Few competitors can rival this portfolio or compete against Alcatel-Lucent's integrated microwave and IP/MPLS solutions — a portfolio and solution that also have the advantage of being supported by a single network and services management platform — the Alcatel-Lucent 5620 Service Aware Manager (SAM).

Few microwave vendors have moved as quickly as Alcatel-Lucent to make the strategic investments necessary to evolve their microwave systems to optimally support IP data services — recognizing that they are the wave of the future. As services continue to evolve to packet technology, an architecture based on supporting packet traffic is the

3 Infonetics Research, "Macrocell Mobile Backhaul Equipment and Services," April, 2014

most logical choice. With that said, for any new technology to ultimately be successful it must also support the traditional services that are already in place. Alcatel-Lucent's packet microwave architecture is built with the understanding that traditional TDM and ATM services also have to be supported over a common network with LTE services to minimize network TCO. To support this approach, the 9500 MPR packetizes traditional services, but does it in a unique way, so that traditional SLAs are maintained.

Delivering faster, more efficient LTE microwave backhaul links

To address growing mobile traffic levels and improve mobile subscriber QoE to reduce customer churn, the 9500 MPR supports a comprehensive array of features collectively referred to as the "capacity toolkit." The capacity tool kit scales microwave backhaul capacity and optimizes LTE RAN performance. The capacity toolkit includes support for the following features:

- **Service-driven adaptive modulation**
  This feature optimizes overall microwave channel throughput, even during adverse propagation conditions. High-priority traffic is always given bandwidth using advanced QoS prioritization and scheduling techniques, even when modulation levels need to decrease in order to maintain path availability under adverse propagation conditions.
- **Cross-Polarization Interference Cancelation (XPIC)**
  This capability doubles the capacity of a single frequency by using both horizontal and vertical electromagnetic polarizations. This increases capacity while also saving spectrum and antenna costs.
- **Higher-order Quadrature Amplitude Modulation (H-QAM)**
  Higher QAM levels increase the number of transported symbols per Hz to help squeeze more bandwidth out of scarce microwave spectrum.
- **Multichannel link scaling**
  This feature scales link capacity by bonding radio channels together into a virtual high-capacity microwave link. It also provides optimum link reliability by delivering protection against channel failures or degradations.
- **Packet throughput booster**
  The packet throughput booster uses advanced packet compression to reduce Ethernet and IP protocol header overhead, increasing radio link throughput over the air interface by as much as 300 percent.

The capacity toolkit features can be deployed individually or flexibly combined to support optimal microwave network capacity and scale.

All the capacity toolkit features take advantage of the 9500 MPR proven QoS capabilities. Backhaul traffic is classified according to industry standards (for example, IEEE 802.1p, IETF IPv4 and IPv6 DSCP, IETF MPLS EXP bits) and is serviced by a scheduler employing deficit weighted round robin (DWRR) algorithms and high-priority queue (HPQ) algorithms. High-priority traffic is associated to HPQ, and is serviced in strict priority queuing before any low-priority traffic. Low-priority traffic is associated to DWRR-controlled queues. Eight queues are associated to each output port, providing operators with enough flexibility to accommodate present and future requirements.

Buffers allocated to queues are configurable to accommodate LTE traffic bursts, and avoid TCP retransmission service-related impacts. The 9500 MPR has been designed to support up to 32 Mb per queue, which enables outstanding packet burst absorption. Traffic can also be identified and rate controlled at the ingress of a microwave network using Ethernet, IP, User Datagram Protocol (UDP) and/or TCP header fields. In addition, traffic shaping can be enabled to tune the rate of traffic leaving a microwave network or network element. This is a mandatory capability to stay within SLA bounds when leveraging leased backhaul services (for example, backhaul to and from a MNO-owned microwave network and a leased fiber backhaul service), or sharing RAN/backhaul architectures.

These powerful QoS capabilities address LTE QoS requirements and ensure that mobile subscriber QoE is consistent with MNO service plans, while also ensuring that the mobile network continues to operate over network impacting events such as weather-induced propagation impairments to microwave links.

To meet the needs of LTE phase synchronization, the 9500 MPR complies with IEEE 1588v2 PTP Boundary Clock and Transparent Clock on-path support. These mechanisms facilitate the accurate end-to-end distribution of synchronization across a packet backhaul network.

Advanced networking to reliability support any LTE RAN deployments

To reliably serve microwave and fiber sites, the 9500 MPR supports both traditional SDH/SONET networking and ITU-T G.8032v2 Ethernet networking. This G.8032v2 support allows networks to benefit from the following inherent strengths of ring architectures:

- Network capacity can be doubled by sending traffic in both directions around the ring when failures are not present.
- Ethernet loops can be easily contained by blocking traffic on selected ring spans, avoiding the need for spanning tree-based network protection mechanisms (for example, Rapid Spanning Tree Protocol (RSTP), which is complex and slow to react to network failures).
- 50 ms protection is also easily implemented by turning traffic away from failed ring spans.
- Reliable transport of LTE traffic, including S1 and X2 LTE interfaces, via E-LINE, E-TREE and E-LAN services

With the option to packetize traditional services, all services can take advantage of the reliability and scale that the G.8032v2 implementation provides. This introduces further operational simplification when compared to hybrid microwave systems, systems that require the complex use of both packet and TDM networking technology to create packet-capable microwave networks.

Backhaul portfolio approach to end-to-end LTE and beyond

Alcatel-Lucent offers an end-to-end portfolio of packet microwave solutions for both macro cell and small cell backhaul. The Alcatel-Lucent 9500 Microwave Packet Radio (MPR) family offers solutions for tail, hub and aggregation sites, across a full range of licensed frequencies (6 GHz to 42 GHz, 80 GHz), and with full support for both TDM and packet-based traffic. The 9500 MPR portfolio also includes a range of unlicensed/lightly licensed solutions optimized for accelerating small cell deployments, including sub-6 GHz radios for point-to-point and point-to-multipoint non-line-of-sight (NLOS) applications, and 60 GHz radios for high-capacity short-reach point-to-point applications.

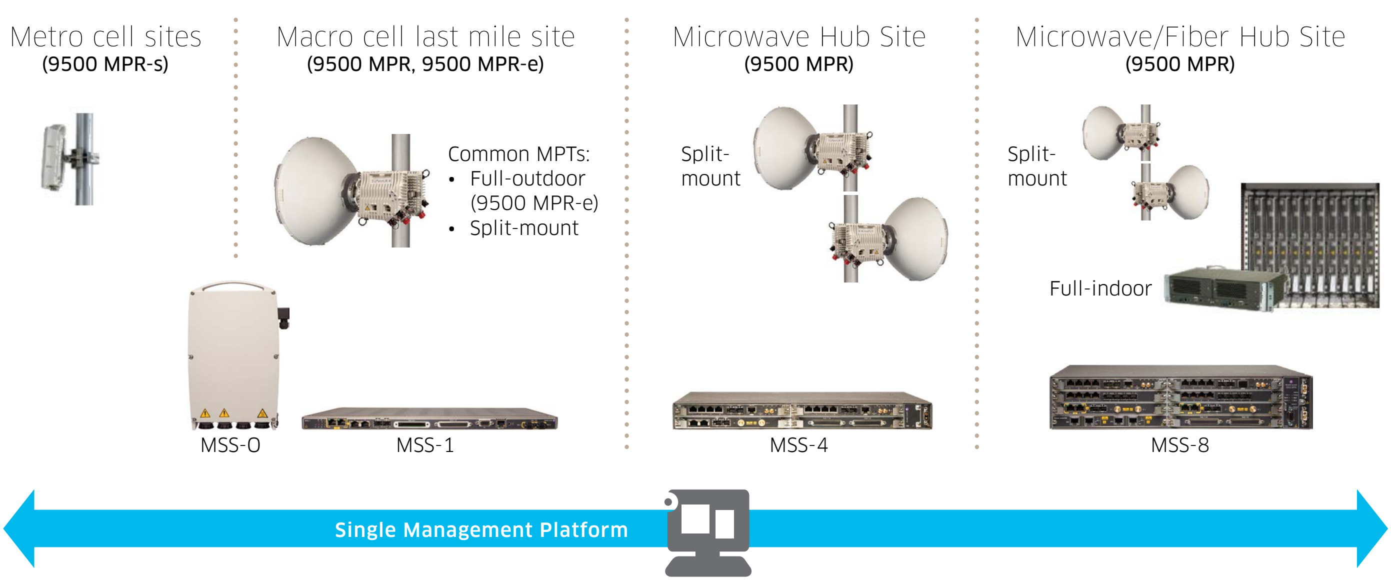
The suite of 9500 MPR Microwave Packet Terminal (MPT) transceivers leverage common technology, independent of whether they are deployed in a split-mount, full indoor or full-outdoor configuration. This capability leads to more deployment flexibility, minimizes customer spares inventory, and results in a lower network TCO.

The 9500 MPR Microwave Services Switch (MSS) indoor and full outdoor units share common technology and software. They offer a complete range of right-sized networking devices to address any microwave site footprint requirements. These small footprint, energy-efficient devices offer industry-leading network scalability and deployment flexibility. They support the port density required to create highly scalable LTE networks. All the indoor units support traditional services such as TDM and ATM, Ethernet services, and IP services over a converged, operationally efficient network.

Figure 4 depicts the Alcatel-Lucent packet microwave portfolio, and the various components that support it:

- **9500 Microwave Packet Radio (9500 MPR):** Overall portfolio of all-indoor, full outdoor, and split-mount packages for use in tail, hub and long-haul packet microwave applications with support for the following frequencies: licensed 6GHz to 42 GHz solutions and 80 GHz millimeter wave solutions
- **9500 MPR-e:** Solution set of 9500 MPR components optimized for Ethernet-oriented, all-outdoor deployments. The 9500 MPR-e can also be co-located with the Alcatel-Lucent 7705 Service Aggregation Router (SAR) (as an indoor unit) for delivering fully integrated IP/MPLS microwave solutions.
- **9500 MPR-s:** Solution set of 9500 MPR components that are optimized for small cell site deployments in the sub-6 GHz, 60 GHz, 80 GHz spectrums.
- **5620 Service Aware Manager (SAM):** Alcatel-Lucent's end-to-end network and service management solution.

Figure 4. Alcatel-Lucent 9500 MPR portfolio



The 9500 MPR-e has been fully integrated into the 7705 (SAR) portfolio to the point where the 9500 MPR-e is a directly supported microwave interface. Microwave-specific cards have been added to the 7705 SAR-8 to support microwave protection and powering. This level of integration offers unique capabilities for deploying IP/MPLS networking over microwave links:

- Simplified operations reduce operating expenses OPEX — the solution configuration is managed as a single network element, under common network management. This unique capability brings a number of OPEX advantages. Regardless of how many radio instances exist, network element maintenance procedures, such as software upgrades and configuration backups, are done only once to all components.
- Further reduction in OPEX is achieved as microwave radios can be directly powered by the 7705 SAR with lightning protection and voltage surge suppression. This simplifies and optimizes cell site battery feed planning and installation.
- Collapsing two platforms into a single compact and very flexible platform brings a number of advantages in reducing real estate requirements, operations complexity and energy costs.

As part of this configuration, the 9500 MPR-e continues to supports advanced features such as hitless adaptive modulation, cross-polarization (XPIC), 1 + 1 hot-standby with space diversity, and header compression for boosting throughput. MNOs can thus optimize the spectrum efficiency and link reliability of microwave links together with delivering powerful 7705 SAR IP/MPLS networking capabilities.

The capacity toolkit, traditional services evolution to all-IP, ITU-T G.8032v2 networking, and a streamlined end-to-end portfolio are all powerful and unique Alcatel-Lucent features. These features can be deployed independently or together. However, it is when they are all used together that the advantages over hybrid microwave systems are even more convincing, and provide the foundation for the following benefits:

- Faster, more efficient links for all services
- Advanced 50 ms protected networking for all services
- A unique, simplified, end-to-end portfolio supporting all services

Together these advantages combine to offer MNOs a unique network TCO advantage.

SUMMARY

To survive in the extremely competitive mobile services market, MNOs must quickly respond to growing traffic demands to deliver a compelling and differentiated mobile subscriber QoE. With the introduction of LTE, small cells and LTE-Advanced, microwave is expected to play an increasingly important role in providing backhaul connectivity where fiber is not available or not economically viable to deploy.

Alcatel-Lucent stands alone in the industry in its ability to rapidly deliver award-winning LTE and beyond microwave solutions with the performance, networking and operational simplicity to address the growing wave of mobile IP services, while also delivering the best mobile subscriber experience at the lowest possible network total cost of ownership.

ACRONYMS

2G	Second Generation Mobile Network
3G	Third Generation Mobile Network
3GPP	Third Generation Partnership Project
4G	Fourth Generation Mobile Network
ATM	Asynchronous Transfer Mode
AAV	Alternative Access Vendor
BSC	Base Station Controller
BTP	Backhaul Transport Provider
E-LAN	Ethernet Virtual Private LAN service
E-LINE	Ethernet Virtual Private Line service
E-TREE	Ethernet Virtual Private Tree service
eMBMS	Enhanced Multimedia Broadcast Multicast Services
eNB	Evolved Node B (LTE base station)
H-QAM	Higher-order Quadrature Amplitude Modulation
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
ITU	International Telecommunication Union
ITU-T	International Telecommunication Union - Standardization Sector
LOS	Line-of-Sight
LTE	Long Term Evolution
MNO	Mobile Network Operator
MPT	Microwave Packet Terminal
MPR	Microwave Packet Radio
MPLS	Multiprotocol Label Switching
MSS	Microwave Services Switch
NLOS	Non-Line-of-Sight
OPEX	Operating Expenditures
PTP	Precision Time Protocol
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
RF	Radio Frequency
RNC	Radio Node Controller
ROI	Return on Investment
RSTP	Rapid Spanning Tree Protocol
SAM	Service Aware Manager
SAR	Service Aggregation Router
SDH	Synchronous Digital Hierarchy
S-GW	Services Gateway (LTE)
SLA	Service Level Agreement
SON	Self Organizing Network
SONET	Synchronous Optical Network
TCO	Total Cost of Ownership
TDD	Time Division Duplexing
TDM	Time Division Multiplexing
UDP	User Datagram Protocol
VoLTE	Voice over LTE
VPN	Virtual Private Network
XPIC	Cross-Polarization Interference Cancelation