MICROWAVE BACKHAUL FOR LONG TERM EVOLUTION

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 Radio Access Network (LTE RAN) complemented with small cells. Supporting this evolution to a heterogeneous network of LTE and small cells requires a flexible backhaul network be in place to support increasing RAN capacity demands and new network topologies, while also minimizing network total cost of ownership (TCO).

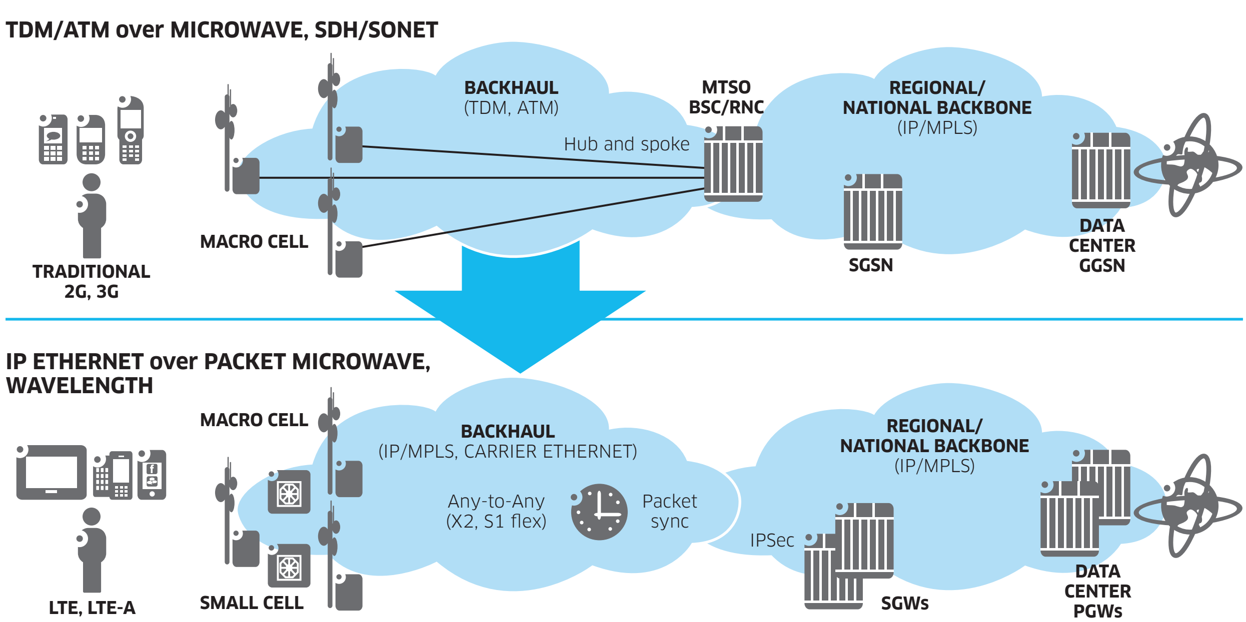
This paper describes the role that microwave plays in supporting the RAN evolution to LTE and small cells. The LTE architectural requirements on backhaul networks are reviewed, followed by microwave deployment economics to support LTE backhaul, and how the Alcatel-Lucent industry-leading packet microwave portfolio economically addresses LTE RAN backhaul requirements.

LTE ARCHITECTURAL REQUIREMENTS

The introduction of LTE has changed the way mobile operators architect their backhaul network — the network segment that interconnects LTE base stations (that is, evolved Node Bs [eNBs]) to Service Gateways (SGWs). As defined by 3GPP, the LTE backhaul architecture is based on an all-IP packet infrastructure. However, options also exist for carrying traditional 2G/Time Division Multiplexing (TDM) and 3G/Asynchronous Transfer Mode (ATM) 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 on when business priorities permit.

The key architecture changes introduced by LTE are depicted in Figure 1 and are elaborated on below.

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



As mentioned above, LTE relies on an IP backhaul infrastructure, which can be achieved by using Ethernet and/or IP services. Traditional 2G and 3G services can also be carried over a converged backhaul network with LTE if their associated TDM and ATM backhaul technologies are adapted to packet using standards-based techniques such as Circuit Emulation (CEM).

To reduce network cost, the LTE architecture eliminates the role of the traditional Base Station Controller (BSC) or Radio Network Controller (RNC). These network functions have been moved to more intelligent LTE eNBs and SGWs. 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, Self-organizing Network (SON), and LTE Advanced (LTE-A) features. The aforementioned E-LAN and IP services can be used to efficiently support the LTE X2 interface. These services support the most optimal direct communication between eNBs, saving on backhaul bandwidth, and minimizing communication delay.
- eNBs need to communicate with a pool of SGWs 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 (SyncE) and IEEE 1588v2 Precision Time Protocol (PTP) are required to deliver synchronization over LTE packet backhaul networks.

Small cells require flexible placement in the network to address RAN capacity and coverage needs. Sometimes this placement means that satellite synchronization reception is difficult to achieve due to the cost associated with placing an antenna (for example, in an underground building). This leads to the need for synchronization to be delivered over the backhaul network.

MNOs also prefer to backhaul small cell traffic to their existing macro cell site locations because they already have backhaul infrastructure such as microwave in place. However, that increased traffic from the small cells places scaling pressure on the existing macro cell backhaul network.

LTE has also been architected to support VoLTE (voice over LTE). 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 SGW.

Addressing the aforementioned LTE architectural requirements requires advanced quality of service (QoS) capabilities to ensure that the end-subscriber 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.

Supporting all of the LTE architectural requirements above requires equipment that has been specifically designed to economically address the needs of LTE networks.

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 is instructive to compare a microwave with a fiber backhaul option in terms of cost to deploy, performance, and LTE bandwidth capacity needs.

Cost to deploy

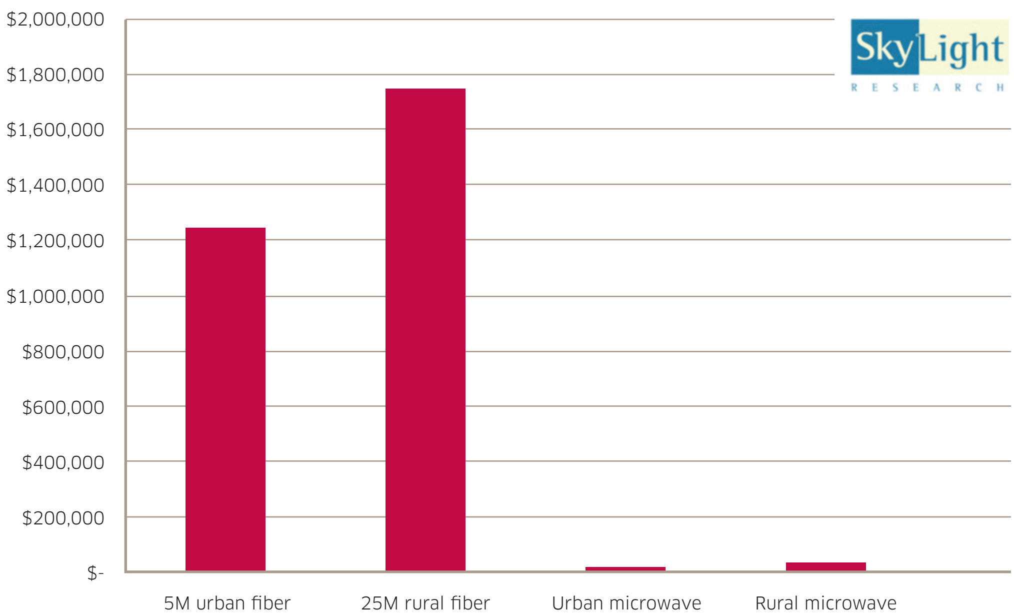
Sky Light Research specifies that the 7/8 GHz frequency bands support the majority of deployed microwave channels globally. Typically, this frequency is used for backhaul between aggregation hub sites, or for rural areas to achieve longer reach. The approximate distance for a 7/8 GHz microwave link at 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.

The lack of fiber is a common issue for rural cell site deployments. It 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. Maintaining the standard five 9s 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 reports that the fiber installation alone can be over $250,000 per mile. This high cost, along with the delays due to permits and construction make fiber an unrealistic expectation for many cell sites. Figure 2 compares microwave versus fiber deployment economics for the preceding rural and urban backhaul examples.

Figure 2. Sky Light Research – fiber versus microwave relative costs for an urban 5-mile link and a rural 25-mile link



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, as LoS microwave links offer similar latency characteristics to fiber.

From a microwave link perspective, MNOs typically require five 9s of availability — approximately 5 minutes of downtime per year. To achieve this level of availability over fiber, a BTP (for example, 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.

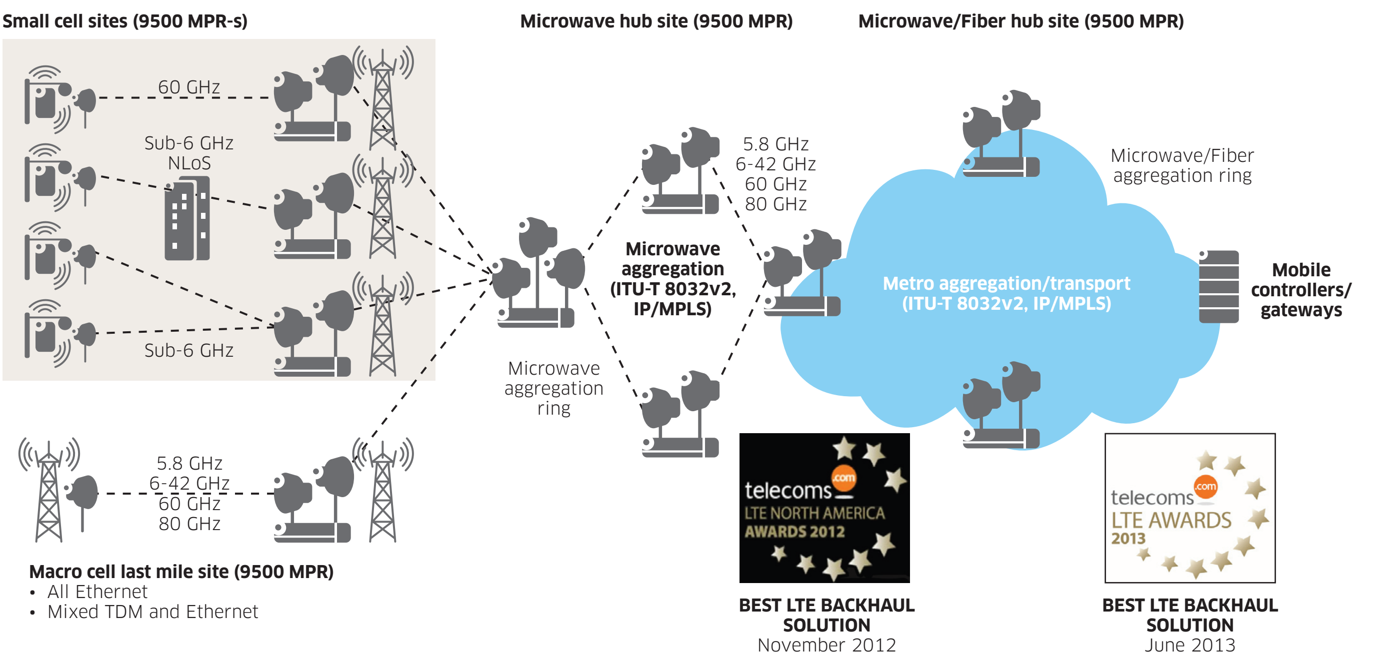
Capacity

From a theoretical point of view fiber is almost unlimited in the capacity that it can support — it is possible today to place 400 Gb/s over a single wavelength (for example, using the Alcatel-Lucent 1830 Photonic Service Switch [PSS]). Microwave has more restrictive bandwidth limitations. Despite these limitations, however, there are techniques to scale microwave capacity without sacrificing radio frequency (RF) performance. Increasingly, these are techniques that can only be utilized by packet microwave systems.

ALCATEL-LUCENT 9500 MICROWAVE PACKET RADIO AND LTE BACKHAUL

The Alcatel-Lucent 9500 Microwave Packet Radio (MPR) holds the leadership position for packet microwave globally, and is a key component in the Alcatel-Lucent award-winning, end-to-end mobile backhaul solution. A key reason for this success is that the Alcatel-Lucent 9500 MPR was initially designed with LTE backhaul 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 from research performed at Infonetics Research indicating that 94 percent of all backhaul equipment spend was on IP/Ethernet equipment, and 51 percent of this spend was on packet microwave-based systems. However, not all packet microwave systems are created equal.

Since its groundbreaking 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 the Alcatel-Lucent end-to-end microwave portfolio or compete against the Alcatel-Lucent integrated microwave and IP/Multiprotocol Label Switching (MPLS) solutions — a portfolio and solution which also has the advantage of being supported by a single Alcatel-Lucent 5620 Service Aware Manager (SAM) network and services management platform.

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

The introduction of LTE and small cells is expected to further increase mobile traffic to the point where there is 25 times more traffic by 2016 (Alcatel-Lucent Bell Labs). 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 toolkit scales microwave backhaul capacity and optimizes LTE RAN performance. The capacity toolkit includes support for:

- **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-Polar 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.
- **Hierarchical Quadrature Amplitude Modulation (HQAM):** Higher QAM levels increase the number of transported symbols per hertz 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 header overhead, increasing radio link throughput over the air interface by as much as 300 percent.

The aforementioned 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 with HPQ, and is serviced in strict priority queuing (SPQ) before any low-priority traffic. Low-priority traffic is associated with DWRR-controlled queues. Eight queues are associated with 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 Transmission Control Protocol (TCP) retransmission service-related impacts. The Alcatel-Lucent 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.

Advanced networking to reliably support any LTE RAN deployments

To reliably serve microwave and fiber sites the 9500 MPR supports both traditional Synchronous Digital Hierarchy/Synchronous Optical Network (SDH/SONET) networking and standards-based ITU-T G.8032v2 Ethernet networking. This ITU-T G.8032v2 support allows networks to benefit from the 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, using 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 ITU-T 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.

End-to-end LTE backhaul portfolio approach

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 family offers solutions for tail, hub and aggregation sites, across a full range of licensed frequencies (6-42 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.

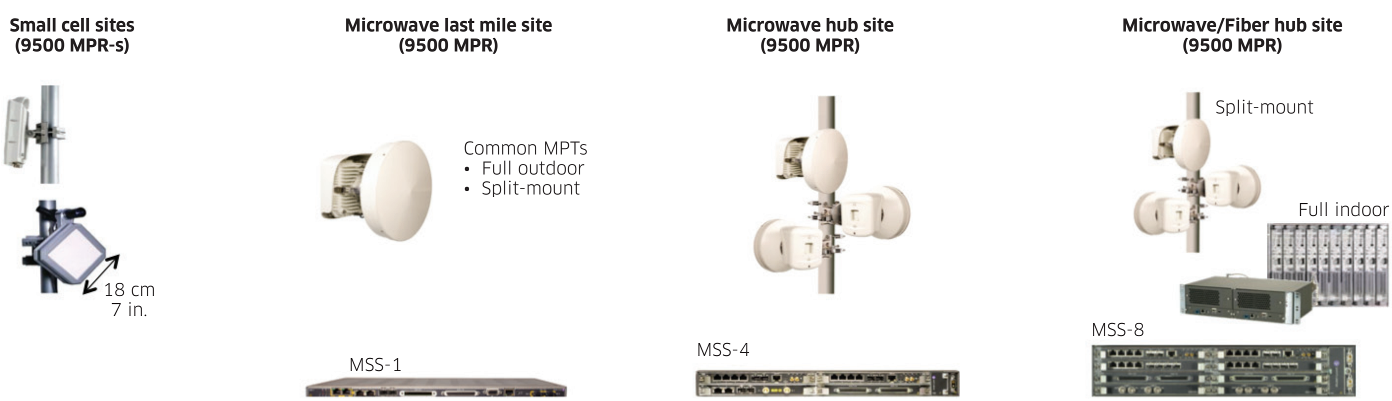
The suite of 9500 MPR Microwave Packet Terminal (MPT) transceivers leverage common technology, independent of whether they are deployed in a split-mount, full indoor, or full outdoor configuration. This capability leads to more deployment flexibility, minimizes customer spares inventory, and results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

The 9500 MPR Microwave Services Switch (MSS) indoor units share common technology and software. They offer a complete range of right-sized indoor units 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 microwave packet portfolio and the various components that support it:

- **9500 Microwave Packet Radio (9500 MPR):** Overall portfolio of all indoor and split-mount packages for use in tail, hub and long-haul packet microwave applications with support for the following frequencies: licensed 6-42 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 collocated with 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 and 60 GHz spectrums
- **Alcatel-Lucent 5620 Service Aware Manager (SAM):** Alcatel-Lucent end-to-end network and service management solution

Figure 4. Alcatel-Lucent 9500 MPR portfolio



INNOVATIVE END-TO-END PRODUCT FAMILY EFFICIENTLY ADDRESSING ALL SITES AND APPLICATIONS

- **FEWER SPARES –** Use of common 9500 MPR transceiver (MPT) outdoor units across all applications
- **LESS SPACE AND POWER –** Indoor units optimized to different site sizes and requirements
- **SIMPLIFIED OPERATIONS –** Common software and management across all components (9500 MPR-s – management only), integrated IP and optical options

The 9500 MPR-e has been fully integrated into the Alcatel-Lucent 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 expense (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 support 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:

- 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 and small cells, 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 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
4G	Fourth-Generation Mobile Network
AAV	alternative access vendor
ATM	Asynchronous Transfer Mode
BSC	Base Station Controller
BTP	backhaul transport provider
CEM	Circuit Emulation
DSCP	Differentiated Services Code Point
DWRR	deficit weighted round robin
E-LAN	Ethernet Virtual Private LAN service
E-Line	Ethernet Virtual Private Line service
eNB	evolved Node B (LTE base station)
E-Tree	Ethernet Virtual Private Tree service
GGSN	Gateway GPRS Support Node
HPQ	high-priority queue
HQAM	Hierarchical Quadrature Amplitude Modulation
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IP	Internet Protocol
IP VPN	Internet Protocol Virtual Private Network
ITU	International Telecommunication Union
ITU-T	ITU Telecommunication Standardization Sector (ITU-T)
LAN	Local Area Network
LoS	line of site
LTE	Long Term Evolution
LTE-A	Long Term Evolution Advanced
MNO	mobile network operator
MPLS	Multiprotocol Label Switching
MPR	Microwave Packet Radio
MPT	Microwave Packet Terminal
MSS	Microwave Services Switch
MTSO	mobile telephone switching office
NLoS	non line of site
OPEX	operating expense
PGW	Packet Gateway
PSS	Photonic Service Switch
PTP	Precision Time Protocol
QoE	quality of experience
QoS	quality of service
RAN	Radio Access Network
RF	radio frequency
RNC	Radio Network Controller
ROI	return on investment
RSTP	Rapid Spanning Tree Protocol
SAM	Service Aware Manager
SAR	Service Aggregation Router
SDH	Synchronous Digital Hierarchy
SGSN	Serving GPRS Support Node
SGW	Service Gateway (LTE)
SLA	service level agreement
SON	Self-organizing Network
SONET	Synchronous Optical Network
SPQ	strict priority queuing
SyncE	Synchronous Ethernet
TCO	total cost of ownership
TCP	Transmission Control Protocol
TDM	Time Division Multiplexing
UDP	User Datagram Protocol
VLAN	Virtual LAN
VoLTE	voice over LTE
XPIC	Cross-Polarization Interference Cancelation