LEVERAGING MICROWAVE PACKET RADIO TO ENHANCE AND EXTEND IP/MPLS BACKHAUL

APPLICATION NOTE

ABSTRACT

Mobile service providers (MSPs) are facing a highly competitive environment in a period of unrelenting data services-driven traffic growth. In order to efficiently scale the mobile backhaul network infrastructure, MSPs are seeking to leverage the most cost-effective backhaul alternatives available at any given cell site, be it over copper, fiber or microwave. In the past, managing a diverse mix of access types has added complexity to mobile backhaul network operations.

Alcatel-Lucent mobile backhaul solutions address the transformation of the backhaul and transport networking elements of a wireless network to a highly scalable, cost-effective IP, Multiprotocol Label Switching (MPLS), and Ethernet packet-switched infrastructure. Multiple cost-effective options are available, based on the leading service routing, packet microwave and packet optical products, defining an industry-leading converged infrastructure to support the requirements of 2G/3G and the transformation into Long Term Evolution (LTE) wireless IP networking.

The IP/MPLS mobile backhaul transport solution, whether over leased line or microwave links, can now be managed in a seamless and consistent fashion, resulting not only in more flexibility in selecting the lowest cost transport alternatives, but also in increased operational efficiency. This brings the optimal combination of cost-effective connectivity through microwave packet radio with the determinism, resiliency, scalability, and end-to-end control and management of IP and MPLS networking.

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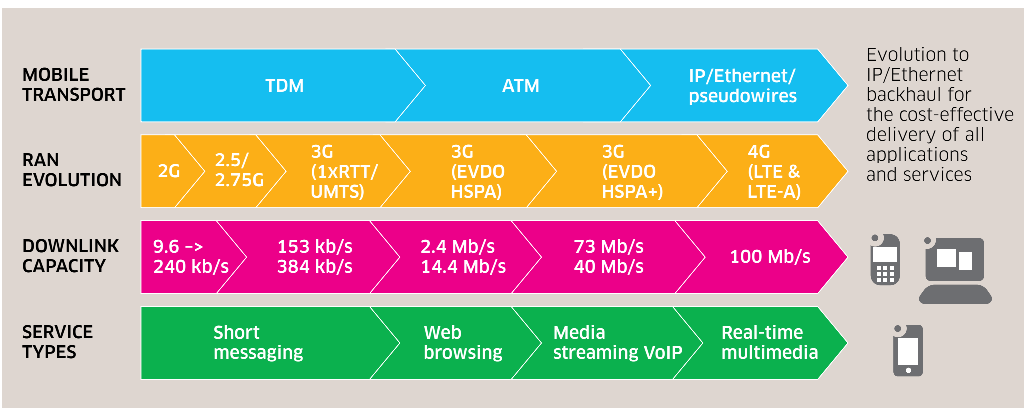
INTRODUCTION

Mobile service providers are facing a highly competitive environment in a period of unrelenting data services-driven traffic growth. In an increasingly data-dominant era driven by the increased availability of smartphones and mobile computing devices, data traffic is escalating backhaul costs, creating a compelling need to optimize mobile backhaul.

There has been a steady increase in download rates as mobile RAN technology has evolved rom 2G to 3G and subsequently to LTE. This has led to significant increases in traffic volumes as illustrated in Figure 1. Simultaneously, the revenue per bit that operators can expect to extract from data services is significantly less than that for voice services.

Figure 1. Evolution of the RAN and mobile transport network



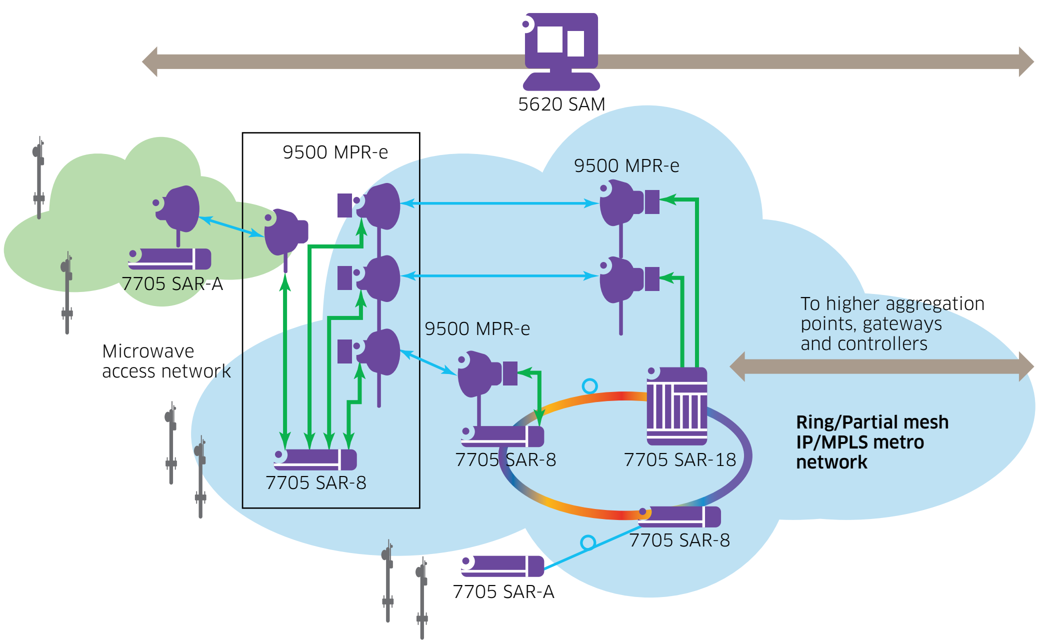
The mobile traffic mix has been profoundly shifted from voice to broadband data. To provide a satisfying user experience, mobile operators are compelled to increase the backhaul network capacity and the number of cell sites. For existing cell sites, the network uplink capacity needs to be increased tremendously. To increase network capacity, operators need to select the most cost-effective physical media in each region and market. Depending on the economics and pragmatic access considerations, the physical media could be copper, fiber or microwave.

It is paramount to choose a backhaul networking technology that can operate over different physical media so that the network can have a single, unified operational model. In many cases, a microwave network can provide improved reach at the edges, allowing cost-effective deployment of base stations where fiber facilities are either unavailable or prohibitively expensive. Also, microwave links can allow for more efficient connectivity options deeper in the network. This microwave network becomes a synergistic and complementary capability for interconnecting base stations as part of the IP/MPLS backhaul and transport network.

PACKET MICROWAVE AND IP/MPLS BACKHAUL ARCHITECTURE

With reference to Figure 2, the Alcatel-Lucent 7705 Alcatel-Lucent 7705 Service Aggregation Router (SAR) is optimized for multiservice adaptation, aggregation and routing of 2G, 3G, and 4G mobile traffic onto a modern Ethernet and IP/MPLS infrastructure. It is available in a range of compact, low-power consumption form factors delivering highly available services over resilient and flexible network topologies. The Alcatel-Lucent 9500 Microwave Packet Radio (MPR) provides an effective transport option, especially for base stations located where cost-effective fiber is not available, for example, at the access portion of the network.

Figure 2. Packet microwave and IP/MPLS backhaul



The Alcatel-Lucent 9500 MPR-e is the zero-footprint outdoor unit with Ethernet access that can be used either in standalone configurations and directly connected to the base station, or integrated to associated indoor networking equipment, such as the 7705 SAR, which is shown in this case. At higher points of aggregation, Alcatel-Lucent 7705 SARs can be used to aggregate traffic over fiber or microwave links in various topologies. 7705 SARs can additionally adapt directly connected base station traffic into the IP/MPLS metro network. The Alcatel-Lucent 5620 Service Aware Manager (SAM) supports an end-to-end management capability across the network components that comprise the packet microwave and IP/MPLS backhaul architecture.

Value of IP/MPLS networking in mobile backhaul

The use of IP/MPLS networking in the mobile backhaul and aggregation network brings a number of advantages to the overall solution:

- IP/MPLS operates over any Layer 1 media or Layer 2 protocol. This allows a great deal of freedom to leverage available media types, such as copper, fiber and microwave for cost-effective scaling, bringing potential operating expense (OPEX) savings in an optimal media selection.

- IP/MPLS can operate efficiently over a wide variety of topologies. For example, linear, tree mesh and ring topologies are all equally supported with consistent, rapid protection techniques. Flexible architectures and resiliency techniques bring improved network availability. This, in turn, can help to reduce subscriber churn for maximum revenue retention. IP/MPLS architectures are ready to offer point-to-point, and point-to-multipoint, Layer 2- and Layer 3-based transport, providing a seamless evolution path for the support of LTE.
- Powerful management tools, based on both MPLS and Ethernet operations, administration, and maintenance (OAM) standards, provide visibility and proactive control at the link, connection and service levels. Common tool suites allow rapid deployment and service level agreement (SLA) validation for fast time to revenue. OPEX savings can also be realized through the use of standard training and procedures.

Whether the transported traffic is legacy in nature (such as time division multiplexing [TDM] or Asynchronous Transfer Mode [ATM]), or IP/Ethernet, MPLS is architected to transport the traffic without any compromise in the requirements. The use of MPLS in particular enables the deployment of modern and resilient topologies in conjunction with microwave transport.

IP/MPLS for 2G, 3G, and LTE transport

In 2G and 3G deployments, all mobile traffic is typically backhauled between the base station and the radio controller complex in a hub-and-spoke architecture, supported typically using pseudowires. When evolving to LTE, to optimize the RAN architecture, the radio controller function is embedded in the enhanced Node B (eNB). Hence inter-eNB communication may now be required during handoff for both control and data plane traffic, in addition to communication between eNBs and packet gateways at the mobile office. IP/MPLS can concurrently support a diverse set of networking capabilities including Layer 2 and Layer 3 virtual private networks (VPNs), which can be deployed to support the evolving business and technical requirements of the operator, on a common MPLS infrastructure.

REQUIREMENTS – FEATURES AND BENEFITS

To properly address mobile backhaul while leveraging microwave access, there are a number of specific requirements that need to be addressed, as follows.

REQUIREMENT	BENEFITS
High reliability and availability	Matching performance standards set in TDM networks improves customer experience, thereby reducing churn.
Scalability and cost effectiveness	Optimized capital and operation expense with a cost-effective, scalable evolutionary platform allows growth proportionate to both the services and bandwidth demands.
Quality of service (QoS)	Maintain differentiation and control of service priority within the network to deliver tiered tariff data and voice services to meet commercial requirements of service providers
Accurate network timing and synchronization	Support accurate timing distribution to base stations for synchronization or as a service to the end customer
Strong network management and OAM capabilities	Delivers the operational service and network layer visibility to ensure the commercial expectations of the mobile data explosion are met while managing OPEX, ultimately in an end-to-end all-IP wireless network

High reliability and availability

In a market experiencing high user churn rates, high network availability is a differentiating factor and can drive customer loyalty and reduce churn. High availability is important with wireless device substitution where mobile devices become the primary communications appliance. Any packet-based solution must meet the resiliency benchmarks delivered by legacy TDM/plesiochronous digital hierarchy (PDH)-based approaches. Transport solution resiliency can be considered in two categories:

- Platform attributes
- Networking capabilities

At the platform level, Alcatel-Lucent has applied considerable focus to achieving high availability operation using Non-stop Routing (NSR) and Non-stop Signaling (NSS). This is part of a concerted thrust to elevate IP/MPLS networks to the high availability levels demanded by packet transport networks. For example, a control plane switchover — scheduled or unplanned — on the 7705 SAR is almost instantaneous. But, importantly, during and after the transition, routing, signaling and forwarding are unaffected. This resiliency of common control elements is inherited by the 7705 SAR-8 and 7705 SAR-18 and represents a significant differentiator for the overall solution.

While strong platform resiliency attributes are needed, the use of IP/MPLS as a packet transport infrastructure provides rapid, deterministic failure accommodation in the network. Traffic engineering tools can be used offline to model single failures and ensure they can be accommodated. Due to the media-agnostic nature of MPLS, traffic carried over microwave links in a MPLS network can benefit from the full range of IP/MPLS protection mechanisms.

Enabling microwave link protection with 2 + 0 configuration

Traditionally, microwave link protection is accomplished using a 1 + 1 configuration, optionally with two frequency channels. In such a case, the radio failure detection and protection mechanism switches the traffic rapidly and transparently.

Another option is to have the radio links configured as 2 + 0. In this case both links are actively carrying traffic in the normal state. When one of the links fails, an MPLS protection mechanism such as fast reroute (FRR) or secondary label switched path (LSP) protection can switch the traffic to the other working link at speeds comparable to Synchronous Digital Hierarchy/Synchronous Optical Network (SDH/SONET) architectures after detecting the link failure. If the traffic load exceeds the capacity of the remaining link, advanced traffic management mechanisms will ensure the protection of the higher priority traffic, with best-effort data being transmitted according to available excess bandwidth. This 2 + 0 configuration can also be easily extended to N + 0.

Scalability and cost effectiveness

Rising traffic volumes, driven by mobile broadband deployment, generate a clear need for a solution that scales up smoothly in a number of dimensions. Packet-based backhaul transport allows bandwidth to be engineered in a very granular fashion so there is no need to stockpile unused bandwidth as often happens in TDM-based backhaul. The use of IP/MPLS protocols to the cell site allows highly scalable fan-in for backhaul connectivity. As traffic volumes grow, the network platforms that comprise the solution provide efficient scalability because of their compact, modular architectures. With service awareness and service-driven adaptive modulation, the 9500 MPR exploits all the air bandwidth, resulting in more transport capacity. The 9500 MPR and 7705 SAR-8 can both scale up to support 12 separate microwave directions as mobile operators expand their geographic coverage. To satisfy the growing demand of bandwidth available to a cell site, multiple parallel microwave links can be utilized in an N + 0 fashion, leveraging MPLS traffic engineering capabilities to distribute traffic among the links.

Another important aspect of scaling is the ability to scale down under certain circumstances to allow growth to be driven by business needs rather than the attributes of the platform/solution. For example, at the edge of the network, data traffic volume may initially be quite low in some cell sites. This application is addressed by a compact 1 RU platform such as the 7705 SAR-A.

A portfolio of products with common network management and operating system software can greatly enhance the rapid, cost-effective growth of a network to support dynamic business needs.

Moving to all-IP routed RAN transport

As the 2G and 3G mobile RAN components (base stations and controllers) evolve to support true IP/Ethernet capability, routing infrastructures such as VPNs can be added progressively in the transport network. This capability can operate in parallel and in series with pseudowire networking for a smooth evolution path for 2G and 3G networks to LTE, leveraging the existing IP/MPLS infrastructure. The Alcatel-Lucent 7750 SR and 7705 SAR product lines offer excellent, resilient and managed routing with strong QoS and Layer 2 or Layer 3 VPN capabilities. Evolution to routed IP RAN transport also supports a logical progression to LTE networking.

Quality of service

The provision of deterministic QoS is important. It provides predictable treatment to individual traffic streams and appropriate priority for high delay-sensitive applications. As well, it allows packet-based synchronization mechanisms to converge rapidly across the packet RAN.

When multiple services are aggregated at the cell site, traffic classification, buffering, and scheduling must be provided for each supported service. For example, voice traffic has very stringent latency and jitter requirements, which translate to a high-priority service with minimal queuing. High-priority data may also require prioritized scheduling but may be less sensitive to delay and more sensitive to data loss — this requires a high-priority classification with deep queuing capabilities. Hierarchical traffic management with shaping provides another control mechanism for traffic entering the network. The 7705 SAR and 9500 MPR provide just such comprehensive QoS functionality for controlling network traffic.

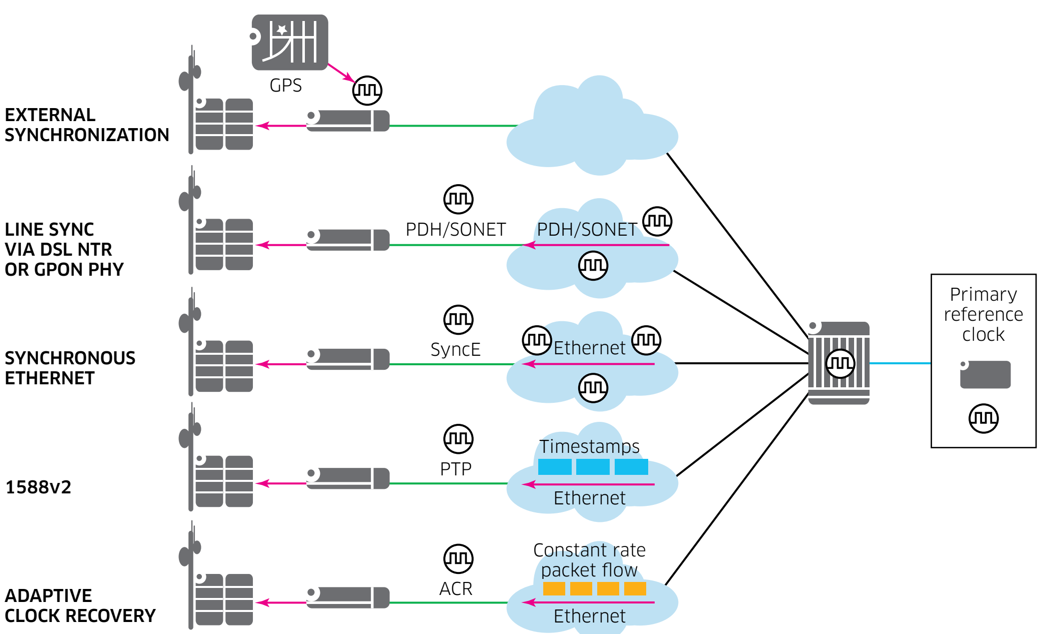
Initiatives such as fixed/mobile convergence and LTE increase the diversity of traffic types overlaid on the backhaul transport network. To accommodate these developments, QoS flexibility, scalability, and performance must be present in the initial deployed platform architecture. Any operator planning to move toward converged service offerings supported on the same network (for example, triple play, enterprise VPNs, or mobile or fixed broadband wireless access), will find that advanced hierarchical traffic management capabilities are powerful competitive resources over the life of the network and much harder to add later.

Applying QoS in a network utilizing packet microwave transport presents certain challenges that require purpose-built products with careful integration testing. The challenges are due, in part, to the relative bandwidth constraint, compared to fiber, for example, and the adaptive nature of microwave connectivity when adaptive modulation is invoked resulting in changing microwave capacity due to weather conditions. The 7705 SAR with 9500 MPR-e solution fully leverages the advanced traffic management features on the 9500 MPR-e radio, including high-priority queuing and frame fragmentation, guaranteeing delivery of real-time traffic with minimum jitter variation (the variation of delay variation) regardless of the atmospheric conditions.

Network timing and synchronization

Synchronization is required to ensure accurate radio framing, effective handoffs and reliable backhaul transport. The Alcatel-Lucent solution provides a range of synchronization options suitable for different environments. The five principal options for synchronization are shown in Figure 3.

Figure 3. Synchronization options



External timing can be used, for example, from a satellite positioning system such as GPS or Galileo. GPS satellites carry atomic clocks and can deliver high-integrity frequency and phase stabilized timing. Line timing can be delivered through the PDH/SDH hierarchy from a clock with a known accuracy. This is useful in cases where there is a PDH linkage into the cell site (for example, an E1/T1 link). The clocking chain must be compliant with G.823/824.

Adaptive clock recovery (ACR) can be used when there is a non-synchronous packet infrastructure between the reference clock and the cell site. TDM pseudowires are established from the 7750 SR in the Mobile Telephone Switching Office (MTSO) to the 7705 SARs at the edge. The ACR algorithm in the 7705 SAR uses the payload traffic stream within the TDM pseudowire to adapt its local clocking. The main determinants of the solution's effectiveness are the power of the ACR algorithm and the QoS characteristics of the intervening packet network between the reference clock and the synchronizing client.

Synchronous Ethernet (SyncE) is a powerful technique offering excellent, non-traffic affected frequency synchronization performance. End-to-end support across the Alcatel-Lucent solution elements is available — from the MTSO to the cell site. Note that a continuous path of SyncE-capable links and nodes is needed from the source along the synchronization distribution chain across the network. The solution supports a valuable extension to standards-based Synchronous Ethernet. Following the recovery of copper-based Ethernet after a media failure, the clock delivery mechanism is smoothly recovered without impact.

In general, synchronization capture and distribution should be considered as part of an end-to-end verified system, rather than a set of per-box capabilities. Techniques such as IEEE 1588v2, as an alternative to ACR, has the advantage of being standards-based, has lower bandwidth requirements, and potentially can provide better performance. In addition, 1588v2 has the benefit of being able to transport phase and time of day, in addition to frequency synchronization.

Implementations should be assessed for the completeness of the solution to include synchronization propagation with appropriate accuracy at an acceptable cost. To deliver high performance synchronization, the 7705 SAR and 9500 MPR microwave link can leverage SyncE combined with synchronous radio or IEEE 1588 plus advanced options such as on-path support to enhance operation across multiple network hops.

Strong network management and OAM capabilities

Network management is provided by the extensive and service-aware management system capabilities of the 5620 SAM. The 5620 SAM provides comprehensive support for fault, configuration, accounting, performance and security (FCAPS). The 5620 SAM application suite is a tightly integrated management system that enables provisioning of an end-to-end service and network bearers using wizards or point-and-click configuration from a single application (Service Manager) without having to individually configure each device in the data path. The 5620 SAM greatly reduces the complexity and risk typically found in provisioning complex services using today’s edge routers.

A unique attribute of the combined 7705 SAR and 9500 MPR solution is the support for a single network element IP address for the integrated system. This greatly simplifies network management operations, consolidating alarm and inventory management, for example. This unified management capability permits the use of a single software bundle and the deployment of a single, unified upgrade procedure for the combined system.

Maintaining service guarantees using the 5620 SAM is a key strength of an end-to-end Alcatel-Lucent solution as the Alcatel-Lucent 5620 Service Assurance Agent (SAA) can be used to minimize operator workload by proactively probing delay, jitter, and loss each service experiences periodically.

The 5620 SAM provides a unique end-to-end management capability across the integrated packet-switched microwave architecture.

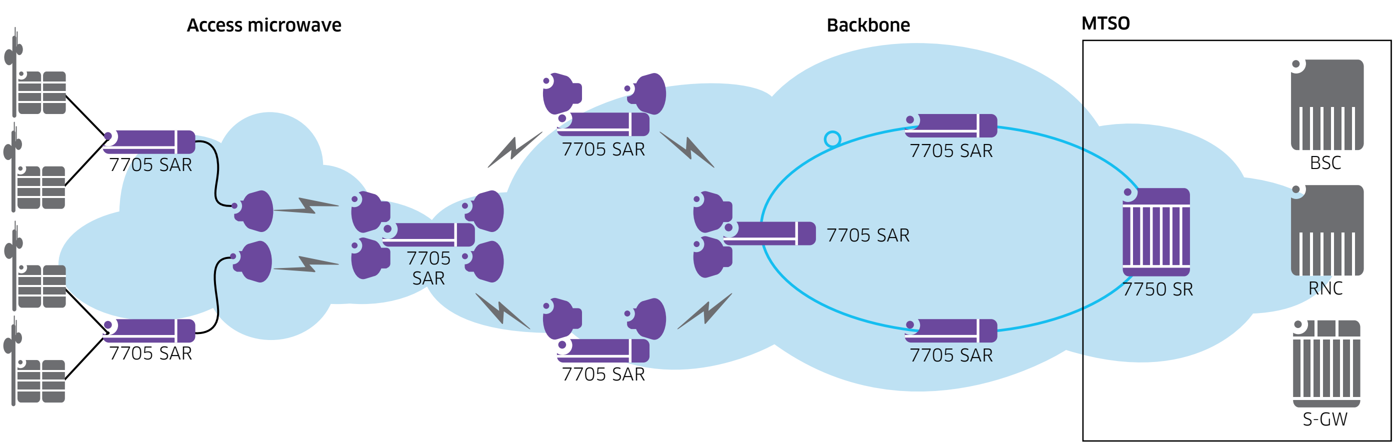
SOME DEPLOYMENT SCENARIOS

A number of potential deployment topologies may exist. Some examples of potential scenarios are captured below.

Backbone microwave ring

In a typical backhaul network, the backbone portion, due to its high resiliency requirement, is often deployed in a ring or mesh topology, using a combination of microwave and fiber media, depending on the terrain. This is depicted in Figure 4.

Figure 4. Backbone microwave ring topology

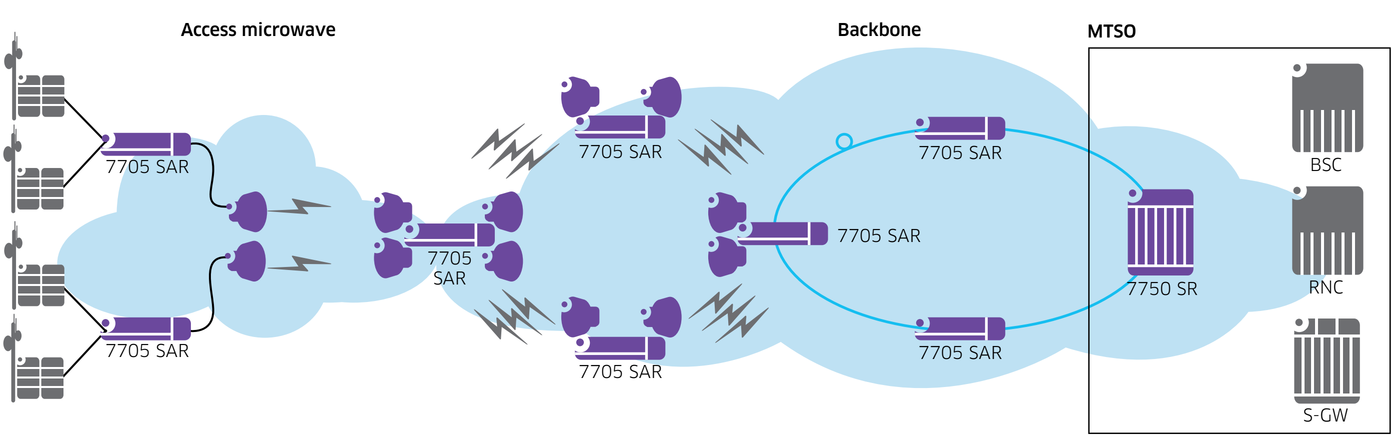


MPLS is a network technology that is well suited to take advantage of such a ring/mesh topology. With its network media-agnostic nature, it can be run seamlessly end to end across a range of media in the backbone.

High-capacity microwave ring

Very high capacity is often required in a backbone ring. To expand microwave link capacity, N + 0 microwave links can be deployed. In essence, N + 0 microwave is a set of parallel microwave links between a pair of IP/MPLS routers or packet nodes. With IP/MPLS, traffic can be distributed (traffic engineered) among the links according to the operational requirements. See Figure 5 for the high-capacity microwave ring topology.

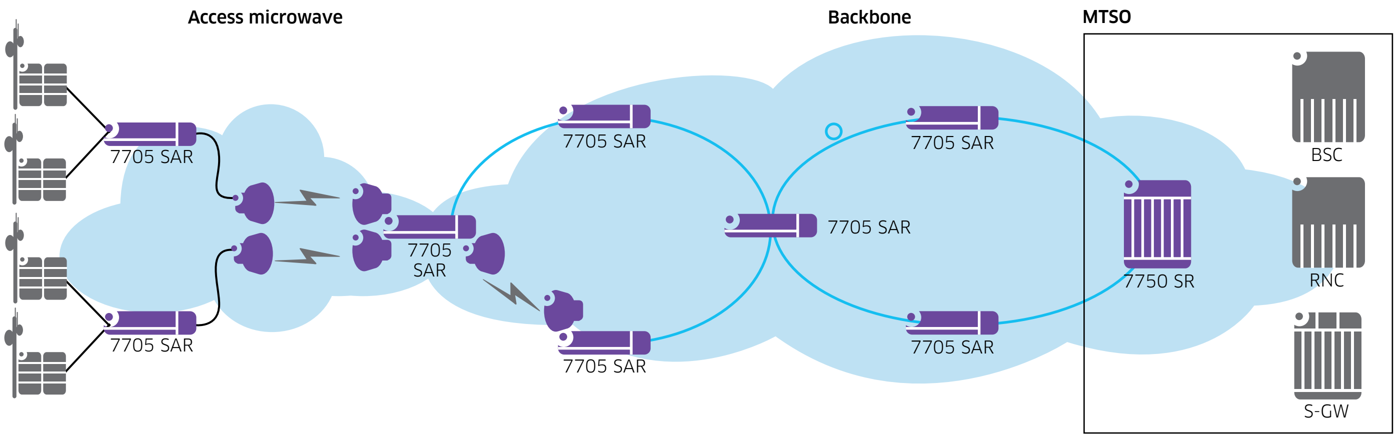
Figure 5. High-capacity microwave ring topology



Hybrid ring

In a ring deployment, due to terrain challenges and the availability of fiber trenching, for example, it might not be possible to access continuous fiber segments throughout the ring. A microwave link can be used as a part of the ring, complementing fiber, as shown in Figure 6.

Figure 6. Hybrid ring topology

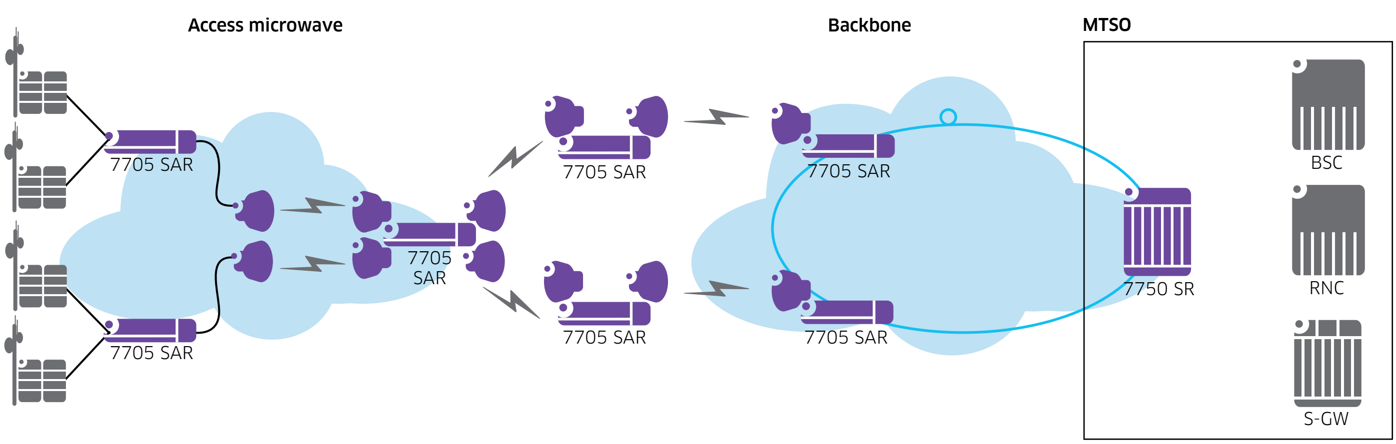


Thanks to the media-agnostic nature of MPLS, this kind of hybrid ring topology can be deployed smoothly with consistent end-to-end MPLS network technology and benefits.

Microwave necklace

In a microwave necklace architecture, topology resiliency is further enhanced by having two microwave gateway nodes deployed at two different hub points in the backbone. In addition to nodal protection, space diversity protection is also provided for the microwave gateway node if these two nodes are deployed in two physically separated locations (see Figure 7).

Figure 7. Microwave necklace topology



CONCLUSION

The relentless growth of mobile traffic and the pervasive nature of base station deployments are driving operators to seek and leverage all options for mobile backhaul infrastructure.

Microwave packet radio is a strong strategic choice for backhauling transformation, in combination with a complete, managed end-to-end IP/MPLS solution leveraging other media as appropriate throughout the often highly heterogeneous backhaul network; for example, fiber, carrier Ethernet, leased lines or broadband infrastructure (such as xDSL or Gigabit Passive Optical Network [GPON]).

Alcatel-Lucent brings deep, global experience and services support in transformational projects, particularly in leveraging the values of a packetized infrastructure in the mobile backhaul network. In addition to highly successful, differentiated products, Alcatel-Lucent provides a single source for a fully managed solution. Comprehensive, ongoing verification testing and wide deployment experiences globally combine to guarantee a successful and timely deployment.

The Alcatel-Lucent packet microwave mobile backhaul solution brings the optimal combination of cost-effective capillarity through packet microwave at the edge of the network with the determinism, resiliency, scalability, and end-to-end control and management of IP/MPLS networking.

APPENDIX

Further product Information

7705 Service Aggregation Router

For full product information see: Alcatel-Lucent 7705 Service Aggregation Router

9500 Microwave Packet Radio

For full product information see: Alcatel-Lucent 9500 Microwave Packet Radio

5620 Service Aware Manager

For full product information see: Alcatel-Lucent 5620 Service Aware Manager

ACRONYMS

ACR	adaptive clock recovery
ATM	Asynchronous Transfer Mode
BSC	base station controller
DSL	digital subscriber line
eNB	enhanced Node B
EVDO	enhanced voice data optimized
FCAPS	fault, configuration, accounting, performance, and security
FRR	fast reroute
GPON	Gigabit Passive Optical Network
GPS	global positioning system
HSPA	High Speed Packet Access

IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
LSP	label switched path
LTE	Long Term Evolution
MPLS	Multiprotocol Label Switching
MPR	Microwave Packet Radio
MSP	mobile service provider
MTSO	Mobile Telephone Switching Office
NSR	Non-stop Routing
NSS	Non-stop Signaling
NTR	Network Timing Reference
OAM	operations, administration, and maintenance
OPEX	operating expense
PDH	Plesiochronous Digital Hierarchy
PHY	physical layer
PTP	point-to-point
QoS	quality of service
RAN	Radio Access Network
RNC	Radio Network Controller
RTT	round-trip time
RU	rack unit
SAA	Service Assurance Agent
SAM	Service Aware Manager
SAR	Service Aggregation Router
SDH	Synchronous Digital Hierarchy
S-GW	signaling gateway
SLA	service level agreement
SONET	Synchronous Optical Network
SR	Service Router
SyncE	Synchronous Ethernet
TDM	time division multiplexing
UMTS	Universal Mobile Telecommunications System
VoIP	voice over IP
VPN	virtual private network