Microwave Technologies for Carrier Ethernet Services

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Abstract

The goal of this document is to provide telecommunication networking professionals an overview of how modern Microwave Technology (Terrestrial Microwave) has become an efficient complement to Fiber and Copper when deploying Carrier Ethernet Services in access networks.

1. Introduction

Customers increasingly want more bandwidth and better service quality to meet their application needs. Carrier Ethernet services are frequently the best selection to meet these requirements. This white paper provides an overview of how modern Microwave technology provides an efficient complement to copper and fiber in the access network.

Some of the characteristics of Carrier Ethernet that make it attractive are:

- Easy to install and use
- Cost effective to buy and operate
- Allows for service flexibility

Carrier Ethernet services are provided over the widely available and well understood IEEE defined Ethernet interface. This interface is inexpensive, standardized and enables subscribers to add bandwidth incrementally, if needed. Ethernet services offer a flexible method for enterprises and individuals to connect remote offices, suppliers and business partners with the QoS and reliability their applications require.

Microwave technology is increasingly used to provide Carrier Ethernet. The main advantages of Microwave based Ethernet solutions are:

- Rapid deployment time
- Cost effective when compared to other approaches
- Offers throughput that rivals fiber for many applications
- Mature carrier-grade solution

Because it uses radio spectrum instead of physical connective it eliminates “right of way” issues that complicate installation of fiber or copper media. In many environments, Microwave can provide the lowest cost per bit for transporting Ethernet services. It is a competitive choice for capacities, up to 1 Gigabit per second and with ongoing developments in Microwave technology we expect to see capacity expand to several Gigabits in the near future.

However, many misconceptions exist regarding Microwave technology as an access media for Ethernet services. These misconceptions include: insufficient capacity, weather influenced performance degradation, and concerns about spectrum availability.

Recent developments in Microwave technology and Ethernet services as defined by the MEF are making these concerns moot and highlighting other benefits of Microwave technology in access networks.

2. Rationale for the Evolution of Microwave

There are significant benefits to using Microwave in the access network. Gigabit capacity is achievable today. This capacity is sufficient for most Carrier Ethernet applications. Two growing applications, cellular backhaul and business services can both be served with Gigabit capacity.

Microwave performs over the distance ranges required for most access networks. From a few hundred feet to many miles, microwave is capable of delivering Gigabit Ethernet services in the distances that service providers require to reach subscribers.

A common assumption is that Microwave requires a clear line-of-site to perform adequately. This is still the case for predictable Microwave operation in licensed frequency bands. However recent technical developments enable Microwave to function in many non near non-line-of-sight applications in lower unlicensed frequency bands.

Another misconception is that Microwave is limited by spectrum licensing issues but today there are Microwave technologies available that can operate in unlicensed spectrum and therefore require no license to operate. One example of spectrum suitable for unlicensed operation is a portion of the 60GHz band. In this section of spectrum, attenuation limits the hop-length and therefore also the interference between different microwave links. However, in most cases licensed spectrum is viewed as a safeguard to predictability and high quality operation. Note that Figure 10 shows the relationship between licensed and unlicensed spectrum.

Today the primary application for Microwave technology is the backhaul of cellular traffic from mobile base stations. More than 60% of the worlds existing Mobile base stations are connected via Microwave. Historically PDH and SDH have been the protocols used to backhaul voice services for GSM and WCDMA systems.

In recent years, with the introduction of Mobile Broadband Data services, there is a shift towards Ethernet backhaul. Ethernet backhaul is often best accomplished with IP based Radio Access Networks (RAN). Rapid transition to IP based Radio Access Networks (RAN) is leading to the deployment of packet Microwave on a large scale. Using packet Microwave for transporting Broadband Data services takes full advantage of the benefits of Microwave radio. These benefits include:

- Increased bandwidth
- Adaptive modulation
- Increased modulation

- Higher throughput capacities

Typically, copper or fiber is used for connectivity in access networks. However, there are instances where these physical media are problematic. Right-of-way was mentioned previously. This refers to instances where it is difficult, costly, or impossible, to pull wire into a subscriber location. Reasons for this may include: lack of legal jurisdiction to cross private property, physical impediments to wire such as water, roads or topology or concerns with security of the media due to interference from human or environmental factors. In these cases Microwave provides a compelling option for connecting subscribers in the access network to facilities and services available in Central Offices and Headend locations.

Figure 1 illustrates how Ethernet-based Microwave backhaul connections will increasingly take the place of legacy-based Microwave backhaul connections (i.e. PDH E1/T1).

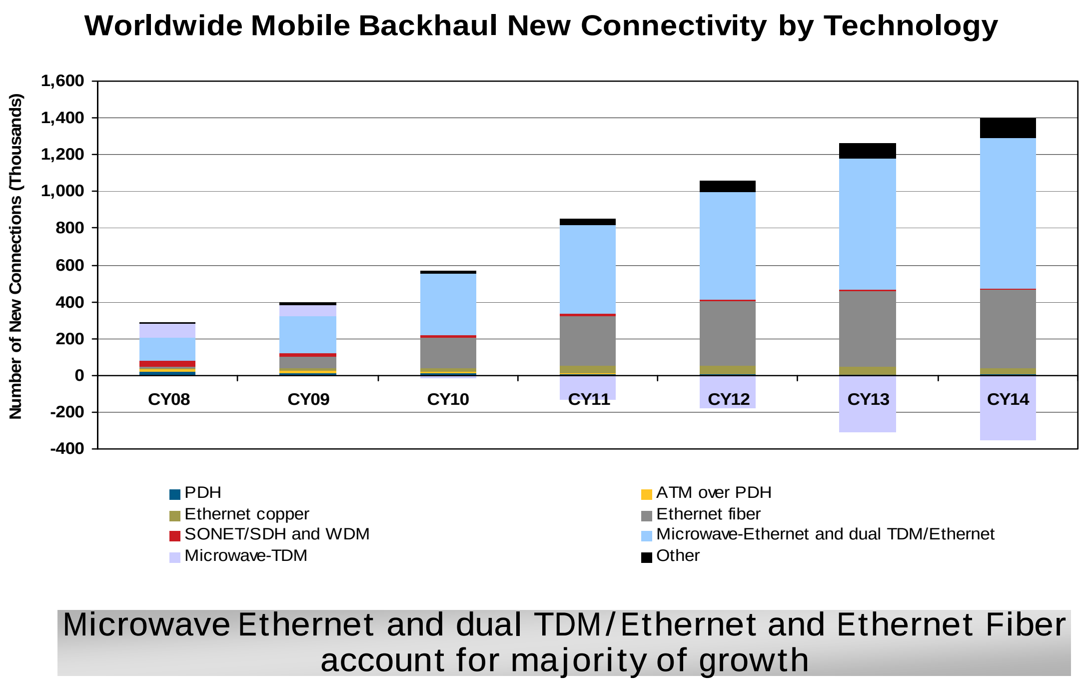


Figure 1 - Source: Infonetics Research, Mobile Backhaul Equipment and Services Market Size, Share and Forecast April 2010

3. The Cost Impact of Data Services on Access Networks

The business model for broadband data traffic requires that service providers examine their access technologies. Data service revenue does not normally grow proportionally with data traffic. This is unlike voice traffic where usage patterns made bandwidth growth stable and predictable. Now, the extreme variability and tremendous bandwidth requirements of data traffic make the access network more important. For mobile data services the cost structure of

TDM access makes this large data requirement expensive to support. Therefore, service providers seek to lower the cost per bit transported. Carrier Ethernet services are one method of lowering the cost of transporting large quantities of data traffic.

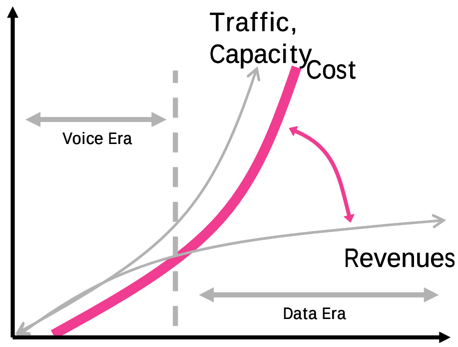


Figure 2

Figure 2 illustrates that TDM access loses its effectiveness as data services become predominant. In order to address the data traffic in an efficient way, service providers need to introduce a data oriented access solution.

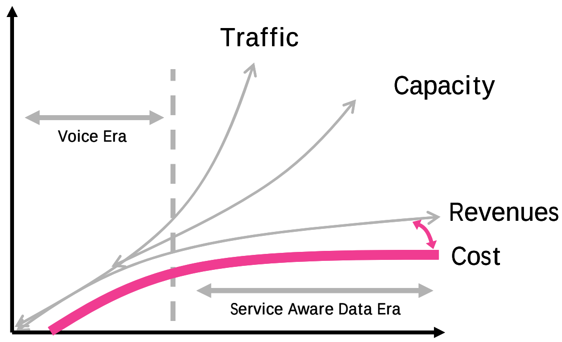


Figure 3

Ethernet services delivered over the latest generation of Microwave equipment, as well as copper, and fiber, can effectively transport data services without impacting legacy voice services. Figure 3 above illustrates how microwave can support data's increased bandwidth requirements without adding proportionately higher access costs. These data and cost trends are driving technical innovation in Microwave technology and this innovation is demonstrated in the growth of Microwave deployments.

4. Today's Microwave Transport Applications

There are two types of Microwave equipment being deployed today, Packet and Hybrid Microwave. They are used in both fully packet oriented networks as well as networks that transport both TDM voice and packet data traffic.

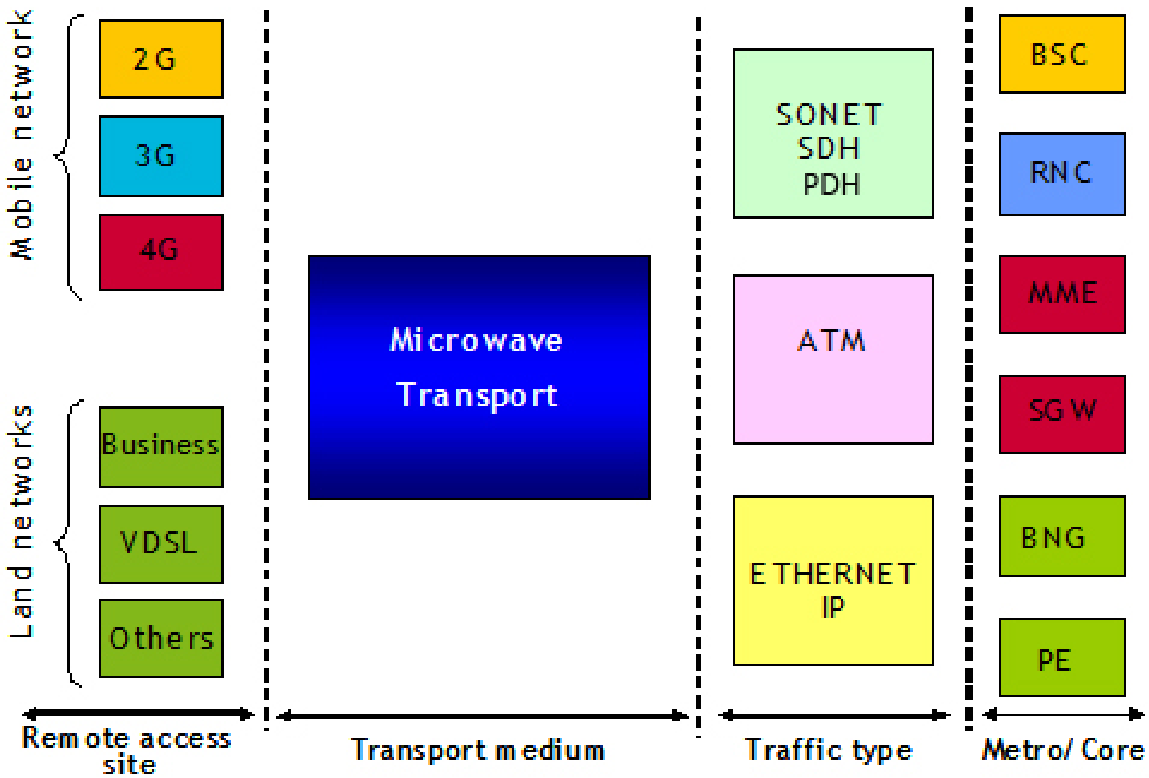


Figure 4

One of the primary uses of Microwave transport applications is connecting customers to core nodes. Figure 4 above illustrates the types of technologies that are often connected to a Microwave infrastructure.

The left side of the figure illustrates the type of customers typically connected to a microwave transport infrastructure.

- Mobile access, belonging to the different generations of mobile services
- Fixed devices (corporate customer-edge or remote VDSL units) to connect users to fixed broadband access)
- Customer premises equipment (CPE)

The right side of the figure illustrates connections in the core nodes:

- BSC, RNC and MME/SGW for mobile services (2G, 3G, 4G respectively)
- BNG for fixed broadband access

- PE router for business applications

Similarly Microwave transport applications enable connections to and from remote sites as part of an aggregation and/or distribution network for other traffic types. A partial list of these applications includes:

- Broadband networks to support the conversion to digital television
- Broadband networks to support DSL access in rural areas, overcoming the distance limitations of the DSLAM and broadband backbone
- Back up routes to Fiber for network protection
- Extend network reach to remote locations or as an alternative to Fiber backbone networks

These applications are becoming more important as service providers support rich media applications like: video, video surveillance, video conferencing, E-Learning, VoIP and disaster recovery. The growth of these applications and cellular backhaul is contributing to a growth in Microwave deployments.

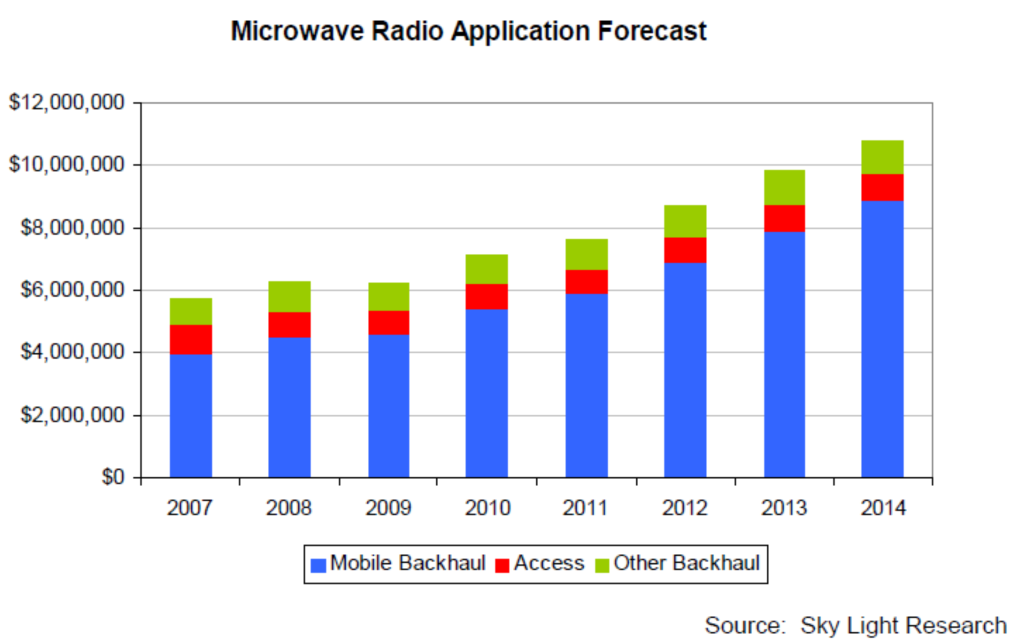


Figure 5

Figure 5 illustrates how Microwave transport for access network reached 12% of the total point-to-point Microwave market in 2009, predominantly driven by the increase in Ethernet traffic. Other backhaul applications reached 14%. These applications are estimated to represent about 18% of the overall point-to-point market by 2014. This is estimated to be approximately $1.9 billion USD according the Sky Light Research report titled “Microwave Point-to-Point Radio Market Trends & Forecast Analysis 2009 – 2014”.

5. Microwave Transport Functionality

Packet and Hybrid Microwave technologies were developed to support the traffic evolution of service provider networks while offering the same or better level of service reliability and flexibility. Therefore, E-Line and/or ELAN services supported by Microwave technologies can be compliant to MEF-9 for service functionality and MEF-14 for service performance. Most Microwave equipment adds functionality for MEF-8 / MEF-18, specifying circuit emulation and ATM pseudowire techniques. These capabilities make Ethernet the common transmission layer for transporting any type of subscriber traffic.

To comply with E-Line and E-LAN service requirements Microwave systems can be deployed as point-to-point, nodal or ring.

- A point-to-point system provides connectivity between two points only
- A Microwave nodal system simultaneously supports multiple radio directions

Point-to-point is the most common microwave application and is generally used to extend service in areas were Fiber and/or Copper are not available or as a backup route to the terrestrial network.

A Microwave nodal system is typically deployed in the aggregation points of a transport network. Access radio links are groomed and switched toward different points of concentration or aggregation depending on the traffic requirements of the network. Ring configurations are used to provide load balancing and resiliency characteristics. A Microwave ring topology is a specific configuration of a nodal system where each nodal radio broadcasts in two different directions connecting to other nodes, which are be use to close the loop allowing the entire configuration to be set up into a ring network.

There are three basic functions to consider in microwave transport:

- Multiservice aggregation
- Networking
- Microwave transmission

Multiservice aggregation is the capability of accepting many source streams from different applications (voice, data, circuit emulated services [CES]) and technologies (TDM, ATM, Ethernet) and adapting them to the transport layer. TDM services can be transported natively or in packet form depending on the type (packet or hybrid) of microwave solution deployed.

Networking refers to all features related to forwarding of the service from source to destination, maintaining the expected quality and level of protection on the data plane.

Microwave transmission is the L1 function of bit transport onto the radio channel along with the associated control functions, including the recent innovations of adaptive modulation and service awareness.

6. Technical Developments that Improve Microwave Transmission

Carrier Ethernet is defined by the ability to insure quality of service, reliability and manageability. Progress in Microwave technology ensures that Carrier Ethernet attributes are maintained end to end.

6.1 Microwave Aware Transmission

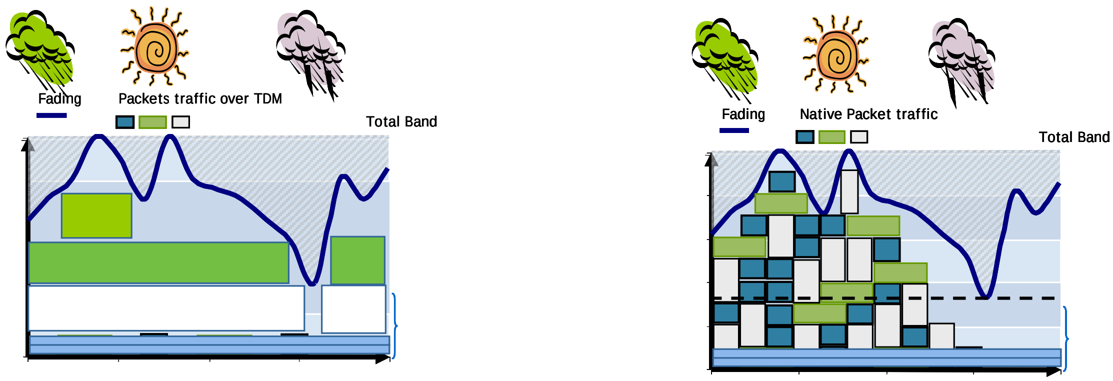
Microwave Aware Transmission (MAT) combines the following 4 features which are available in today's Packet and Hybrid Microwave solutions supporting MEF Certified Ethernet Services. These features are:

- Optimized radio transmission
- Adaptive modulation
- Packet QoS
- Service aware traffic management

6.1.1 Optimized Radio Transmission

Optimized Radio Transmission (ORT) refers to the ability to intelligently compress packet transmissions according to the categorization of incoming traffic by type (i.e. CESoE (MEF8), SAToP/CESoPSN, ATM PWE3, Ethernet, etc.) and service (TDM voice, VoIP, real-time service, or best effort data).

6.1.2 Adaptive Modulation



Traditional radio solution

Microwave Packet Radio solution

Figure 6

Adaptive Modulation is an important new technology for Microwave networks. This technique is used to increase radio throughput by adjusting the modulation scheme as propagation conditions change. Figure 6 illustrates how adaptive code modulation technology can automatically adjust modulation modes and dynamically enable service transport according to the performance of air interface channels that might be affected by bad weather conditions.

The modulation mode can be changed (for example, from 256QAM to 64QAM or QPSK) to enable error-free communications. In adverse conditions for example, the access bandwidth of the Microwave air interface may be decreased from 800Mbps to 600Mbps this means that the Microwave equipment must prioritize high availability services over best effort services. The equipment will then automatically recover the original rate when the channel quality is recovered.

Adaptive code modulation technology increases bandwidth capacity and enables Microwave equipment to be deployed in densely populated areas.

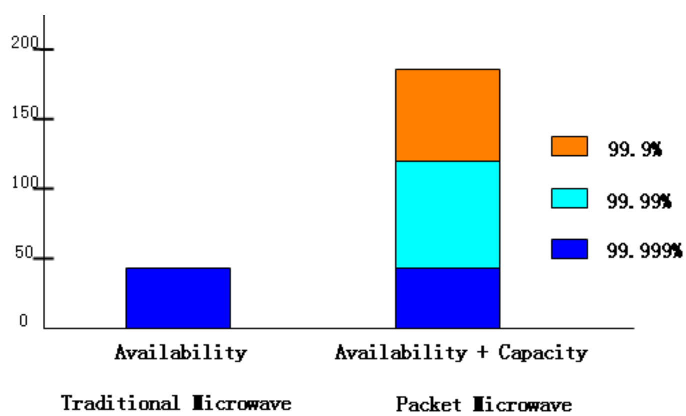


Figure 7

Adaptive modulation can simplify network planning issues and improve the efficiency of spectrum use. Figure 7 illustrates that adaptive modulation techniques insure that high priority services, shown in indigo blue, are prioritized ahead of other traffic types, shown in light blue and orange.

6.1.3 Packet QoS

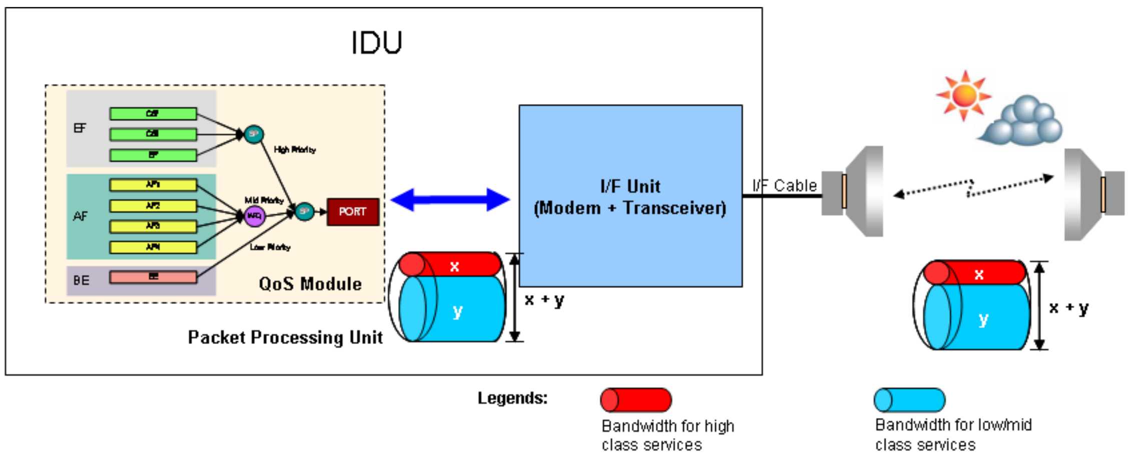


Figure 8

QoS in Microwave systems can be achieved by combining adaptive modulation technology and QoS mechanisms that adjust traffic management policy in real-time based on the performance of the air interface as shown in Figure 8.

Microwave systems have the ability to adapt traffic throughput to the available bandwidth by discarding packets according to standards based QoS markings performed at PWE3/MPLS level or at Ethernet level. When the full bandwidth is restored on the air interface the equipment will automatically resume forwarding all packets.

6.1.4 Service Aware Traffic Management

Service aware traffic management refers to the ability to differentiate packets by type. The transmitted data stream may be composed of E1/T1s, ATM, IP, or Ethernet. These packets may come from multiple sources and may have different quality requirements. For instance, ATM traffic from a 3G base station may carry voice (a high priority, real time service) and data (a lower priority and possibly non-real-time service). Service awareness gives the Microwave network the ability to differentiate, classify, and transmit packets according to class of service markings. Service aware traffic management is used in the transmission process, for example by applying different compression algorithms to specific packet types.

6.1.5 Ethernet OAM

Management is a dynamic and important component of Carrier Ethernet services. A number of standards bodies are working in a coordinated fashion to create the tools service providers and users require. The IEEE has a number of standards that include management components. These include 802.3 clause 57 - Ethernet in the First Mile, 802.1ag - Connectivity Fault Management among others. The MEF is in the forefront of defining management of Ethernet Services. Management features exist in MEF-13 – UNI Type 1, MEF-16 – Ethernet Local Management Interface, MEF-20 UNI Type 2 and ongoing work includes SOAM for performance monitoring and fault management. The ITU-T has additional standards including: Y.1730/Y.1731 – Ethernet OAM, G8021/G8032 – Ethernet Protection and Y.1573 – Performance and Availability. In addition, the IETF and TeleManagement Forum also define mechanisms that assist with the end-to-end management of Ethernet services.

Microwave equipment vendors are continually adding management features that monitor, report and troubleshoot Ethernet services at the link and service layers. This insures that the Ethernet service can be managed in the Operator, Provider and Customer domains.

6.2 Nodal Function

The nodal function enables ingress services from one radio direction to be forwarded to another radio direction without the need to “go out” to an external device such as an Ethernet switch or an SDH ADM. The nodal function enables overbooking of burst of data services while insuring that real time services receive high priority treatment. The result is an optimization of radio bandwidth resources and increased scalability.

A specific functionality provided by the nodal function is ring deployment. This configuration enables advanced load-balancing and resiliency capabilities on microwave networks that are similar to those provided by fiber and copper technologies on aggregation networks.

6.3 Increase Data Rates

There are a number of approaches to increasing throughput over a microwave link. First, as we discussed, capacity is boosted by higher order modulation. Second, adding more spectrum increases capacity. A third approach combines a number of microwave carriers into a single Microwave transmission link.

Increasing modulation makes the radio more sensitive to propagation anomalies such as rain and multi-path fading. To avoid shorter Microwave links the increased sensitivity can be compensated for by: 1) higher output power, 2) larger antennas and 3) more advanced receiver functions such as error correction algorithms. Alternatively Adaptive Modulation can be used for packet based Microwave systems to maximize throughput during all propagation conditions preserving a cost efficient solution.

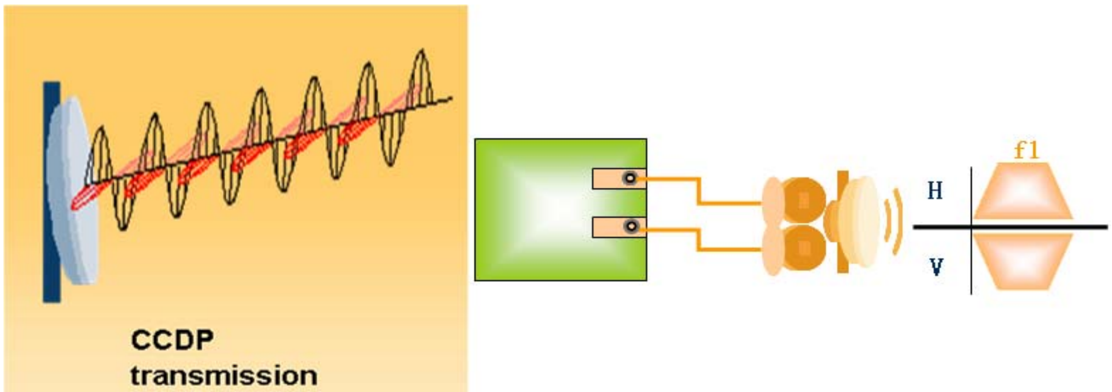


Figure 9

Microwave provides a range data rates from several hundreds of million bits per second up to multi-Gigabit per second.

The flexible data rates of packet technology allow microwaves to increase the data rate as much as possible in each channel. Figure 9, illustrates the cross-polarized channel configuration, enabled by cross polarization interference cancellation (XPIC) technology, to double the data rate without increasing channel bandwidth.

Another mechanism used in microwave networks is the ability to transmit in diverse frequencies simultaneously. This mechanism doubles the capacity over the air by using two different transmission channels at two quite different carrier frequencies. The big advantage with respect to using two contiguous carrier frequencies is resilience in case of fading due to bad weather conditions. The usage of very different frequencies implies that bad weather conditions will not impact the two carriers at the same time. So, in case of fading at least one of the two channels is always available.

Another factor increasing the effectiveness of microwave technology is use of the E-band spectrum. E-band has more than 10GHz spectrum at 70GHz~100GHz. This yields multi-gigabits per second throughput.

Figure 10 illustrates the total amount of spectrum that can be used for Microwave communication between the 4GHz and 90GHz. The availability of spectrum varies between countries, and the trend is for governments to make new bands available to enable competition and more subscribers.

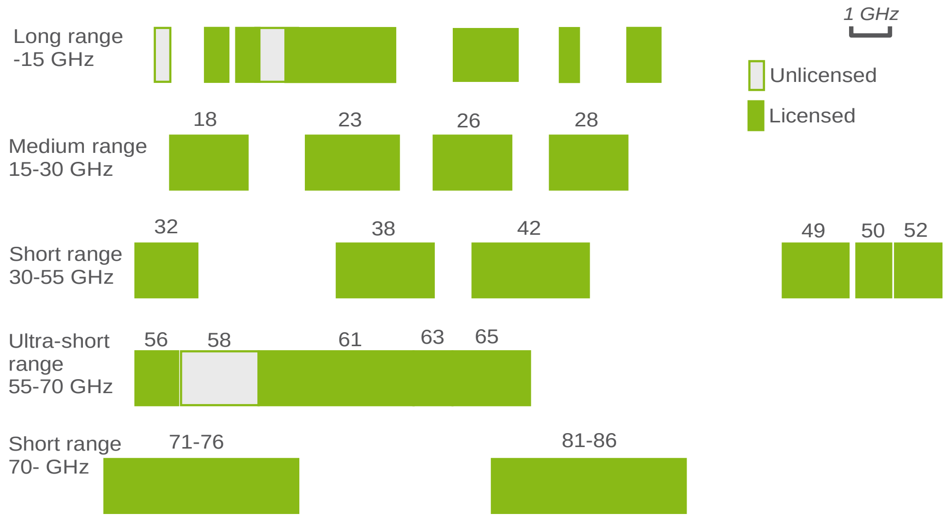


Figure 10

6.4 Timing/Synchronization Distribution

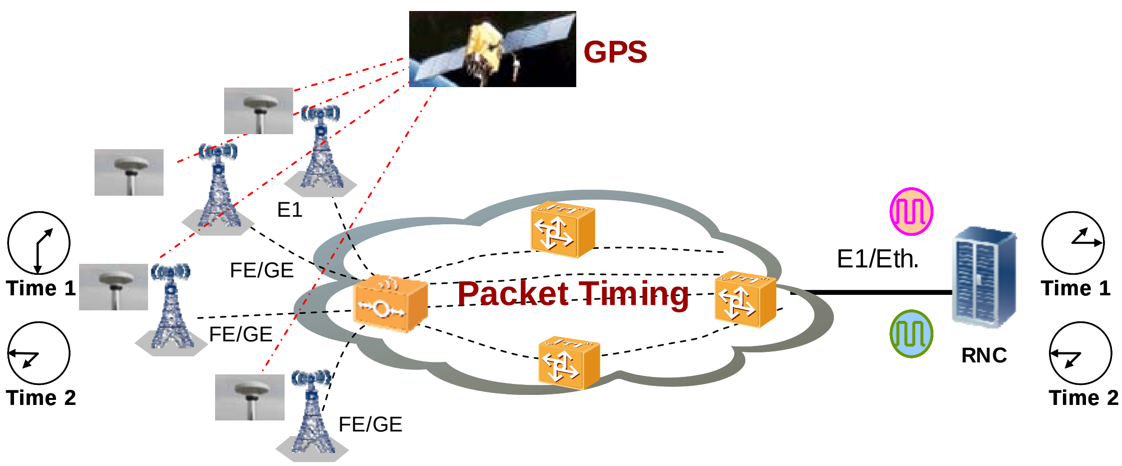


Figure 11

Figure 11 shows some of the mechanisms used for transporting and distributing time/synchronization across a microwave based network. These include:

- GPS (external mechanism)
- Synchronous Ethernet
- Packet-based clock recovery (i.e. ACR, IEEE 1588v2)

Besides traditional GPS based timing synchronization method, Synchronous Ethernet and IEEE 1588v2 can be seen as complementary methods for the transport of timing over a packet network; both are used in practical scenarios

for timing distribution. Adaptive clock recovery may be use to synchronize T1/E1 circuit emulation (example: MEF-8).
Microwave radio transmission over the air interface equipment is synchronous and can be used to distribute a timing signal over the air interface and across the network. Microwave nodes supporting synchronous Ethernet can be part of the clock synchronization chain just like other Ethernet nodes that support synchronous Ethernet. In addition, the service aware capabilities of today's microwave radios, assure optimal transfer of timing distribution.

E1/T1 line clock, recovered from a PDH or SDH connection, as well as Synch-In/Synch-Out signals (e.g. sine wave at different frequencies), are also supported for frequency distribution in hybrid microwave scenarios (traditional PDH or SDH access or aggregation).

Today's Microwave equipment can support multiple sources of synchronization. This means that the path through the network from the synchronization source(s) to each network element can be protected with multiple synchronization sources and multiple transport paths.

6.5 Carrier Grade Protection

In order to comply with the restoration demands of Carrier Ethernet and the requirements of contractual service level agreements (SLA), microwave transport can be configured to provide a full set of carrier grade protection methods with no single point of failure.

This configuration includes elements such as an Ethernet switching fabric, the TDM cross connect (if it is part of the network), Ethernet traffic ports, E1/T1 ports, equipment controllers and radio transceivers.

In addition, Microwave transport supports resiliency protocols for Ethernet and TDM. These include:

- For Ethernet services there is the IEEE standard RSTP/MSTP, or the ITU carrier class resiliency protocols like Ethernet Linear Protection (G.8031) or Ethernet Ring Protection (G.8032).
- For TDM services there are the SNCP or BLSR protocols.
- For Ethernet ports (UNI's, or ENNI's) IEEE defines link aggregation (LAG).

Other Microwave specific network protection mechanisms include:

- 1:1 Hot Stand-by protection
- 1+1 Frequency Diversity protection

7. Hybrid Microwave

Hybrid Microwave handles packets and TDM natively (without mapping onto another protocol), transporting multimedia traffic efficiently and allowing operators to launch data services cost-effectively without impacting traditional TDM services.

Hybrid Microwave transport is an interesting new choice for operators that require the coexistence of both TDM/ATM circuit services and Carrier Ethernet packet services. The Microwave interface can encapsulate TDM and packet services into a unified Microwave frame prior to transmission. Hybrid Microwave supports three types of interface modes: TDM, hybrid (TDM + packet), and packet.

Figure12, Illustrates the main functions of a Hybrid Microwave radio system:

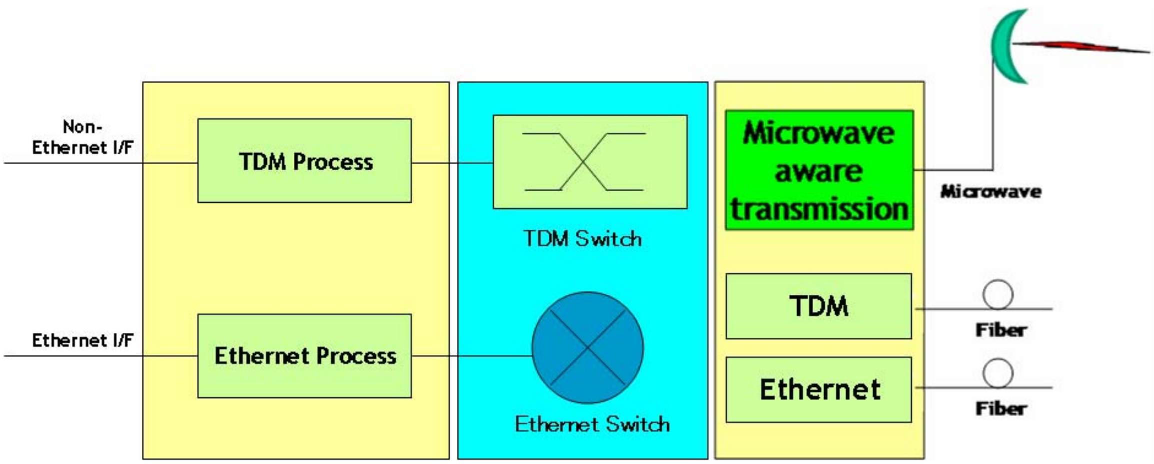


Figure 12

A separate TDM processing unit at the top of the illustration handles TDM circuits and the Ethernet switch at the bottom of the illustration handles the Carrier Ethernet packets. Then the native TDM and Ethernet traffic streams receive independent allocations of the total available Microwave radio link capacity.

A separate QoS handling capability of the Ethernet multiplexer ensures differential treatment of IP/Ethernet packets according to their QoS markings. Finally, both traffic streams are mixed at the Air Frame Multiplexer on the RF card before being transmitted via the dish antenna to the receiving remote station.

This functionality ensures efficient handling of multiservice traffic and a flexible network migration strategy for mobile backhaul networks.

The building blocks comprising Hybrid Microwave are:

- Standard Ethernet interfaces, either on the access or network side (UNI)
- Standard TDM interfaces, either on the access or network side (like E1, T1, SDH)
- A Carrier Ethernet switch
- A TDM cross connect
- A Microwave Aware transmission complex, capable of accommodating the functions driving the microwave transmission

This architecture simplifies network transition pressures. Voice can be sent over the TDM network with guaranteed quality. Rapidly growing data traffic can be sent over the Carrier Ethernet network with QoS to differentiate high and low priority traffic This approach requires operators to maintain two end-to-end networks, TDM and packet.

Hybrid Microwave supports a nodal function which gives it the capability to:

- Forward traffic from microwave and non-microwave directions simultaneously
- Mix and interleave traffic flows from the multiple radio directions and local access, effectively separating the Carrier Ethernet traffic and the TDM traffic.

8. Packet Microwave

Packet Microwave handles Carrier Ethernet packets natively, transporting multimedia traffic efficiently and allowing operators to launch data services cost-effectively without impacting traditional voice service. With Packet Microwave the operator maintains a single packet network that hosts both TDM and IP/Ethernet traffic.

From a functional perspective, Packet Microwave equipment is represented as illustrated in the next picture, figure 13.

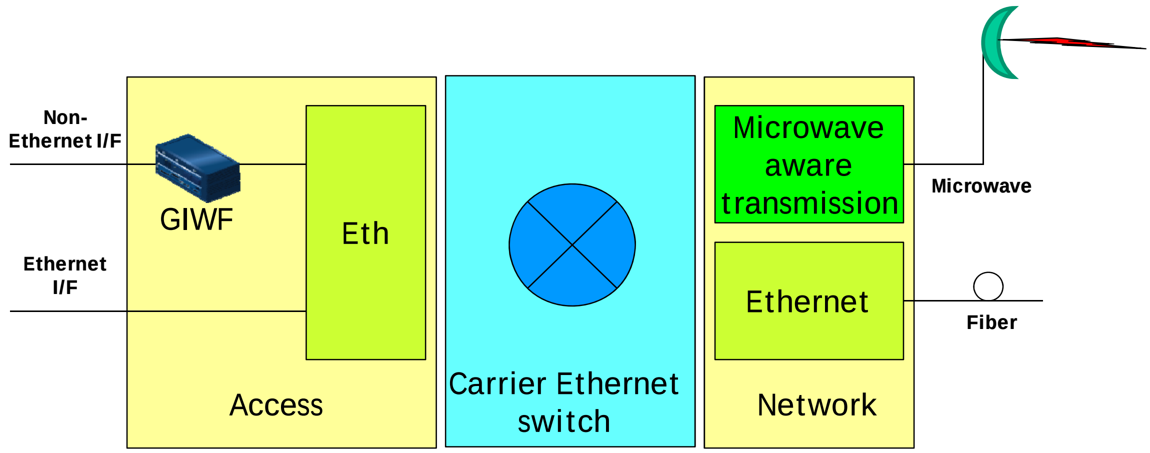


Figure 13

Packet Microwave converges the Ethernet and Non-Ethernet (e.g.TDM, ATM) traffic over a single packet transport layer called the multiservice aggregation layer, using industry standard Pseudo-Wire and Circuit Emulation technologies (e.g. CESoE (MEF-8) SAToP/CESoPSN, ATM PWE3; HDLC PWE3 and others).

E1/T1, ATM and IP/Eth are carried over a common layer and therefore over one single physical interface, sharing a common packet transmission infrastructure, regardless of the nature of carried traffic. Carrier Ethernet becomes the single convergence transport layer.

The building blocks comprising Packet Microwave are:

- An interworking function to accommodate Non-Ethernet (legacy) traffic to Carrier Ethernet (e.g. TDM circuit emulation services, such as CESoE (MEF-8), SAToP/CESoPSN; ATM PWE3; HDLC PWE3)
- Standard Ethernet interfaces, either on the access or network side
- A Carrier Ethernet switch
- A Microwave Aware Transmission

The presence of a Generic Interworking Function (GIWF) assures the encapsulation of legacy non-packet ingress traffic into packet streams. MEF-22 describes the capability of Circuit Emulation at the GIWF for mobile backhaul. The key advantage of handling only packet traffic on the microwave link is flexibility; the operator can add/remove TDM links over time, and migrate to all IP in the future. Packet Microwave radio can be used in any deployment scenario, mixing and matching any combination of access and aggregation technology. The GIWF, if implemented end-to-end, eliminates the need to operate a TDM network parallel to the packet network.

Packet Microwave is based on a single service switch core that drives all microwave and non-microwave directions.

Because it is a Packet Node, Packet Microwave supports the nodal function, giving it the capability of:

- Driving several Microwave and non-microwave directions simultaneously
- Mixing and interleaving traffic flows from the multiple radio directions and local access, handling all the traffic over a common multiservice aggregation layer

9. Conclusion

Microwave technologies are evolving to meet the needs of service providers that seek to offer Carrier Ethernet services. As this evolution occurs, it is desirable to have seamless transport services across the entire network. A Microwave infrastructure that is capable of delivering differentiated Carrier Ethernet services provides an important option to enhance overall network reach.

Packet and Hybrid Microwave technologies enable efficient transmission of both TDM circuits and IP/Ethernet packets over the same radio link, enabling reliable transport network migration. These new Microwave radio technologies offer cost-effective and innovative wireless transmission solutions for Carrier Ethernet services; giving operators a next-generation transport alternative for building voice and data networks.

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