EFFICIENCY IMPROVEMENT
OF FIXED WIRELESS NETWORKS
IN AN NGN ENVIRONMENT

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Abstract: Microwave systems have played an important role in the successful deployment process of cellular mobile networks and as a direct broadband connection to fixed business users. The trend towards higher bandwidth ubiquitous mobile connectivity represented by upcoming technologies ("beyond 3G") and all packet based network architectures (NGN: Next Generation Networks) is creating a set of new requirements for systems in the microwave domain. The paper describes associated system requirements and provides guidelines to ensure the technical and business success story in the new environment.

Keywords: Communication Networks, Adaptive Systems, Ethernet, Microwave Systems

1. INTRODUCTION

Microwave LOS (Line of Sight) technology in PTP (Point to Point) and PMP (Point to Multipoint) configuration has been extensively and very successfully used in the past to provide fixed network access to base stations of various mobile cellular standards and their evolution to broadband mobility. The success story has started with the deployment of 2nd generation mobile systems all over the world and will continue with the evolution of 3rd generation technology currently under way. Longer term evolutions for even more broadband capabilities will require a backhaul performance which needs to be substantially more powerful as compared to conventional solutions. On top of that, other standardised technologies for NLOS (Non Line of Sight) broadband access like Fixed and Mobile WiMAX, WiBro and enhanced WLAN are evolving into the same direction. Microwave backhaul was and is the perfect enabler for such technologies as in most cases, spectrum availability at low frequencies is very limited and consequently, self backhaul – although technically possible – normally is not a viable option.

2. NEW APPLICATIONS

On top of that, microwave radio solutions in different topologies and frequency bands are perfect for Metro Ethernet applications in scenarios where direct fast and broadband access is required for corporate or business customers with higher bandwidth demand as compared to cellular mobile or fixed residential cellular systems and in cases where limited or no direct access to a broadband wireline network is available. Consequently, these applications are commonly referred to as fiber extension networks. They can favourably be combined with BWA (Broadband Wireless Access) systems as these in most cases are limited in available bandwidth due to the well known bandwidth constraints at lower frequencies.

3. THE NGN ENVIRONMENT

All of these application areas are characterised by an NGN (Next Generation Network) feature set which reflects the migration of all network aspects to packet based architectures (Fig.1). Such approaches are driven by general network convergence trends and generally have been accepted to replace conventional solutions.

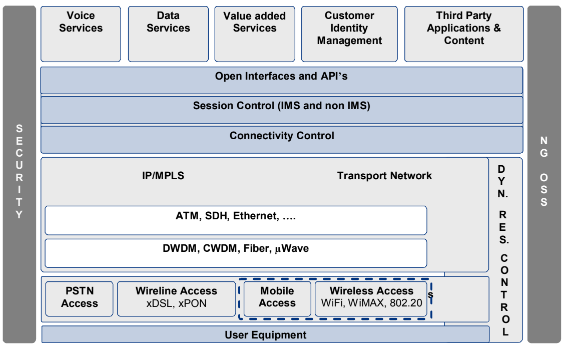


Fig. 1. NGN Reference Model (Source: Detecon)

Besides the general end-to-end packet based architecture, the most important and relevant new requirement for the access and transport layer is given by the presence of a dynamic resource control capability in order to comply with the considerably higher throughput and network efficiency requirements. This is of particular and vital importance for any wireless solution in this area as frequency resources are always scarce compared to wireline systems.

In contrast to that, the standard feature set of PTP microwave radios today still comprises solutions for relatively simple service agnostic bit transport based on framed TDM approaches (PDH or SDH) with a set of very high transmission quality, spectrum efficiency and link availability requirements. Interfaces and data rates are normally configurable in various options together with the possibility to (statically) optimise channel bandwidth availability, throughput and range by the selection of appropriate modulation and channel coding schemes. Consequently, data oriented services (ATM, Ethernet) are normally mapped into PDH or SDH frames according to the relevant standards.

This mapping based on the given TDM granularities is not compliant with the NGN environment by mainly two reasons: the end to end packet control is not able to have any influence on the air interface characteristics and at the same time, the mapping inhibits an efficient dynamic resource control and normally leads to a substantial truck roll effort in case transmission capacities have to be varied in the network.

4. NEW APPROACHES

4.1 Adaptive Modulation

Due to the frame based nature of legacy approaches, the corresponding solutions are asymptotic, i.e. a small improvement in a certain parameter or feature set requires a relatively big engineering and/or hardware effort and consequently increases cost. A classical example is given by the well known link range calculation procedure: required link availability, rain attenuation, bandwidth and system gain are the determining parameters which are more or less fixed for a given scenario. For a TDM based PTP solution no further degrees of freedom exist, i.e. a change in throughput either requires a link re-planning procedure or leads to an underutilisation of the scarce resource. As a consequence of that, links are only designed for a small fraction of their operational time and as such over-dimensioned.

Packet based radios are more flexible in a way that throughput and link range are no longer fixed but variable and consequently can be traded off against each other. As a consequence of that, longer links can be established leading to considerable savings in infrastructure cost.

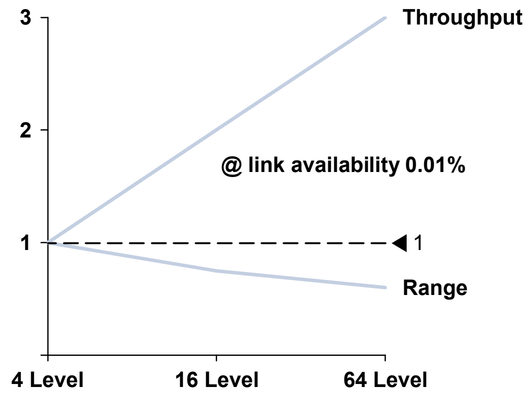


Fig. 2. Throughput and range for configurable modulation. Note: link availability = 0.01%

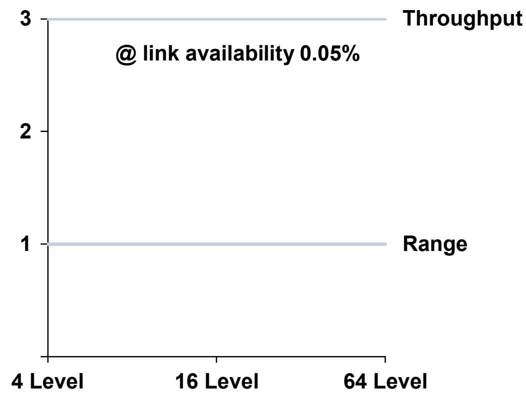


Fig. 3. Throughput and range for adaptive modulation. Note: link availability = 0.05% for max. throughput

As shown in figs 2 and 3 this is of course only possible if a throughput less than the maximum throughput can be tolerated for a short amount of time.

Such technologies are well known from modern PMP air interface technologies (WiMAX, ETSI BRAN HiperAccess) and require packet or cell based (or both) modem approaches with adaptive PHY mode switching capabilities (commonly referred to as "adaptive modulation"). Switching needs to be instantaneous (i.e. on a per burst basis) and error free.

Applied to the classical PTP link design, more degrees of freedom now exist: depending on the QoS (Quality of Service) requirements, throughput can be traded off versus distance and longer links are normally possible leading to savings in infrastructure cost that can be a multiple of the radio equipment. Nevertheless, a minimum QoS requirement needs to be maintained requiring a measurement of the relevant traffic parameters e.g. by packet inspection (see chapter 4.3).

Similar to PTP systems, adaptive modulation also can improve the performance of PMP systems.

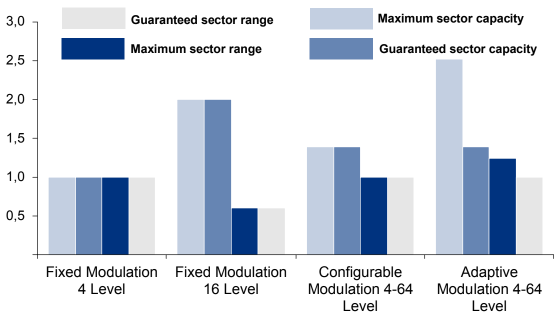


Fig. 4. PMP sector throughput and sector capacity improvement using true adaptive modulation.

Note:

- link availability: 99.995 %
- equal distribution of terminals in the sector
- configurable modulation used on a per terminal basis.

As shown in fig. 4, adaptive modulation can improve all system parameters simultaneously. Again, a QoS measurement and control protocol has to be implemented.

It should be noted that adaptive PHY mode switching is normally triggered by threshold signal to noise ratios. As a consequence of that, a correct interworking of the adaptive modulation with the usually present AGC (Automatic Gain Control) or RTPC (Remote Transmit Power Control) has to be implemented.

4.2 Topology Agnostic Systems

From chapter 4.1 is becomes apparent that with new technologies the differences between the classical PTP – PMP paradigm are about to vanish. As long as the classical approach has handled PTP and PMP with completely different air interfaces and hardware solutions, the choice for one or the other hasn't been an easy task. As a consequence of that, PTP systems have mostly been preferred as switching to PMP requires an additional system decision with all consequences on capital and operational expenses. On top of that, the business case for PMP alone is sometimes difficult to justify.

On the other hand, PTP might not always be the optimum solution, in particular if backhauling of broadband mobile cellular systems is considered. Due to the fact that such systems require a denser cell structure, PTP backhaul can run into difficulties with spectrum efficiency and public acceptance due to the multitude of antennas used in dense nodes.

The ideal system therefore has to be engineered in a way that it supports a variety of network topologies such as:

- PTP topologies
- Star or daisy chain topologies
- Multiple PTP topologies
- Ring and mesh topologies
- PMP topologies
- Repeater topologies

System architectures capable to provide such flexible network configurations need to be more sophisticated as compared to the usual terminal configuration. A possible solution is given by so-called flexible microwave nodes comprising a packet based software configurable modem, an Ethernet/MPLS engine and a configurable RF system for PTP/PMP and multiple PTP operation.

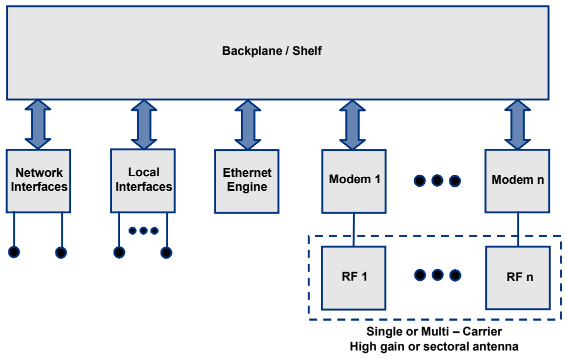


Fig. 5. Microwave node architecture based on backplane/shelf design with plug-in modules

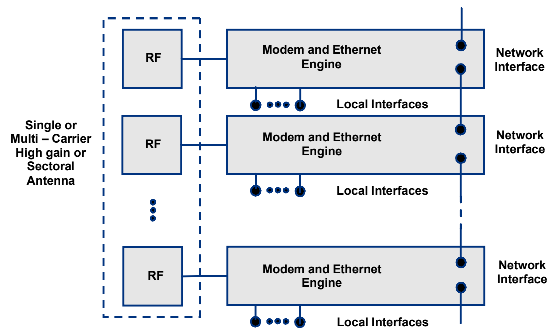


Fig. 6. Microwave node architecture based on a single board design with staggering

For the designer, options as described in figs. 5 and 6 exist. Both have their characteristic advantages and disadvantages and need to be optimised with respect to cost, flexibility, size and development effort.

Obviously, the shelf approach is the best solution for dense PMP or star topologies, whereas the staggered approach will be the preferred solution for more distributed networks consisting of individual PTP elements or lower capacity PMP and/or single link arrangements.

4.3 Carrier Class Ethernet Functionalities

Conventional radio solutions do not care about the individual service they are transmitting but only optimize the pure transmission task. This view has a long tradition and a lot of good rationale as the underlying principle is simple and well adapted to a radio solution that is supposed to replace a wireline leased line: it just works in the same way and often network operators explicitly require that.

Modern networks work in a different way. Network topologies are more distributed than dedicated, network resources need to be shared in order to improve efficiency and connections (if present at all) are virtual rather than real and physical.

Mapping of data traffic to TDM based networks is a technical option and supported by standards but only works in a sufficiently effective way in transport and core networks where bandwidth is a commodity. Such strategies will fail in access networks (in particular in wireless access networks) due to the highly inefficient mapping onto the smaller TDM granularities that are available there.

Nevertheless, there is no option to compromise on quality of service. Modern microwave radios following the principles described above need to implement a set of carrier class Ethernet functionalities (e.g. defined by the Metro Ethernet Forum). On top of that, the radio has to be "service aware" looking at the functionalities described in 4.1.

The implementation of such functionalities can either be performed by a full CAC (Connection Admission Control) for connection oriented services or via a generic check (e.g. on a packet inspection basis) whether the total system resources are able to support the requested service without deteriorating established services.

Ethernet in many cases will be the dominant future solution as compared to TDM and ATM due to its ease of use, its cost effectiveness and its flexibility and scalability. Nevertheless, Ethernet use with carrier class attributes requires the additional definition of models and procedures to achieve that.

<u>Classical mobile cellular operators</u> using self-build RANs normally have an excellent knowledge of control plane issues mainly driven by their experience with GSM and UMTS (e.g. PNNI). In case they plan to migrate to an all IP RAN, it is quite probable, that they will adopt similar control plane instruments (e.g. MPLS) relatively quickly. Any equipment strategy trying to play on this market therefore needs to implement a corresponding evolution strategy today, even if these functionalities are not immediately required.

<u>Carrier's carrier operators</u> have to work with a higher variety of scenarios both in terms of capacity but also w.r.t. the network layer. Core networks in use can have any technology base: SDH/SONET, carrier class Ethernet, MPLS and/or ATM or mixtures thereof. User interfaces are generally IP based but due to the fact that legacy mobile systems need to be connected, show a considerable amount of conventional variants. The control plane knowledge in many cases is not that well developed or even no control plane is used (at least in the access portion of the network). Corresponding product solutions that are attractive to them need to have a high degree of flexibility and scalability from simple (e.g. leased line) to more sophisticated variants.

<u>Utility companies</u> often start with a network optimized to their own demands, which can comprise very special types of services like telemetry (real-time requirements). As they see business customers as new market opportunities, similar characteristics as compared to the carrier's carrier case exist. Mobile cellular RAN normally is not a key application for utilities.

<u>Wireless service providers</u> using licensed or un-licensed technologies such as WiFi, WiMAX or similar, often are looking for broadband and reliable connections of their access networks (single cells, sectored cells, hot spots or meshed networks). As such kind of network can be quite powerful w.r.t. traffic engineering; the associated backhaul can be fairly simple. Such solutions of course may also be attractive for carrier's carrier and utility applications including the feature set mentioned above.

Conventional network dimensioning leads to situations that can be very expensive and inefficient if multi-service scenarios have to be considered. This is in particular true for access networks and mostly true for wireless networks looking at their limited bandwidth situation.

Nevertheless, a full knowledge of any type of service is not necessarily required in all cases. Consequently, we need to differentiate between services and their associated quality parameters that the network must know about and areas where service awareness is desirable but not mandatory (or even obsolete).

Consequently, it is more important to interpret "service awareness" as the capability of the network to be (preferably dynamically) compatible with certain service requirements such as delay, delay jitter, packet loss, reachability, resilience, load balancing, multicast capabilities, statistical multiplexing etc. This can be achieved by mapping of certain services onto specific discriminators (e.g. a VLAN) that are visible to the transport or access network (a job that can be done by a CPE) or by enabling the network to look into higher layer protocols (sniffing, e.g. DiffServ). On top of that, alternatives exist like L2 and L3 VPNs that can be implemented outside the transport network using techniques like virtual routers and MPLS.

Service	Prio	EIR/PIR CIR	Eth. QoS	IP QoS
2G BH	H	C	-	-
3G BH	M	V	-	-
E1/T1 LL	H	C	-	-
Circuit Switch	H	C	-	-
VPN	M	V	Yes	Yes
VoIP	H	V	Yes	Yes
CCTV	L	V	Yes	P
WiFi BH	H	C	Yes	Yes
WiMAX BH	H	C	Yes	Yes
DSL BH	H	C	Yes	Yes
Internet	L	V	-	P

Table 1: Typical services and service requirements/ attributes

Abbreviations:

BH: Backhaul
LL: Leased line
H: High
M: Medium
L: Low
C: Constant
V: Variable
CIR: Committed information rate
EIR: Excess information rate
PIR: Peak information rate
P: Possible

The basic advantages of packet transport are seen in terms of increased network efficiency due to an arbitrary switching granularity and an easier grooming as a consequence of that. Logically, strategies mapping packet transport on TDM granularities (e.g. PDH E1/T1 or SDH/SONET VC12/VT15) are only efficient if the mapping is ideal, i.e. the pipes are reasonably filled. Such strategies may work for larger granularities (e.g. VC4 and beyond) but fail in the access area. Another advantage is given by the capability to use statistical multiplex strategies as long as the QoS requirements allow that. Again, this only works if the shared resource for the statistical multiplex is large enough.

Looking at possible service transport technologies, two basic philosophies have to be considered: connection-oriented transport and connection-less transport.

The motivation for connection-oriented transport is originating from the migration of TDM bases leased lines towards Ethernet based leased lines. This is in particular applicable if legacy TDM services have to be transported over packet based networks. The corresponding (high) QoS is established by means of static configuration or reservation strategies (e.g. RSVP) and guarantees best control of network resources, high QoS, reasonably easy end-to-end management and traffic engineering. On the negative side we are focused with a higher OpEx because such networks do not support plug and play but require a careful connection management either in a manual way (which can be extremely cumbersome as many connections have to be set up) or by using end to end signalling protocols.

It should be noted that these issues have been solved within ATM based RANs using e.g. PNNI. It is nevertheless very unlikely that Ethernet focused operators will re-use PNNI. As a consequence, for such networks and applications a new control plane is required. Technologies of choice for connection oriented Ethernet transport are: E-Line (native Ethernet), E-Line (using tunnelling techniques) and PWE (Pseudo Wire Emulation), i.e. Ethernet over packet switched tunnels, which can be of any kind: IP, MPLS, Frame Relay, ATM, Ethernet (Fig. 7-8).

Technologies for connection less Ethernet transport are interesting because of the potential to save OpEx: in connection-less environments the network is capable of learning its connectivity (plug and play). If advanced QoS isn't required, additional savings w.r.t. CapEx may exist by using cheap LAN technology (hardware). Potential candidates are: E-LAN (Fig. 9) with native Ethernet (Transparent Q-Bridge) and PVLAN (Private VLAN).

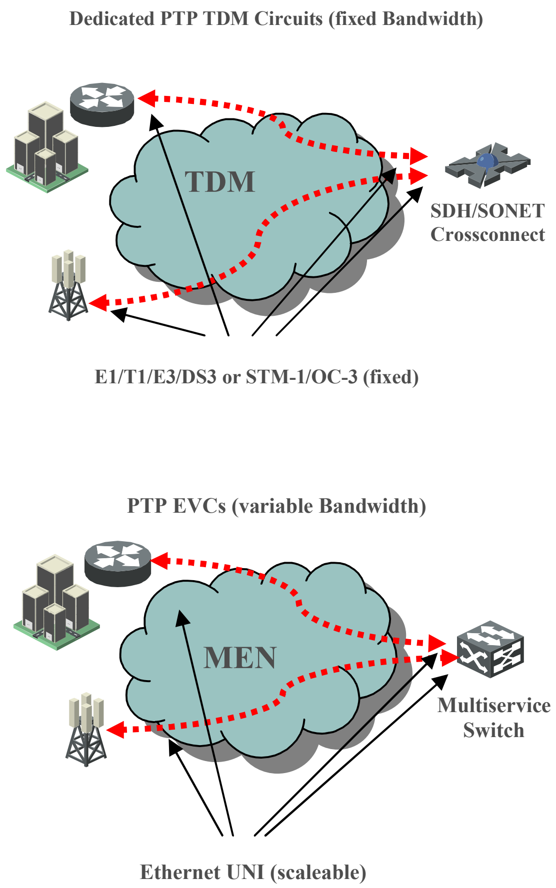


Fig. 7. EPL (Ethernet Private Line) application and its TDM equivalent

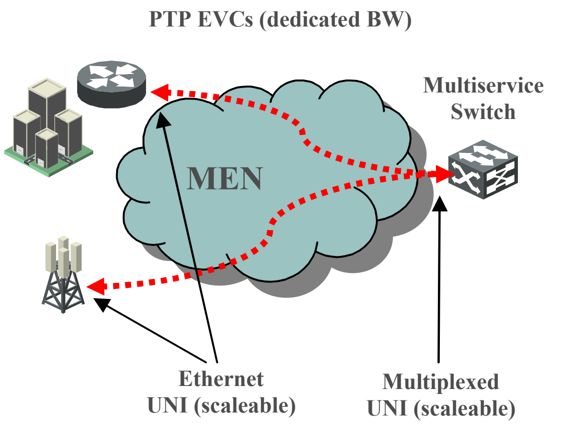


Fig. 8. EVPL (Ethernet Virtual Private Line) application

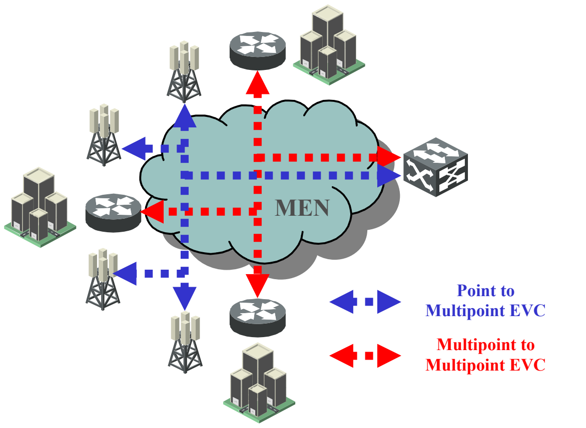


Fig. 9. Capabilities of E-LAN services

E-LAN services provide a higher level of networking functions and as such are required for Multipoint VPNs and transparent LAN services. This is of particular interest for intra-company connection applications. Full transparency of control protocols is guaranteed and new VLANs can be connected without any network change or coordination with the MEN provider. Such solutions also could gain attention in co-located Ethernet RAN applications and in case of network sharing.

5. BUSINESS CASE

As every new approach, a strategy to optimise network intelligence rather than further commoditizing simple and well known solutions is not straightforward but requires a careful and longer term optimization process. The more the networks get OpEx dominated, the more important such optimizations are. This is even true if more advanced and intelligent solutions tend to be slightly more expensive at the beginning of their respective product lifecycle. Various business case analyses have shown that the following key criteria are determining the longer term operational cost level to a high extent:

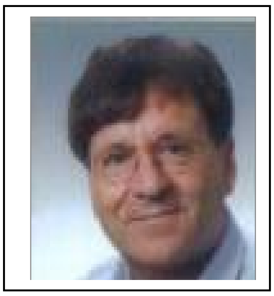
- scalability and efficiency
- network level intelligence
- end to end configuration capabilities
- soft migration capabilities
- inherent service awareness
- simple configuration and logistics
- hardware reuse for different topologies

These OpEx dominating parameters get more and more important with upcoming next generation mobile cellular solutions originating from the classical telco world (UMTS and its evolution to LTE) and the competing more IT centric approaches like WiMAX and its evolution to more broadband capabilities. All these solutions require powerful backhaul capabilities with transmission capacities far in excess of what is used today. Due to the much denser cell structures of such advanced systems, backhaul cost will increase to more than 50% of the overall network cost compared to cost contributions in the order of 15 to 20% for conventional macro and rural cell structures.

As self backhauling – although sometimes aggressively marketed – is not a viable option in most cases due to missing frequency resources at lower bands, microwave solutions will remain to be very attractive also for the future success of broadband wireless mobility.

Design criteria as described in this paper are seen to be key for the continuation of the success story for microwave systems also in the future.

BIOGRAPHY



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