WHITE PAPER

Next-Generation Mobile Backhaul Requirements as Outlined by the NGMN Alliance

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Introduction

Scope

The Next Generation Mobile Networks (NGMN) Alliance[1] is an initiative by a world-wide group of leading mobile operators to provide a coherent vision for the mobile network technology evolution beyond 3G, and for the competitive delivery of mobile broadband wireless services (www.ngmn.org). The vision of the NGMN Alliance is to provide a platform for innovation by moving towards a single integrated network for the seamless introduction of mobile broadband services. The target architecture defined by these recommendations will be an optimised Packet Switched (PS) network architecture, which will provide a smooth migration of existing 2G and 3G networks towards an IP network – along with improved cost competitiveness and higher broadband performance.

The Technical Working Groups of the NGMN Alliance have issued in the first release of the **Optimised Solution for Backhaul Transmission** document during the last quarter of 2008. The document defines a set of high level backhaul specifications and provides a list of 91 requirements aimed at supporting the construction of Next Generation Mobile Networks (Project 11).

This paper will provide an introduction to the main NGMN Backhaul Requirements as defined by the NGMN Alliance. We will provide insight into the impact that NGMN will have on future backhaul network designs, and how it aims to boost performance while keeping costs at check. The paper will specifically focus on requirements for Backhaul Performance and Backhaul Optimization, and will suggest a set of tools that will enable operators to implement those requirements painlessly and cost efficiently.

Introducing NGMN Backhaul Requirements (v3.0)

Next Generation Mobile Networks, or NGMN, is a concept defined in order to support up and coming LTE/4G services by enabling a single, shared, end-to-end packet transport network for voice and data for all NGMN radio access.

Experience with 3G and HSPA network has shown that backhaul engineering is not an easy task. Data is consuming more and more network resources and makes the “traditional” voice-related network usage statistics obsolete. Unlike voice, data traffic is difficult to predict. Bursts of usage may occur at a certain time point threatening to exhaust the network’s capacity, while at other times there may be little or no usage at all. Therefore, the planning and designing of a backhaul link from the single base station can sometimes be difficult and may also become a significant source of added costs. The NGMN document defines a list of

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[1] “NGMN Alliance” in this paper refers to the world-wide group mobile operators. Where NGMN is mentioned on its own, this paper refers to the NGMN technical concept

requirements for the backhaul system, and makes recommendations on how to optimize the transport the transport network.

The underlying assumption of NGMN is that the key objectives of 4G/LTE networks are to support higher data rates, improve spectral efficiency, reduce network latency, support flexible channel bandwidths, and simplify or flatten the network by utilizing an all-packet (Ethernet/IP) architecture. According to the NGMN Alliance requirements, the future networks will enable an end-to-end packet transport using harmonised and shared transport network allowing network cost reduction. Likewise, shared transport also minimises the costs for nodes needed for protocol translations. Therefore, future transport network nodes are required to be access and service agnostic. In short, NGMNs will need to deliver with higher network performance and optimization.

The 91 backhaul requirements (represented by the letter R and a corresponding number in the table 1 below) may divide in to these two main subjects. A sub-sections high level categorization would be as follows:

	High Level Requirement	NGMN Requirement (v3.0)
Performance	Backhaul Bandwidth Requirements	R12,R13,R14,R15,R17,R57,R58,R59
	Service QoS Mechanisms	R2,R3,R4,R5,R6,R7,R9,R10,R11,R16,R21, R22,R23,R24, R34,R36,R37,R48
	Integration: support for legacy protocols and multi-vendor interoperability.	R17,R26,R27,R28,R29,R32,R33,R35,R50, R51,R52,R53,R54,R55,R56
	Availability: high MTBF and robust redundancy mechanisms	R38,R40,R41,R42,R43,R44,R45,R82
	SLA monitoring / reporting	R46,R47,R48,R49
Optimization	Traffic aggregation and efficiency	R1,R2,R3,R8,R25,R59,R80
	Service OAM for fast fault detection, isolation and resolution	R30,R31,R32,R34,R35,R59
	Minimized physical footprint and power consumption	R59,R83,R84,R85,R86,R87,R88
	Simplicity and speed of planning, installation & commissioning	R39,R59,R77,R78,R79,R81,R90,R91

Table 1: NGMN high level requirement divided into categories

NOTE

Notes: NGMN requirements not reflected in this table are – Multicast (R18-R20) and Security (R61-R76)

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NGMN Terminology

- **aGW** - Access Gateway defined as the NGMN Edge Core Node to which NGMN RAN has to be connected. As an example, in 3GPP LTE/SAE, aGW refers to the Serving Gateway (S-GW), Mobility Management Entity (MME) and Multimedia Broadcast Multicast Service Gateway (MBMS-GW) which might be implemented as one or separated network elements.
- **e-NB** - Enhanced Node B defined as the NGMN Base Station

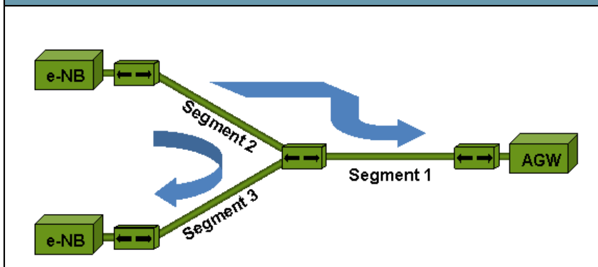
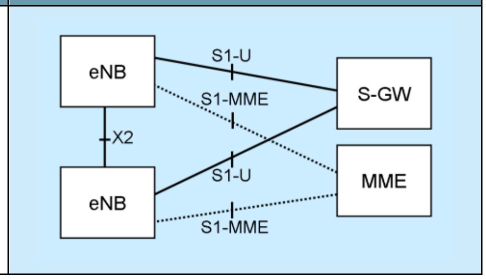
NGMN Terminology	3GPP Terminology
	

Table 2: NGMN alliance mobile network terminology versus 3GPP terminology

Backhaul Performance Requirements

NGMN backhaul will be based on an optimized and fast Packet Switched infrastructure. Throughput will need to be scalable, allowing for diverse deployment options that match specific operators' network and traffic requirements.

Backhaul Bandwidth

The backhaul solution is required to provide Asymmetric bandwidth of up to 450/150 Mbps Downstream/Upstream. This calculation assumes that a cell site comprises up to 3 sectors, and that all three sectors can simultaneously support the highest peak rate of 150/50Mbps. Lower bandwidths may be used for micro-sites and rural base stations, whereas higher rates may be required in cases such as multi-band base stations. We can assume that the need for capacity will develop over time and that each operator will upgrade in its own pace. Hence, scalability is important component in NGMNs. Existing scalability models from leading equipment vendors provide a simple migration path beginning with low throughput, and easily upgradeable to higher capacities using a remotely software configurable license key.

The NGMN Alliance also recommends that next generation mobile backhaul solutions make use of transport network layer optimization or compression techniques (e.g. Header/Payload Compression) in order to improve throughput efficiency and further reduce end to end delay budget. Table 3 below depicts the capacity increase that can be obtained by a point-to-point microwave system through the use of an advanced header compression mechanism.

Ethernet Packet Size (bytes)	Capacity Increase by Comparison
64	45%
96	29%
128	22%
256	11%
512	5%

Table 3: Ethernet Header Compression (source: Ceragon Networks)

For example, let us look at a microwave system operating at a 28MHz channel with 128QAM modulation. Such a system can deliver throughputs of up to 150Mbps without any compression mechanism. By implementing advanced header compression, the same system can deliver up to 225Mbps[2] over the same bandwidth and using the same modulation.

Quality of Service Mechanisms

According to requirement R4 the e-NB/aGW must map the radio QoS Class Identifiers (QCI) to transport QoS markings (L2 and/or L3 according to operator design choice). The transport QoS markings will then be used by the Transport Equipment to classify the traffic that needs to be carried in each Class of Service (CoS) supported over the Backhaul network.

CoS Mapping may be implemented through a Traffic Classification and Policing system that examines the incoming traffic and assigns the desired priority according to the marking of the packets (based on the user port/L2/L3 marking in the packet). In case of congestion in the ingress port, low priority packets will be discarded first.

Although without looking beyond the IP header (which require deep packet inspection) the Metro Ethernet Network (MEN) is agnostic to QCI mapping and only considers the transport QoS values, the NGMN Alliance mentions that Transport equipment may add an underlying transport layer with different extra marking as long as it maintains the end–to-end QoS consistency (see example in Table 4 below).

In order to comply with the above requirement there is a need for a coordination mechanism between e-NB/aGW Transport Modules and the Transport Equipment. A microwave radio system that features fully integrated Ethernet networking capabilities and service demarcation functionalities will ensure proper mapping of CoS between the e-NB/aGW and the backhaul network.

[2] *Assuming a 64-bytes packet size*

Examples of NGMN RAN Traffic		Example of QoS mapping in Transport Modules		Examples of QoS re-marking in Transport Equipment preserving QoS consistency	
UMTS	WiMAX	Name	VLAN Priority	Class Type	VLAN Priority
Network Sync (e.g. 1588v2)	Network Sync (e.g. 1588v2)	Network Control	7	High Priority	5
Mobility & Signaling traffic	Mobility & Signaling traffic	High-1	6		
Conversation Class (Real Time)	Class 1 (Interactive Gaming – Real time), Class 2 (VoIP, Video Conferencing – Real Time)	Expedited	5		
Streaming Class (Real Time)	Class 3 (Streaming Media – real time)	High-2	4		
Interactive Class (non Real Time)	Class 4 (Information Technology – non Real Time)	Low-1	3	Assured	3
		Assured	2		
Background class (non Real Time)	Class 5 (Media Content Download – non Real Time)	Low-2	1	Best Effort	1
		Best Effort	0		

Table 4: Example for Transport Equipment preserving QoS consistency (source: NGMN alliance)

NGMN transport systems will need to provide superior packet scheduling mechanisms in order to ensure high QoS. Hence they would need support at least four priority queues that would be served according to scheduling schemes such as strict priority, Weighted Round Robin (WRR) or Hybrid (one or two "strict" or highest priority queues and the rest according to WRR). An example of a packet schedule mechanism is shown in Figure 1 below.

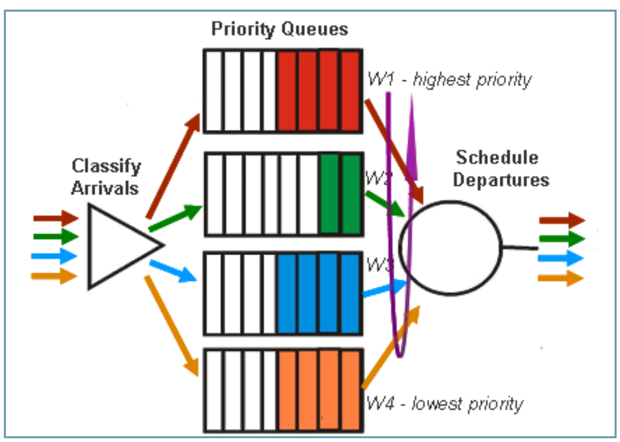


Figure 1: Example: priority queues that are served according to several types of scheduling schemes

The performance attributes of each CoS are for future study and should be in line with the Standardized QCI characteristics specified by 3GPP in TS 23.203 V8.2.0. Currently the MEF (Metro Ethernet Forum) "Mobile backhaul Implementation Agreement" suggests specifying the QoS parameters with references to 3GPP TS 23.107, but it may also consider 3GPP TS 23.203 in the future.

Delay and Delay variation

Delay, or Latency, refers to the overall network response speed to service demands. Latency is primarily experienced by the user mainly in delay-sensitive applications, such as VoIP and Video over IP.

According to requirement R48 of the NGMN Alliance document, an NGMN Backhaul solution must guarantee maximum end-to-end, two-way delay of 10 milliseconds. It should furthermore guarantee 5 milliseconds when and where it required by the operator. Ultra low latency should be maintained even when users are on the move in between base stations.

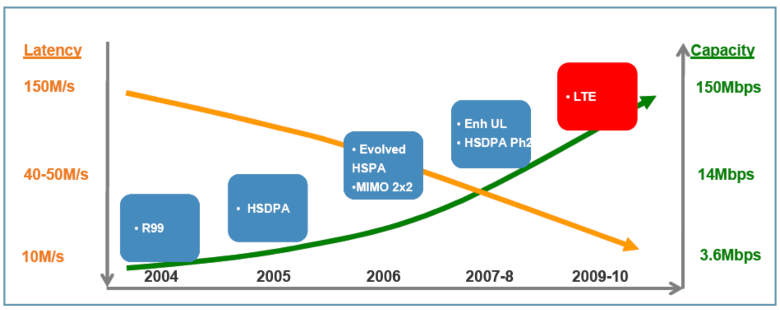


Figure 2: Mobile network capacity and latency requirements

But reaching the NGMN Alliance requirement for very low latency does not come without a challenge. There are three major architectural issues that can pose a threat to achieving cost efficient, low-latency over radio and core transport systems; (a) the high number of complex nodes needed to transfer user traffic; (b) the functional split requiring a complex communication between the nodes involved (3GPP X2 interface); (c) the mapping and encapsulation protocol structure. Therefore, in order to comply with the requirement for low latency, there is a need for a simplified system and protocol structure.

In order to overcome this hurdle, the NGMN architecture will be optimised in such a way that the number of complex nodes will be reduced. Complexity and overheads will be dealt with and reduced in order to allow better utilization of the NGMN Backhaul resources. This can be further explained using the example below:

Next generation backhaul networks will need to support both packet (IP/Ethernet) traffic as well as legacy TDM (Time Division Multiplexing) traffic (E1/T1) - because most 4G base stations will be co-located with 2G/3G base stations. Assuming that operators will choose to maintain only one transport network, the issue of supporting two types of service simultaneously needs to be addressed. One way to support both TDM and IP is to map one technology over the other using either Ethernet over TDM (EoTDM) mapping or Pseudowire emulation. Both methods are viable, but will consequently add overhead.

The main reservations operators might have regarding EoTDM mapping is the encapsulation “tax” and lower overall spectrum utilization. Pseudowire, used to carry TDM traffic over all-IP networks, has the advantage of reducing truck rolls by eliminating the need to physically handle TDM cross-connect at the cell site. Still, Pseudowire carries its own emulation "tax" and has an additional impact of latency and jitter on synchronization requirements (see item 2.4 below). An alternative, more cost efficient method for delivering mobile traffic is a system that can carry both native (un-mapped) Ethernet and native TDM simultaneously relieves the need to encapsulate or emulate the signals. This so called "hybrid" approach, that can also be simply referred to as Native[2], is ideal for reducing the complexity of the mobile backhaul network in order to comply with the strict delay figures outlined by the NGMN alliance.

Synchronization Distribution

Mobile backhaul networks have traditionally relied on TDM technologies including PDH and SDH/SONET microwave radios, low capacity SDH/SONET fiber rings, and copper-based E1/T1 leased lines. These networks carried and distributed the network-wide primary reference clock from which each base station derives its radio frequency. In order to maintain accuracy within 50ppb[3] of the nominal radio frequency, the network input had to be stable within a 15ppb margin.

During the evolution towards NGMN the transport backhaul network will gradually shift from TDM to all-Packet transport. In truth, packet-based technologies are already being widely deployed for mobile backhaul. However, synchronization has so far been a cause for concern for operators, and in some cases it was the main reason stopping them from totally substituting their existing TDM network. Using TDM and packet in parallel (Hybrid/Native[2]) is a viable interim step. In the long run however, the majority of operators will seek ways to migrate completely to packet backhaul. This will be facilitated by overcoming the inherent Asynchronous characteristics of packet technology. We will discuss how this will be implemented in the following paragraphs.

NGMN Backhaul solutions will need to support clock distribution to the e-NB for frequency synchronisation and should also support phase/time alignment. Several methods have been considered for synchronisation, either as a single solution or a combination of solutions. Physical-layer-based methods such as Synchronous Ethernet (ITU-T G.8261/2/4, for frequency only) and Protocol-based methods such as NTP[4] or IEEE1588v2 with/without intermediate nodes support (e.g. transparent clock implementation in intermediate backhaul nodes for IEEE 1588v2) were part of the suggested methods.

IEEE 1588v2 and Synchronous Ethernet should not be regarded as being contradictory. In fact, they complement one another. Existing backhaul solutions are focusing on Synchronous Ethernet handling with IEEE 1588v2 awareness to reliably reduce delay and delay variation (jitter) over packet based transport. Figure 3 below shows several approached to Ethernet Synchronization predicting the number of sites using each of the alternatives.

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[3] *ppb – parts per billion*

[4] ppb – parts per billion

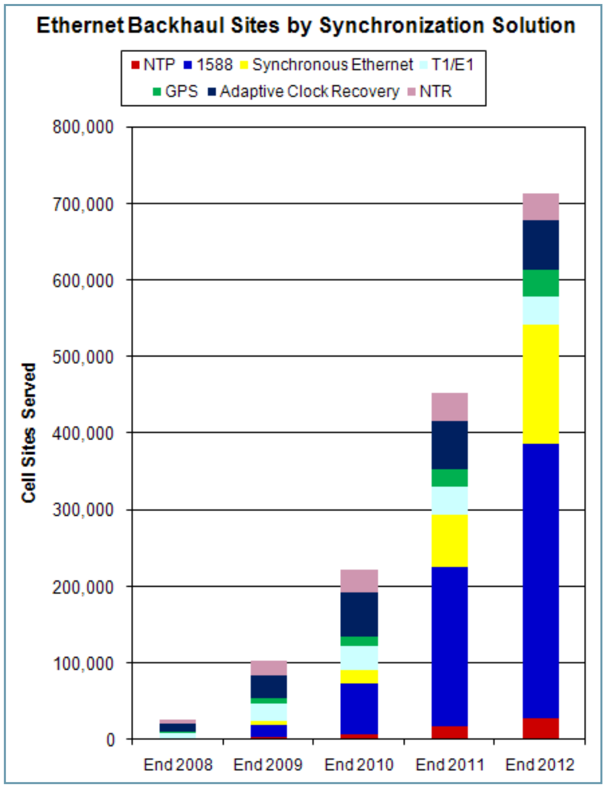


Figure 3: Synchronization Approaches to Ethernet Backhaul (Source - Heavy Reading's, Ethernet Backhaul Quarterly Market Tracker Nov.2008)

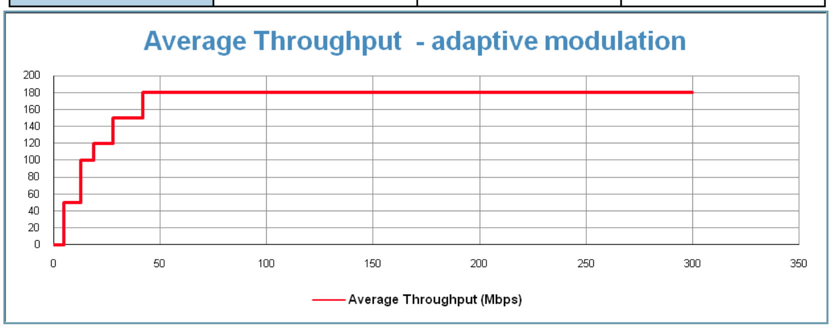
To conclude this chapter we need to remind ourselves that ensuring synchronization in a packet transport is a complicated issue. Attention has to be paid to certain network design aspects such as network reconfiguration and automatic rerouting of traffic should be minimized since it causes step changes in packet delay. Moreover Quality of Service should be applied at every highly loaded node, to avoid timing packets being queued behind other traffic. Existing techniques are already being put to the test in live deployments, and as they evolve, they will play an important role in driving the migration to IP.

Link Availability and Fault Restoration

Different types of protection could be implemented to achieve a certain operator-decided availability figure for a service or traffic type. Some examples are: service protection, link protection, node protection, etc. According to request R38 - operators MUST be able to design an end-to-end NGMN Backhaul solution by changing the availability figures of one (or several) Backhaul segments in order to achieve better cost efficiency. To do that, the wireless backhaul equipment should be able to support Adaptive Modulation & Coding (ACM).

ACM is a technology that allows the wireless link to adjust itself to changing weather conditions in order to support several types of availability for different types of service. In other words, ACM helps to guarantee the highest possible availability for high priority (real-time) traffic while temporarily reducing the availability of best effort traffic. The main innovation ACM brings to packet radio networks, which helps to set it apart from legacy SDH/SONET, is that it allows the system to flexibly manage availability. Where in the SDH/SONET world availability would be 99.999% or nothing, ACM enabled systems, such Ceragon's wireless platform, to dynamically assign (or take away) availability according the quality of the link at any given moment. This mechanism is depicted in Table 5 below.

Modulation	Average Throughput	Availability	Unavailability
Outage – 5minutes and 15 seconds per year			
QPSK	50 Mbps	99.999 %	5min, 15sec
16QAM	100 Mbps	99.997436 %	13min, 29sec
32QAM	120 Mbps	99.996384 %	19min, 0sec
64QAM	150 Mbps	99.994746 %	27min, 37sec
128QAM	180 Mbps	99.993123 %	41min, 38sec



Wireless link: 4.3km path, 28MHz channel, 1ft antenna

Table 5: Example of a wireless link supporting moderate degradation of availability to achieve a cost efficient solution using Adaptive Coding & Modulation (source: Ceragon networks)

NGMN Alliance R42 states that for Backhaul segments with high availability requirements, 99.99% service continuity should be the target figure. This means that during 99.99% of the time, an NGMN Backhaul solution will not experience interruptions that cause the mobile connection to fail - forcing users to set up their service connection again. It is also recommended that the overall "allowed" outage time is in the range of 500 milliseconds – 2 seconds for a single outage.

Operators who would wish to guarantee a certain, typically high level of Quality of Experience (QoE) should have the option to define more stringent requirements. This would mean that an NGMN Backhaul solution will never experience interruptions that can impact QoE of mobile users in specific pre-defined services (video streaming, voice etc.). As a reference the order of magnitude of such allowed interruption time would be in the range of 50msec - 250msec according to the NGMN alliance document.

Backhaul Optimization Requirements

Setting up communication networks and running them is a complex task – one that involves many activities including planning, configuration, optimization, dimensioning, tuning, testing, recovery from failures, failure mitigation, healing and maintenance. These activities are critical to the success of network operation and are today extremely labour-intensive. Hence they are costly, prone to errors and may consequently result in customer dissatisfaction. The network concept suggested by the NGMN Alliance aims to be a self-organizing network that includes self-optimisation features and can progress to become a fully automated network.

End-to-End Service Manageability and Monitoring

The NGMN management system is quite different from legacy mobile networks mainly due to two main requirements. One is the requirement to support a Multi-Operator Radio Access Network (RAN) Sharing. The other is the requirement to support a Multi-Vendor environment (R26) under interoperable management and traffic engineering tools such as end to end service level management. Both these requirements will serve to reduce the network's Operational Expenditure (OPEX).

End-to-end Operation Administration and Maintenance (OA&M) is another important requirement from the NGMN backhaul system. According to items R30 and R32 of the NGMN Alliance document, a backhaul solution must be able to monitor the OA&M capabilities of the underlying network elements either pro-actively or passively as well as on-demand. By integrating OA&M functionality into backhaul equipment, for example in a high-capacity point-to-point microwave system, operators can reduce their overall costs by eliminating the need for external OA&M components and dramatically simplifying the management of Ethernet backhaul networks. With reactive and proactive end-to-end OAM tools operators can maintain their SLAs (service level agreements) and ensure complete end-user satisfaction regardless of how many different networks stand between two service end-points[5].

Supporting Existing Mobile Network Generations

It is highly likely that many 4G / LTE/ NGMN mobile networks will co-exist with the GSM/UMTS networks for at least a few more years. This also dictates that 4G/LTE/NGMN base stations will be co-located with legacy base stations. In order to ensure service continuity with transparent user experience, the NGMN backhaul network is required to simultaneously inter-work with existing 2G/3G mobile network generations which are not necessarily packet-based (R52 and R80 of the NGMN Alliance document). In other words, backhaul transport

[5] Some of these reactive and proactive OA&M tools were effectively demonstrated during the Carrier Ethernet world congress interoperability event 2008 organized by EANTC with the collaboration of the MEF. During the event Ceragon platform was the first microwave radio solution to demonstrate wireless link with a fully integrated Ethernet switch supporting OAM capabilities.

carriers will need solutions that can support both TDM (E1/T1) services and advanced Ethernet services.

Let us look for a moment at how the issue of supporting legacy services is addressed in wireless (microwave) mobile backhaul. In order to support a mix of legacy TDM services and Ethernet service over a single NGMN backhaul network operators maintain several options including the design of an all packet network using Pseudowire technique to handle the TDM. The advantage of Pseudowire is that it enables the operators to completely discard their TDM installed base. Yet, as we have discussed in item 2.3 above, Pseudowire requires a more careful planning and introduces latency. Another option, the so called hybrid or Native[2] approach, allows both TDM and Ethernet to be carried over a single microwave links. Though both techniques are valid the operator should take in to consideration issues such as system and network complexity, overheads and of course delay and delay variations.

Network Dimensioning and Scalability

Section 6.3.1 of the NGMN Alliance Optimized Backhaul Requirements document is aimed to illustrate possible NGMN implementations. Several use case scenarios have been considered including a set of different topologies (Star, Tree, Ring or Mesh) and different transmission technologies including wireless (e.g. Point-to-Point microwave) and wireline (e.g. Point-to-Point Fiber, xDSL). A possible implementation scenario is shown in Figure 4 and discussed further in the following paragraphs.

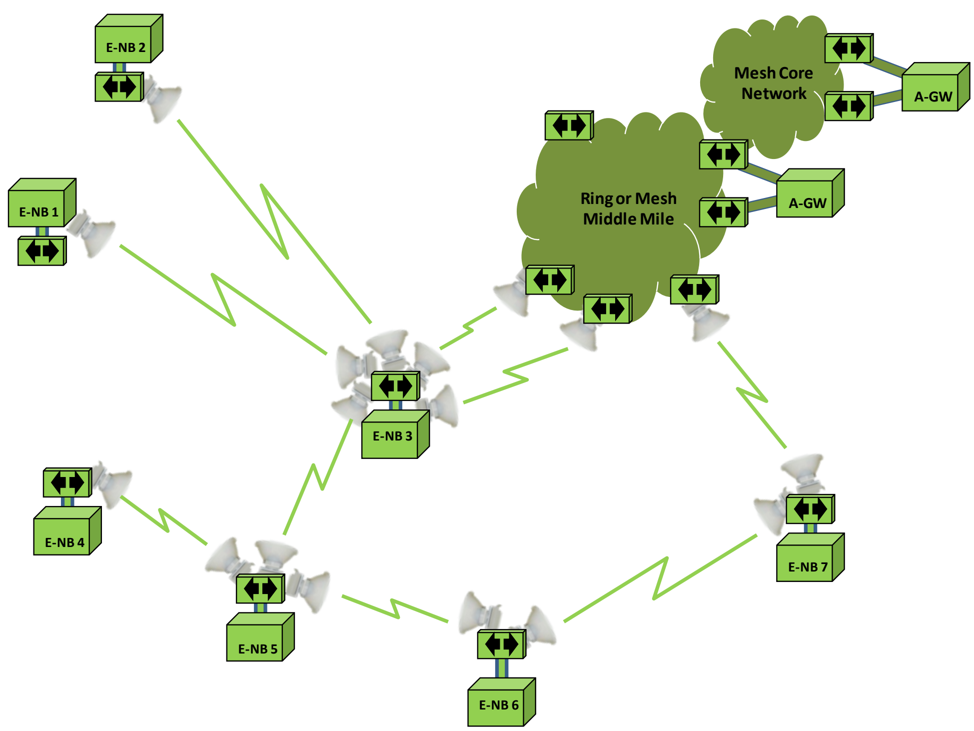


Figure 4: "Scenario-2" taken from the NGMN optimized backhaul requirements document

As an example for an NGMN network, 6 interfaces between e-NB and aGW (i.e. S1 in 3GPP LTE standard) and 20 interfaces between e-NB's (or X2 for 3GPP LTE) per e-NB could be implemented in a scenario where aGW's are deployed in the current 3GPP SGSN[6] or RNC[7] site.

One possible worst case scenario, depicted in Figure 4, considers aGW's deployed in current SGSN location and 8000 Micro/Macro e-NB's that are distributed in the following way: 5 Micro/Macro e-NB's per microwave chain, 20 microwave chains per "Metro Point of Concentration", 20 "Metro Point of Concentrations" per "Regional Point of Concentration" and 4 "Regional Point of Concentration" per aGW site.

To support this massive demand for connectivity where each e-NB may be connected to one or several e-NB's (i.e. X2 interface in 3GPP LTE standard) an auto-discovery mechanism may be used in order to reduce the operational effort (the exact protocol and mechanism to be used is pending further study).

The transport connectivity for X2 interface should not necessarily be physical Mesh. In Figure 5 below Enhanced services, such as Metro Ethernet Forum (MEF) E-LAN / E-Line support, could be used to enable the Ethernet switch to optimize traffic patterns between neighboring sites either over a single or over multiple EVCs. As an example, Ceragon's microwave platform integrates a layer-2 Ethernet switching functionality fully compliant with MEF-9 & MEF-14 standards for all service types (EPL, EVPL and ELAN). For network scalability the operator may apply logical separation between sub-nets using layer 3 routers.

[6] *Serving GPRS Support Node*

[7] *Radio Network Controller*

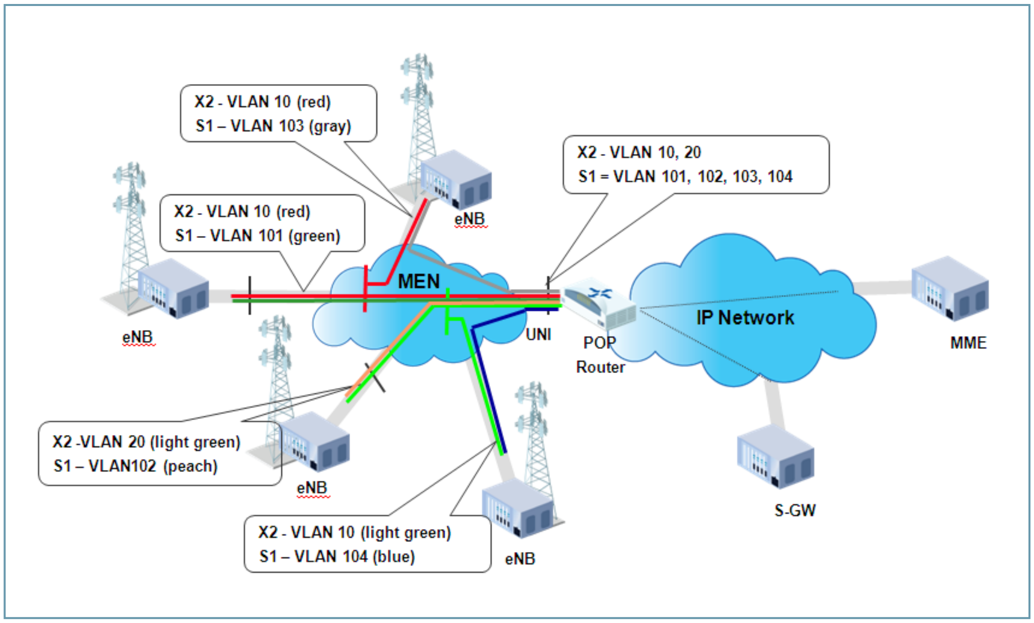


Figure 5: NGMN use case where C-VLAN's 10 & 20 are for the X2 interface (E-LAN) and C-VLAN's 101, 102, 103, 104 are for the S1 interfaces (EVPL)

NGMN Go Green - Footprint and Power Reduction

The drive to produce more energy-efficient products for next generation networks is not new. What is new is the increasingly intense focus by operators and vendors to reduce power consumption across all cell-sites.

Since operators must still support existing customers and legacy systems such as GSM, TDM, or even analog systems, the result may often be that three or more systems of different generations are simultaneously maintained at a single co-located site. Overlays create numerous problems for carriers ranging from pinched space requirements to a cascade of load demands in support systems such as air conditioners, backup systems and several types of backhaul technologies to support the different types of services (TDM/Packet). All this usually adds up to high usage of power. Not surprisingly operators are highly motivated to reduce the costs associated with upgrades in any way possible, with power usage reduction as a primary target.

The issue of power and footprint reduction has also driven equipment vendors to come up with innovative solutions. For example, a microwave system can feature an integrated Ethernet switch side by side with a TDM (E1/T1) cross connect – both drawing power from the same power source while optimizing footprint at the cell site. Such a solution, like the one offered by Ceragon, not only eliminates the need for external switches and/or TDM cross-connects, but can also displace PDH microwave links, further minimizing the overall footprint within the cell site. Thus, operators can leverage their wireless backhaul to build a converged network serving all types of services and deployment scenarios. An additional power-saving feature recommended by the NGMN Alliance (R88) would allows the system to automatically switch to the mode with the lowest possible power consumption when possible in accordance with current traffic load, environmental conditions and more...

Summary

The concept of NGMN will bring a significant change to the market in that it is set to be based on a single, shared, end-to-end packet transport network for voice and data for all LTE and NGMN radio access. NGMN backhaul solutions will need to handle much higher capacities than today. 50 Mbps per sector – or over 150 Mbps per base station - will require support for transmission capacity of peak traffic that amounts to over 100 times that of 2G networks. In addition, NGMNs transport network will be capable of efficiently supporting the QoS categories required to provide the highest possible user experience. To do so, advanced end-to-end management and monitoring techniques will need to be implemented.

Driven by the world's leading Operators, the NGMN Alliance has also defined a set of requirements aimed to lower system costs and operating expenditure (OPEX). The group additionally addressed "Green" issues such footprint and power reduction. Steps to carry out the NGMN Alliance requirements are already being taken by forward thinking system manufacturers

References

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Appendix A – Ceragon's Wireless Ethernet Backhaul Solution

Ceragon offers a family of high-capacity LTE-ready wireless backhaul solutions that answer the requirements set by the NGMN Alliance including:

- **Capacity**
  - FibeAir Ethernet microwave family of products covers the entire licensed frequency spectrum and offers a wide capacity range, from 10Mbps to 500Mbps (full duplex) over a single radio carrier, using a single RF unit.

- **Synchronization delivery**
    - Ceragon's synchronization solution ensures maximum flexibility by enabling the operator to select any combination of techniques suitable for the network. Combinations of the following techniques can be used: Synchronization using native E1/T1 trails, “ToP-aware” transport and Synchronous Ethernet.
- **Availability**
    - Ceragon wireless backhaul solutions several types of protection schemes in order to support the high availability requirements. The microwave equipment was designed according to carrier-class standards supporting redundant integrated carrier Ethernet switch and numerous redundant radio techniques. From a networking perspective the platform support ring protection based on Rapid Spanning Tree Protocol (RSTP) that assures path protection with fast restoration so that service interruption time will be within the requested range of 50ms - 250ms as specified in the NGMN alliance document.
- **Management**
    - Ceragon’s FibeAir® IP-10 was the first microwave radio with a fully integrated Ethernet switch supporting OA&M capabilities. This achievement was demonstrated at the Carrier Ethernet world congress interoperability event 2008 organized by EANTC with the collaboration of the MEF (http://www.eantc.com/events-showcases/archive-2007-2008/carrier_ethernet_world_congress_2008/intro.html).
    - Ceragon is continuing to develop its Management tools and features including the interoperability of its products with other vendor’s management tools as part of a bigger network concept called MAST™– Mobile Architecture for Service Transport which is a Multi-Vendor environment. Teaming with some of the industry’s leading players – including Cisco, ECI, RAD, Telco Systems as well as others
- **Support for legacy services**
    - Ceragon’s Native[2] (Hybrid) solutions allow both TDM and Ethernet to be carried over a single microwave links. Ceragon also supports Pseudowire technology for TDM transport over packet networks.
- **Scalability**
    - Ceragon’s FibeAir IP-10 features a unique, modular nodal solution to enable carriers to cost-effectively scale their backhaul networks. Multiple FibeAir IP-10 indoor units (IDUs) can be combined in a modular way to form highly integrated and fully redundant nodal configurations with an extended number of supported radios, TDM and Ethernet interfaces. Using this approach, any

tail site can be seamlessly upgraded to chain or node sites, fully re-using the installed equipment.

Footprint and power reduction

- Ceragon's FibeAir IP-10 features and integrated Ethernet switch alongside a TDM cross-connect - both drawing power from the same power source while optimising footprint at the cell site. An additional Ceragon is focusing on power-saving feature which allows the system to automatically switch to the mode with the lowest possible power consumption when possible in accordance with current traffic load, environmental conditions and more.

For more information please visit our web site: http://www.ceragon.com

ABOUT CERAGON

Ceragon Networks Ltd. (NASDAQ: CRNT) is the premier wireless backhaul specialist.

Ceragon's high capacity wireless backhaul solutions enable cellular operators and other wireless service providers to deliver 2G/3G and LTE/4G voice and data services that enable smart-phone applications such as Internet browsing, music and video.

With unmatched technology and cost innovation, Ceragon's advanced point-to-point microwave systems allow wireless service providers to evolve their networks from circuit-switched and hybrid concepts to all IP networks.

Ceragon solutions are designed to support all wireless access technologies, delivering more capacity over longer distances under any given deployment scenario.

Ceragon's solutions are deployed by more than 230 service providers of all sizes, and hundreds of private networks in more than 130 countries.

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