



MOBILE BACKHAUL EVOLUTION AND CONVERGENCE

E-SEMINAR WHITE PAPER

NEC's Vision for Mobile Backhaul presents the view of dramatic changes in transport network architecture over the next decade. These changes are driven by the new ways in which businesses and consumers will use mobile telecommunication networks in the future.

The explosion in demand for Mobile Broadband services represents a major growth opportunity for network operators who will increasingly look for new Mobile Backhaul solutions to deliver differentiated high quality services at optimal cost.

As the established market leader in Backhaul solutions NEC has a first hand view of market and technology trends for Next Generation Mobile Networks. In this white paper we explain the key trends in Backhaul network transformations.

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NETWORK TRANSFORMATION FOR MOBILE BROADBAND

Advanced Mobile Broadband services require a level of sophistication which is far removed from most of the networks today. Designed to carry voice and some data, existing networks are ill equipped to handle dynamic traffic flows and highly customised quality of service requirements of the future. Legacy technologies were designed for predictability and one-size-fits-all services. The time has come for a radical rethink of the network as a whole, and specifically Mobile Backhaul which is often an afterthought and a subsequent bottleneck. Backhaul is not just a cost problem; it is an integral part of a sophisticated engine delivering new business models and profitability.

UPGRADING THE MOBILE ACCESS NETWORK

The first priority in capturing the broadband opportunity is to provide more capacity and coverage in the access network. Current industry consensus points towards HSPA+ and LTE as the two coexisting radio access technologies to deliver capacities needed to fulfil user expectations. WiMAX will also have its place in the market, as DSL substitution in emerging markets or as niche application in public infrastructure elsewhere.

Overwhelming majority of traffic generated on mobile broadband is data. LTE and HSPA networks use IP transport as opposed to ATM and E1 transport on 3G and 2G access networks respectively. On the other hand current Backhaul networks are TDM based and dependant on the E1/T1 connectivity and as such are not suited for efficient transmission of data traffic. In addition, next generation RAN introduces a new flatter architecture in the Core network that will eventually cause the traffic to be more dynamically distributed in the transport network. This is why any RAN upgrade is intrinsically linked to the evolution of a Backhaul network. Backhaul has to evolve from TDM to packet based architecture in order to deliver economically efficient solution.

Technology	Standard	Data Rates	BS / Node B I/F
GPRS/EDGE (2.5G)	3GPP R97 (GPRS) 3GPP R98 (EDGE)	40Kbps/14Kbps 130Kbps/130Kbps	Voice & Data: A-bis over E1 / SDH 
W-CDMA (3G UMTS)	3GPP R99	384 Kbps/384 Kbps	Voice & Data: ATM over E1 / SDH 
HSPA (3.5G)	3GPP R5 (HSDPA) 3GPP R6 (HSUPA)	14.4Mbps/384Kbps 14.4Mbps/5.72Mbps	Voice: ATM over E1 / SDH Data: IP over MLPPP/E1 or FE 
HSPA+ (Almost 4G)	3GPP R7 3GPP R8	28 Mbps/11 Mbps 42 Mbps/11 Mbps	Voice & Data: IP over GE or FE 
LTE (4G)	3GPP R8 (All IP)	138 Mbps/37 Mbps	Voice & Data: IP over GE or FE 

1 RADIO ACCESS TECHNOLOGIES AND CORRESPONDING TRANSPORT INTERFACES

The issue for operators is to decide the timing and pace of their technology migration in the Radio Access Network. If an operator opts for a conservative approach and slow rollout there is a risk of missing the opportunity and losing competitiveness. On the other hand, the success of a more aggressive rollout will depend on the alignment of radio access and backhaul transport strategies.

The risk of not having joined up radio access and backhaul strategies is a failure to meet expectations of network users because of capacity bottlenecks. Another pitfall is in throwing money at the problem through wasteful over-provisioning of capacity, typically caused by the reluctance to replace legacy technologies with new more efficient solutions. Either way the result is ‘profitability black whole’ unless RAN and Backhaul strategies are developed in unison.

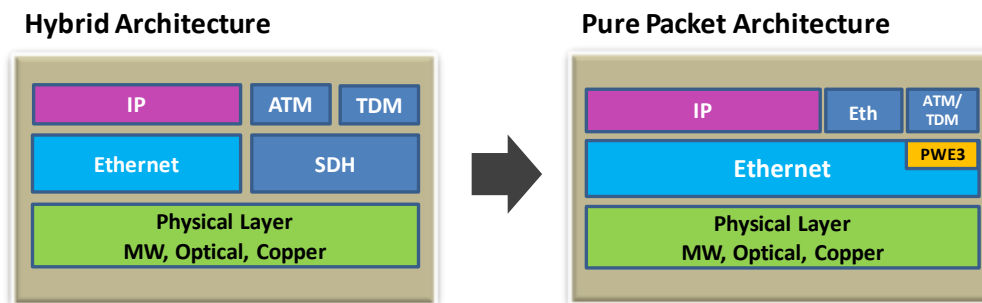
MOBILE BACKHAUL FOR LONG TERM EVOLUTION

Existence of different strategies for the rollout of Radio Access Network and corresponding backhaul deployment strategies may at first suggest divergent set of requirements that will be difficult to address with a common approach to backhaul transport. However, backhaul requirements are consistent between the two evolutions strategies described.

This convergence of requirements is due to the fact that regardless of the starting point today, all operators have the same end objective which is a LTE based network for mobile broadband. Related network evolution steps will be common and the difference will lie in whether all operators will experience all of the transformation stages or whether some can accelerate or side step one or two of the stages. Dominant operators with the legacy infrastructure have the most complex task ahead of them.

The challenge lies in the complexity of managing the transition to packet backhaul whilst maintaining existing high quality of legacy services. For many years to come Backhaul will have to accommodate not only HSPA+ and LTE but also to simultaneously provide transport solution for a full range of legacy RAN transport technologies.

With today's hybrid approaches packet data traffic is either carried encapsulated into TDM transport or alternatively it is transported separately over a public internet. Hybrid approaches of tomorrow will reverse the hierarchy by carrying TDM traffic encapsulated over packet based transport. And eventually 2G networks will be turned off allowing for the pure packet transport network for Mobile Broadband.

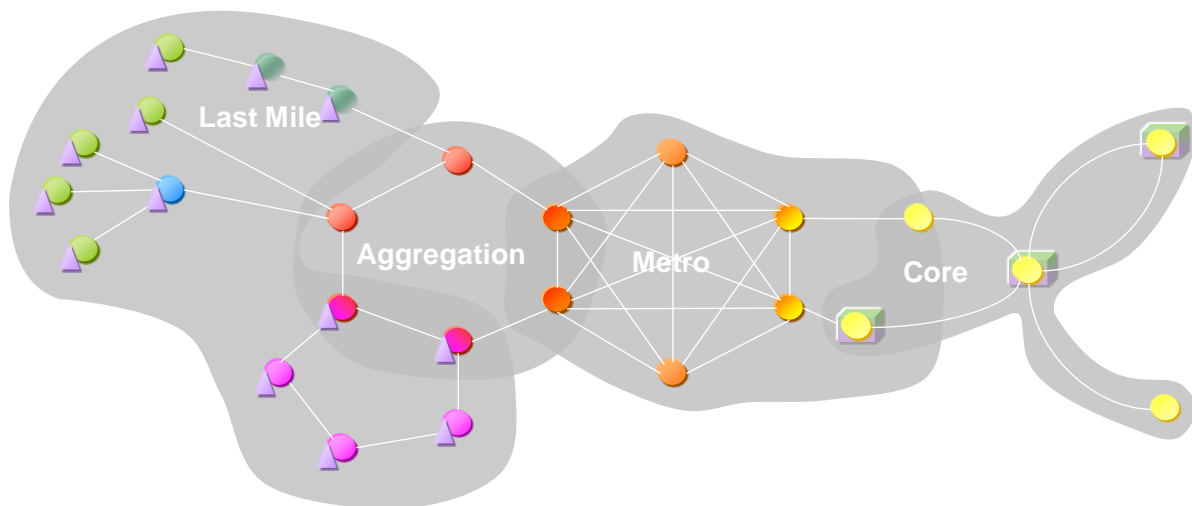


2 THE MIGRATION FROM HYBRID TO PURE PACKET PROTOCOL STACK

This gradual transition is the driving force behind key trends in Mobile Backhaul transport evolution. To understand these trends it is important to provide the technical definition of Mobile Backhaul network itself. Mobile Backhaul is the transport network that provides connectivity from Radio Access base stations (i.e. cell sites) to their corresponding control and switching elements located deeper in the core of the network.

Backhaul network spans from the Cell Site Transport Gateways, 'Last Mile' Domain, Aggregation Domain, through to the Metro Network Domain and ending with the Core Network Transport Gateways. Transport Nodes reside at the border of each of the domains and they provide traffic

management capabilities such as switching and performance monitoring. Backhaul network can use a variety of physical transmission technologies including optical fibre, microwave radio, copper DSL and occasionally satellite. There is more variety of physical transmission in the Last Mile and Aggregation domains with microwave radio having a majority share, whilst the Metro and Core networks predominantly employ high capacity WDM optical transmission.



3 MOBILE BACKHAUL NETWORK TOPOLOGY

Taking this definition of the Mobile Backhaul as the starting point, we can identify four overarching trends for its evolution over the next decade. Following are explanations of these trends.

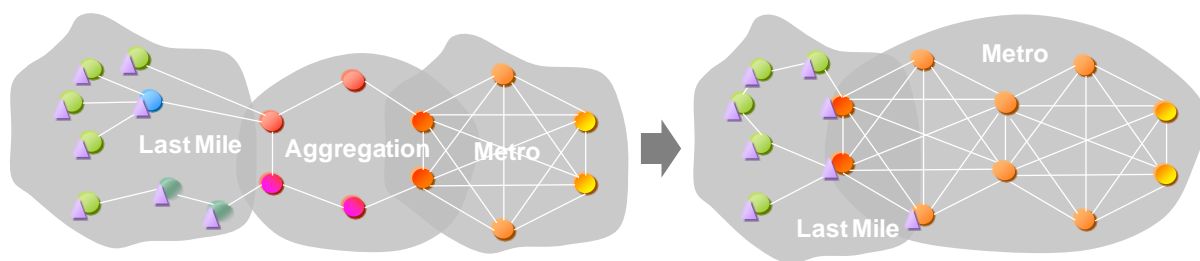
METRO AND AGGREGATION EXTENSION

Metro and Aggregation domains have different topology characteristics. Today's Metro networks naturally carry higher aggregated traffic volumes and therefore need more transmission capacity compared to the Aggregation network. Metro networks are also more advanced in the adoption of packet switching and mesh topologies. On the other hand, Aggregation networks have a more diverse mix of ATM/SDH and Ethernet supporting multi-layered services and ring topologies.

Inevitably, as packet data traffic continues to increase and dominate over TDM traffic, Aggregation domain will increasingly extend to the Cell Site Gateway, and in turn Metro Domain will extend further out towards the edges of the network. Last Mile connections will become increasingly shorter and in some cases will cease to exist altogether and RAN cells will be located on the Aggregation nodes.

The reason, and the advantage, of the migration of Aggregation function closer to the Access network is to achieve aggressive statistical multiplexing of data traffic. Peak-to-mean ratio of traffic generated on a LTE network will be very high, which in turn could result in very poor utilisation of available network capacity if all links are designed simply for the sum of peak capacities from all the RAN nodes.

As an example, link utilisation in the first hop for 10MHz 2x2 MIMO LTE macro cell is estimated at 50%, dropping to 20% for 20MHz 2x2 nodes. If aggregation nodes are located far from the RAN, carrying these inefficiencies across the Last Mile network will quickly amount to high cost per megabit of traffic. Alternative to aggregation is to design access links for less than peak demand but this would jeopardise quality of experience for the network user.



4 METRO AND AGGREGATION DOMAIN EXTENSION

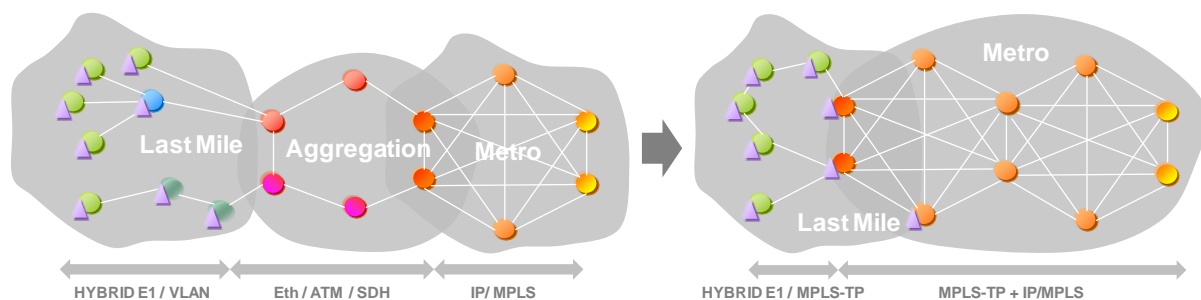
Locating the Aggregation node close to the RAN has another advantage in LTE backhaul. LTE network demands not only more capacity, but also lower round-trip latency (down to 10ms end user latency) and improved traffic path resilience. These requirements can only be fulfilled by changing the tendency to use long tree-and-branch chains in the Last Mile. These chains are often bottlenecks causing congestion and latency delays. The new Last Mile and Aggregation network will have fewer tree-and-branch hops, and ring topology will be extended to improve traffic resiliency closer to the network edge..

ENHANCED EFFICIENCY WITH PACKET BACKHAUL

As highlighted earlier in this paper, TDM transport is inherently inefficient in carrying the traffic which is overwhelmingly packet data. This is due to rigid framing structures of E1, ATM and SDH protocols that cannot encapsulate variable data frames without a significant loss of capacity. It is difficult to fit square pegs in round holes and the only long term solution is to employ packet transport based on Ethernet and MPLS.

However, ATM and SDH are highly engineered technologies that allow a great deal of traffic management and network control. Ethernet is less mature in this regard which raises the challenges of how to achieve the same level of quality on packet transport whilst not increasing technology costs. This is why a particular attention needs to be paid to Ethernet/MPLS synchronisation and timing, operations and maintenance (OAM), quality of service (QoS), resiliency and security.

Due to network economics, the main demarcation point in the evolution from TDM to packet transport will be the first Aggregation node described in the previous section of the paper. From this node towards the RAN we will see a hybrid approach between two types of transport. And from the Aggregation node towards the core we will see consolidation of transport based on Ethernet and MPLS. This is why an Aggregation node needs to act as the gateway between two approaches by supporting both hybrid and pure packet transport.



5 MPLS PACKET BACKHAUL MIGRATION

The hybrid transport needs to be applied in the Last Mile due to bandwidth constraints. Last mile links will remain limited in bandwidth not because of limitations in maximum transmission rates, but because fibre connectivity is CAPEX intensive, microwave radio spectrum is either not available or is expensive, and copper DSL has distance and performance limitations. Therefore in terms of transport in the Last Mile, using 'native' hybrid of E1s and VLANs is the most efficient approach.

The hybrid approach, simultaneous direct modulation of the physical bearer using both transport technologies, utilizes more of the available bandwidth compared to using Pseudo-Wire Emulation (PWE). With PWE data traffic is carried encapsulated within the TDM frame, or vice versa, TDM traffic is carried encapsulated within the packet. In each case the resulting deep 'protocol' stack consumes precious bandwidth and presents the bottleneck risk.

During initial stages Last Mile hybrid will consist of E1s and Ethernet VLANs. VLANs will need to be enhanced with Ethernet OAM in order to monitor performance whilst the additional benefit of keeping E1s in Last Mile links is to provide proven reliable sync to the base station.

Last mile Ethernet links will gradually migrate from VLAN to MPLS-TP in order to enable consistent path management between the Last Mile, Aggregation and Metro network domains. MPLS-TP uses the same Label Switch Path (LSP) techniques for provisioning as in the MPLS Metro and Core networks. Using the same approach will result in a unified, end-to-end path provisioning and management across whole of the Backhaul, simplifying the networks operations and thus reducing the costs. E1 circuits will be decommissioned only if bandwidth constraint is removed or 2G/3G is switched off, neither of which are likely to happen for the best part of the decade. By this time packet synchronisation technologies should be mature to deploy in the network cost effectively and in large volume.

The migration to packet in the Aggregation and Metro will be different to the one in the Last Mile. Today there are large numbers of ATM and Next-Generation SDH solutions in the Aggregation and Metro networks, originally deployed to support 3G and 2G RAN over the previous decade. By now these networks are beginning to age and are becoming more expensive to run from the perspective of power and footprint efficiency. Also in some cases the capacity is running out and with increasing data traffic on the network incremental upgrades are becoming less and less effective.

To reduce the Total Cost of Ownership (TCO) Aggregation and Metro networks need to be gradually refreshed and upgraded to MPLS based transport. There are two technology options available to operators, MPLS-TP and IP/MPLS, and the choice between the two depends on the trade-off between flexibility of IP/MPLS dynamic switching and OAM control and resilience of MPLS-TP. Both technologies bring strong PWE functionality and as such are well suited to support gradual migration from the legacy protocols.

	MPLS-TP	IP/MPLS
Service Model	P2P, L2VPN (VPLS)	L3VPN (most common), L2VPN
Transport Oriented	Yes	No
Transport Mechanism	Pseudo-wire (PW) over LSP	IP over MPLS / PW/LSP
Data Plane	MPLS	MPLS
Control Plane	Static (NMS), GMPLS (under proposal)	BGP, RSVP-TE, LDP, OSPF-TE
QoS Support	E-LSP/L-LSP	E-LSP/L-LSP
OAM & NMS	MPLS-TP	MPLS
Multicast	H-VPLS, IGMP Proxy/Snooping	IP Multicast
Synchronization	TDM/SDH, Sync Ethernet, 1588v2	Application Specific
Protection	MPLS based	MPLS based

6 MPLS-TP AND IP/MPLS TECHNICAL COMPARISON

As it provides high level of OAM capability analogous to ATM and SDH, MPLS-TP is the logical choice for the network wide deployment acting as an underlying connectivity protocol. On the other hand IP/MPLS provides more routing intelligence and will be tactically deployed in the selected points in the network to support routing functions of LTE described in the next section. Another key advantage in the selective use of IP functionality is that it reduces equipment complexity and therefore reduces power and footprint consumption across the network.

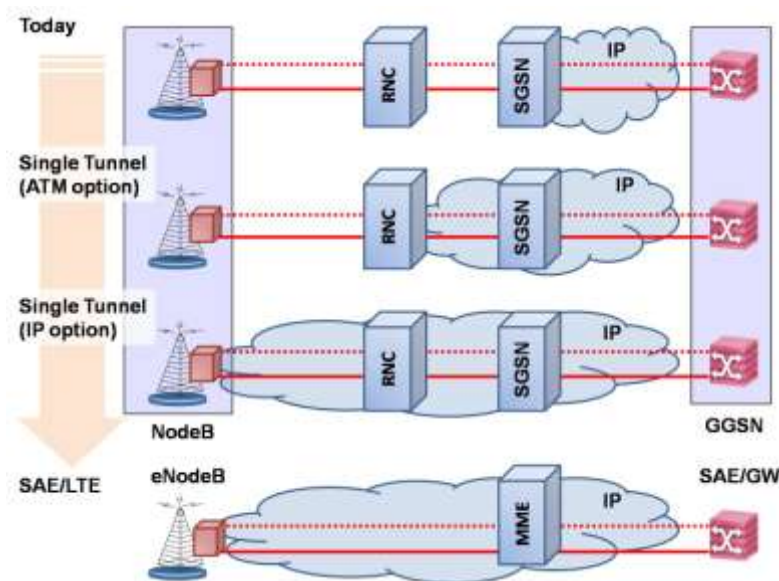
Previously mentioned stringent latency demands of LTE also apply to Aggregation and Metro domains, and by removing TDM protocols the need arises for the new synchronisation and timing solutions. As it has been extensively documented in the industry forums, IEEE 1588v2 and Synchronous Ethernet technologies have been developed for this purpose and in combination they will address the requirement of the next generation backhaul. However, both of these technologies will need to continue to be proven in the large scale carrier networks before being widely adopted.

The last but not the least, one of the fundamental differences between legacy and packet based network is in the move from fixed to non-deterministic bandwidth planning and management. This flexibility of packet based transport allows for a much finer and more flexible differentiation in the Quality of Service (QoS) provisioning on different traffic flows. Therefore there is a requirement for a powerful set of policy-based QoS capabilities to release and monetise the value of differentiated bandwidth services.

In a typical scenario, high availability bandwidth will be allocated to voice and signalling traffic, followed by real time services, with other data traffic taking the lowest priority.

TRAFFIC REDISTRIBUTION WITH LTE EPC

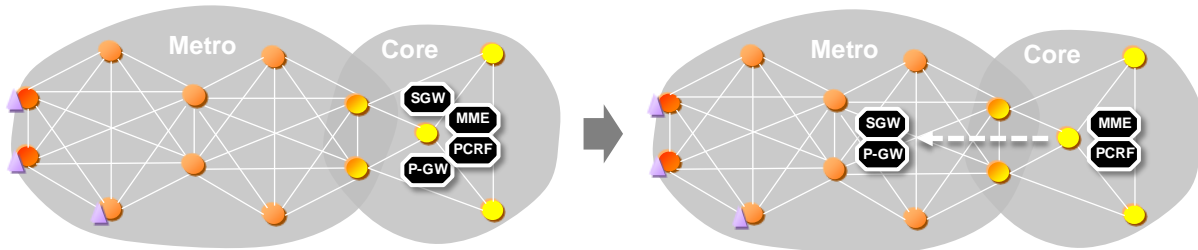
Architecture of the Mobile Core network is changing in two ways. Firstly, LTE Evolved Packet Core (EPC) employs a much flatter architecture with IP transport, in contrast to the tiered architecture of 3G with RNC and S/G-GSN hierarchy and ATM transport. In LTE, the communication between the access nodes, enhanced Node Bs (eNBs), and EPC functions will take place over the S₁ interface which is analogous to the cascade of Iu interfaces in 3G UMTS. New to LTE is the introduction of the X₂ interface for control data communication between neighbouring eNBs. As a result, some of the control traffic in LTE will be routed across the transport Aggregation node without traversing to and from the Core transport network.



7 MOBILE CORE NETWORK EVOLUTION

Secondly, the four functions that comprise EPC (SGW, PDN-GW, MME and PCRF) can be physically separated and relocated in a distributed manner out of the transport Core network and into the Metro transport network. Moving two gateway functions SGW and PDN-GW, jointly known as SAE-GW, closer to the edge of the network would result in a smoother distribution of traffic across network domains which in turn would help reduce latency and the need to provision ultra high capacity in the

Core network. Whether these benefits can be realised will depend on cost-of-ownership economics of the EPC equipment.



8 SAE-GW TRANSPORT NETWORK MIGRATION

Both of the EPC change trends point to some level of IP routing in the transport network. If the traffic on the X2 interface becomes high in volume, or if it does become advantageous to decentralise the EPC then the Backhaul transport will need to provide a higher level of IP routing functionality and IP data security closer to the edge of the network.

CONTINUOUSLY INCREASING CONNECTIVITY AND CAPACITY

Gradually growing capacities in the radio access network and further convergence of mobile and fixed broadband Backhaul will mean that more and more capacity will be needed all the way from the Transport Access Gateway through to the Transport Core Gateway. The choice of the transmission technology to address this demand for capacity is based on the economic balance between the physical top-line throughput and the flexibility of deployment. Due to different scaling in the throughput per number of links, the trade offs vary between the Last Mile, Aggregation and Metro domains.

		LAST MILE			AGGREGATION			METRO		
		Ca	F	Co	Ca	F	Co	Ca	F	Co
Wireline	Optical WDM	√			√	√	√	√	√	√
	Copper DSL			√						
Wireless	Microwave	√	√	√	√	√	√			
	Millimetre Wave	√	√	√	√		√			

9 PHYSICAL LAYER TECHNOLOGIES (CA = CAPACITY, F = FLEXIBILITY, CO = COST)

In choosing the type of transmission, or physical layer technology, fibre is without doubt the ultimate solution for next generation networks as it provides unlimited capacity and low latency. However it is expensive and slow to install, particularly in the Last Mile where the business case becomes favourable only for very high bandwidth demands.

Until the Last Mile fibre becomes commercially viable, DSL technology is available as the other wireline option. But DSL is a short lived choice due to its inherent limitations. Bonded copper solutions improve the performance of DSL but even then the capacity and reach of DSL will only be sufficient as a medium term workaround.

Wireless, including both micro and millimetre wave radio, will continue to offer the best value as the transmission technology because it is more flexible and faster to deploy compared to wireline options. Microwave is the dominant solution in backhaul networks today and next generation radio allows relatively seamless upgrade on existing infrastructure for capacities of up to 1Gbps.

As an overall trend, capacity upgrades in Aggregation and Metro networks will be in the form of upgrades of optical line transmission rates to 1Gbps and 10Gbps, and the transition from C-WDM to D-WDM. Nearer to and within the Last Mile microwave radio will continue to command a major share of deployments thanks to its flexibility of deployment. There will be some adoption of millimetre wave in the geographies where the microwave spectrum becomes congested. Copper lines will in parts be upgraded to VDSL but ultimately will be replaced by fibre WDM-PON.

In general, Last Mile connectivity will continue to be a major battleground for the operators because of its exceptionally high capex caused by the cost of civil works and strict demands in local market regulation.

FAST, FLEXIBLE AND COST EFFICIENT BACKHAUL FROM NEC

Mobile Backhaul is critical to the success of Mobile Broadband. Popularity of smart devices, mobility and web applications will continue to increase data traffic in the network. The networks will converge towards all-packet transport layer with mesh topologies gradually extending across all domains from

the core to the access network. Physical connectivity and capacity will remain a challenge due to high levels of up front investment needed and network sharing will continue to be adopted.

All of these changes represent unique business opportunity for network operators who will increasingly look for new transport solutions to deliver high quality services at optimal cost. Whilst the complexity and range of requirements are daunting, NEC is at the forefront of networking technologies with an insight and understanding needed to provide new solutions. NEC's vision of Backhaul Evolution and Convergence reflects these evolving requirements and it guides our technology development.

Based on our vision of future evolution and convergence in Backhaul, NEC's solutions have been created to answer the need for advanced products and services needed to plan, build and operate profitable backhaul networks. This is a broad proposition that explicitly seeks to address full set of operator needs: technical, operational and commercial. The risk of investment is reduced with long platform lifecycles based on flexibility and smooth upgradeability. Designed with the best engineering quality these advanced products confirm NEC as the trusted partner to help network operators deliver customer satisfaction and profitability for any backhaul migration challenge.

- The end -