White Paper

Demystifying LTE Backhaul

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White Paper

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Introduction

Long Term Evolution (LTE), developed by the Third Generation Partnership Project (3GPP), is the term used for a high-performance Fourth Generation (4G) technology and network architecture. The objectives of LTE are to increase network capacity and throughput by enabling greater speeds with lower packet latency. This allows the growing field of wireless communications to support multimedia applications and enable true wireless broadband technology.

LTE is based on a completely new concept in mobile networking which simplifies the architecture while increasing connectivity. An LTE implementation produces a more efficient and flexible network, easy to deploy and operate. Adopted by both GSM and CDMA operators, LTE is the next evolutionary step for today's deployed 3G networks, whether they are based on wideband CDMA (W-CDMA), High Speed Packet Access (HSPA), and HSPA+. As such, LTE is expected to become the first unified global standard for cellular communications.

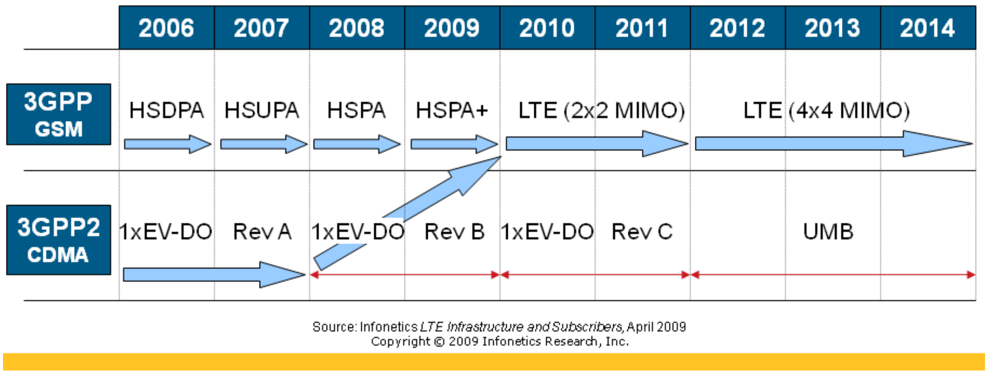

Figure 1: Cellular network evolution

What Does it Take to be LTE-ready?

LTE promises faster data rates at lower cost, improved spectral efficiency with reduced latency, and flexible channel bandwidth. To achieve these goals, LTE specifications deal with network elements (NEs) beyond the air interface. Most important and the key to LTE, is the simplicity of dealing with only one network protocol in an all-IP network while championing a flat packet-based architecture that eliminates separate controllers such as BSC and RNC devices.

LTE implementation significantly impacts every aspect of network design and operation. Network operators need to develop a comprehensive end-to-end (E2E) network architecture, from cell site to core, that can work with and take advantage of all the benefits of the new LTE standard while simultaneously remaining capable of optimizing legacy 2G and 3G service delivery. Networks must support the complete range of technologies, services, deployments, and migration paths.

This paper focuses on various aspects of network infrastructures and how they are affected by LTE implementation.

From Hierarchical to Flat Infrastructure

Traditionally, cellular networks such as 2G and 3G are hierarchical in nature. Base stations communicate with their respective controller (BSC or RNC) over a backhaul network. The controllers are connected to the core elements over the backbone network (packet core through Serving GPRS Support Nodes (SGSNs) and voice core through Mobile Switching Centers (MSCs)). There is no direct communication between the base stations and the core elements.

LTE defines a network architecture that eliminates the controller. Controller functions are redistributed to the core and the new eNB base stations (terminology for LTE base stations). A logical interface between eNBs, the X2, allows communication between base stations during handovers. eNBs are also connected through two different S1 interfaces to the Evolved Packet Core (EPC): the S1-MME to the Mobility Management Entity (MME) and the S1-U to the Serving Gateway (S-GW). MMEs handle authentication and signaling aspects of the mobility management control plane. S-GWs terminate the user plane traffic. eNBs may be connected to a pool of S-GWs and MMEs, configured as a many-to-many relationship between MMEs/S-GWs and eNBs.

The following figure taken from 3GPP TS 36.300 illustrates LTE network architecture.

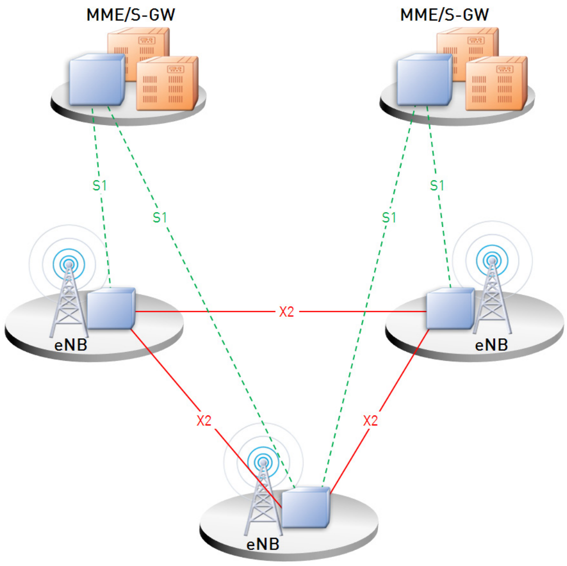

Figure 2: Overall LTE architecture

LTE's flat architecture model enables a wide range of options for network topology design, ranging from a variation of simple traditional hub and spoke architecture to full mesh topology. Alternatively, network operators can select points of connectivity between adjacent nodes for a partial mesh topology. This reduces the pressure on core nodes without the higher traffic flow complexity and load of a full mesh topology.

LTE networks can be implemented with either Layer 2 or Layer 3 VPNs, since LTE establishes the standard of network behavior (QoS, security, synchronization, etc.) while leaving the implementation details up to the network operators. Network operators are free to tailor the network architecture to their unique set of circumstances, balancing factors such as cost, management complexity, location, traffic patterns, scalability, and delay. For example, infrastructure in crowded urban areas with high traffic loads requires more direct connectivity between base stations compared with infrastructure in isolated rural areas with remote hub sites.

LTE's flexibility enables load balancing through the use of pooled resources. A virtual pool of MMEs supports load sharing across all participating MMEs. It also improves network resilience since the MMEs can be dispersed geographically across a large area.

Some implementations for LTE backhauling networks are described here.

- **Hub and Spoke Topology**: The following figure illustrates a network architecture in which the EPC elements are collocated in a centralized location. An E-Line connects each base station to the central site. This architecture is very similar to a traditional hub and spoke 2G and 3G backhauling infrastructure.

  This type of architecture is typically applied when there are only a limited number of subscribers. It could also appeal to operators that initially cannot justify a distributed deployment but can move on to a mesh topology when the number of subscribers and services increases.

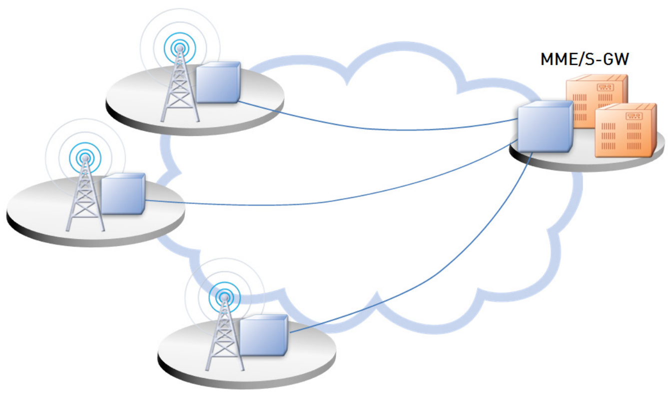

Figure 3: LTE architecture with hub and spoke topology

- **Full Mesh Connectivity**: The following figure illustrates a network architecture that uses full mesh connectivity to enable direct any-to-any communication. Each eNB is connected to the respective controllers and to each neighboring eNB via E-Line or E-LAN service.

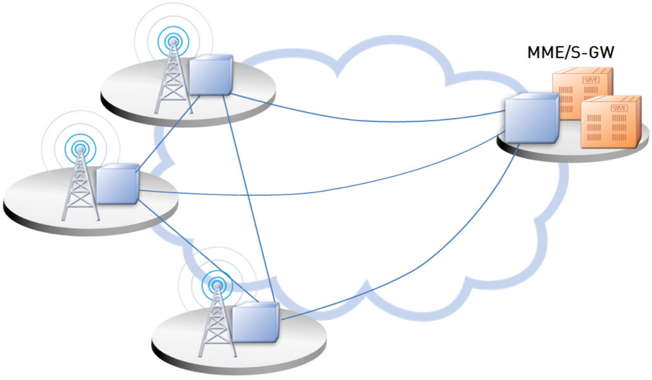

Figure 4: LTE architecture with full mesh topology

- **Connectivity via Hub**: The following figure illustrates a network architecture that uses a hub and spoke configuration in the access region up to a Layer 2/Layer 3 aggregation point. At that point traffic is aggregated towards the core while also enabling the associated X2 connectivity.

  In *Backhaul Evolution Strategies for LTE Operators,* Heavy Reading summarizes the debate between Layer 2 and Layer 3 as follows:

  > *Whereas the relative pros and cons associated with deploying a Layer 2/3-based backhaul can be considered objectively, the reality on the ground is quite different. On the ground operators have to map these theoretical debates onto the reality of their current legacy network and the available budget for investing in new IP-oriented skill sets. The operator with a lot of IP-trained personnel in its transport group has a lot more latitude to consider a fully dynamic, fully meshed, IP backhaul based on IP/MPLS with LTE in mind. By contrast, the operator that has very little by way of IP-savvy people running its backhaul network is a lot more likely to take fright at the prospect of a Layer 3-based backhaul. Instead, it is more likely to prefer the greater familiarity, and as they see it, the greater simplicity, of a Layer 2-based [infrastructure].*

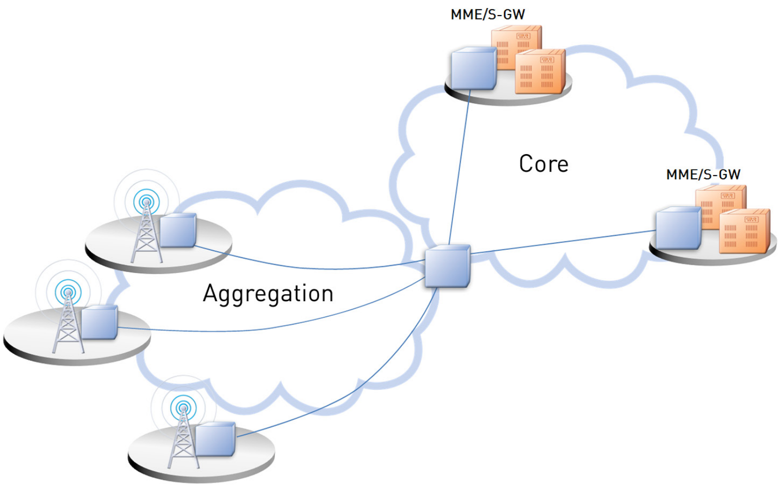

Figure 5: LTE architecture with hub-based connectivity

Scalability to Match Expanding Consumer Demands

Mobility has reached new heights, with consumers expecting the same types of service from their cell phones as they receive on their home computers. Voice services are only a small part of this. Data services, like streaming video, Web surfing, and peer-to-peer networking have opened up a whole new world for the consumer. Greater bandwidth, the latest technology, lower cost, faster speed, enhanced data services — expectations are that the whole user experience must be richer, even as it becomes cheaper.

LTE networks are able to meet the demand for massive bandwidth capacities engendered by multiple services. Base stations may reach peak rates of 1000 Mbps in the future, a huge increase over the current 2G/3G capacities. However, the average load capacity that is actually required is a function of many different real-world factors. For example, the number of subscribers, the capabilities of their mobile devices, the licensed spectrum available, the network topology, the spectral efficiency, even the speed with which subscribers are moving, all affect the average load at a cell site.

Network operators require an infrastructure that can efficiently handle the average load today as well as scale up to the maximum load required tomorrow. Smooth scaling capabilities are essential for operators who want to reduce CAPEX.

Scalability applies to more than just bandwidth capacity. It is a critical factor in many aspects of network architecture and implementation:

- **Services**: To provide more capacity at less cost, networks are migrating from TDM-based services to Ethernet transport protocols, a natural fit for the new packet-based high-bandwidth applications demanded by consumers. While native Ethernet support is essential for the latest multiplay service standards, the network infrastructure must continue to provide legacy 'bread and butter' TDM-based services to the existing client base. No network operator is going to eliminate existing infrastructures and risk losing the clients that they serve. The all-IP networks of tomorrow must be able to integrate with and support legacy 2G and 3G network infrastructures.

- **Capacity**: LTE base stations may reach peak rates of 1000 Mbps in the future, two orders of magnitude beyond today's 2G/3G. Pay-as-you-grow architecture is essential to avoid paying today for technologies and features that will be required only in the future.

- **Data Processing:** With the wide range between average and peak data traffic loads, network operators must find a balanced approach that optimizes traffic management for average loads while also handling peak loads efficiently. Sophisticated scalable MPLS, Layer 2, or Layer 3 capabilities must be activated in various network locations to optimize traffic load and network resource utilization while maintaining required end-user satisfaction.

- **Optical and Microwave Technology**: The ultra-fast, ultra-high-capacity networks of tomorrow will require the latest in cutting edge technology to actually provide the capacity and speed of which they are capable. These include WDM or ROADM technology to enhance fiber capacity, hybrid or pure packet microwave radio equipment to increase the bandwidth provided over the air, and PON access infrastructures to increase last-mile wireline capabilities. The network infrastructure itself must be able to integrate and grow from legacy equipment and protocols to broadband technologies, while enabling operators to leverage their current infrastructure to the maximum.
- **Core Intelligence Distribution into the Backhaul**: Service control, policy enforcement, and mobility management entities are all part of the LTE EPC. Most likely, initial rollout will centralize these entities and form a traditional hub and spoke backhauling architecture. However, as LTE service picks up, various EPC elements will need to be pooled and/or distributed to reduce the burden on core elements and increase network efficiency. Distribution of the core elements is associated with new logical connectivity topologies that support new eNB-core relationships. The backhaul infrastructure design must be flexible enough to accommodate this change when required.

A pay-as-you-grow architecture, smoothly scalable in every respect, is essential to avoid implementing and financing technologies, features, capacities, and capabilities that will only be required in the future.

Enabling Highest Quality of Service

Mobile networks that add real-time performance-sensitive multiplay data services to their business plan must be able to provide the high quality of experience (QoE) and stringent QoS consumers have come to expect.

LTE networks must be able to support multiple classes of service (CoS) with guaranteed QoS and equitable traffic distribution. The appropriate level of service must be provided consistently, and on an end-to-end basis, across multiple network regions, regardless of the complex mix of technologies and protocols along the way. For an optimal user experience with the most delay-sensitive applications, strict SLAs must be met. Effective QoS is also essential to achieve the low latency requirements of LTE.

Effective traffic engineering and traffic management through IP-MPLS/MPLS-TP, synchronized for both TDM and packet traffic, are essential to support differentiated mobile, business, and consumer services over an IP/Ethernet transport network. SPs must be able to design MPLS tunnel paths with directed traffic flow for optimal resource utilization, maximizing throughput while minimizing congestion.

LTE's flat distributed architecture enables tighter integration of the transport and mobile layers, making it possible to offer enhanced QoS that is more closely tailored to the customer profile (usage, location, devices, etc.) as well as coordinating network resources and load. SLAs can more exactly be tailored to each subscriber, offering a personalized selection of tiered service level options that balance price and performance. With accurate usage data, operators can optimize their fair-use policies, enabling enhanced resource allocation among subscribers. A much richer customer experience is ensured and network resource utilization is optimized, leading to a lowered OPEX.

Collecting customer usage data on a network-wide basis also provides a valuable source of intelligence for network operators. This enables accurate planning of new business models and network services.

Network Evolution: Becoming a Total Communications Provider

The world of telecommunications is driven by changes in consumption patterns. Telecommunications is moving from voice PSTN to VoIP, from TDM leased lines to Ethernet VPNs, from TDM-based 2G and 2.5G mobile networks to 3G IP to 4G LTE networks, and from simple best effort high-speed Internet access to advanced multiplay networks offering mobile as well as fixed-line service for small and medium businesses (SMB) and home use. Today's challenge is to build an infrastructure that meets both today's and tomorrow's network requirements, maximizing bandwidth capacity while minimizing costs as it provides the highest standard of service over a dynamically changing network environment.

Many mobile operators see significant business opportunities in offering communication packages that also include consumer broadband and business services. In many countries there are significant opportunities for carriers that can deliver state-of-the-art Ethernet services to businesses or broadband services to consumers and SMB.

Figure 6: Service offerings of a total communications provider

Several options are open to mobile operators who want to become a total communications provider. They can use the traditional wireline methods, such as DSL or PON, or broadband wireless technologies, such as WiMAX, HSPA, or LTE, or utilize a combination of both these approaches.

The key word is convergence. Network traffic is evolving from mostly circuit-switched TDM-based to predominantly Ethernet packet-based. Leading analysts believe that the most cost-effective solution to address this shift lies in converged packet optical transport capabilities that simplify and modernize as they transition to NG all-packet networks.

While the ultimate goal is an all-IP pure-packet network infrastructure, network operators must be able to leverage their existing infrastructure as they begin to add LTE to the mixture. Networks must be able to migrate smoothly from TDM to Ethernet, from low rates to high rates, and from point-to-point or hub and spoke to many-to-many communications.

In a typical deployment scenario, network operators currently working with a 2G/3G infrastructure want to be able to leverage their existing infrastructure to the maximum as they gradually add new technologies and capabilities such as packet-based services, Ethernet microwave (MW) technology, and 4G LTE networking to the mix. With such a complex mixture of technologies, services, and infrastructures, operators require smooth scalability, easy interoperability, and reliable QoS and OAM mechanisms as they gradually migrate towards comprehensive E2E service provisioning across every technology and service configuration.

Another common approach includes designing new packet Ethernet-based carrier class architectures that function independently of any parallel TDM-based networks. Carrier Ethernet Switch Routers (CESR) are a key element in this architecture.

In both these approaches, the new or evolving network architecture must enable the introduction of new Ethernet and IP services while continuing to support legacy TDM services with the highest level of reliability and performance characteristics.

Service-enabling intelligence must be embedded in the infrastructure to enable the smooth introduction of additional services, such as IPTV and VPNs. Hierarchical QoS is also a must to guarantee and differentiate service offerings and thereby enable maximum revenue-generation for all services—new ones, such as LTE or IPTV, as well as traditional ones, such as GSM backhauling. Carriers must have the necessary flexibility to offer a mix of guaranteed and best-effort services, control jitter and delay, and apply treatment on a per-customer or per-service basis.

Carrier class packet infrastructures must support a wide range of OAM tools to facilitate network health monitoring and troubleshooting. These capabilities are essential for network operators committed to guaranteed service delivery.

Initially, the new infrastructure may support only packet-based services such as LTE backhauling or VPN Ethernet-based services to the business community. 2G and 3G backhauling can be added at a later stage as business needs dictate. For all of this to happen, the packet infrastructure must support synchronization, as explained in the following section.

Each one of these approaches includes advantages and disadvantages. The key is for every network operator to choose the approach that best meets their needs.

Synchronization

Mobile service is, by definition, a service provided while in motion. This type of service requires a series of 'in the air' handoffs that can be completed correctly only when the base stations and their controllers are fully synchronized to a common timing reference signal. Lack of synchronization can trigger failures in many different areas, including dropped calls, interference between channels, slow handover between cells, and speech clipping (loss of speech segments).

In a multitechnology context, synchronization becomes a significant issue. For example, while TDM is a naturally synchronous protocol, Ethernet is asynchronous by definition. Nevertheless, network operators must be able to provide consistent, across-the-network synchronization mechanisms or they will not be able to successfully support essential services, such as voice over packet infrastructures or call handover between cell sites.

Mobile backhauling is currently provided almost exclusively by SDH/SONET networks. Such networks provide reliable service transport and reliable frequency distribution. GPS-based systems provide phase synchronization if it is required. Currently, the combination of SDH/SONET systems and GPS as needed is considered the gold standard against which all newer backhaul innovations are measured.

With the introduction of packet-based infrastructures, new alternatives have been developed for network synchronization. Two of these are described here:

- **Synchronous Ethernet (SyncE)** is a powerful physical layer approach to frequency synchronization. SyncE provides an elegant effective solution to the lack of synchronization in traditional Ethernet. SyncE is based on the well-established SDH/SONET synchronization model, extended for Ethernet-based networks. It uses the physical layer interface to forward timing from node to node, similar to timing distribution in SONET/SDH networks. The SyncE solution is fully compatible with traditional Ethernet and is defined in ITU-T standards G.8261, G.8262, and G.8264.

  SyncE implementations can be augmented with Differential Clock Recovery (DCR) mechanisms to ensure proper reconstruction of each individual E1/T1 clock, similar to the construction of an independent E1/T1 clock in traditional SDH/SONET systems.

- **IEEE 1588v2** is a packet-based synchronization method that offers both time and frequency synchronization over an asynchronous packet network. IEEE 1588v2 is based on the exchange of timing packets to synchronize many slave/client elements to a master clock. IEEE 1588 implementations can be augmented with DCR mechanisms to ensure proper reconstruction of each individual E1/T1 clock, similar to the construction of an independent E1/T1 clock in traditional SDH/SONET systems. IEEE 1588 master-slave functionalities must be implemented at network edges. These implementations are independent of the underlying packet transport systems and can therefore provide synchronization over the existing infrastructure.

Depending on the specific LTE standard, LTE networks can work with both frequency and time synchronization mechanisms as needed. To address the different requirements of co-existing network architectures and configurations, effective synchronization capabilities should incorporate multiple options at multiple levels, such as SyncE at the physical layer and IEEE 1588v2 at the packet level.

E2E Network Management

LTE's flexible architecture model requires enhanced management capabilities that can handle a wide range of network configurations, working with a wide range of technologies and standards, on an efficient E2E basis. The network management system (NMS) must simplify network configuration and operation, support service provisioning over multiple layers and product lines, and enhance network functioning for optimal bandwidth utilization and efficient service.

Intelligent unified management systems provide benefits beyond simple network monitoring. Network policy enforcement helps optimize resource allocation while enforcing fair-use standards. Network planning tools help service providers analyze user traffic patterns, design new business models, and develop new services and applications.

ECI 1Net: Implementing a Network Today for the LTE of Tomorrow

ECI Telecom provides solutions tailored to the needs of each network operator and service provider for any context and environment. As a solution provider, we support the full network life cycle while balancing between:

- Retaining existing legacy network while implementing leapfrog strategies
- Designing a network-wide strategy which can cope with significant local variations
- Considering the long-term business strategy simultaneously with short-term objectives
- Building the capability for long-term growth without over-investing in the short term
- Retaining the flexibility to use the best backhaul bearer technology for any given deployment scenario

Since no two networks are exactly alike, a solution must be tailored within the context of the existing infrastructure, strategy, and business plan, and the availability and cost of alternatives.

A variety of product offerings combined with intelligent network design tools and consultancy services enable ECI Telecom to provide a pay-as-you-grow approach, maintaining a tight link between backhauling and networking CAPEX. ECI 1Net product offerings for wireless backhaul are illustrated in the following figure.

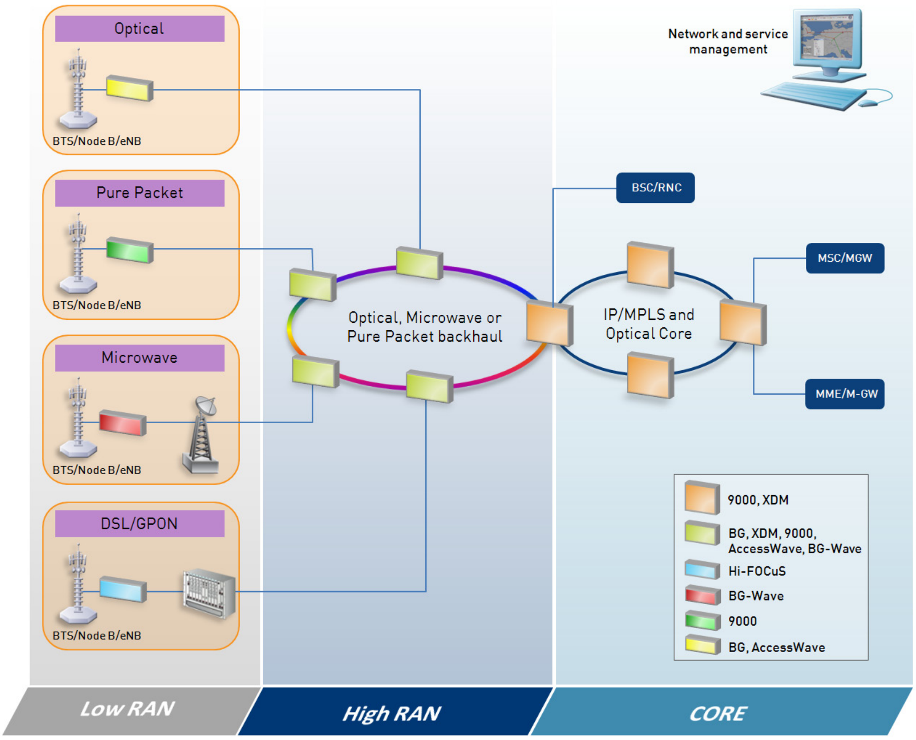

Figure 7: 1Net for wireless backhaul

ECI's solution enables network operators to utilize their existing infrastructure to the maximum while gradually building an overlay of pure packet-based infrastructure dictated by the specific business case and operator strategy. All NEs playing a role in the solution are managed by a single unified management system, assuring seamless network evolution.

This pragmatic approach enables network operators to cope with increasing traffic challenges through gradual controlled changes to infrastructure and minimal changes to operating procedures.

With our combination of advanced technology and down-to-earth attitude, ECI is the partner to take your network from 2G to 3G and beyond, from 3G ATM to 3G IP to 4G/LTE, and from a mobile backhaul focus to a converged service infrastructure. Whichever path is right for you, whatever your goals, ECI is the partner you need to build a more profitable transport network, one that works exactly for you.

The 1Net product portfolio is summarized in the following table.

Table 1: 1Net product portfolio

Backhaul technology	Cell site	Aggregation hub	Central hub
CESR	9300 family	9300/9600 family	9600/9700 family
Multiservice and WDM	BG family AccessWave	BG/XDM-100 family	XDM-100/ XDM-1000 family
MSAN (xDSL, GPON)	Hi-FOCuS family	Hi-FOCuS family	
Microwave (Hybrid and pure IP)	BG-Wave family	BG-Wave family	BG-Wave family

ECI provides seamless interworking across all these technologies and media, with all NEs controlled by the powerful LightSoft® multilayer management suite. Planning and design tools are available for enhanced network efficiency, with a user-friendly GUI that makes their use simple. A portfolio of professional services, including planning and software tools, completes the picture, making it possible to design and implement the network you envision.

About ECI Telecom

ECI Telecom is a leading global provider of intelligent infrastructure, offering platforms and solutions tailored to meet the escalating demands of tomorrow's services. Our comprehensive 1Net approach defines ECI's total focus on optimal transition to Next-Generation Networks, through the unique combination of innovative and multi-functional network equipment, fully integrated solutions and all-around services.

For more information, please visit http://www.ecitele.com.

1Net

1Net defines ECI's focus on facilitating our customers' optimal transition to Next-Generation Networks, through the unique combination of innovative and multi-functional network equipment, fully integrated solutions and all-around services

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