

## Migration to All-IP RAN Transport

### Overview

Mobile network infrastructures are quickly evolving as mobile operators expand beyond voice to bring high-speed services, available from IP networks and the Internet, to subscribers. The result is the emergence of networks that are becoming mobile versions of the high-speed Internet or a “mobile Internet.” As the leader in IP networking, Cisco is uniquely positioned to help mobile operators deliver what some analysts predict will be a 100 percent increase in mobile data traffic by 2013.

One of the key areas of focus for mobile operators in this transition time, as they rush to deliver robust mobile Internet services, is the Radio Access Network (RAN). Mobile operators must dramatically reduce the cost per bit in their current backhaul solutions while providing transport for third-generation (3G) technologies, the next wave of Long Term Evolution (LTE) technologies, and traditional technologies. The move to the all-IP RAN is the single largest infrastructure challenge facing mobile operators.

This paper explores the strategy recommended by Cisco for mobile operators to implement an IP RAN backhaul network that is independent of the RAN as they migrate to an all-IP RAN. This strategy allows mobile operators to cost-effectively provide the bandwidth, backhaul scalability, affordable transport, and intelligent network features necessary to support the Connected Life, the Internet-everywhere experience. As devices in the RAN evolve to support IP, Ethernet, and other transport types, mobile operators can replace portions of the RAN, such as radios, in a graceful and cost-efficient manner. A review of current and evolving RAN architectures and migration strategies follows, along with a review of carrier-class features necessary in the all-IP RAN, and finally relevant Cisco® products and technologies.

### The Changing Landscape

Today, the RANs of mobile operators are being stretched to their limits by the changing requirements of converged multimedia traffic and rising traffic volumes. RAN infrastructures are currently a mix of 2G and 3G technologies. GSM operators are using TDM as well as 3G technologies such as ATM, and more recently Ethernet and IP, to enable high-speed data and voice. Operators with Code Division Multiple Access (CDMA) architectures are using Multilink Point-to-Point Protocol (MLPPP) to bond multiple T1 or E1 lines for backhaul over native IP. And the WiMAX standard is also gaining momentum worldwide, delivering data using the 802.16e for fixed and mobile services.

Faced with the convergence of traditional and newer services, mobile operators are embracing IP and often Multiprotocol Label Switching (MPLS) due to the enhanced ability of these technologies to provision, scale, and manage multiple services. The move to IP has occurred in the network core outward but RANs have not been adapted to efficiently handle IP broadband traffic due to the high costs of replacing aggregation and cell site infrastructures. Many mobile operators are therefore looking into intermediate solutions to ease the cost of eventually evolving to an all-IP RAN.

As mobile operators migrate from 2G and 3G to native IP radio (such as LTE and WiMAX), the right independent backhaul transport can support it all and also serve as the foundation for the next generation to come. Supported solutions include current interim solutions in the RAN using existing T1 and E1 circuits, such as:

- T1/E1 TDM transport
- T1/E1-based MLPPP transport
- T1/E1-based ATM/IMA transport
- Ethernet transport over pseudowire
- Native IP

Along with many new, very compelling application services, LTE will usher in technologies that will drive bandwidth demands much higher in mobile networks while making networks more difficult to manage. For example, an LTE deployment is estimated to require 200 to 300 Gbps bandwidth at the aggregation site and 100 to 200 Mbps per cell site multiplied by thousands of sites. Cisco has anticipated these changes, providing traffic management, provisioning tools, and methods of scaling networks based on the intelligence and robust transport properties of the IP Next-Generation Network (NGN).

Interim RAN backhaul solutions, such as the Cisco Mobile Transport over Packet (MToP) solution that uses pseudowires, support a wide variety of transport options with clocking and many value-added intelligent features. These interim solutions allow mobile operators to utilize the radios they have without needing to upgrade them right away while relying on the many features of the IP NGN to provide the bandwidth, scalability, and intelligent traffic-handling features required. Later, when radio standards and vendor solutions have evolved to capably support the all-IP, end-to-end mobile network, mobile operators can upgrade their radios gradually without worrying about compatibility and stability issues and large capital investments.

### **The Importance of Maintaining Separate RANs and Transport Networks in the Near Term**

In the process of converting their RAN backhaul from circuit-switched to packet-switched solutions, many mobile operators are choosing to deploy Carrier Ethernet transport between the cell site and the radio network controller (RNC) and from the RNC to the mobile switching center (MSC) to provide higher bandwidth at a much lower cost. Cisco believes that the most cost-effective strategy is to first focus on building an independent transport network not bound by radio type or generation. Maintaining separate RANs and transport networks at this stage of the migration to all-IP mobile networks will enable mobile operators to:

- Benefit from a physical demarcation between Node Bs and the transport network for operations, administration, and maintenance (such as loopback and BER testing), including the monitoring of service-level agreements (SLAs)
- Use pseudowire or MLPPP interfaces to leverage all traditional equipment and technology in the RAN while providing robust, highly cost-effective broadband transport and backhaul utilizing the intelligence of IP and in some cases MPLS, including quality of service (QoS) and IP SLA features for a higher quality of experience
- Provide IP Security (IPSec) for traversing non-trusted transport networks
- Provide a logical point to deploy traffic shaping and traffic policing QoS policies to guard against congestion due to high-bandwidth mobile applications

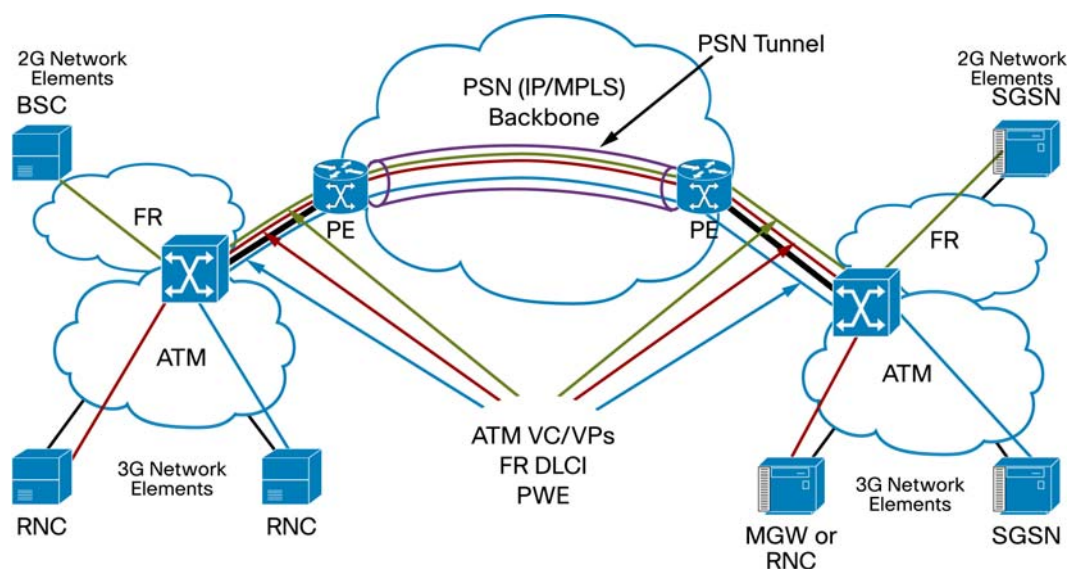
Several radio vendors have announced or will soon announce Carrier Ethernet interfaces on their 3G radio equipment installed in Node Bs and RNCs. These products will initially be based on pseudowire cards added to equipment chassis that will provide pseudowire interfaces between the RAN and the access network. Full integration of these enhanced Node Bs and RNCs with IP traffic – including WiMAX and the 3GPP LTE – is expected to follow. However, implementing an independent RAN transport infrastructure allows mobile operators to address bandwidth, transport, and backhaul cost challenges right away without the added pressure, CapEx, and complexity of replacing or upgrading all of the radios in the RAN infrastructure with products from different vendors that are at different stages of supporting IP traffic.

### Backhaul Approaches in GSM Networks

Wireline service providers have realized that moving to a packet-based network from a traditional TDM network addresses the throughput requirements from end users whose requirements have been growing exponentially. Packet networks have also provided a cost-efficient transport option as compared to traditional TDM networks. Packet-based transport has been extended into the mobile space where GSM/UMTS Release 4 transport networks address the core, inter-MSC, and inter-RNC connectivity in a capacity-driven and cost-efficient manner. Today this transport method has been extended to the RAN to migrate traditional transport methods, such as TDM and ATM pseudowire emulation edge-to-edge (PWE3), as well as to provide a means to recover clock over a packet network.

Instead of deploying a wide-area ATM network in the core, mobile operators have instead deployed converged IP or IP/MPLS core networks that are able to transport older traffic types along with new high-speed multimedia traffic using pseudowire encapsulation. In addition, operators have started the migration away from their monolithic MSCs toward a distributed model whereby an MSC server and media gateway replace the TDM voice trunks between sites with VoIP interfaces using Release 4 architecture, Figure 1.

**Figure 1.** Pseudowires Across Core to Tunnel Legacy ATM Interfaces Between RNC Sites and RNC and MSC Sites

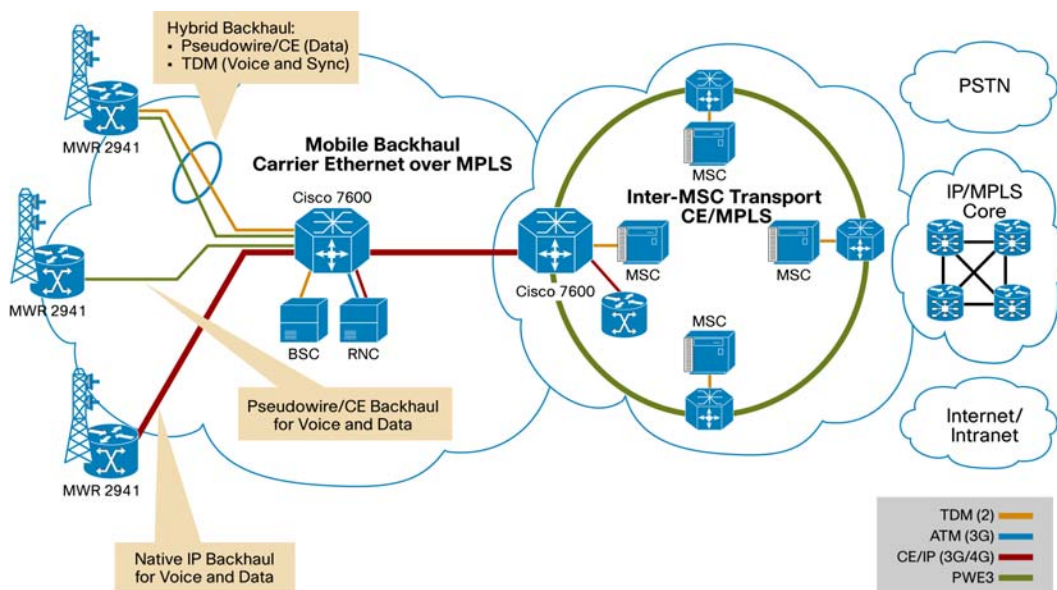


The ability to transport wide-area ATM interfaces over an IP/MPLS core, coupled with the adoption of Release 4 voice over IP (VoIP), have allowed operators to deploy converged core networks able to transport all traffic. This has further increased Cisco's importance among mobile operators.

For the RAN, Cisco has engineered the Cisco Mobile Transport over Packet (MToP) solution for RAN aggregation, which allows for an incremental, cost-efficient transition to a Carrier Ethernet RAN without service disruption. Cisco MToP uses MPLS technology to extend the packet-based core already deployed by many mobile service providers out to the edge of the network. MToP pseudowires – which are MPLS virtual circuit “tunnels” – aggregate and transport TDM, IP, Ethernet, and ATM traffic, as well as clock synchronization, from the RAN to the network core. The solution increases the bandwidth available for backhaul and other services by an order of magnitude but at a tenth of the cost per bit when compared to T1 and E1 service. It is fast and easy to deploy. Another benefit is that MToP uses the existing MPLS infrastructure for the highest levels of traffic grooming and network management, QoS, and the ability to assign classes of service.

With Cisco MToP in the RAN, ATM switches in the RAN can be removed. Cisco 7600 Series Routers equipped with Cisco Circuit Emulation over Packet (CEoP) shared port adapter (SPA) cards handle transport of all traffic types and interface with all traditional SONET/SDH equipment, Figure 2.

**Figure 2.** MToP in the RAN Solution in a GSM Network



The CEoP SPA module in the MToP solution lets the mobile operator take advantage of packet transport networks and the savings in operational expenses (OpEx) with next-generation Carrier Ethernet compared to traditional leased-line TDM services.

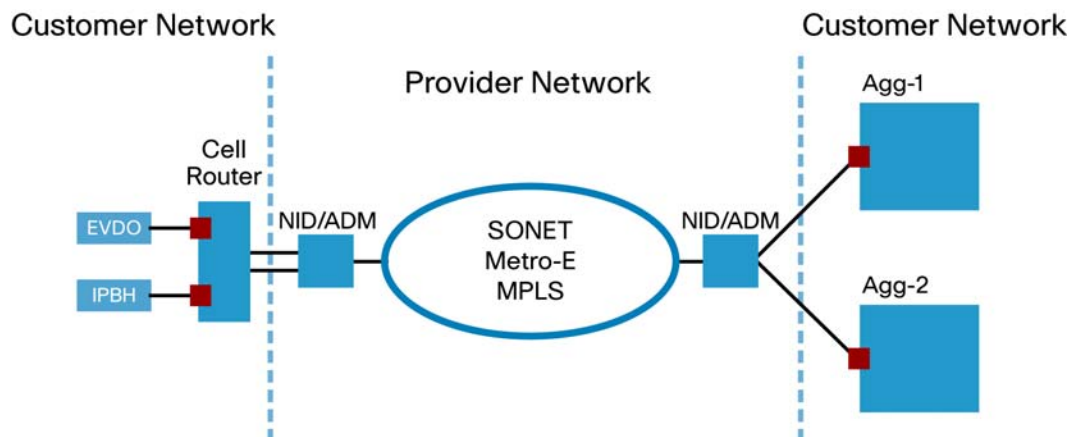
### Backhaul Approaches in CDMA Networks

CDMA operators are in the final stages of evolving the RAN to all-IP. Over the past few years RAN vendors have evolved their base stations to support IP interfaces. IP is used to natively transport both 1xRTT voice and EVDO data from the cell site to the mobile telephone switching office (MTSO). Today IP-based 1xRTT and EVDO traffic is transported over T1/E1 lines using MLPPP. The majority of these base stations can be easily upgraded to support a native Ethernet interface in lieu of a TDM interface.

In preparation for LTE, many CDMA operators are migrating their backhaul from TDM to Ethernet. This migration is fairly straightforward for operators who already have IP-enabled base stations. In this environment there is no need to support circuit emulation or TDM pseudowires, thus simplifying

the configuration of the RAN. The RAN can be based on simple IP routing protocol or static routing. The typical RAN configuration is shown in Figure 3.

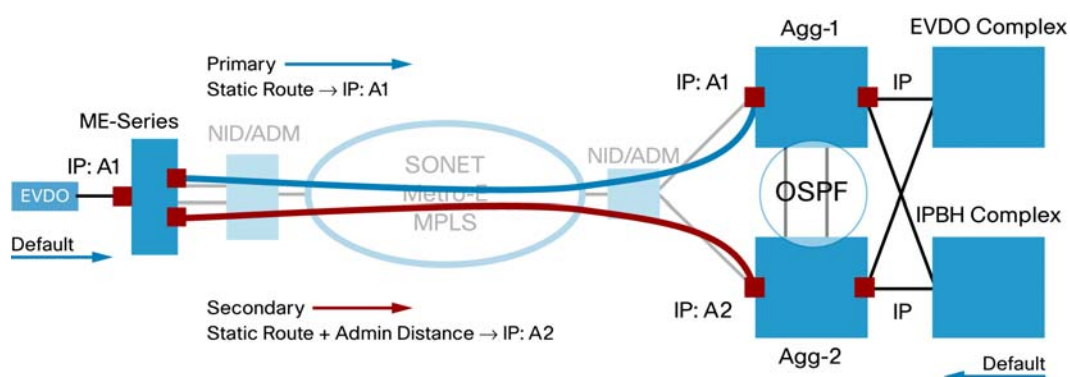
**Figure 3.** RAN Backhaul in CDMA Networks



The cell site router provides connectivity for the various IP-based radios in the cell site over User-Network Interface (UNI) ports. It also interfaces with the service provider network interface device on its Network Node Interface (NNI) uplink ports. At the MTSO, a pair of aggregation Layer 2 and Layer 3 switches aggregate all cell sites in a given area. The service provider is responsible for providing a logical connection from the cell site to both aggregation switches. This logical connection may be provided using various technologies, such as Ethernet over SONET, MPLS pseudowire, or Metro Ethernet Virtual Circuit.

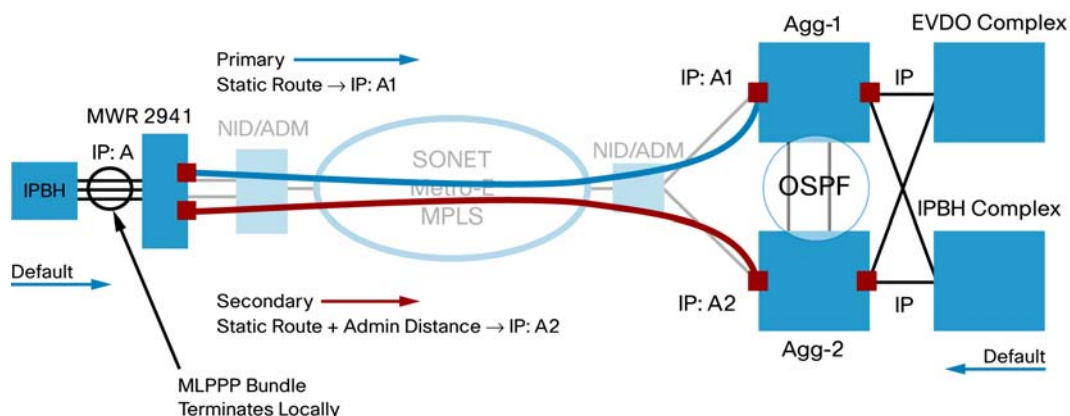
After a logical connection is established between the cell site and the aggregation switches, IP reachability can be configured, as shown in Figure 4.

**Figure 4.** IP Reachability Between Cell Site and Aggregation Switches



IP reachability between the cell site and the aggregation switches is established using static routing. Fast failure detection is accomplished by tying Bidirectional Forwarding Detection (BFD) to static routes. In the event of an aggregation node or link failure, BFD will trigger a switchover to the secondary path.

When a mobile operator is required to support TDM interfaces, the architecture shown in Figure 5 may be used.

**Figure 5.** Support of TDM Interfaces in a CDMA RAN

To support transmission over T1/E1 lines using MLPPP, the MLPP bundle is terminated on the cell site router. IP is used to route all traffic from the cell site to the MTSO. This approach provides a consistent all-IP routed solution for Ethernet and T1/E1 cell sites.

The solution provides an end-to-end, all-IP architecture for Ethernet backhaul. Because there is no need for MPLS pseudowires to support TDM traffic, the architecture is simplified and builds on IP as the foundation technology in the RAN. The architecture is easy to configure and manage. It is also very flexible because it can support the LTE X2 interface and provide other features to increase the scalability of the RAN.

Like their GSM counterparts, mobile operators with CDMA architectures are well advised to develop the RAN and the transport network separately at this evolutionary stage of the mobile Internet. While the CDMA world already has wide deployments of IP-enabled radios, it does not yet have Ethernet-capable radios. The cost to upgrade radios to provide Ethernet to the cell sites is prohibitively expensive now. Some analysts predict that once LTE becomes the norm, CDMA operators will need devices in each cell site with 30 Ethernet interfaces, enabling 500 MB of bandwidth.

In the meantime, bonding T1/E1 lines into a single pipe using MLPPP and then transporting native IP backhaul is an efficient, scalable, and affordable interim solution. Mobile operators can concentrate more resources on the transport network, which will provide the intelligence, bandwidth, and scalability once LTE and end-to-end IP make GSM and CDMA network architectures more uniform.

### Requirements for an All-IP RAN

A true all-IP RAN architecture will have to support multiple radio types where each radio element has its own transport properties and requirements to support the edge and core. Any all-IP RAN backhaul network must address the recent radio developments such as WiMAX and LTE, where the network connection is a native Ethernet/IP interface. An all-IP RAN backhaul solution will also have to include a method for migrating existing or traditional transport types to a packet infrastructure.

In the all-IP RAN, pseudowires, MLPPP, and other workarounds will no longer be needed as Ethernet connections with IP or IP/MPLS services will carry backhaul from the cell site to the core.

Critical features necessary in an all-IP RAN will include:

- Scalability
- Bandwidth
- Redundancy
- High availability
- A demarcation point between the RAN and transport networks for testing and SLA monitoring
- Core and cell site redundancy
- Content delivery
- QoS
- Layer 3 routing
- Security

Several of these issues are new to the departments that supported traditional synchronous TDM RAN backhaul networks. Migration to an all-IP Carrier Ethernet RAN will be a multiyear process for most mobile operators who primarily have 2G and 2.5G networks in place today. Ultimately, mobile networks will collapse backhaul technologies in favor of IP services running from the cell site all the way back to the network core and the NOC.

### **The NGMN Alliance's Requirements for Optimized Backhaul**

The Next Generation Mobile Network (NGMN) Alliance is defining requirements from leading operators for a 4G, all-IP network, providing guidance to the 3rd Generation Partnership Project (3GPP). Cisco is an active member of the Alliance and is contributing to the IP RAN architecture definition based on Carrier Ethernet and MPLS. With the increasing diversity of services traveling across mobile networks, all traffic is not the same. It varies based on characteristics such as burstiness, volume, end-to-end delay, variance, and tolerance for dropped packets. It is vital to be able to identify, classify, and prioritize traffic across the transport network.

Additionally, mobile operators should be able to enforce different levels of service for prepaid customers, roaming customers, local customers, or business customers paying different subscription rates and with different service bundles. With Node Bs able to classify traffic at the edge of the network, mobile operators can prioritize traffic appropriately. And wholesalers should be able to prove that they can enforce strict SLAs for customers.

### **Addressing Bearer Traffic and Clocking Requirements**

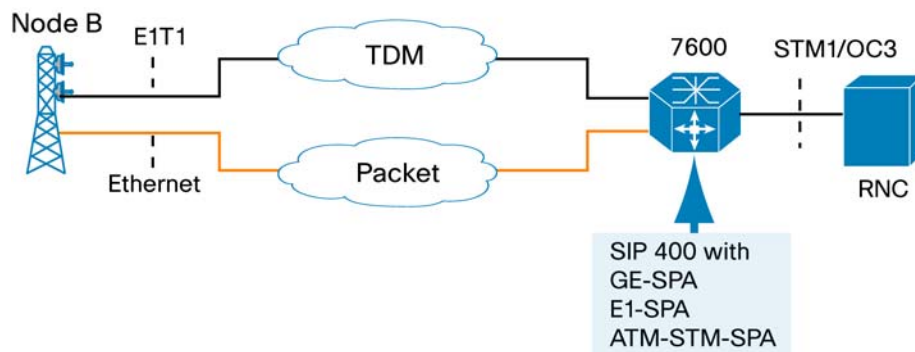
The need for IP or IP/MPLS-based RAN transport for newer radio endpoints is clear. The challenge for most mobile operators is how to migrate to full packet-based transport. This migration can be separated into two primary aspects:

- Bearer traffic (voice, data, control)
- Clock recovery over a packet core

In both GSM and CDMA environments, the initial incentive for migrating to a packet core is to meet the high throughput requirements for different varieties of high-speed traffic. Most operators will start to offload this traffic from their E1/T1 lines to some type of DSL or Ethernet service.

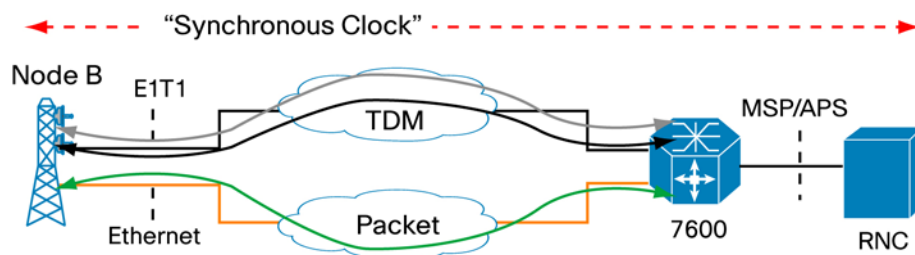
As shown in Figure 6, both the traditional TDM network and the packet network exist in parallel. This allows the operator to separate the data traffic for more efficient transport without sacrificing the voice or control traffic. The diagram shows the Node B as the radio endpoint in a GSM network. This typically uses ATM as a means for transport. To upgrade these radio elements, most radio vendors are developing modules that convert the ATM bearer to an ATM PWE3 that uses Ethernet connectivity to transport the traditional ATM traffic. This solution has a fast time to market and is relatively inexpensive.

**Figure 6.** Offloading High-Speed Traffic to DSL or Ethernet Service



In addition to the ATM bearer traffic, clocking between the core radio and edge radio elements must be addressed. In this hybrid mode, the clock can be recovered via the E1/T1 lines. In Figure 7, the dark blue line represents voice virtual circuits, the light blue line represents control virtual circuits, and the green line represents high-speed downlink packet access (HSDPA) and high-speed uplink packet access (HSUPA) ATM PWE3 connections.

**Figure 7.** Maintaining Synchronous Clock Between the Core and RAN



Different clock recovery methods are becoming available where clocking information can be sent natively over the packet core and accurately recovered at the edge. Due to the deployment of these packet networks, radio vendors are developing new radio platforms with native Ethernet/IP interfaces. These newer platforms will leverage the packet cores and provide a way to eliminate the costly TDM E1/T1 lines for voice and control bearer traffic and for clock recovery.

In CDMA networks, clocking is available from traditional 3G infrastructures that typically have a GPS antennae in the cell site to provide clocking. Timing over packet is therefore not necessary. As mobile operators roll out LTE, if timing is an issue, a separate GPS can be supplied for radios, traditional clocking solutions from 2G equipment can be used, or a timing-over-packet solution can be another option. These approaches give CDMA operators many options for reusing clocking technologies as they move to LTE.

The migration to a packet core makes the RAN scalable to support newer radio technologies as they are deployed. The consideration of macro-range coverage through WiMAX and in-building radio coverage through Femtocell is influencing the development of Ethernet/IP interfaces that will allow these radio elements to be connected anywhere in the overall packet network.

### QoS in Transport

The increased demand for bandwidth in mobile networks is primarily driven by the explosion of 3G-capable smart devices. These advanced smartphones and PCs with data cards are capable of not only voice, but high-bandwidth multimedia data applications including video. Cisco WebEx™, BitTorrent, and YouTube are just a few examples of high-bandwidth applications that are being used heavily in mobile networks. These bandwidth-intensive applications today are moving over transport infrastructure alongside voice traffic. Voice is a latency-intolerant application whereas data and data applications can tolerate a certain amount of latency. Currently, most mobile operator networks are configured for single service, with all traffic types being treated equally and best effort relied on for delivery of packets. The ability to prioritize latency-sensitive and non-latency-sensitive traffic as it is queued up to go across the RAN transport network is critical for maintaining a good mobile user experience.

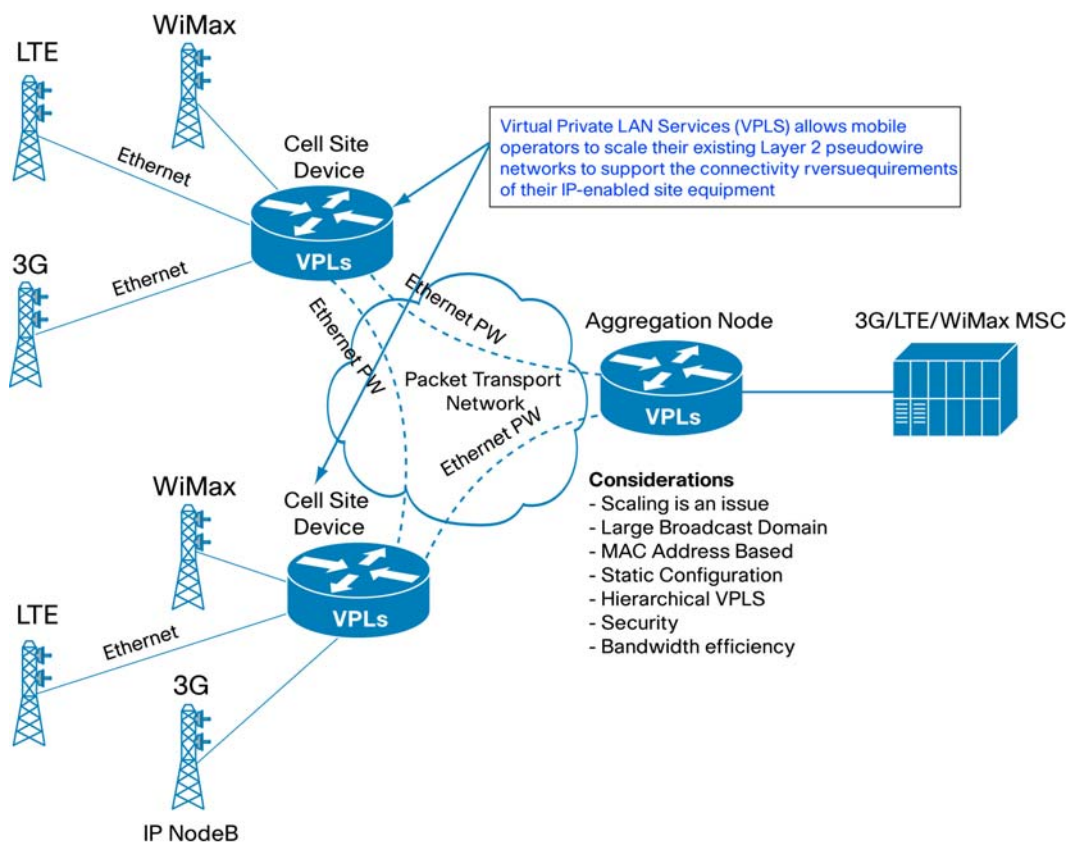
Even though most mobile operators take peak time-of-day bandwidth needs into consideration when designing their transport networks, backhoe fade, fiber cuts, and other types of outages cause intermittent bottlenecks in the transport network. The ability to configure traffic shaping, traffic policing, and QoS parameters at the edge of network will provide mobile operators with the critical control they need to make sure latency-intolerant applications like voice will be supported in times of network congestion.

### Layer 2 and Layer 3 Comparisons for Packet Core

As transport networks for RANs evolve to packet-based infrastructures, mobile operators are faced with the decision to build a Layer 2 or a Layer 3 packet transport core. Which option is best will vary from operator to operator based on their specific needs and requirements. For example, the primary topology for an existing 3G network is hub-and-spoke where the primary communication path is directly to and from the cell site and Mobile Telephone Switching Office (MTSO) with little to no communication directly between cell sites. In 4G and LTE, however, the concept of inter-cell site communication is introduced. Partial and full mesh topology requirements like those seen in 4G and LTE should be considered when determining a flat Layer 2 network or a routed Layer 3 network.

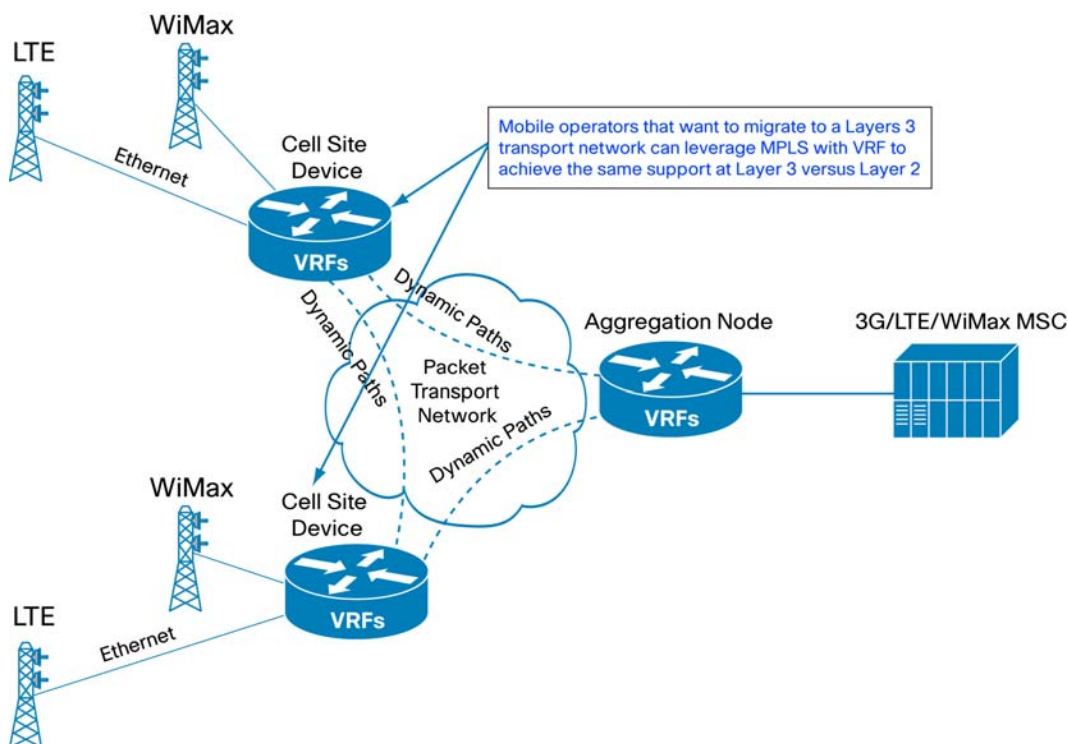
The variables in choosing a Layer 2 over Layer 3 solution are very similar to those considered by engineers during the transition from Layer 2 switches to Layer 3 routed networks. Many analogies apply when considering which option is best for the mobile operator. Cisco will support either environment.

**Layer 2 Core Networks:** Virtual Private LAN Service (VPLS) is the principal technology implemented by service providers that want to deploy and maintain flat Layer 2 networks, Figure 8. VPLS is an Ethernet-based service that looks like a Layer 2 VPN. VPLS supports geographically distributed Ethernet LANs (for example, cell sites) where multiple locations can reside on the same broadcast domain if so desired. It uses MPLS as the transport/backbone network to carry the packets. VPLS supports point-to-point and multipoint configurations, and uses the MAC address to locate the other endpoint. The IP address is not used.

**Figure 8.** Layer 2 Transport Option for the RAN

**Layer 3 Core Networks:** MPLS Virtual Routing and Forwarding (VRF) is used for Layer 3-aware transport networks, Figure 9. MPLS offers a fully meshed architecture where all sites can communicate directly with any other site without having to run through a hub and host location first. Two key benefits are improved site-to-site performance and fewer burdens imposed on remote locations. Network meshing and the addition of subsequent network devices are automatic functions of MPLS “connection-less” technology, making the addition of cell sites less challenging for operations staff. Mobile operators that want to migrate to a Layer 3 network with MPLS and VRF will be able to support the dynamic traffic requirements of their increasingly technology-rich cell site devices.

**Figure 9.** Layer 3 Transport Option for the RAN – All-IP, IP Node B, WiMAX



There are some key differentiators between Layer 2 VPLS and Layer 3 MPLS, as shown in Table 1.

**Table 1.** Layer 2 VPLS and Layer 3 MPLS Comparisons

Feature	Layer 2 VPLS	Layer 3 MPLS
<b>Dynamic path establishment</b>	Supported with VPLS	Supported with MPLS
<b>Scaling</b>	Up to 1000 nodes per Layer 2 domain (H-VPLS can help scaling)	Hierarchical not an issue
<b>Ability to route between directly connected cell sites</b>	Not supported if on separate broadcast domain (Layer 3 needed to go between broadcast domains)	Supported
<b>Endpoint Identification</b>	MAC address	IP address
<b>IP address transparency</b>	Supported	Not supported without Layer 3 VPNs
<b>Cost of hardware</b>	Less expensive	More expensive
<b>Operation/craft expertise</b>	Lower	Higher
<b>QoS capabilities</b>	Lower	Higher
<b>Broadcast domains</b>	Supported (both point-to-point and multipoint)	Not supported in a routed network
<b>Support for network growth</b>	Manual effort Configuration-intensive	Easier with support of Automatic Discovery

While Cisco does remain technology-agnostic in the Layer 2 verses Layer 3 debate for IP RAN backhaul, as the operator evolves to a 3GPP LTE network there are distinct competitive advantages to a Layer 3 infrastructure. Fortunately, the Cisco IP RAN portfolio natively supports both Layer 2 switching and Layer 3 routing.

## Green Initiative for All-IP RAN

Another anticipated benefit of the evolution to the all-IP RAN is devices and technologies with significantly lower energy consumption due to more efficient design, fewer platforms needed, and virtual maintenance. An October 2008 white paper based on research by Alcatel-Lucent that was highlighted in Light Reading directly addressed the basic power savings associated with TDM compared to IP networks. Power costs and consumption for a 10,000-line TDM switch and a two-frame compact IP Multimedia Subsystem (IMS) configuration in North America came to one-tenth that of a comparable TDM network. Another finding by Pyramid Research, based on an estimated 160 million circuit-switched lines in Canada and the United States in 2008, estimated that each 10,000-line switch utilizes 925,000 kilowatt hours (kWh) per year, coming to US\$7.95 per line or \$1.27 for all 160 million installed lines. An IP solution would use only 102,000 kWh a year and cost \$144 million.

The Alliance for Telecommunications Industry Solutions (ATIS) Network Interface, Power, and Protection Committee (NIPP) is in the process of developing and ratifying standards that will include consumption targets for power systems for telecommunications equipment to help lower power usage. And the IEEE P802.3az Energy Efficient Ethernet Taskforce is working on energy-efficient Ethernet ports that will also help to minimize power usage.

Another indirect green benefit of the high-speed mobile Internet is reducing carbon emissions through increased reliance on teleconferencing and video conferencing instead of face-to-face meetings. A study by The Climate Group found that previous, conservative estimates have suggested that virtual meetings could replace between 5 and 20 percent of global business travel.

While already a leader in energy efficiency for network infrastructure, Cisco product development continues to enhance efficiency, reusability, and recycling ability. Cisco has also introduced “EnergyWise”, software that can monitor, manage and reduce electricity use.

## All-IP RAN Total Cost of Ownership

While evaluating the technical requirements for the evolution to the all-IP RAN, mobile operators are intent on ensuring that their technology choice provides the most cost-effective solution. Given that transmission costs on average consume 19 percent of mobile operators’ operational expenditures, according to a February 2007 report by Unstrung Insider, reducing this cost is vital to an operator’s long-term financial stability, especially with increasing traffic predictions and reduced revenue per user. A comparison between different technical solutions must include both the capital and operational expenditures. A well constructed TCO study will also include network growth over a period of five years.

Cisco has modeled a wide range of technical options using the TCO approach and has shown that a migration from a Plesiochronous Digital Hierarchy (PDH) and Synchronous Digital Hierarchy (SDH) infrastructure to IP or IP/MPLS is extremely cost-effective and ROIs can be extremely fast especially if the mobile operator already has an existing IP or IP/MPLS network. The simulation focuses on GSM network architectures and includes a wide range of capital and operational costs, including the major costs related to backhaul. Note that the costs for SDH and Ethernet backhaul were based on industry figures.

Four major scenarios were modeled using a Monte Carlo approach, which allows for a wide range of input parameters to be randomized within a known variance. The outputs are then mapped onto a probability density function to illustrate the spread of results. The scenarios included:

- Scenario 1: SDH infrastructure
- Scenario 2: Microwave backhaul from cell site to a pre-aggregation device with an MPLS-based Ethernet network between the pre-aggregation device and the aggregation device
- Scenario 3: MPLS from the cell site using Metro Ethernet
- Scenario 4: Hybrid model using DSL backhaul for data and SDH for voice and signaling

The results of the simulation are summarized in Figure 10 and Figure 11.

**Figure 10.** Total Cost of Ownership for Different All-IP Backhaul Solutions

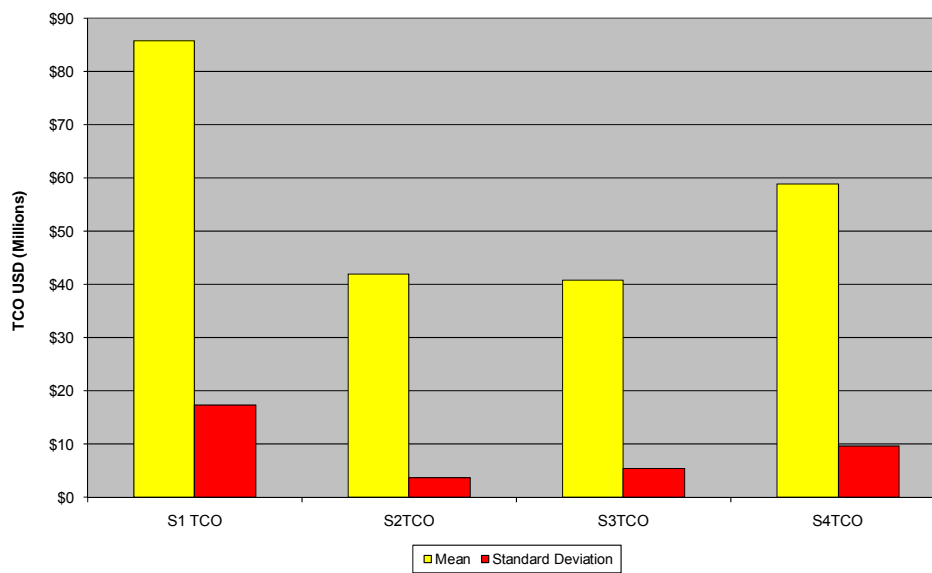
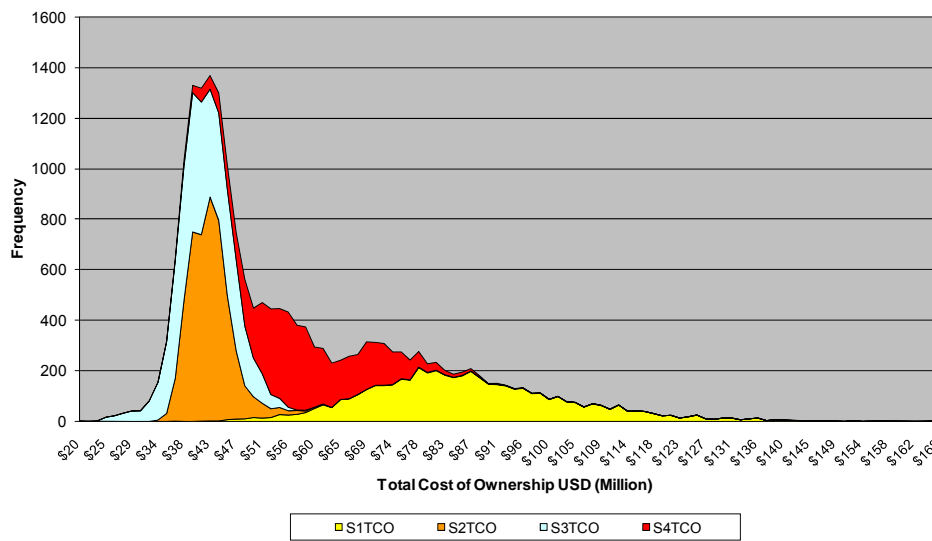


Figure 11 provides a comparison of the average and standard deviation of the different scenarios. Both of the MPLS solutions provide significant TCO savings compared with a continued build-out of the SDH infrastructure.

A number of input parameters have been randomized within a reasonable variance. The figures provide a view of the spread of the different scenarios and allow a comparison to be made where the input parameters are not well known. From the diagram the two MPLS options again illustrate the lower TCO compared with the baseline scenario.

**Figure 11.** Comparison of Average and Standard Deviation of Different Scenarios



In summary, IP and IP/MPLS solutions provide a TCO saving of between 25 and 40 percent over a five-year period. This result is based upon the assumption that the initial SDH network has been built and is considered a sunk cost. All additional equipment purchases for the SDH network are then compared to a complete build-out of a number of different IP and IP/MPLS solutions.

The analysis clearly showed that the costs for PDH and SDH backhaul are onerous and that the savings when moving to Metro Ethernet-based technologies in conjunction with IP/MPLS-based pay for themselves in a relatively short period of time.

Most mobile operators have not one but several different combinations of transport and RAN solutions. Comparisons of one type of backhaul scenario versus another are therefore approximate at best. Additionally, costs for network connections vary throughout the world, but Table 2 contains an approximate cost comparison of high-speed data backhaul using E1/T1 lines versus Ethernet connections over pseudowires, as in the Cisco MToP solution. The tremendous savings possible using Cisco MToP is clear. (Note: Five E1/T1 lines equal one 10-Mbps Ethernet connection. For high-speed data service for LTE backhauling, one 100-Mbps Ethernet connection is presumed necessary.)

**Table 2.** Monthly Comparison of E1/T1 Backhaul versus 10/100 Mbps Ethernet Connection Using MToP

Traditional Connection: E1/T1 Lines	Cost
E1 (1.5 Mbps) or T1 (2.0 Mbps) per month	\$150–300
E1 or T1 per year	\$1800–3600
x 5 per base station for 3G service per year	\$9000–18,000
<b>Cisco MToP</b>	Cost
10/100 Ethernet connection using pseudowires per month	\$50–100
10/100 Ethernet connection using pseudowires per year	\$600–1200

Savings based on the TCO for an all-IP RAN would be similar if not greater than the Cisco MToP solution as compared to traditional backhaul approaches. With the all-IP RAN, GSM operators can utilize the same equipment used for the MToP solution, simply adding more Ethernet ports to their cell site routers.

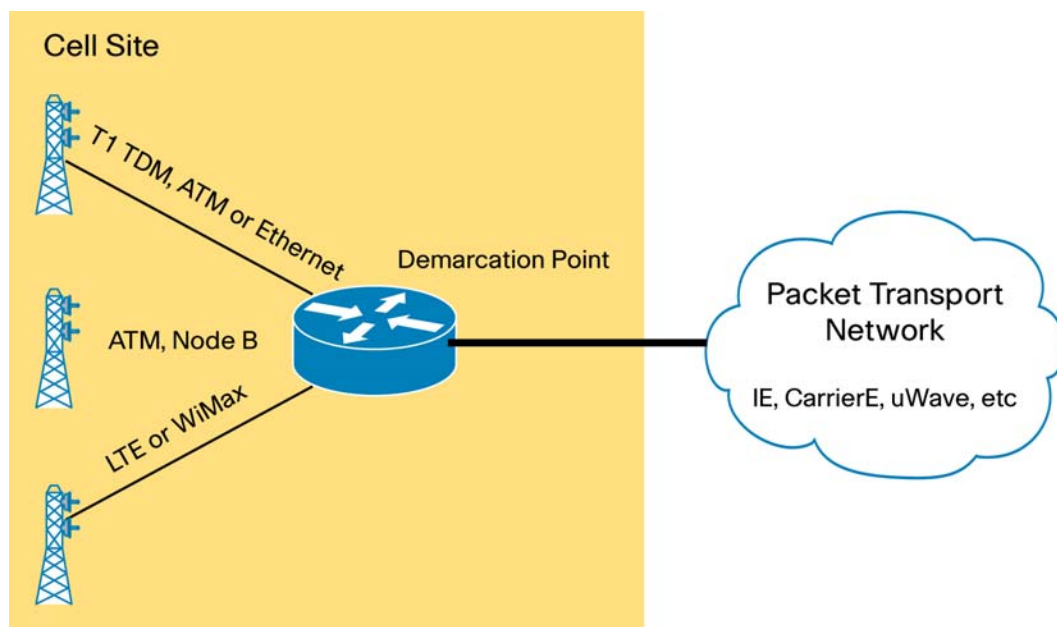
CDMA operators who already have all-IP RANs today are already enjoying many of the lower TCO benefits of having moved beyond TDM backhaul. They too can leverage their existing equipment in their continued evolution to bring Ethernet to the RAN. All that will be required are Metro Ethernet switches in cell sites.

### Maintaining a Demarcation Point between the RAN and Transport Network

The T1/E1 point-to-point circuits used in today's backhaul networks are terminated at cell site locations at demarcation points called "smart jacks." The smart jacks are the interconnect point in the cell site where the T1/E1 service terminates and the mobile operator cell site equipment connects to them. These smart jacks offer a demarcation point where circuit testing such as loopbacks and Bit Error Rate Test (BERT) can be performed to test for integrity and continuity of the backhaul network. The demarcation point also offers an interconnect point for circuit-testing equipment such as T1 Bit Error Rate Detector (T-BERD) to be inserted.

It is advantageous to decouple the cell site radio interface from the packet-based transport network while preserving the operational functionality of the demarcation point provided in the older T1/E1 backhaul networks. To do this, a separate device is required between the transport network and the Ethernet-enabled radios in the RAN, Figure 12. This device provides the operations personnel with a cell site touch point where operational-level tests can be run.

**Figure 12.** Demarcation Point Between the RAN and Transport Network

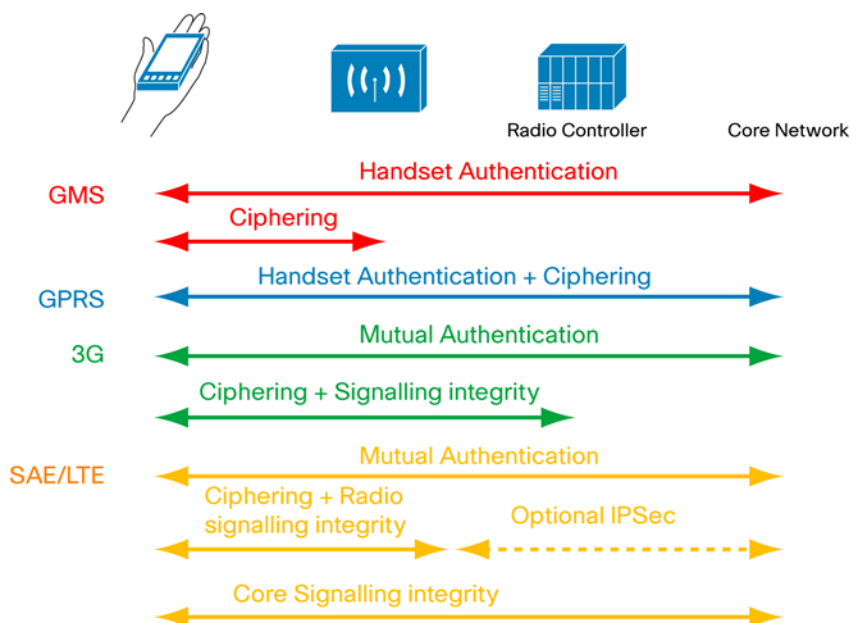


Letting the cell site routers instead of the radio perform packet marketing, QoS, security, SLA monitoring, and other services provides mobile operators with a lot of flexibility as radio-equipment vendors now supply varying levels of functionality in their products. Here too, maintaining an independent transport network lets mobile operators pursue upgrades to their radio equipment more gradually, reducing cost and upgrade pressures in the near term.

### Evolving IP Security for Mobile Networks

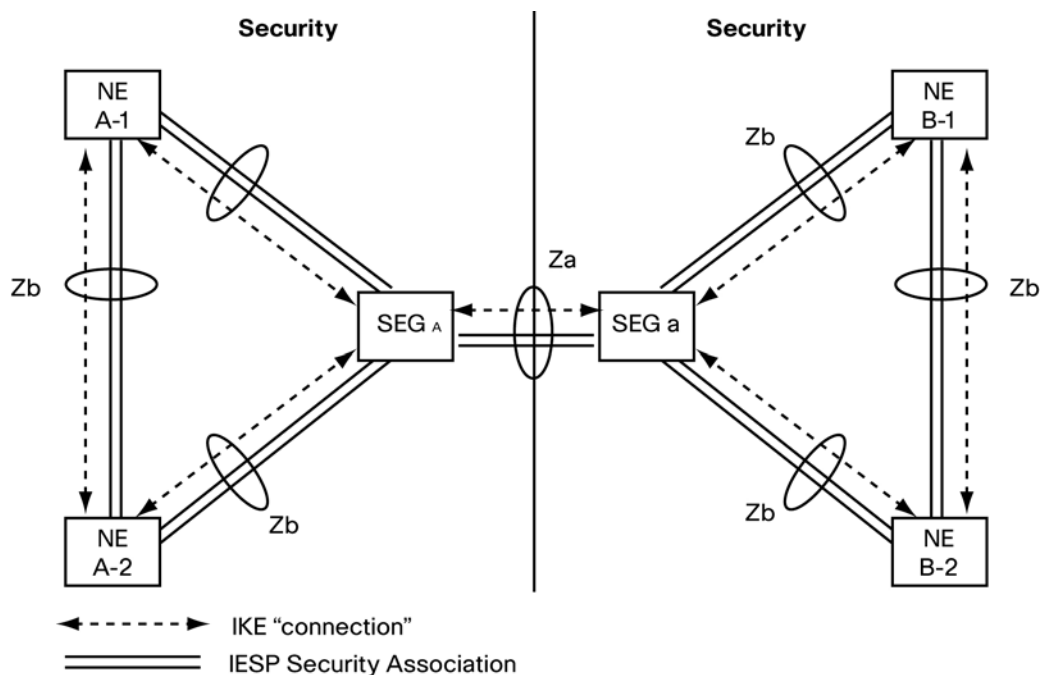
The security of mobile systems has evolved from the original unidirectional authentication and base station ciphering in GSM to the mutual authentication and RNC-based ciphering with 3G and back toward base-station-based ciphering, Figure 13.

Figure 13. 3GPP Security Evolution

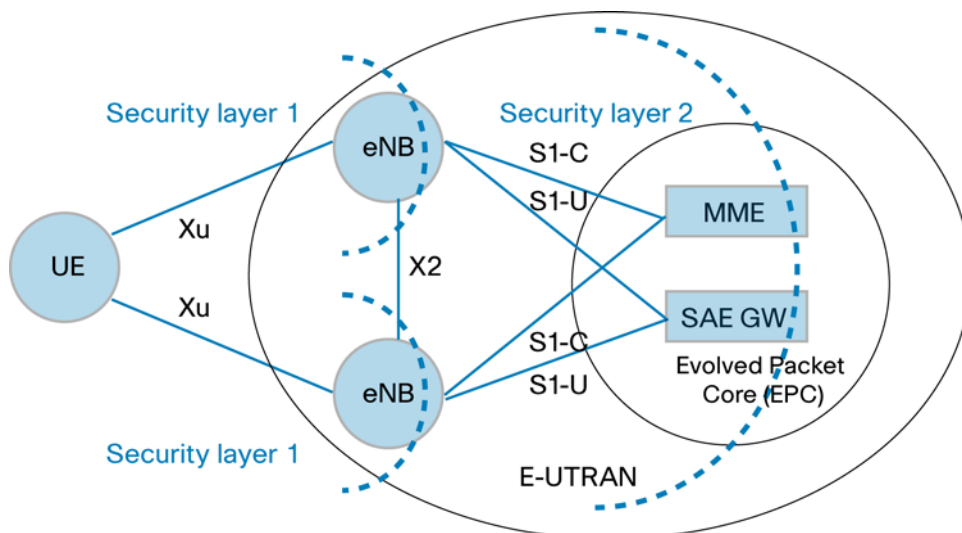


3GPP has defined a security solution for protecting intra-operator interfaces called Network Domain Security/IP Layer Security (NDS/IP). An ESP Security Association will be used for all control-plane traffic that needs security protection. While it is not recommended to use unsecured links for connecting base stations with each other and with their access gateways, the use of IPsec should be restricted to protect those interfaces transported over unsecured links, Figure 14.

Figure 14. 3GPP-Defined NDS Architecture for IP-Based Protocols



Because the design of LTE terminates the user-plane security at the base station, the overall architecture includes two security levels. The first protects interfaces between the handset and the base station while the second protects internal interfaces between the base stations and between the base station and the Evolved Packet Core, Figure 15.

**Figure 15.** First and Second Security Layers in LTE

3GPP has defined the protection of IP-based control-plane signaling for the Evolved Packet Core and the LTE RAN, as defined in 3GPP 33.401. This standardizes the use of IPsec ESP according to RFC 4303 using Internet Key Exchange Version 2 (IKEv2) certificate-based authentication for both the base station to the Mobility Management Entity (MME) control plane and the base station-to-base station control plane. Tunnel mode IPsec is mandatory and transport mode is optional. On the user plane, the use of ciphering protection on the link between the base station and MME and on the link between base stations is optional.

CDMA security protocols are designed to provide voice, signaling, and data privacy as well. In CDMA networks, security protocols rely on a 64-bit authentication key and the Electronic Serial Number (ESN) of the mobile handset. A random binary number called RANDSSD, which is generated in the Home Location Register (HLR), also plays a role in the authentication procedures. The authentication key is programmed into the mobile handset and is stored in the HLR. CDMA systems also use the standardized Cellular Authentication and Voice Encryption (CAVE) algorithm to generate a key called the Shared Secret Data (SSD). The SSD is used for creating authentication signatures and for generating keys to encrypt voice and signaling messages.

As both GSM and CDMA operators migrate to LTE, they will adopt security procedures that more closely resemble GSM/LTE.

### **IP SLA and Ethernet Operations, Administration, and Maintenance in the All-IP RAN**

As mobile operators expand their RANs to include IP and Ethernet broadband services, it is important that they keep in mind the operations requirements of these networks and the capabilities of Ethernet Operations, Administration, and Maintenance (OAM) and Cisco IOS® IP SLA to provide the same capabilities they enjoy today.

The ability to monitor and manage SLAs for service provider transport networks is a key capability for mobile operators. Standards-based protocols such as One-Way Active Measurement Protocol (OWAMP), Two-Way Active Measurement Protocol (TWAMP), and Cisco IOS IP SLA can meet these needs.

- OWAMP as defined by RFC 4656 is designed to allow measurement of one-way latency and loss between IP endpoints.

- TWAMP as defined by a draft RFC extends OWAMP to support two-way or round-trip delay and loss measurement. OWAMP measurement accuracy is limited by several factors, including the precision to which time can be synchronized between the endpoints and the manner in which OWAMP packets are handled inside each endpoint. Nevertheless, OWAMP and TWAMP may be candidates for connectivity monitoring in alternative backhaul environments where Cisco IOS IP SLA is used today.

Cisco IOS IP SLA is a capability embedded within almost all devices that run Cisco IOS Software. It allows Cisco customers to understand IP service levels for IP services, increase productivity, lower operational costs, and reduce the frequency of network outages.

Cisco IOS IP SLA can perform network assessments, verify QoS, ease deployment of new services, and assist administrators with network troubleshooting. Service-level assurance metrics and methodologies are based on the use of active traffic monitoring – the generation of traffic in a continuous, reliable, and predictable manner – for measuring performance. IP SLA can simulate network data and IP services and collect network performance information in real time. This includes data regarding response time, one-way latency, jitter, packet loss, voice quality scoring, and server response time. Cisco IOS IP SLA can also monitor performance for different classes of traffic over the same connection.

Mobile operators are also working with wireline and cable service providers to meet their RAN transport network needs, especially at the network edge. Using Cisco IOS IP SLA, for example, wholesalers can keep track of and report on the end-to-end services they are providing. Mobile operators are pursuing this wholesale model, reselling the bandwidth as a managed service. Some are placing cell site routers in the cell sites of other mobile operators, routing traffic over their own network and then dropping it at the aggregation sites or core of the mobile operator.

The ability to monitor, troubleshoot, and meet SLAs for these third-party Ethernet networks is a requirement. Until recently, Ethernet lacked OAM functionality like that found in SONET/SDH or ATM, and therefore was not characterized as “carrier-class.” Recent developments in the ITI and IEEE standards bodies and among vendors have provided OAM capabilities for Ethernet networks. This has enabled mobile operators to utilize these networks to meet the demands of their operations staffs.

### **Cisco Products for the RAN Evolution**

Cisco’s portfolio of IP RAN solutions offers the mobile operator (and the transport carrier who wishes to offer IP RAN backhaul as a service) a complete end-to-end infrastructure from the core to the cell tower. While providing immediate cost reductions and bandwidth expansion, Cisco offers features and capabilities truly unique in the industry. These capabilities provide unmatched traffic handling during peak hours, unrivaled security and resiliency, and levels of performance and scaling required both today and in the future.

The mobile service provider network, along with user applications, is evolving to all-IP. As the undisputed IP leader, Cisco provides the technology, solutions, and expertise that mobile operators need as they transition to next-generation networks. Deploying solutions that deliver greater network intelligence, integration, and overall flexibility will not only give operators short-term benefits but will ultimately boost their competitive advantage. Ensure that your 3G and 4G network can support high-bandwidth services by reaching out to Cisco and its partners for assistance in taking advantage of the many compelling benefits of a packet-based RAN backhaul network today.

## Conclusion

The rapid pace of technological change is impacting mobile networks as never before and mobile operators are faced with hard choices as to where to focus resources. The Cisco strategy of maintaining separate RANs and transport networks while migrating to an end-to-end all-IP network is a prudent way for mobile operators to protect existing investments in radio equipment while bolstering their transport networks with capacity, intelligence, and features that allow for scalability and bandwidth-intensive services and applications.

While the ultimate vision embraced by many mobile operators and industry analysts is to replace TDM and ATM equipment and bring IP services over Carrier Ethernet to the cell site, a complete retrofit of infrastructure to make this possible would also incur huge capital costs. Instead, a growing number of mobile operators are deploying viable solutions that separate RANs and transport networks and allow interconnections using solutions such as Cisco MToP and MLPPP. Only Cisco has the MToP solution, the end-to-end IP MPLS NGN architecture, and the vision to help mobile operators migrate their networks to the newest and best technology solutions without causing service disruptions and operational challenges and incurring major costs. With the coming of LTE, mobile operators will see even more pressures on their networks and the dual network strategy proposed by Cisco will ensure that they have carrier-class features in place in the transport network while the RAN technologies undergo a revolution in features and functionality.

## For More Information

### Cisco IP NGN and IP RAN solutions for Mobile Operators

<http://www.cisco.com/go/mobiletransport>

### MToP in the RAN

[http://www.cisco.com/en/US/netsol/ns732/networking\\_solutions\\_solution.html](http://www.cisco.com/en/US/netsol/ns732/networking_solutions_solution.html)



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