Benefits to Using Layer 3 Access for IP Radio Access Networks

What You Will Learn

The Cisco® Visual Networking Index projects the expected growth and volume of network traffic during the period 2009-2014. This forecast shows mobile data traffic experiencing tremendous growth, with video as the major component of this traffic increase. The migration of applications and services to IP started years ago and is reaching the mobile backhaul market.

The main goal of service providers is to find the right balance between network evolution of transmission and the transport infrastructure's capital expenditure (CapEx) and operating expenses (OpEx).

One major debate is how to implement the IP service in the mobile radio network backhaul, and in particular which layer is the best for the backhaul: Layer 2 (switched) or Layer 3 (routed).

In the traditional first-, second-, and third-generation (1G, 2G, and 3G) Radio Access Network (RAN) architecture, where each cell site node is connected to a central aggregation node, the backhaul network portion access - or last mile - has a hub-and-spoke design. This means that there has been no reason to use Layer 3 in that part of the network.

The extension of ring topologies, especially in metropolitan areas, supports Long Term Evolution (LTE) that introduces eNodeB (enhanced NodeB). This migration to direct communication is a good reason implemented Layer 3 technologies, not only in the aggregation, but also in the access portion of the RAN backhaul network. The initial deployment of Layer 3 in the backhaul demonstrates its flexibility by reducing the traditional operational time for radio network upgrade and rehoming.

This document describes the scenarios and cases where service providers gain benefits by using a Layer 3 solution in a mobile (3G) backhaul network.

Introduction

The Cisco Visual Networking Index (VNI) is the company's ongoing effort to forecast and analyze the growth and use of IP networks worldwide. The Cisco VNI Forecast methodology rests on a foundation of analyst projections for Internet users, broadband connections, video subscribers, mobile connections, and Internet application adoption. Highlights of the 2010 VNI Forecast include the following:

- Global IP traffic will increase by a factor of five from 2008 to 2013, approaching 56 exabytes per month in 2013, compared to approximately 9 exabytes per month in 2008.
- By 2013, annual global IP traffic will reach two-thirds of a zettabyte (673 exabytes). A zettabyte is a trillion gigabytes.
- By 2013, the various forms of video-TV, Video on Demand (VoD), Internet Video, and Point to Point (P2P) video-will exceed 90 percent of global consumer traffic.
- By 2013, global online video will be 60 percent of consumer Internet traffic (up from 32 percent in 2009).
- Mobile data traffic will roughly double each year from 2008 through 2013.

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Looking deeper into mobile traffic, the VNI Global Mobile Traffic Forecast Update, 2009-2014, makes the following predications.

- Globally, mobile data traffic will double every year through 2014, increasing 39 times between 2009 and 2014. Mobile data traffic will grow at a compound annual growth rate (CAGR) of 108 percent between 2009 and 2014, reaching 3.6 exabytes per month by 2014.
- Almost 66 percent of the world's mobile data traffic will be video by 2014. Mobile video will grow at a CAGR of 131 percent between 2009 and 2014. Mobile video has the highest growth rate of any application category measured within the Cisco VNI Forecast at this time
- Smartphones and portables will account for 91 percent of all mobile data traffic by 2014. This is primarily due to the much higher usage profile of laptops and the suitability of mobile broadband handsets for high-speed, high-quality video.

Because smartphones and portable data modems (for example, iPad with 3G) support bandwidth-intensive applications that are popular with users, the average smartphone user generates 10 times the amount of traffic generated by the average nonsmartphone user.

The expenditure to build out networks to provide this increasing bandwidth does not linearly match revenue growth. As Cisco engages with service providers of all types and in all parts of the world, we find that the biggest concerns can be summed up as innovation, monetization, optimization, and enablement.

- Innovation is essential to delivering more advanced services to an increasingly wide range of customers and devices. More often than not, these services have to be delivered in a highly competitive and constantly changing environment.
- Monetization refers to the need to find new ways to generate revenue with that one critical asset that all service providers have-the network.
- Optimization involves reducing costs and increasing average revenue per user (ARPU), which is necessary for profitability.

Underlying these three factors, are a host of challenges related to operational complexity and enablement. As the services and solutions become increasingly complex, it is critical to be able to efficiently deploy, maintain, and operate the network so the service provider’s infrastructure delivers the entire spectrum of benefits and value.

Cisco contends that IP networking is the only choice that supports this kind of flexibility and growth. Carriers are moving to converged infrastructure with IP networks in mobile and wireline applications. The following section examines this infrastructure in more depth.

Network Overview

In existing cellular networks, RAN backhaul is defined as the connection between the radio at the cell site and the radio controller.

As shown in Figure 1, backhaul comprises the “last mile” between the base station and the base station controller (BSC) or radio network controller (RNC), as well as the transport network between the BSC or RNC and the core network. This backhaul network can be delivered by any number of methods or can be outsourced fully or partially to third-party wholesale network providers.

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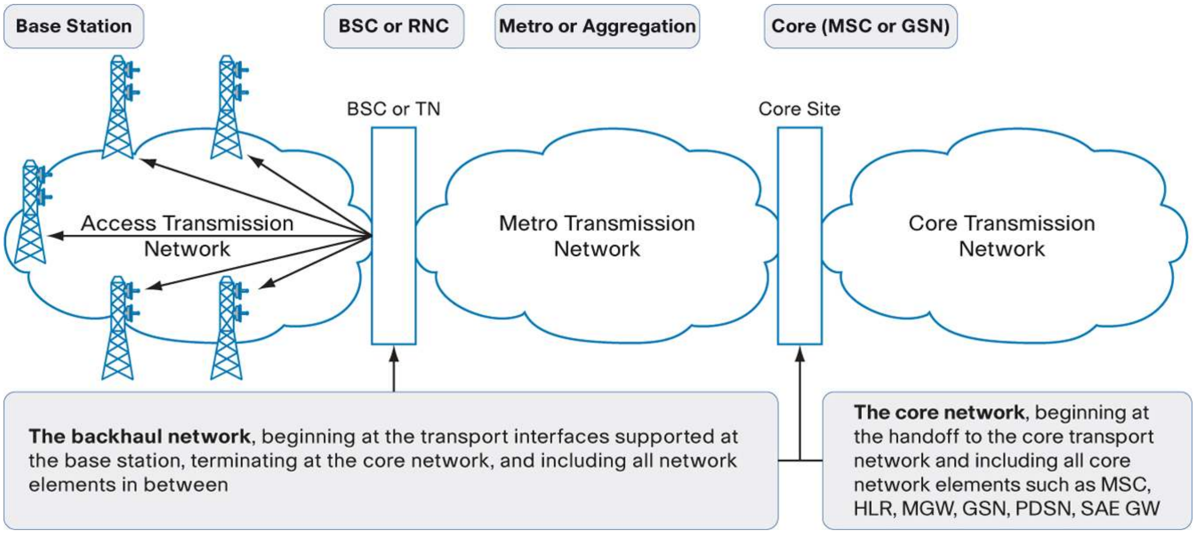
Figure 1. Mobile Backhaul Network Location



Depending on the technology, there are various names for these components, but their locations in the network and functions remain largely the same (Table 1).

Table 1. Mobile Backhaul Network Primary Locations

Mobile Generation	Cell Tower	Controller	Interface
2G	BTS: Base Transceiver Station or Base Station	BSC: Base Station Controller	Abis
3G	NodeB	RNC: Radio Network Controller	Iub
4G	eNodeB	Split between eNodeB, MME, and Serving Gateway (SGW)	S1

Backhaul spans the connection from the cell tower through the aggregation network (assembling connections from multiple cell sites) and then handing off the signals to the controller.

The options for backhaul technology are determined by the connections supported by the radio and controller. Either the connection has to be carried natively or tunneled and encapsulated. Additionally, the connection must support or transparently pass the protocols used by the interface between the cell tower and the controller.

Considering the same network from a network viewpoint instead of a cellular viewpoint, we introduce the access and aggregation parts of the RAN network. As shown in the Figure 2, there are different names for the same functions in mobile backhaul (cellular) and carrier Ethernet (network) views, but the layout of the network and component roles are the same.

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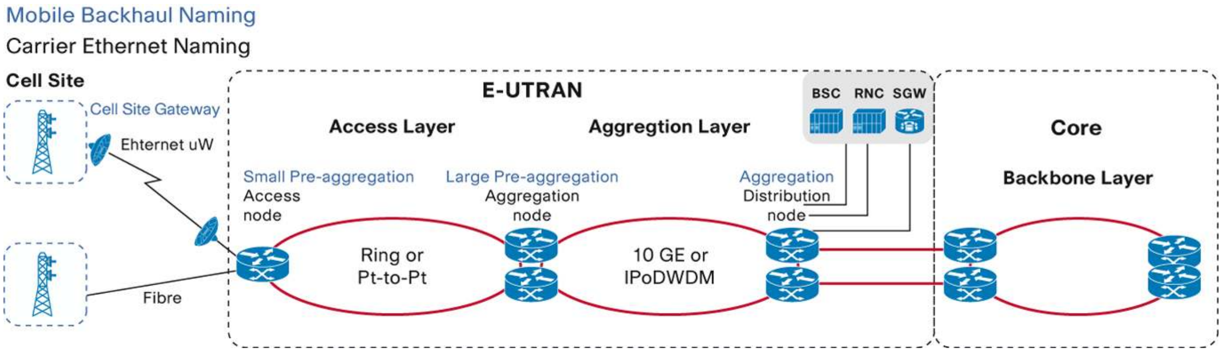
Figure 2. Mobile Backhaul Access and Aggregation



The network options for RAN backhaul are:

- IP: includes IP, IP/Multiprotocol Switching (IP/MPLS), MPLS-Transit Profile (MPLS-TP), and Ethernet
- Time-division multiplexing (TDM): includes SONET/SDH, Frame Relay (FR), and Asynchronous Transfer Mode (ATM)

Note that microwave and optical technologies (including Optical Transport Network [OTN] and dense wavelength-division multiplexing [DWDM]) are Layer 1 technologies that can support IP or TDM backhaul.

Service providers are striving to reduce operating costs, and converging all networks into a single one is a major factor in achieving savings. The challenge is that the mobile architectures originated with different technologies (TDM, FR, and ATM).

As an example, current Global System for Mobile Communications (GSM) and Universal Mobile Telecommunications System (UMTS) networks are predominately based on SDH as the convergence technology, using 2-Mbps transport connections dedicated to either 2G or 3G mobile RAN traffic. The primary issue with the SDH-based architecture is a lack of scalability. Initial LTE bandwidth calculations show a requirement for 40 Mbps on average to each cell site location, a requirement that could grow to 300 Mbps over time.

This document will focus on IP technologies and the choices associated with them, because IP is the only technology that has the scalability, flexibility, and comprehensive features needed to deal with the accelerating increase in data traffic.

Layer 2 and Layer 3 Considerations for IP RAN

As transport networks for RANs evolve to packet-based infrastructures, mobile operators are faced with the decision to build or extend Layer 2 or Layer 3 into the access.

The following variables all affect technology decisions.

- Operator: Mobile operators can build the backhaul-dedicated infrastructure based on microwave, fiber, or leased services. The network design would be very different for a mobile service provider than for a transport provider delivering a backhaul service for mobile operators.
- Radio technology: Building from a traditional radio system (2G, 2.5G, or 3G) is different than building from a fourth-generation (4G) LTE or WiMAX system. This is further complicated because 3G systems may be TDM-based with Circuit Switched (CS) data, TDM-based with IP bearer, or Ethernet-based.

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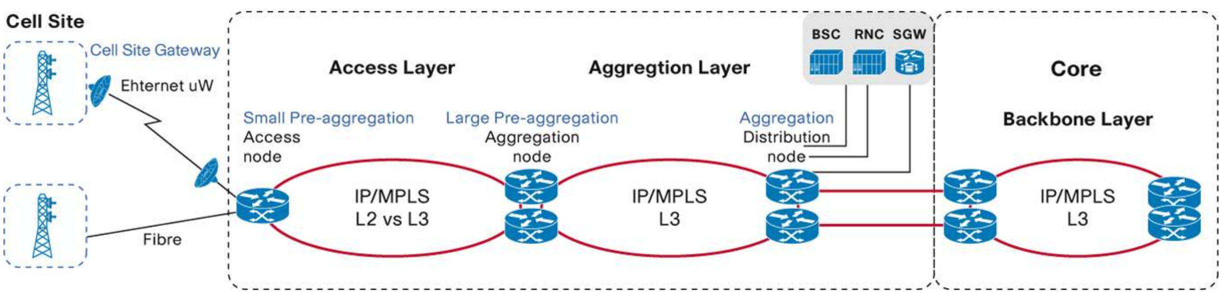
- Transport requirements: Whether the requirement is to transport native Ethernet and IP or transport TDM and ATM from the base station is a fundamental technology decision determined by the radio equipment and controller. IP/MPLS is still most suited to transport TDM and ATM using pseudowires, as most operators have no level of exposure to or comfort with Layer 2 Tunneling Protocol v3 (L2TPv3) IP tunneling. Layer 2 technologies, although capable, have some operational and scaling challenges.
- Timing technology: Although a Layer 2 system is good for timing with Synchronous Ethernet (SyncE), a Layer 3 system affords significantly more options for timing, including the most-requested 1588v2.
- Backhaul technology: TDM backhaul, fiber, fixed-line Ethernet, microwave (uWave), and Ethernet all promote different designs and considerations linked to the topology.
- Backhaul topology: Layer 3 fits very well in mesh network or ring topologies, Point to Multipoint (P2MP) and partial-mesh architectures, and less well in P2P architectures.
- Cost: Layer 2 is perceived as requiring lower CapEx, but may require higher OpEx, as described later.

Figure 3 shows that the core and aggregation networks are already using Layer 3 technology, and MPLS is the most common choice.

Figure 3. Typical Mobile Backhaul L3 Core and Aggregation Network



The best option for access 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 intercell site communication is introduced. The new partial and full mesh topology requirements of 4G and LTE networks should be considered when determining if a flat Layer 2 network is sufficient or a routed Layer 3 network provides the best choice. Cisco will support either environment. The rest of this document will detail benefits of a Layer 3 selection, while allowing that L2 may be the preference for some carriers.

- Layer 2 (switched) networks: In a Layer 2 network, MAC addresses are used to locate endpoints. There are limitations on the size of MAC address tables, and this constrains the size of Layer 2 networks. Nonetheless Layer 2 networks provide excellent emulated LAN and line functionality supporting point-to-point, hub-and-spoke, and other topologies. Note that in a pure Layer 2 network, an IP address is not used for routing.
- Layer 3 (routed) networks: Using IP addressing, Layer 3 networks provide larger and more flexible networks in comparison with Layer 2 networks. Cisco's Service Provider System Unit uses MPLS and Virtual Route Forwarding (VRF) in addition to IP to implement RAN backhaul. This solution offers the advantages of virtualization, keeps the same Interior Gateway Protocol (IGP) between the core and aggregation, and avoids the need to use IPoMPLS (IP over MPLS) because MPLS is used in the aggregation. Both IP and MPLS provide the advantages of Layer 3.

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MPLS offers a fully meshed architecture where any site can communicate directly with any other site without having to run through a hub and host location first. Two major 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 “connectionless” 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-abundant cell site devices.

Table 2 describes the different protocol mechanisms that can be used in the backhaul access area.

Table 2. Mobile Backhaul Protocol Comparison

	IP	MPLS	EoMPLS Pseudowire	Ethernet
Operation, administration, and maintenance (OAM)	Ping, traceroute	Label Switched Paths (LSP) ping, traceroute	Label Distribution Protocol (LDP), CW pseudowire OAM+802.1ag	802.1ag
Performance management	IP service-level agreement (SLA)	IP SLA	Y1731	Y1731
Protection in rings	IGP, Bidirectional Forwarding (BFD, loop free alternates (LFA) Fast Reroute(FRR)	IGP, LDP, LFA, FRR, traffic engineering (TE) FRR	LSP protection	Resilient Ethernet Protocol (REP)
Traffic engineering in rings	No	Yes, with TE	As per MPLS	Yes, by REP G.8032
X2 communication	Yes	Yes	No	Yes, shared VLAN
Packet microwave coverage	No	Partial	Not yet	Yes, by all
Overhead	Low	Average if IPoMPLS	High	Low
Plesiochronous Digital Hierarchy (PDH) and Ethernet transmission	Yes	Yes	Yes, with MPLS	No
Provisioning effort	Average	Average, high with TE	High	Low if shared VLAN
Interworking with IP/MPLS core and aggregation	IP or MPLS VPN	E2E {end-to-end} LSP or service level	PWE {pseudowire} to VRF, Virtual Private LAN Services (VPLS), MS-psuedowire	Ethernet to VRF, VPLS, Virtual Private Wire Services (VPWS)

There are some crucial differentiators between Layer 2 VPLS (Ethernet) and Layer 3 MPLS, as shown in Table 3.

Table 3. Layer 2 vs Layer 3 Network Operation Differences

Feature	Layer 2 VPLS	Layer 3 MPLS
Dynamic path establishment	Supported with VPLS	Supported with MPLS
Scaling	Up to 1000 nodes per Layer 2 domain (Hierarchical VPLS can help scaling)	Hierarchical; not an issue
Ability to route between directly connected cell sites	Not supported if on separate broadcast domain (Layer 3 needed to go between broadcast domains)	Supported
Endpoint identification	MAC address	IP address
IP address transparency	Supported	Not supported without Layer 3 VPNs
Operation and craft expertise	Lower	Higher
Quality-of-service (QoS) capability	Lower	Higher
Support for network growth	Manual effort, configuration intensive	Easier with support of automatic discovery

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Recommendation

Cisco remains technology-independent on the issue of using Layer 2 or Layer 3 for IP RAN backhaul, but as operators evolve to a 3rd Generation Partnership Project (3GPP) LTE network there are distinct competitive advantages to a Layer 3 infrastructure. Fortunately the Cisco Unified RAN solution natively supports both Layer 2 switching and Layer 3 routing.

This document will explain the benefits of extending a Layer 3 infrastructure further into the RAN network.

Benefits of Layer 3 Infrastructure for Mobile Operators

The following are benefits of a Layer 3 infrastructure. Each will be explained in detail:

- X2 LTE interface
- Service support, video, and Internet offload
- Support for other devices
- Network flexibility

The following arguments against extending Layer 3 into the access will be discussed with a response to each:

- Advantages really apply to data only
- X2 usage is currently only 5 percent
- Why not home to the MTSO?

LTE Background

Understanding the benefits of a Layer 3 decision requires more background on LTE and Evolved Packet Core (EPC) technology. The LTE and EPC evolution involves moving the radio and core networks towards an IP-only architecture.

Figure 4 highlights the 3GPP-based reference architecture. The radio technology will change and result in greater bandwidth and speeds. The flattening of the architecture (removal of the RNC) will result in greater intelligence in the eNodeB. Evolved UMTS Terrestrial Radio Access Network (E-UTRAN) is the official 3GPP name for the radio access network of LTE. The X2 interface between eNodeBs will carry control plane (X2-c) and user plane (X2-u) traffic.

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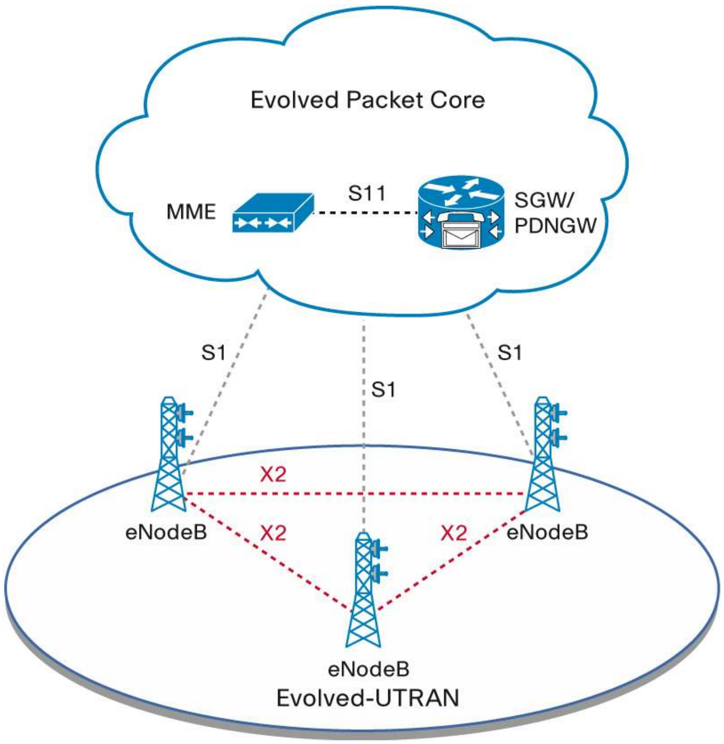
Figure 4. LTE Interfaces



The LTE architecture introduces additional requirements on the underlying transport network, including the following.

- Flattened mobile architecture: The traditional mobile infrastructure is very hierarchical, with connection-oriented service requirements and one-to one relationships (that is, IP NodeB has a one-to-one relationship with the RNC). The LTE-enhanced NodeB (eNB), now part of the IP infrastructure, will have a one-to-many relationship with the core gateways, SGWs, and Mobility Management Entities (MMEs). This implies that the underlying infrastructure must offer this capability in a scalable and secure manner.
- X2 interface: The X2 interface is a direct communication between eNodeBs. There never was direct communication between radio base stations (BTS, NodeB) prior to LTE. This interface will be used for control plane and bursts of user plane traffic during handover.

Rationale

X2 LTE interface

As described above, the X2 LTE interface allows handoffs between towers without involving the MTSO. The X2 interface can be used for user handoffs between cell sites. This avoids congestion elsewhere in the network or adding load to the MTSO. It is believed that these will be easier user handoffs and should result in less interruption to voice and video traffic.

Current estimates indicate that the combined X2-c and X2-u traffic could be between 4 and 10 percent of the core-facing bandwidth (S1-u) and the delay should be less than 30 ms. (Some bandwidth estimates are 2 to 5 percent.) This traffic is of the utmost importance, and it is clear from future releases (LTE Advanced) that more user plane traffic will traverse this interface. Also in the 3GPP Release 10 specification, there will be stringent latency requirements necessary to implement features such as collaborative Multiple Input Multiple Output (MIMO).

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Requirements in the region of 10 ms latency are currently being considered. This means that time sensitivity will increase and there may be more value to routing these requests locally (not through the MTSO), especially in areas of higher network latency.

Service Support, Video, and Internet Offload

- Video services: The LTE specifications include support for E-MBMS (Enhanced Multicast Broadcast Multimedia Services) for delivering services such as mobile TV, in competition with TV broadcast based on Digital Video Broadcast-Handheld (DVB-H). In this specification the E-MBMS Gateway (MBMS GW) is a logical entity that has a user plan interface (M1) with eNodeBs. The MBMS GW main function is the sending or broadcasting of MBMS packets to each eNodeB transmitting the service. IP Multicast is used in M1 interfaces for point-to-multipoint delivery of user packets.

  IP Multicast and Multicast VPN will become crucial requirements for any mobile operator with an ambition to offer IPTV services that today are suffering scalability performance issues. The use of a converged IP network to distribute the content will be vital to the future of a converged wireline and wireless offering.

  The Evolved Multimedia Broadcast Multicast Service (E-MBMS) offering will require multicast support between core elements as outlined above. The solution is to deliver Layer 3 Multicast and Multicast VPNs out to the very edge of the network. This will allow optimized replication and routing, which is extremely difficult to achieve over any Layer 2 technology considered today.
- Multiservice network: Not all services are hosted and controlled on the same MTSO (for example, Internet offload). A Layer 2 network has to backhaul to a MTSO and then route through the core, while a Layer 3 network can route different services separately and optimally.
- Traffic and Internet offload: Some operators are examining the possibility of offloading specific traffic types as early as possible in the backhaul infrastructure (also referred as Selected IP traffic offload in 3GPP). Operators do not see a value in carrying specific traffic types across core bandwidth. In fact, the operators may be adding little value and so want to hand the traffic over to a third party as soon as possible.
- Video optimization: Some operators are carrying large amounts of video. This accounts for a high percentage of their total traffic, even 70 percent. Distribution of gateways allows operators to use technologies such as caching, offload, and local insertion to save on transport costs. Although caching and distribution can be supported in Layer 2 as well as Layer 3, the extra flexibility of Layer 3 to route allows proximity routing as well as congestion to be factored into the cache selection.

Other Device Support

The flexibility of Layer 3 networking supported by Layer 3 termination closer to the edge facilities other radio device support. Not all devices on the same tower need to go to the same MTSO. There are frequently several devices at any tower location including GSM, UMTS, Trueposition911, OAM, and soon LTE. These devices do not terminate at the same MTSO location where the Ethernet RAN or traditional TDM terminates.

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Network Flexibility

A Layer 3 network is viewed as more flexible to optimization and supports easier additions, moves, and changes. For example, radios may be rehomed to other MTSOs based on capacity issues or movement of a population such as to the beach during the summer. Also, new LTE radios may be terminated to the S and P gateways further on the edge access of the network or net-to-Internet touchpoints. As an example, a large European backhaul provider stated at the Mobile Backhaul Asia Conference in Bangkok, March 16, 2011, that rehoming upgrades in their traditional point-to-point network took about 8 hours per cell site, compared to only minutes in their new Layer 3 architecture. This offers insight into the tremendous operational savings advantage of Layer 3 over Layer 2 architecture.

Network Topology Migration

Deployment of eNodeB and LTE is a compelling event not only for migrating the infrastructure from TDM and ATM to Ethernet and IP, but also for reviewing the network topology. Hub-and-spoke microwave topology can be turned into a ring topology, changing the 1+1 link protection into a network-based protection (using 1+0 links), improving the network availability and resiliency, and also saving CapEx and OpEx.

Microwave ring topology advantages include:

- Fewer links: High Availability with 1 per direction, instead of 1+1 per direction
- Higher resiliency: Ring protection and path diversity
- High availability: Immunity from site failure
- High-frequency reuse: Only two links per node, with a single pair of frequencies per ring
- Lower power consumption and occupied footprint (maximum two radio units, east and west, per hub)

Security

From a security point of view, Layer 3 supports the use of more sophisticated management capabilities such as access control lists (ACLs) to enforce some degree of traffic partitioning (for example, core traffic should only pass to Security Gateway, and X2 can have regionalization enforcement). The capabilities to do this are far more extensive at Layer 3 than they are at Layer 2.

Arguments Against Layer 3 Deployment

The following section provides an analysis of some of the most frequent arguments against a Layer 3 deployment decision, along with an explanation why each point is not a sufficient counterargument.

Layer 3 Advantages Apply to Data Only

There is a suggestion that the rationale for making a Layer 3 decision applies mostly to data traffic. A service provider should examine why they would want to make a decision based on immediately observable traffic patterns when a flexible Layer 3 network supports additional services, video caching, Internet offload, and future X2 applications. It may well be true that a voice-only cellular network does not need to move to Layer 3 (or even IP) yet, but the VNI data and usage patterns show how networks will be affected in the future.

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X2 Is Currently only 5 Percent of Network Traffic

Ultimately, the question is: Is LTE X2 a justification for full mesh Layer 3 or VPLS? The answer is a function of the traffic latency requirements, traffic size, and RAN ownership. The amount of X2 traffic will depend on the sizing of the cell coverage area and the relative mobility of users.

- Variables 1 and 2: Cell size coverage area and user equipment mobility percentage

  If a service provider has small coverage areas and highly mobile users (for example, in cars), there will be much more X2 handoff traffic as users move from tower to tower. Conversely, if the service provider has large coverage areas and minimally mobile users, there will be minimal X2 handoff traffic.
- Variable 3: Application type

  Voice and video may need higher-speed interfaces. Data may not require as much bandwidth.
- Variable 4: Physical plant

  If the operator does not own the physical infrastructure in the RAN backhaul area, it is harder to build eNodeB meshes for better mobility. It may be difficult to get a wholesale backhaul provider to offer a network supporting these new services.

Most walking and bicycling users only connect to one or two towers during a mobility session. Users in motion (for example, in cars or trains) generally connect to five or six towers during a mobility session.

If mobility is only needed for a small group of towers, why is the bearer being transported by expensive links back into the network based on traditional models? Why increase the latency and experience for the mobile user during handoff if the x2 bearer can be used economically and efficiently? It is preferable to terminate the traffic as close to the user as economically viable and allow the IP traffic to find its way to the applications as soon as possible.

Because X2 handoff is a new approach, we do not have good information about the size of the traffic. Although estimates suggest it will only be 5 percent of core traffic, there is no reason to assume the current state is the future state, and there are significant benefits from building a meshed L3 network.

Why Not Home to MTSO?

The answer is flexibility for video caching, Internet offload, additional services and devices, as well as support for current and future applications that will use the X2 interface.

If X2 is used in a MTSO-homed network, it will traverse the path to the MTSO. The X2 service plane target latency is 50 ms+. The MTSO backhaul should be able to accommodate this traversal, although during network stress period, X2 could be affected.

When voice and video over LTE is more widely deployed, we will see whether dropping a few packets is better than delivering them late, although avoiding extra backhaul reduces the chance for dropped packets or delays.

Conclusions

Cisco's Unified RAN Backhaul and Mobile Packet Core (MPC) solutions support both Layer 2 and Layer 3 models. Given this flexibility, in cases where a provider opts to use Layer 2, Cisco's solution supports L2 natively, but also offers Layer 2 over Layer 3, which provides an easy transition to an all-Layer 3 model over time.

This document has presented the Cisco VNI predictions of escalating growth in data traffic in mobile networks, especially with the emergence of video. To compete effectively today and cope with the expected changes to network traffic, service providers need a network that supports innovation, monetization, optimization, and enablement. After examining variables affecting technology decisions, this document presented arguments why a

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Layer 3 decision gives the service provider advantages in supporting a variety of services, allowing offload and video optimization as well as network flexibility and enhanced security, and reducing overall network operational costs. Arguments supporting a Layer 2 decision were examined and refuted.

The flexible termination and routing of Layer 3 provides the capability to freely switch and terminate the various flows from a tower to its gateway and then to the application. The result is that a Layer 3 network allows a service provider to compete and win in today's network environment while making a strategic investment for tomorrow's LTE system and predicted accelerating bandwidth requirements.

For More Information

For more information, please visit the following websites:

- Cisco Visual Networking Index
- Mobile Internet solutions
- Architectural Considerations for Backhaul of 2G/3G and Long Term Evolution Networks White Paper
- Evolution of the Mobile Network White Paper

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