White Paper

Evolving to LTE: Cisco's Seamless Migration for CDMA Operators

What You Will Learn

With the convergence of the Internet and wireless communications, mobile data services are undergoing tremendous growth. However, the mobile wireless environment is failing to fully meet user expectations, due to limitations on access speed. If mobile operators are to succeed in today's communications landscape, they must address the quality of experience for their users.

This paper outlines how mobile operators can prepare their networks to support 4G broadband services that will improve the user experience and yield new revenue opportunities. Specifically, it discusses how Cisco can assist operators in their move toward Long Term Evolution (LTE), a 3rd Generation Partnership Project (3GPP) standard that represents a significant advancement in mobile technology.

With industry-leading mobile infrastructure solutions from Cisco, operators can:

- Gradually transition from 2G/3G to 4G without a comprehensive network upgrade
- Support 2G/3G and 4G functionality on a single platform
- Meet LTE requirements for increased data rate capacity, reduced latency, and improved spectral efficiency
- Provide transparent roaming between the High Speed Packet Access (HSPA) network and the LTE network
- Take a phased approach to migrating the HSPA network to LTE by upgrading the core network to Evolved Packet Core (EPC) elements without an overlay Radio Access Network (RAN)

Overview

Designated as a 4G mobile specification, LTE is designed to provide multi-megabit bandwidth, more efficient use of the radio network, latency reduction, and improved mobility. This combination aims to enhance the user's interaction with the network and create further demand for mobile multimedia services. With wireless broadband, users can more readily access their Internet services, such as online television, blogging, social networking, and interactive gaming - all while on the go.

Changes in mobile communications have always been evolutionary, and the deployment of LTE will be the same. The transition from 3G to 4G will occur over a period of several years, as is the case still with the transition from 2G to 3G. As a result, mobile operators must look for strategies and solutions that will enhance their existing 3G networks while addressing their 4G deployment requirements without the need for a "forklift" upgrade.

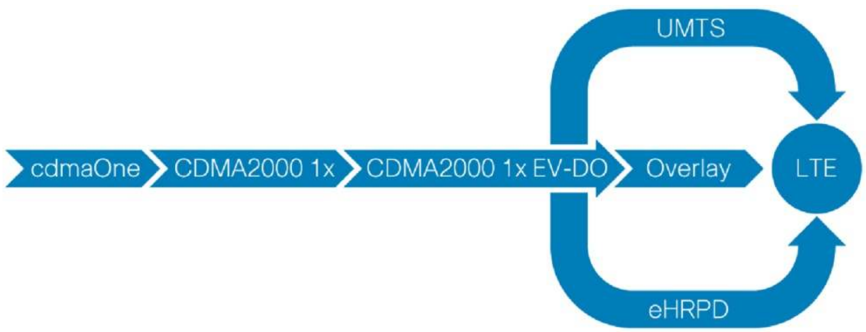
Cisco® solutions meet the specific needs of the mobile operator's packet core network. Our solutions deliver superior performance in the existing network while being readily upgradable to the requirements of LTE. Our offering already includes many of the elements required of the 4G network, including integrated intelligence, simplified network architecture, high-bandwidth performance capabilities, and enhanced mobility. Furthermore, Cisco solutions are capable of supporting multiple functions in a single node, allowing a single platform to concurrently act as a 2G/3G and 4G node. All of this functionality is available through a software upgrade, protecting today's investment and eliminating the need to replace costly equipment.

Evolving the Packet Core

Radio access solutions are a primary consideration of the LTE deployment strategy (Figure 1), as LTE affects the mobile operators' most valued asset, spectrum. As an equally important part of this equation, the multimedia core network will play a central role in enhancing mobility, service control, efficient use of network resources, and a seamless migration from 2G/3G to 4G. As a result, the LTE evolution calls for a transition to a "flat," all-IP core network with a simplified architecture and open interfaces. This requirement is defined by the System Architecture Evolution or SAE, also known as Evolved Packet Core (EPC), which is the 3GPP specification for changes to the core network architecture. A key SAE goal is to enhance service provisioning while simplifying interworking with non-3GPP mobile networks. This goal is especially critical for CDMA operators that have chosen to migrate to LTE.

CDMA Upgrade Paths to Wireless Broadband

Figure 1. Multiple Migration Paths to LTE for 3GPP2 Mobile Operators



Mobile operators are looking for the best multimedia core solutions to deliver an optimum user experience and build an efficient network. Key considerations for the multimedia core network include:

- **Integration of intelligence at the access edge:** As a greater variety of services and user types cross the mobile network, it is critical to increase network and subscriber intelligence. Through this intelligence, including quality of service (QoS) and policy enforcement, mobile operators will better understand individual users and their transactions and be able to shape the service experience and optimize network efficiency.
- **Simplified network topology:** In order to effectively deliver the enhanced performance of LTE, the network will need to be simplified and flattened, with a reduction in the elements involved in data processing and transport.
- **Optimized backhaul:** With the introduction of 4G, the transport backhaul is a key consideration. Many are realizing this after the fact. It is very important to deploy a core network solution that is flexible enough to offer a smooth migration from centralized (longer backhaul) to distributed (shorter backhaul) core network nodes.
- **Converged mobility and policy:** Maintaining the subscriber session is an important consideration during 4G to 2G/3G mobility events. Additionally, unified policy management in the network is critical for efficient

service delivery over mixed 4G and 2G/3G networks. It is therefore important to deploy a core network based on a single mobility and policy control paradigm.

- **Increased performance characteristics:** Clearly, the intent of LTE is to improve the performance and efficiency of the network. To realize the full potential of LTE, mobile operators must deploy core solutions that can meet the demands generated by increased mobile multimedia services and a growing subscriber base, including increased network capacity requirements, thousands of call transactions per second, and significant throughput.
- **2G/3G to 4G migration:** As mobile operators migrate their networks to LTE, they will seek to minimize cost and maximize subscriber usage. This will require core solutions that can address 2G/3G network requirements while at the same time be used for 4G network introductions. Operators will want to avoid a comprehensive upgrade while deploying best-in-class solutions based on open standards. Additionally, mobile users will expect a uniform service experience across both networks, with consideration to the bandwidth differences.

While the evolution to 4G technologies will likely take many years, it is imperative for mobile operators to identify multimedia core elements now that will most effectively migrate them to a 4G network in the future.

Cisco is exceptionally well positioned to address these challenges and assist in the migration to LTE. Our solutions are designed for the specific requirements of the next-generation multimedia core network. As a result, these solutions already address the key considerations listed above, including the ability to support both 2G/3G and 4G functionality in a single platform. A single node can appear as a 2G/3G node to the 2G/3G radio network and as a 4G node to the 4G radio network. This capability provides major benefits to mobile operators that want to smoothly migrate their networks, maximize their investments, and offer an exceptional experience to their customers.

LTE Requirements

With specifications nearing completion, the 3GPP is finalizing 4G access and core specifications, with the primary goals of increasing bandwidth, improving spectral efficiency, reducing latency, and enabling improved mobility.

The LTE specifications call for peak data rates of 150 Mbps downlink with 2x2 multiple input multiple output (MIMO) and 75 Mbps uplink with 1x2 MIMO over 20-MHz channels in frequency-division duplexing (FDD) mode. This increased capacity is set to arrive as existing 3G networks begin to strain under the dramatic usage increases of bandwidth-intensive applications, long-duration services, and signaling overhead.

Latency is another issue tackled by the LTE standards. Transition times in the control plane are designed to be between 50 and 100 milliseconds (ms), depending upon the state of the session (dormant to active). The user plane will also have reduced latency, with less than 5 ms in unload condition from a small IP packet.

Spectrum efficiency will also be improved and the radio architecture simplified. This will be achieved through a single element called the Evolved Node-B (eNodeB) that is packet based, reduces the number of single points of failure, supports end-to-end QoS, and has an optimized bearer plane with a reduced number of hops.

Mobility is also an extremely important factor. As specified, the radio network will be optimized for higher performance and seamless handoff between multiple access technologies. For Code Division Multiple Access (CDMA) operators, their selection of an evolution path will have an impact on their ability to provide seamless roaming between their High-Rate Packet Data (HRPD) network and the LTE network.

Aside from the improvements made in the access portion of the network, the most dramatic and important changes will be in the packet core.

System Architecture Evolution

SAE/EPC specifies the network architecture in 3GPP 4G core networks. SAE/EPC promises an all-IP core network with a simplified and flattened architecture that supports higher throughput, lower latency, and mobility between 3GPP (Global System for Mobile Communications [GSM], Universal Mobile Telecommunications Service [UMTS], and LTE) and non-3GPP radio access technologies, including CDMA, WiMAX, Wi-Fi, HRPD, evolved HRPD (eHRPD), and European Telecommunications Standards Institute (ETSI)-defined Telecommunications and Internet Converged Services and Protocols for Advanced Networking (TISPAN) networks.

SAE Network Functions

SAE defines a series of new network functions that flatten the architecture by reducing the number of nodes in the network, which promises to reduce capital and operational expenditures. This, in turn, lowers the overall cost per megabyte of traffic running over the EPC, while improving network performance.

- **Mobility management entity (MME):** The MME resides in the control plane and manages states (attach, detach, idle, RAN mobility), authentication, paging, mobility, roaming, and other bearer management functions.
- **Serving gateway (SGW):** The SGW sits in the user plane, where it forwards and routes packets to and from the eNodeB and packet data network gateway (PGW). The SGW also serves as the local mobility anchor for inter-eNodeB handover and roaming between two 3GPP systems.
- **Packet data network gateway (PGW):** The PGW (sometimes called the PDN gateway) acts as the interface between the LTE network and packet data networks (PDNs), such as the Internet or SIP-based IP Multimedia Subsystem (IMS) networks (fixed and mobile). The PGW is the mobility anchor point for intra-3GPP access system mobility and for mobility between 3GPP access systems and non-3GPP access systems. The function is responsible for IP address allocation, charging, deep packet inspection, lawful intercept, policy enforcement, and other services.
- **Evolved packet data gateway (ePDG):** The ePDG is the primary element responsible for interworking between the EPC and untrusted non-3GPP networks, such as a wireless LAN. The ePDG uses Proxy Mobile IPv6 (PMIPv6) to interact with the PGW when the user equipment (UE) is in an untrusted non-3GPP system. The ePDG is involved in the policy and charging enforcement function (PCEF), meaning that it manages QoS, flow-based charging data generation, gating, deep packet inspection, and other functions.
- **HRPD serving gateway (HSGW):** The HSGW provides the interworking between HRPD and EPC networks. The HSGW is part of eHRPD, an evolution option for CDMA operators that helps ensure converged mobility and management between HRPD and LTE networks.

Standard Interfaces and Protocols

SAE/EPC also supports standard interfaces and open protocols aimed at enabling operators to launch services and applications with Internet speed, while also reducing the overall cost per packet through the inherent advantages of going all-IP.

Standardized interfaces and protocols also enable operators to achieve a best-in-class approach with their network infrastructure. By eliminating proprietary protocols, operators can establish an open network that empowers them to select the vendors they deem most qualified to deliver a specific network function without having to worry about interoperability issues.

Converged Mobility and Policy Management

In 2G/3G networks, diverse schemes were used for mobility management within and across the access technology boundary. So an operator choosing to deploy a 2G access technology of one kind and a 3G access technology of a different kind had to deploy two divergent mobility management schemes in the same network. This caused serious issues and, more importantly, impeded rapid deployment of some access technologies. 3GPP SAE/EPC is an attempt to address this issue.

With a single, comprehensive architecture, SAE/EPC supports all access technologies - 2G/3G and 4G from all standards-defining organizations. The basis of this convergence is the use of an IETF-defined mobility management protocol such as Proxy Mobile IPv6 (PMIPv6). If an operator wants to deploy any access technology with a 3GPP SAE/EPC core, a single mobility management protocol such as PMIPv6 is all the operator needs. This is a significant step toward building a single common IP core for future access technologies with superior mobility. Operators have the freedom to choose any access technology without having to worry about a complete overhaul of their existing IP core or an IP core overlay.

As part of the evolution to SAE/EPC, 3GPP2 (Figure 2) is defining the interworking between LTE and eHRPD as an optional method to interwork HRPD with SAE/EPC networks using PMIPv6.

Evolution of the Packet Core

The benefits of SAE/EPC highlight the growing importance of a common packet core across multiple access technologies. As many operators transition from disparate 3G specifications (UMTS and CDMA2000) to LTE/SAE, there is the potential for significant network simplification and cost savings, as well as greater efficiencies within the core network.

Integrating SAE Core Network Functions

The SAE specifications call out the MME, SGW, and PGW as specific network functions, but do not define them as separate nodes in the network. In keeping with the intention of having a simpler and flatter architecture, these three functions can logically be integrated into one node. However, this will require a solution that is capable of this integration and can deliver the benefits of such integration.

For instance, the MME, SGW, and PGW can be combined into one carrier-class platform. By collapsing these functions, operators could reduce the signaling overhead, distribute session management, and take advantage of the control- and user-plane capabilities of the carrier-class node.

Alternatively, an operator could deploy the MME separately from the combined SGW and PGW, resulting in reduced signaling overhead (S5 and S8 would be internal), fewer hops on the bearer path, less backhaul, reduced signaling on the S7/Gx interface, and a lower session requirement for the PGW. This also provides for a single location for policy enforcement and charging data generation.

Figure 2. Example of Cisco 3GPP2 HRPD Deployment

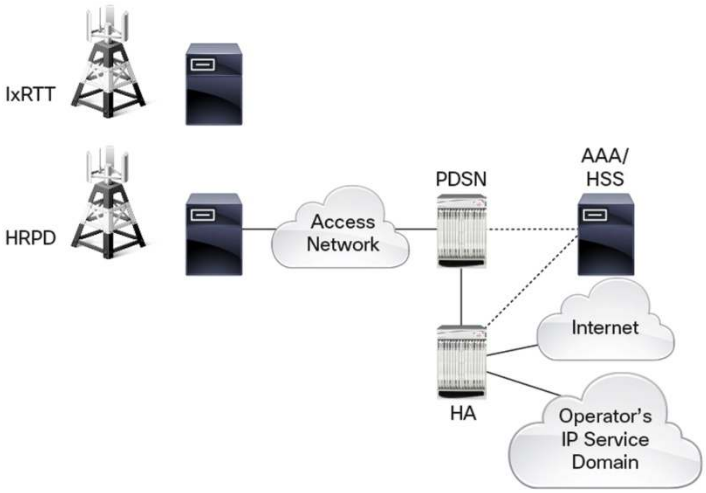
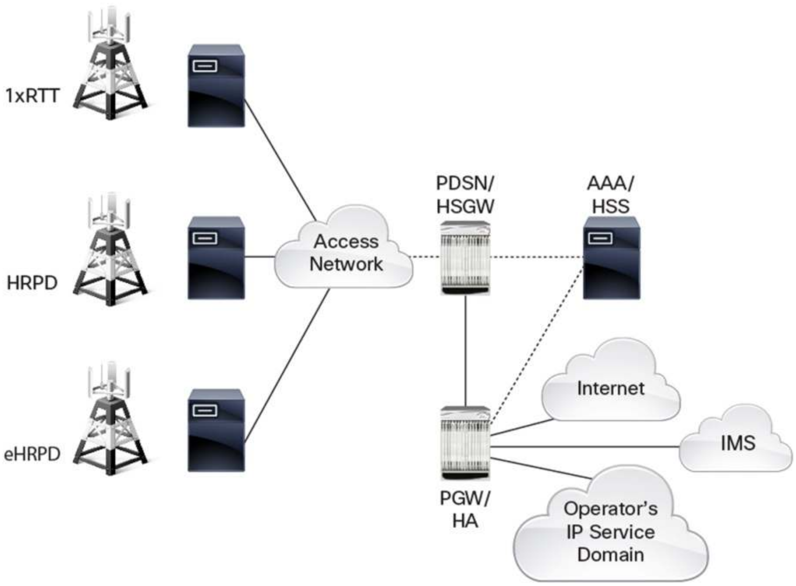


Figure 3. Benefits of Cisco Solution for HRPD Evolution to LTE Using eHRPD



The advantage of integrating or collapsing functional elements into one carrier-class node is paramount to the goals of simplifying and flattening the network while also reducing latency.

Convergence of 3G and 4G Core Networks

The concept of collapsing SAE functions (Figure 3) can be taken a step further. The move to LTE will be an evolution, meaning that many 3G, 2.5G, and even 2G networks - whether 3GPP or 3GPP2 - will remain operational for many years to come. Mobile operators can seize this opportunity to combine SAE and eHRPD functions with CDMA functions (3GPP2 packet data serving node [PDSN], Home Agent), easing network migration, reducing signaling overhead, enhancing resource utilization by sharing common session data storage, and improving mobility between 2G/3G and 4G access systems. Most importantly, operators have the potential to achieve this without a “forklift” upgrade by using their existing 3G deployed base. This results in dramatic savings in capital and operating expenses and reduces the risk involved in adding a new, unproven access technology.

Universal Roaming

By operating 2G/3G and 4G functions on the same core platform for 3GPP and non-3GPP (for example, CDMA) access systems, operators can more easily achieve inter-technology handover and universal roaming/interworking between access networks with reduced signaling overhead over the air and in the network. With LTE/SAE specifications detailing a common, converged core, universal roaming will be critical.

Since LTE/SAE is becoming the network evolution choice of many CDMA operators, 3GPP and 3GPP2 are defining interworking specifications for optimized handover management between 3GPP2 radio access technologies and LTE, using EPC as the converged core. Key to this interworking will be seamless mobility and handover between the two technologies - one of the goals of a migration to eHRPD.

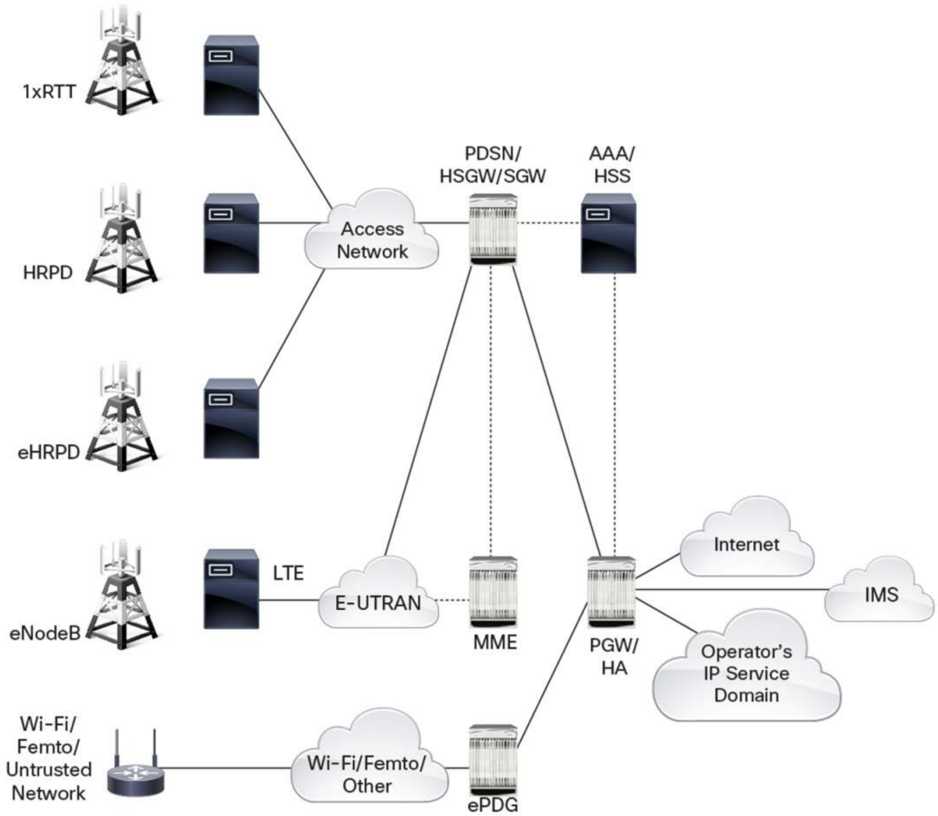
The Cisco Difference

Cisco brings a history of innovative solutions that already meet many of the requirements of LTE and SAE, such as integrated intelligence, simplified network architecture, high-bandwidth performance capabilities, and enhanced mobility.

Additionally, mobile operators will benefit from solutions that can provide 2G/3G functionality now and evolve to 4G functionality later. Cisco’s solutions are capable of supporting 2G/3G today, and through software upgrades these solutions are designed to support 4G functionality when LTE networks are deployed. Furthermore, they are capable of supporting multiple functions in a single node. This allows a single platform to concurrently act as a 2G/3G and 4G node, providing a true evolution path.

The flexibility of Cisco’s multimedia core platform provides multiple migration options from 3G/HRPD to 4G/LTE. Options include the phased approach to LTE through eHRPD and the cutover approach with coexisting but pure overlay HRPD and LTE networks.

Figure 4. Addressing LTE Core Network Functionality in ASR 5000 Series with Software Upgrade



eHRPD: Paving the Way to LTE

One of the key issues in the evolution from existing HRPD networks to the LTE EPC is that, as currently defined, the two networks will be overlay networks. New LTE RAN and packet core networks must be rolled out from day one, limiting interworking between the LTE and HRPD networks. This limits mobility for customers and also limits the sharing of common functions such as policy, charging, and authentication.

Today's mobile subscribers are used to a seamless service experience, which would require operators to deploy LTE networks widely from day one or find a way for the LTE and HRPD networks to work together. 3GPP2 is defining such an interworking method by evolving existing HRPD networks to LTE through a step called evolved HRPD (eHRPD).

By transitioning their HRPD networks to eHRPD as the first step, CDMA operators can take a phased approach to migrating toward LTE. They can upgrade a portion of their core network to EPC elements without an overlay RAN, and they can phase in the RAN over time. The mobile operator obtains many features of LTE plus gains the benefit of being able to interwork the eHRPD network with the LTE network.

The introduction of eHRPD requires the introduction of an HRPD serving gateway (HSGW) - the element that provides interworking between the HRPD access node and the LTE EPC - and the PGW. With the intelligent Cisco solution, the existing PDSN can be integrated with or upgraded to the HSGW, while the PGW can be integrated with or upgraded from the existing Home Agent (or provided as a separate node) through a simple software upgrade.

Although eHRPD will be attractive to many operators, Cisco also supports migrating directly to LTE from HRPD. In addition, the flexibility of the Cisco ASR 5000 Series multimedia core platform enables a CDMA mobile operator to optionally migrate first to UMTS before going to LTE.

Integration of Multiple Core Functions

With an adaptable solution, Cisco does not require operators to perform “forklift” upgrades when evolving to LTE, whether through eHRPD or directly from HRPD to LTE. Cisco systems - whether deployed as PDSN, Home Agent, or Packet Data Interworking Function (PDIF) - are designed to be integrated with or upgraded to eHRPD and LTE functional elements (MME, HSGW, SGW, PGW, and ePDG) through a simple software upgrade (Figure 4). If the eHRPD evolution path is taken, the final step to LTE in the core network is to add the MME and upgrade the existing HSGW to an SGW.

The integration of both 2G/3G and 4G core network functions is an ideal solution for operators looking to achieve capital and operational efficiencies along their upgrade path. For example, a single node acting as a colocated PDSN/HSGW/SGW and a node acting as a co-located PGW/HA (Home Agent) can serve both the 2G/3G network and the 4G network. At the same time, Cisco’s solution offers the flexibility to decouple functions when the network traffic and density grow. With substantial 2G/3G core investments already in place, operators can ease their 4G evolution by gradually converting existing 2G/3G systems into combined 2G/3G/4G systems, and ultimately to 4G only. This integrated solution will also simplify 2G/3G-to-4G roaming capabilities.

Intelligence in the Network

Key to creating and delivering high-bandwidth multimedia services in 2G/3G and 4G networks and meeting subscriber demand is our solution’s capability to recognize different traffic flows. This capability allows it to shape and manage bandwidth while interacting with applications to a very fine degree and delivering the QoS required. Our system does this through its session intelligence, which uses deep packet inspection technology, service steering, and intelligent traffic control to dynamically monitor and control sessions on a per-subscriber/per-flow basis.

Our solution’s interaction with and understanding of key elements within the multimedia call - devices, applications, transport mechanisms, and policies - assists in the service-creation process by:

- Enabling intelligent QoS control based on service type, user profile, and business policy
- Extending the visibility of the access technology type in the SAE nodes; the PGW can automatically adapt QoS for ongoing sessions - for example, when the user equipment performs a handover between LTE and CDMA
- Providing a greater degree of information granularity and flexibility for billing, network planning, and usage trend analysis
- Sharing information with external application servers that perform value-added processing
- Exploiting user-specific attributes to launch unique applications on a per-subscriber basis
- Extending mobility management information to non-mobility-aware applications
- Enabling policy, charging, and QoS features

Architecture Philosophy

The LTE/SAE architecture calls for the separation of the control and bearer planes into different functional elements (as previously outlined). Cisco brings a high level of expertise in call control and packet forwarding within a multimedia core network.

The Cisco ASR 5000 Series multimedia core platform uses a distributed architecture that combines high-performance processing, significant memory, and a powerful switch fabric to more intelligently and reliably handle mobile sessions. In these systems, call control and packet forwarding paths are separated on different control and data switch fabrics. This reduces traffic-flow inefficiencies, diminishes latency, and accelerates call setup time and handoffs.

Standards Initiatives

As a market leader in multimedia core networking, Cisco, has taken an active role in 3GPP, 3GPP2, WiMAX, Internet Engineering Task Force (IETF), and Next-Generation Mobile Networks (NGMN) in helping ensure that the SAE standard contains requirements that allow operators to select best-in-class solutions in order to deliver a true, carrier-class wireless broadband network. As an example of our contribution, Cisco is the key contributor, co-author, and strong advocate of the core mobility management protocol in SAE - PMIPv6. Cisco is also harnessing its extensive expertise in multi-technology interoperability in taking a lead on interworking requirements among access technologies, including eHRPD, WiMAX, and LTE, among others.

Cisco made significant contributions to 3GPP2 for defining eHRPD-enabling evolution and mobility management between eHRPD and LTE networks. Also, Cisco made significant contributions in 3GPP SAE for defining procedures for handovers between access technologies using multiple types of mobility management schemes and combinations of access technologies.

Furthermore, Cisco is the primary contributor to NGMN's converged mobility initiative in Project 5. Cisco continues to lead development of IETF standards that are essential in fulfilling the promise of 3GPP SAE in the areas of mobility management, optimized handover, fast handover, transition scenario handling, and authentication, authorization, and accounting (AAA).

Resources

1. 3GPP Americas white paper: "UMTS Evolution from 3GPP Release 7 to Release 8 HSPA and SAE/LTE," December 2007
2. Qualcomm, Inc. white paper: "Evolved Packet System (EPS): An Overview of 3GPP's Network Evolution," December 2007

For More Information

For more information, visit http://www.cisco.com/go/mobileinternet.

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Printed in USA C11-609207-01 12/13