The Role of IP in Next-generation CDMA Mobile Networks

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Transforming and future-proofing mobile networks with scalable, IP-based UMB technology

Introduction

Operators are seeing increasing demand for advanced mobile services such as mobile TV, IMS-based blended services and a variety of mobile content offerings. These services are driving increases in mobile data traffic which is expected to accelerate over time. To address this demand, mobile networks are rapidly transforming to be competitive, characterized by increasingly powerful radio access networks and multi-media centric core network architectures.

One of the key features of these new networks is their reliance on IP-based radio access networks (RAN) along with core architectures and converged transport networks that ensure a quality end user experience for these advanced mobile services. One of the great benefits of this approach is the ability to leverage the dramatic cost savings that IP/multiprotocol label switching (MPLS) multi-service backbone networks offer.

An IP-based transport infrastructure – incorporating Alcatel-Lucent Service Routers – ensures the quality of service needed by end users deploying mobile applications. However, to take full advantage of the benefits of IP in the transport layer, IP capabilities must be extended into the RAN.

A “flatter” IP-based mobile network architecture – with fewer nodes, fewer layers and thus lower latency, along with new radio interfaces with much higher data transfer rates – is at the heart of the next-generation mobile network evolution.

For networks based on the 3GPP2[1]-developed CDMA2000 family of standards, this transition is already underway and operators will be making the move to IP-based services when the first VoIP networks are rolled out on the 1xEV-DO[2] Rev A air-interface through 2007-2008.

The next generation of air-interface and access network standards are aimed at providing end-to-end IP support integrating a new broadband OFDMA[3]-based air-interface with IP-based access network interfaces and elements. The gains from such networks range from support for bandwidth-intensive applications and latency reduction to overall savings in network CAPEX and OPEX.

1 Third Generation Partnership Project 2
2 1 Carrier Evolution for Data Optimized
3 Orthogonal Frequency Division Multiple Access

In March 2005, the 3GPP2 air-interface technical specification group (TSG-C) held a workshop to consider the future evolution of air-interface technology in 3GPP2. This was followed by a workshop in June to consider the evolution of the network architecture. The 3GPP2 Steering Committee constituted an Advanced Technology Evolution ad-hoc committee to develop a white paper on technology evolution for CDMA2000 over the next decade. Ultimately, work was started on a systems requirement document for the enhanced packet data air-interface.

By introducing the first proposal (in January 2006) with its partners for air-interface evolution in 3GPP2 and later driving the standardization process for both air and access network interfaces, Alcatel-Lucent has helped to prepare the next-generation of mobile networks for the CDMA2000 community of operators.

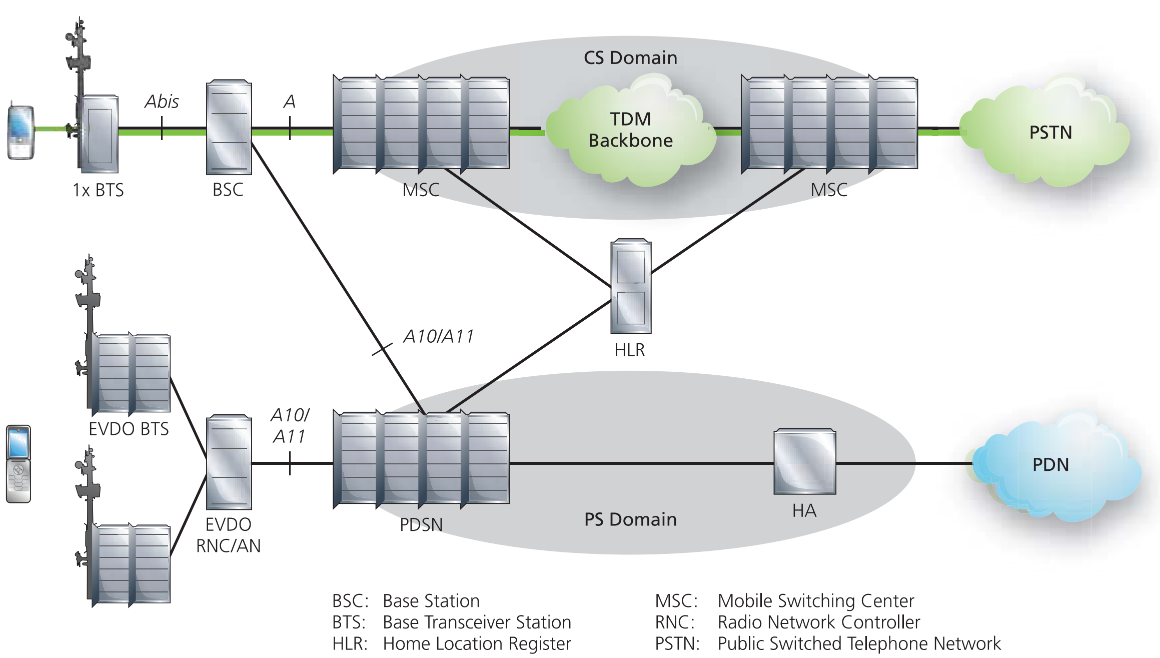
As a result of these efforts, 3GPP2 will complete a suite of specifications in 2007 for the air-interface, access and core network for the next-generation IP-based technology designated as Ultra Mobile Broadband (UMB).

Current CDMA Architectural Framework

What is different about the UMB architecture and today's CDMA networks? We should first look at the way these networks function today.

The majority of currently deployed networks can be represented as in Figure 1.

Figure 1: **Mobile network architecture – 3GPP2**



This 3GPP2 architecture is based on a clear split between a circuit-switched (CS) and packet-switched (PS) domain.

- The CS domain is mainly used for voice traffic and legacy CS data services. The MSC[4] supports call control and switching functions. The interfaces between nodes are TDM[5]-based in 2G networks, and ATM[6]-based in 3G networks.
- The PS domain is used for data applications. IP is used at the application level between the mobile terminal and the PDN. The A10/A11 interface is generally high speed Ethernet based.

Evolution drivers

In the 3GPP2 view, the most important drivers for air-interface evolution are the needs to support broadband IP services such as video-streaming, video-telephony and video-conferencing, and to gain spectral efficiencies (users/Hz) to further improve the economics for VoIP[7].

These dynamics are complicated by the growing demand for converged services and the desire of end users to maintain the same kind of experience they have on their fixed network in the mobile environment. Fixed networks are undergoing a revolution in terms of the kinds of services they support, with newer services such as IPTV, video sharing and VoIP making major inroads with consumers and businesses alike. Alcatel-Lucent primary market research among consumers in Western Europe shows that Internet Interactive TV (IPTV) is their number one preferred converged service, with Person to Person Video Sharing ranking third in priority. Research among enterprise end users shows that VoIP Solutions is their number one preferred service, with Video Conferencing also ranking in their top 10 preferred services. Transport infrastructures are already evolving to support these new services, and extending these capabilities into the mobile realm looks like a foregone conclusion. These developments bring with them a host of challenges.

1xEV-DO Rev 0 based networks provide high-speed packet data, but are already experiencing the problems noted above, with network bottlenecks appearing as packet data usage grows. With the deployment of 1xEV-DO Rev A networks throughout 2007, the resulting higher speed radio capabilities on the network side will exacerbate these problems.

When the initial 1xEV-DO standards were established, the benefits and practicality of IP-based transport were not clearly understood. Today, however, the necessity to move to an end-to-end IP scheme is increasingly evident with benefits ranging from lower cost support for bandwidth-intensive applications to better end-to-end QoS support for latency-sensitive services.

The 3GPP2 participants expect additional performance improvements (in latency and QoS) will be seen after flattening the network and moving IP to the edge of the RAN, i.e. into the BTS.

By using generic IETF[8] protocols (as opposed to 3GPP2 access specific technology) between the RAN[9] elements, co-existence of and interoperability between different air-interface technologies are facilitated. Such a network, based on IP interfaces and IMS services architecture, is the most cost-effective and scalable platform to deliver a wide range of IP-based applications.

4 Mobile Switching Center
5 Time Division Mulitplexing
6 Asynchronous Transfer Mode
7 Voice over IP
8 Internet Engineering Task Force
9 Radio Access Network

Introducing IP into the RAN

The 3GPP2 context of introducing IP into the RAN can be viewed as essentially having two components. The first is collapsing Layer 2 functions into the Base Station. The second is the extension of IP to the Base Station. The first step is – for the most part – a pre-cursor to the second and can be seen as enabling the extension of native IP to the edge of the network. Moving the basic radio resource management functions, Layer 2 mobility management and the paging functions to the base stations avoids centralization (such as with 1xEV-DO & RNC equipped nodes) preventing these nodes from becoming bottlenecks. Mobility management itself is simplified by removing the one additional layer of mobility that exists in a 2-node (RNC-BTS) RAN. The need to distribute Layer 2 functions across base stations becomes even greater when deploying pico (smaller) cells where the numbers of such cells exceeds current macro-cells by at least an order of magnitude.

Extending IP to the BTS, offers several advantages. Content may be located, hosted and cached at IP-aware base stations potentially avoiding the use of backhaul for providing some services. IP packets may be inspected at the point of the entry into the network to provide better QoS support. IP packet filters at the point of ingress (as opposed to deeper in the network) ensure that best effort data does not inadvertently preempt real-time traffic. From an over-the-air perspective, schedulers handling the downlink transmission to the mobile can use information in IP headers to ensure adequate QoS support.

The benefits of IP from a transport/ backhaul perspective are fairly obvious. In fact, the various 1xEV-DO standards developed in 3GPP2 have always supported IP transport in the RAN, and now have been extended to encompass CDMA2000 1X as well. The choice of IP transport is strongly motivated by the high cost of T1 leased lines. Secondly, IP is already being adopted in other parts of the network and introducing IP for transport in the RAN unifies the network on a single technology, reducing complexity and improving performance. There is also the additional potential for sharing network resources as other access tech-nologies (WiMAX, DSL, etc.) adopt IP for transport.

The IMS Core and the RAN

IP Multimedia Subsystem (IMS) has been introduced into 3GPP- and 3GPP2-compliant mobile networks to enable the launch of a variety of multimedia and content services that use common applications and services delivery platforms. A similar approach has now been adopted by TISPAN (Telecoms & Internet converged Services & Protocols for Advanced Networks) for fixed networks, leading most operators to adopt IMS as the core network of the future, regardless of access method.

For the effective delivery of IMS-based IP services, content-aware transport networks are preferred. Early IMS services such as mobile instant messaging and Push-to-Media applications are currently being launched, and more advanced, bandwidth-intensive services such as multi-party mobile video gaming will be introduced in the near future.

IMS and its extensions will clearly continue to be the services architecture for the evolved 3GPP2 networks.

The Ultra Mobile Broadband System

The UMB air-interface and network mark a substantial improvement over 1xEV-DO. The new air-interface integrates the best features of OFDMA and CDMA. The network architecture is simplified further extending IP visibility to the enhanced Base Station (eBS).

The most important characteristics of this air-interface are:

- Higher peak data rates and spectral efficiency and lower latency:
  - Transmission bandwidth ranges from 1.25 MHz to 20 MHz;
  - Peak data rates of up to 280 Mbps over 20 MHz on the downlink;
  - Over 250 VoIP users can be supported on a 5 MHz FDD system;
- Edge-of-cell bit rates are augmented by the use of dynamic frequency re-use schemes;
- Support for a raft of peak rate and capacity improving multi-antenna technologies (MIMO, SDMA) is included.

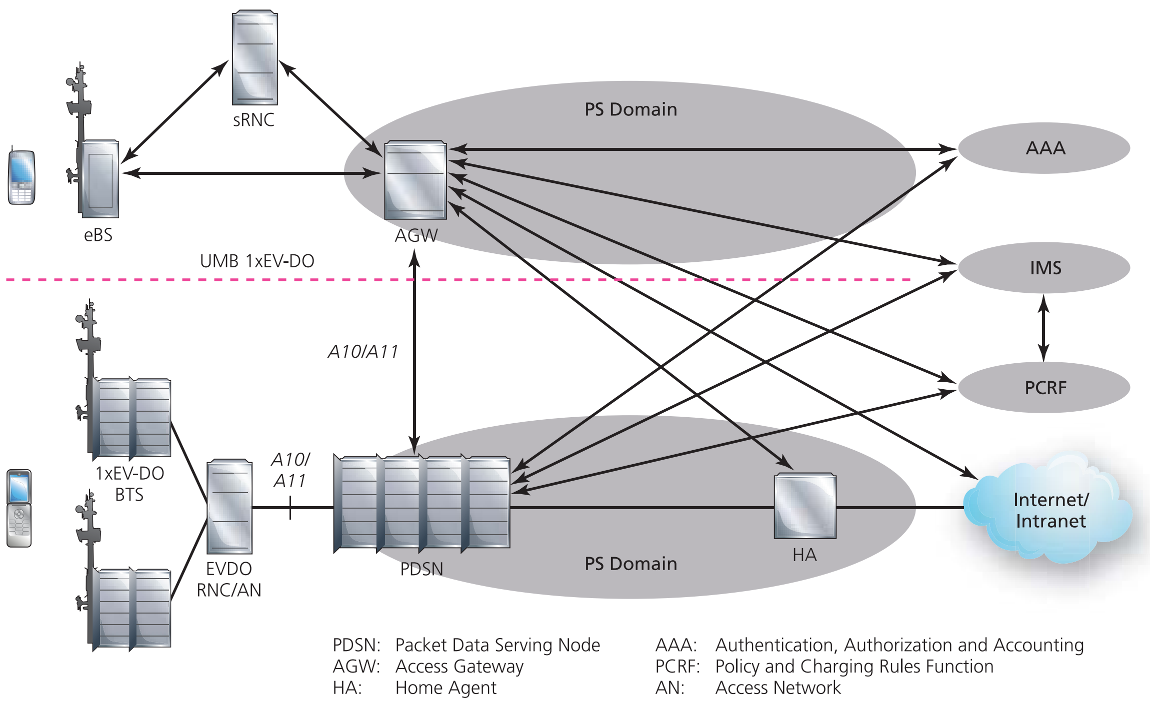
The UMB architecture is illustrated at a high-level in Figure 2.

Among the salient features of this network architecture are:

- From a three-node architecture in 1xEV-DO, an UMB network is evolving towards a two-node only semi-flat architecture.
- The AGW is an access agnostic system that could potentially enable access for multiple access technologies. It is the anchor point for mobility between different access systems. This gateway (serving as the edge of the core network) has a south bound interface to the network of eBSs and a north bound interface to the Home Agent.
  - The AGW is the IP point of attachment while the eBSs have IP visibility;
  - IETF interfaces (PMIP) will likely be used between the AGW and the eBS.
- The eBS gathers almost all the purely radio-oriented functionalities with the exception of paging-related functions and authentication. These latter functions are placed in a logical entity called the session reference network controller (sRNC). The sRNC itself may be centralized or distributed in implementation. When distributed, the network architecture collapses to a two node architecture.
- The set of eBSs is intended to be connected to the set of AGWs through a pure IP backbone that offers an any-to-any connectivity scheme (i.e. any eBS can communicate with any AGW). This provides significant advantages from a scalability and redundancy management perspective.

All mobility management at Layers 1 and 2 occur at the eBS; the airlink supports different serving eBSs on forward and reverse links thus optimizing the links in either direction. There is no need for support of uplink macro diversity. Broadcast and multicast services on the forward link continue to be supported with much higher data rates.

Figure 2: **From HRPD[10,11] to UMB**



IP Header compression is critical to maintaining air-interface transport efficiency for services like VoIP. It is performed at the eBS which takes advantage of lower-layer information to perform local-repair to recover from decompression failures. These failures might otherwise result in outages in a more traditional multi-node architecture where header compression is performed deeper in the network.

Inter-working with Other Access Technologies

One of the drivers for designing the UMB architecture based on IP interfaces and IETF protocols is to facilitate the integration of and interoperability between different access networks. Alcatel-Lucent intends to drive the standardization effort to facilitate interoperability between 3GPP2 and 3GPP systems.

We also continue our efforts to closely align the 3GPP2 and 3GPP architectures and share key technical approaches across the two domains.

The 3GPP2 UMB radio specifications will be published in the first half of 2007, and the remaining UMB specifications are scheduled for completion in October 2007. UMB-compliant networks are likely to appear in 2009 to 2010.

10 High Rate Packet Data
11 Access Gateway

Conclusion

The world of communications is moving to IP in virtually every dimension and the mobile network is no exception. This is a natural progression, driven initially by the introduction of IP into the transport domain and the increasing adoption of IMS as the enabling core network for advanced multimedia services for mobile, fixed and converged networks. As demand of these advanced services increases – particularly in terms of the introduction of VoIP and other latency-sensitive real-time services – demand for bandwidth on mobile networks also will increase.

The high-bandwidth radio interface and "flat" IP network architecture of UMB and other next-generation mobile network technologies offer a very effective means of ensuring the end users have a positive experience by providing higher data throughputs (both downlink and uplink), lower latency and easier network and service QoS management.

As importantly, the move to IP-based architectures will help operators deliver these new services in a cost-effective manner, both through the inherently lower cost of IP packet delivery and the opportunity to utilize key elements of their network to support both fixed and mobile services.

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