

All-IP 1xEV-DO Wireless Data Networks

A Technical White Paper



Airvana
Accelerating • Access • Anywhere



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Introduction

The Internet and Mobile Wireless are the defining technologies of our times. Today, they are converging and promising to dramatically reshape society. Mobile Internet services will help people work, entertain, and communicate anytime, anywhere—using a variety of devices such as cell phones, Personal Digital Assistants (PDAs), and laptops. Driven by the Wireless Internet's enormous potential and reacting to declining Mobile voice revenues per subscriber, operators are pegging their future growth on Wireless Internet services.

While operators agree that Mobile Internet services are critical to their future success, there is less agreement on what technology will best help them achieve their goals. The conventional wisdom is that voice-centric 3G¹ technologies will help operators deliver Wireless Internet services. But are they the right choice?

Recently 3GPP2, a global 3G standards organization, adopted a new air interface standard for Wireless Internet called 1xEV-DO (1x Evolution – Data Only). 1xEV-DO, officially known as IS-856, embodies a new air interface technology specifically designed for packet data and offers a bandwidth efficiency for data traffic that is 3-4 times greater than current 3G standards such as W-CDMA or 1xRTT. 1xEV-DO achieves a peak data rate of 2.45 Mbps on the forward link (from the Base Station, *BTS*, to the user) using only 1.25 MHz of spectrum. The technology is ideal for high-speed Mobile as well as Fixed Wireless Internet services. In this white paper, we explain what it is in 1xEV-DO that makes it so superior compared to 1xRTT and W-CDMA for Wireless Internet.

The upcoming shift in wireless networks from voice to 3G-packet voice and data networks also raises the question of what Radio Access Network (RAN) architecture is best suited to meet the demands of 3G-multimedia traffic. Many believe the answer lies in Internet Protocol (IP). There is wide expectation that operators can reduce operating and equipment costs and make their networks more scalable by migrating to All-IP architectures. Several global standards bodies such as 3GPP, 3GPP2 and MWIF are developing IP architectures for next generation RANs.

1. 3G is the generic name for mobile wireless systems that offer advanced voice and data services, the first two generations refer to the existing analog and digital cellular networks respectively. W-CDMA and 1xRTT are popular voice centric 3G standards. 1xEV-DO is an emerging Data Only 3G standard.

However, operators are being cautious in migrating to IP networks due to the technical complexity associated with delivering voice services on IP networks. 1xEV-DO's data-only architecture offers an excellent, low-risk opportunity for operators to deploy All-IP RANs and gain experience with IP-based technologies prior to evolving their voice network to IP. In this paper we will show how the combination of 1xEV-DO with an All-IP architecture can offer significant financial, operational and technology benefits to wireless operators.

Why 1xEV-DO?

The wireless operator's business case for Wireless Internet services depends strongly on two performance factors:

- **Subscriber Capacity**—The number of subscribers that can be served in each cell using a fixed amount of spectrum (for example, 1.25 MHz);
- **Offered Service Level**—The average data throughput that can be offered to each subscriber.

Since most Internet applications (web browsing, e-mail, video streaming) have asymmetric bandwidth requirements, with a typical ratio of download to upload traffic of about six to eight, optimizing the forward link (from the Base Station to the subscriber) is especially important for Wireless Internet.

Two primary factors determine forward-link performance:

- **Burst Data Rate**—The data rate the subscriber sees when receiving packets from the Base Station. When the system is lightly loaded, with only few active subscribers, achievable burst data rates directly determine the actual data throughput the subscriber sees.
- **Multiplexing Efficiency**—A measure of how well the Base Station divides air resources among many active subscribers. When the system is loaded, with many active subscribers accessing the Internet at the same time, the actual throughput that the subscriber sees also depends on this factor.

Generally, improving these two performance factors directly increases the subscriber capacity and the service level that can be offered, hence directly enhancing the wireless operator's business case. Now, we discuss in more detail how 1xEV-DO compares to other air interface standards in these two areas. As we shall see, during busy periods, 1xEV-DO networks can offer three to four times better bandwidth efficiency compared to 1xRTT and W-CDMA, where a factor of 2 improvement is achieved by

increasing the burst data rates and an additional factor of 1.5-2 improvement is achieved by increasing the multiplexing efficiency. Table 1 compares 1xEV-DO's forward link burst rate and average throughput with other 2.5G and 3G mobile wireless technologies.

Table 1: Comparison of Average Throughput of 2.5 and 3G Technologies¹

Technology	Carrier Bandwidth	Forward Peak Rate (kbps)	Mature Network Average Throughput per RF Carrier per Sector			Normalized Mature Network Average Throughput per 5 Mhz per Sector		
			Stationary	Pedestrian	Vehicular	Stationary	Pedestrian	Vehicular
1xEV-DO	1.25 Mhz	2458	1400	1080	530	4200	3240	1590
cdma2000 1x	1.25 Mhz	625	450	350	350	1350	1050	1050
WCDMA	3.84 Mhz	2000	1500	1100	900	1500	1100	900
GPRS	0.20 Mhz	115	40	40	40	80	80	80

Source: Qualcomm Inc., The Economics of Wireless Mobile Data

Increasing the Burst Data Rate

An ideal air interface for packet data services offers each subscriber the highest data rate that can be supported at any given instant. This requires that the system be able to:

- Adapt its data rate to channel conditions which are often rapidly varying due to subscriber mobility and fast signal fading;
- Apply advanced coding and multi-level modulation techniques;
- Take advantage of macro diversity to better combat fading.

By using superior techniques in all these areas, 1xEV-DO delivers average burst data rates of 600-1200 Kbps per subscriber, where the upper range is achieved using antenna diversity in the subscriber terminal. This is at least two times higher than what is achievable with existing voice-centric 3G standards, such as 1xRTT or W-CDMA (when normalized to the same amount of spectrum used).

1. The cdma2000 Forward Peak Rate number is based upon a cdma2000 standard that is not widely implemented. Networks going to service in 2001/2002 will have a Forward Peak Rate of 307 kbps with vehicular speeds approaching 144 kbps under ideal conditions.

Adaptive Rate Operation

Cellular CDMA voice systems are designed to provide a constant bit rate, typically somewhere between 8-16 Kbps, to each voice call. The Base Station adjusts its transmit power based on power control feedback received from the handset so as to maintain the target bit rate in the presence of varying channel conditions. If the bit rate drops below the target rate, even temporarily, the voice call can be lost.

For packet data on the other hand, it is not nearly as important to guarantee a certain data rate as long as some minimum performance level can be maintained. Further, in sharp contrast to voice, packet data user experience improves significantly with increasing data rate. Therefore, an air interface designed for Wireless Internet should provide the highest data rate possible at any given instant, and this requires a system that can adapt the data rate based on the channel quality seen by each subscriber.

Existing 3G packet data systems 1xRTT and W-CDMA have voice-centric designs that are optimized for delivering a fixed data rate, with no efficient mechanism for adapting the data rate based on subscriber's channel quality. The result is a significant loss in capacity. For example, a user may end up being served at 32 Kbps, even when the channel conditions would have allowed a much higher data rate.

1xEV-DO uses a powerful adaptive-rate scheme that allows the Base Station to rapidly (once every few milliseconds) adapt its data rate for each active user. To make this possible, all active terminals constantly measure their channel condition based on pilot signals being received from all surrounding Base Stations and report back to the radio network the maximum data rate at which they can receive. This allows the Base Station to serve each user at the highest data rate their channel condition would permit. Depending on the data rate, which ranges anywhere from 38.4 Kbps to 2.45 Mbps, the 1xEV-DO Base Station also selects a suitable multi-level modulation format (QPSK, 8-PSK, 16-QAM). Adaptive-rate operation in 1xEV-DO further includes a sophisticated Hybrid ARQ scheme that provides additional robustness against any inaccuracies in the data rate estimation by the terminal, especially in situations that involve high mobility.

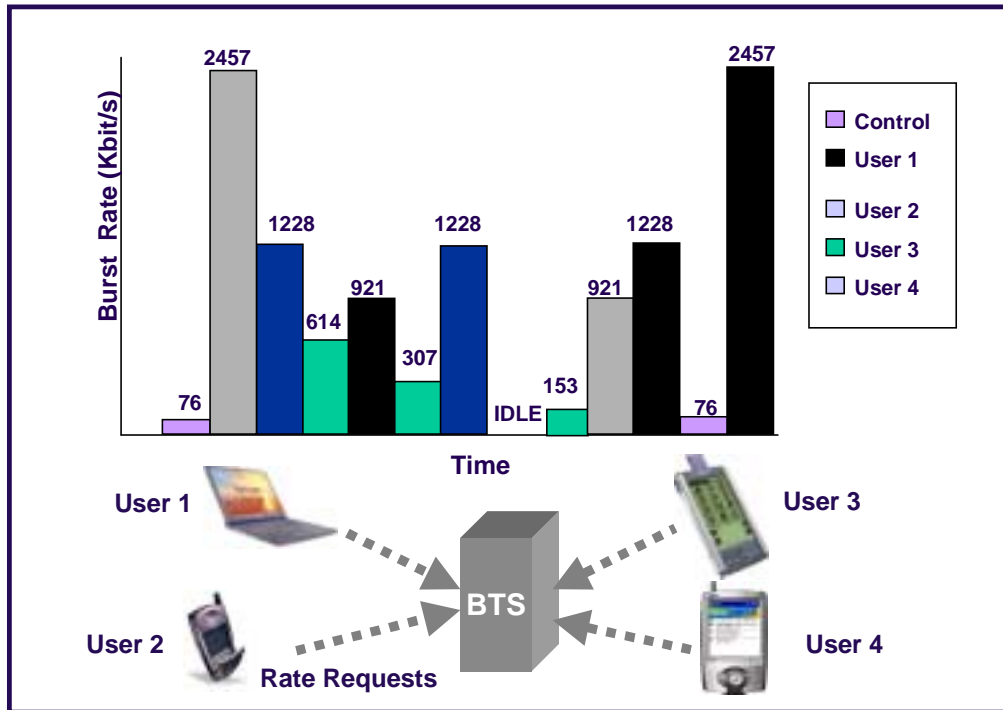


Figure 1. Adaptive Modulation Scheme in 1xEV-DO

Advanced Coding and Modulation

One of the most significant recent developments in the area of error control coding was the invention of turbo coding. Conceptually, turbo coding is a powerful error correction scheme, which allows a communication system to operate near the Shannon limit, at least as far as its performance in the presence of receiver noise and interference is concerned. 1xEV-DO, like other 3G air interface standards, uses a powerful Turbo code with 100-400% redundancy. On the forward link, its maximum redundancy is 33% greater than that of 1xRTT.

Furthermore, 1xEV-DO is expected to become the first commercially available mobile wireless cellular system to use multi-level modulation (8-PSK and 16-QAM). Existing 3G standards are limited to QPSK. Use of higher-level modulation allows 1xEV-DO to operate at higher bandwidth efficiencies.

Macro-diversity via Radio Selection

The importance of macro-diversity in combating fading is well known in cellular communications. In voice-centric CDMA systems such as 1xRTT and W-CDMA, macro-diversity is achieved using soft handoff. In forward link soft handoff, multiple Base Stations transmit the same air link frame, allowing the mobile station to combine the received signals to improve reliability in the presence of fading. However, since multiple radios end up

using air resources for sending the same frame, the real benefit of forward link soft handoff on system capacity is much less than the macro-diversity gains.

In addition to using up excessive air resources, forward link soft handoff in packet data systems also pushes the packet scheduling from the Base Station to the radio network controller. This introduces delays and significantly reduces the packet scheduling efficiency.

1xEV-DO overcomes these shortcomings by using a macro-diversity scheme that is based on radio selection diversity. In radio selection diversity, each active terminal measures the received pilot signal quality from all the radios in its near vicinity and then tells the network the radio from which it wants to receive. This allows the network to serve the subscriber from the radio that can achieve the highest data rate. The radios then coordinate with the radio network controller to ensure that packets are correctly delivered to the serving radio and the serving radio schedules the packets for transmission at the data rate selected by the subscriber terminal.

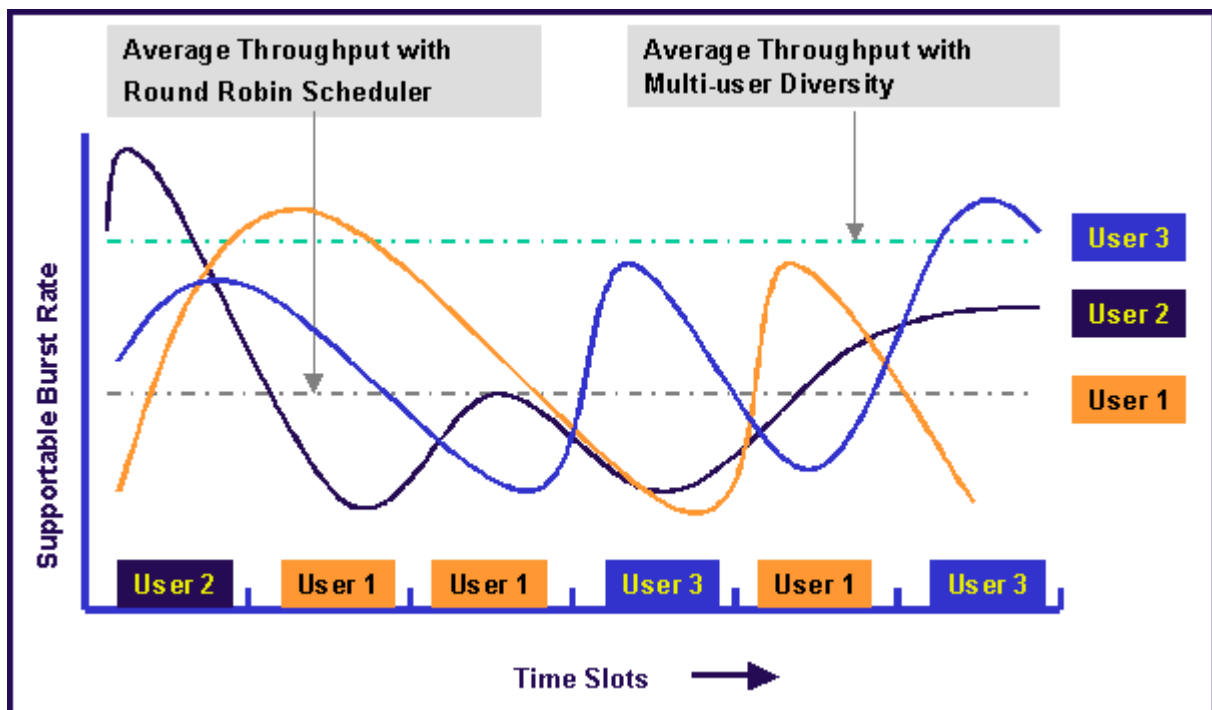


Figure 2. Increased Average System Throughput with Multi User Diversity

Efficient Multiplexing with Multi-User Diversity

In Wireless Internet, the Base Stations need to divide the available forward link throughput among all active subscribers using some form of multiplexing. The efficiency of such multiplexing critically affects the system performance, particularly during busy periods.

In cellular CDMA voice systems, a single Base Station can support multiple voice calls by allocating the available transmit power and code space (code division multiplexing) among all calls. Existing 3G packet data systems use a similar approach to support multiple active data users. Such systems often allocate more air resources (power) to users when they are experiencing poor channel conditions in order to maintain a target data rate. This approach, while quite appropriate for voice, is actually counterproductive for packet data, since a user who is experiencing very poor channel conditions can siphon off significant bandwidth away from others.

To improve the multiplexing efficiency, 1xEV-DO uses a packet-based time-division multiplexing scheme. The Base Station transmits short packets to users one at a time using all available air resources (power and code space) and at the maximum data rate the recipient's channel conditions would allow. A scheduler in the Base Station determines the sequence in which packets are transmitted. How this scheduler is chosen greatly impacts the overall system performance. For example, a round-robin scheduler that allocates the same amount of time to active subscribers provides each with an effective throughput that is $1/N$ 'th their burst data rate.

A very important feature of 1xEV-DO is its ability to schedule packets based on user's channel quality. This improves the multiplexing efficiency significantly over the round-robin scheduler. By serving active subscribers when their channel condition is relatively good, the effective throughput seen by each active subscriber is significantly improved (Figure 2). In the communications literature, this improvement is often referred to as the multi-user diversity. Multi-user diversity depends on a number of factors, but can easily reach 50-100% with only few active users.

Other 1xEV-DO Features

Reverse Link Even though the reverse link is relatively less important in Wireless Internet, it nevertheless is desirable to achieve good efficiencies on the reverse link in order to effectively support applications, such as uploading e-mail attachments and IP-based videoconferencing.

In contrast to the forward link, reverse link in 1xEV-DO uses code division multiple access (CDMA). Reverse link CDMA provides excellent bandwidth efficiencies and greatly simplifies the subscriber terminal operation. Various studies show that CDMA is very attractive for reverse link of packet data systems, since it naturally supports statistical multiplexing and provides a low-delay means for carrying TCP acknowledgments.

A key advantage of 1xEV-DO over 1xRTT and W-CDMA on the reverse link is its adaptive rate capability. 1xEV-DO supports data rates from 9.6 to 153.6 Kbps. With adaptive rate control, the Base Station can control the data rate of the terminals, both individually and globally, and thereby increase total reverse link throughput while controlling interference. When correctly used, such rate control allows the Base Station to achieve a reverse link throughput that can be as much as 50 percent faster than voice-centric 3G systems.

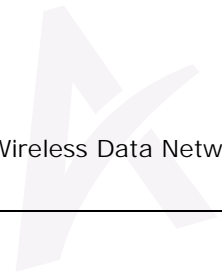
Always-On Operation

Always-on operation is an important feature of any high-speed Internet access system. This means that when a terminal is ready to send or receive data, it does so almost instantly without lengthy connection set-up procedures.

In all mobile wireless access systems, a subscriber terminal is in either an active or dormant state, and transmits or receives packets only when it is active. Such two-state operation is needed to:

- Allow an inactive terminal to go to sleep to conserve battery power
- Reduce required addressing overhead for forward link frames
- Better manage the forward and reverse link performance.

In 1xEV-DO, when a terminal is in an active state, it is said to have “a connection” with the network. The concept of a connection is akin to a call in voice systems with some very important differences. In voice, a call typically lasts a couple of minutes. In packet data on the other hand, a connection may be very short and may have to be set-up and torn down several times during a packet data session. For example, in a web browsing session, it may be desirable to tear down a connection between page downloads, in order to make room for other users.



An important feature of 1xEV-DO is its ability to support quick connection set-up and teardown. Terminals can initiate connections by sending a very short connection request message to the Base Station. Since this message is designed specially for packet data, it is shorter than similar messages used in voice-centric 3G systems.

1xEV-DO also has a Fast Re-Connect capability that allows the network to quickly re-establish a connection with a subscriber. This feature is extremely useful, particularly in fixed or nomadic packet data applications.

Inter- operability

A great aspect of 1xEV-DO is that it is an international standard supported by several standards bodies, including 3GPP2, TTA, CDG and ITU. This ensures interoperability between terminals/handsets and the radio network.

There is also a network standard for 1xEV-DO, called the 1xEV-DO Interoperability Specification (IOS), which defines the interfaces between the various elements of a 1xEV-DO network. This includes the interface between the radio access network and other network equipment, including Packet Data Serving Node's (PDSN), Authentication, Authorization and Accounting (AAA) servers, as well as interfaces between different vendor's 1xEV-DO radio access networks. These standards give wireless operators greater freedom in vendor selection allowing them to use the best available equipment in every part of their network.

1xEV-DO even supports interoperability with 1xRTT and IS-95A/B CDMA voice networks, which means a user with a dual-mode (CDMA/ 1xEV-DO) handset can receive or initiate voice calls even when actively engaged in a 1xEV-DO data session.

The technologies described above give 1xEV-DO the best per user throughput and subscriber capacity of any 2.5 or 3G technology. This directly enhances an operator's business case for 3G.

Operators can not only deploy mobile services but also have the flexibility to offer "fixed" and nomadic services with capabilities similar to broadband services like DSL and Cable.

Users can run regular web applications, not just custom, low-speed content like WAP, which opens up new market segments such as anytime, anywhere access to corporate networks from Laptops and PDAs.

Why IP in the Radio Access Network?

Globally, IP networks have become the de-facto standard for transporting data traffic. Wireline service providers have leveraged IP's global economies of scale to reduce their equipment and operating costs. Operators have also benefited from IP's status as an open, evolving standard to rapidly create new services such as Internet access, streaming multimedia, Voice over Internet Protocol (VoIP) and Virtual Private Networking (VPN). The same benefits are now available to wireless service providers. There are several areas in which IP technology can be beneficially applied to Radio Access Networks:

Flexible, Low-Cost IP Transport

The use of IP as a backhaul transport technology can deliver significant benefits to wireless operators. In IP Transport, Base Stations communicate with Base Station Controllers (BSC) using IP as the common Layer 3 protocol. This brings tremendous flexibility to an operator in choosing a Layer 1/2 backhaul technology. For example an operator may choose Frame Relay, ATM, Metro Ethernet or even dedicated T1/E1s as the Layer 1/2 backhaul service based on a variety of criteria such as cost, availability, delay etc. Operators can even use multiple services simultaneously. For example, some Base Stations can be connected to a BSC using dedicated T1/E1s – using leased lines existing in today's cellular network – while others can be connected to the same BSC using Frame Relay.

A recent study conducted by Airvana along with Verizon¹, MCI² and Yipes³ showed that backhaul costs can be reduced by as much as 70% by using packet-based L1/L2 backhaul services as compared to traditional dedicated T1/E1s. The study compared the monthly backhaul costs for a 1xEV-DO network of 75 Base Stations and 1 Base Station Controller deployed over a small (500 sq. mile), medium (2000 sq. mile) and large (5000 sq. mile) area. The study showed that as a deployment area becomes larger, dedicated T1/E1's become less cost effective because of their distance-based tariffs. In such situations, operators can gain significant cost reductions by using Frame Relay or IP router services. The study also showed that emerging Metro Ethernet IP services can have a potentially dramatic impact on backhaul costs, especially since 3G services like 1xEV-DO consume large amounts of backhaul bandwidth. The results of such a

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1. Verizon is a national telecommunications company that provides T1/E1 leased lines, Frame Relay and IP services
 2. MCI is a leading global carrier that provides IP and Frame Relay services
 3. Yipes is a leading provider of metropolitan Ethernet services

study could vary depending on a number of factors, in particular geographic location, however one thing seems to be certain: IP transport gives multiple backhaul options to an operator, which can lead to significant operational savings and fast time-to-market.

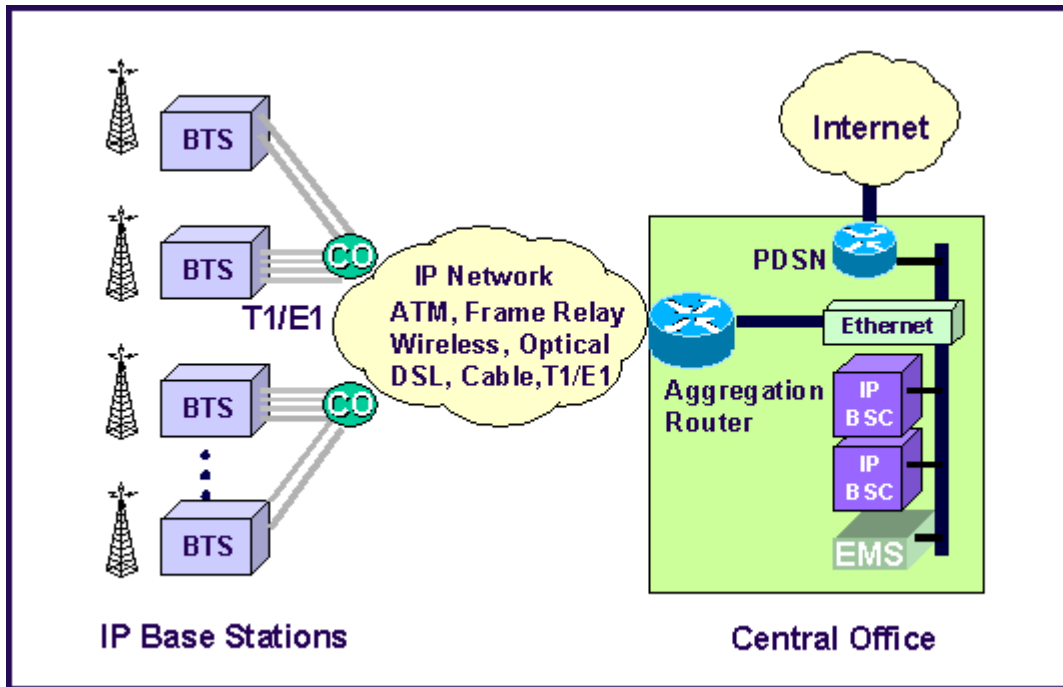


Figure 3. All-IP Radio Access Network Architecture

Another benefit of using IP transport for backhaul is that one central office can support Base Stations spread out over a large geographic area, which eliminates the need for multiple central offices and duplicate network equipment. In traditional cellular networks, the cost of operating a backhaul network is one of the largest operating expenses. Most operators build their own dedicated backhaul networks to connect Base Stations to Base Station Controllers -- typically using dedicated T1/E1 circuits. Since leased lines are often tarified based on their distance, service providers often build multiple central offices to house Base Station Controllers, even in a relatively small geographic area. This reduces backhaul costs, but requires multiple central offices that are expensive to build and maintain. IP transport technology is ideal to overcome these limitations and reduce a service provider's operating and equipment costs.

**Standards-based
Network
Elements**

All IP RANs give operators the choice to use low-cost, off-the-shelf network components. For example, off-the-shelf multi service aggregation switch/routers can be used to terminate the Layer 1/2 transport protocols and forward the traffic as IP packets to the Base Station Controller. Not only are such IP switch/routers cheaper and have a faster technology evolution as compared to traditional voice telecom equipment, but also bring additional benefits. For example, operators get a wide choice of network interfaces such as T1, E1, T3, and OC3 for terminating backhaul traffic on the aggregation router. The aggregation router also isolates the Base Station Controller from the backhaul network, which allows an operator to change the backhaul network as IP technology and tariffs evolve without making any changes to the Base Station and Base Station Controller. For example, an operator who quickly deploys 1xEV-DO services using existing T1/E1 lines, will be able to evolve its backhaul to lower-cost Metro Ethernet services when these become more widely available, by simply adding new interface cards to the aggregation router - without impacting the Base Stations or Base Station Controllers.

**Enhanced
Scalability
and Mobility
Support**

Data Networks evolve at a much faster pace than voice. It is therefore very important for next generation wireless networks to scale well and support the independent evolution and upgrade of individual network elements. An All-IP architecture is a powerful way to achieve this goal. Figure 3 shows an example of how Base Stations and Controllers scale in an all-IP network. Unlike traditional cellular networks, All-IP Base Station Controllers are connected to an aggregation router over an Ethernet LAN. As more Base Station's are added to the network, one simply adds additional Base Station Controllers to an existing rack and connect them using Ethernet. Even though a new Base Station Controller is a separate piece of hardware, from an IP perspective, it acts as if it was logically part of the original Base Station Controller. This allows multiple BSCs connected over an Ethernet LAN to act as a single Base Station Controller and support a very large number of Base Stations, dramatically improving system scalability.

**Superior
Fault
Tolerance**

One of IP's fundamental strengths is its fault-tolerant architecture. IP networks can reroute packets to alternate links in case a link becomes congested or unavailable. A 1xEV-DO IP RAN can deliver carrier-class reliability and support multiple levels of fault tolerance by building upon this attribute. The failure of an entire BSC is perhaps the most catastrophic network failure. Even in the event of such a failure, Base Stations can automatically reroute users to another BSC on the IP network.

Furthermore, IP-based RAN architectures support load balancing which increases the utilization of network nodes and modules and reduces the number of users who might be affected by a failure.

These features can be effectively applied in an IP RAN to build a very high availability wireless network.

**Standards-
based Quality
of Service**

In response to intense competition, wireless service providers are looking for ways to differentiate their services by offering differentiated services. IP-based 1xEV-DO RAN elements, in particular the scheduler in the Base Station can be designed to deliver Quality of Service (QoS) differentiation using established IETF standards such as DiffServ and MPLS. The ability of All-IP 1xEV-DO RAN elements to deliver end-to-end QoS using open, interoperable standards can enhance an operator's ability to create and bring new, differentiated services to market.

**Ease of
Network
Management
and
Configuration**

In today's wireless networks, configuration and management of network elements is an expensive, time consuming, manual operation. In All-IP RANs, elements can be remotely configured and managed using open protocols such as SNMP and web technologies such as XML and HTTP. The use of open protocols also simplifies the task of integrating a vendor's management system with third party OSS and management platforms. Remote management and configuration of network elements via open protocols and familiar client platforms such as browsers helps keep network management costs low.

All 1xEV-DO Networks Are Not Equal

In this paper we have shown why 1xEV-DO is an extremely compelling technology for 3G wireless data services. Deploying IP-based 1xEV-DO networks for packet data services is the right way to start the migration of the circuit switched/ATM RAN to an All-IP multimedia RAN.

However, not all 1xEV-DO networks will be equal. The choice of product and network technologies can have a profound impact on an operator's capital and operating costs. Airvana is a startup company founded by executives from Motorola, Nortel, Lucent and Cisco that has developed All-IP 1xEV-DO Radio Access Network products that will enable high-speed, 3G mobile and fixed wireless data services. Airvana's RAN products optimize 1xEV-DO's air interface performance and leverage the benefits of IP technology outlined in this paper to deliver a solution that radically changes the economics of deploying 3G – today. For more information on Airvana's unique All-IP 1xEV-DO products and technologies, please contact us at www.airvananet.com.

1xRTT	A 3G Mobile Wireless technology based on CDMA that doubles the voice capacity of current CDMA mobile systems, and adds packet data capability.
3G (Third Generation)	Generic name for mobile wireless systems offering advanced voice and data services. The first two generations refer to existing analog and digital cellular networks respectively. W-CDMA, 1xRTT and 1xEV-DO are the most popular 3G standards.
3GPP	A global standards body that is developing 3G standards based on W-CDMA technology to evolve current GSM networks.
3GPP2	A global standards body that is developing 3G standards based on CDMA 1xRTT, 1xEV-DO technology to evolve CDMA networks.
ATM (Asynchronous Transfer Mode)	A networking protocol capable of carrying multiple traffic types (voice, video, data) at various speeds.
BTS (Base Transceiver Station)	Radio equipment that cellular operators need to place at the center of each cell, usually simply called a base station.
BSC (Base Station Controller)	A wireless network equipment that controls Base Stations.
CDMA (Code Division Multiple Access)	A global Mobile Wireless technology based on a method of sharing available spectrum among many users by modulating each user's signal using a unique code.
Ethernet	The world's most widely deployed standard for Local Area Networking; it operates at 10, 100, 1,000 and 10,000 Mbps.
Frame Relay	A widely used connection-oriented packet data networking technology.
IS-95	The industry standard name for 2G CDMA Mobile wireless technology.
Metropolitan Ethernet	A low-cost Metropolitan Area Network technology that transports user data as Ethernet frames over an optical network, typically in a metropolitan area.
PSK (Phase Shift Keying)	Spectrally efficient modulation technique where the information is encoded into one of two or more unique symbols that are then used to modulate the phase of the frequency carrier.
QAM (Quadrature Amplitude Modulation)	Spectrally efficient modulation technique where the information is encoded into one of four or more unique symbols that are then used to modulate the amplitude and phase of the frequency carrier.
QPSK (Quadrature Phase Shift Keying)	A special case of PSK and QAM with 4 unique symbols.
RAN (Radio Access Network)	The part of a wireless network that includes the Base Stations and Base Station Controllers.
VoIP (Voice over IP)	A method of sending voice information over a packet-switched network, such as the Internet, using the Internet Protocol (IP).
VPN (Virtual Private Network)	A networking technology used to send data securely over public data networks.
WAP (Wireless Application Protocol)	A protocol stack for sending simplified Web pages to wireless devices. It replaces web protocols with its own, requiring that pages be written in WML, not HTML.
W-CDMA (Wideband CDMA)	A 3G CDMA system that is an evolution of the current GSM network. W-CDMA operates on a 5 MHz channel and supports voice and data services.



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