ArrayComm

iBurst™

Personal Broadband System

System Overview




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Important Notice

1. INTRODUCTION

The iBurst™ system is a mobile broadband Internet access system that provides end users with:

- Broadband Internet access service: Internet access service comparable to DSL and cable
- Mobility: Anywhere, anytime access with the freedom to move
- High-speed connectivity: Individual connection speeds of up to 1 Mbps
- Access through standard devices: The iBurst wireless modem connects to standard IP-enabled devices like laptop and desktop PCs and PDAs
- Open access: Access all favorite Internet content, applications and services
- Simplicity: Easy to obtain and use — plug it in, turn it on

From the end user's perspective, the iBurst system provides high-speed, untethered access to the Internet, virtual private networks (VPNs) and other IP networks from the widest possible range of devices, including laptop computers and PDAs. With the iBurst system, users need not adapt their computing habits, applications or devices to match their access method of the moment. This is in stark contrast to data-over-cellular solutions such as Wireless Access Protocol (WAP), where the access method forces the choice of a particular device (e.g., a cellular phone) and applications. The iBurst system provides a seamless broadband Internet computing and communications experience. Peak data rates are in excess of 1 Mbps per user.

From the service provider's perspective, the iBurst system enables access to a new class of wireless customers using the same hardware, service and management bases as for its wired customers. iBurst network sessions are delivered to service providers using familiar wired methods: either through Point-to-Point Protocol (PPP) over Layer 2 Tunneling Protocol (L2TP) or via pre-terminated IP sessions. Most medium- and large-scale service providers already have the necessary hardware and software to support iBurst network subscribers. When connecting to a service provider via the iBurst system, a user's experience is that of connecting *directly* to the service provider. Service providers have a direct relationship with their customers, including billing and branding.

From the core network operator's perspective, the iBurst system offers the most cost-effective, spectrally efficient, broadband mobile access network available. ArrayComm's IntelliCell® technology is integral to the iBurst system, resulting in high data rates, massive capacity and minimal capital and operating expenses. The wired backhaul and core transport networks use open data networking standards and equipment, providing the operator with flexibility in networking technology and vendor and device selection. The access platform is designed to carry the subscriber traffic of many service providers, creating a compelling wholesale business opportunity for network operators. Moreover, it is a direct extension of the wired broadband wholesale infrastructure employed by major operators today. The iBurst system provides these operators with an additional means to derive returns on that investment.

The following sections describe the iBurst network architecture, services, system equipment, standards and deployment.

2. NETWORK ARCHITECTURE

2.1 Architecture of Current Wired Networks

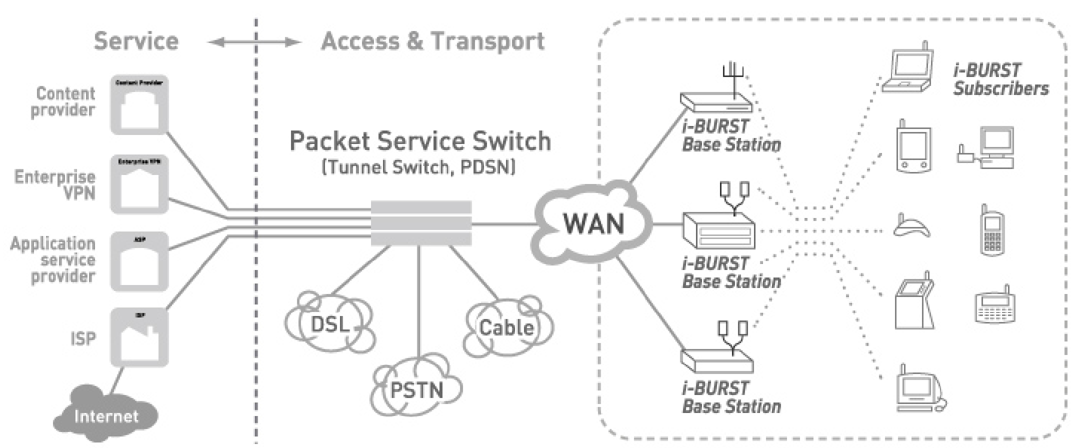
In the past, IP service providers were required to maintain and operate two sets of platforms: one platform concerned with service, including content, billing and subscriber management; and another concerned with remote access termination and interconnection to the Public Switched Telephone Network (PSTN). The second platform was expensive to maintain and operate, but service providers' principal business depended on connecting to consumers.

In recent years, access aggregation technologies have been developed that allow a common access and transport network to bear the traffic of subscribers from multiple service providers. Separating access and transport from service accomplishes two things:

1. It eliminates the burden of building out an access network, reducing the barrier to entry for new service providers and improving the growth potential for existing service providers.
2. It promotes technical and business efficiencies for access and transport enterprises due to economies of scale and the ability to resell that access infrastructure to multiple service providers.

Figure 1 depicts a common-access and transport iBurst network allowing several service providers to simultaneously provide branded services to their respective end users. A separate business unit of the access and transport operator could, itself, be one of those service providers.

Figure 1: Common Access and Transport Network



The access and transport operator aggregates a variety of "last mile" access technologies and then switches end-user sessions to the appropriate service provider. Key to this scheme is the packet services switch (PSS), which acts as an aggregation point and as a "switchboard" to route user sessions. The switching decisions are typically made on the basis of structured usernames provided by the user during PPP authentication. For example, logging in as "joe@aol.com" would cause the user session to be directed to AOL's site and request authentication for user "joe," while logging in as "mary@arraycomm.com" would cause the user session to be connected to ArrayComm's site, perhaps for corporate VPN access, and request authentication for user "mary." PSS technology is widely deployed in the networks of major ISPs and carriers. In addition to aggregating user sessions from a variety of media, it presents these sessions in a unified fashion to the service provider's network, freeing the service provider of the need to maintain different content and service bases for each access class.

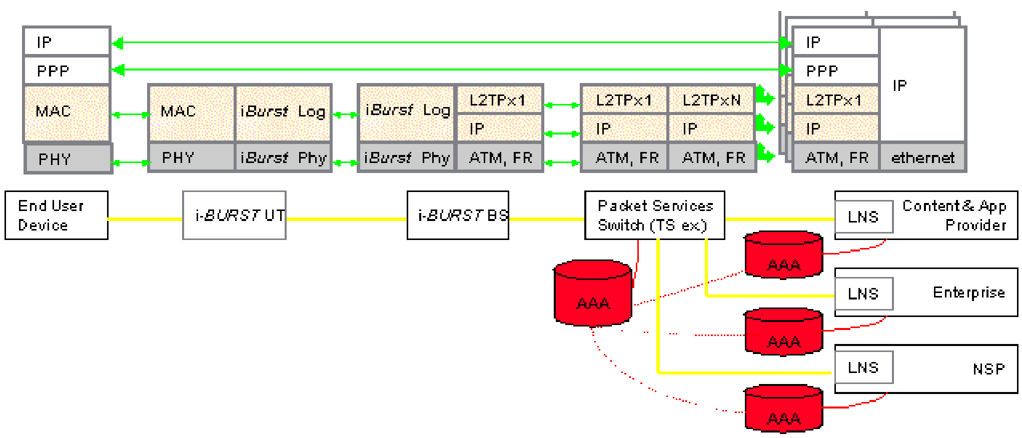
2.2 iBurst Architecture

The iBurst service architecture directly extends the wired broadband service architecture outlined above. Wholesalers of wired access already have the necessary wired infrastructure to support the iBurst access system. Standard end-user service provider tools can be used to terminate, manage and provision the iBurst' system's broadband wireless users. In addition, any end-user device — laptop, PDA, etc. — supporting the pervasive PPP access protocol and equipped with an iBurst modem can be used for access.

2.3 Protocol Stack

The iBurst system enables end-to-end IP-over-PPP connectivity between the service providers and their customers, consistent with the predominant service model in the wired access world. Moving left to right in Figure 2, one can see that a user's PPP session is carried by a variety of different media and protocols.

Figure 2: iBurst User Data Network Elements and Protocol Stack



First, the session data traffic has to flow from the end user device to the iBurst user terminal. The physical connection between these two might be Universal Serial Bus (USB), for example, or PCI in the case of an end user device containing an integrated user terminal. The protocol layers associated with this connection are simply labeled Media Access Control and Physical (MAC and PHY, respectively) to represent the broad range of options. In the case of an Ethernet connection, the PPP over Ethernet (PPPoE) protocol would be used to encapsulate the PPP session over this link. Between the user terminal and the base station, the PPP session is encapsulated and transported by the iBurst air interface. The air interface, described in more detail in Section 1.5, provides a reliable (i.e., essentially error-free) link for users' PPP session data. Transmission errors are corrected at the radio link layer through channel coding and retransmission. For purposes of illustration, the air interface appears as two layers in the figure: a physical (PHY) radio layer and a logical (LOG) layer representing the protocol messages and state machines. PPP session data traffic arriving at the base station is decapsulated from the air interface for further transmission on the wired network.

The base station is the boundary between the wireless access portion of the iBurst system and the backhaul and transport portions of the network operator's network. PPP sessions from all of the base station's active subscribers are aggregated at the base station and passed upstream to the packet services switch device using L2TP. L2TP was designed specifically for the efficient backhaul of multiple PPP sessions between two entities in a transport or backhaul network. A single virtual tunnel is capable of transporting a large number of simultaneous PPP sessions. L2TP is therefore a scalable solution and one that is easily provisioned within the backhaul and transport network, since no per-user (per-PPP session) provisioning is required. L2TP can be transported via many different wide-area network (WAN) technologies, such as UDP/IP over ATM, frame relay and gigabit Ethernet. The iBurst system has been designed to be WAN technology-neutral. Network operators may freely choose among WAN technologies based on considerations of network economics, pre-existing plant, target over-subscription and service levels, etc.

Traffic from the base stations in a metropolitan area is aggregated at a packet services switch that serves as the boundary between the access and transport portion of the iBurst network and the service portion. The packet services switch aggregates PPP sessions from the access network and switches them, as described above, to their respective service providers. The connection between the service providers' equipment and the packet services switch is again L2TP over a WAN interface. But the L2TP tunnel between the packet services switch and a particular service provider's L2TP network server (LNS) carries only that service provider's traffic – in contrast to the L2TP tunnels on the access side of the switch, which consolidate the PPP sessions of all subscribers connected to a particular base station.

The L2TP tunnel between the packet services switch and a service provider's platform is terminated at an LNS. User PPP sessions are decapsulated from L2TP and then terminated; user data traffic then moves about within the service provider's network and beyond as IP traffic. In addition to terminating the PPP session, the LNS typically provides the following important services for the user's session:

- IP address management
- Traffic shaping and rate policing
- Collection of billing data, including connect time and number of bytes transferred
- User authentication

It is important to note that these are the same services provided by the LNS for dial-up, DSL or cable users accessing the service provider's network through a packet services switch or other aggregation device that presents those users' PPP sessions via L2TP. The aggregation device in this case not only aggregates user sessions from a variety of media, but also presents these sessions in a unified fashion to the service provider's network, freeing the service provider of the need to maintain different content and service bases for each access class.

Figure 2 also depicts Authentication, Authorization, Accounting (AAA) servers and AAA connections between the access and transport domain and the service domain. In the scenario described above, these connections were not required. Subscriber-specific operations such as authentication, billing data collection, etc. — which each require access to a user's service profile — are performed completely in the service providers' networks. However, it is also possible for the network operator's packet services switch to provide virtual LNSs as a value-added service for its service provider customers. In this case, the virtual LNSs are remote authentication dial-in user service (RADIUS) clients of their respective service provider's RADIUS server, requesting authentication information from that server and sending billing data back to it.

The preceding description applies to cases in which the PSS is a tunnel switch. The same conditions apply when the PSS is a PDSN, except that the IP encapsulation protocol between the BS and the PSS is generic route encapsulation (GRE) rather than L2TP.

3. SERVICES

3.1 Introduction

As seen in Section 2, the iBurst system provides an end-to-end IP connection for users by extending access aggregation architectures to mobile broadband access. Network and service providers can leverage existing equipment, tool and content bases to support iBurst end users, while the end users experience the best of the wireless and wired worlds — the broadest range of applications and end-user devices, coupled with the freedom to move and high data rates.

The ultimate end-user services enabled by the iBurst system are built upon a wide range of lower-level services implemented in the network operator's and service providers' networks. These lower-level services are often generically referred to as "FCAPS" for *fault*, *configuration*, *accounting*, *provisioning* and *security*.

The "Services" section of the present document focuses on four key services — billing, roaming, service levels, security and IP address management — as provided by both the network operator and the service provider.

3.2 Billing

There are two billing relationships in the iBurst system. One is the retail billing relationship between the service providers and their end-user customers. The other is the wholesale billing relationship between the network operator and its service provider customers.

There are two basic elements of the billing process: billing data collection and billing generation. RADIUS is the standard retail billing data collection and exchange protocol in the Internet world. LNSs in the iBurst network act as clients of RADIUS servers and generate records for each subscriber session containing, at a minimum, subscriber session identifiers, connect time and number of bytes transferred upstream and downstream. RADIUS typically generates a single "start" and "stop" record for each session, although it can be extended to generate intra-session records for real-time billing applications (e.g., for prepaid services). This basic RADIUS data can be complemented with a wide range of additional billing data, including subscriber service level, time of day, location, access method, and transactions such as one-time purchases (e.g., of music) and subscriptions (e.g., to a stock ticker service or a conference series). Once the billing data have been collected, customer bills can be generated either directly by the individual service provider or by a third-party billing bureau on its behalf. Billing bureaus can also generate consolidated bills on behalf of multiple service providers. Network operators bill their service providers on the basis of a different but equally extensive set of criteria. These criteria can include the following:

- Size and number of WAN links between the service provider's network and the network operator's packet services switches
- Base level of over-subscription in the backhaul network for the service provider's customers
- Quantity of data transferred between the service provider and its customers in a given period

3.3 Roaming

The iBurst system has been designed to allow end-users to access services in multiple localities regardless of whether the iBurst system is operated across the nation by a single entity or a number of local or regional "affiliate" network operators. When "roaming" in different covered localities, end users seamlessly connect to local networks and perceive the service to operate exactly as it does in their local coverage area.

3.4 Service Levels

The basic end-user service offering in the initial implementation of the iBurst system is a connection with independent uplink and downlink peak rates subject to a certain level of over-subscription in the network. A service provider's Gold level of service might be 1 Mbps/345 kbps (down/up) with 20x over-subscription, for example, while the Silver level of service might be 384 kbps/128 kbps (down/up) with 20x over-subscription. The LNS terminating a user's PPP session performs the necessary throttling to effect the peak uplink and downlink rate limits specified in that user's RADIUS profile.

This same notion of service is used by DSL and cable services. The model is familiar to consumers, and it provides significant flexibility to network and service operators in engineering the tradeoff between network capacity, service quality and service cost. Typically, the access and transport network is engineered with one level of over-subscription, with a separate level of over-subscription selected for the links between that network and the service provider's equipment. The advertised level of over-subscription is usually calculated as the product of those two numbers.

3.5 Security

Comprehensive data security solutions require authentication elements and encryption elements. The authentication elements irrefutably identify the parties to a communication, while the encryption elements ensure that only those parties authorized to view the communication can do so. An application running within an end-user's iBurst session traverses multiple networks — the access and transport network, the service provider's network and, ultimately, the application's destination network — and security must be provided locally within each of these domains as well as in an end-to-end fashion for the application.

Figure 3 below shows the principal security tools available by network domain in the iBurst network. With the exception of the air interface encryption, mobility authentication and base station authentication provided by the iBurst air interface, all of these security solutions exist in today's IP world.

Figure 3: iBurst Security Elements

Domain	Security Tools
Access and Transport Network	• Session-based iBurst air-interface encryption and authentication • iBurst mobility authentication (used during handover) • Internet Protocol Security (IPSec) • Multi-Protocol Label Switching (MPLS) • Route authentication
Service Provider Network	• IPSec • Route authentication • PPP user authentication
End-user Session and Application	• PPP encryption • IPSec • Application security (e.g., https)

Note that IPSec, which provides encryption and authentication services, is used in two ways. In the network operator's and service providers' networks, it is used to encrypt the L2TP tunnels that bear many users' sessions. (It also may be used to encrypt and authenticate other data such as management streams within the network.) In the end-user domain, IPSec may be applied again to some or all of the data flowing within a user's session, as in a VPN. IPSec forms the underpinning of most secure VPN solutions.

3.6 IP Address Management

The iBurst system's PPP encapsulation method supports both IPv4 and IPv6 addressing for end-user devices, with addresses typically being assigned during the IP control protocol (IPCP) phase of the PPP negotiation. Because the users' IP sessions are treated as opaque data in the access and transport network, the various service providers' address spaces can overlap with no ill effects. This is an important feature. Many commercial service providers and essentially all corporate networks assign IP addresses drawn from the same pool of so-called "unroutable" or "private" IP addresses.

IP addressing within the access and transport network is independent of the addressing used for the end-user equipment. The network operator's decision to upgrade its infrastructure equipment, including components specific to the iBurst system such as base stations, to IPv6 can be made independently of the addressing scheme used by service providers for their end-user customers.

4. SYSTEM EQUIPMENT

4.1 User Terminals and Chipsets

The iBurst user terminal is the interface between the iBurst air interface and the end-user device. The iBurst system has been designed to support the widest possible range of IP-enabled end-user devices, including laptop and desktop PCs, PDAs, Webpads and application-specific devices; several classes of user terminals are therefore required. Common to all of these devices is the iBurst UT chipset, a custom multi-chip solution including all of the baseband and RF components necessary to implement an iBurst user terminal, along with a standardized software API. The chipset has been developed to enable the rapid development of differentiated user terminals by a variety of manufacturers. It is being used in the initial iBurst user terminals, which are PC card and USB devices designed for mobile/personal applications on laptop and desktop devices. ArrayComm's partners also will embed it in application-specific devices.

Figure 4: iBurst User Terminal Roadmap

Market Segment	Mobile Professional	Enterprise Vertical	Lifestyle Trendsetter	Broadband Residential	SOHO
Platforms	Laptop PDA 	PDA Application-Specific 		Desktop Laptop Web-Box 	
Modems	Broadband Modem PDA Module PCMCIA Card 	PDA Module OEM Module 		Broadband Modem 	
Applications	E-mail Internet Access VPN Access Mobile/Vertical Applications Remote Sync	E-mail Internet Access VPN Access Mobile/Vertical Applications Remote Sync	E-mail Internet Access Audio/Video Remote Monitor Mobile Applications Gaming	E-mail Internet Access Audio/Video Gaming	E-mail Internet Access

4.2 Base Stations

The iBurst base station is the bridge between the wireless and wired portions of the network. Viewed from the wired network, the base station is an access aggregation device that aggregates the PPP session data of the end-users that it is serving. In this sense, it plays an analogous role to a Digital Subscriber Line Access Multiplexer (DSLAM) in a DSL network.

The iBurst base station is manageable via both Simple Network Management Protocol (SNMP) and a command-line interface, both of which access the same underlying management and monitoring data. The data are comprised of industry-standard SNMP Management Information Bases (MIBs) and an enterprise MIB that control and monitor the iBurst radio interface. ArrayComm's patented IntelliCell technology, implemented at the base station, ensures the highest possible spectral efficiency, and hence lowest access infrastructure costs, for the iBurst mobile broadband application.

4.3 Packet Services Switches

The Packet Services Switch (PSS) serves several important functions in the iBurst network. First, it is an aggregation point in the access and transport network for all of the base stations connected to it. Second, it provides a switching function, connecting end-users' sessions to their retail service provider. Third, it is the interface between the wholesale and retail portions of the network. Finally, it plays a key role in supporting transparent handover of user PPP sessions as the users move from base station to base station.

PSSs are industry-standard devices and are one of two types, both of which are supported by the iBurst network. A PSS may be a "tunnel switch," which is the wired aggregation networking nomenclature for a PSS. Alternatively, it may be a packet data serving node (PDSN), the 3GPP2 (CDMA 2000) nomenclature for a PSS. PDSNs and tunnel switches are substantially similar products. Both are available from a wide range of wired and wireless infrastructure vendors.

Large PSSs (of either variety) can handle in excess of 100,000 simultaneous end-user sessions. Even with service penetrations as high as 5 percent, a single PSS can conservatively serve an area of several million POPs, which may even encompass multiple geographic markets.

5. AIR INTERFACE

5.1 Introduction

The key features of the iBurst system air interface are:

- TDD/TDMA, 625 kHz channel spacing
- Initial per-user data rates up to 1 Mbps downlink, 345 kbps uplink in a fully loaded system
- 4 bps/Hz/cell spectral efficiency (20 Mbps in 5 MHz)
- 3:1 downlink/uplink throughput asymmetry
- Tiered modulation and channel coding for link quality adaptation
- Forward error correction (FEC) and automatic repeat request (ARQ) for error-free link within coverage area
- Bandwidth on demand, dynamic resource allocation
- IntelliCell spatial processing for enhanced signal quality, resource management and collision resolution
- Mobility (handover) support
- Built-in air interface quality of service (QOS) support

The iBurst system's spectral efficiency yields a system capacity that allows that experience to be delivered simultaneously to many users in a cell, reducing the cost of service delivery for this mass-market broadband service. The iBurst access system is optimized to exploit the full potential of IntelliCell signal processing, thereby providing a robust, high-speed connection for mobile users with a minimum of radio infrastructure. The iBurst system's exceptional capital and operating cost benefits derive directly from IntelliCell technology.

The spectral efficiency of a radio system — the quantity of billable services that can be delivered in a unit of spectrum — directly impacts network economics and service quality. Spectrally efficient systems have the following characteristics:

- Reduced spectrum requirements, minimizing up-front capital expenses related to spectrum
- Reduced infrastructure requirements, minimizing capital and operating costs associated with base station sites, translating into reduced costs per subscriber and per covered population element
- High capacity, maximizing the system throughput and end-user experience even under load

Base station coverage area also has a profound effect on wireless system economics. It affects capital expenditures by determining the number of base stations required to cover an area. It also affects operating expenditures by determining the number of sites and backhaul links — connections from the individual base stations to the network core — that must be leased. The iBurst system's adaptive antenna technology increases the coverage area of its base stations by roughly a factor of 15 as compared to other systems offering comparable data rates. Combined with the system's spectral efficiency, the result is a scalable wide-area broadband access system with unmatched economics.

The acquisition of spectrum is a key component of the cost structure of wireless systems, and two key features of spectrum have great impact on that cost — the spectral efficiency of the wireless system and the type of spectrum required to implement the system. As mentioned earlier, the iBurst system is especially efficient in its use of spectrum and requires far less of it per unit of delivered service than other technologies. A fully capable and commercially viable iBurst system can operate in as little as 5 MHz of unpaired spectrum with a total of 20 Mbps throughput per cell in that amount of spectrum — much less than other wireless technologies require to provide the same amount of capacity.

Equally as important to the cost of wireless systems is the type of spectrum required. The spectrum allocation required for the iBurst system is different than for most wide-area, mobile wireless systems, and cellular voice systems in particular. The iBurst system uses a technique named time-division duplexing (TDD) in which base stations and users share a single block of frequencies, alternatively transmitting in time. TDD is especially suited to data applications where the traffic to and from the users is not symmetric (e.g., a single mouse click in a web browser can result in many megabytes of data returned from the network). TDD is also employed in 802.11 wireless local area networks (WLANs). In contrast, cellular voice systems and their descendants employ frequency-division duplexing (FDD) in which separate frequency blocks are used for transmissions from the user and the network, respectively. FDD systems do not have the same flexibility to adapt to data asymmetry as TDD systems, since the ratio of uplink and downlink resources are fixed by the spectrum allocation. Since almost all 1G, 2G and 3G systems require FDD spectrum allocations (paired blocks), FDD spectrum tends to be expensive as the auction participants include the major cellular carriers. TDD spectrum suitable for the iBurst system is therefore generally far less expensive on a per-Hertz basis than that sought after by cellular voice operators.

5.2 IntelliCell

At the core of the iBurst system is ArrayComm's IntelliCell adaptive antenna (spatial processing software) technology. Proven in commercial deployments serving more than six million customers worldwide, IntelliCell technology dramatically increases the efficient use of radio spectrum and results in exceptional improvements in the capacity, coverage and service quality of wireless networks.

IntelliCell technology creates these significant benefits through interference management and signal quality enhancement. A typical base station uses a single antenna or pair of antennas to communicate with its users. An IntelliCell-equipped base station employs a small collection of simple antennas, an "antenna array," with sophisticated signal processing to greatly reduce the amount of excess energy radiated by the base station. At the same time, the signal processing allows the base station to listen selectively to its users, mitigating the effects of interference presented by other users in the network. The antenna array also provides a gain in signal powers, improving the quality of the radio link for the same amount of total power radiated by the base station and user terminal. Improved link quality translates into higher data rates, extended range and longer battery lifetimes at the user terminals.

With IntelliCell technology, each cell in a network can use the same frequency allocation by eliminating inter-cell interference. In fact, IntelliCell technology even enables a system to reuse a frequency allocation within a given cell by directing energy only where it is required.

Proven in more than 100,000 commercial infrastructure deployments as of early 2002, IntelliCell technology increases the capacity of cellular networks by factors of from three to 40. IntelliCell technology has been applied to widely deployed air interfaces such as Global System for Mobile Communications (GSM), Personal Handyphone System (PHS), Advanced Mobile Phone Service (AMPS), and Wideband-CDMA (W-CDMA), as well as to a wireless local loop (WLL) application and the iBurst system. While it provides benefits to all of these systems, the highest benefits are achieved when the air interface has been designed from the outset to leverage maximum benefits from adaptive antennas as the iBurst system has. Extensive simulation and field testing with operators and infrastructure manufacturers have shown capacity increases of from three to 10 for GSM, PHS, AMPS and W-CDMA. While these improvements are significant, the resulting spectral efficiencies are still far lower than that of the iBurst system since the protocols have not been optimized to take advantage of IntelliCell technology.

5.3 Spectral Efficiency

Spectral efficiency measures the ability of a wireless system to deliver information, "billable services," with a given amount of radio spectrum. In cellular radio systems, spectral efficiency is measured in bits/second/Hertz/cell (bps/Hz/cell). Many factors contribute to the spectral efficiency of a system, including the modulation formats, air interface "overhead" (signaling information other than user data), multiple access method, and usage model, among others. The quantities just mentioned all contribute to the bits/second/Hertz dimensions of the unit. The appearance of a "per cell" dimension may seem surprising, but the throughput of a particular cell's base station in a cellular network is almost always substantially less than that of a single cell in isolation. The reason is self-interference generated in the network, requiring the operator to allocate frequencies in blocks that are separated in space by one or more cells. This separation is represented by a reuse factor, where a lower number is representative of a more efficient system.

A representative spectral efficiency calculation proceeds as follows. Consider a typical deployment of a PCS-1900 (GSM) cellular network:

- 200 kHz carriers
- Eight time slots per carrier
- 13.3 kbps of user data per slot
- Effective reuse of seven (i.e., effectively seven channel groups at 100 percent network load)

The spectral efficiency is therefore:

(8 slots x 13.3 kbps/slot) / 200 kHz / 7 reuse = 0.08 bps/Hz/cell

This value of approximately 0.1 bps/Hz/cell is generally representative of high mobility 2G and 3G cellular systems, including CDMA systems of all types. While CDMA systems may use the same frequency band at each cell, channels in CDMA are distinguished by codes in that frequency band, and a given base station only uses a fraction of the available codes to mitigate interference in the network.

Using IntelliCell technology, the iBurst system is able improve the radio signal up to 100 times by a combination of interference mitigation and signal enhancement. This allows the system to do the following:

- Increase the modulation class, thus increasing the data throughput within a given spectral allocation
- Reduce the reuse factor to 0.5 — the same frequency can be used twice in all cells of the network

So, in comparison, the iBurst system's spectral efficiency is represented in the calculation below:

- 625 kHz carriers
- Three time slots per carrier
- 475 kbps of user data per slot
- Effective reuse of 1/2

Which yields the following spectral efficiency:

(3 slots x 475 kbps/slot) / 625 kHz / 0.5 reuse = 4.28 bps/Hz/cell

5.4 Radio System Capacity & Economics

The iBurst system's spectral efficiency of 4 bps/Hz/cell means that an iBurst radio network can support a given mobile customer base with far fewer sites and far less spectrum than would be required with other technologies — and, hence, with greatly reduced capital and operating costs. With 10 MHz of usable spectrum, for example, each iBurst base station would provide 40 Mbps of access capacity. In contrast, a 2G or 3G system with a spectral efficiency of 0.1 bps/Hz/cell, would provide only 1 Mbps of access capacity per cell in that same 10 MHz. In a capacity-limited rollout situation, a system with 2G- or 3G-like spectral efficiency would therefore require forty times (4/0.1) the number of base stations as the iBurst system and have a correspondingly higher cost of service delivery.

Extensive analyses of iBurst system rollouts at a five percent level of subscriber penetration for the top 100 U.S. cities show that a significant fraction of the cells will be coverage-limited rather than capacity-limited. The iBurst system's advantage in terms of infrastructure reduction is hence a weighted average of its IntelliCell technology's range and capacity advantages. IntelliCell technology's improvement in link quality or signal strength translates roughly into a doubling of range (or a quadrupling of area) for the iBurst system.

The capital and recurring costs of operating a cellular network are almost directly proportional to the number of base station sites. The use of IntelliCell technology minimizes the iBurst system's radio infrastructure requirements.

5.5 Roadmap

iBurst technology will evolve over time, providing the network operator and its service provider customers with improved operating efficiencies and a richer set of service offerings. The core technology will evolve in three major areas.

5.5.1 Spectral Efficiency and Peak Data Rates

The iBurst air interface — the organization of data and messages exchanged between the base station and user terminals — and its integral IntelliCell adaptive antenna processing are what make the iBurst radio access solution truly unique from the perspectives of cost and performance. ArrayComm is committed to the continued development and refinement of the iBurst air interface.

Protocol support for carrier aggregation and higher-order modulation in the 2004-2005 timeframe, coupled with improvements from elsewhere in the industry in signal processing hardware, will lead to cost-effective terminals capable of 5 Mbps peak rates. Based on its history of performance improvements in other IntelliCell applications, ArrayComm is also confident that it can improve the spectral efficiency of the system to at least 6 bps/Hz/cell by 2006, a 50 percent increase in the quantity of billable services delivered per unit of spectrum. As the adaptive antenna processing is largely implemented in software at the base station, the network operator will be able to upgrade its network through a simple software download to its base stations with no hardware upgrade needed.

5.5.2 Network Features

ArrayComm's near-term network roadmap is focused on enriching the types of service differentiation offered over the iBurst air interface. Today, the iBurst system supports different grades of service to the extent that peak data rates can be independently specified on a user-by-user basis, with the enforcement of those service definitions being performed at the LNS. By the end of 2002, the iBurst air interface will support a much richer set of service management options, including peak data rate limits, relative priority and the partitioning of base station resources among various user groups. Full integration of this air interface functionality with the remainder of the network, including service provisioning, will occur during 2003.

The iBurst system's standards-based networking approach also allows the iBurst network operator and service providers to avail themselves of advancements in IP networking from elsewhere in the industry.

5.5.3 Chipsets

To maintain its position as the premier provider of iBurst chipsets, ArrayComm is actively engaged in reducing chip sizes and power consumption, while increasing the level of chipset integration. ArrayComm has already moved the iBurst user terminal implementation from an FPGA to an ASIC with peripheral general-purpose processing and control chips. The next major revision of the ASIC will be a fully integrated system-on-a-chip, performing all of the baseband processing for the iBurst protocol. This revision of the baseband chip will be available in early 2003, and available to ArrayComm's manufacturing partners for integration into their products. Advance design information for that chip is already being shared with those partners.

In parallel with the evolution of iBurst technology, the manufacturers of iBurst infrastructure and terminal equipment (ArrayComm's licensees) will also be innovating to improve the cost effectiveness and diversity of iBurst hardware offerings, such as dual-mode iBurst/802.11 terminal devices. Low-power, small form-factor chipsets from ArrayComm will enable a diverse market of general-purpose terminals such as PCMCIA terminals, and, ultimately, special-purpose embedded terminals in devices such as MP3 players.

6. DEPLOYMENT STATUS

6.1 Manufacturing Relationships

ArrayComm has a number of manufacturing partners and licensees for iBurst radio equipment.

Kyocera Corp. of Japan, best known for its cellular radio equipment including CDMA handsets, is developing iBurst system base stations and user terminals. ArrayComm and Kyocera have worked closely in the past on other systems; the two companies have developed a highly productive working relationship, allowing solutions such as the iBurst system to be rapidly transferred to Kyocera for productization.

LG Electronics of South Korea, a major global player in telecommunications and electronics, will also manufacture and distribute base stations and user terminals. They expect commercial product availability in the second half of 2003.

For the iBurst chipset, ArrayComm has cultivated two key partners to date. Taiwan Semiconductor Manufacturing Corporation (TSMC) will produce the chipset from ArrayComm's design. TSMC is the world's largest independent semiconductor foundry. ArrayComm has also partnered with ARM Holdings, the leading provider of semiconductor intellectual property, for the ARM processor at the core of the iBurst chipset.

6.2 Field Trials

The iBurst system has been in development since 1997, with over-the-air testing commencing in late 2000. Extended outdoor testing has been conducted at ArrayComm's facilities and at operator facilities in the United States and abroad since early 2001. ArrayComm operates a trial network in the vicinity of its offices in San Jose for the purposes of technology demonstration and development.

In November 2002, ArrayComm's subsidiary Personal Broadband Australia Pty Ltd. (formerly CKW Wireless) began the pre-commercial rollout of an iBurst network in Sydney, Australia, in collaboration with a consortium of partners. The pre-commercial deployment consists of up to 12 base stations and covers 150 square kilometers. The purpose of the pre-commercial phase is to assess operational performance, determine service offers, deploy end-to-end processes, test service integration and develop and assess operational and technical parameters. Six base stations are already deployed, and they have shown excellent technical and user experience results.

ArrayComm also has conducted two trials in South Korea, the leading nation in per capita broadband penetration worldwide. In January 2003, leading telecommunications operator KT and ArrayComm completed the initial phase of an iBurst system trial. The trial took place in both an urban and a rural site over several months. It included highly successful testing of the system's wide-area wireless broadband capabilities, including data speed, range, scalability, capacity, and interoperability with wireless LAN "Wi-Fi" service. With trial systems supplied by Kyocera Corp., four companies — KT, ArrayComm, LG Electronics and Kyocera —jointly performed testing during the trial.

In addition, Hanaro Telecom of South Korea deployed an iBurst system in its broadband access network in Seoul in January 2002. "Network integration" consisted simply of attaching the base station to a tunnel switch already owned by Hanaro and used to serve DSL customers. Air interface performance was compared to that of 802.11 WLAN and CDMA 2000, and was shown to be clearly superior for wide-area, broadband applications.

7. STANDARDIZATION

The wired elements and IP networking aspects of the iBurst system are wholly based on data networking standards. The use of technologies ratified by recognized standards organizations promotes three important benefits: peer review for quality and feasibility, interoperability among different vendors' products, and multiple sources of supply (with attendant competition and reductions in price) for equipment.

ArrayComm is already taking the necessary steps to standardize the remaining elements of the system, the iBurst air interface in particular, through the newly formed IEEE 802.20 working group. The projected timeline for the development of the 802.20 standard calls for its approval by the IEEE by December 2004.

In addition, ArrayComm has created an iBurst Forum comprising original equipment manufacturers (OEMs), operators, and technology providers that are committed to commercializing and maintaining the iBurst system as a de-facto standard. Based on the needs of its members, the Forum will maintain the roadmap for future iBurst system enhancements, perform interoperability testing, and generally promote the iBurst system in the global marketplace. The Forum will drive industry momentum for the iBurst system and attract additional OEMs. Carriers will derive the benefits of knowing that they will have healthy competition in their supply chain and components purchased from multiple vendors will be network compliant and interoperable.

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