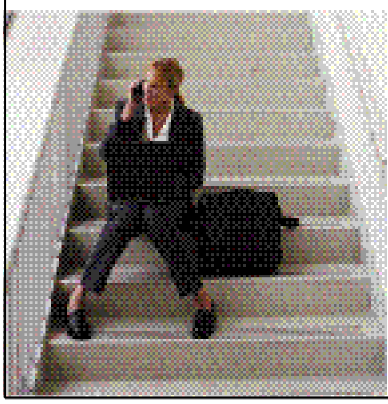
ArrayComm.



iBurst Technical Profile

September 18, 2003

Table of Contents

1 Introduction

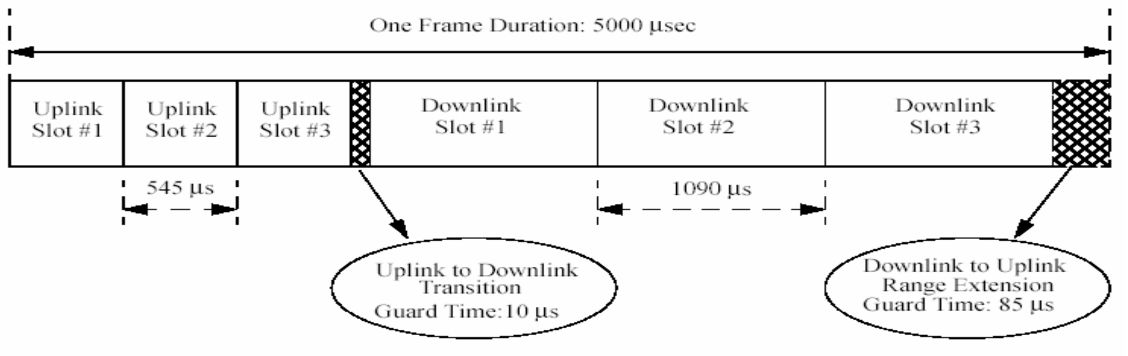
The iBurst System Overview provides an excellent starting point in understanding the business value, operation, and architecture of the iBurst system. This Technical Profile document provides additional performance, configuration, and commercial details not included in the Overview, and it is designed to inform seriously interested service providers' choices about mobile broadband technologies.

2 Multiplexing and Duplexing Method

The iBurst system is TDD/TDMA (Time Division Duplex/Time division Multiple Access). This duplex technology and protocol are designed expressly for adaptive antenna array technology at the base station for maximum capacity, coverage, and throughput benefits.

Each TDD/TDMA frame is deployed in a narrow bandwidth allocation (625 kHz, including all required guard bands) with a duplex period of 5 mSec/frame. Each 5 mSec frame has 3 uplink timeslots and 3 downlink timeslots. Keeping in mind the asymmetric nature of data traffic models, one third of the slot is uplink and two third of the slot is downlink as shown in Figure 1.

Figure 1: iBurst Frame Structure

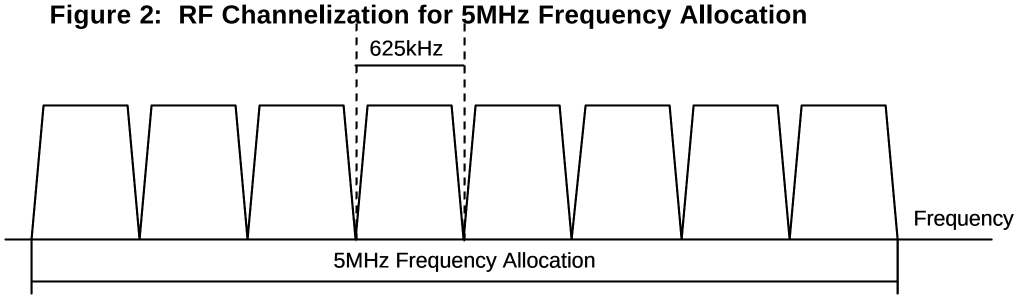


Advanced adaptive antenna techniques on the base station allow for further multiplexing in the spatial domain. Typical iBurst systems support 3 spatial channels in each timeslot with future increase in that number supported by protocol design.

3 Channel Bandwidth

An iBurst spectral allocation is divided into one or more RF channels of bandwidth 625 kHz each. Figure 2 depicts an allocation of 5 MHz divided into eight RF channels.

Figure 2: RF Channelization for 5MHz Frequency Allocation



4 Frequency Reuse (SDMA or Spatial Channels).

The iBurst air interface is designed specifically to take advantage of spatial processing and maintain high system capacity using the Adaptive Array Antenna Technology. The spatial processing will improve SINR on both uplink and downlink and allows for reliable high data rate and high system wide spectral efficiency.

- Signals from multiple spatially separate sensors are processed to improve system performance
- Spatial processing combines signals from multiple antennas with a set of weights – referred to as “spatial weights”
- Performance improvements include:
  - direct quantities: SNR, SINR (presence of interference)
  - indirect quantities: cell range, cell capacity

Number of antennas and antenna spacing are key parameters influencing the performance of the array.

This powerful spatial processing technology allows iBurst system to support up-to 3 simultaneous users (in the current implementation) in the same conventional RF resource (iBurst channel, timeslot combination) within the same cell or sector. This translates into a frequency re-use factor of 1/3.

5 Modulation Format

The iBurst system uses multiple modulation formats and modes. The iBurst system supports nine modulation classes (or modclasses) to maximize user data throughput. The modclasses provide a mechanism for adapting over a window of approximately 16dB in link budget to minimize ARQ retransmissions and maximize throughput for traffic channel (TCH) transmission.

The link adaptation algorithm in the Base Station (BS) selects mod classes for uplink and downlink traffic depending on various factors including signal quality (SINR), data rate requirements and power constraints. The mod class selection is done based on the path loss (β) estimated by the BS from the RA (Random Access) burst and can happen once in 10 ms (2 frames). The BS informs the uplink and downlink mod class selections to the User Terminal (UT) using AA (Access Assignment) message. Then UT uses the mod class for the traffic channel. When the traffic stream starts, the UT sends available power using fast associated control channel (FACCH) during even frames and after that the BS sends back the recommended mod class (RMC) to UT during odd frames. The BS uses the UT power information to derive and inform the UT of the recommended modclass, following which the UT uses the RMC as the modclass for the uplink.

Table 1 shows the modulation formats and modes of the iBurst system. And it also shows downlink and uplink throughput for the user using a single time slot and the user using a single carrier.

Table 1: Modulation Formats and Data Rates

Mod Class	Modulation Format	Single Time Slot Down Link Throughput (Kbps)	Single Carrier Down Link Throughput (Kbps)	Single Time Slot Up link Throughput (Kbps)	Single Carrier Up link Throughput (Kbps)
0	p/2-BPSK	35.2	105.6	6.4	19.2
1	p/2-BPSK	49.6	148.8	12.8	38.4
2	QPSK	81.6	244.8	25.6	76.8
3	QPSK	126.4	379.2	43.2	129.6
4	8-PSK	161.6	484.8	57.6	172.8
5	8-PSK	198.4	595.2	72.0	216.0
6	12-QAM	262.4	787.2	97.6	292.8
7	16-QAM	307.2	921.6	115.2	345.6
8	24-QAM	353.6	1060.8	-	-

6 Peak User Bit Rates UL/DL

The iBurst system supports timeslot aggregation (up to 3). At maximum downlink utilization, a single time slot on a single carrier can support a maximum downlink data rate of 353.6 kbps. Higher per user data rates can be achieved by aggregating time slots (up to 3), resulting in a maximum downlink throughput of 1.06Mbps.

At maximum uplink utilization, a single carrier and a single timeslot can support a maximum uplink data rate of 115.2 kbps. Higher per user data rates can be achieved by aggregating time slots (up to 3), resulting in a maximum uplink throughput of 345.6 kbps.

The iBurst System also supports the ability for User Terminals to aggregate carrier resources (up to 4), effectively increasing the maximum downlink and uplink throughput by a factor of 4.

7 Maximum Downlink Capacity per site (or sector)

As explained in Section 6 above, at maximum downlink utilization, a single time slot on a single carrier can support a maximum downlink data rate of 353.6 kbts/sec.

Assuming a 5 MHz block of spectrum and 3 spatial channels, the maximum number of timeslots with simultaneous transmission of data is (8 iBurst Carriers/5 MHz x 3 Time Slots/Carrier x 3 Spatial Channel/ Timeslot) 72. However, one time slot is reserved for the broadcast channel (BCH) and 1 spatial channel for RACH, which results in 68 simultaneous timeslots. This results in a maximum downlink capacity of 24.05 Mbps (68 x 353.6 kbps) in 5 MHz block of spectrum.

8 iBurst Capacity in a Network

iBurst capacity of a single basestation in an iBurst network is calculated by doing a full network level simulation that accurately models the behavior of the air interface including adaptive antenna behavior, power control, link adaptation, error correction etc. The simulator models macro-cellular deployment of basestations providing continuous coverage across a large geographical area and hence includes the effect of **inter-cell interference** along with **intra-cell interference**. Using the technique of Monte-Carlo simulation, uplink and downlink statistics are gathered for multiple placements of users within the network and throughput of a single base station is calculated by averaging the performance over the network.

The following assumptions were used as input parameters to the analysis:

- 1.9 GHz frequency
- 129kbps uplink and 595kbps downlink at cell edge
- 12 antenna omni Base Station
- Indoor coverage with 90% area coverage probability, full coverage outdoors
- Carriers: 8 i.e. 5 MHz deployment
- Spatial Channels: 2 (average load)

With this set of assumptions a single base station in an iBurst network can support an aggregate throughput of **15 Mbps in the downlink** and **5 Mbps in the uplink**. This aggregate throughput is divided among the end users with a maximum of 1 Mbps per link. The actual number of simultaneous sessions supported would depend a lot on the service model and usage. Section 16 shows an example scenario that calculates this number for the given set of usage assumptions.

9 iBurst Coverage

The coverage analysis is based on ArrayComm's iBurst link budget for 1.9GHz. The following assumptions were used in generating these coverage results:

- 1.9 GHz frequency
- 129kbps uplink and 595kbps downlink at cell edge
- 12 antenna omni Base Station
- Carriers: 8 i.e. 5 MHz deployment
- Base Station Antenna height: 100 feet or approximately 30metres
- Spatial Channels: 2 (average load)
- Power Class I User Terminals @ 31dBm Tx power
- Outdoor coverage

Results and other assumptions are listed in Table 2 below.

Table 2: Coverage Results at 1.9 GHz

Parameter	Units	Rural Base Station	Rural User Terminal	Suburban Base Station	Suburban User Terminal	Urban Base Station	Urban User Terminal
Hardware Configuration							
Number of RF Channel		8	1	8	1	8	1
Number of Antennas		12	1	12	1	12	1
Number of Spatial Channels		2	1	2	1	2	1
Transmitter Power	dBm	36	31	36	31	36	31
Antenna Gain	dBi	12	2	12	2	12	2
Antenna Height	ft	100	5	100	5	100	5
Tx Losses (Smar Antenna, Cable, etc.)	dB	2	0	2	0	2	0
Rx Losses (Smart Antenna, Cable, etc.)	dB	2	0	2	0	2	0
Maximum Allowed EIRP	dBm	57.2	37.2	57.2	37.2	57.2	37.2
Parameter	**Units**	**Downlink**	**Uplink**	**Downlink**	**Uplink**	**Downlink**	**Uplink**
Grade of Service							
Data Rate	kbps	595.2	129.6	595.2	129.6	595.2	129.6
Modulation Class		5	3	5	3	5	3
Pathloss Summary							
Hardware Link Budget	dB	157.4	160.4	157.4	160.4	157.4	160.4
BCH Pathloss	dB	163.6		161.5		161.5	
PCH Pathloss	dB	159.4		157.3		157.3	
TCH Pathloss	dB	152.1	155.0	149.9	152.9	147.9	152.9
Maximum Pathloss	dB	**152.1**		**149.9**		**147.9**	
Coverage Results							
Radius	miles	9.38		3.22		1.28	
Coverage Area	$miles^2$	275.98		32.48		5.16	
Radius	km	**15.00**		**5.15**		**2.05**	
Coverage Area	km^2	706.50		83.14		13.20	

10 Terminal Devices (CPE)

10.1 Configurations

10.1.1 Stand Alone type

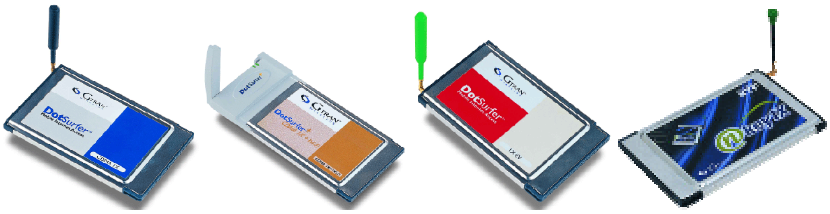
The stand-alone type subscriber modem is used either with a desktop PC or networking equipment (i.e. home network). Conceptual sketches of the stand-alone type (proposed by OEMs) are shown below.

Figure 3: Stand Alone Type UT Configurations

10.1.2 PCMCIA Types

The PCMCIA type subscriber modem is used with a Notebook PC or PDA. The shape of PCMCIA type is similar to Wireless LAN subscriber card except for antenna part. Conceptual diagrams of the PCMCIA type are shown below.

Figure 4: PCMCIA Type UT Configurations



10.2 Technical Specifications

See Table 4 on the following page.

10.3 Antenna Requirements

Antenna Type: Omni

Gain: 2dBi or 7dBi (2dBi typical)

10.4 Subscriber Portability

Current implementations of the iBurst UT store UT profile information (i.e. UTID) in FLASH memory. SIM card support for iBurst UT profile information is currently under investigation and will be supported based on operator and service provider requirements.

10.5 Firmware Upgrade

Both end user and over-the-air upgrades to User Terminal firmware are possible. Current implementations of the terminal device allow for the user to upgrade the terminal firmware from the host PC. The terminal configuration window of the host PC user interface software indicates the current version of the terminal firmware. A user can check the current version against a version made available thru a service providers support website. If a newer version exists, the new version can be downloaded and a terminal firmware update utility can be launched to install the terminal firmware. Optionally, a service provider may provide end users with a support agent that automatically checks to see if a newer version of the terminal firmware is available.

Over-the-air terminal firmware upgrade support is planned for release in the Q1/04 timeframe. Over-the-air terminal firmware upgrade support will allow service providers to upgrade terminal firmware (as long as terminal is active) without interaction of the end user.

Table 3: User Terminal Technical Specifications

<table>
<tr><th rowspan="2">Terminal Equipment Parameter</th><th colspan="3">Specification</th></tr>
<tr><th>Stand-alone without battery</th><th>Stand-alone with battery</th><th>PCMCIA Card</th></tr>
<tr><td>Dimensions [mm] (W X D X H)</td><td>145 X 95 X 20</td><td>180 X 105 X 20</td><td>115 X 54 X 5</td></tr>
<tr><td>Weight</td><td>150g</td><td>200g</td><td>50g</td></tr>
<tr><td>Data Interface</td><td>USB and Ethernet</td><td>USB and Ethernet</td><td>PCMCIA</td></tr>
<tr><td>Data Rates Supported</td><td colspan="3">- Up-link : 345.6kbps/carrier
- Down-link: 1.06Mbps/carrier, (20Mbps/cell in 5MHz)</td></tr>
<tr><td>Transmit Power</td><td>30 ~ 32dBm</td><td>30 ~ 32dBm</td><td>25 ~ 27dBm</td></tr>
<tr><td>Power Control Dynamic Range</td><td colspan="3">Power control step size: 1dB (tolerance: ± 0.5dB),
Minimum transmit power must be less than –20dBm.</td></tr>
<tr><td>Antenna Type & Gain</td><td colspan="3">Type : Omni, Gain : 2dBi or 7dBi (2dBi typical)</td></tr>
<tr><td>Power Details and cell technology (including any integral backup)</td><td>AC 100~240V,
Max. 15VA</td><td>AC 100~240V.
Max. 20VA
Battery; 7.4V,
1800mAH,
Type: Li-ion</td><td>PCMCIA</td></tr>
<tr><td>Re-charge time (from exhausted)</td><td rowspan="2">No battery</td><td>2 hours</td><td rowspan="2">No battery</td></tr>
<tr><td>Typical Duration (from full charge)</td><td>6 hours</td></tr>
<tr><td rowspan="2">User Indications (e.g. LEDs, real-time status software for PC)</td><td colspan="2">1. Link activity (Data rate)
2. Link status
Green means the UT connects the BCH.
Red means out of range.
3. Power-on.</td><td>1. Link status
2. Power-on</td></tr>
<tr><td colspan="3">Will offer function that indicates real-time status for PC, using of the software driver.</td></tr>
</table>

10.6 User Terminal Authentication

iBurst UT's will support three types of certificates for use during UT authentication. These are:

10.6.1 Identity Certificate

This certificate is generated by an iBurst Certificate Authority (CA) and factory seeded in the UT by the UT manufacturer. It ties the UT's hardware serial number to an elliptic curve public/private key pair using the elliptic curve K-163 defined in FIPS-186-2. A UT public key can be represented by 164 (163+1) bits. The UT uses this certificate to automatically obtain a Service Authorization or Network Access Certificate over the air interface from a management entity in the operator's or ISP's network. This certificate is only used if the UT doesn't have a valid Service Authorization or Network Access Certificate. While the Identity Certificate is factory seeded in the UT it may never be used if the Service Authorization or Network Access Certificates are obtained by some other means (e.g. surface mail, EUD download or operator programming).

10.6.2 Service Authorization Certificate (Optional)

This certificate is acquired by the UT at service authorization time over the air interface. It ties a service identifier (i.e. IMSI) assigned to the UT with a service type and an elliptic curve public/private key pair using the elliptic curve K-163 defined in FIPS-186-2. A UT public key can be represented by 164 (163+1) bits. This certificate is only used in deployments where Network Access Certificate validity is restricted to a single network access. In such deployments the service authorization certificate is used each time the UT powers up. It is used to obtain the Network Access Certificate from the local management entity.

10.6.3 Network Access Certificate

This certificate is an extension of the Service Authorization Certificate. It is used each time a UT establishes a new communications link with a BS except in cases where this link is established to obtain a Service Authorization or Network Access Certificate in which cases either an identity or a service authorization certificate are presented. The Network Access Certificate is the nominal credential provided by the UT to register with a base station. It either persists across network accesses ¾ a series of immediately consecutive iBurst sessions with one or more BS's, or it must be "refreshed" at the beginning of each network access, or on some other periodic basis, by means of a Service Authorization Certificate.

11 Voice Support through VoIP

The iBurst air-interface is well suited for supporting both circuit-switched and packet-switched data traffic. Therefore, by supporting VoIP calls using assigned circuits on the air-interface, iBurst can naturally meet the tight delay requirements of VoIP while simultaneously supporting more general data traffic.

VoIP requires a data rate of 10 kbps on both links and tolerable end-to-end delay of about 125-150 ms. Based on these delay and throughput requirements, iBurst could support VoIP today as a transparent application. However, there is currently no reasonable guarantee of maintaining call quality when a BS becomes heavily loaded. This reasonable guarantee can be easily addressed by using the iBurst QoS framework.

The iBurst QoS can support persistent streams (i.e., air-interface circuits), which would establish and maintain a very low delay and low delay jitter connection across the air-interface. This would be a robust approach for meeting the strict delay requirement of VoIP applications. The higher layer messaging required to set up persistent streams for VoIP users would fit naturally within the iBurst QoS framework. In 5 MHz of spectrum, 69 simultaneous VoIP calls can be sustained which can support a population of 550 0.1 Erlang voice users with 1% blocking probability. This capacity can further be increased using subrate channels.

Since iBurst uses advanced coding and spatial processing techniques to achieve high throughput, the throughput capacity of a persistent stream far exceeds the throughput requirement of VoIP. Therefore using a persistent full-rate stream is overkill. Subrate channels could also be used to meet both the delay and throughput requirements of VoIP applications. Though not yet completely supported, subrate channels have been envisioned for low data rate, low latency applications from inception of the iBurst protocol and are currently anticipated in the protocol design. iBurst uses a TDM structure for subrate channels to multiplex multiple users on a single (spatial) channel – the number of TDM subframes is called the decimation factor. The protocol will likely support decimation factors of 1 (full rate), 2, and 4.

Assuming quarter-rate channels are used to support VoIP applications, the call capacity of the 5 MHz BS is 276 simultaneous calls. This supports a population of 2,530 0.1 Erlang voice users with 1% blocking probability.

VoIP support is summarized in Table 4 below.

Table 4: VoIP Capacity

iBurst System	VoIP Call Support
Current pilot	Transparent. Works well when lightly loaded. No reasonable guarantee of maintaining call quality when heavily loaded.
QoS framework	550 0.1 Erlang voice users with 1% blocking probability
QoS framework with subrate channels	2,530 0.1 Erlang voice users with 1% blocking probability

VoIP can be immediately supported as a transparent application over iBurst. As long as the BS is not heavily loaded, this is quite sufficient. When the BS becomes heavily loaded, the delay requirement may be violated.

The first generation commercial iBurst system will have QoS support. It would be relatively straightforward to support VoIP calls using persistent streams. Both VoIP calls and general data traffic can be accommodated naturally in iBurst. The BS scheduler is free to partition the conventional channel resources between VoIP traffic and general data traffic in essentially any manner, e.g., first-come-first-served, soft partition of conventional channels between VoIP and general data, etc., depending on the needs of the network operator.

12 Mobility (and Handover Support)

12.1 iBurst Network Mobility

12.1.1 iBurst Network Mobility Functionality

The iBurst system fully supports mobility. iBurst supports handover at the user-session level, which allows users to access applications of choice without worrying about loss of connectivity while moving around in the iBurst coverage area. Handoff is the process of transferring an active iBurst user session from one Base Station to another without interrupting service. Inter Base station handoffs are possible as long as both Base Stations have back-haul connectivity to a common PSS(Packet Services Switch or PDSN). Session management is isolated from handover, and the subscriber is unaware of an impending handoff.

When a User Terminal (UT) wakes up, it scans the BCH carriers and performs a cell selection algorithm to determine the best basestation with which to communicate. This procedure is called initial cell selection. The effective data rate and the latency of a data stream, as the user moves from one cell to the other, is dependent on the performance of handover. Initial cell selection and handover are UT-centric. The UT makes the decision based on the signal measurements.

As a user moves from one cell to another the probability of ping-ponging between the BS's is minimized by using hysteresis. Hysteresis depends on the fluctuation of the received signal. The received signal at the UT fluctuates due to the motion and the fluctuation is dependent on the velocity of the user and needs to be adapted based on the velocity of the user. The following parameters are considered for the handover decision:

- Broadcast channel(BCH) receive signal strength(RSSI)
- Path loss between UT and BS(based on the difference between the BCH transmit power reported in the BCH burst and the BCH receive signal strength).
- Relative distance between UT and BS(Based on the BCH receive timing alignment).
- Base Station load factor(reported in the BCH burst).

In iBurst, user sessions between the Base Stations and the PSS are encapsulated in a Layer 2 tunnel. Supported Layer 2 tunnelling protocols include GRE and L2TP. Handover in iBurst allows a user to seamlessly move from one Base Station to another – hence moving from one Layer 2 tunnel (GRE or L2TP in the figure) to another – without interrupting the user session.

The UT connects to one or more end-user devices (EUDs) and establishes a wireless connection to a Base Station on the other side. On the EUD, an Ethernet/USB/PCMCIA interface is used. The UT receives Ethernet frames from one or more EUDs, and these frames contain PPP (PPPoE) packets. On the wireless interface, the UT communicates to the Base Station to establish a registration. When an EUD establishes a PPP session, the Base Station opens an L2 tunnel to the PSS. The PSS begins PPP negotiation with the EUD and, based on the entered username, the PSS passes the session over another Layer 2 tunnel to an ISP's L2TP network server(LNS).

The iBurst system is designed for optimal data rates and capacity when users are moving less than 20Km per hour. However, the iBurst system can support mobility as described below.

Simulations of the iBurst system in urban, suburban and rural environments have been conducted to estimate the maximum speed a mobile can move and still not suffer significant degradation in data rate. Here we define significant degradation as the maximum supportable data rate being less than 70% of the peak data rate. The results are shown in Table 5

Table 5: Mobility Limits in Different Environments

Environment	Speed (kmh)
Urban	40 ~60
Suburban	60 ~ 80
Rural	> 100

12.1.2 iBurst Network Mechanism for Mobility

The iBurst system achieves network level handoffs using SimpleIP.

Intra-PDSN handover is achieved using SimpleIP only. And inter-PDSN handoffs using SimpleIP is achieved by using the concept of a Control Node. PDSN vendors such as CommWorks, support the Control Node feature whereby up to 256 PDSNs are aggregated and appear as a single monolithic PDSN.

The CommWorks Foreign Agent Control Node (FACN) selects the least loaded PDSN within PDSN groups, handles handoffs and provides the control mechanism for managing multiple Packet Data Serving Nodes (PDSNs)

With its ability to ensure redundancy and high performance, each FACN easily manages as many as 250 individual Packet Data Serving Nodes (PDSNs), allowing wireless providers to deploy a highly distributed architecture. Utilizing the FACN, Base Stations can view 250 PDSNs as one single PDSN capable of supporting approximately 1 million Point-to-Point (PPP) sessions.

When a UT handoffs to a BS that is connected to a different PDSN (i.e., inter-PDSN, inter-BS handoff) the FACN ensures that the existing user PPP session is maintained by the original PDSN.

Once the UT has established a PPP session with the PDSN, the PDSN sends a Registration Update to the FACN. The FACN maintains a database of registered UTs. UTs that have been successfully authenticated and connected at the PDSN during PPP negotiation in previous sessions. Each time a UT re-connects at the PDSN by establishing a PPP connection, the PDSN updates the FACN database with UT profile and session information.

With iBurst by using the FACN, inter-PDSN, inter-BS handoffs can be achieved using SimpleIP instead of using MobileIP.

12.2 Inter Operator Roaming

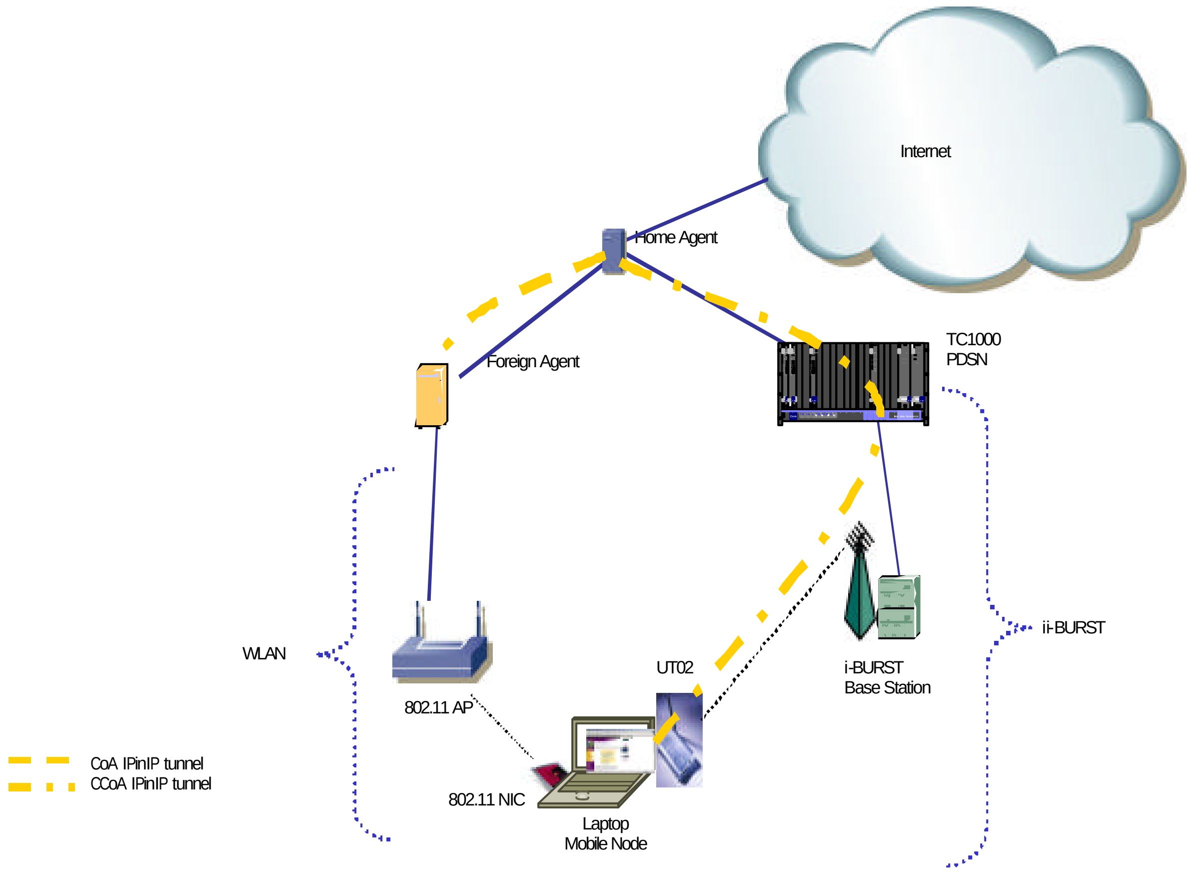
The iBurst protocol supports the user roaming between the networks of multiple operators. In the case where operators use separate bands, there is no requirement for guard bands as long as the operators synchronize the BS frame timing to a common reference. The frame timing must be accurate to within +/- 2 msec. Each operator is then free to do independent BCH planning within their band without coordinating with other operators. It is the responsibility of the User Terminals to decide which is the preferred operators network to use. The BCH scanning algorithm employed by the User Terminals will support the ability for inter-operator roaming.

12.3 Inter System Roaming

Transparent, seamless roaming between iBurst and a WLAN based infrastructure is supported. An iBurst user is able to perform handoffs between the two systems without any loss in connectivity and without any degradation of service.

In an iBurst system, iBurst<->WLAN handover is based on Mobile IP. In a Mobile IP infrastructure, handoff is realized through the interaction of a Mobile Node with Mobility Agents (Home Agent, Foreign Agent).

Figure 5: iBurst/WLAN Interoperability Configuration



The main components of this configuration are:

The Mobile Node, running an IPv4 Mobile IP client software,

- The Home Agent
- The Foreign Agent, servicing a WLAN cell

Here, the Mobile Node decides to handoff from one system to the other based on monitoring WLAN metrics (WLAN signal strength fading, cost, etc). The roaming handover is seamless to the subscriber and the IP session is maintained during the transition.

13 Latency

The iBurst system added latency has been characterized under bursty traffic conditions. The mean uplink TCP segment delay of iBurst is 20ms and the mean downlink TCP segment delay of iBurst is 30ms. Round trip ping latency of an iBurst network is approximately 30ms.

14 QoS Management

14.1 Radio System QoS

iBurst QoS allocates air-interface traffic resources relative to pre-defined user profiles. End user applications use the user subscribed QoS profile. The iBurst Air Interface Standard to be released in Q3/03 (Version 1.3) will allow iBurst Base Station and User Terminal equipment to support QoS mechanisms such as intelligent packet scheduling, queuing that provide air-interface QoS and user traffic prioritisation.

iBurst supports a low latency, bandwidth on demand, spectrally efficient MAC. Actual measured end to end (UT to ISP) round trip latency is 30 ms. The latency of 30ms is for 50 byte packets and includes the following:

- 10 msec for stream open
- 10 msec to transmit
- 10 msec for return

Time sensitive traffic such as VoIP impose <150 ms end-to-end delay requirement. As the iBurst UT to ISP latency is 30-50 ms, IBURST can comfortable support VoIP with current MAC mechanism. Additional performance gains can be achieved by QOS mechanism.

VoIP over iBurst has been successfully demonstrated with commercial VoIP applications using Dialpad, Net2Phone and commercial ISP SIP servers.

14.2 QoS Management

The DiffServ standard provides differentiated classes of service for Internet traffic, to support various types of applications, and meet specific business requirements. DiffServ offers predictable performance (delay, throughput, packet loss, and so on) for a given load at a given time. DiffServ splits Internet traffic into different classes with different QoS requirements. iBurst QoS provides direct mapping to the IETF DiffServ standard. Prioritised user traffic will be mapped to DiffServ Per Hop Behaviour profiles at the Base Station. iBurst QoS implementation supports externally configurable QoS parameters and advanced QoS schemes.

Figure 6: iBurst QoS Architecture

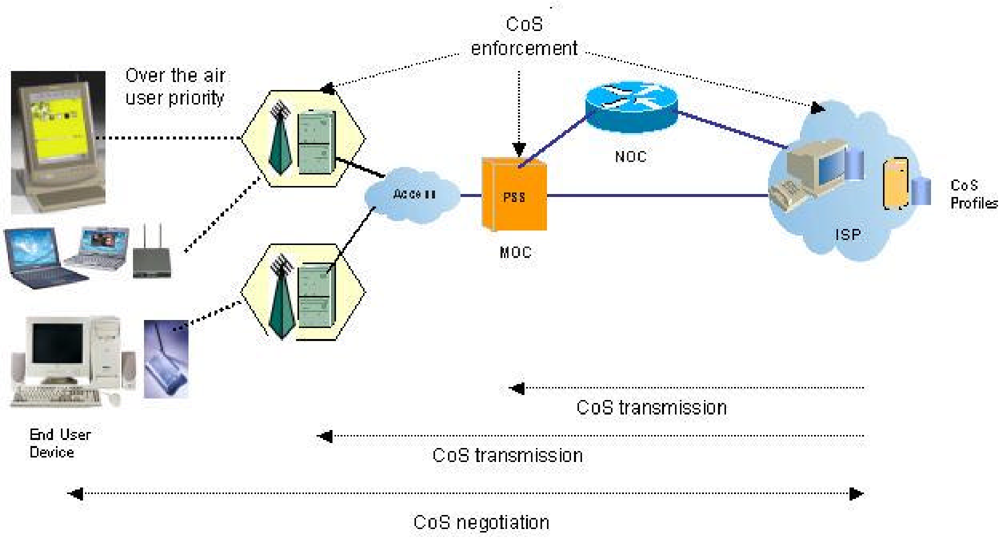


Figure 6 shows a representative iBurst system with end-to-end QoS. The iBurst network supports the following external parameters.

- **Class of Service**: A Class of Service (CoS) is a QoS parameter that represents the relative priority of users with reference to other classes. Standard IP mechanisms are used for CoS profile specification, CoS negotiation and CoS transmission from the ISP to the Packet Service Switch (PSS) and iBurst Base Station.
- **Peak throughput**: Peak Throughput on a per user basis is specified in the iBurst user profile. It is possible to specify unique downlink and uplink throughput rates for each Class of Service.

The iBurst network supports advanced QoS schemes and parameters. The QoS schemes can be specified/engineered by an iBurst OEM or by a System Integrator while implementing QoS in the iBurst Base station and during deployment. Configuration and tuning of QoS parameters are enabled by the following QoS schemes:

- **Weighted fairness**: Weighted fairness is a scheme wherein subscribers belonging to different class of service prevent air-interface hogging by users belonging to other classes. This ensures that low-priority CoS subscribers are not prevented from transmitting or receiving data due to large number of higher-priority subscribers.
- **Partitioning**: Partitioning enables operators to dynamically re-configure available resources on per ISP or per service level basis. As an example, the available resources in a Base Station can be partitioned for 50% Gold users, 30% Silver users and 20 % Bronze users. An alternate partition maybe, 20% Gold users, 30% silver users and 50% bronze users.
- **Utilization efficiency**: Utilization efficiency enables effective utilization of wireless resources when the number of users competing to use the resources exceeds the number of free or available wireless resources. This ensures that

service degradations are minimized in a heavily loaded system to maximize the air-interface utilization efficiency.

14.3 Multiple Customer QoS support

Radio resources in the iBurst system are allocated in response to demand, link conditions and Quality-of-Service (QoS) profiles defined by the operator. Certain QoS features apply to individual users, while others apply to groups of users (user aggregates).

The two principal per-user QoS parameters are rate limiting and relative priority. Rate limiting allows individual users' peak uplink and downlink rates to be "capped." iBurst's relative priority facility ensures that users with higher relative priority will have their data delivered before that of users with lower relative priority. Per-user QoS is defined in the service domain, e.g., at a RADIUS server, and propagated from the service domain to the user's serving Base Stations using IETF DiffServ markings. A DiffServ MIB at the Base Station allows the operator to inform the Base Station scheduler of the particular DiffServ markings in use and their proper interpretation.

The principal air interface QoS feature for user aggregates is resource partitioning. Resource partitioning allows fractions of the Base Station resources to be reserved for each user aggregate. For example, if network resources are being wholesaled to two ISPs, the network operator might decide to reserve 30% of the Base Station resources for the users of ISP #1 and the remaining 70% of the resources for ISP #2. In practice, this reservation would be "soft" in that ISP #1 would be guaranteed no less than 30% of the Base Station resources, while ISP #2 would be guaranteed no less than 70% of the Base Station resources. Resource partitioning is also defined through the DiffServ MIB at the Base Station.

Since per-user QoS is subjugated to aggregate QoS -- i.e., aggregate QoS is applied first to partition resources and then per-user QoS is applied within those constraints -- aggregate QoS can be thought of as a mechanism for the operator to differentiate service among its customers, while per-user QoS is a mechanism for service providers to differentiate service among their customers (end-users).

iBurst's QoS facilities, when used in concert with standard network engineering and dimensioning practices, aid operators and service providers in creating and differentiating robust wireless services.

15 System Architecture

15.1 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.

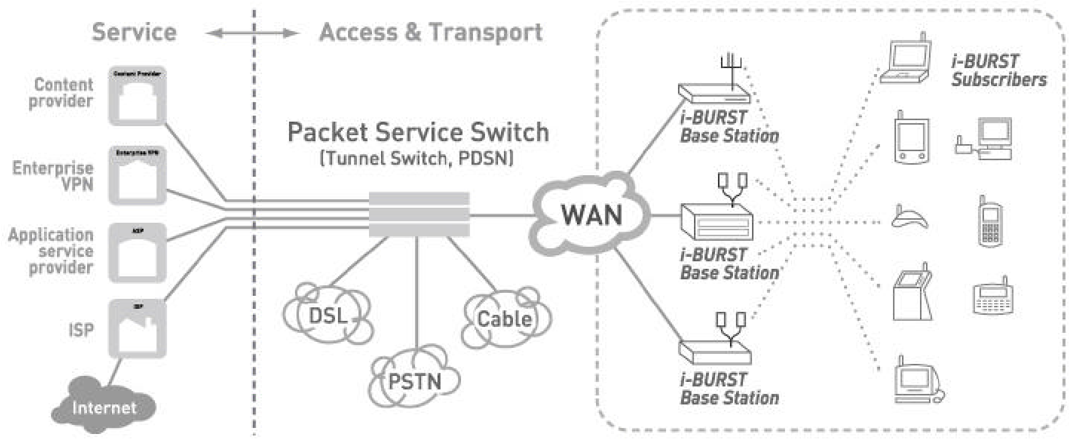
In recent years, access aggregation technologies have been developed that allow a common access and transport network to bear the traffic of subscribers from multiple service providers. Separating access and transport from service accomplishes two things:

(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 7depicts 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 7: 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.

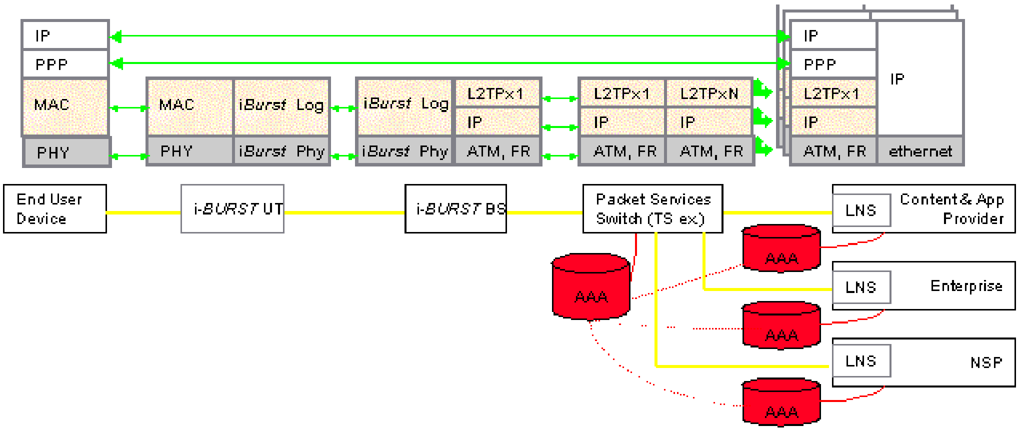
15.2 iBurst Architecture

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.

15.3 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 8, one can see that a user's PPP session is carried by a variety of different media and protocols.

Figure 8: 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 labelled 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 8 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.

16 Reference Deployment Scenario

The following is the list of parameters/requirements define a typical reference deployment scenario.

- Urban propagation environment
- 15,000 subscribers out of which 20% are active at a given time
- Deployment coverage area is 100 km^2
- Average data rate per active session is 25 kbps
- ADSL like data rates and user experience

Section 8 calculates the aggregate capacity of a single iBurst basestation in a network scenario as 1.5Mbps downlink, 5 Mbps uplink. This analysis was done for supporting 595 kbps downlink/129 kbps uplink data rates per sessions at cell edges hence gives an ADSL like experience to the user.

Section 9 calculates the coverage of the iBurst base station in an urban scenario for a similar user data experience of 595/129 kbps as 13.20 km^2. Using these values, the reference network deployment scenario can be calculated as follows:

To satisfy coverage requirements:

Number of iBurst base stations needed = 100/13.2 or 8 base stations.

To satisfy capacity requirements:

Number of iBurst base stations needed = (25 kbps*15,000*0.2)/ 15 Mbps or 5 base stations.

Hence, the reference deployment scenario will need 8 base stations that will be operating at 62.5% capacity on an average.

It is important to note that the range and capacity numbers used for the above analysis assumed 2 spatial channels on an average. *One could easily get higher ranges by going down to lesser number of spatial channels on an average which could make sense in initial rollouts where systems are lightly loaded and coverage is the main concern.*

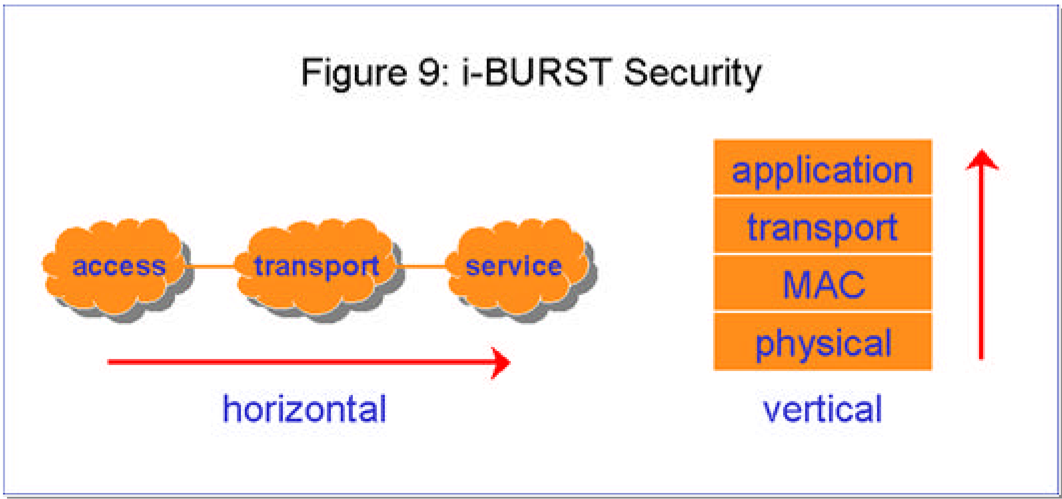
16.1 Estimated Costing of iBurst System Radio (Infrastructure) Segment for the reference scenario

ArrayComm does not dictate either base station prices or iBurst modem prices. They will be largely determined by the cost structure of iBurst vendors and market forces. ArrayComm will refer requests for detailed cost information about user terminal and base station equipment to our manufacturing partners. Beyond the airlink elements, the network support for the iBurst system depends significantly on the service definition and the amount of re-use of existing network back-end resources (e.g. billing systems, network element management systems, etc.). However, as a general point of reference, our planning, operator case modeling and discussions with operators do indicate consistently that the economics of a greenfield iBurst network deployment is competitive with DSL or cable modem broadband services on a per-user basis. Generally, equipment capex per sub for an iBurst system is less than US$100 in a fully-deployed network. With due considerations to specifics of deployments in each specific case, taking into account facilities leasing or purchase, and variable factors in each market, we have found that *total infrastructure cost per subscriber for single digit market penetration (3% to 7%) is always below $200.00 per subscriber*, and breakeven occurs at anywhere from 3% to 5% penetration for competitive service pricing.

17 iBurst Security Considerations

Considerable attention has been paid to developing a comprehensive iBurst security solution. Given the architecture of iBurst, we have used pre-existing, industry-wide solutions except for the air interface, where a new solution had to be devised.

The basic air interface security concept is that Security is both "horizontal" and "vertical" (Figure 9 below), and the Air interface provides encryption and authentication.



The key features of iBurst Air Interface Security are as follows:

- Authentication
    - mutual public key authentication of network and UT
    - UT authentication minimizes traffic upstream of BS
- Encryption
    - RC-4 stream cipher with up to 192 bit key
    - secure IV updates & key diffusion for robustness
- Validation
    - independent review by industry expert
    - authentication and confidentiality verified

iBurst End-User Security is provided by the set features listed in the table below:

Protocol Level	End-User Mechanism
MAC	♦Air interface BS authentication ♦LNS end-user authentication ♦Air interface data encryption
Transport	♦IPSec/VPN encryption ♦IPSec/VPN authentication
Application	♦Encryption and authentication (https, ssh, …)

iBurst ATN Security is provided by the set features listed in the table below:

Protocol Level	ATN Mechanism
MAC	♦MAC-specific encryption ♦MAC-specific authentication
Transport	♦IPSec encryption/authentication ♦MPLS partitioning ♦L2TP authentication
Application	♦SNMP authentication ♦ssh encrypt/auth for management

18 iBurst Market Acceptance

ArrayComm and its partner companies in the iBurst enterprise have strived to offer from the start to the marketplace (of "Greenfield" and incumbent operators) a viable business model for adoption of iBurst: The key components of this model are:

- Industry-standard base system architecture
- Capable and Reputable OEMs, capable of scaling up manufacturing and support
- Multi-sourcing for all system components
- Industry standard network elements and subsystems

- End to End carrier class service parameters. This entails using LICENSED spectrum for the radio access segment, and preferably in widely available and suitable bands in important economic regions, ensuring economies of scale for parts, availability, etc.

Two strands of marketing efforts are in place, supported by OEMs (Kyocera, LG Electronics, etc.), by distribution and logistics companies such as Mitsubishi International, (a) mostly focusing for now on Pacific Rim markets and (b) by a consortium of system integration/ specialist companies led by Burst Communications for Europe, West Asia and Africa:

The announced or planned iBurst deployment agreements are:

- Australia (nationwide): Consortium in place, commercial service starts in 4Q03
- USA (suitable spectrum auctioned): Planning underway. Final decision pending.
- Korea: Multiple Pilots in place: final decision pending spectrum allocation and government industrial policy.

The second strand (Europe, West Asia) has been considerably slowed-down for years by the UMTS capers (regulatory hurdles, spectrum and policy issues, general slowdown, etc.) and is getting revived fast under the circumstances:

We can disclose that deals are being finalised, with pilots in final stages of planning in various markets such as

- South Africa (with existing wireless operator)
- Mexico (with IP network operator)
- Russia (multiple parties, considerable interest because of antiquated copper access network, and large distances)
- Number of secondary markets in Western Europe (rural and regional, smaller countries which cannot afford UMTS)
- Peripheral markets in the Middle East and Africa.

In all the above markets, iBurst is being marketed by the OAK Global consortium as a wireless broadband access system for basic high-performance and low cost system (with ease of use –no installation of UT - and deployment being a key feature), in essence, an ubiquitous DSL access system, and not as a competitor to 2G or 2.5 G cellular systems.

In conclusion, it can be reasonably assumed that by 2007, iBurst systems may cover a population of 400-500 million people out of a total of about 1 billion in at least ten markets.

19 Development Roadmap

The current release of the iBurst protocol and ASIC from ArrayComm support full functionality of a quality wireless broadband and mobile computing service. In addition, it also supports portability and mobility. Vendors such as Kyocera and LGE may decide to add more features, particularly in iBurst network control and management and network interfaces, to make their products more competitive and easily field deployable, the basis set of functionality from vendors is designed to represent a fully-formed set of network elements that can be used to support commercial deployment now. iBurst Protocol v1.3 (the current release) offers:

- TDMA/TDD channel structure.
- Efficient allocation of traffic resources in response to demand and link conditions
- Power control, tiered modulation and forward error control (FEC) to address different link conditions and UT capabilities
- ARQ for reliable data delivery
- Link-level encryption, BS and UT authentication to guarantee the confidentiality of both user and system control data
- Link and network layer handover procedures to ensure seamless continuity of end-user sessions as UTs traverse the access network
- Ability to aggregate multiple 625 KHz carriers
- Quality of Service (QOS) support
- Intrinsic support for adaptive antenna (spatial) processing to achieve high data rates for many users within a cell and network

ArrayComm is committed to enhance iBurst features and performance through future protocol releases. Feature availability will be determined based on feedback from iBurst field deployment and operator requirements. Our current research and development effort, in summary, focuses on the enhancements at the level of iBurst core technology include:

Air Interface:

- enhancements for increased throughput, efficiency
- additional QoS/CoS features

ASICs:

- reduced form factor, power consumption, increased radio integration
- support for higher data rates

Network & Services:

- enhanced manageability of terminals and base stations
- extended range of ISP-definable service types and billing options

The enhancements in the network and service aspect will largely be driven by vendors who supply iBurst commercial products and compete in the market place. ArrayComm will work with iBurst vendors to facility the development.

Enhancements to our manufacturing partners' product roadmaps — beyond the initial releases of base stations, PCMCIA-card and desktop user terminals are of course also market driven, similarly dependent on operator feedback and requirements. Through our discussions, we do understand that vendors have devoted a great deal resources on enhancements of their respective commercial products. For base stations, concepts in development include alternative RF electronics configurations for optimized support of booth rooftop and tower-top deployment. For user terminals, future enhancements include higher data rates, tighter intergration in multifunction devices (such as personal media gateways or modem/router/firewall/print-server comb inations), lower power, and smaller form factors (such as flash memory cards). A great deal investment has also been made in iBurst system management software from the element control and management to network control and management and in friendliness.

20 Interoperability

Understanding the interoperability is the key to the success of iBurst commercialization, ArrayComm has designed and is implementing through collaboration of iBurst vendors, three mechanisms for maintaining the interoperability of iBurst equipment.

First, we are the sole source of the ASICs required to build any user terminal, which ensures a common foundation for protocol implementation. In all our licensing agreements, we require strict adherence to iBurst interoperability requirements for any iBurst user devices.

Second, our contracts with our manufacturing partners prohibit them from introducing proprietary variations in the implementation of the protocol in the user terminal's software. Because of these two elements, all the iBurst user terminals will be functionally identical, and therefore interoperability between manufacturer X's user terminal and manufacturer Y's base station is automatic.

Third, to validate that this works in practice, ArrayComm and its initial partners (Personal Broadband Australia, Kyocera, and LG Electronics) are establishing the iBurst Forum, an organization chartered to catalyze the development of the personal broadband industry through coordinated commercialization of iBurst technology. In addition to activities related to international standards, business development, and marketing, the Forum has initiated a technical working group focused on the development and implementation of interoperability standards and test procedures. The leading iBurst vendor Kyocera is interested in sponsoring and hosting an interoperability labor to certify designs of iBurst products. Without exception, every manufacturer with whom ArrayComm is engaged, whether signed licensees or prospective, is interested in participating in the iBurst Forum precisely because interoperability is so crucial to the system's broad adoption and success — a goal toward which we are all working diligently. As the Forum's membership grows beyond the initial founders and multiple manufacturers come on-line, an independent test lab will be selected to certify interoperability on behalf of the Forum.

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