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GENERATIONS II

LCC International Inc

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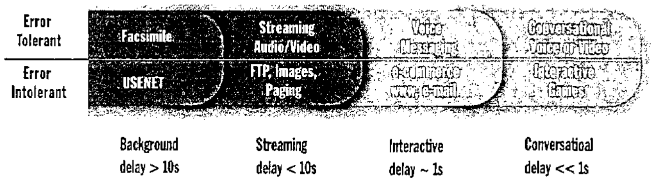
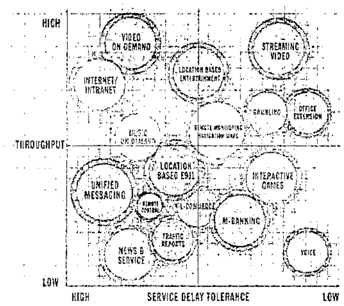
The ITU has defined four (4) classes of service for 3G networks; Background, Streaming, Interactive and Conversational. The main distinguishing factor between these service classes is how delay sensitive the traffic is: background class is the most delay insensitive traffic class while conversational class is meant for traffic which is very delay sensitive.

Conversational and streaming classes will be mainly used to transport real-time traffic, while the interactive and background classes are mainly used to transport more traditional internet applications like www and email.

Application



Classes of service and associated application examples
Source: ITU



3G services vs. their quality of service parameters
Source: UMTS Forum, ITU, LCC

Delay Tolerance

Due to increased bandwidth requirements and/or higher power requirements for services that need high data rates or are delay sensitive, the cell sizes of 3G systems will shrink in comparision to 2G systems. The following table shows possible 3G services and their predicted effect on the infrastructure requirements.

SERVICE	GRADE OF SERVICE	PEAK BIT RATE	INTERACTIVITY	NUMBER OF CELLS COMPARED TO 2G*
Experts on tap	Conversational	M	H	↗
Navigation map (assistance)	Interactive	L	M	→
Traffic reports	Interactive	L	L	→
Location based entertainment	Interactive	M	M	↗
M-shopping	Interactive	L	M	→
Office Extension	Streaming	M	H	↑
Voice	Conversational	L	H	→
Video on demand	Interactive	H	L	↑
Messaging	Conversational	M	L	→
Location based emergency	Interactive	L	L	→
Video news	Background	M	L	→
Music on demand	Streaming	M	L	↗
L-commerce	Interactive	L	L	→
Gambling	Interactive	M	M	↗
Translation service	Interactive	L	H	→
Video telephone with translation	Conversational w/Video	M	H	↑
Interactive game	Conversational	L	H	↗
On-line news services	Interactive	L	M	→
M-auctioning	Interactive	L	M	↗
Subscription news	Background	L	L	→
Video telephone	Conversational w/video	M	H	↑
On-line video	Conversational w/video	H	H	↑
Video conference	Conversational w/video	H	H	↑
E-postcard	Background	L	L	→

LEGEND: MODERATE INCREASE ↗ NO CHANGE → INCREASE IN CELLS ↑
H=HIGH M=MEDIUM L=LOW

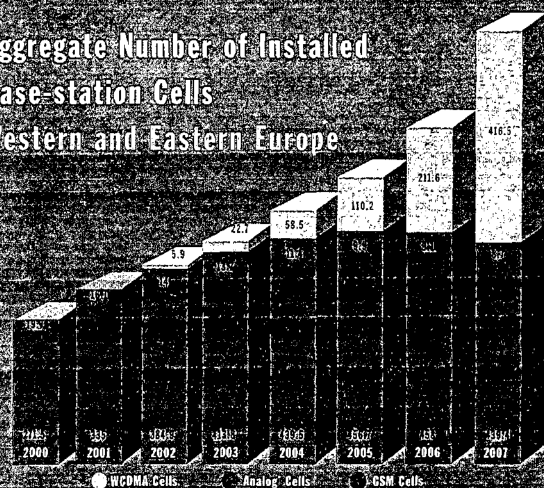
ased on a 2G network of average cell density.

Western Europe Subcribers by Technology

	2000	2001	2002	2003	2004	2005	2006
Total Subcribers	242,540,390	288,694,100	310,089,938	323,260,531	330,202,319	334,303,921	336,033,969
Analogue	1,995,848	653,873	75,291	0	0	0	0
GSM	240,521,058	276,018,974	234,878,322	144,655,945	68,111,868	35,409,294	32,215,023
HSCSD	15,656	265,652	993,045	1,515,449	1,291,714	847,649	432,015
GPRS	7,828	11,702,992	70,340,458	158,707,766	211,360,749	198,133,526	145,438,769
EDGE	0	52,610	1,472,961	3,180,906	3,660,709	2,804,964	1,171,037
UMTS	0	0	2,329,861	15,200,464	45,777,278	97,108,489	156,77,125
POPULATION	389,379,523	390,158,282	390,938,599	391,720,476	392,503,917	393,288,925	394,075,503
TOTAL MOBILE PENETRATION	62%	74%	74%	[illegible]	84%	85%	85%
NET ADDITIONS	87,510,390	46,153,710	21,395,838	13,170,592	6,941,789	4,101,602	1,730,048
SUBSCRIBER GROWTH RATE	56%	19%	7%	4%	2%	1%	1%

Source: The Strategis Group

Aggregate Number of Installed Base-station Cells Western and Eastern Europe



Total Analog comprises TACS 900, NMT 450 and NMT 900
Also data relates to installed and active BTS cells

Source: The Strategis Group

North American Subscribers by Technology

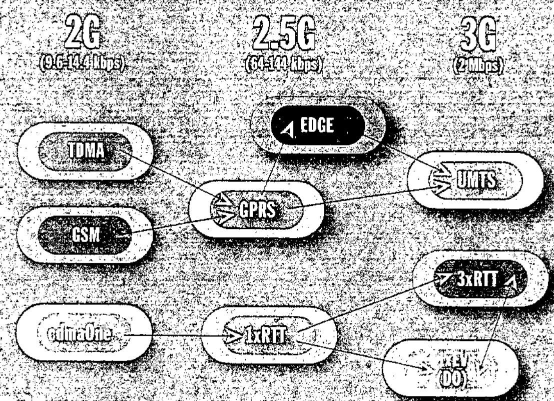
Technology	2000	2001	2002	2003	2004	2005
Analog	40,409,504	33,722,335	25,099,236	16,020,445	7,539,229	3,251,530
2G- CDMA	24,697,771	34,528,830	43,881,457	53,864,656	58,391,491	54,039,759
2G- TDMA	23,651,462	32,158,433	39,204,072	43,571,937	44,042,579	38,069,107
2G GSM	8,234,702	12,564,749	15,958,339	19,024,704	20,249,082	18,432,136
2G ESMR	7,944,705	9,595,661	11,242,211	13,100,931	13,873,619	12,820,931
2.5/3G CDMA	0	0	1,345,905	2,980,700	9,156,964	22,132,020
2.5/3G TDMA	0	0	1,202,443	2,411,134	6,906,765	15,591,229
2.5/3G GSM	0	0	489,480	1,052,767	3,175,465	7,548,854
2.5/3G ESMR	0	0	344,616	724,964	2,175,663	5,250,821
3G only	0	0	0	0	1,070,743	5,585,596
CDPD	173,083	227,090	332,509	315,883	252,707	151,624

Source: The Strategis Group

Impact of Wireless Today and Tomorrow

Understanding the Impact of the Wireless Generations

The migration of 2nd generation networks to 3rd generation networks is a phased progression with an intermediate step commonly called 2.5 generation in between. The following charts and graphs illustrate the migration paths for the various technologies and show some of the services possible with each.



2G Technologies	Supported Data Rates	Supported Services	Comment
GSM 900/1800/1900	9.6 kbps (max)	Circuit Switched	
TDMA (IS-136)	9.6 kbps (max)	Circuit Switched	
CDMAOne (IS-95A/B)	14.4 kbps (max)	Circuit Switched	
2.5G Technologies			
GPRS	115 kbps (max)	Packet & Circuit Switched	
1xRTT	144 kbps (max)	Packet & Circuit Switched	
1xEV (data only)	2.4 Mbps (max)	Packet Switched	
3G Technologies			
W-CDMA	Peak rate of 2 Mbps	Packet & Circuit Switched	Initial implementation will be a parallel packet switched network. Phase II 3G networks will implement an all IP core network
cdma2000	Peak rate of 2 Mbps	Packet & Circuit Switched	Initial implementation will be a parallel packet switched network. Phase II 3G networks will implement an all IP core network

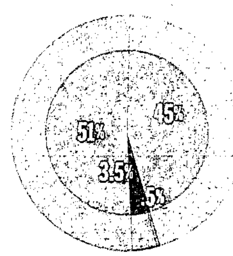
LCC
the knowledge that powers the network

C. Thomas Faulders III
Chairman and Chief Executive Officer

TO MY FELLOW SHAREHOLDERS:

The new millennium represented a landmark year for LCC. 2000 represented a re-dedication to professional excellence. As a team, now over 900 strong, the employees of LCC have established and continue to refine the steps necessary to ensure that our service model represents one of the highest quality offerings available to the wireless voice and data community.

Our year over year revenue increased almost 100 percent resulting in record revenues. Net income increased dramatically. Earnings per share went from double-digit losses to double-digit gains. Our balance sheet has never been stronger with over $42 million in cash and short-term investments and no debt. And, as we exited the fourth quarter, our operating margins represented 8% of revenues – a long way from the significant losses the Company produced in 1999 and earlier.



TOTAL 2000 REVENUE=$150.4 MILLION

Consulting · O & M · Design · Deployment

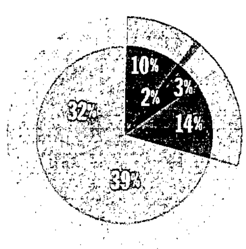
While operating leverage contributed to some of the enhanced financial performance seen in 2000, the majority of the year's success was a result of the hard work and dedication demonstrated by LCC's employees. The company was faced with tremendous growth challenges throughout the year and our employees met each hurdle with professionalism and enthusiasm. Some of the accomplishments we achieved during 2000 were:

Through a series of planning sessions, the leadership of the Company developed and implemented a 5-year strategic plan. In addition to bringing additional focus to our business development and operational teams, this process kicked off our growth initiatives.

The Company successfully completed the sale of our tower portfolio to Pinnacle towers for one of the highest valuations the industry has seen.

We made great strides into the fixed wireless market. Despite deployment postponements resulting from the tight capital markets, we are still focused on this emerging market. Strategic relationships with Nucentrix, Sprint Broadband, WorldCom Wireless, several unlicensed band carriers as well as Cisco Systems will continue to be nurtured until the fixed wireless market begins moving aggressively again.

Investments in and partnerships with Mobilocity, a leading provider of m-business strategic consulting and implementation services; TMNG, a leading provider of management services to the global telecom industry; Plan + Design, a German based wireless network deployment firm; and Transmast, a Finland based provider of turnkey services for base stations for wireless networks have enhanced our end-to-end solutions approach to our customers.

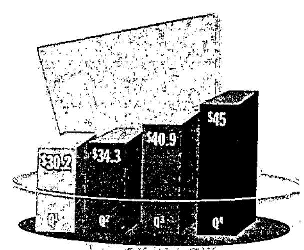


TOTAL 2000 REVENUE=$150.4 MILLION

Europe · Latin America · Africa · N. America · XM · Asia

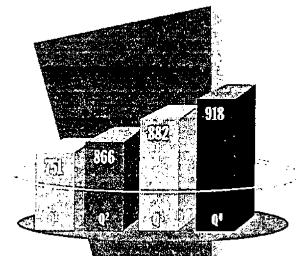
Several key hires made throughout the year have greatly improved our operational efficiencies and go to market approach.

Growth in our Consulting and Operations & Maintenance (O&M) practices were key to our ability to offer complete turnkey solutions to our customers. Both of these groups achieved commendable results as start-up organizations. Most significantly, our consulting group designed a "3G showcase" that takes audiences through the technical, financial, regulatory, marketing and competitive challenges an operator faces while planning and implementing their 3G networks. To say that their efforts were well received is an understatement. On the O&M side, we now



2000 REVENUE PER QUARTER (in millions)

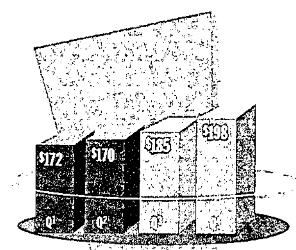
have contracts with Click GSM in Egypt (formerly Misrfone), OneTel in Australia, Pinnacle Towers and XM Satellite both in the United States.



EMPLOYEES AT THE END OF EACH QUARTER

In order to support the growth associated with the burgeoning mobile, fixed, satellite and supporting wireless markets, our Human Resources department hired over 500 people in 2000. Our employee community now consists of over 50 nationalities and we currently are working on over 200 projects in over 30 countries.

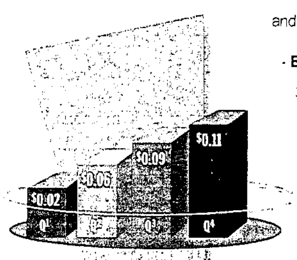
Our world-renowned Wireless Institute of LCC (WI-LCC) was relaunched this year and opened to the public. The WI-LCC now offers over 90 courses which are taught in our headquarters in McLean Virginia, in our EMEA Headquarters in London, England and via the World Wide Web.



2000 REVENUE PER EMPLOYEE
(in thousands)

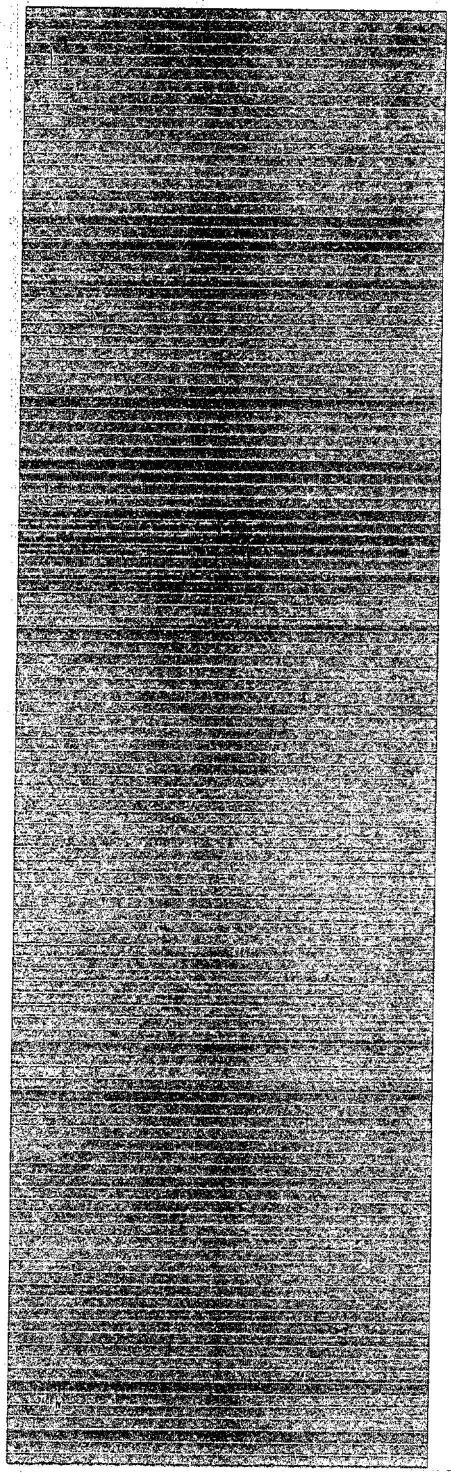
Our year would not have been such a success without new business. Although awarded in 1999, this year, XM Satellite represented approximately 40% of our revenues and affords us the honor of claiming the industry's largest turnkey project of its kind. Other noteworthy clients and projects include:

- **UbiquiTel,** a Sprint affiliate for which we provided design and deployment services to support their 7-market rollout,
- **Vodafone's Click GSM,** for whom we provided all of their deployment services in support of their nationwide Egyptian GSM buildout,
- **Sprint PCS,** a long time U.S. client who continues to rely on LCC for design and optimization support for their PCS and fixed wireless networks,
- **Telfort,** a GSM carrier in the Netherlands for whom we are providing design services for their 2G and 2.5G networks,
- **BT Cellnet,** who we are supporting as they begin their transition from a GSM network to a 3G network,
- **Nucentrix,** a fixed wireless operator in the U.S., for which we provided support for their FCC licensing activity along with technology assessment and deployment activities, and
- **Hutchison3G,** a winner of one of the UK's 3G licenses, for whom we are providing consulting and design support to enable the buildout of their next generation network.



2000 FULLY DILUTED EARNINGS PER SHARE
(excludes gain from tower sale)

As we look to what 2001 will hold for LCC, we see tremendous growth opportunities. There continues to be an enormous amount of emphasis by wireless operators around the world on second generation networks. 2.5 and 3G builds and transition projects will drive our growth in Asia and Europe, and fixed



wireless, although temporarily stalled due to tight financial markets, will eventually require an immense amount of support in the United States and elsewhere.

LCC has never been in better operational and financial shape. We are a strong and focused company with a team incented to achieve record results. Our balance sheet is strong and we have a large and mainly blue chip customer base. We have all of the necessary components to continue 2000's trend of improving shareholder value.

We received a remarkable amount of positive feedback, request for and even several awards for last year's Annual Report—Generations. As a result, our 2000 Annual Report is again a non-traditional approach to the typical shareholder communication. Generations II is an evolution of last year's piece where we looked at the different generations of mobile wireless. This year we look at the wireless industry from more of an application based viewpoint, specifically focusing on mobile wireless, fixed wireless, satellite, the core network and issues surrounding the convergence of these areas.

The objective of Generations II is to once again provide an educational and informational look at the wireless industry from primarily a technical perspective. The breadth and depth of LCC's technical knowledge will become apparent as one reviews the contents of Generations II. In addition, we have provided profiles of LCC employees and projects that best represent LCC's diverse capabilities.

As a services company, our employees and their knowledge and experience are our most important and valued assets. This 2000 annual report is a representative sample of LCC's vast knowledge and talent. I hope you find Generations II informative and useful; but most importantly, I hope it gives you insight into the challenges facing the wireless community, as well as a better understanding of how this great industry of ours will progress and grow over time.

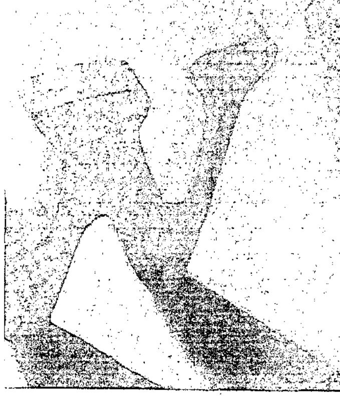
Sincerely,

C. Thomas Faulders III

The wireless industry has once again entered into a new growth stage – the data age. Wireless data is driving service providers to leap frog to systems that will support high-speed data services as well as bring voice quality in synch with landline standards. Today's wireless communications industry combines the two fastest growing sectors – the Internet and wireless voice.

This new combined entity will be the fastest growing industry segment in the world. How will carriers prepare for wireless data services? How will the conversion from circuit switched to packed switched networks really work? When and where will these new technologies be deployed first? Generations II will begin to answer these questions, plus explain how this new wave of enhanced telecommunications services will take wireless to places some never imagined.

GENERATIONS II



The latest version of our Generations report will look at the wireless industry from more of an application based viewpoint versus the technology track discussed in Generations (LCC's 1999 Annual Report). As the era of convergence becomes more and more of a reality, it is important to understand the issues and challenges associated with migrating to a universal standard which will bring together mobile, fixed wireless and satellite applications under one global standard. No longer will networks be designed and optimized using traditional RF methodologies. Gone are the days when it was fairly simple to predict wireless network performance. 3G network performance prediction requires complex analysis of various parameters. The diversity and unique nature of data services and features will place demands on the network not yet experienced in modern wireless telephony.

LCC is leading

the charge in helping wireless operators...

around the world tackle the issues facing them as they migrate their networks to incorporate the most sophisticated features and functionality. Exemplified by the employee and project profiles throughout Generations II, our teams of professionals are using innovative techniques to model the impact of a range of data services on networks. They are designing and deploying technologies not yet in use by the public and are participating in field trials of new technologies that will change the way people work and communicate forever.

Our report represents the diverse talent and knowledge that makes up LCC. We hope you find Generations II informative and useful, but most importantly, we hope it gives you insight into the challenges facing the wireless community, as well as a better understanding of how this great industry of ours will progress and grow over time.

At LCC,

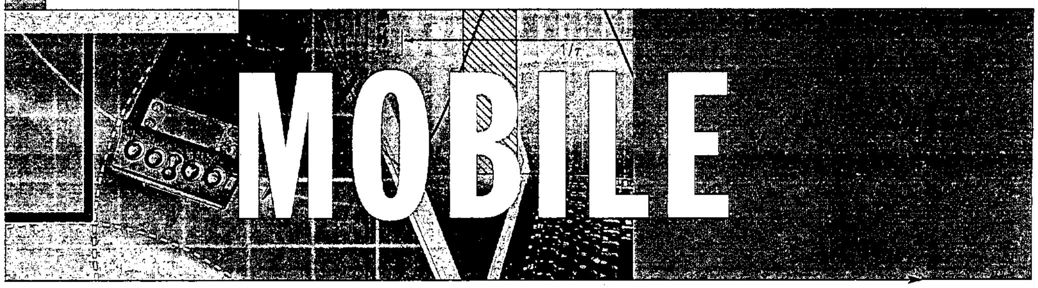
our mission is "to be the leading global telecommunications partner by creating and implementing end-to-end solutions. We achieve this through our most valuable asset, outstanding people, who leverage technology, innovation and energy to achieve breakthrough results for our clients".

Since 1983, LCC has led the way in helping wireless operators around the world tackle the issues they face in developing networks to incorporate the latest, most sophisticated features and functionality. Our ability to be vendor, technology, application and spectrum independent enables any wireless participant to benefit from our impartial and complete end-to-end services. With over 50 nationalities represented in our ranks, our employee base is as diverse as our clients. Operators, infrastructure vendors and tower companies on every continent benefit from LCC's services.

Today, LCC continues to lead the way in creating a world where the most sophisticated technologies are being integrated into wireless systems thereby creating new and breakthough services. Through the use of innovative techniques, LCC's professionals are now able to model the impact of a range of data services on networks. As a result of these initiatives, we are helping to create a world where marginal voice quality and Internet access via a tethered PC are things of the past. We are enabling increased data rates and better and more sophisticated applications to support the world's "on the go" mentality. We are creating the networks on which subscribers will use a single wireless device that will host voice and data services of all types. We are designing and deploying technologies not yet in use by the public and are participating in field trials of new technologies that will change the way people work and communicate forever.

Generations II is an example of the diversity, incredible knowledge set and vast experience that exists within the halls of LCC. We hope you enjoy our report and encourage you to contact us for more information about how the next generation of wireless impacts you.

Recently, there has been a proliferation of wireless data devices and some limited Internet services for mobile communications.



Although the general expectations of the public are not quite met due to several factors impeding on the projected take-off rate of mobile data services, the wireless industry is pushing hard to deliver what 2.5G and 3G technologies have promised.

WIRELESS DATA ACCESS SPEED can generally be classified into two categories based on wireline terminology: These are narrowband access (less than 64 kbps) and broadband access (greater than 64 kbps). Most of the offered mobile data services today fall under the narrowband category. Simple data push, 2-way SMS and limited Internet access are supported in various parts of the world at narrowband speeds. For example, in Europe and other parts of the world, narrowband data access is supported at 9.6 kbps using GSM circuit switched networks, while in North America, CDMA (IS-95) supports circuit switched services at 14.4 kbps. In addition to CDMA data access, there is a network overlay of Cellular Digital Packet Data (CDPD), a packet-switched service at maximum speeds of 19.2 kbps on both CDMA and TDMA networks in the US. In Japan, on the other hand, data services offered on NTT DoCoMo's i-mode network operate at 9.6 kbps.

In the United States and elsewhere, there are other dedicated mobile data networks already serving a niche segment of the wireless market. Advanced Radio Data Information and Service (ARDIS) offered by Motient Inc. provides 2-way low rate data messaging with low subscription rates. BellSouth Mobile Data flagship, called RAM, also supports two-way messaging now used by AOL as an interactive messaging service. There are also paging networks such as Skytel with two-way messaging capabilities. Another interesting independent wireless network that provides efficient access to the Internet is Metricom's Ricochet network. Metricom's Micro Cellular Data Network (MCDN) supports users at 28.8 kbps with a 2.5G type upgrade option that allows access speeds of 128.8 kbps.

Except for Metricom's 128 kbs MCDN system whose coverage is currently limited to 12 cities in the US, all the existing wireless mobile data technologies classified under 2G support data services at narrowband speeds. The deployment of 2.5G technologies such as GPRS and cdma2000 phase 1 (also known as 1x Radio Transmission Technology or 1xRTT) are necessary interim technologies that will reach and exceed the 64 kbps narrowband speed ceiling. These technologies are currently being deployed in Europe, Asia and North America to support increased demand for medium speed mobile data services. However, 3G networks will be the ultimate platforms for supporting broadband speeds (greater than 64 kbps) required to enable true multimedia communication and will spur the development of Internet, mobile e-commerce (m-commerce) and location-based services. The questions in the minds of the expectant subscribers remains simply, "when will these 3G services be available, at what speeds (or quality) and how much will they cost?" As wireless mobile operators continue to consider these questions as part of their criteria for planning and deploying these imminent 3G networks and services, the infrastructure vendors as well as the handset suppliers are working hard to deliver 2.5G technologies across all 2G wireless mobile platforms.

3G TECHNOLOGY DEVELOPMENT

With the final harmonization of the various 3G standards, and the ensuing approval of the 3G family of standards (Figure1.1), contract announcements for 3G network roll-out by various operators has increased in the last few months. The most adopted standards for 3G among those approved by the ITU were W-CDMA (UMTS) and cdma2000, both of which have been planned for deployment by several operators. Refinements to W-CDMA and cdma2000 standards have been, and continue to be made, by the 3GPP and 3GPP2 standards bodies set up to promote the two versions of CDMA for 3G (refer to Figure 1.1), respectively. Since then, infrastructure vendors have continued to provide trials and showcase their 3G system portfolio and capabilities to various operators that have secured 3G licenses as well as those with the potential for one.

3G wireless networks have been envisioned to become platforms that will enable the following forms of communications:

- People to people (both real-time and non-real time communications)
- People to devices (includes access to the Internet, Intranets, etc.)
- Device to device (home and office appliances, vending machines, transportation systems, etc.)

THE FIRST TWO CATEGORIES INVOLVE 3G NETWORKS WITH ENHANCED USER TERMINAL CAPABILITIES that will enable location-based, m-commerce and true multi-media services. The third category involves the use of ad-hoc networks such as Bluetooth. The Bluetooth concept will enable the widespread use of 3G applications and permit peer-to-peer communication between devices in a locale with the capability for autonomous network configuration. Perhaps the most appropriate description of a mobile ad-hoc network is a network formed without any central administration consisting of mobile nodes that use a wireless interface to send and receive packet data. The nodes in such a network configuration can serve as both routers and hosts, and therefore forward packets on behalf of other nodes as well as run user applications. Bluetooth devices are expected to debut shortly after 2.5G and operate in the 2.4 GHz ISM band. This unlicensed band operation option is intended to enable cheaper Bluetooth devices and have a global appeal since the 2.4 GHz band is globally a free unlicensed resource. There are other ad-hoc networks such as the 802.11 LAN and HyperLAN, both of which fall under the realm of fixed broadband wireless access.

1.0. ISM: industrial scientific & medical

cdma2000 (1xRTT)

1xRTT is the first phase of the cdma2000 (3G) specifications. It is the growth path for ANSI-95 (CDMA) systems but commonly addressed as a 2.5G wireless technology. It allows packet switched data and is fully compatible with IS-95 A/B terminals. Compared to ANSI-95 CDMA (2G), 1xRTT provides a significant increase in voice capacity due to a continuous coherent reverse link pilot combined with fast reverse and forward power control. Separate data supplemental channels are engaged to support higher data rates up to 144 kbps in the first phase and subsequently, 307.2 kbps.

1xRTT allows higher data rates through several mechanisms. While GPRS technology aggregates time slots and uses various error protection schemes to crank up data rates over a single GSM carrier, 1xRTT aggregates multiple Walsh (channel separation) codes where up to one fundamental channel and two supplemental channels can be aggregated. Another mechanism for achieving higher data rates is through the use of different spreading factors. The lower the spreading factor, the lower the processing gain, and hence the lower the coverage radius. However, lower spreading factors can be assigned to many users to provide access to a greater number of subscribers, albeit at a reduced throughput. Clearly, a trade-off between capacity, coverage and throughput is used to achieve the operators target objectives.

THEORETICALLY, 1xRTT WILL ALLOW DATA RATES BETWEEN 9.6 AND 307.2 kbps.

However, the initial implementation of 1xRTT will limit data rates to a maximum of 153.6 kbps. Just as in GPRS, higher data rates will have lower coverage radii due to lower processing gain as well as higher Eb/No requirements. Hence, implementing a system that provides continuous 153.6 kbps coverage will require a high cell density.

1xEV-DO

1xEV-DO (1x Evolution, Data Only) is a technology originally proposed by Qualcomm but currently undergoing standardization by the TIA (Telecommunications Industry Association). It is an extension of the ANSI-95 CDMA technology that is meant for data users only, employing a channel bandwidth of 1.25 MHz. The channel is optimized for packet data. The peak data rates per user are 2.4 Mbps in the forward (BTS to MS) link, and 307 kbps in the reverse link. In a typical implementation, a 1.25 MHz bandwidth is cleared for 1xEV-DO, while separate antennas are used to direct the packet data traffic via access points. 1xEV-DO may be deployed together with 1xRTT on separate channels in areas with increased voice and high-end user data traffic demand.

GPRS Networks

General Packet Radio Service (GPRS) is a technology that is an add-on to GSM to provide packet switched data services as well as higher data rates than GSM can offer. GPRS offers higher data rates by using multiple time slots and various error protection schemes. GPRS theoretically allows aggregation of up to eight time slots for a single user. The varying degree of error protection, known as Code Sets (CS-1 through CS-4), allow higher data rates by allowing more user data bits (by using a smaller number of error protection bits).

In reality, aggregation of eight time slots would require multiple receivers. A maximum of four time slots can be aggregated with current receivers, virtually halving the maximum data rate that can be achieved by GPRS. Multiple receivers will not only increase subscriber element cost, it will also reduce battery life. At present, only code sets 1 and 2 are available from manufacturers. Implementing higher code sets, 3 and 4, when available, will provide higher data rates in limited areas. If the data rates associated with higher code sets are to be made available everywhere, operators face implementing a higher density of sites. Because most GPRS operators will face implementation of UMTS, it may make better financial sense to deploy UMTS to achieve higher data rates and more capacity (through better spectrum efficiency) than to increase site density in order to provide higher GPRS data rates.

The timing of availability of the service in Europe is going to be dictated mostly by the availability of GPRS handsets. Initial handsets will not have the capability to combine more than two time slots, and hence the data rates will be limited. With code set 2, assuming up to four time slots can be combined by the end of the year, peak data rates of 53.6 kbps will be possible. The observed data rates in GPRS networks that are up and running are in the 20 to 30 kbps range.

A Global 3G CDMA Model

A 3G operator may select one of the several listed access methods together with one or more core network options to implement a 3G network.

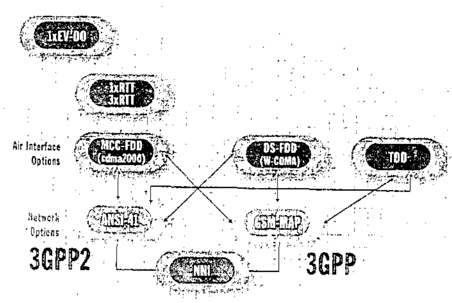


Figure 1.1

3GPP (2) = 3rd Generation Partnership Project
DS = Direct Spread
FDD = Frequency Division Duplex
MC = Multi-Carrier
NNI = Network-to-Network Interface
TDD = Time Division Duplex

Future Generation Mobile Wireless Networks (4G and Beyond)

4G may encompass high frequency links to fixed and ad-hoc networks, multiple interfaces and virtual reality. Some major network features that will emerge in 3G phase 2 (a.k.a consolidation phase) but get carried over to 4G include an all IP network, possibly utilizing IPv6 supporting all the necessary QoS requirements for real time data exchange and voice.

4G promises to integrate different modes of wireless communications, starting from indoor networks such as wireless LANs and Bluetooth, to cellular networks, as well as radio and TV broadcasting, to satellite communications. With 4G, some sort of seamless merger between multiple standards will be required, so that users of mobile devices can roam freely from one standard to another. From the service perspective, 4G may mean that the computer world, the telecommunications world, and the audio and video world will merge/converge and a single network management function will be used to enable resource allocation based on demand and the specific user location.

NETWORK DESIGN AND DEPLOYMENT CHALLENGES

The advent of third-generation mobile wireless networks will bring about significantly different traffic from second-generation networks. The emphasis in the design of second-generation networks was on voice traffic, with limited data traffic. As such, second-generation networks were inherently circuit-switched networks. To efficiently accommodate the increase in data traffic in 3G systems, as well as provide spectrally efficient data transport, packet-switching techniques were introduced into the wireless network backbone. In circuit-switching, a channel is engaged for the exclusive use of a call, for the duration of the call. Using a voice call as an example, since a typical call uses a channel approximately fifty percent of the time, the remaining capacity of that channel is wasted. In packet-switching, however, a channel may be shared among several users. Even though several users may be "connected," they may not have any data to send at any given moment; thus, packet-switching takes advantage of statistical multiplexing to share channels among several users.

Site and traffic distribution affect system capacity. Discontinuity (burstiness) of packet data traffic creates dynamic loading on the network radio interface. Delay requirements for different data services, including Automatic Repeat reQuest (ARQ) schemes, as well as the strict delay conditions of real-time services, become difficult to provision for in a mixed traffic environment.

Currently, wireless network operators are faced with several options for evolving their 2G networks to support advanced data services over packet based core networks. The various network upgrade options are highlighted in the pullout section of Generations II. Both technical and cost considerations influence the adoption of any migration path to 3G.

Current mobile networks were designed for voice and narrowband data traffic. The emerging 3G networks will be designed with wideband capabilities, allowing significantly higher data rates for mobile multimedia and Internet-based services of the future. The effects of the introduction of packet-switched services as well as higher data rates will pose significant challenges to the design of the R.F. and backbone networks.

DESIGNING 3G NETWORKS

will introduce another dimension of complexity relative to the design of 2G networks. Starting from the initial stages, such as accurately estimating cell counts for business planning purposes, performing the actual design and then optimization, require specialized knowledge and know-how. Link budgets, crucial tools for accurate site counts, are simple spreadsheets for 2G systems, but complex programs for 3G. Dealing with multiple mixes of packet and circuit-switched traffic, all with varying QoS requirements, adds another dimension of complexity, as does managing the complex inter-relationship between capacity and coverage for multiple service types for CDMA networks.

3G MARKET STATUS

As contract announcements for 3G system deployments in Europe and Asia have been announced, there has been a cooresponding tremendous increase in the development of plans to deploy 2.5G networks that will bridge 2G to 3G.

Network Roll-out Plans

TDMA operators in the Americas are increasingly signing on to the GSM/GPRS network evolution path, with announcements that they will roll out GSM/GPRS services in tandem with their existing IS-136 networks. Drivers for such developments include the need for competitive network differentiation, increased efficiency of GSM voice over TDMA, and ability of operators to have a global roaming footprint. However, operators that don't have enough spectrum bandwidth to take a new path (via GSM/GPRS) to 3G may still continue to provide data overlays using CDPD technology. A migration option for such operators will be to either deploy EDGE technology when it is ready or 1xRTT.

There are also deployment strategies that some of the major global operators have opted for, which target a specific market segment. A well-established European operator that has wireless presence in major European and Latin American markets has indicated that the 3G networks planned for Italy and Germany will initially target small and mid-sized corporate (business) customers. Whether the business case for such niche customers is achievable or not, it clearly points to the fact that the impact of WAP enabled devices that support corporate applications will play a major role in the 3G wireless market.

Network Infrastructure and Terminals

It has been estimated that about 25 to 30 wireless networks based on 3G will be globally deployed by year-end 2002. Although there are about seven wireless infrastructure vendors, 75% of the 3G contracts that have been announced so far are related to only half of these vendors. Clearly timing in infrastructure delivery will be the most critical factor to the widespread availability of 3G services.

Analysts are increasingly attributing mobile Internet growth to features on handsets rather than the specific services available from each operator. In particular, data gathered after the successful deployment of i-mode services in Japan has indicated that handset selection is one of the most important drivers of wireless data subscriber growth *[3G Mobile]*. It is anticipated that in most GSM markets, the tri-mode handset that will have the greatest penetration would be the GSM/GPRS/WCDMA, leaving the EDGE option with a potential for lower penetration.

Bottom line, the likely dual or tri-mode handsets will incorporate interim (2.5G) technologies that are able to gain wide acceptance, and for which the services supported remain appealing to subscribers.

PROJECT PROFILE: WIRELESS COMMUNICATIONS SERVICES (WCS)

AS DESCRIBED BY RAYMOND LI | PRINCIPAL ENGINEER

Wireless Communication Services is a provider of mobile wireless services in Thailand. Using the GSM 1800 and 2.5G technology, WCS implemented a 2500 base station network and one of the first GPRS networks in Asia.

PROJECT STATUS UPON ENGAGEMENT:

LCC's timing for this project turned out to be impeccable because WCS had received 6 vendor proposals a week prior to our arrival and had just started its vendor evaluation and selection process. Our initial role was to simply assist in the vendor evaluation process; however, I knew we could better serve our client by recommending a more comprehensive approach to this project.

THE LCC SOLUTION:

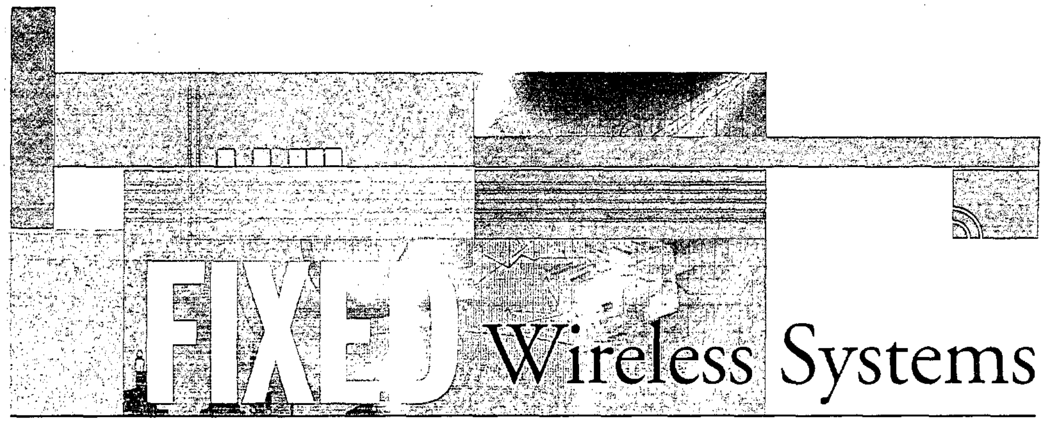
Seizing the opportunity to demonstrate LCC's capability of offering a comprehensive network solution, the LCC team voluntarily took up the lead roles in evaluating both RF and Fixed Network design aspects of all vendor proposals. As part of the Fixed Network evaluation process, we initiated and issued an RFQ Transmission Addendum, and later took up the sole responsibility in evaluating all vendors' transmission network proposals.

As a result of our early work on the vendor evaluation project, the LCC team was appointed to the prime RF and Fixed Network positions for the production of Detailed System Design (DSD) documents with 2 Vendors for their detailed network design, implementation schedules, roll-out processes, practices and standards. Realizing our value, WCS decided to use the LCC team to lead the roll-out of about 2500 base stations and nation-wide GSM and GPRS fixed network implemented throughout Thailand. The LCC RF team was also assigned the prime technical role to set up uniform standards for the system's frequency planning, and the lead role in the selection of the hardware equipment to be used for drive testing and in-building measurements.

Recently, LCC's role was expanded to complement our current engineering work to include Quality of Service measurement and analysis of their GSM network.

BENEFITS CLIENT RECEIVED AS A RESULT OF LCC'S SERVICES:

As a result of LCC's knowledge of the vendor selection process and our extensive background in GSM/GPRS 1800 network design and implementation, WCS has maximized its investment in its system. By setting up uniform technical standards for network implementation, WCS's network performance is assured to be the most efficient and offer highest quality services among all existing cellular networks in Thailand. And, by carefully managing the system's infrastructure vendor and implementation strategy, we have ensured that WCS's strategic goals have been leveraged and that all technical and financial goals and objectives have either been met or exceeded.



FIXED Wireless Systems

In the developed countries around the world, most households are linked via a copper line into the public switched telephone network (PSTN).

2.0. *PSTN: public switched telephone network*

This copper connection, commonly referred to as the "local loop",

forms a physical connection between the household and the nearest PSTN Central Office (CO) or distribution point. A household with wired connection to the PSTN can telephone anyone else in the world, so long as the other person is also connected to the PSTN.

The problem is that more than half the world's population has never made a telephone call and does not have access to a PSTN. The costs associated with implementing the local loop from the nearest PSTN CO or distribution point can be prohibitive for much of the world economies.

This fact provided the impetus for the initial growth of Fixed Wireless Access (FWA) systems. *Initial system costs for wireless access network* construction are dominated by investment in acquiring and constructing *the network distribution points, related hardware and software, and the* trunking network required to backhaul the traffic to the nearest CO or switching center. *Once the nodes are in place, connections to the PSTN* can be made from surrounding points via wireless access without *having to physically lay down a network.*

Public safety and government policy may have been early drivers for early FWA systems, but today there are other factors driving its development – namely, competition and convergence.

The introduction of competition, through the privatization of national telephone monopolies took place in the 1990s. New entrants in the market often saw wireless as a means to quickly and cost effectively offer a competitive, reliable and integrated alternative to wireline services (collectively twisted-pair, coaxial cable and fiber). To provide a wired local loop access, it is necessary to provide a "local loop" from a central distribution point to each house. This requires digging up roads, laying cable and repairing the road; a costly endeavor in any metropolitan area.

To provide FWA, a provider must set up transceivers. Service can be offered to any customer within the coverage area of the transceiver. The main costs of a FWA network are the cost of installing a transmitter, the number of subscribers covered by the transmitter, and the cost of the subscriber unit. Key variables in the business case of a FWA system are:

- The number of subscribers or households in the coverage area
- The cost of the subscriber units
- The cost of the transmitter equipment.

Convergence is a term that has been used frequently when speaking about the confluence of services being offered by broadcasters, telecommunication companies and Internet companies. Already we are seeing broadcasters offering broadband multimedia content to home computers. Telecommunication companies have added broadband data services to their portfolios, cable companies are offering Internet access via their existing plant, and ISPs are offering voice, video and other multimedia services online.

Convergence has also driven the need for broadband networks in order to handle the higher data rates needed for multimedia services. Many new entrants in the broadband market have chosen a mixture of FWA and wired networks to offer service.

But whether an operator chooses to deploy a narrowband system for voice and low speed data, or he chooses a broadband wireless system for multimedia services, his technology choices will be governed by two basic principles: rapid deployment and minimal costs. In many cases, these two factors are best met with a Fixed Wireless System deployment.

Narrowband vs Broadband

The traditional definition of narrowband in North America is based on the BellCore T-carrier hierarchy. The operational range of narrowband is up to 1.54 Mbps (T1), with 64 kbps (DS0) as the common base unit for communications. In the rest of the world, the upper limit is 2 Mbps (E1).

In general, broadband and narrowband networks have converged, to the extent that current broadband networks offer data rates that traverse both narrowband and broadband. Clearly, this feature allows equipment vendors to cater for a wider market. The networks are therefore designed to dynamically support requested data rates and hence offer what is now called Bandwidth-on-Demand. As such, the rest of this presentation will discuss general broadband networks.

Defining Broadband

One of the latest trends in enhancing communication systems involves the use of broadband technology. The term "broadband" refers to telecommunication that provides multiple channels of data over a single communications medium.

Broadband technology allows for high-speed convergence of voice, video and data under a single transmission medium. It is a service requiring transmission channels capable of supporting rates greater than 1.5 Mbps. The high data rates impose larger bandwidth requirements and push the carrier frequencies higher in the spectrum. The effective increase in bandwidth can be used to:

- Deliver Internet content faster
- Deliver compelling next generation content such as streaming video, electronic magazines and 3D product visualizations
- Deliver video and data together
- Deliver better video and graphics

2.0. Mbps: megabits per second

As a greater number of people access the Internet, they continue to want more information at faster speeds. As a result, access providers need wider bandwidth to support basic demands and multimedia services involving two-way data, voice and video. While no single option appears to be the best fit for everyone's access need, the various wireless and non-wireless broadband high-speed data transmission technologies include:

- LMDS (*Local Multipoint Distribution Service*)
- MMDS (Multipoint Multichannel Distribution Service)
- DSL (Digital Subscriber Line)
- Cable Modems
- Optical Fiber
- Satellite

Why Do We Need Broadband?

The high-speed transmission of data, voice and video is transforming the way we live and work. While the *1200 bits per second (bps)* speed of 1980s modems was fine for text-based networks, the current standards of v.90 modems (about 45Kbps) or even ISDN (64Kbps or 128Kbps) is proving to be the major limiting factor of what can be done with the Internet. Broadband technologies provide access to the Internet significantly faster than traditional narrowband modems. Coupled with "always on" access, broadband will provide consumers with a range of enhanced services. Figure 2.2 identifies various applications that can be transmitted via broadband technology, along with time estimates for each application at various transmission speeds.

Analysts predict that broadband technologies will produce applications that will change the way consumers communicate, educate, shop and entertain. Broadband access technology allows the delivery of an entirely new breed of media services and communication applications, which include:

- High Speed Internet Access
- Videoconferencing
- Corporate Intranets and Extranets
- Telemedicine
- File Transfer
- Telecommuting
- Interactive Distance Learning
- Home Shopping and Banking

Broadband Spectrum Allocation

Most of licensed and unlicensed broadband spectrum are summarized in Figure 2.1.

BAND	FREQUENCY	BANDWIDTH
ISM	915 MHz	26 MHz
WCS	2.3 GHz	30 MHz
ISM	2.4 GHz	83 MHz spread spectrum
MMDS	2.1 and 2.5 to 2.7 GHz	186 MHz in 6 MHz channels
FWA	3.5 GHz	Available outside of US (50 MHz proposed by FCC)
GWCS	4.9 GHz	25 to 50 MHz proposed by FCC
U-NII	5.2 to 5.8 GHz	300 MHz total (200 MHz for outdoor use)
DEMS	24 GHz	400 MHz
LMDS	28 to 31 GHz	1.3 MHz
MMW	10.5 to 42 GHz	Various bands worldwide

Figure 2.1

ISM–Industrial, Scientific, and Medical
MMDS–Multichannel Multipoint Distribution Service
GWCS–General Wireless Communications Service
U-NII–Unlicensed-National Information Infrastructure
MMW–Millimeter Wave
WCS–Wireless Communicaitons Service
FWA–Fixed Wireless Access
DEMS–Digital Electronic Messaging Service
LMDS–Local Multipoint Distribution Service

Until the FCC opened up the U-NII frequency band, in 1997, the available unlicensed spectrum was frequency allocated for the ISM band, which was opened in 1989. FCC surmised that companies have to coordinate how they use the frequency. So, while the spectrum is unlicensed, it is closely regulated by the FCC under Part 15 of the Rules with an extensive list of requirements.

Frequencies available outside the US for broadband fixed wireless access are 3.5, 10.5 and 26 GHz.

SAMPLE MULTIMEDIA FILE SIZES

Application	Information Content	Transmission Speed		
		28.8 kbps	384 kbps	1.5 Mbps
Facsimile Page	250 Kilobit	8.7 sec	0.65 sec	0.2 sec
Digitized Photo	1 Megabit	34 sec	2.6 sec	0.7 sec
X-Ray	12 Megabits	7 min	31.3 sec	8.0 sec
Encyclopedia	280 Megabits	2.7 hrs	12 min	3.1 min

Figure 2.2

Broadband Technologies

There is typically no simple answer when choosing an access technology and each solution has its trade-offs. Choosing such a technology for an MMDS broadband solution is no exception. In the MMDS frequency band, there are several RF anomalies in a non-line-of-sight (non-LOS) environment such as fading, multipath and delay-spread that must be overcome in order to successfully market broadband wireless access systems to the general public in an economical manner.

With the market in its infancy and hardware vendors continuing to jockey for position, there are currently several technologies being touted as the best solution. At this time, there is no one accepted access technology or modulation standard. However, after the past few years of developers brainstorming in their labs, vendors and operators deploying and testing trial systems and operators now launching commercial networks, a few access technologies and modulation schemes are beginning to rise to the top. This being said, these first generation systems are being deployed with the realization that they do not provide the non-LOS service required to reach many potential customers. Second generation technologies are being discussed, designed and tested, and standards bodies are being formed in order to solve this non-LOS issue and the RF anomalies it presents.

Distribution of Global Incremental BWA Equipment Sales by Region

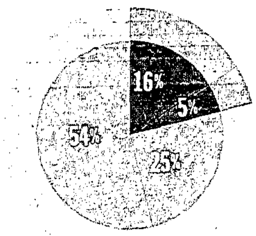


Figure 2.3

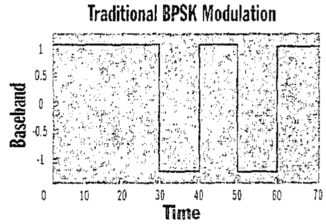
Vendors are in various stages of design, development, testing and/or production of their equipment. The two major duplexing technologies being developed are time division duplex (TDD) and frequency division duplex (FDD). Below is a brief discussion on each of the main duplexing technologies being used followed by the modulation or enabling schemes being considered and/or deployed to maximize spectral efficiency and minimize the effects of RF anomalies in a non-LOS environment.

TDD - Time Division Duplexing is a technique of providing two-way or duplex communications where the downstream and upstream paths share the same frequency at different times.

FDD - Frequency Division Duplexing is a technique of providing two-way or duplex communications using frequency pairs where one frequency is allocated to the upstream path while another frequency is allocated to the downstream path.

Below, in order of complexity, are various modulation schemes either currently used in BWA systems today or planned for deployment in systems of the future. Along with this complexity comes the benefit of increased data rate performance and/or improved non-LOS operation.

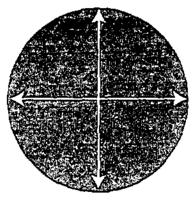
Traditional BPSK Modulation



BPSK - Binary Phase-Shift Keying

In BPSK modulation, the carrier can shift between two possible states or phases separated by 180 degrees and with constant amplitude. In digital form, these modulation states are either a "1" or "0". In this scheme, the rate of change of the phase is the same as the rate of change of the digital bits (or bit rate). Only one bit is transmitted per cycle (called symbol).

2.0. BWA: broadband wireless access



4 QPSK

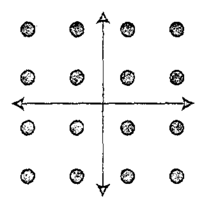
QPSK - Quadrature Phase-Shift Keying

QPSK modulation provides a constant amplitude carrier shifting between four possible phase states (also called symbols) separated by 90°: 0°, 90°, 180°, 270°. In QPSK modulation, two successive bits are paired to form a symbol. The rate of change of the phase states (or symbol rate) is half of the bit rate (two bits per symbol). Theoretically, twice the information can be transmitted in a given bandwidth compared to BPSK.

QAM - Quadrature Amplitude Modulation

In QAM schemes, the carrier amplitude varies in addition to the phase. QAM modulation schemes exist for 4, 16, 64 and 256 phase states or symbols. In 16-QAM, there are 4 levels of phase and 4 amplitude levels resulting in 16 phase states in the *I/Q plane*. Each symbol represents four bits, two for amplitude and two for phase. Thus, the symbol rate is one fourth of the bit rate.

Extrapolating this thinking to higher order QAM schemes, 64-QAM consists of 64 phase states, each symbol represents 6 bits, the symbol rate is one sixth of the bit rate, etc. Symbol rates above 64 are not currently deployed because of increased complexity and susceptibility to noise due to the closeness of the phase states. The higher the QAM density, the higher the signal-to-noise ratio required. As coding schemes improve and processing speeds increase, higher order QAM schemes will become viable.



16-QAM

OFDM – Orthogonal Frequency Division Multiplexing

In OFDM, multiple narrowband independent or uncorrelated carriers (or tones) are used to divide the data into bursts throughout the designated wideband spectrum. Each data burst is comprised of a series of initial known data bits followed by the data symbols. The initial data bits are used as a buffer to absorb any multipath signals from the previous data burst. The duration of the initial data bit stream should be greater than the delay spread of the multipath signals expected in the environment. Each of these subcarriers is modulated using a modulation scheme such as BPSK, QPSK or 64-QAM. Higher order modulation schemes allow higher data throughput.

There are several OFDM variants being developed by vendors. Cisco uses VOFDM, or Vectored OFDM, which adds hub and CPE spatial diversity to OFDM, thus improving the system tolerance to noise, interference and multipath. Other vendors are proposing a TDD system using OFDM.

Adaptive Modulation

Adaptive modulation is a technique where, through feedback, the equipment will automatically and dynamically select an optimal scheme from some or all of the above modulation schemes. This modulation selection will be based on near real time RF channel and data rate demands. By dynamically optimizing the upstream and downstream channels to varying conditions, higher quality-of-service and bit rates can be achieved. From initial evaluation, it appears that this technique of adaptive modulation has great promise and is currently being developed and tested by several vendors in anticipation of incorporating this technique into next generation BWA systems.

Other Technology Improvements

The need for better system performance will always exist. Customers are constantly demanding higher data rates, improved coverage and cheaper service. With higher data rates, new services like voice over IP, video on demand, virtual private networks, etc. will become the norm. Additional modulation techniques, smart antenna technology and other improvements are being developed and tested in hopes of improving BWA system performance and meeting customer demands for better performance at a reasonable cost.

Design

In a broadband fixed wireless design, contiguous network coverage is not necessarily a requirement. Coverage areas are defined around known customer locations – in contrast with mobile wireless designs where there is an element of uncertainty surrounding subscriber locations. Thus the broadband fixed wireless design strategy is simple – provide coverage only to those potential customers that fit the business plan.

RF planning is one piece of the design puzzle that must be addressed. Various design issues are faced for any selected frequency band – whether it is line-of-sight for millimeter wave frequencies, or stringent power restrictions for unlicensed frequencies. Proper RF planning also requires an understanding of equipment capabilities and limitations. Hub sites must be selected for optimal coverage to customer locations, and frequencies must be efficiently assigned (and reused) to effectively carry customer traffic while causing minimal intra- and inter-system interference. The tools required for effective RF planning include a design software package (which may utilize accurate terrain, morphology, demographics and building databases), interference measurement equipment and field survey equipment. A well-trained engineering staff with design experience is critical because a network must be well designed before it is deployed.

Network planning is another key piece of the design puzzle. With little or no operational data to work with, a network must be dimensioned to accommodate an expected traffic load. Network expansion must be considered ahead of time during network planning. Numbering and addressing schemes should be mapped out prior to provisioning the first customers. Efficient backhaul and interconnect plans must be utilized to accommodate network traffic. Network security must be addressed with the appropriate implementation of encryption and firewalls, as well as identification and authentication databases.

2.0. Morphology: land use data

Deployment

While a network that is well-designed up front will be less complicated to deploy, there are still many issues that must be dealt with during deployment. Detailed site-specific designs are required if deployment is to go as smoothly as possible, with fine-tuning kept to a minimum.

Issues regarding site readiness abound. Adequate equipment space – indoor space for equipment, as well as rooftop/tower space for antenna mounting – must be secured. Physical accessibility/security, wind/tower loading, and environmental considerations must all be taken into consideration. Adequate power sources, grounding, lightning protection and aesthetics must be provided for. A site must not only be designed to meet today's needs, but also to accommodate future growth.

Enough planning and forethought should allow installation to be completed with as few crises as possible. Experienced installers and technicians will be able to bring a site design from a blueprint into reality. Standardized quality control methods ensure trouble-free running of cable, finishing of connectors and cable ends, water- and weather-proofing, antenna alignment, physical connections and mounting integrity. Configuration and commissioning should follow a well-scripted procedure.

Post-Deployment

Network optimization involves end-to-end monitoring of system performance. RF system performance can be quantified in terms of coverage, interference and bit error rates. Network traffic should be monitored to isolate and correct problems before they become severe.

System maintenance should provide a means for immediate troubleshooting of service interruption problems. Scheduled maintenance periods should be established to accommodate less severe issues, or to perform firmware or hardware upgrades.

Network management involves many tasks. Network elements must be individually monitored and configured. On a larger scale, network performance involves examining alarms and events and being able to avert trouble spots and network outages. A help desk and trouble ticketing platform can be integrated to provide a seamless proactive/reactive mechanism that quickly isolates and resolves problems in a timely manner.

PROJECT PROFILE: NUCENTRIX BROADBAND NETWORKS

AS DESCRIBED BY SALMAN YUSUF | SENIOR PRINCIPAL ENGINEER

Nucentrix Broadband Networks, Inc. provides wireless broadband network and subscription television services using up to 196 MHz of radio spectrum in the 2.1 GHz and 2.5-2.7 GHz range, commonly referred to as Multichannel Multipoint Distribution Service (MMDS).

PROJECT STATUS UPON ENGAGEMENT:

MMDS has existed primarily as an analog, one-way, video distribution service. In September of 1998, the FCC amended its rules to allow for the use of MMDS spectrum for *fixed*, two-way digital voice, video and data communications. In March of 2000, the FCC announced an initial one-week filing window from July 3-10, in which applications could be filed for two-way licenses. Later, the filing window was moved to August 14-18.

LCC was engaged to provide all technical support associated with Nucentrix's two-way FCC filing for 70 markets (37 primary and 33 secondary markets) in Texas and the Midwest region.

THE LCC SOLUTION:

MMDS equipment vendors offer multiple options when it comes to channel bandwidth, channel throughput, data rate and output power. Each of these parameters have a direct or indirect effect on the cell radius. Our first challenge was to evaluate all these options and prepare a set of design guidelines. After studying over fifteen different design scenarios, we identified a set of parameters that helped us meet Nucentrix's design objectives.

Next, we had 30 days to design 37 markets, issue search rings, have site acquisition staff visit all 37 markets and provide 3 candidates per search ring. This process also entailed having engineers review/rank all candidates and select the best site for acquisition/leasing. We quickly assessed the workload and added to the site acquisition staff already deployed in the field. Also, we realized that if we issued search rings without pre-qualified sites and asked site acquisition staff to provide potential candidates, the process would have taken more time than what was available. Therefore, leveraging one of LCC's differentiators, we utilized the LCC network and contacted our other nationwide and regional projects to provide us with a list of friendly sites in Texas and the Midwest. We also obtained tower and building databases from Crown Castle, Pinnacle, American, SBA, Center Point and all registered sites from FCC. As a result of these efforts, we were able to filter the databases based upon our design criteria and came up with a list of preferred sites. We used these in all of our 37 markets, thus reducing site acquisition field-work by half.

The final challenge was to run an inter-system interference analysis with the incumbent operators and eliminate interference completely with the 'unfriendly' incumbents. We started the interference analysis during the first week of June. On several occasions, interference analysis had to be re-run after several markets had been completed, due to changes in the planning software. However, we were constantly reviewing our design process and refining it to ensure we were working at peak efficiency to meet the aggressive project timeline. The entire LCC team (accompanied by 22 computers working around the clock) worked 12-14 hours per day, including weekends, to ensure that Nucentrix met the FCC's filing deadline.

THE BENEFITS OF LCC'S SERVICES:

As a result of LCC's integrated design and deployment services, Nucentrix not only met the FCC's allotted deadline for all 70 markets, but also did it in record time and at significant cost savings. All told, the LCC team took what should have been a year-plus project and completed it in 135 days (i.e., 1.9 days per market).

Thanks in part to the quality work LCC completed during the licensing process, once the licenses are issued, Nucentrix will be able to deploy high-speed Internet services in record time, thus enabling them to become the leading provider of broadband services in all 70 of their markets.

'2.0. ISDN: integrated services data network

Satellite SYSTEMS

Due to their high altitude, a single communication satellites' transmission can "see" large geographical areas.

Early generations of communication satellites have essentially functioned as overhead wireless repeater stations, providing communication links between two remote sites.

More recent satellite networks are no longer passive systems; they often incorporate inter-satellite links, on board switching, data buffering and signal processing.

Satellite communication networks are characterized by:

- Wide area coverage of the Earth's surface
- Long transmission delays
  (as compared to terrestrial systems)
- Transmission costs independent of distance

Satellite Constellations

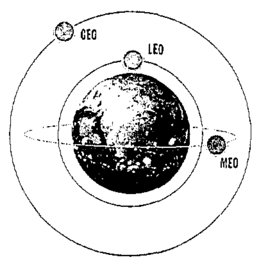


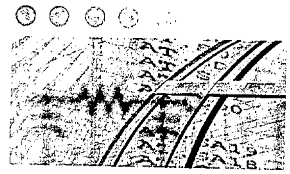
Figure 3.1

Satellite networks are often positioned at one of three standard orbits: Low Earth Orbit (LEO), Medium Earth Orbit (MEO) or Geostationary Earth Orbit (GEO). Figure 3.1 shows the various satellite constellation configurations.

Figure 3.2 demonstrates that the satellite network constellation affects the network's capabilities and design

	GEO	MEO	LEO
Altitude of Satellite	35,000 km	5,000-10,000 km	500-1,500 km
Average number of satellites needed for global coverage	3	10	20-100
User terminal power requirements	HIGH	MEDIUM	LOW
Round-trip tramission delay requirements	250 ms	16.5-33 ms	2.5-8 ms
Advantages	- covers large area of earth's surface - 15 year life span	- moderate launch costs - acceptable round-trip delays	- low launch costs - short round-trip delays - small path loss
Challenges	- large round trip delays - weak signals require expensive receiver systems	- moderate to high path loss	- 5yr life span - Van Allen radiation belt

Figure 3.2



Depending on the types of services they offer, communication satellite networks generally fall into three types of service classifications:

Fixed Satellite Service (FSS):

Services between a satellite network and one or several fixed terminal point(s) on the surface of the Earth. (Orion, GE Americom)

Mobile Satellite Service (MSS):

Services between a satellite network and one or several mobile terminal(s) on the surface of the earth. (Motient and Inmarsat)

Broadcast Satellite Service (BSS):

One directional services between a satellite network and many distributed terminals on the surface of the Earth. (XM Radio, Sirus Radio)

Figure 3.3 shows the spectrum allocations and list some systems which are either operational or planned for each of these services.

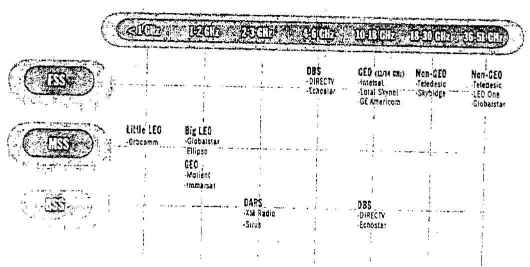


Figure 3.3

INTEGRATION INTO IMT-2000

The initial applications of satellite technology have been to serve niche markets for location services, mobile roaming, and remote telephony. While not a substitute for land-based networks, the new digital satellite systems could potentially become important complementary components of a worldwide system. Many satellite systems will offer dual handsets capable of being used either with the satellite system or with the land-based systems, whichever is more convenient or lower-priced.

With the introduction of 3G technologies, Satellite Radio Interface (SRI) proposals have been incorporated into the IMT-2000 initiative. Major SRI proposals include: Satellite Wideband CDMA and Satellite Wideband Hybrid CDMA/TDMA, both proposed by European Space Agency (ESA); ICO-RTT, a proposal based on 10 MEO satellites placed in 2 planes at 10390 km, proposed by New ICO (recently re-emerging from a Chapter 11 bankruptcy and merging with ICO-Teledesic); and Satellite CDMA, a proposal based on LEO satellites in 7 planes at 2000 km, proposed by South Korea TTA.

SRI can be attractive because it can provide certain services more naturally and perhaps more cost effective than terrestrial solutions. These services can include:

- Broadcasting and multicasting of information such as music, news, paging, and weather information.
- Localization and navigation services such as positioning systems for the fleet management, localization and recovery of stolen vehicles, traffic monitoring and traffic information distribution, radio guidance, and emergency services for search and rescue operations.
- Wide area communications such as communications for ships, airplanes, and offshore platforms.

Some of the undesirable characteristics of SRI include:

- Delay and excess attenuation due to distance between user and satellite(s).
- Shadowing and fading, particularly for low elevation angles.
- Doppler effect, due to motion between user and satellite.
- Time variance of performance, particularly coverage areas for non-geosynchronous satellite constellations

An integrated system that includes both terrestrial and satellite component could be particularly attractive, since each system could complement the shortcoming of the other system. The Technical Committee Satellite Earth stations and Systems (TC SES) of the European Telecommunications Standardization Institute (ETSI) has established a working group on the satellite component of UMTS systems known as S-UMTS working in technical specifications for various interfaces between the satellite components and the UMTS terrestrial and Core Network.

PROJECT PROFILE:
XM SATELLITE RADIO

AS DESCRIBED BY PAUL CHELSON | VICE PRESIDENT | DEPLOYMENT SERVICES

XM Satellite Radio is deploying a next-generation radio system, the first major breakthrough in this medium since FM radio. While satellite based, the satellite systems are supplemented with a 1500 site repeater network, deployed across 97 cities throughout the United States.

PROJECT STATUS UPON ENGAGEMENT:

LCC began working for XM even prior to the license award when XM was in the process of determining the best technology to choose to support its terrestrial repeater network. After all technical, business and financial considerations were weighed, XM, largely based upon LCC technical input, selected geostationary positions for their two high powered satellites. In order to supplement satellite coverage in urban areas, LCC recommended a terrestrial based repeater network.

At the project onset, LCC faced the industry's largest turn-key project of its kind – a 1500 radio broadcast repeater network to be designed, deployed and optimized in an 18 month period.

THE LCC SOLUTION:

LCC's responsibilities included all aspects of this fast paced deployment – the turn-key delivery of the repeater network, including RF design, system design, site acquisition, zoning, engineering, construction and testing.

In order to manage all aspects (cost/schedule/technical) of this project, LCC employed its turn-key management expertise, including:

- Using Systems Integration "best practices", including:
    - Minimizing interfaces and handoffs
    - Using national experts in each subject discipline required on the project
- Detailed site-by-site management and tracking, using WINDS as the data management system for all site data (as Peter Drucker is noted for saying, 'if you can't measure it, you can't manage it')
- Selecting managers that combine personnel management and technical program management – a rare combination, but the right one for a successful deployment

Establishing decentralized operations, including:

- 6 hub offices strategically located around the country
- 11 additional small city offices for managing key markets
- Building out and testing the network city –by city, but with all in parallel – the reason for the need for the decentralized operations.

BENEFITS CLIENT RECEIVED AS A RESULT OF LCC'S SERVICES:

There is a well-known project maxim that says: "fast – cheap – good – you can have any two." If any two are pushed to the extreme, then I think that this maxim does hold. Our challenge was to work with the customer to maintain a balance between cost—schedule—and technical specs, in order to get all three in the best manner possible. I believe that we successfully did this on the XM project. LCC is delivering a cost-effective system that meets the customer's timelines, and that exceeds all technical specifications for the system.

In the process of meeting all customer and project deadlines, the sheer magnitude of the XM project meant that we, as a company, have grown and refined our technical skill base and our mid-level management ranks—at its peak, the XM project team was over 300 people strong. We know how to manage large teams for successful nationwide deployments, managing all aspects of cost, schedule and technical requirements.

This is no small feat. This is an industry where massive schedule slips or cost overruns are common. For XM Satellite Radio, LCC delivered, in a complete turn-key fashion, a 1500 site deployment on schedule and on cost, meeting all performance objectives. Not many companies can say they've done this.

The Core Network

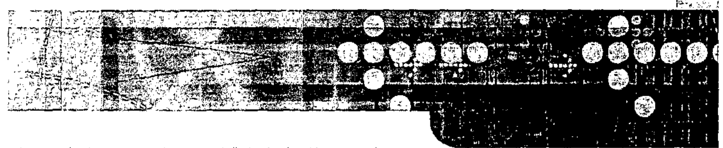
4.0. ReFLEX: paging technology developed by motorola

Mobile Wireless Voice and Data Networks

Data is a growing segment of mobile wireless traffic. There are various types of mobile wireless networks in place worldwide that handle data. One category is networks that are dedicated to providing data services. These networks fall in two sub-classes- one sub-class that uses dedicated or exclusive spectrum, and another that completely or partially uses shared spectrum such as Industrial Scientific Medical (ISM) bands. ISM bands are portions of the electromagnetic spectrum set aside for use in an unlicensed manner and have strict power emission requirements. Examples of the former are networks using Mobitex, ReFLEX, and ARDIS technologies; these networks offer data rates mostly at sub-14.4 kbps. Metricom's Ricochet service in the United States is an example of the latter; it offers data rates from 28.8 to 128 kbps. To emphasize, these are mobile wireless networks; there are several fixed wireless networks that also provide data and voice services.

Another category is networks that provide voice and data services. These networks are the current cellular networks using various technologies such as ANSI-95 (Code Division Multiple Access - CDMA), ANSI-136 (Time Division Multiple Access - TDMA), the Global System for Mobile Communications (GSM), and the Personal Handphone System (PHS). To date, several schemes have been employed to provide low bit-rate data services on these networks. One scheme is Cellular Digital Packet Data (CDPD), which offers data rates up to 19.2 kbps. The deployment of CDPD varies from operator to operator and is deployed mostly on ANSI-136 networks. Another scheme used on GSM and CDMA networks is a form of Circuit Switched Data, which allows data rates of 9.6 or 14.4 kbps.

In circuit switching, a dedicated path is established between users for the duration of the call. Circuit switching is appropriate for applications that cannot tolerate delay and those that transmit continuous or nearly continuous traffic. In packet switching, channel capacity is shared among several users. Bursty and non-real-time traffic is more suitable for transmission on packet switched channels. By sharing a channel resource, packet switching increases the efficiency of the channel and also reduces the cost to subscribers. ANSI-95 networks that have been upgraded to IS-95B can offer maximum data rates of 115.2 kbps on the forward link (base station to mobile device) and 76.8 kbps on the reverse link (mobile device to base station). IS-95B upgrades have been performed in South Korea, and deployed in Japan, but have not been widely performed in the U.S. Hence, most data services being offered today on cellular networks are low bit-rate. In order to be able to offer higher data rates, cellular networks are being upgraded worldwide. Most upgrade schemes under consideration will offer packet switched data services. The introduction of packet switching will require significant changes in these networks, especially in the backbone portion of the networks. There is another category of upcoming wireless networks that are high speed but are meant mostly for indoor applications with limited mobility, such as HIPERLAN and IEEE 802.11. These types of networks are meant primarily for Wireless Local Area Networks (WLAN), and some may eventually find outdoor use. IEEE 802.11 networks are defined in several bands, including infrared, 2.4 GHz ISM, and 5.7 GHz ISM, and are defined to offer data rates of 1, 2, 11, and 54 Mbps. There are also standards for exchanging data in an untethered manner, such as Bluetooth, which is a new standard that will enable wireless communication between devices at rates up to 1 Mbps at distances up to 10 meters (optionally up to 100 meters). These networks and standards are targeted for use in ISM bands.



Migration of Cellular Mobile Wireless Networks to Packet Switched Networks

In the past, GSM networks have handled data in a circuit switched manner. With the introduction of General Packet Radio Service (GPRS), the capability of handling packet switched data is being introduced. In Europe, most GSM networks are being upgraded for GPRS, with initial service already available in some countries, although there is a lack of GPRS handset availability at present. The introduction of GPRS in GSM networks requires a software upgrade at Base Stations and Base Station Controllers (BSC), although whether a mere software upgrade is sufficient may depend on the age or version and vendor of the infrastructure in place. Another primary change required is the introduction of a new set of infrastructure elements, called Serving GPRS Support Nodes (SGSN) and Gateway GPRS Support Nodes (GGSN), and a packet switched backbone network to support packet switched user traffic. The backbone network refers to the fixed part of the network that carries traffic between Base Stations and external networks. GGSNs act as interfaces to external packet networks such as the Internet, and route packets to SGSNs. SGSNs maintain knowledge of the location of Mobile Terminals and thus are responsible for mobility management and delivery of packets. The type of modifications required in the backbone network for GPRS also hold for Universal Mobile Telecommunications System (UMTS), or Wideband-CDMA (W-CDMA), a 3G technology.

For ANSI-95 networks, the path to offering higher data rates through the introduction of cdma2000 1xRTT and 3xRTT is similar in that it requires the addition of new infrastructure and a packet switched network in the backbone network. The Packet Data Serving Node (PDSN) in cdma2000 networks offers functionality equivalent to the SGSN and GGSN.

Operators that currently have Personal Digital Cellular (PDC) or Personal Handphone System (PHS) systems, mostly in Japan, are likely to migrate to one of W-CDMA or cdma2000 systems, which are considered as "3G" systems. 3G systems are designed for higher data rate services, and from the start will be built to offer packet switched data services as well as circuit switched voice and data services. Eventually, most services may be transported in a packet switched manner.

Challenges in Upgrading Cellular Networks for Packet Switched Data

Whereas indoor and dedicated categories of mobile wireless data networks have been built from the start to support packet switched data, that is not the case for cellular networks. Until now, cellular operators have built a circuit switched backbone network infrastructure. Now they face a challenge of implementing a packet switched backbone network. At present, most operators deploy Time Division Multiplexed (TDM) T1 or E1 lines for connectivity to and from Base Stations. To use the same transport network efficiently for both circuit switched and packet switched traffic, and hence possibly to reduce transport network costs, they must deploy an Asynchronous Transport Mode (ATM) or Internet Protocol (IP) network. Hence, they face challenges of introducing packet switched traffic in their networks and configuring their network for ATM and/or IP. They also face challenges in making certain that packet data users can roam and packet data calls can be handed off among various networks. Building networks that are able to support various Quality of Service (QoS) criteria for different applications also poses significant challenges. Figure 4.1 shows the basic architecture of a GSM network, and Figure 4.2 shows the basic architecture of a GPRS network. The diagrams show only a logical interconnection of elements; a real network will consist of multiple infrastructure elements of each type, hence introducing significant complexity.

In a future vision of mobility devices, it will be usable on various types of mobile and fixed networks, wireless and tethered. Mobile IP is a technology that will allow such mobility, with improved mobility management and security. In another future improvement, an all IP network is envisioned, where voice traffic will also be carried over IP, initially in the core part of the backbone network, and eventually in the entire network.

In summary, cellular operators upgrading their networks to offer packet switched data services will face significant engineering challenges in migrating to a backbone network that will support packet switched traffic. The engineering challenges will include adding a packet switched backbone network, introducing ATM and/or IP as a common transport mechanism, building the network for reliability, scalability, and for acceptable cost, and acceptable QoS. Operators face significant choices in designing their backbone network, choices that will impact network cost, quality, and the ability of the operator to grow the network elegantly. Other challenges will include making certain that roaming and handovers work seamlessly for packet switched calls, IP address management, and security. Once networks are built, managing them will also require considerable expertise.

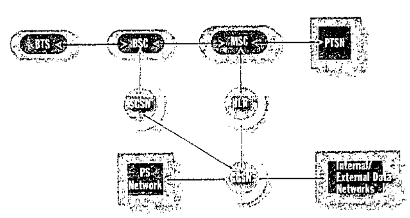


Figure 4.2 Basic GPRS Network Architecture (UMTS Rel. '99 is Similar)

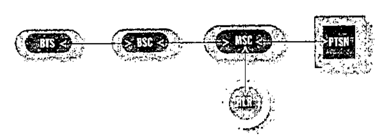


Figure 4.1 Basic GSM Architecture

PROJECT PROFILE: HUTCHISON3G

AS DESCRIBED BY MARK NAVOLIO | PRINCIPAL ENGINEER

Hutchison3G UK Holdings Limited ("Hutchison3G"), holds license "A" from the UMTS auction held by the UK government in April 2000. License "A" was the largest block of spectrum auctioned in the UK. It was set aside for a new entrant to the market. The license consists of 15 MHz of paired spectrum, and 5 MHz of unpaired spectrum. Hutchison3G UK is in the process of deploying a countrywide network based on the W-CDMA UMTS standard.

PROJECT STATUS UPON ENGAGEMENT:
LCC has been engaged by Hutchison3G to provide several different services for the radio planning department, chiefly radio network planning and high level engineering consulting.

As LCC's managing engineer on this project, my initial responsibility was to propose different deployment strategies and to assess the risk factors, establish the relative cost per strategy and quantify the associated coverage/capacity/quality expectations. Upon the decision of the network rollout director (and the H3G corporate board of directors), it was then my job to proceed with defining the technical specifications for the radio planners.

THE PROBLEM:
Evaluating the different strategies was a daunting challenge. Foremost was the difficulty of quantifying the significant impact the traffic was going to have on the network design. The 2G technologies are mostly concerned with the location and number of users. However, the UMTS adds another dimension to the equation. This third dimension consists of the myriad of different services available and their corresponding data rates. The data rates vary dramatically from 12.2 kbps to 2 Mbps and have a significant impact on the physical design of the sites. Adding to this were the technical differences such as cell breathing, soft and GSM hard handoffs.

THE LCC SOLUTION:
Prior to my arrival at Hutchison3G, I managed a CDMA build in Canada, an effort that was to last for almost 2 years. The IS-95 standard shares many of the same technical attributes of UMTS. The project was taken from conception to the design and build phase and then finally to launch.

Concurrently, I had gone though rigorous CDMA and UMTS training provided by LCC's Wireless Institute.

As a result of this extensive CDMA practical experience and Wireless Institute training, I was selected to join the UMTS design effort in the UK. LCC was chosen for this contract because we were one of the few companies in the world who could provide engineers who had both the practical knowledge of CDMA and the technical training for UMTS.

Garnering this experience, I began the task of evaluating the different deployment strategies available given a range of palatable risks, resources, budget and time constraints. As project manager, I was able to quickly assess the project requirements and proceeded to elaborate on the specific working procedures and goals. The LCC engineers are now fully integrated within H3G organization and continue to fulfil the build and design commitments.

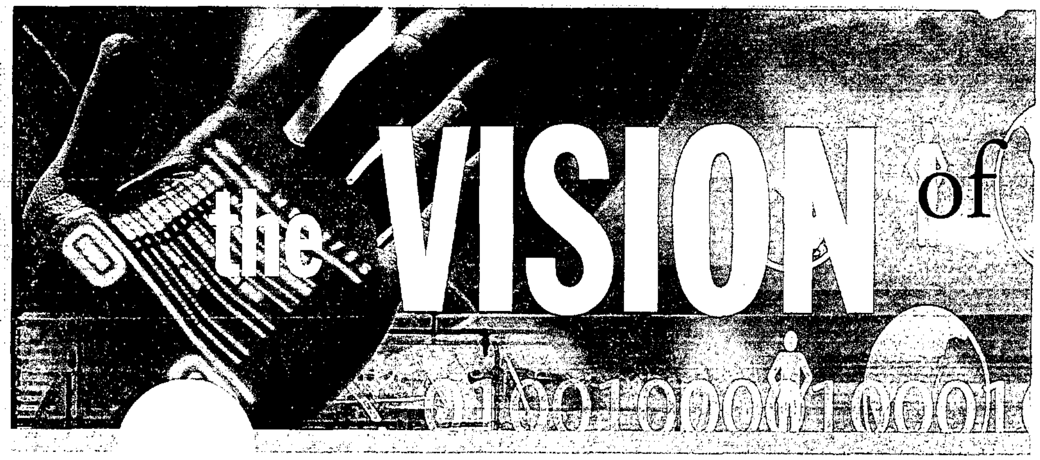
Health and safety issues are paramount in the European community and ensuring Hutchison's compliance and communication to the public is fundamental to their success of the entire network.

The Health and Safety project focuses around issues related to the Electromagnetic Emissions (EME) and the safe compliance according to international standards. On behalf of Hutchison, LCC is serving as the principal representative of an inter-operator (Hutchison3G, One-2-One, British Telecom, Orange and Vodafone) working group whose goal is to establish the engineering criteria for radio emissions safety. I am the sole Technical Advisor to the Site Acquisition Department relative to the EME Safety. In connection with this responsibility and as Hutchison3G's Health and Safety Technical Coordinator, I routinely give testimony to British government officials on health and safety matters.

I am also responsible for authoring all technical writings and consultation documentation for issues relating to EME H&S. LCC will assess the RFI and RFQ of the different hardware and software required for the Health and Safety services and EME Research. (I am in the process of setting up a table of known research and the writing of layman's comments for each study. It is our goal to provide these comments to the site negotiators and local council members to facilitate the understanding of the technical ments and arguments for each research study.) Finally, and perhaps most importantly, we are setting up the Health and Safety departments that will ultimately reside within Hutchison so to maintain the EME health and safety standards for their nationwide network.

BENEFITS CLIENT RECEIVED AS A RESULT OF LCC'S SERVICES:
As with most LCC projects, our work with Hutchison started in a minor role and grew based upon the value that the LCC team provided. As with all new operators and systems, there are many disciplines that must come together in order to design, deploy and optimize a wireless network. However, when you add the challenge of implementing a new technology to rolling out of a new network, you need seamless integration of these disciplines along with experience, skill, leadership and innovation in order to be successful. I believe that LCC is contributing to all of these elements. As a result, we will be able to assist Hutchison3G address all of the traditional technical issues as well as the new challenges associated with this next generation network.

'4.0. *ATM: asynchroncous transfer mode*



5.0. *LAN: local area network*

Convergence has long been a buzzword in the wireless industry, implying the closer interworking between fixed and mobile telecommunications.

In the new wireless Internet world, the vision of fixed mobile convergence has expanded to include creating seamless multimedia services that transcend fixed and mobile, wired and wireless, voice and data, and the public and private network distinction. The result is a single, multi-purpose integration of networks that converges diverse access and transport technologies around a core IP-based network, seamlessly and efficiently drawing them together into one global network.

The new vision encompasses complementary satellite and terrestrial components, enabling users to roam on satellite networks and receive service in the developing world where there is no terrestrial system in place. The terrestrial components comprise wireline voice and data networks, as well as fixed wireless networks such as LMDS and MMDS, next generation wireless LANs such as HiperLAN2, personal area networks via Bluetooth, and 3G mobile technologies.

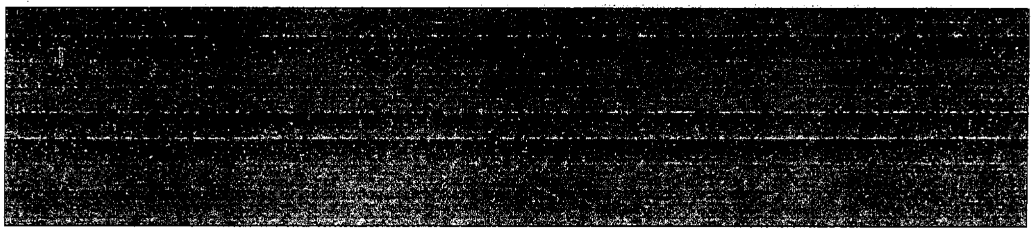
Wireless operators are interested in providing solutions that combine the qualities of fixed and mobile networks in a manageable and cost effective way to both the business user and consumer. They are looking for ways to drive down costs, stay ahead of the competition, and significantly improve their customer's experience. The integration of the telecom and IT industries has resulted in the wireless Internet offering the network operators a diverse range of attractive new business opportunities with new revenue streams.

Economic and Technical Requirements of Convergence Solutions

The truth is that there are many different paths to benefit from convergence, giving the operator multiple implementation choices. The economics associated with convergence must be evaluated for any investment decision. Proper planning is required to protect the investment in existing equipment and to design for evolving business needs.

The business case for bringing voice traffic onto the data network is compelling. The wireless carriers currently offer voice services on a circuit switched network, and some are beginning to deploy a packet switched data network to support 3G services. Each network requires separate facilities, separate management, and separate support personnel. Consolidation requires global, scalable, carrier grade reliability and voice quality over IP networks, coupled with integrated, end-to-end operations, administration, maintenance and provisioning support, billing and customer care. Additional technical challenges requiring investment include seamless interoperability, roaming, IP address management, and security. These challenges must be quantified because the operator requires a return on investment.

With the added complexity in the new wireless value chain, operators must evaluate various potential revenue scenarios such as standard billing schemes based on minutes of use, time of day, geographical location, etc., or m-commerce features such as transaction commission, service charges, click-through charges, pay-per-view and advertising. Furthermore, the cost and complexity of managing services across multiple access media must be invisible to the user. Ultimately, subscribers will expect the billing plans to be transparent, simple and provide value for money.



Lifestyle Changes Through Convergence

"Seamless Delivery of Personalized Services for Anyone, Anywhere at Anytime" characterizes the future vision of converged services for IMT-2000. An IP based communications architecture enables "always on" personal networks with individual preferences for services, information and access devices revolutionizing the way users manage their hectic lifestyles. Improvements in speech recognition technologies have led to the emergence of voice web portals enabling spoken access to email, traffic updates, scheduling, and v-commerce.

The "always on" mobile office provides increased responsiveness and improved productivity. New services let busy professionals concentrate on business, rather than juggling multiple messaging services and devices. Road warriors and telecommuters can have the same voice services they have in the office with the same extension, voicemail, corporate dialing plan, and productivity features. By connecting with the corporate managed IP network from home, a branch office, airports, or the hotel they gain LAN data connectivity as well as the same voice services.

The key to wide scale user acceptance lies in analyzing the way we live our lives and translating the technological capabilities into user centric solutions. Beyond the convenience of mobile payment systems or the freedom of anywhere, anytime video conferences, the vision of convergence is that it will lead to fundamentals changes across all aspects of our personal, family and business daily life.

And this is just the beginning

CLIENT PROFILE: LCC'S 3G SHOWCASE

AS DESCRIBED BY BARBARA PAVONI, SENIOR DIRECTOR, STRATEGIC TECHNICAL CONSULTING

LCC's Technology, Research and Innovation (TRI) group focuses on cutting edge wireless technology and services. As a professional services firm, LCC is only able to provide value to our clients if we stay on the leading edge of new advances in the wireless industry. The TRI group focuses on the evolution of technology in the wireless industry, and understanding how these changes will have an impact on operators, vendors and financiers in the wireless community.

PROJECT BACKGROUND:

Long before Europe and Asia began auctioning off spectrum for 3rd Generation networks, standards committees such as the ITU, 3GPP and 3GPP2 were defining how these systems would work. In conjunction with the standard development, the group of which I am a member, TRI, began studying the unique challenges 3G operators will face in implementing these new data centric systems.

Our group's goal was to develop internal expertise and processes so that we were prepared to assist our clients as these new systems began to emerge. As 2000 began to come to a close, the TRI group felt the time was right to take our knowledge and processes to the operators to discuss our thoughts on the major challenges of implementing 3G. In order to facilitate this process, the TRI group designed a "3G showcase" that takes audiences through the technical, financial, regulatory, marketing and competitive challenges an operator faces while planning and implementing their 3G networks.

THE LCC SOLUTION:

During the latter part of 2000 and into the first quarter of 2001, the TRI group visited over 20 operators, vendors and financial analysts in Asia, Europe and the Americas. We shared, what, in our view, were going to be the challenges of Planning, Designing and Deploying 3rd Generation Networks.

Unlike second generation or even 2.5G networks, third generation networks will require a very unique set of design assumptions based upon the various service offerings and associated traffic allocation. Third Generation networks will require system operators to develop new network dimensioning algorithms that will accommodate the multiple subscriber usage characteristics associated with the plethora of data applications proposed for 3G networks. For example, subscribers will have the ability to not only select from a wide variety of services but will able be able to select the urgency in which they want the network to treat their usage. This dynamic must change the way 3G wireless networks are planned, designed and operated.

Our 3G Showcase focuses on these technical challenges along with how these issues will impact all other areas of a carrier's operations. This project has been an exciting challenge for the group, as it has involved traveling to over 10 different countries, and numerous time zones in order to meet with high-level executives and their teams to discuss the immediate challenges facing 3G operators. It has also allowed us to participate in interactive discussions to determine possible approaches and solutions.

THE RESULT OF LCC'S INITIATIVE:

In addition to the technical interchanges that took place at each presentation, each client was anxious to hear LCC's observations on how other operators were approaching 3G. While many of the teams we met were already well versed on the challenges facing them, they were eager to discuss LCC's ideas and approaches to these challenges and hear some of our experiences in solving other challenges for new systems around the world. (It is interesting to note that while some of the challenges seem to be universal, there are several differences between how 3G networks implementations is being viewed around the world.)

Our showcase project has proven successful on several fronts. We have been engaged by several 3G operators to assist in their design and implementation efforts. We have gained a much deeper understanding of which challenges the operators in various areas of the world consider critical and which are secondary. This deeper understanding of our clients has been extremely beneficial as we continue to refine LCC's next generation service offerings.

As shown from left to right:
Mark Ein, Neera Singh, Greg Ledford, C. Thomas Faulders III, Susan Mayer, Dr. Rajendra Singh

C. Thomas Faulders III

Chairman & Chief Executive Officer

Tom Faulders was appointed Chairman, President and Chief Executive Officer of LCC International, Inc., on May 25, 1999. Prior to LCC, Mr. Faulders served as Executive Vice President, Treasurer and Chief Financial Officer of BDM International, Inc. from 1995 until the company was sold to TRW in 1998. During his tenure with BDM, Mr. Faulders also developed BDM's rapidly growing commercial business and served as President of the Company's Integrated Supply Chain Solutions unit. Prior to BDM, Mr. Faulders was with Comsat Corporation, a provider of international communications and entertainment, as Vice President and Chief Financial Officer from 1992 to 1995. From 1985 to 1992, he served in several senior sales, marketing and finance positions with MCI Communications Corporation, a long distance service provider. Mr. Faulders graduated from the University of Virginia with a BA in economics and The Wharton School, University of Pennsylvania with a MBA in finance and information systems.

Mark D. Ein

Director

Mark D. Ein has served on LCC's board of directors since the Company's initial public offering in September 1996. Mr. Ein is the founder and CEO of Venturehouse Group, LLC, a technology holding company that creates, invests in and builds Internet, technology and telecommunications companies. Prior to forming Venturehouse Group, Mr. Ein was a Principal with The Carlyle Group, a large private equity firm with offices around the world. From 1992 to 1999, Mr. Ein was responsible for many of Carlyle's telecommunications investment activities. Mr. Ein has also worked at Brentwood Associates, a leading West Coast venture capital firm, and Goldman Sachs & Co. Mr. Ein is a graduate of University of Pennsylvania's Wharton School of Finance and received his MBA from the Harvard Business School. Mr. Ein also serves on the Board of Aether Systems, where he was a co-founder, as well as the boards of several private companies.

Steven Gilbert (not pictured)

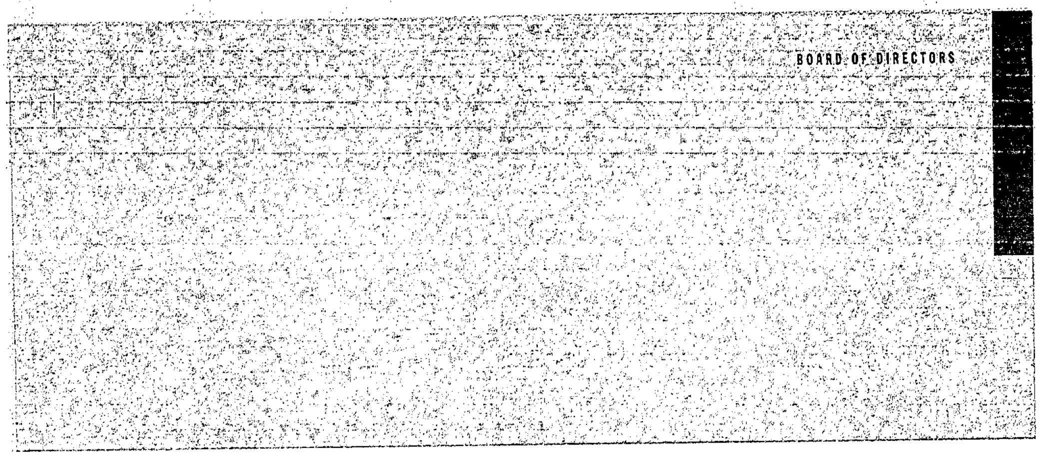
Director

A member of LCC's board of directors since 1999, Steven Gilbert is chairman of Gilbert Global Equity Partners, L.P., a billion-dollar private equity fund. From 1992 to 1997, Mr. Gilbert was the founder and managing general partner of Soros Capital, L.P., the principal venture capital and leveraged transaction entity of the Quantum Group of Funds, and a principal advisor to Quantum Industrial Holdings Ltd. He was also the managing director of Commonwealth Capital Partners, L.P., a private equity investment firm. From 1984 to 1988, Mr. Gilbert founded and was the managing general partner of Chemical Venture Partners (now Chase Capital). He has 30 years of experience in private equity investing, investment banking and law, and also serves as a director of several multi-national high tech companies.

Greg Ledford

Director

A member of LCC's board of directors since October of 1999, Mr. Ledford is a Principal at The Carlyle Group, a private investment firm, where he specializes in high-tech investment activities. Prior to joining The Carlyle Group in January 1988, Mr. Ledford was Director of Capital Leasing for MCI Telecommunications. Mr. Ledford joined Carlyle as a Vice President and from 1991 through 1997, was Chairman and CEO of The Reilly Corporation, a Carlyle portfolio company that was successfully sold in September of 1997. Mr. Ledford is a graduate of the University of Virginia's McIntire School of Commerce and received his M.B.A. from Loyola College.



Susan Mayer

Director

The newest member of LCC's board, Ms. Mayer is president of WorldCom Ventures, a subsidiary of WorldCom, Inc., where she manages over $1 billion worth of WorldCom assets in the telecom-focused venture capital fund. Ms. Mayer and her team leverage WorldCom's vast resources and partnerships to help develop great companies by identifying and accelerating emerging technologies and services. Prior to founding WorldCom Ventures, Ms. Mayer held several senior management positions at MCI Communications Corporation including senior vice president of ventures and alliances, president and chief operating officer of SkyMCI and senior vice president of MCI corporate development. Ms. Mayer has also held strategic management positions with Communications Satellite Corporation and The Boston Consulting Group. A Masters in Business Administration graduate of Harvard University, Ms. Mayer also serves on the Board's of several publicly and privately held companies.

Neera Singh

Director

Neera Singh, a director on LCC's board of directors, co-founded LCC International with her husband Dr. Rajendra Singh. She served as executive vice president for LCC until the company's initial public offering in September 1996. She currently serves as co-chair of the Members Committee of Telcom Ventures. While at LCC, Mrs. Singh pioneered LCC's software product, ANET (Advanced Network Engineering Tool), the industry's first RF planning tool. ANET quickly became the standard for designing complex cellular networks around the world. Her continued involvement in the business led to the development of CellCAD (Cellular Computed Aided Design), the industry's first UNIX-based planning and optimization tool. Mrs. Singh holds a masters degree in chemical engineering from Kansas State University.

Dr. Rajendra Singh

Director

Dr. Rajendra Singh is a director on LCC International, Inc.'s board of directors. He and his wife Neera co-founded LCC in 1983. He served as president of LCC until September 1994 and currently serves as chairman of the Members Committee of Telcom Ventures, an investment firm specializing in wireless system operators and emerging wireless technologies. Dr. Singh is also one of the co-founders and currently serves on the board of directors of Teligent Inc., a Competitive Local Exchange Carrier (CLEC) and Aether Systems, a leading provider of wireless data products and services. He also established, developed and directed APPEX Inc., a billing services firm prior to selling it to Electronic Data Systems (EDS) in October 1990. Dr. Singh received his doctorate degree in electrical engineering from Southern Methodist University in 1980. He has a distinguished record of academic achievements beginning with a published doctoral dissertation on "Spectrum Efficient Schemes for Mobile Radio Communications." He organized and participated in the CTIA scientific panel that investigated time dispersion for TDMA and FDMA. As a former faculty member of both Kansas State University and City College of New York, and a member of numerous electrical engineering societies, Dr. Singh has contributed extensively to the academic and professional development of the wireless telecommunications industry.

CORPORATE OFFICERS AND MANAGEMENT TEAM

CORPORATE OFFICERS

C. Thomas Faulders III
Chairman and
Chief Executive Officer

David Walker
Senior Vice President,
Chief Financial Officer & Treasurer

Mike McNelly
Senior Vice President,
Americas

Peter Deliso
Vice President, General Council & Secretary

Tricia Drennan
Vice President,
Corporate Communications
and Investor Relations

Terri Feely
Vice President, Human Resources

LCC MANAGEMENT TEAM

Frank Aghili
Vice President, Design Services

Kamal (KK) Arora
Vice President, Wireless Institute of LCC

Paul Chelson
Vice President, Deployment Services

Jamie Donelan
Vice President, Corporate Comptroller

Alfredo Echeverria
Vice President, Program Management

Vicent Gwiazdowski
Vice President & Chief Operating Officer, EMEA-AP

Royce Kincaid
Vice President, Business Development (Americas)

Hans Kwaaitaal
Regional Director, Northern Europe

Jay Lee
Regional Director, Asia Pacific

Paul Luebbe
Vice President, Sales (Americas)

Wael Morsy
Regional, Director, The Middle East & Africa

Carlos Nicolini
General Manager, Brazil

Steve Pearson
Vice President, Finance

Jeffery Pugay
Vice President, Sales, Broadband Wireless
Applications & Vendors

Jim Smith
Vice President, Sales, Integrators & Towers

Steven Stravitz
Vice President, Marketing

June Swanhart
Vice President, Contract Management

REPORT CONTRIBUTORS

LCC Investor Relations would like to give special thanks to the following LCC employees for their significant contributions to this Report: Wendy Charron, Dr. Usman Goni, Barbara Pavon, Vikrant Tannan and Salman Yusuf.

Shareholder Information

Investor Materials:
Investor information including additional annual reports, 10Ks, 10Qs or other financial literature is available without charge. Please contact our Investor Relations Department at the Company's headquarters.

Annual Meeting:
Shareholders as of April 18, 2001 are eligible to participate in LCC's annual meeting of shareholders. The meeting will be held on Tuesday, May 24, 2001, at the Company's Headquarters located at 7925 Jones Branch Drive, McLean, Virginia. The meeting will begin at 10:00 a.m. (local time).

Stock Exchange Listing:
The common shares of LCC International, Inc. trade on the Nasdaq Stock Market under the symbol LCCI.

LCC on the Internet:
LCC's home page on the World Wide Web contains background on the Company and its services, financial information and job listings as well as other useful information. Our Web page is located at www.lcc.com

Transfer Agent and Registrar:
American Stock Transfer & Trust, 40 Wall Street, 46 Floor, New York, NY 10005. Stockholders may call 212/936-5100 with any questions regarding transfer of ownership of LCC stock.

Independent Auditors:
KPMG, LLP, Washington, D.C.

Corporate Counsel:
Hogan & Hartson, LLP, Washington , D.C.

Design: Alpert & Alport, Inc., Herndon, Virginia

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c/o Regus Business Center
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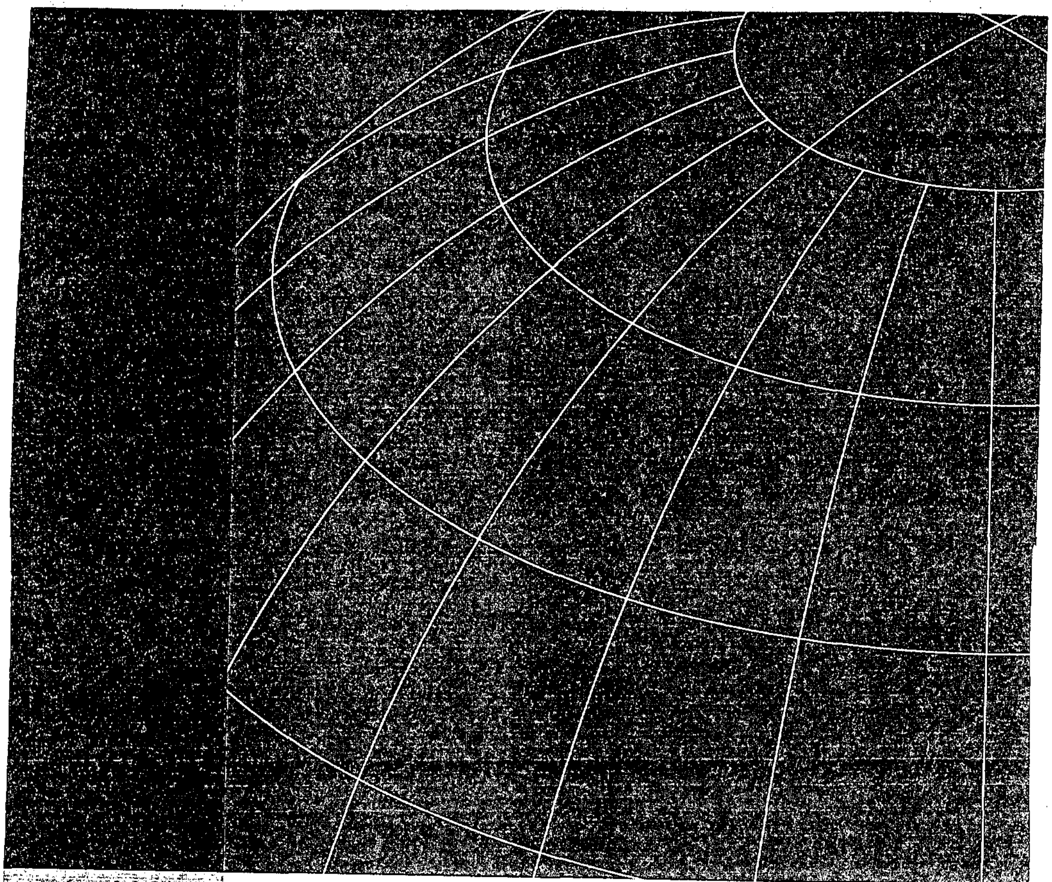
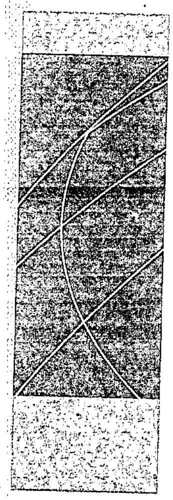
Main Facsimile: +65 438 0681

LCC
the knowledge that powers the network™



THE KNOWLEDGE THAT POWERS THE NETWORK™

LCC®



Corporate Information

LCC International, Inc. is a global leader in voice and data design, deployment and management services to the wireless telecommunications industry. A pioneer in the industry since 1983, LCC has performed technical services for the largest wireless operators in North and South America, Europe, The Middle East, Africa and Asia. The Company has worked with all major access technologies and has participated in the success of some of the largest and most sophisticated wireless systems in the world. Through an integrated set of technical business consulting, training, design, deployment, operations and maintenance services, LCC is unique in its ability to provide comprehensive turnkey services to wireless operators around the world.

LCC OFFICERS

Tom Faulders
Chairman, Chief Executive Officer & President

David Walker
Senior Vice President & Chief Financial Officer

Carlo Baravalle
Senior Vice President, Europe, Middle East & Africa (EMEA)

Mike McNelly
Senior Vice President, The Americas

Peter Deliso
Vice President & General Counsel

Tricia Drennan
Vice President, Corporate Communications & Investor Relations

Terri Feely
Vice President, Human Resources

Vince Gwiazdowski
Vice President & General Manager, Asia Pacific

LCC MANAGEMENT TEAM

Frank Aghili
Vice President, Design Services, North America

Kamal (KK) Arora
Vice President, Wireless Institute of LCC

Malcolm Bore
Vice President, General Manager, LCC SWT UK

Paul Chelson
Vice President, Operations, EMEA

Alfredo Echeverria
Vice President, Program Management & Deployment Services, North America

Antonio Harnecker
Vice President, Sales & Marketing, EMEA

Carlos Nicolini
General Manager, Brazil

Steve Pearson
Vice President, Finance, The Americas

Jeffrey Pugay
Vice President, Business Development, North America

Sam Singh
General Manager, Middle East & Africa

Steven Stravitz
Vice President, Marketing, North America

Paul Thurneysen
Vice President, Sales Engineering, North America

Marc Weinberg
Vice President, Sales, North America

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Fax: +1.703.873.2100

Investor Materials
Investor information including additional annual reports, 10Ks, 10Qs and other financial literature is available without charge. Please contact our Investor Relations Department located at the Company's corporate headquarters.

Annual Meeting
Shareholders as of April 4, 2002 are eligible to participate in LCC's annual meeting of shareholders. The meeting will be held on Thursday, May 23, 2002, at the Company's Headquarters located at 7925 Jones Branch Drive, McLean, Virginia. The meeting will begin at 10:00 a.m. (local time).

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Transfer Agent and Registrar
American Stock Transfer & Trust, 40 Wall Street, 46 Floor, New York, NY 10005. Stockholders may call +1.718.921.8381 with any questions regarding transfer of ownership of LCC stock.

Independent Auditors
KPMG, LLP, Washington, D.C.

Corporate Counsel
Hogan & Hartson, LLP, Washington, D.C.

Caution Concerning Forward-Looking Statements
Statements included in the documents contained herein which are not historical in nature are forward-looking statements made pursuant to the safe harbor provisions of the Private Securities Litigation Reform Act of 1995 including, without limitation, statements regarding increased demand for the Company's services, the Company's ability to secure new business, and those factors highlighted in LCC International, Inc.'s Annual Reports on Form 10-K and Quarterly Reports on Form 10-Q, which could cause the Company's actual results to differ materially from forward-looking statements made by the Company.

the knowledge that powers the network™

Letter to Shareholders

2001

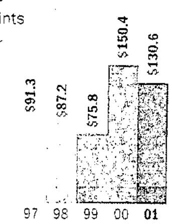
TO MY FELLOW SHAREHOLDERS,

In the past couple of years the employees of LCC have done a terrific job of growing our service offering and customer base, expanding our global reach and establishing an operational structure that is second to none in the wireless infrastructure services sector. 2001 was no exception.

A TIME OF CHANGE

There were many highlights during 2001. We secured 27 new customers. We stayed true to our disciplined acquisition strategy and made two strategic purchases during 2001 and early 2002. We added new sales channels via partnering agreements and successfully developed several new services that have been well received by the wireless marketplace.

Unfortunately, saturated markets, strong competition, declining profit margins and considerable fees paid to governments for third-generation licenses coupled with tight capital markets and a slowing economy left mobile operators and the overall wireless community with slower than expected growth and reduced capital expenditure budgets. These constraints hampered our ability to exceed the growth objectives we had projected for ourselves in early 2001.

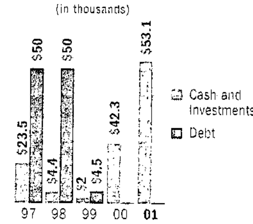


Revenue
(in thousands)

FINANCIAL STRENGTH AND ACCOUNTABILITY

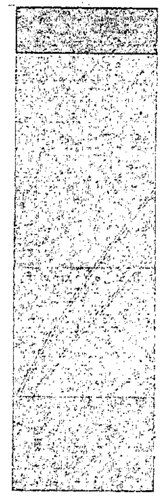
We were proud to be the only company in our peer group to be profitable for the full year 2001. And, in spite of the challenges faced by the wireless community during 2001, we exceeded our revenue targets of $125 to $130 million in addition to significantly improving the overall financial standing of LCC. In 2001 we:

- Monetized otherwise worthless assets into valuable one-time gains which resulted in a cash balance of over $50 million at the end of 2001
- Recovered previously written-off receivables as a result of a diligent financial organization and strong customer relationships, and
- Exited 2001 with a debt free balance sheet that included no off balance sheet financing or debt.



Cash and Short Term Investments & Debt
(in thousands)

LCC STYLE AND VALUES



LCC'S STYLE

Lead by example. Live by your word and MAKE IT HAPPEN! Serve your customers to the best of your ability. Conduct yourself with honesty, integrity, and fairness, in a manner that will bring credit to your self, family, customer, and the company at all times. Operate in the center of the field of ethical standards and behavior. Listen to your customers and colleagues, understand their needs and be open to new ideas. Create and maintain an atmosphere of mutual trust and respect. Encourage every team member to take risks, exercise initiative, deliver quality results, and never be afraid to make mistakes. Create a supportive environment that nurtures professional growth. And finally, as we build this great company, HAVE FUN!

LCC'S VALUES

WE MAKE THINGS HAPPEN FOR OUR CLIENTS...
with innovative, end-to-end solutions and excellent service, we achieve break-through results for our clients.

WE TREASURE OUR EMPLOYEES...
by attracting, developing and recognizing outstanding employees, and caring for them.

WE REWARD OUR SHAREHOLDERS...
by continually strengthening our financial performance from which everyone benefits.

WE OPERATE WITH INTEGRITY...
by treating our customers and employees in a fair, equitable and respectful honest manner.

WE PROMOTE TEAMWORK...
by combining diverse, multinational talents worldwide to accomplish common goals.

WE STRIVE FOR EXCELLENCE...
by continually challenging ourselves, developing our skills, and striving for the highest quality performance with both our internal and external clients.

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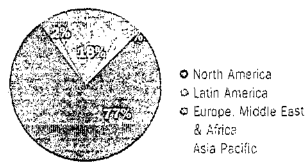
It will be a challenging year for LCC. However, as we have global operations, we are well positioned to and confident that we will take advantage of the hot spots for new licenses issuances, subscriber growth and the resulting quality of service requirement and 3G network build-outs.



2001 Percentage of Revenue by Region

A PROMISING OUTLOOK

Although 2002 has started off with many of the same barriers that were experienced during 2001, we believe the underlying drivers for the industry look quite positive in the years ahead:

- Mobile phone customers and usage continue to grow. Mobile phones are displacing wireline service not only in Europe, but now also in the US. A recent UN report projected that at year-end 2001 there were in excess of 1 billion fixed lines compared to 1 billion wireless phones. The report went on to project that by the end of the first quarter of 2002, the number of fixed lines and wireless phones are expected to be equal.
- New technology, equipment and terminals for both 2.5 and 3G are now available for network installation and commercial use.
- Emerging countries are looking to either upgrade wireless networks or install new ones.

OUR CULTURE COUNTS

Our employees, culture and business practices make LCC unique. I would especially like to recognize and thank the employees of LCC who continue to embody the company's values, style and mission to be ***"the leading global telecommunications partner by creating and implementing end-to-end solutions. We do this with our most valuable asset, outstanding people, who leverage technology, innovation, and energy to achieve breakthrough results for our clients."*** It is through their dedication to operational excellence and their commitment to refining the steps necessary to ensure that our service model represents one of the highest quality offerings available to the wireless voice and data community that we will continue to grow and deliver enhanced shareholder value.

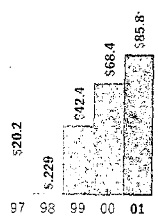
LCC is grateful for your ongoing trust and support. We look forward to continuing to demonstrate how focus, dedication and perseverance will ensure that LCC remains one of the most trusted and successful outsourcing partners in the wireless community.

Sincerely,

C. Thomas Faulders III
Chairman & Chief Executive Officer
April 2002

These achievements can be attributed to a proactive financial organization that has been and continues to be committed to analyzing and monitoring those areas of accounting, which, in this post Enron environment, have proven to be problematic. We continue to pay special attention to those accounting areas open to management judgment including:

- revenue recognition,
- allowance for doubtful accounts,
- accounting for income taxes, and
- impairment from long-lived assets.



Total Shareholder's Equity
(in thousands)

OPERATIONAL FOCUS AND QUALITY WORK WILL KEEP US STRONG

For the full year 2001, LCC was able to maintain profitability and positive cash flow by focusing on our clients' needs and controlling costs. However, the consequence of the downturn of the wireless sector resulted in a loss in the fourth quarter–the first loss posted since the third quarter of 1999. In addition, although we are very proud of the work we accomplished throughout the year, most notably our work on the XM Satellite Radio project–the largest turn-key project of its kind and the first broadcast system to compete with AM and FM radio in over 100 years–we became highly dependent on XM revenue which represented 44 percent of our 2001 sales. Replacing this revenue in a difficult market is, at best, challenging.

In response to these challenges we have invested in upgrading several of our key components for continued success:

- We put in place a new and seasoned business development and sales team in our America's region.
- We hired a new management team to lead our Europe, Middle East and Africa (EMEA) region.
- We renewed our focus on Asia Pacific by transitioning one of our most experienced executives into a general manager position and reestablished an active local presence in the region.
- We made two strategic acquisitions in our EMEA region so as to bolster our services capability in preparation for the anticipated growth in 3G network deployment.

GLOBAL OPPORTUNITIES PREVAIL

In spite of the relatively unfriendly capital markets, we are seeing a good deal of wireless activity around the world–especially in the Europe, Middle East, Africa and Asia Pacific regions–which leads us to be optimistic about LCC's business prospects for 2002 and beyond.

By staying focused on operational execution and sales growth, we are very positive about LCC's long-term outlook especially given the fact that it is expected that revenue from non-U.S. operations, for the first time in the Company's history, will exceed those from U.S. operations in the coming years.

ADDENDUM TO GENERATIONS II

Voice vs. Data

In the previous two annual reports, LCC's view on the evolution of wireless access technologies was presented. We have discussed in detail the radio access technology migration paths from 2nd Generation to 3rd Generation networks.

In this year's update, we focus our attention on an evolution that is taking place in the core network of these wireless systems; the gradual migration from voice centric networks to networks whose major goal is the wireless delivery of data services. The GPRS and 1xRTT networks recently launched around the world have begun the process of introducing packet switched networking into the wireless environment. UMTS networks soon to be launched in Europe will continue the evolution of the wireless network core from circuit switched to packet switched technology.

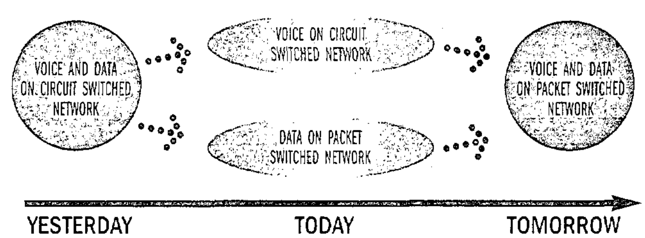


Figure 1–Convergence of Circuit and Packet Switched Networks

It is important to understand that the discussion of voice versus data is not synonymous with analog versus digital. Most modern telecommunications networks today are already largely built on digital transmission. This means that the analog signal must first be encoded prior to transmission. The analog voice signal is converted to digital 1s and 0s by an encoder. The encoder will sample the incoming analog voice signal at a rate of 8,000 samples per second. The amplitude of each sample is given a pre-established binary code, which is determined by the height of the sample. An example of an encoder is shown in the figure below:

8000 SAMPLES PER SECOND
8 BITS PER SAMPLE (250 CODE LEVELS)
64,000 BITS PER SECOND

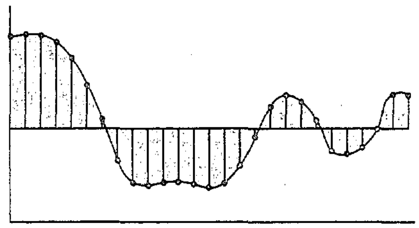


Figure 2–Analog voice signal encoded to a 64 kbps digital signal

When digitization of voice signals was originally introduced in the early 1960s, 8 bits were used to encode each voice sample thus producing a 64 kbps standard rate for digital voice. Today's encoder technology has advanced to the point where good quality voice can be encoded at much lower rates, however, since the majority of the active and transmission components of the world's telecommunications networks were built around the 64 kbps rate it would be impractical and excessively expensive to chance the basic rate.

As an example, the modern GSM network uses a voice encoder that can transmit voice at rates as low as 8 kbps on the radio part, however, a transcoder at the MSC transforms the signal to 64 kbps prior to sending it through to the external networks.

Now that we understand that both voice and data are transmitted across today's telecommunication networks in the form of bits, let's look at how bit streams generated by voice calls differ from those generated by a pure data call.

CHARACTERISTIC	VOICE	DATA
Bit Rate Characteristics	Continuous real-time stream	"Bursty"
Bit Rates	Constant Bit Rate (< = 64 kbps)	Variable Bit Rate depending on application
Quality of Service	Low probability of blocking Delay intolerant	Application dependent ☐ delay tolerance ☐ throughput ☐ latency
Symmetrical / Asymmetrical	Symmetrical – Same bandwidth in both direction required	Asymmetrical – Generally greater bandwidth in one direction than the other, however both are variable.
Traffic Modeling	Erlang Model	Unknown: Simulation is currently the best way to understand data traffic.
Average Call Holding Time	*3-4 minutes (residential)* 6 minutes (business)	*33 minutes or higher*

Source: January 2002 Internet Usage Stats, CyberAtlas

Table 1–Main Differences Between Voice and Data

The above chart depicting voice versus data networks illustrates that the nature of voice versus data traffic can vary greatly.

Circuit vs. Packet Switched Networks

Today's wired and wireless networks are largely circuit switched networks, designed and dimensioned to carry voice calls. In circuit switched networks, a dedicated path through all transmission portions of the network is created to connect two parties. This path is held for the duration of the call, thus tying up network resources while the call is in place.

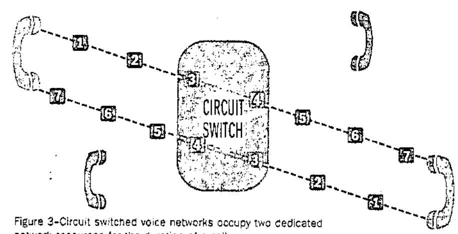


Figure 3–Circuit switched voice networks occupy two dedicated network resources for the duration of a call.

Circuit switching is ideal when data must be transmitted quickly and must arrive in the same order in which it was sent. This is the case with most real-time data, such as voice and video conferencing.

The disadvantage of circuit switched networks for data calls becomes obvious when one considers the resources that are tied up in order to support variable bit rate (VBR) data services. For example, with Internet browsing, one might be on-line for over 30 minutes. However, during much of that time, the connection is essentially idle while the user reads the Web page. Packet Switched networks are more efficient and robust for data that can withstand some delays in transmission, such as e-mail messages and web pages.

Packet Switched networks do not use dedicated paths but rather take user data streams and break it down into smaller segments called packets. Control information is added to tell the network where each packet should end up and the packet is sent on its way. As opposed to circuit switching, where a dedicated circuit is created to connect two or more parties, in packet switching one person's data travels along side everyone else's.

Connectionless packet switching is a method of transporting packets within the network where each packet is given a global address containing source and destination information. The packets are individually routed through the network, and may follow different physical paths based on network conditions. Connectionless switching provides no error or flow control, which reduces reliability, and has increased overhead because of the amount of addressing information that must be included in each packet.

Connection-oriented packet switching establishes a path in which all data packets follow in order. Connection-oriented packet switching uses a call set-up packet to establish a virtual circuit where packets follow each other sequentially from source to destination. Instead of global addressing, the packets use a logical channel number to identify where the packet fits into the overall message. This method has the advantage of reducing the addressing overhead and can be used with error detection and flow control, increasing reliability.

Planning and Design for voice and data networks

In today's wireless networks the radio resources used to gain access to network services, whether they be voice or data services, are shared. While we have shown that packet based networks can more efficiently use available resources for variable bit rate data, the fact remains that the use of radio resources for data services reduces the amount of available resources for voice services.

Although data usage is projected to grow quickly over the next several years, voice is still the primary application of wireless networks and wireless service providers need to take care when adding data services, that they do not reduce the quality of their voice offering.

As we have said, data traffic can be quite unpredictable in nature and there are no proven methods of modeling the behavior of data traffic as there are with voice services. The best way to understand how data will effect the network is through simulation.

The following figure shows the results of traffic simulations LCC engineers ran to understand how packet switched data with a peak rates of 64, 144, or 384 kbps will effect the blocking rate of voice services on the cell. It should be noted that the assumption is that all radio resources are shared between voice and data services, with a "first come, first serve" priority for access.

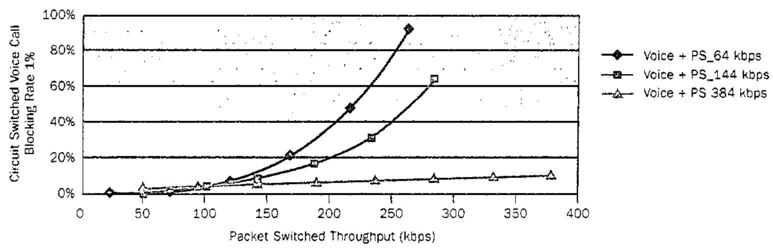


Figure 7–Packet switched throughput versus voice blocking illustrating the trade-offs between voice and data quality when sharing resources

Figure 7 shows that if the wireless service provider were to offer their customers a packet data service with peak data rates of 144 kbps, then the maximum throughput of the cell/sector cannot exceed 200 kbps or else voice blocking will exceed 2%.

Simulations like this are critical for the wireless service provider to understand the trade-offs between various data service offerings and voice capacity.

Once the service provider has determined what types of data services to offer, the next step is to take a look at the resources required to support these services. LCC's dimensioning tool was developed specifically for this purpose.

As the demand for data services increases we expect that the ability to design effective networks will take on an increasing important role. The new complexities that packet based services will introduce into the a network's quality of service criteria will require engineering analysis and optimization that far outweighs the level of effort associated with today's networks.

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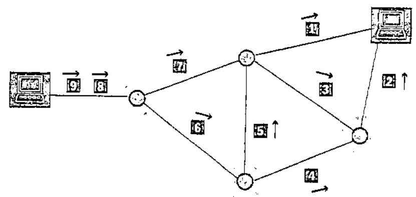

Figure 4–Data transmission via a connectionless packet switched network enables each packet the ability to find the optimum route to its destination.

Packet networks provide an economical means of transmitting variable bit rate (VBR) data. Packets are only sent when needed, thus freeing up resources in the network. Voice and constant bit rate data may not fare as well on the packet network as a certain amount of delay can be introduced through the packet network transmission, however, in the past few years the technology has begun to appear that will allow voice and data calls to be transported on packet networks.

Next Generation Networks: All-Packet Network Architecture

With the introduction of General Packet Radio Service (GPRS) in Global System for Mobile communications (GSM) networks, or 1X-RTT in Code Division Multiple Access (CDMA – ANSI-95) networks, the network architecture is as shown in Figure 5. In this architecture, there usually is a legacy circuit core network in place to carry voice and circuit switched data traffic, and a packet core network is introduced to carry packet data traffic. Although the circuit core network carries mostly voice traffic, parts of it may be a packet ATM network. In the referenced architecture, the circuit call switching is centralized, and the hardware-based switching infrastructure manages the switching as well as the call control. Figure 5 shows a very simplified view of the elements and architecture; it does not show application servers, support systems, roaming gateways, Home Location Registers (HLR), etc. In this diagram, the IWF (Inter-working function) is an inter-working function between the MSC and external packet networks; on the MSC side, the IWF puts out circuit switched data.

Figure 5–GPRS and 1xRTT networks route voice and data on individual networks

As stated previously, carrying voice over packet networks allows a better utilization of the transport bandwidth resource. That is one reason for a carrier to migrate to an all-packet core network, i.e., have a common core network that carries voice calls as well as packet data traffic. From a carrier's perspective, it is also desirable to manage a simplified network, as well as reduce costs. Having a common core network for voice as well as data achieves these goals. Another reason to carry traffic on an IP network versus leased circuits is because

ADDENDUM TO GENERATIONS II

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leased circuits typically have a distance-sensitive cost, whereas IP networks, for example if leased as a Virtual Private Network (VPN), typically do not incur distance sensitive costs, but are typically priced based on the amount of bandwidth required.

Next generation base stations will contain packet (ATM or IP) interfaces, and hence will allow a packet network to exist even in the access network, thus allowing for an all-packet wireless backbone network. If eventually Voice Over Internet Protocol (VOIP) is introduced from a user device, then the network can truly become an All-IP network (or All-Packet network).

Introduction of packet interfaces on various elements allow a common packet core network. Another consideration for operators is to have the flexibility to rapidly introduce new applications and services. Switching and call control are both managed by current generation Switches. The next generation call handling architecture separates the media processing (switching), media control and management, and the application layers, with open interfaces between the three layers. This allows rapid integration of applications, and facilitates interoperability because of open interfaces (at least in an ideal world).

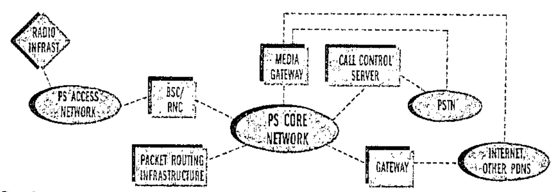

Figure 6—Next generation network architecture combines voice and data traffic on a packet switched core.

Figure 6 shows a common core network, as well as the introduction of new elements, a Media Gateway, and a Media Gateway Controller. The Media Gateway handles the calls themselves, and the Media Gateway Controller manages the call. This type of solution is also known as a Softswitch. A Media Gateway typically does conversion between some sort of legacy voice and Voice Over Packet (VOIP or VOATM), typically VOIP. For voice calls, the Media Gateway Controller translates between SS7 on the PSTN side to one of various IP-based call control protocols such as the Service Initiation Protocol (SIP), H.323, H.248, etc., on the packet side. These elements also allow movement from a centralized processing architecture to a more distributed processing architecture. Eventually, besides a unified core network, there may also be integrated infrastructure that handles both voice and multimedia traffic.

After or as existing mobile wireless service providers have completed migrating to 2.5G/3G radio networks, the next evolution may happen on the backbone network side, in terms of a movement to all-packet networks as well as introduction of modular and distributed switching and call control. Of course, legacy networks will not go away overnight, and not all operators will be convinced that this is the right path for them. After all, incumbent operators have huge investments in legacy infrastructure. To stay competitive, however, operators will need mechanisms to rapidly introduce new services. A significant challenge operators will face when going to a unified packet network is maintaining quality of service on voice calls. In the long term, benefits of going to a common core network will be a reduction in capex and opex, and the benefit of going to a modular infrastructure structure with open interfaces will be an ability to rapidly integrate new services as well as the ability to buy interoperable infrastructure from different vendors.