Personal Digital Wireless Telecommunications
An Investigation and Evaluation
of Technologies and Services

Final Report

Prepared for Business New Brunswick

Bernd Kurz
Information Technology Centre
Faculty of Computer Science
University of New Brunswick
30 April 2002

Acknowledgments and Disclaimer

The research work presented in his document was carried out under contract with Business New Brunswick (BNB) of the Government of New Brunswick through the Information Technology Centre in the Faculty of Computer Science at the University of New Brunswick. This support for the IT and Telecommunications research and industry sectors is gratefully acknowledged.

The provision of equipment and/or air time by both New Brunswick PCS Service Providers, NBTel Mobility and Rogers AT&T is gratefully acknowledged.

Data for this research work was collected from published material and public announcements as of February 2002. As the telecommunications sector is in a fast pace of change, this data may not represent the latest facts as of today.

Executive Summary

Wireless telecommunications used to be about voice, today it is more about data than voice. By the end of the year 2000, for the first time in history the number of data messages sent has exceeded the number of voice calls made in data-enabled public cellular systems. Wireless data services have emerged as a catalyst for new mobile computer-centric applications and have grown exponentially. Contrary to the early analog wireless voice services that enjoyed a quick and successful public acceptance in North America, the market penetration of its digital wireless counterpart has been slow and painful due to a splintered deployment of too many incompatible technologies, and has been shrouded in mystery.

The objectives of this research project are to shed light onto the current state of personal digital wireless data communications, both by investigating the evolution of its technologies and by field tests with the latest end user devices and public services. This combination helps to develop an awareness of today's public wireless services and applications, that is needed to make an informed decision on the use of wireless telecommunications by business and public alike. The focus is mainly on data services in New Brunswick and Canada, with an overview of the scenarios in the United States and overseas.

A complete inventory of public wireless WAN telecommunications technologies is presented first, from the early 1st generation analog technologies, such as AMPS, which are currently being decommissioned worldwide in favor of 2nd generation digital technologies, such as TDMA, GSM and CDMA. Emphasis is placed on recent data extensions, such as SMS, CSD, PSD and GPRS, leading to 2.5th generation wireless technologies as we have seen them emerge over the past 2 years. At this time GSM/GPRS is the dominant technology in the world with a 72% market penetration. An overview is given of the migration paths to 3rd generation wireless network infrastructures, that will take place over the next 5 years. This will eventually lead to a seamless integration of many types of wireless networks and accommodate mobile data and voice devices alike. In addition to public wireless systems, an overview is presented of wireless computer networks of the WLAN and WPAN type. While the WLANs have become a mature commodity, WPANs are just entering the market place and are still in their infancy. The incorporation of WLANs as lower tiers of public cellular networks offer their operators an interesting possibility to deliver more capacity and higher data rates to end users without depleting the capacity of the cellular systems.

In order to appreciate today's evolution of wireless telecommunications to next-generation systems, a review of the historical development is presented. Whereas Europe has learned its lesson from the failure of its early mix of multi-standard country-specific analog systems as a public commodity, and deployed a uniform single-standard GSM public telecommunications infrastructure, North America repeated the early mistakes of the European telecommunications bodies. After an unprecedented success of its early single-standard analog system AMPS, North America still suffers from the splintered deployment of up to 7 incompatible digital network standards, particularly in Canada where the generally low population density cannot support this

mix of technologies. Poor area coverage, isolated subscriber pools, no inter-network roaming, and a late adoption of digital data services caused the wireless telecommunications industry to fall behind the rest of the world. A quick and drastic reversal of this policy is needed, combined with a competition by services rather than by technology and closer co-operation between network operators, to bring sustainability back into this industry and afford subscribers an adequate geographic coverage, better digital data services and roaming across the continent and worldwide.

The United States lead Canada in the fragmentation of the digital wireless sector by licensing and deploying too many digital wireless network standards. However, starting in 2000, a collapse of this jungle of technologies became evident, leaving two major technologies, CDMA and GSM, offered by the major network operators. In addition, co-operation agreements between the three GSM operators continent-wide created a powerful lobby group and lead the way to better geographic coverage, unrestricted roaming and access for subscribers to their home services anywhere and anytime.

A survey of public wireless networks and services in New Brunswick revealed a patchwork of data offerings over multiple and incompatible networks with different subscriber plans. NBTel Mobility's offers different types of data services over three independent networks, CDMA, CDPD and Ardis. Similarly, Rogers AT&T offers separate data services over TDMA and Mobitex. Until early 2002, no provider has offered a single network solution for all data service needs. Rogers AT&T has introduced the global standard GSM/GPRS into New Brunswick during the 1st Quarter of 2002. This is currently the only network that has the potential to offer the elusive single-network/single end user device solution with cost-effective data transport mechanisms at acceptable data rates for all data activities, including voice. NBTel Mobility is planning to offer similar services by a move to the 2.5th generation CDMA2000 network by 2003.

End user devices are the means for a subscriber to participate in wireless telecommunication services. An overview of end user devices of the phone-centric type (e.g. cellular phones) and computer-centric type (e.g. PDAs) is given, along with their capabilities and limitations. Today we see a consolidation of legacy end user devices, such as phones and PDAs, into Smart devices, that seamlessly integrate data and voice communications into a single handheld device, particularly suitable for the business person on the move. Just recently released, there is still much room for improvement and an opportunity for both hardware and software developers to contribute integrated hardware and user-friendly client software solutions.

A set of wireless telecommunications field test were conducted over a 6 month period in New Brunswick and the Maritime Provinces. This hands-on investigation focused on the availability, usability and quality of network services including achievable data rates, the usability of end user devices and the content of network services. It was found that CDMA and TDMA based CSD services provide superior availability and usability, despite their need for dial-up. It was found that PSD services, such as CDPD, do not have the same desirable availability and desirable capacity, however offer 'always-on' connectivity as preferred for many long-term interactive data services. The measurement of effective data rates revealed unexpectedly to disappointingly low rates from

3.5 kbps to 10 kbps, much below the advertised maximum rates of 9.6 kbps to 19.2 kbps. The geographic coverage in major cities and along highways, both in New Brunswick and its neighboring Maritime provinces was found adequate, however rural areas receive poor to non-existent digital coverage.

A cost analysis based on a North American cost model was performed to highlight the cost incurred for both end user devices and operating cost, for typical data-borne business activities such as PIM synchronization, data base interrogation and web browsing. It is shown that CSD with its as-connected charge basis is cost-effective only for low-volume streaming data applications, whereas PSD with its as-used charge basis under various subscriber plans is cost-effective for a wide range of interactive data activities. A cost-optimizing strategy is presented with guidelines for the selection of the best subscriber plan. The existing practice of charging public wireless data services by a long-term package subscription (end user device and fee plan) is an inheritance of archaic Telco services of the past, creating an immobile pool of subscribers, poor selection of end user devices, a stagnant upgradability path to new technologies and a barrier for subscribers to benefit from competition among network service providers. This marketing approach needs to be changed to an open pricing policy, separated by services and end user devices, with flexible data-oriented and voice/data-combined fee structures. End user devices need to be available on the open market for unrestricted upgradeability to the latest technology as needed by business. The implementation of better user-administered charging systems, such as with GSM’s SIM card account, is required to render wireless data services more cost-effective to occasional users.

The services and applications offered through the wireless networks’ Content servers and portals were evaluated for their usefulness and value. A wide range of useful data services and applications are available today, such as SMS, WAP browsing, just-in time information services, location-dependent services and PIM synchronization, which are regarded as Killer applications worldwide. However, the late arrival of adequate public data-enabled wireless networks and data-oriented user fee structures in North America has delayed the public acceptance of these mobile services and applications. By the end of 2000 the penetration of mobile data users was 23% in Europe and 7% in North America. The unawareness of these services has also placed the provision of adequately formatted web pages for mobile end user devices, such as PDAs, on a low priority. While web services are plenty in English, only a few sporadic web sites were found in French. Both wireless network operators and web service/application providers need to expend further efforts into the creation and marketing of suitably formatted web sites, in both official languages, in order to tap into this almost untouched market for the business and private person on the move. A readily accessible range of just-in-time, location-dependent and entertainment features will be crucial to the success of mobile data services in the future.

Table of Contents

List of Figures

List of Tables

Glossary

AMPS	Advanced Mobile Phone System
CCT	Circuit
CDMA	Code Division Multiple Access
CDPD	Cellular Digital Packet Data
CF	Compact Flash (card)
CSD	Circuit-Switched Data
CSMA/CA	Carrier-Sense Multiple Access/Collision Avoidance
CSMA/CD	Carrier-Sense Multiple Access/Collision Detection
D-AMPS	Digital Advanced Mobile Phone System
DECT	Digital Enhanced Cordless Telephone
DoCoMo	Japan's Department of Communications for Mobility
DSSS	Direct Sequence Spread Spectrum
DUN	Dial-Up Networking
EDGE	Enhanced Data for GSM Evolution
EMS	Enhanced Messaging Service
ETSI	European Telecommunication Standards Institute
FDX	Full Duplex
FEC	Forward Error Correction
FHSS	Frequency Hopping Spread Spectrum
FPLMTS	Future Public Land and Mobile Telecommunication System)
FR	Full Rate (speech codec)
3G	3rd Generation
4G	4th Generation
GEO	Geostationary Earth Orbit
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobility (formerly: Group Special Mobil)
HDX	Half Duplex
HR	Half Rate (speech codec)
HSCSD	High Speed Circuit-Switched Data
IMT-2000	International Mobile Telecommunications - 2000
IMTS	Improved Mobile Telecommunications System
iDEN	integrated Data Enhanced Network
IEEE	Institute of Electrical and Electronic Engineers
IP	Internet Protocol
IrDA	Infrared Data Association
ISDN	Integrated Services Digital Network
ISM	Industry, Scientific and Medical
ISnn	Interim Standard #nn
ITU	International Telecommunications Union (formerly: CCITT)
LAN	Local Area Network

LEO	Low Earth Orbit
MAP	Mobile Application Part
MASC	Multi-Cast Address-Set Claim
MTS	Mobile Telecommunications System
NMT	Nordic Mobile Telephone
NTT	Nippon Telephone & Telegraph
OFDM	Orthogonal Frequency Division Multiplexing
PC	Personal Computer
PAN	Personal Area Network
PCMCIA	Personal Computer Memory Card International Association (card)
PCS	Personal Communication System/Service
PDA	Personal Digital Assistant
PDC	Personal Digital Communication
PDC-P	Personal Digital Communication - Packet Data
PHS	Personal Handiphone System
PIM	Personal Information Manager
PKT	Packet
PPP	Point-to-Point Protocol
PSD	Packet-Switched Data
PSTN	Public Switched Telephone Network
RF	Radio Frequency
SD	Secure Digital (card)
SIM	Subscriber Identity Module
SMS	Short Messaging Service
SS	Spread Spectrum
SS7	Signaling System 7
T9	Text-by-9-keys (Tegic)
TD-CDMA	Time-Domain - Code Division Multiple Access
TDMA	Time Domain Multiple Access
UMTS	Universal Mobile Telecommunications System
US, U.S.	United States
VHE	Virtual Home Environment
WAP	Wireless Applications Protocol
W-CDMA	Wideband - Code Division Multiple Access
WEP	Wired Equivalent Privacy (encryption)
Wi-Fi	Wireless Fidelity
WLAN	Wireless Local Area Network
WMAN	Wireless Metropolitan Area Network
WPAN	Wireless Personal Area Network
WWAN	Wireless Wide Area Network
3GPP	3rd Generation Partnership Project (for GSM members)
3GPP2	3rd Generation Partnership Project (for CDMA members)

1. Overview of Current Digital Wireless Communications Technologies and Standards

1.1 Introduction

Wireless communications systems use the air space as medium and modulated radio frequency (RF) signals as carrier of information. Although voice was the primary information carried in the early days of wireless communications, data has become a major source of information in the recent past. Today's modern digital wireless communications systems consider voice as a type of data, i.e. time-critical data, and thus integrate any form of information into one transparent data type.

Wireless communications systems are distinguished by the RF bands in which they operate and the modulation technique they use. This is called the air interface. The allocation of RF bands varies with country, and the use of the bands may be licensable or not depending on the band and national government regulations. Typical RF bands in use today are

800, 900 MHz and 1.8, 1.9, 2.1 GHz for terrestrial cellular WWANs;
2.4 and 5 GHz for terrestrial WLANs and WPANs.

Wireless communications systems are also distinguished by their geographical coverage, such as

wireless wide area networks (WWAN), more than 100 km, may be cellular-type;
wireless metropolitan networks (WMAN), 1km to 100 km;
wireless local area networks (WLAN), 10 m to 1 km;
Wireless personal area networks (WPAN), up to 10 m.

Wireless communications systems use a single shared medium for information exchange, the air space or ether. This medium represents a single collision domain for simultaneous transmission events. In addition, the geographical extent of this medium can render some stations invisible to some others. These peculiar properties distinguish wireless communications from wireline communications and raise challenges to control access to the medium and handle partly invisible stations. Wireless communications also suffers from considerable impairments due such effects as natural radiation, industrial RF emissions, microwave emissions (2.45 GHz), weather, obstacles causing reflections and multi-path effects. The resulting effect is a high error ratio of 10^{-3} to 10^{-6} as compared to wired/fibre links with ratios as high as 10^{-12}. These natural phenomena limit the achievement of increased data transmission rates by mere physical-technological advances and require sophisticated logical protocol advances for performance improvements.

Wireless communications systems use a limited RF real-estate which can accommodate only a finite number of communications channels, each having a certain bandwidth (about 4 kHz for voice). Early wireless communications systems share a limited number of RF channels for the

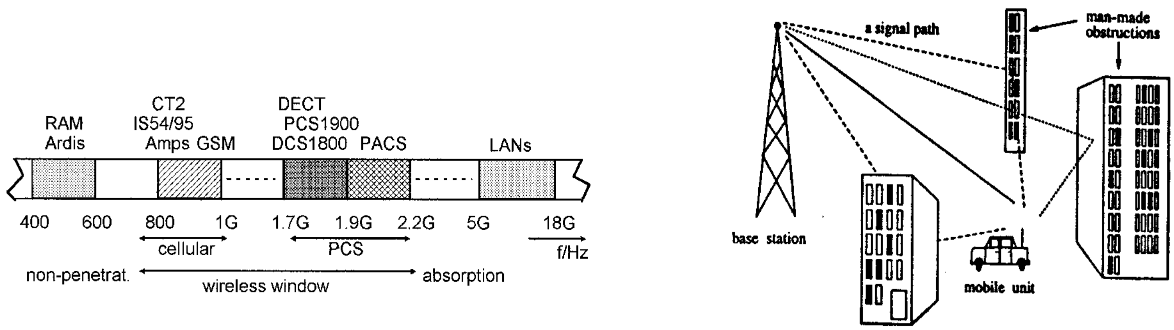


Fig. 1.1 Radio Frequency Spectrum for Wireless Telecommunications and Radio Frequency Propagation (left), and Impairment due to Multi-Path Reflections (right)

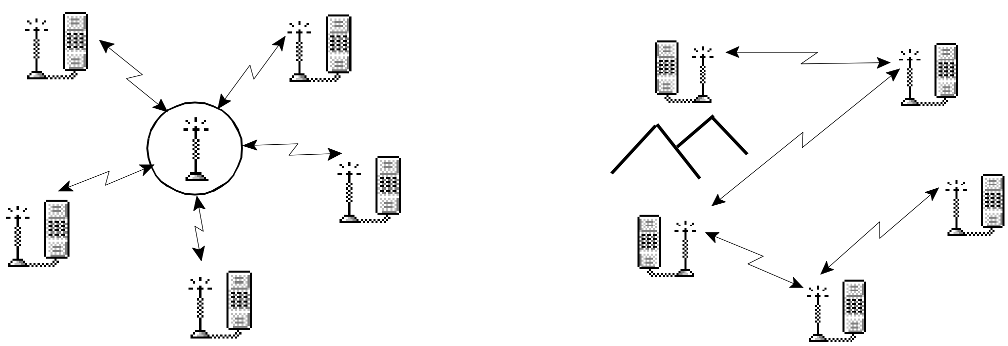


Fig. 1.2 Peer-to-Peer Networking (left) and Centralized Networking (right)

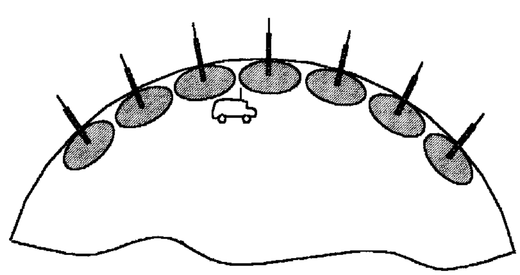


Fig. 1.3 Cellular Wireless Networking Scheme

entire coverage region, which severely limits the number of simultaneous connections. Most of today's wireless communications systems utilize a cellular approach which allows for the reuse of RF channels in geographically disparate regions with non-overlapping cell coverage. This permits a much higher number and density of simultaneous connections across a network of interconnected cells. The penalty for this advantage is an increase in complexity because of the requirement for hand-offs of calls from one cell to the next if the mobile network terminal is in motion.

Wireless communications systems are also distinguished by the communications scheme used to interchange information between network nodes. Most traditional systems use an access-point approach, where all communications travel through a central access point (base station), establishing a single point of control, but also a fixed network capacity and a single bottle neck of performance and failure. Some recent wireless systems promote a peer-to-peer scheme where all communications is relayed via the participating network terminals from source to destination, leading to a network with distributed control, a growing network capacity with the number of active terminals, and thus improved performance and diminishing failure rate.

Current wireless technologies and standards for WWANs, WLANs and WPANs are considered in view of their above-mentioned characteristics. A clear distinction is made between traditional public carrier networks (mostly cellular telephone) and general purpose computer-oriented networks. As a prelude, the early analog Advanced Mobile Phone System (AMPS) is also included as it is still used for data communications with digital extensions. Public carrier related wireless telecommunications technologies are commonly identified by their generation (time of introduction). The generations are indicated as 1G, 2G, etc. Digital wireless technologies of the 2^{nd} and 2.5^{th} generation (2G and 2.5G) are typically grouped together under the term PCS (Personal Communications Systems/Services).

1.2 Wireless Wide Area Networks (WWAN) - Public Carriers

(a) **AMPS** (Advanced Mobile Phone System, 1G) is one of the earliest (1984) analog wireless cellular communications system deployed in the Americas and some countries around the world. It is an analog system with no native digital or data capabilities. It operates in the 800 MHz range with 832 RF channels allocated to two competing public carriers. The analog modulation and fixed allocation of non-shared channels (one channel to one voice connection) make it a bandwidth-inefficient system with no simple technological means to improve its performance in the future.

Similar analog systems have been deployed originally in most countries around the world over the past 20 years, such as Nordic Mobile Telephone (NMT) and C-net in Europe and NAMTS in Japan. Today, AMPS and similar systems have come to the end of their life spans and are being decommissioned in some regions in favour of newer digital systems. As of early 2001, Europe, Australia, China and other regions have no more analog systems.

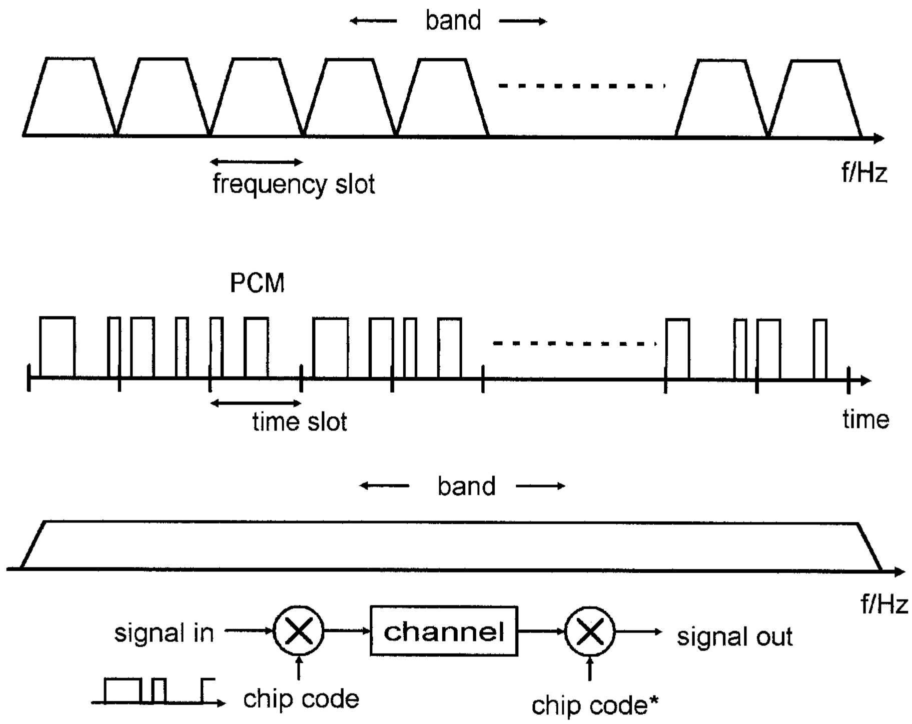


Fig. 1.4 Multi-Access Technologies for Wireless Networking
from top to bottom: FDMA, TDMA, CDMA

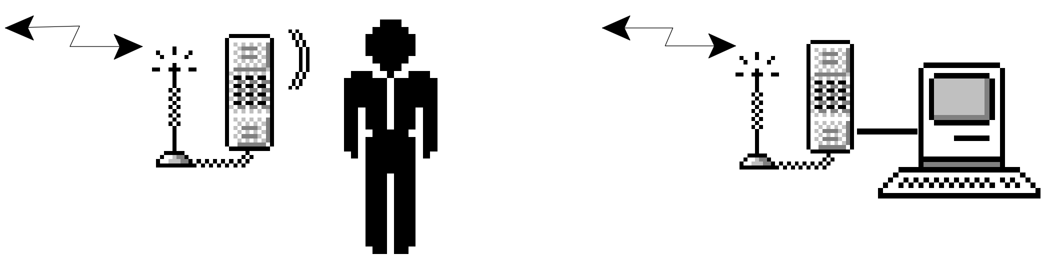


Fig. 1.5 Phone-centric (left) and Computer-centric (right) Wireless Access

(b) **TDMA** (Time Domain Multiple Access, 2G) is one of the earliest (1989) digital technologies for wireless cellular systems, although derivatives are also used by non-cellular wireless communications systems. TDMA is the basic technology deployed in the earlier D-AMPS (IS54) and was further developed and standardized as IS-136. It is a proven technology and is widely used in the Americas and some countries around the world. TDMA is actually a combined Frequency Domain Multiplexing (FDMA) and TDMA technology, although the single generic term TDMA is customarily used. The allocated RF band is segmented into narrow-band frequency channels (30 kHz), and each channel multiplexes 3 time slots that carry digitized voice from independent connections (9.6 kbps minimum per connection). The time slot allocation is fixed. This digital communications scheme improves the bandwidth-efficiency over analog schemes. Although the digital nature of TDMA would lend itself naturally to digital data transmission in addition to digitized voice, the emerging need for a full set of native data capabilities (messaging, packet-switching and circuit-switching) has not been foreseen at the time of its development, and thus the addition of seamless data integration has been a challenge. Circuit-switched data and SMS (short messaging service) were retrofitted at a later time. TDMA uses the IS41 signalling standard and operates in either the 800 MHz or the 1900 MHz range.

The TDMA technology has been the basis for successful further developments of newer time-multiplexed communications systems and standards, such as GSM (see the next section). However, there are no plans for further developments of TDMA itself, and most existing TDMA-based systems currently migrate to GSM systems.

(c) **GSM** (Global System for Mobility, 2G) is a cellular digital technology, based on the TDMA approach, with significant improvements in both bandwidth-efficiency and seamless integration into land-line digital telephone networks. GSM multiplexes 8 time-slots in a 200 KHz wide RF channel (9.6 Kbps minimum per connection). GSM was conceived in 1982 and developed in France by a research group called ‘Group Special Mobil’ (the original name for GSM) and has undergone an evolution from GSM I to GSM II with limited data integration. It was subsequently designated as the single standard for digital wireless cellular technology for Europe by the European Telecommunications Standard Institute (ETSI). Since then it has been adopted by over 170 countries and over 400 public cellular network operators around the globe, making it by far the most common digital cellular system in the world. Optional voice-activity detection improves the bandwidth-efficiency, and slow frequency-hopping improves the resistance to interference and has the beneficial effect of a statistical multiplexer. In addition, Full-rate and Half-rate (FR, HR) codecs are available to scale the number of simultaneous connections to the expected call density. GSM uses the MAP (Mobile Application Part) signalling protocol and operates in the 900 MHz, 1800 MHz (known as DCS1800) and 1900 MHz ranges, the latter mostly in the Americas (known as PCS1900).

GSM is not only an air interface, but defines an entire framework of integrated communications services, closely aligned with the prevalent digital telephony standard ISDN (Integrated Services Digital Network). Its MAP protocol runs over ISDN’s SS7 protocol as an extension. GSM offers basic native data services for digital data exchanges in the form of full circuit-switched data (CSD) and short-messaging service (SMS). Evolved services for improved digital data communications are offered by GSM's extensions GPRS (General Packet Radio Service, 2.5G) for packet-switched connections, HSCSD (High-Speed Circuit-Switched Data, 2.5G) for fast circuit-switched connections, and EDGE (Enhanced Data for GSM Evolution, 2.5G) for both switching techniques. GSM offers an early implementation of user mobility by its SIM card (Subscriber Identity Module). This processor-based Smart Card contains the subscriber's personal profile, such as Home network provider, telephone number, accounts, services subscribed, etc., which is transferred into the wireless handset once the card is installed in it. Thus, subscribers can take their identities from phone to phone in GSM systems around the world, making a convenient global roaming possible.

(d) **CDMA** (Code Division Multiple Access, 2G) is an advanced air interface technology which originates from military communications, using spread spectrum (SS) modulation. It combines very high bandwidth efficiency (i.e high subscriber density) and flexible variable data rates with robustness and security. CDMA does not segment an allocated RF band into narrow-bandwidth sub bands but each channel (9.6 Kbps minimum per connection) uses a full-width 1.25 MHz RF sub band, and all channel signals overlay in this sub band. This is achieved by spreading the narrow-band data signals' spectra over the entire RF sub band by either the Direct Sequence spread-spectrum (DSSS) or the Frequency-Hopping spread-spectrum (FHSS) modulation. The DSSS approach modulates a channel signal by a pseudo-random multi-bit sequence for wider bandwidth, whereas the FHSS approach moves the channels' spectra in a pseudo-random fashion across the wide RF sub band. The receiver extracts its signal information from the overlaid signals by a sophisticated correlation technique.

Despite their many advantages, earlier CDMA systems suffered from inherent problems, such as the 'near-far' problem, where transmitters near a receiver can overpower the latter and make decoding of spread signals from a far transmitter unreliable. Qualcomm developed a solution for this and other problem in 1989 and made the entry of CDMA technologies into the commercial digital wireless cellular market a reality, at the cost of complexity. Qualcomm's technology was subsequently standardized as IS95a (now called CDMAone) and is one of the dominant technologies in the Americas, and emerging gradually in other countries around the globe. IS95a allows up to 131 connections in a 1.25 MHz wide sub band with excellent voice quality. Although circuit-switched data capabilities were designed into the system, the emerging need for a full set of data capabilities (including messaging and packet- switching) was initially not foreseen, and thus no seamless data integration was available. SMS was added as a retrofit at a later time, and an evolved IS95b (2.5G) version was announced in 1997 with native packet-switching data capabilities of 64 Kbps. CDMA uses the IS41 signalling standard and operates in either the 800 MHz or the 1900 MHz range.

It is unlikely that installed CDMA-IS95a systems will be further developed for full data enabling. Rather, the current CDMA standard is evolving into CDMA2000 which forms the first step towards the next 3rd-generation wireless communications networks (3G).

(e) **iDEN** (Integrated Digital Enhanced Network, 2G) is a technology that evolved from the TDMA principles. The developer, Motorola, integrated several user-oriented data services in addition to digitized voice, such as two-way messaging, and group calls (conferencing). Networks based on iDEN are predominantly deployed in the Americas with some operations in Asia Pacific. iDEN operates in either the 800 MHz or the 1500 MHz range.

Because of its small market penetration, iDEN is not seen as a major player in the future digital wireless communications market, despite its desirable digital data capabilities.

(f) **PDC** (Personal Digital Communication, 2G) was developed in 1991 as a derivative of TDMA with special enhancements partly adopted from GSM that lends itself to regions with an extremely high connection (subscriber) density and expected high call congestion, such as city centres and indoor environments (e.g. malls, offices). PDC is the most efficient TDMA technology in existence, comparing favourably with CDMA. In most congested areas it can double the available channels by reducing the communications quality. It has a native digital data support, and with its extension PDC-P the system also offers packet-switched data connections in addition to circuit-switched data and messaging. Group calls (virtual private networks) are possible. PDC also supports user mobility by personal Universal Access Numbers. PDC operates in the 800 MHz and 1500 MHz ranges.

PDC is currently used only in Japan with its very high population density..

1.3 Wireless Wide Area Networks (WWAN) - General

(a) The **Iridium** satellite-based telecommunications system (1992) was the first attempt to build a WLAN with truly global coverage by a single-standard system. Motorola was the leader in this vison. In order to allow RF transmission and reception with low-power handheld devices and much shorter propagation delays, a low-earth-orbiting (LEO) system of 66 satellites was conceived which orbit the earth at an altitude of 780 km, rather than using 3 to 4 geostationary satellites (GEO) at a distance of 35,800 km. The VSAT satellites' (very small aperture terminal) limited coverage on earth create a cellular-type network, however with the cells moving continuously. Voice and low-rate data communications (2.4 Kbps) are supported, as well as global paging services.

Due to the initial high cost of end user devices (phones) and tariffs, the services were targeted at resource businesses, exploration activities, construction, and the like, rather than at every-day use by ordinary people. Iridium was said to have discontinued its services in the recent past, but they have been made available again in Canada and elsewhere in Spring 2001.

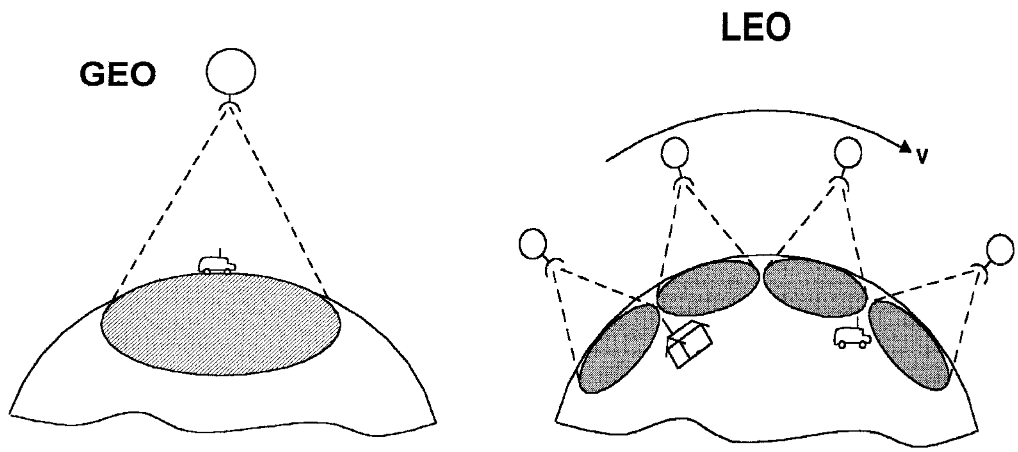


Fig.1.6 Satellite Communications Schemes
Geo-stationary-orbiting (left) and Low-earth-orbiting (right) Systems

Source: globalstar.com

Source: sagem.com

Fig.1.7 Example of Satellite Phone Ericsson R290

Fig. 1.8 Example of DECT Phone

(b) **Globalstar**, in 1999, started up a second version of a LEO-based satellite telecommunications system, similar to Iridium. A constellation of 48 satellites cover about 80% of the earth's surface from an altitude of 1,414 km. Gobalstar uses CDMA/SS technology over a 1.23 MHz wide channel within the Ka band (18-31 GHz). Advanced hand-held multi-band/multi-mode phones are now available that can be used to either access Globalstar's satellite network or either one of AMPS, GSM or CDMA cellular public carrier networks. Globalstar supports messaging services, fax and streaming data (up to 9.6 Kbps) in addition to voice. Satellite communications requires a direct line-of-sight to the satellite, and indoor connections are normally not possible.

Since February 2001 Globalstar's services are available in Canada.

1.4 Wireless Local Area Networks (WLAN) - Public Carriers

(a) **DECT** (Digital Enhanced Cordless Telephone) is a technology that provides voice and data communications in a local environment. Similar to the common cordless telephones, it offers many features of TDMA. DECT was developed through ETSI (original name is European Enhanced Digital Telephone). DECT was perceived as a cellular system with access nodes at every street block in a city. With its small-size micro cells it ideally suits public residential or corporate environments, accommodating a much higher connection density than standard cellular systems such as GSM. Roaming from cell to cell is possible by an optional automated or manual hand-off procedure. DECT phones also allow local intercommunications among themselves via an access point without incurring any call charges. In addition to voice, the DECT technology offers digital data communications at a rate up to 552 Kbps. DECT operates in narrow parts of either the 1800 MHz or the 1900 MHz range.

DECT has been deployed in Europe and is seen as a complement to GSM, serving the residential subscriber base. Interconnectivity with, and roaming in, GSM cellular systems are part of the future standards for multi-tier wireless telecommunications systems. The first DECT-compliant telephones have just become available in North America, though as stand-alone systems with multi-handset capability but without many features, such as data capability and automated roaming. They are operating in the 2.4GHz band.

(b) **PHS** (Personal Handiphone System) is an equivalent to the DECT system and is exclusively used in Japan.

1.5 Wireless Local Area Networks (WLAN) - General

(a) **IEEE 802.11**

The first widely accepted standard for wireless local area networks was introduced in 1997 by the Institute of Electrical and Electronic Engineers (IEEE). The 802.11 standard defines a family of WLANs with varying performances from 1 to 54 Mbps, centralized

(Infrastructure) and peer-to-peer (Ad-hoc) access modes and automated roaming between local cells (Service Sets).

802.11b (Wi-Fi)

Currently, the most popular standard is 802.11b, also called Wired-Fidelity (Wi-Fi) if the implementation adheres fully to the standard. It defines the architecture and operation of a wireless LAN with data rates up to 11 Mbps, reliable data delivery and two operating modes, peer-to-peer (ad hoc) and via central access point (infrastructure) for interconnection with other networks. The MAC layer protocol is similar to the Ethernet protocol (Carrier-Sense Multiple Access with Collision Detect, CSMA/CD) but accounts for the fact that all RF transmissions take place in a shared collision domain (space) and resolves the problem of hidden nodes, i.e. their RF transmission is invisible to a subset of other nodes in the network, by using the Carrier-Sense Multiple Access with Collision Avoidance (CSMA/CA) protocol. The 802.11b WLANs function similarly to Ethernet LANs with a faster rate of performance degradation due to the complexity of the access protocol.

The typical range of 802.11b WLANs is up to 100 m outdoors and 20 to 40 m indoors, however outdoor reliability is questionable due to a high susceptibility of the RF transmission to humidity. Connectivity is severely limited by solid walls and steel ceilings. It is possible to build a net of adjacent WLANs, each occupying a different non-interfering channel, (3 out of 13 channels in North America) similar to a cellular network. As well, up to 3 geographically-coincident cells can be deployed to achieve an aggregate data rate of 33 Mbps for high-density communication environments. However, the limit of 3 overlapping RF channels makes scaling of 802.11b a difficult process. IEEE 802.11b-based WLANs support automatic roaming between the individual WLANs. Network components compliant with 802.11b are also compatible with the former lower-bit rate versions conforming to the original 802.11 standard (1, 2 and 5.5 Mbps). The 802.11b standard utilizes the unlicensed 2.4 GHz ISM (Industry, Scientific, Medical) band, using DSSS modulation technology. The transmission power is typically 100 mW (0 dbm) with permissible power to 1 W (20 dbm) in North America only (mostly for long-distance and outdoor applications).

The 2.4 MHz RF band is also used by other commercial wireless devices, such as cordless phones, audio/vide transmitters, industrial RF applications and microwave ovens. Thus, this band is in danger of becoming overcrowded and offering a very noisy environment for future usage. In addition, the 2.45 MHz RF frequency is one of the resonance frequencies of water molecules and, thus, absorbed readily by moisture (used by microwave ovens for heating). As a consequence, this frequency is not ideal for wireless outdoor applications.

A large number of 802.11b-compliant network components are available off the shelf. This has lead to low-cost WLAN solutions with reliable acceptable indoor performance close to the wired 10 Mbps Ethernet LAN. The 802.11b technology has become a commodity, it is mature with excellent vendor-interoperability, wide operating system support and ease of

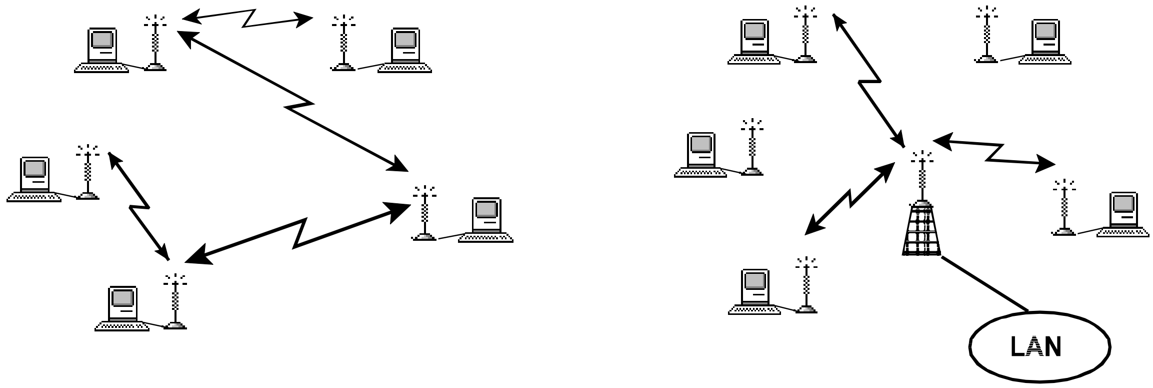


Fig. 1.9 Operating Modes of IEEE 802.11 WLANs
Ad-hoc mode (left) and Infrastructure mode (right)

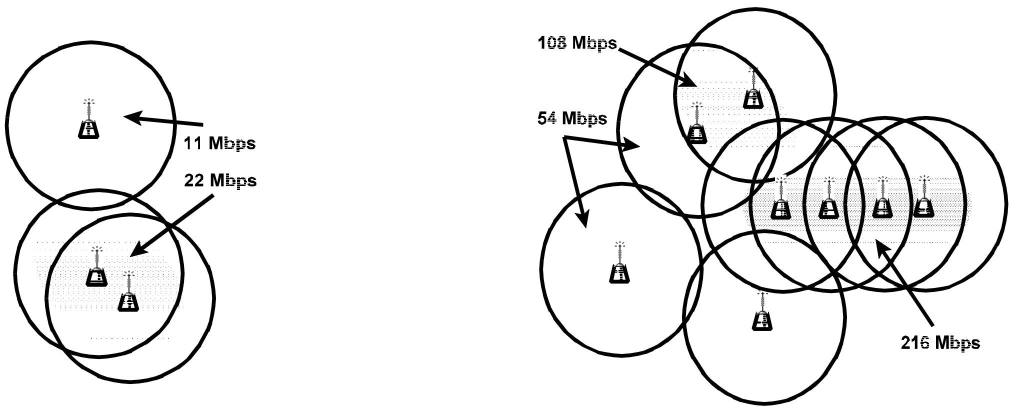
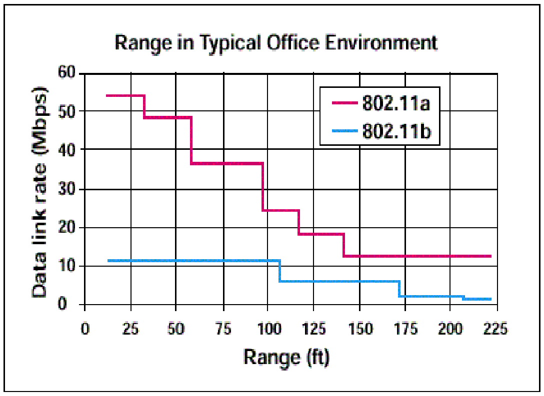


Fig. 1.10 Scalability of IEEE 802.11 WLANs
Three overlapping cells for 802.11b (left) and 8 overlapping cells for 802.11a (right)



Source: Atheros Communications Inc.

Fig. 1.11 Expected Range of IEEE 802.11 WLANs installation and use with computerized equipment.

IEEE 802.11a

The 802.11a standard defines a WLAN with data rates up to 54 Mbps and operation modes identical to the 802.11b standard (see above). Although defined in 1997, it did not immediately gain the same wide-spread acceptance as 802.11b. However, the need for higher data rates and better scalability than offered by its 11 Mbps counterpart has spurred an accelerated development of 802.11a devices, which are now appearing in the market place. The IEEE 802.11a standard is based partly on ETSI's Hiperlan 2 wireless local area network. IEEE 802.11a is a current standard in North America but only a draft standard in Europe until conflicts with the existing Hiperlan 2 are resolved.

The typical range of 802.11a WLANs is up to 100 m outdoors and 20 to 40 m indoors. The RF propagation is well suited for outdoor applications, but connectivity is even more severely limited by solid walls and steel ceilings because the RF waves are readily absorbed and attenuated by any obstacles in the line-of-sight. The standard offers up to 8 non-overlapping RF channels, thus simplifying the efficient planning and layout of multiple cells environments. As a result, it has an improved scalability for high-density communication environments, where up to 8 geographically-coincident cells can be deployed to achieve an aggregate data rate of 432 Mbps (low and middle bands). Network components compliant with 802.11a are not compatible with the 11 Mbps version 802.11b.

The 802.11a standard utilizes the unlicensed 5 GHz U-NII band, using orthogonal frequency domain multiplexing (OFDM) technology. This frequency band is little populated at this time and is affected much less by interference of other RF sources. This band is subdivided into 3 ranges, each one dedicated to specific applications. The low range (5.15-5.25 GHz is geared to short-range indoor applications with a maximum transmit power of 50 mW, the medium range (5.25-5.35 GHz) is meant for longer-range indoor applications with up to 250 mW, and the high range (5.725-5.825 GHz) is reserved for outdoor building-to-building links with up to 1 W transmission power. Due to the separation into 3 non-overlapping frequency bands, communications systems with different characteristics do not compete with each other.

The first 802.11a products are currently appearing in the market place (February 2002).

(b) **Bluetooth (IEEE 802.15)**

The Bluetooth wireless personal area network standard (named after the Danish king Harald Blaatand, 940-981) is an emerging standard for short-range wireless links, intended to replace cabling between portable and fixed electronic devices. Its key characteristics are robustness and transparent use, low complexity and low cost. Bluetooth was developed by Ericsson of Sweden in 1994. Despite being an industry standard, it has gained worldwide vendor support as of this time.

Bluetooth builds a short range peer-to-peer network (pico-cell) with up to 8 devices and link lengths up to 10 m. Bluetooth networks are normally not permanent. A network is established within a limited region (<10 m) whenever a minimum of two Bluetooth devices discover each other and communicate. This network disappears when all devices leave the area of coverage. Bluetooth is a personal area network and is meant to be controlled by one person at a time. It has no roaming capability and entry into an existing network requires a strict authentication procedure. Bluetooth provides communication channels for voice (dedicated) and for packet-switched data (shared) at an aggregate data rate up to nominally 1 Mbps. Channels are configurable symmetrically or asymmetrically at varying data rates. A future version is planned to have a nominal 2 Mbps data rate for improved multi-media applications and a larger link range. LAN access points are available to form clusters of devices connected to a larger LAN, enabling global connectivity of Bluetooth devices, e.g. over the Internet. Bluetooth operates in the unlicensed ISM-band at 2.4 GHz, It uses shorter packets and thus gains precedence over IEEE 802.11b WLAN transactions. IEEE is currently developing a draft standard 802.15 for the Bluetooth technology and its coexistence with 802.11b WLANs.

Early Bluetooth network products, that became available in early 2001, were mostly cellular phone-related, such as wireless hands-free handsets and connectivity kits for phones with PC computers. Other specific applications followed, such as automotive sanity-monitoring with alarm messages sent to cellular telephones, and local wireless access to vending machines through Bluetooth-enabled cellular phones. By the end of 2001 an explosion of Bluetooth-based computer devices took place. Laptop computers (IBM, Sony) and PDAs (iPaq) are available with built-in Bluetooth modules, as well as printers (HP) and wired LAN access points. A range of PCMCIA and CF card adapters are available to retrofit any computer device with Bluetooth connectivity. The various communication activities are enabled by software clients (called Profiles), accompanying each Bluetooth device. Profiles include communication activities such as service discovery, serial access, dial-up networking, LAN access, file transfer, printing and handset (microphone and speaker) operation. The fast-paced hardware development was, however, not quickly enough followed by the software tools. Currently, Bluetooth networking suffers from the lack of vendor inter-operability, extensive profile implementation, operating system support, and the lack of a user-unfriendly set-up and operation. This is expected to be remedied before the end of 2002.

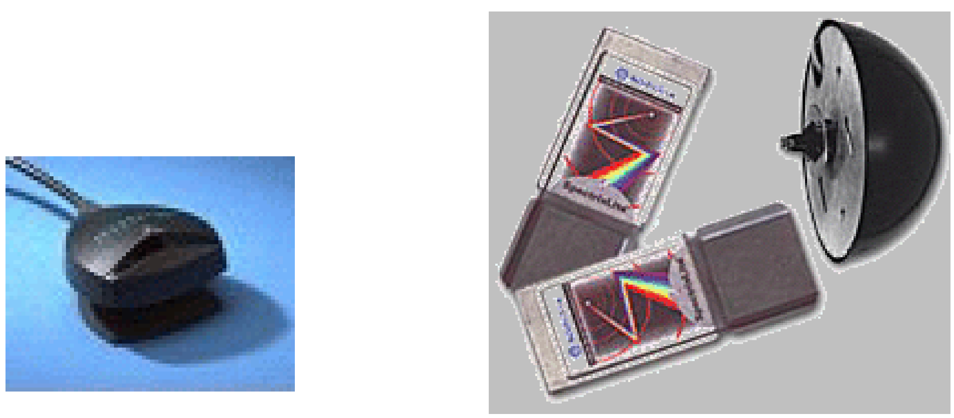
(c) **Infrared (IrDA)**

Infrared (IR) data communications technology uses invisible infrared light at approximately 850 nm wavelength as medium. This is a non-licensable medium requiring a clear line-of sight between the communicating devices. The use of IR data communication was pioneered by remote controls for television sets and similar devices. For computer-oriented data communications the Infrared Data Association has established the IrDA networking standard, now being deployed in many laptop computers, PDAs and phone devices.

Source: sonyericsson.com

Source: compaq.com

Fig. 1.12 Examples of Bluetooth-Enabled Devices
Ericsson T68 phone (left), Motorola, with Wireless Headset (centre), Compaq iPaq H3870



Source: extendedsystems.com

Source: spectrixcorp.com

Fig. 1.13 Examples of IrDA Networking Devices
Xtend IR USB Adapter (left), Spectrix IR PC-card adapters and IR Access Hub

IrDA networking establishes a point-to-point communications link up to 1 m (WPAN) at data rates at 115 kbps to 4 Mbps, depending upon the computer device's capability. Automatic service discovery and authentication are part of the protocols, as well as file transfer and dial-up networking. IrDA technology is widely used for synchronization of Personal Information Managers (PIMs) in cellular phones, pocket, handheld and laptop computer devices and has grown into a mature, reliable and unobtrusive technology.

Commercial IR WLANs have been pioneered by Photonics in early 1990. IR WLANs operate up to 10 Mbps and can replace standard wired 10 Mbps Ethernet LANs and 11 Mbps RF-based WLANs (802.11b) with similar performance but at a lower costs than the wireless RF counterpart. The coverage is up to 30 m omni-directionally and up to 300 m with directed IR beams. IR LANs offer unique characteristics such as being secure and safe, which lend these networks ideally for specific applications where RF-based WLANs are inappropriate. IR light is containable in closed rooms with no energy escaping into adjacent areas, so no eavesdropping is possible, and a secure network is established. IR light does not produce and is not affected by electromagnetic radiation. Thus, IR networks are permissible for use in hazardous and explosion-prone areas, and they are advantageous in industrial areas heavily contaminated by radio-frequency noise.

Although IR LAN technology has not kept pace with the market penetration of RF-based WLANS, such as IEEE802.11b, they have found use in niche areas where other LANs are not suitable as mentioned above. Spectrix, Extended Systems and Photonics are the main manufacturer of IR WLAN networks.

1.6 Digital Data Capabilities and Data-Only Networks

First generation analog wireless communications systems, such as AMPS, were designed for voice communications only and have no native data capabilities. Even early standards of digital wireless systems of the 2nd generation, which treat voice as digital data, often have no full set of data communications capabilities (messaging, packet-switching and circuit-switching). Most systems were retrofitted with a circuit-switched data capability using the voice channel and a rudimentary text messaging, using the signalling channels. The latter includes the Small Messaging Service (SMS) of GSM, and similar but more advanced message services in iDEN and PDC.

For data communications purposes two data delivery arrangements are distinguished, depending upon the delivery location of data at the mobile subscriber location. In the phone-centric case, the data-related client software is part of the cellular telephone device and processes the data internally, e.g. for display purposes. SMS operates this way. In the computer-centric case the data is received by the phone device or wireless modem and routed to a data port, where it can be accessed by a connected electronic device and its client software, such as in a PDA (Personal Digital Assistant) or lap-top computer.

Different data communications applications require different data transport mechanisms to be used efficiently and economically. Bursty data traffic, e.g. e-mail and Web browsing, benefits from a packet-switching protocol, where idle times on a channel can be used for other active data streams. This channel sharing reduces the cost of communications and tariffs are typically based on the number of packets transferred and not on the connect time. IP-based packet switching capabilities are preferred today because of immediate interoperability with the global Internet. On the contrary, time-critical data streaming applications, e.g. for video and other multi-media streams, require a reserved channel with guaranteed data rate, such as offered by circuit-switched connections. Because of the dedicated use the tariffs for this type of data communications are based on connect time, and sessions have to be established for each communications session.

Both types of the above-mentioned data communications facilities are offered as extensions to several current wireless telecommunications standards. Circuit-switched connections need to be dialled-up to a special data port (phone number). The packet-switched connections are normally 'always on' without the need to establish a session.

(a) **CDPD** (Cellular Digital Packet Data) implements packet-switched data communications on the 1st generation analog AMPS network. CDPD was developed by IBM and McCaw Cellular Communications. CDPD is an additional protocol layer over the AMPS air interface, accepting IP-based data packets from the network and forwarding the packets over idle channels to a mobile device, such as a telephone, PDA or lap-top computer, the latter two devices requiring a CDPD modem. CDPD activities are normally pre-emptible by voice activities and thus no consistent data rates can be guaranteed. An option exists to dedicate one or more voice channels to data only and have data subscribers compete over those channels. CDPD typically operates at up to 19.2 Kbps, but can fall back to much lower effective rates if the voice network becomes busy and congested. The IP-based packet transport offers ready interoperability with the global Internet. As a packet-switched method it is 'always on' and usage fee is normally based on the number of packets transferred.

Because CDPD is used with the older analog networks with no further enhancements planned, it is a terminal technology.

(b) **SMS** (Short Message Service) is an integral part of the GSM wireless communications systems to communicate short messages to/from a cellular telephone via the central telephone switch. Both one-way and two-way SMS implementations are available. In a two-way deployment cellular phones can also send messages to the central switch provided that the phones permit text entry on their keypads. A SMS message can contain up to 160 text characters. The EMS extension also accepts binary files, such as small graphics, animations and sound files (ringing tones). The SMS service is internally implemented as a packet-switched service normally using the signalling channels, thus the tariff is based on the number of packets transferred.

Native SMS, as initially conceived for GSM, uses the telephone number as destination address. SMS messages are relayed to other mobile phones by a network-internal SMS gateway, creating a very responsive messaging system. In 1999 SMS-like messaging has also been incorporated into other 2nd generation PCS systems, such as TDMA and CDMA but because of incompatibilities native SMS roaming is patchy. In order to extend the roaming range ‘SMS e-mail’ has been introduced. Here, SMS is used as a transport mechanism for short e-mails and is processed by an E-mail gateway with store-and forward into the Internet. The limit of 160 characters per SMS message is a disadvantage to this application as longer e-mails need to be segmented into multiple SMS messages, although an extension to 469 user characters (3 concatenated messages) is offered by some networks.

Native SMS has been available in GSM systems since early 1990. It is often used for notifications of incoming voice-mails, for the replacement of pagers, and for short personal message exchange. In a push-mode it is used to update news, stock-quotes and location-aware (i.e. cell-aware) short advertisements. SMS has become so popular that in Fall 2000 the number of SMS messages sent has exceeded the number of voice calls made in European GSM systems, reaching 200 Billion SMS messages worldwide in 2001.

(c) **GPRS** (General Packet Radio Service, 2.5G) is an extension to GSM that permits packet-switched data communication. It is integrated into the GSM system and uses one or more time-slots to carry digital data. Each time-slot can carry a varying amount of data depending upon the encoding scheme, yielding channel rates of 9,600 to 21,400 bps. Current implementations support 9,600 to 13,100 bps (GSM vocoder voice codec). Thus, varying data rates from 9,600 bps (1 time-slot) to a theoretical maximum of 171,200 bps (8 time-slots) are achievable. Currently, implementations up to 115 Kbps are practible. Due to the error recovery protocol, the actual user data rates are lower than stated above. The used time-slots are shared with other services and thus the actual data rates can be lower when the network is busy and congested. As an IP-based packet-switching method GPRS is ‘always on’ and the usage fee is normally based on the number of packets transferred.

GPRS is the first step of the migration path for GSM to 3rd generation systems (3G) such as UMTS. The packet-switching nature of GPRS significantly improves data-based services, such as E-mail and Web browsing, as well as bandwidth-hungry multi-media services to both phones and attached electronic devices and makes these bursty data services deliverable in a cost-effective manner.

(d) **HSCSD** (High-Speed Circuit-Switched Data, 2.5G) is another extension to GSM for fast circuit-switched connections. Contrary to voice, which always uses one time-slot per connection, HSCSD can use multiple time-slots (up to 4 for uplink and up to 4 for downlink simultaneously) to achieve high data rates over reserved connections, and is thus suitable for time-critical multi-media communication. Guaranteed data rates are 9,600 bps (1+1 time-slots) to 38,400 bps (4+4 time-slots) per direction in full-duplex mode. Extensions to 14,400 bps per time-slot are planned, for a total of 57,600 bps per direction. As a circuit-switched technology a session has to be established for every connection with the required number of time-slots, and the usage fee is based on the number of channels used and the connect time.

HSCD is the companion extension to GPRS in the first step of the migration path to 3rd generation systems (3G) such as UMTS.

(e) **EDGE** (Enhanced Data for GSM Evolution, 2.75G) is envisaged as an extension to GSM, combining both packet-switched and circuit-switched data communications in one module. Thus, it replaces both GPRS and HSCSD. By using more advanced modulation techniques, the achievable data rates are higher, up to 384,000 bps.

EDGE was developed for a face-paced migration of GSM to 3rd generation systems (3G), such as UMTS. It is expected that most GSM cellular network providers will move to EDGE within 2 to 3 years after the introduction of GPRS.

(f) **CDMA IS95b** (2.5G). The CDMA-based digital wireless standard IS95a does not have a full set of native data communications capabilities. A packet-switching data communications service at 64 Kbps has been included as part of enhancements in the standard IS95b announced in 1997. It is unlikely that this standard will be deployed widely because it would quickly be superceded by the migration to the 3rd generation systems (3G, CDMA2000). In CDMA IS95a systems data communications is only possible by using an established voice circuit and routing the data to the external port of, e.g. a cellular telephone. For bursty traffic, such as Internet browsing or data base inquiries, this is however a costly solution.

(g) **Mobitex** is a packet-switched data-only network developed by Ericsson. It provides personal services, such as Internet access, two-way paging, wireless banking and news and stock quotes. For businesses, it extends company intranets and gives access to company resources for people on the move, enabling such tasks as submitting service orders, credit card verification and remote monitoring and servicing, and remote meter reading. In addition, many third-party applications are accessible through Mobitex. Mobitex is a turn-key approach to wireless communications with standard PDAs (Palm, Blackberry) and lap-top computers with the appropriate Mobitex-enabled modem installed. Mobitex requires a proprietary MASC (Multi-Cast Address-Set Claim) protocol above the air interface for network access. It can carry data at rates up to 19.2 Kbps and operates in the 800 MHz and 900 MHz ranges.

The Mobitex network is often used to add digital data capabilities to 2nd generation wireless cellular networks without this capability, such as TDMA. Rogers AT&T is a service provider for Mobitex in Canada, and Cingular Networks (previously Bell-South) in the US.

(h) **Ardis** (also called DataTac) is a turn-key approach to wireless data-only networking similar to Mobitex. It provides similar personal and business services and has a large following by leading Fortune100 companies, such as IBM, Pitney Bowes and NCR. Ardis was developed by Motorola. It carries data at rates up to at 19.2 kbps and operates in the 800 MHz range.

Ardis enables digital data capability for 2nd generation wireless cellular networks without this capability, such as CDMA. Bell Mobility is a service provider for Ardis in Canada, and Motient Networks is a provider in the US.

(i) **Ricochet** is a high-speed data-only network (28.8 Kbps to 128 Kbps) developed and deployed by Metricon. It has been available only in the major US urban areas until end of 2001 when it went out of business.

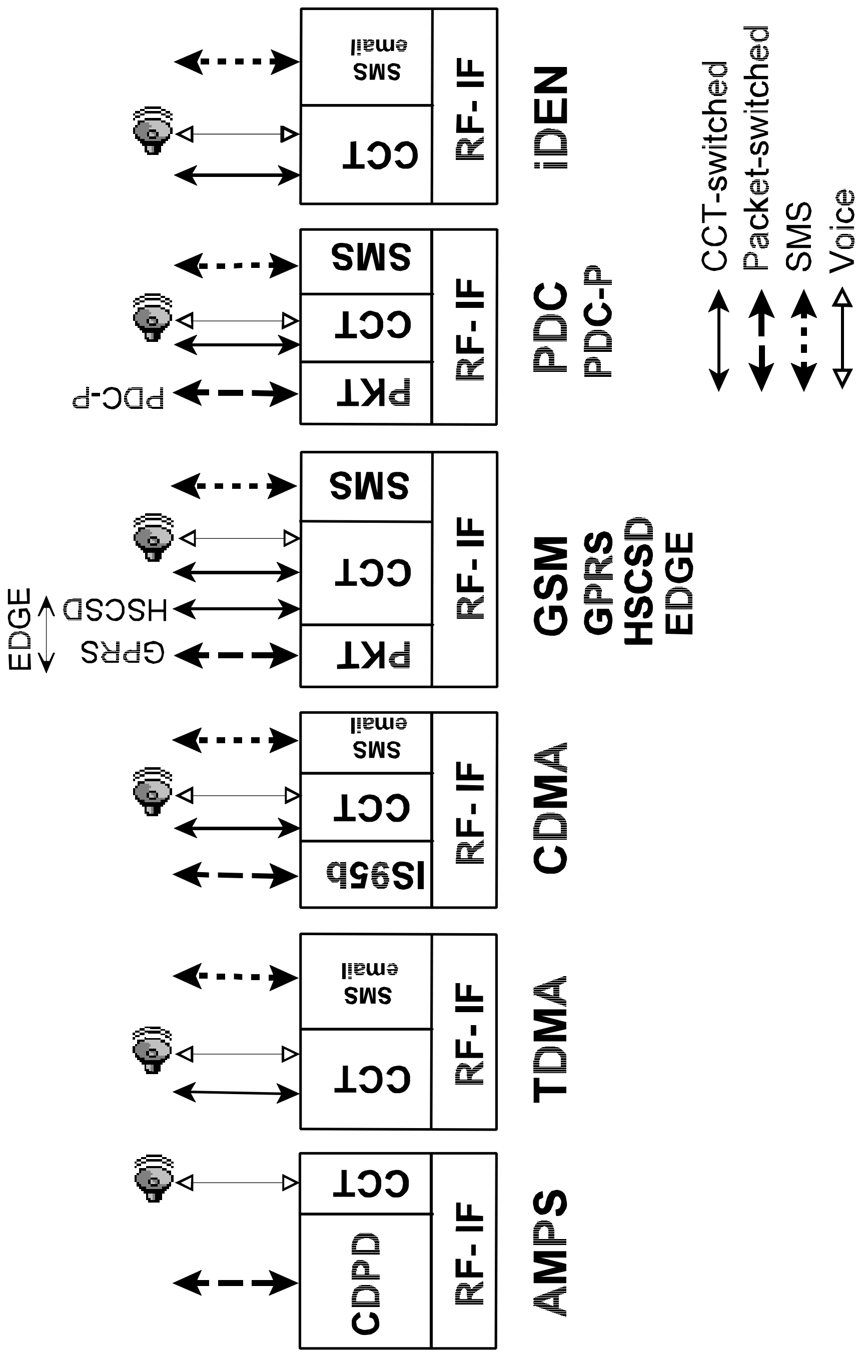


Fig. 1.14 Voice and Data Capabilities of Digital Cellular Technologies

2. Brief History of Evolution of Wireless Communications

It is informative and interesting to investigate the evolution of wireless communications in various regions of the world. The different avenues and paces that lead to today's state of the public wireless telecommunications systems in each region reveal that different forces are at work in each area. Because of their importance in population size and the creation of innovative technology, the three regions Americas, Europe and Japan, are used as examples. Each region evolved very differently in the past, and this development was shaped by one or more of the following forces: geography, population density, technology awareness of business and residents and the monopoly of public carriers.

2.1 Americas

The mobile wireless communications era started in 1947 with the Mobile Telecommunications System (MTS), followed by the Improved Mobile Telecommunications System (IMTS) in 1964. Both systems were analog and non-cellular, that is they were restricted to too few connections in a large coverage area to become a suitable personal communications technology for wide-spread public use. These systems pre-date the cellular era.

Starting in 1984 a 1st generation single-standard analog cellular communications system, AMPS, was deployed by all public carriers in the US and Canada. AMPS allowed for a competition by two cellular service providers, called wire-line and non-wire-line, to offer competitive voice-only services, by allocating one half of the available 832 voice and control channels in the system to each provider. This regulation made possible the use of the same type of central base hardware by the providers and the same cellular phones by the subscribers. By virtue of scale and a large number of deployments of the same hardware by a range of network providers, this lead to a relatively cost-effective implementation of the cellular infrastructure. It also made switching between providers easy and allowed continent-wide roaming, where agreements exist between providers.

The uniform cellular environment established by AMPS was conducive to an extensive area coverage, regardless of geography and population clustering, and subsequently to a quick public acceptance of cellular telephony. The single standard made cellular telephones affordable for subscribers. It was this coherent approach that lead to an explosion in subscriber numbers in the first 10 years of service.

With the advent of digital personal computers (PC) which could be networked, by end of the 1980 decade, the need for digital data services arose. AMPS did not have this capability by design. Therefore a data-enabling overlay was developed to enable digital data communications over the analog cellular network, either through analog phones, used as RF modems, or through separate RF modems connected to PCs and lap-top computers. The CDPD technology satisfied this requirement. I has since then mostly been used by government, industry and businesses. As a consequence, the CDPD facilities are still sporadically distributed in region where business use warrants it.

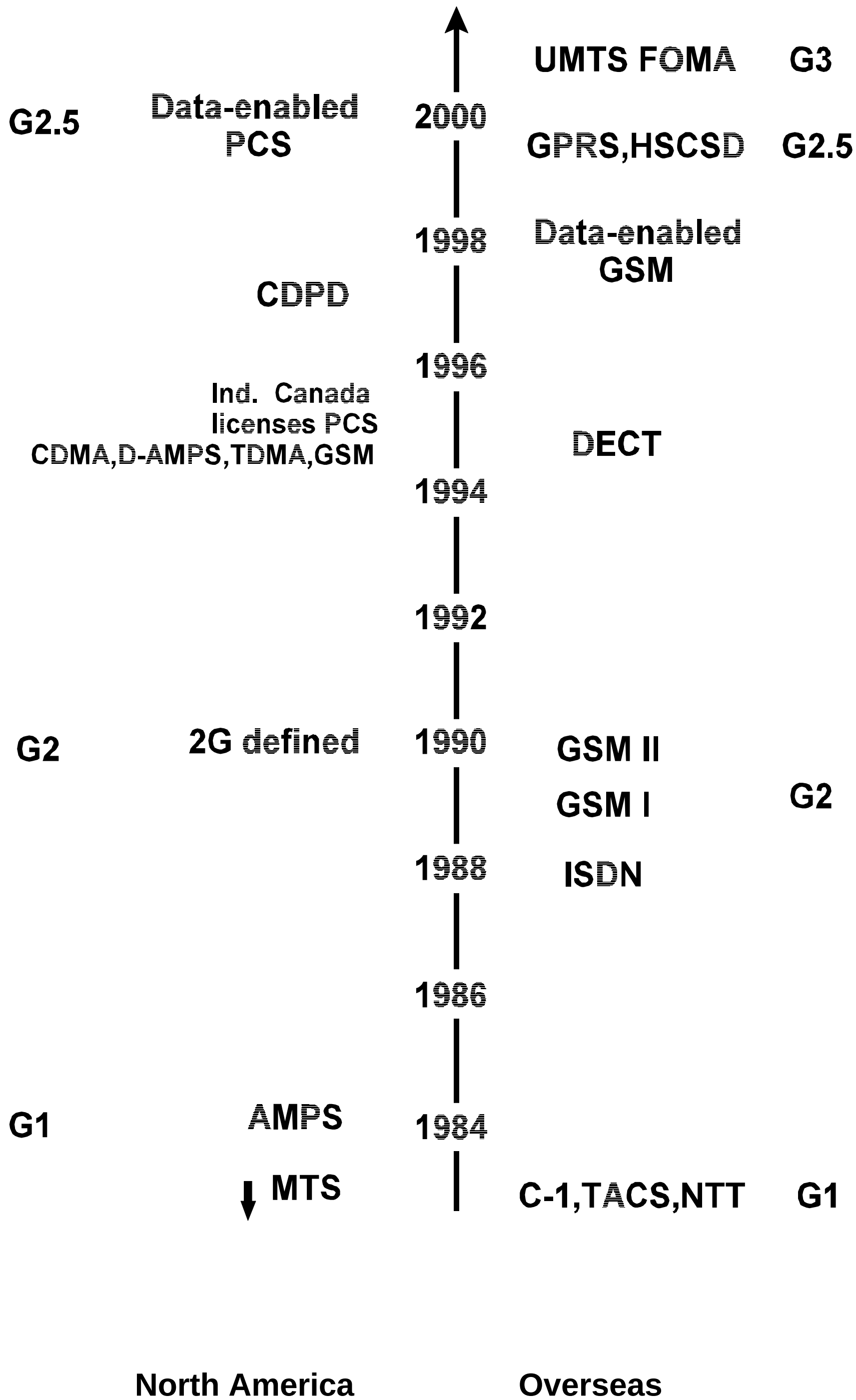


Fig. 2.1 Time-Line of Historical Evolution of Public Cellular Telecommunications

Starting in 1990, national and international standards started to emerge defining the 2nd generation of digital wireless communications systems. In 1994, Industry Canada approved and allocated four different digital wireless technologies to four different service providers. These technologies were not dictated by government but chosen by the participating telecommunication service providers. Canada thus followed the path that the US laid out earlier. In Canada these technologies and providers were:

CDMA (IS95a, by Qualcomm)	Mobility Canada
TDMA (IS136)	Cantel (today Rogers AT&T)
TDMA (D-AMPS, IS54)	Clearnet (now Telus Mike)
GSM (PCS1900 at 1900 MHz)	Microcell (today Fido).

Unfortunately, all four technologies were incompatible. The need for different end user devices (phones) for the systems made inter-operability and inter-roaming impossible. This lead to a duplication of network resources and isolated subscriber pools. The benefit of scale for a cost-effective infrastructure implementation thus failed to manifest itself again as a catalyst for a fast-paced deployment, as it did during the earlier AMPS era. The diversity of infrastructure might have lead to stronger competitiveness and advantages to the subscribers if the environment had been suitable to maintain the profitability of all four providers, such as in a country with a larger and more uniformly-distributed population as the US. In hindsight, this approach failed in Canada because of its vast geographic coverage and its small and clustered population. The result is that today only two public carriers (Bell Wireless Alliance and Rogers AT&T) have a digital network in all provinces, but only in the major city areas. Rural areas will likely never see digital coverage if the simultaneous use of several incompatible technologies is prolonged. The other two carriers today (Microcell/Fido and Telus) focus their presence on areas of high population density and business density, such as Ontario, Quebec, Alberta and BC. Fortunately, all digital phones are multi-mode devices that support either CDMA/AMPS, TDMA/AMPS or GPS/AMPS, so that a fall-back on the existing analog system is possible, with the loss of all digital network features. Unfortunately, current multi-mode devices do not support combinations of digital technologies, such as CDMA, TDMA and GSM.

The decision to license four different and incompatible technologies has impeded a quick and uniform growth of digital networks and has splintered the service provision of digital services in Canada. The US has not fared much better but could sustain this splintering effect more readily.

Early 2nd generation digital telephone systems did not have a full set of native digital data communications capability. Starting 1999 these data capabilities were added by extensions to the network standards leading to 2.5th generation systems. However, both TDMA and CDMA only offer SMS-like messaging and circuit-switched data capabilities which are suitable for short messages and e-mail, but are extremely costly for popular activities such as a Web browsing and data base access due to the bursty nature of the resulting data traffic. By resorting to existing data-only networks (e.g. CDPD for Mobility Canada) and by partnering with existing digital data-only networks (Mobitex for Rogers/AT&T and Ardis for Mobility Canada) both network providers added packet-switching capabilities to their networks, but in most cases for nontelephony devices only, such as PDAs or lap-top computers. Among the four initial providers, only the Microcell/Fido (GSM) was able to evolve to GPRS in summer 2001 and started to offer a full range of digital data services optimized to each service, SMS, E-mail, Web browsing and general data transfer. By early 2002 Rogers AT&T, the successor of Cantel, started to migrate their TDMA system to GSM and started to offer GPRS services similar to Microcell/Fido's services across Canada. At the same time all TDMA-based networks in the US took the same step of migration to GSM/GPRS and started to offer voice and data roaming in all of their networks, including the Canadian GSM networks. In addition, roaming capabilities are extended worldwide by agreements with other global GSM network providers. This is the first evidence of a powerful cooperation between digital network providers to offer the seamless services across the North American continent that subscribers could enjoy for almost 10 years in the analog AMPS networks. Unfortunately, at this time only subscribers to the GSM cellular networks can benefit from this long overdue development, but not yet subscribers to CDMA-based cellular systems.

An early migration to 3rd generation wireless communications systems (3G), such as GSM–based UMTS or CDMA-based CDMA2000, would bring back the needed uniformity in equipment and services and would lead to a more homogeneous provisioning of state-of-the-art digital wireless communications services to all regions of the country. It would be advantageous for Canada to have a single-standard digital network, and have several service providers compete in providing services using this single network standard and multi-band/single-mode end user devices, as is the case for the older AMPS system or the GSM system worldwide.

2.2 Europe

The evolutionary process of wireless cellular networks in Europe was shaped by the national monopolistic powers of the postal institutions, which governed all public communications aspects in addition to mail services and banking, up to the 1980 decade. This era was followed by a break-up of these monopolies in many European countries and deregulation of the public communications services, permitting competition for the first time in history. The thrust towards a united Europe compounded the positive effects on a coherent telecommunications standard across the European continent.

Starting in early 1980, the first analog cellular communications networks appeared in most countries in Europe, pioneered particularly by the Scandinavian countries. However, each country developed its own proprietary wireless network, incompatible with other networks across national borders. This lead to exorbitantly expensive wireless telephony devices and services with a very slow penetration into the market place during the first 10 years. Wireless communications did not become a commodity for the normal residents.

The shortcomings of the early analog wireless communications networks, such as low capacity and incompatibility with each other, were recognized by the European standardization bodies at a time when the European Union thrived and national postal institutions were broken up into segments, such as Telecom bodies, now only dealing with land-line and wireless public telecommunications systems. Two important single unifying standards were approved for public telecommunications services by the end of the 1980 decade, ISDN (1988) and shortly after GSM (1989). These standards apply to all European countries and were the only standards to be deployed. GSM offers a tight integration into the ISDN land-line network and allows global Europe-wide roaming with one single telephone set. The GSM I standard quickly evolved to GSM II with basic digital data capabilities, such as SMS. The deregulation of the public communications services permitted competition, and gradually up to four service providers emerged in several countries. Since all providers operate over GSM-compliant networks, though occasionally on different RF bands (900 MHz and 1800 MHz), subscribers are able to access all GSM networks with simple multi-band wireless telephone sets, and readily switch from one to the other provider, or roam without restrictions across national borders.

The mere scale of the common infrastructure made digital wireless communications affordable to the providers as well as to the subscribers, and an explosion in subscriber numbers occurred over a short period of less than 5 years. This fast penetration was helped by the high and uniform population densities in European countries and the almost 100% cellular RF area coverage per country, including rural areas. Today subscriber rates reach 70% of the population in Finland, and 40%-60% in most other European countries. The GSM standard was quickly accepted as a de-facto world standard and deployment spread to the Middle East and Africa, followed by Pacific Asia.

Spurred by the initial development of UMTS, the cordless DECT telephone systems was introduced in selected countries, such as Italy, in 1994. It was meant as a local low-tier micro-cell wireless system as companion to the GSM wireless network. However, automatic roaming between the two tiers was not implemented and the DECT system mainly found public acceptance as a stand-alone cordless telephone due to its many digital convenience features.

In 1998 all GSM networks across Europe started to offer E-mail (over SMS) and Web browsing services using the WAP standard. This was followed in 2000 by an upgrade to 2nd generation GSM networks offering full digital data capabilities, such as GPRS and HSCSD, for business and multi-media applications. In Spring 2000 the wireless data traffic exceeded the wireless voice traffic in Europe for the first time.

It is evident from the above historical sketch that the European nations learned a lesson from the failure of their early analog wireless communications networks as a communications commodity. By a uniform deployment of a single GSM standard across national borders they built a sustainable infrastructure to the advantage of all subscribers that is cost-effective by its mere scale of deployment. This helped them to provide leading-edge communications services to business and personal subscribers alike, and become one of the world leaders, closely behind Japan, in the wireless communications sector.

2.3 Japan

The first analog cellular telephone system started commercial operations in 1979, based on the AMPS standard. Japan always presented a challenging environment for public communications because of its very high population density. For that reason, Japan decided to develop further proprietary systems to better fit this market place. In 1991 NTT DoCoMo introduced the first 2nd generation digital wireless cellular network, PDC. PDC is TDMA-based and developed on GSM principles with significant improvements to handle higher capacity voice and data traffic. The extension PDC-P added packet-switching data capabilities to the original standard. The i-Mode suite of digital Internet access services, including Web browsing and E-mail, became available in 1999. This service became extremely successful in a technology-aware society of young people.

Japan is the first country which started public trials of its 3rd generation UMTS-compliant digital wireless network FOMA in May 2001. Massively overscribed within the first month, the network still experiences the usual technology start-up problems but is expected to reach full-fledged viable commercial operations during 2002.

3. Next Generation Telecommunications Networks and Services

The early years of 1990 were marked with two emerging perceived needs in public telecommunications. Firstly, the successful introduction of the first generation of analog cellular networks worldwide spurred the interest for, and proved the benefits of, mobility in telecommunications, particularly for business use. Secondly, the increase of the use of multi-media information, such as text enhanced by graphics, audio and rudimentary video. The then existing classical wireline and wireless telecommunications networks were not designed and thus not suitable for efficient transport of these multi-faceted data streams with different transmission requirements, except for the land-line ISDN network that integrates the transport of voice and low-speed data. In addition, the existing wireline and wireless networks were typically stand-alone networks and did not provide seamless interconnectivity, except for the GSM-based wireless network with ISDN by mid 1990.

3.1 IMT-2000

In 1990 the International Telecommunications Union (ITU), in cooperation with leading public telecommunications providers, defined a framework for the next generation of global telecommunications networks and services, named Future Public Land and Mobile Telecommunication System (FPLMTS). This early development lead to a family of recommended standards and was later renamed IMT-2000 (International Mobile Telecommunications). Today, the telecommunications networks adhering to IMT-2000 specifications are often referred to as 3G or 3rd generation Telecommunications systems and services.

IMT-2000 was conceived as a single standard for global telecommunications towards which all existing telecommunications systems worldwide will eventually converge. However, this idealistic vision did not realize because of the strong lobbying and irreconcilable attitudes of two camps of wireless telecommunications standards bodies, those promoting networks based on GSM technology and those based on CDMA technology. In 1998 the former camp established the 3GPP (3rd Generation Partnership Project) collaboration agreement for GSM, and the latter established the 3GPP2 (3rd Generation Partnership Project) collaboration agreement for GSM. Although both camps seek to move towards the IMT-2000 specifications and recommendations for 3G telecommunications networks and services, the implementations will use different and incompatible technologies. In Europe, the European Telecommunications Standards Institute (ETSI) defined the Universal Mobile Telecommunications System (UMTS) standard on the basis of the evolved GSM technology. In North America, the CDMA technology was chosen as the core of the 3G telecommunications networks by 3GPP2, known as CDMA2000.

Because of the much quicker and wider global market penetration of the GSM technology as a single standard, the trial implementations of UMTS started earlier in 2001 and will reach commercialization status earlier. CDMA did not reach wide global acceptance as a single standard because of its slow and painful evolution in a splintered North American public wireless telecommunications market, thus CDMA2000 will likely face resistance in quick

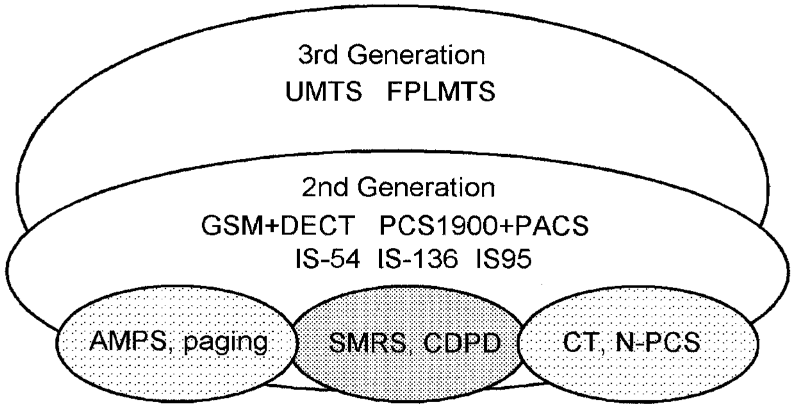
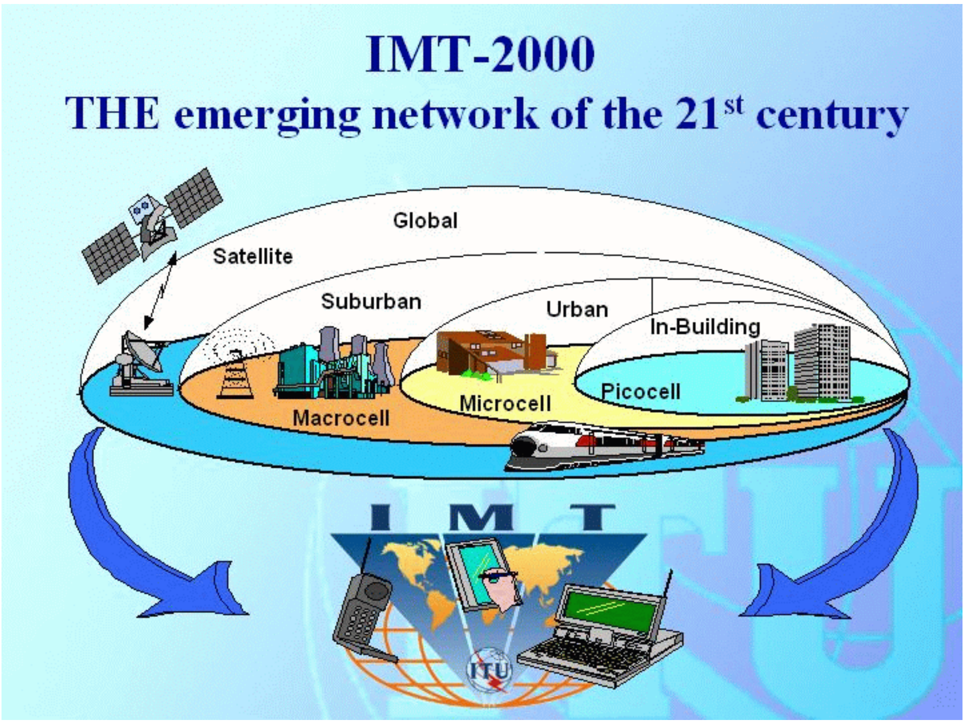


Fig. 3.1 Hierarchy and Evolution of Public Telecommunication Frameworks



Source: imt-2000.org

Fig. 3.2 Architecture of IMT-2000

acceptance due to poor global roamability. However, the superior technology and better bandwidth efficiency of CDMA2000 makes it a strong competitor to UMTS. The future will show if the push of the market place or the push of technology will help either UMTS or CDMA2000 gain dominance. For some time into the future it can be predicted that two incompatible technologies will co-exists, thus defeating the vision of IMT-2000 of a single global technology standard for public wireless telecommunications networks and services.

Because of the advanced specifications and trial deployment of UMTS telecommunications systems at this time around the globe, the UMTS is used here as an example to highlight the major features of next-generation 3G networks and systems. The implementation of CDMD2000 is expected to follow a similar path**.**

3.2 UMTS

UMTS (Universal Mobile Telecommunications System) is the recommended implementation standard of ETSI for IMT-2000 compliant 3G networks and services, and adopted by 3GPP. It evolved from GSM with 3GSM extensions, and the GSM core network is closely aligned with the ISDN core network. UMTS is to be commercially deployed in Europe, Middle-East, Africa and Asia Pacific where GSM systems exist, starting 2002.

UMTS seeks to converge all wireless telecommunications systems into one hierarchical structure of operationally compatible networks. This multi-tier structure comprises a family of separate but interoperable cellular networks with different characteristics from pico-cell size (e.g. Bluetooth WPAN), over micro-cell size (e.g. IEEE802.11 WLAN), mini-cell size (e.g. GSM WWAN) to mega-cell size (e.g. Globalstar satellite system), with automated roaming within a particular network and among the tiers depending upon the need for communications services. UMTS promotes the always-best-connected paradigm (ABC) where a client is always connected to the best available network to provide the required services at the least cost and by the most efficient use of communications resources. For example, an office worker at a fixed location would connect to a personal network, WPAN, whereas a pedestrian would slowly roam through a WLAN with limited local extent, so as not to tie up a scarce channel in a large-extent cellular WWAN. However, a client in a fast-moving car or airplane would connect to a cellular WWAN or satellite network, respectively, in order to reduce the frequency of hand-offs .

UMTS emphasizes a consistent Virtual Home Environment (VHE), complete with personalization and services, accessible from any UMTS-compliant network around the globe. In addition, the UMTS network structure will provide increased capacity, IP-based data capability, higher-speed connections from 144 kbps over 384 kbps to 2 Mbps (tier and motion dependent) and a far greater range of services for unrestricted global mobility of subscribers, terminals and services, such as personal profiles and single personal identification number (like GSM's SIM), and resource and service discovery anywhere on the globe. The core of UMTS is built on the evolving GSM core network, with a recommended air interface of the CDMA type, accommodating both legacy air interfaces of the spread-spectrum type (W-CDMA) and the time-time-domain multiplexing type (TD-CDMA). Multi-mode terminal devices are specified for global access to the UMTS network family. UMTS terrestrial and satellite networks operate in the 1800, 1900 and 2100 MHz ranges.

UMTS also recommends well-defined incremental migration paths from GSM-II to UMTS.

3.3 CDMA2000

CDMA2000 is the recommended implementation standard of the 3GPP2 for IMT-2000 compliant 3G networks and services. It evolved from CDMAone (IS95a and IS95b) and is operated over the ANSI41 (IS41) core network standard. CDMA2000 is to be commercially deployed in the Americas and other regions where CDMA-based systems exist, starting in 2002.

CDMA2000 establishes an integrated network and services as outlined for the UMTS system in Sect. 3.2.

The standards bodies comprised by 3GPP2 recommend well-defined incremental migration paths from CDMAone to CDMA2000.

3.4 Migration Paths to 3G and 3G Technology Deployment

The move from the current 2nd Generation wireless telecommunications systems to 3G is very expensive in terms of new RF spectrum licenses and upgrade/replacement of network infrastructure for the network operators. It is equally expensive for the subscribers in terms of new phone handsets, RF modems and computer devices with built-in RF modems. For this reason, the 3GPP and 2GPP2 consortia have defined migration paths with incremental network and services enhancements.

3GPP recommendations relate to the upgrade of current GSM and TDMA based network systems. The first phase involves the incorporation of GPRS to deliver packet-switched data services up to 171,200 kbps (115,200 kbps with error control) and HSCSD for circuit-switched data services up to 57,600 bps full-duplex (2.5G). Most GSM network providers have already deployed GPRS offering typically up to 40...60 kbps data rates, however the availability of HSCSD is rare. The second phase of migration calls for the replacement of both GPRS and HSCSD by EDGE, offering both packet-switched data and circuit-switched data up to 384 kbps without error control (2.75G). The final phase of migration is the upgrade to full 3G UMTS network capabilities with an enhanced air interface (WCDMA, 5 MHz wide RF channels) and the offering of mobile services across a hierarchy of interconnected networks.

The GSM upgrade process suffers from the need to replace or significantly upgrade the network infrastructure at each phase of the migration path, thus making the evolution to 3G expensive. At each phase new network and subscriber hardware is incompatible with the previous phase’s hardware. This requires subscribers to acquire new end user devices, a fact which might slow down the upgrade process unless considerably subsidizes end user devices are offered by the network services providers, or multi-mode devices will become available.

The recommendations of 3GPP2 for the migration of current CDMA (CDMAone, IS95a) based network systems consist of three phases. The first phase involves the incorporation of packet-switched data services up to 64 kbps, leading to IS95b (2.5G). Most CDMA network providers have opted to not consider this phase due its expected short live span. For this reason most CDMA networks currently do not offer any packet-switched data service, which leaves them in the precarious situation of losing business customers to GSM/GPRS network providers because the cost of using available circuit-switched data services over voice channels is prohibitively expensive for interactive applications, such as web browsing and data base enquiries over wireless corporate network connections. The second phase of migration calls for the introduction of a new air interface with codecs, 1xEV (one-times evolution, e.g. 1xRTT in CDMA2000-1) with new modulation schemes that are capable of data rates at up to 144 kbps (2.75G). It is expected that initially 50...70 kbps will be available. This modulation scheme uses the same 1.25 MHz wide RF channels as the current CDMAone scheme, thereby guaranteeing coexistence with current modulation schemes. The final phase of migration involves a replacement of the current modulation scheme to reach 3G compliant data rates by utilizing 3.75 MHz wide RF channels and employing the 3xEV air interface and codecs, such as 3xEV-DO or 3xEV-DV (three-times evolution, 3x1.25=3.75; CDMA2000-2).

The CDMA upgrade process benefits from the compatibility and coexistence of air interfaces and modulation schemes throughout the migration path. This is expected to offer backward compatibility of end user devices designed for future phases, and forward compatibility of current devices with the next-phase evolution although subject to the unavailability of newly introduced network features. These benefits significantly lessen the burden of upgrade at each phase of the migration path to both network operators and subscribers. A subscriber needs to acquire a new end user device only in order to utilize all of the new network offerings, such as increased data rates and multi-media communication, but not to continue operating the device on the network at the service level of the previous network phase.

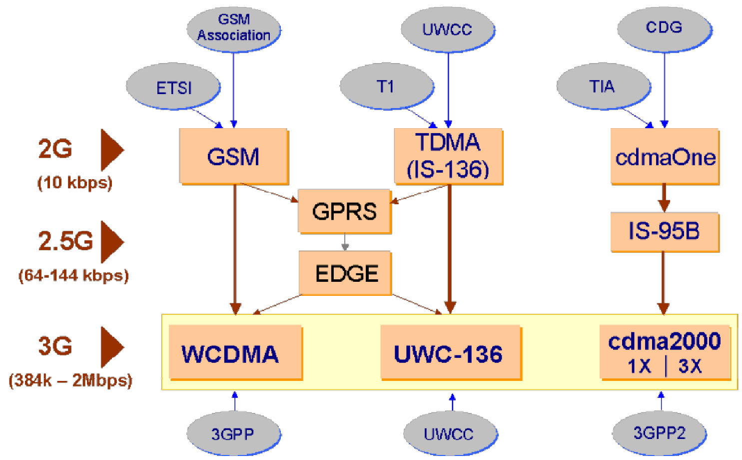
Currently a large number of 3G trials are announced worldwide and in progress, with a few early commercial 3G networks already in operation. A selected list of trials and commercial operations follows, grouped by technology and listed in chronological order.

3GPP:

Japan, DoCoMo, FOMA-UMTS commercial operation since September 2001
Germany, Group 3G, UMTS since 2001
USA, AT&T, Cingular and Voicestream, GSM-EDGE trials since 2002
Canada, Rogers AT&T, GSM-EDGE trials in Toronto since 2002

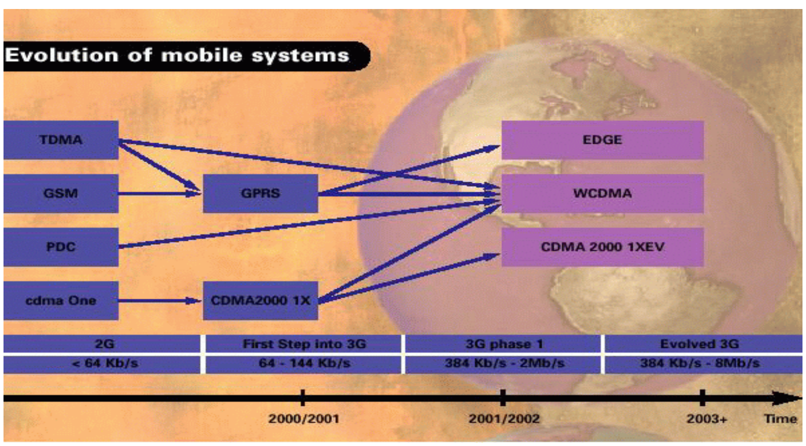
3GPP2:

Korea, CDMA2000 commercial operation since 2001
Australia, Telstar, CDMA2000 trials since 2001
USA, Verizon, CDMA2000, commercial operation since February 2002
USA, Sprint, CDMA2000, trials since February 2002
Canada, Bell Mobility, CDMA2000 1xRTT trials announced by 2002-2003



Source: uwcc.org

Fig 3.3 Migration Paths for CDMA, TDMA and GSM towards 3G Networks



Source: uwcc.org White Paper on 3G Evolution

Fig. 3.4 Time-Line of Migration to 3G Networks

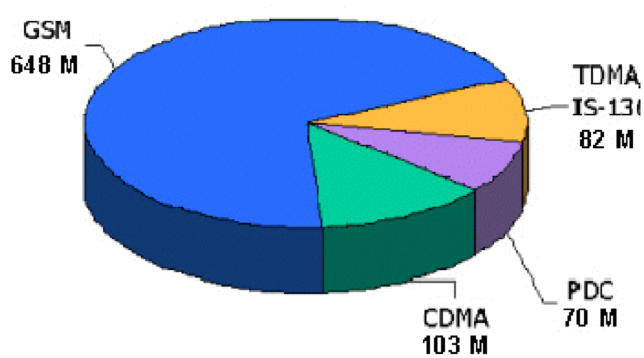
4. Current Wireless Communications Technology Deployment

The deployment of digital wireless networks (PCS) in selected parts of the world is listed. The focus is on Canada, but an overview over other important global regions is included as well. The mix of standards is emphasized and their interoperability is outlined. Statistical data on the coverage is shown.

4.1 Global Deployment Patterns and Statistics

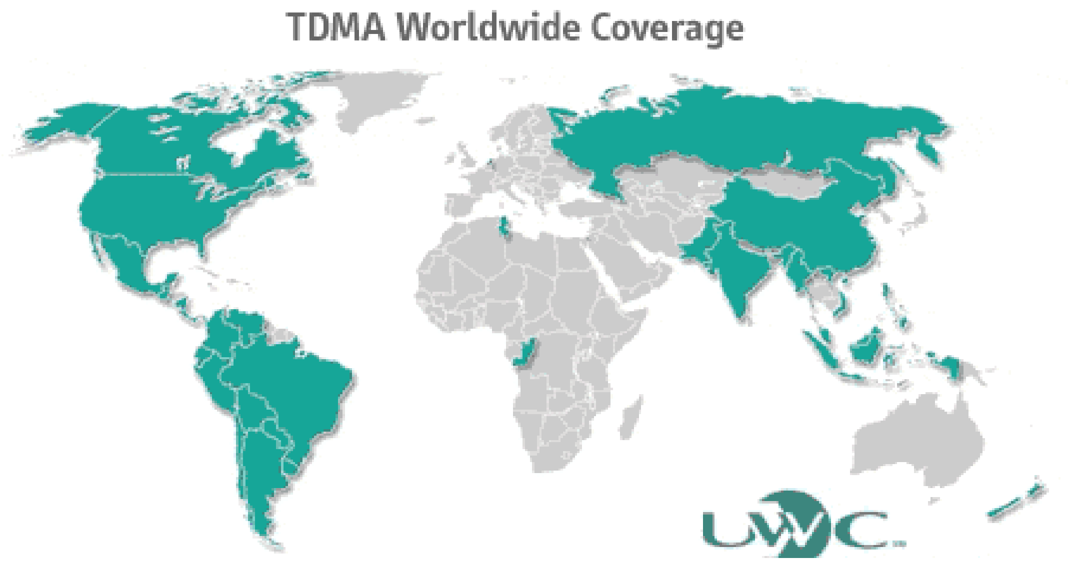
GSM is currently the dominant wireless telecommunications standard in the world. It is operated in 174 countries and by 429 network operators and has 648 Million subscribers, which is a global market penetration of 72%. This is followed by CDMA-based network installations with 103 Million subscribers or 11%, and TDMA-based networks with 82 Million subscribers or 9%. Among the remaining wireless standards, approximately 70 Million subscribers, or 8%, use networks based on the PDC standard. This is a significant market share considering the fact that PDC is used only in a single country, Japan.

In Europe, GSM is the dominant technology with a market base of very close to 100%. The same is true for the telecommunications market in the Middle-East.



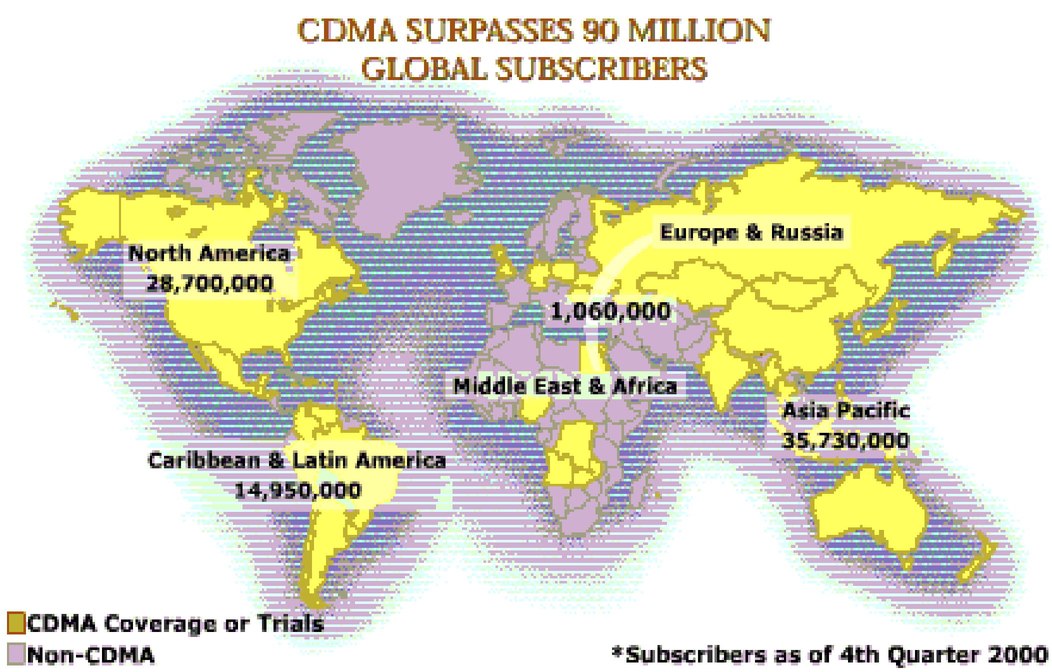
Source: EMC World Cellular

Fig. 4.1 Worldwide PCS Subscribers by Technology (in Millions)



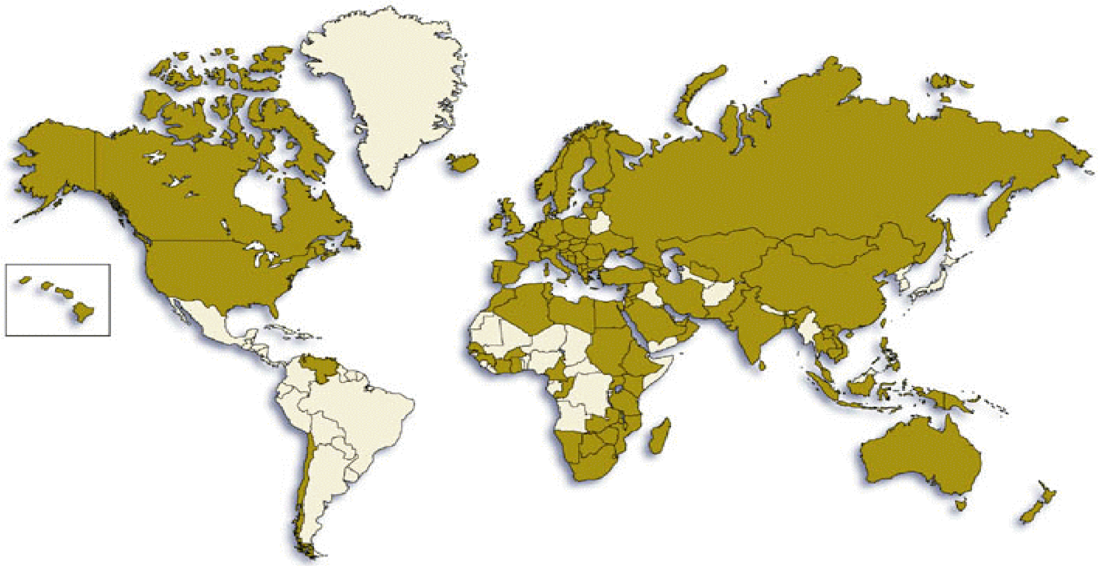
Source: www.uwcc.org

Fig. 4.2 Worldwide TDMA Presence.
Green area indicates digital network coverage



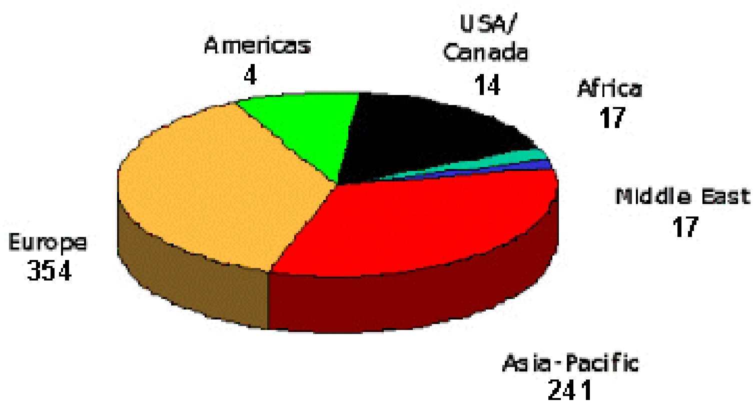
Source: www.cdg.org

Fig. 4.3 Worldwide CDMA Presence.
Yellow area indicates digital network coverage



Source: www.gsmworld.com

Fig. 4.4 Worldwide GSM Presence.
Tan area indicates digital network coverage



Source: gsmworld.com

Fig. 4.5 Distribution of GSM Subscribers worldwide (in Millions)

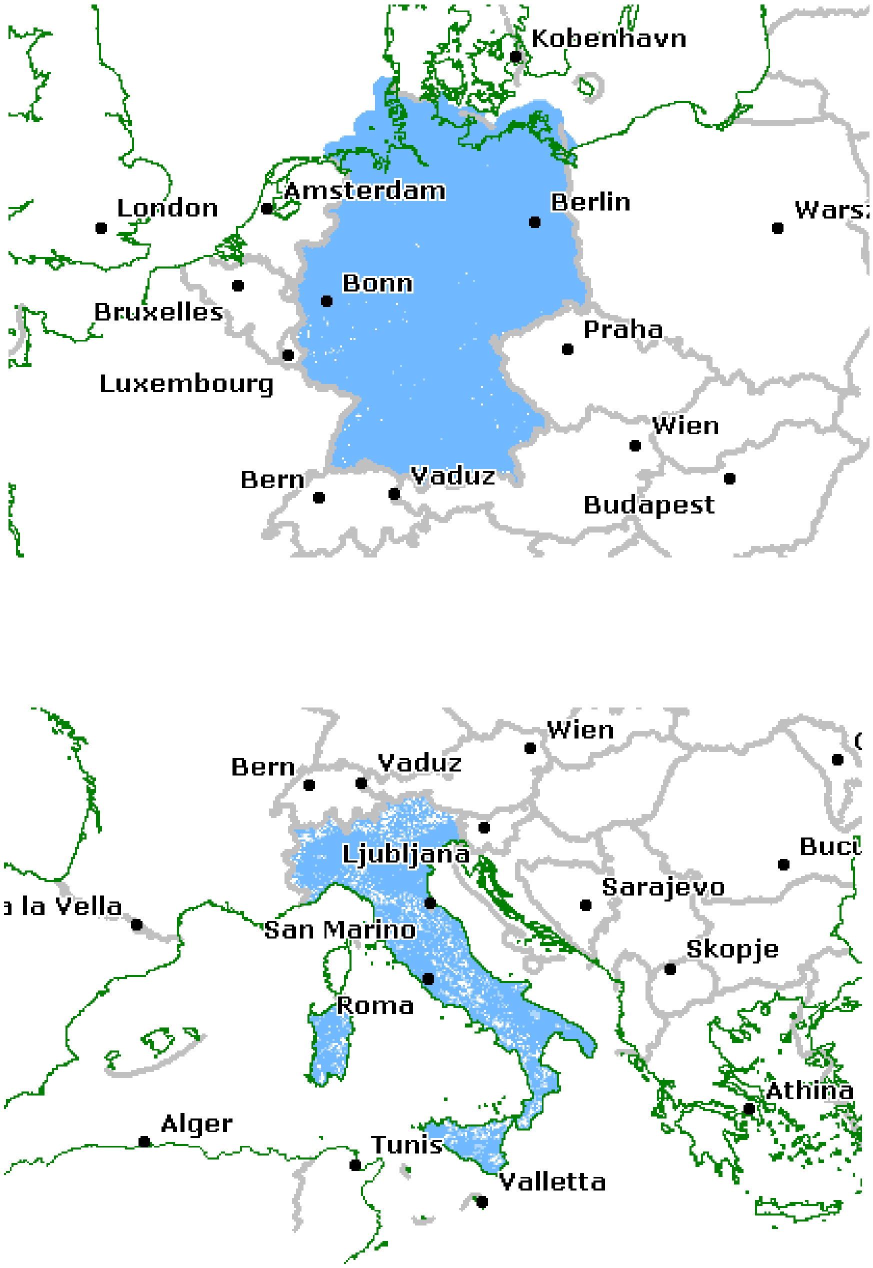
4.2 Europe

The current deployment of digital wireless telecommunications systems in Europe is easy to characterize. The network access provisioning is local to each country, and there are normally more than one provider in each country. However, all European public wireless network carriers use a single network standard, GSM. There exist however different evolutions of GSM across Europan countries, and even within a given country. But this does not exclude the use of any GSM network by a subscriber with a GSM handheld telephone at the available technology level. The differences in GSM networks are mainly related to the deployment of extensions that enable messaging and full digital data communications, such as GPRS, HSCSD and EDGE. All GSM providers offer basic data communications services, such as SMS, E-mail and Web browsing, the latter two services either over a circuit-switched or over a more economical packet-switched connection. The different network service providers in each country compete in providing services and often target different user groups, such as commerce, industry, travellers and teens, by partnering with third-party application providers who offer services relevant to the respective groups.

As an example, the digital wireless offerings in Germany are briefly considered. Each of the four providers covers exhaustively the entire country, T-D1, D2, E-plus and VIAG Interkom. T-D1 is the wire-line provider (former postal institution) whereas the other three providers were established after the deregulation of the public communications system in Germany. T-D1 and D2 operate GSM systems in the 900 MHz range, whereas E-plus and VIAG run GSM in the 1800 MHz range (PCS1800). All providers offer packet-switched GPRS services. D2 is the first provider which offers high-speed data communications over HSCD as of the end of 2000. All cellular digital telephones and modems are multi-band and permit access to either provider. Thus, subscribers are free to purchase any compatible phone and install their SIM card for immediate use. All four public carriers permit roaming and messaging between their networks, though at an additional roaming cost.

The services of T-D1 and, to some extent also D2, are geared towards the needs of business, including paging, fax, push-type news and stock quotes, access to company LANs, on-line banking and air line reservations/check-ins. The less conservative providers E-plus and VIAG also offer entertainment-related services for the younger generations, such as chat-rooms, music and gaming access including video games.

The RF coverage by each provider is close to 100% both in major cities and rural areas alike. This ideal situation is made feasible by sharing of infrastructure and by the homogeneously high density of the population and of businesses across the country. Particularly the eastern part of Germany (formerly GDR) is exceptionally well served by the digital wireless telecommunications providers because the land-line telephone system was in a degraded and inadequate state at the time of unification in 1989, and the immediate start of the establishment of a wireless communications system remedied this situation quickly.



Source: www.gsmworld.com

Fig. 4.6 GSM Coverage in Europe by Examples: Germany and Italy.
Blue areas indicate digital network coverage

4.3 Japan

Japan's wireless 2nd generation offerings are controlled by NTT (Nippon Telephone & Telegraph) DoCoMo. PDC-P is the current wireless bearer of voice and the i-Mode Internet services. Similar services are offered over the FOMA UMTS network on a public trial basis.

4.4 USA

Similar to the scenario in Canada, the deployment of digital wireless networks (PCS) in the US indicates a mix of four major standards offered through six major public carriers. No one public carrier provides full coverage of the US geographical region, but most offer full coverage in major urban areas. Two public carriers, Cingular (formerly Bell South) and Voicestream have a complementary coverage of nearly the entire US continental regions, but currently with incompatible network standards , TDMA and GSM, respectively. Cingular is currently deploying GSM overlays in their TDMA networks, and in the future these two wireless network providers are likely to provide a seamless roaming capability with multi-band GSM terminal devices, such as cellular telephones, however still requiring roaming between two service providers. The remaining public carriers provide network coverage that is sporadic and focussed mainly on the densely populated areas.

A brief overview of the six major digital wireless PCS providers, along with the network properties and data capabilities, follows.

(a) **AT&T Wireless**
Operates a TDMA network of the IS136 type but is currently moving to GSM/GPRS. Data capability is added through access to CDPD over their older analog AMPS networks. Although AT&T's AMPS network almost fully covers the North American continent, the digital PCS offerings are sporadic. CDPD data communications is only offered in selected areas of the North-East, Florida, Texas and California. AT&T Wireless is the partner for roaming in the US for subscribers of Rogers AT&T, both for analog AMPS and the digital TDMA.

(b) **Cingular**
The former Bell South cellular network is now operated by Cingular. The network is based on TDMA technology, and Cingular is currently installing GSM overlays in the TDMA networks. Digital data communications capability in the original TDMA networks is achieved by partnering with the Mobitex data-only network and access to their data services. Cingular is one of the US providers that is currently testing GPRS as an extension to their GSM network. GPRS will act as the packet-switching data transport mechanism that will enable powerful data capabilities at economical costs in the near future. The coverage of Cingular is centred in the south-western part of the US and California with almost 100% coverage in these regions.

(c) **Sprint PCS**
Although the older analog AMPS network covers most of the continental US, the CDMA-based digital network coverage is small and centred in areas of the largest population densities.

(d) **Verizon**
Verizon operates a CDMA-based digital communications network. Communications of data-based services and applications is achieved through CDPD over the analog AMPS network.

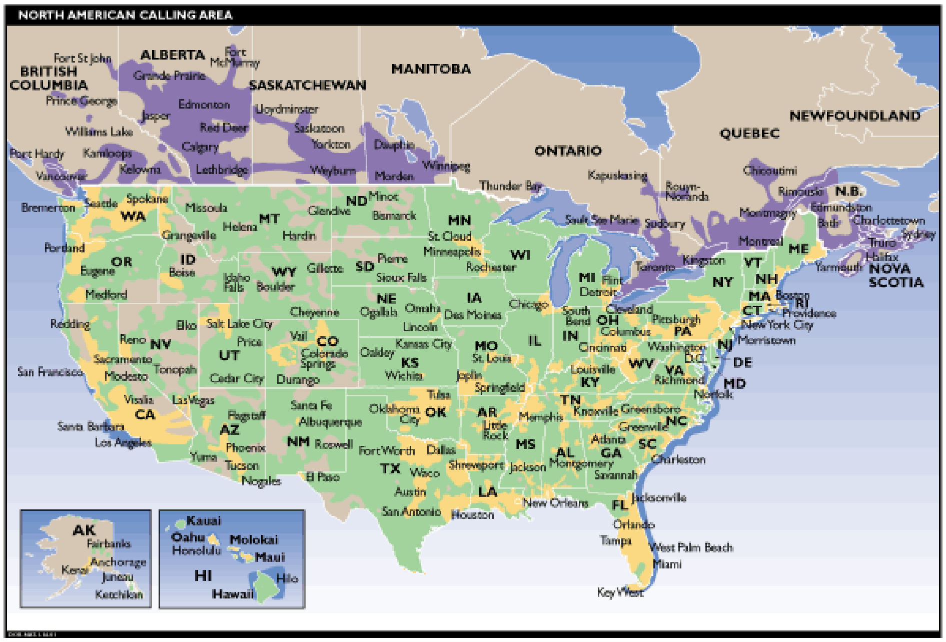
(e) **Voicestream**
The original GSM network in the US is operated by Voicestream. A derivative of the original GSM standard is used, which operates at 1900 MHz (PCS1900) but retains the core network of GSM. Voicestream was partly acquired by Deutsche Telekom (German public GSM network provider), a company with more than a decade of GSM experience. The push towards further expansion of the largest GSM network in the Americas is evidenced by the introduction of GPRS in 2001. This packet-switching extension to GSM will enable the best available data communications facilities and bring higher bandwidth and multi-media capabilities. Voicestream's GSM coverage focuses on the north-eastern, north-western and south-central part of the US. This coverage nicely complements Cingular's coverage and creates a seamless GSM network across all states of the US after Cingular's conversion to GSM is complete, although roaming is still necessary across the two public network providers

(f) **Nextel**
Nextel is offering a small iDEN network in the major urban areas of the US. Nextel is the roaming partner for the Canadian Telus Mike provider.

A brief summary of the US digital wireless network providers is presented in Table 2.2

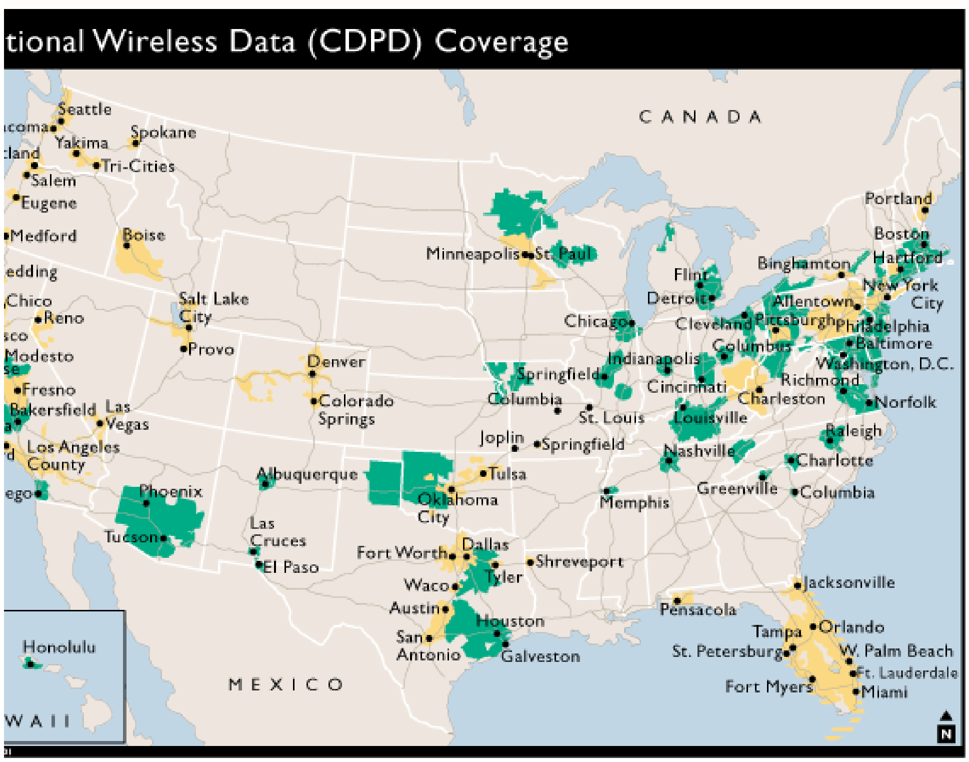
Provider	**AT&T Wireless**	**Cingular**	**Sprint PCS**	**Verizon**	**Voicestream**	**Nextel**
Voice/Data Technology	TDMA GSM	TDMA GSM	CDMA	CDMA	GSM	iDEN
Packet Data technology	CDPD GPRS	Mobitex GPRS	testing 1xEV	CDPD	GPRS	

Table 4.1 US Digital Wireless Network Providers



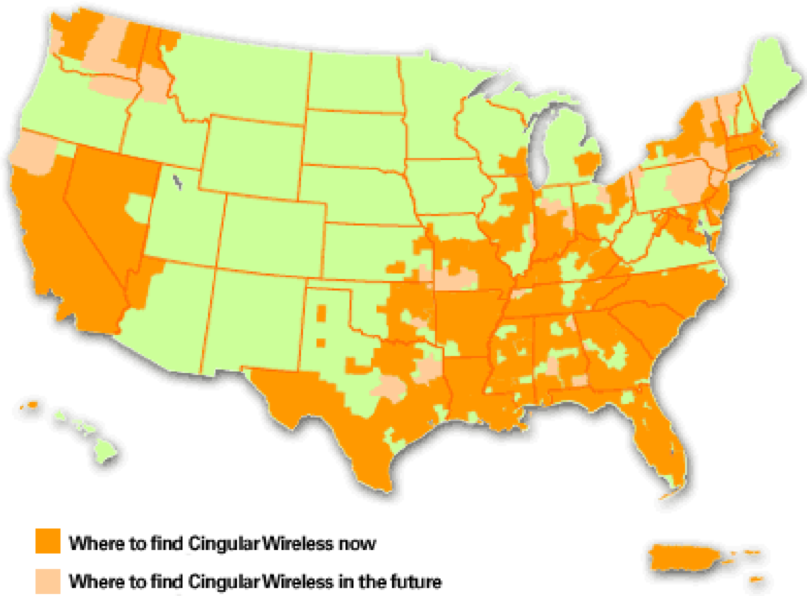
Source: www.uwcc.org

Fig 4.7 AT&T TDMA Coverage in the US.
Yellow area indicates digital network coverage



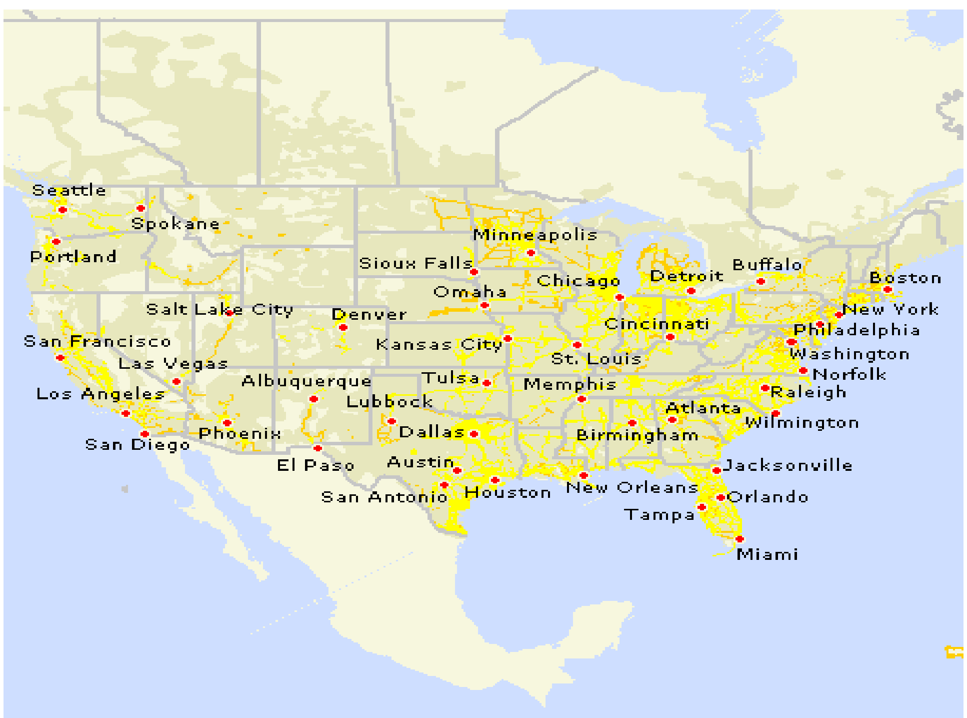
Source: www.sierrawireless.com

Fig 4.8 AT&T CDPD Coverage in the US.
Yellow area indicates digital network coverage



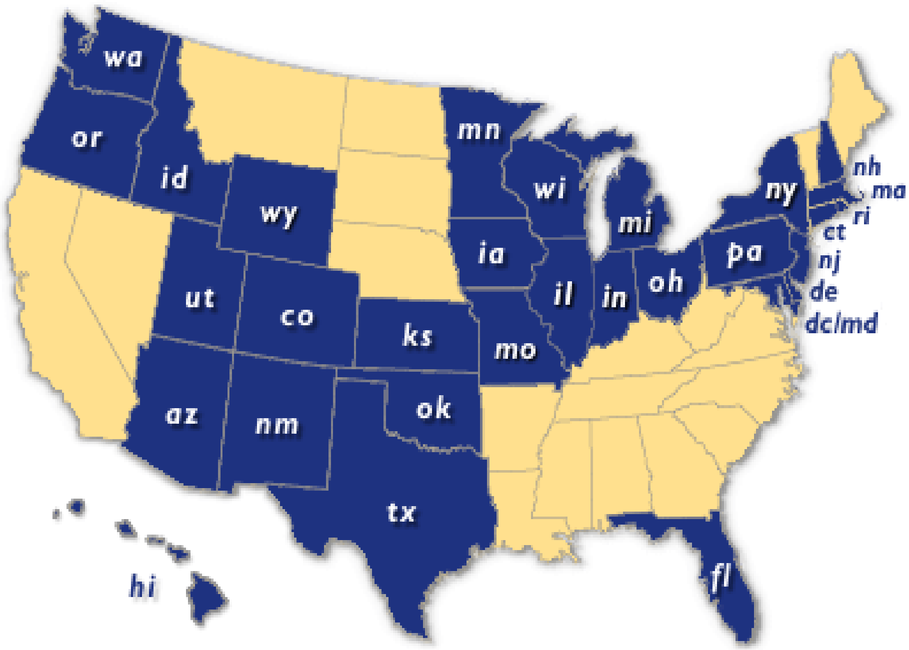
Source: www.uwcc.org

Fig. 4.9 Cingular TDMA Coverage in the US.
Orange area indicates digital network coverage



Source: www.cdg.org

Fig. 4.10 Sprint CDMA Coverage in the US.
Yellow area indicates digital network coverage



Source: www.gsmworld.com

Fig. 4.11 Voicestream GSM Coverage in the US.
Blue area indicates digital network coverage

4.5 Canada

The deployment of digital wireless networks (PCS) by Canadian public carriers indicates a mix of seven standards, among of them four major ones (CDMA, TDMA, GSM, iDEN) and three minor ones (CDPD, Mobitex, Ardis). There is no single digital wireless network that has a large area coverage. There is no single digital wireless network that offers all desirable digital services in a one-network one-device fashion. In most cases digital services are only available in major cities and along major highways. Some network providers restrict their services to the most densely populated areas, which are few in Canada. All network providers offer different services over separate networks requiring different end user devices and different subscription plans. There is no inter-operability between any two standards due to the lack of multi-band/multi-mode cellular telephones or wireless modems for this relatively small market.

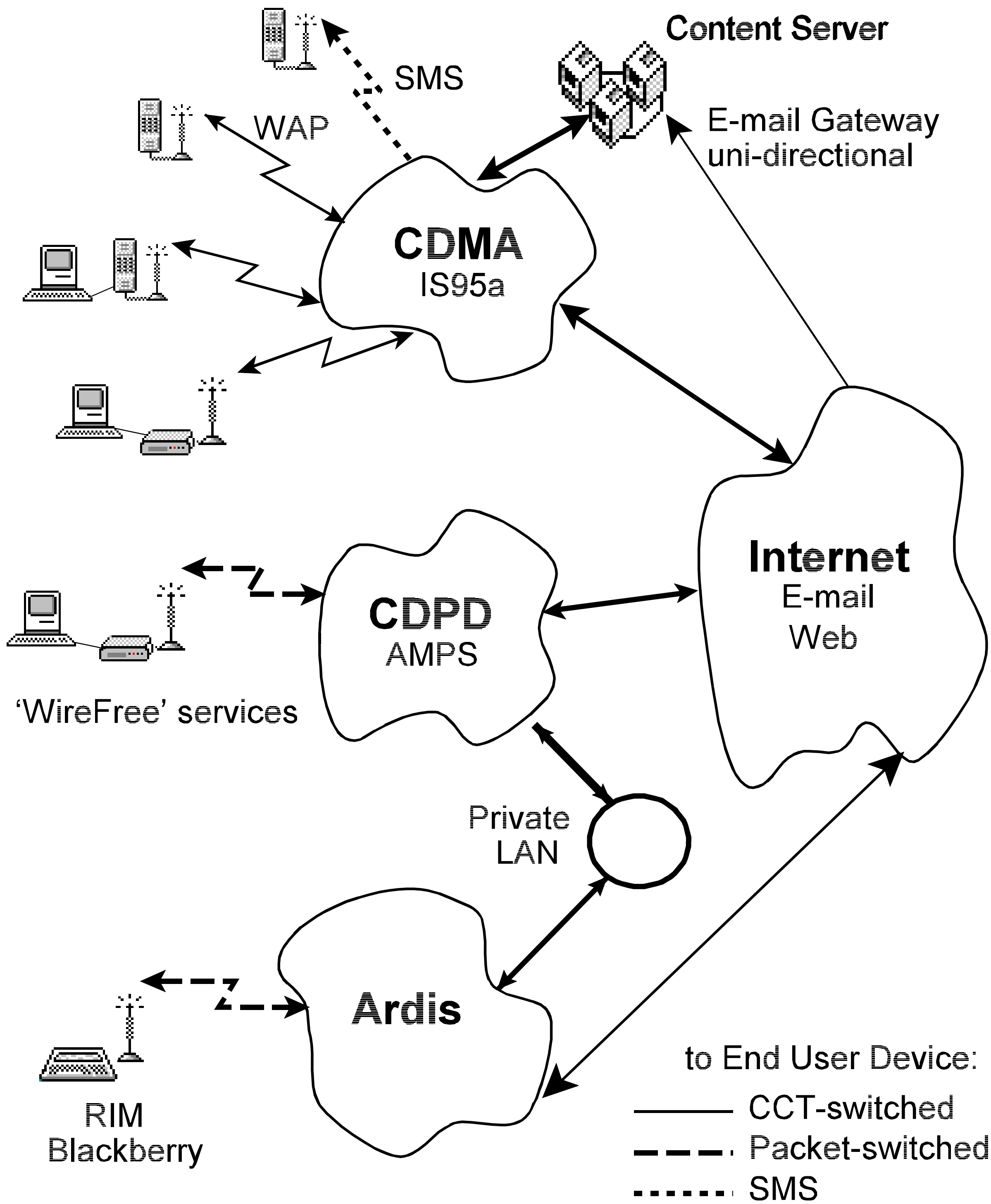
(a) **Bell Wireless Alliance**

The service resellers are located in each province, such as NewTel Mobility, NBTel Mobility, etc. The network standard is IS95a (CDMA) operating at 800 and 1900 MHz.

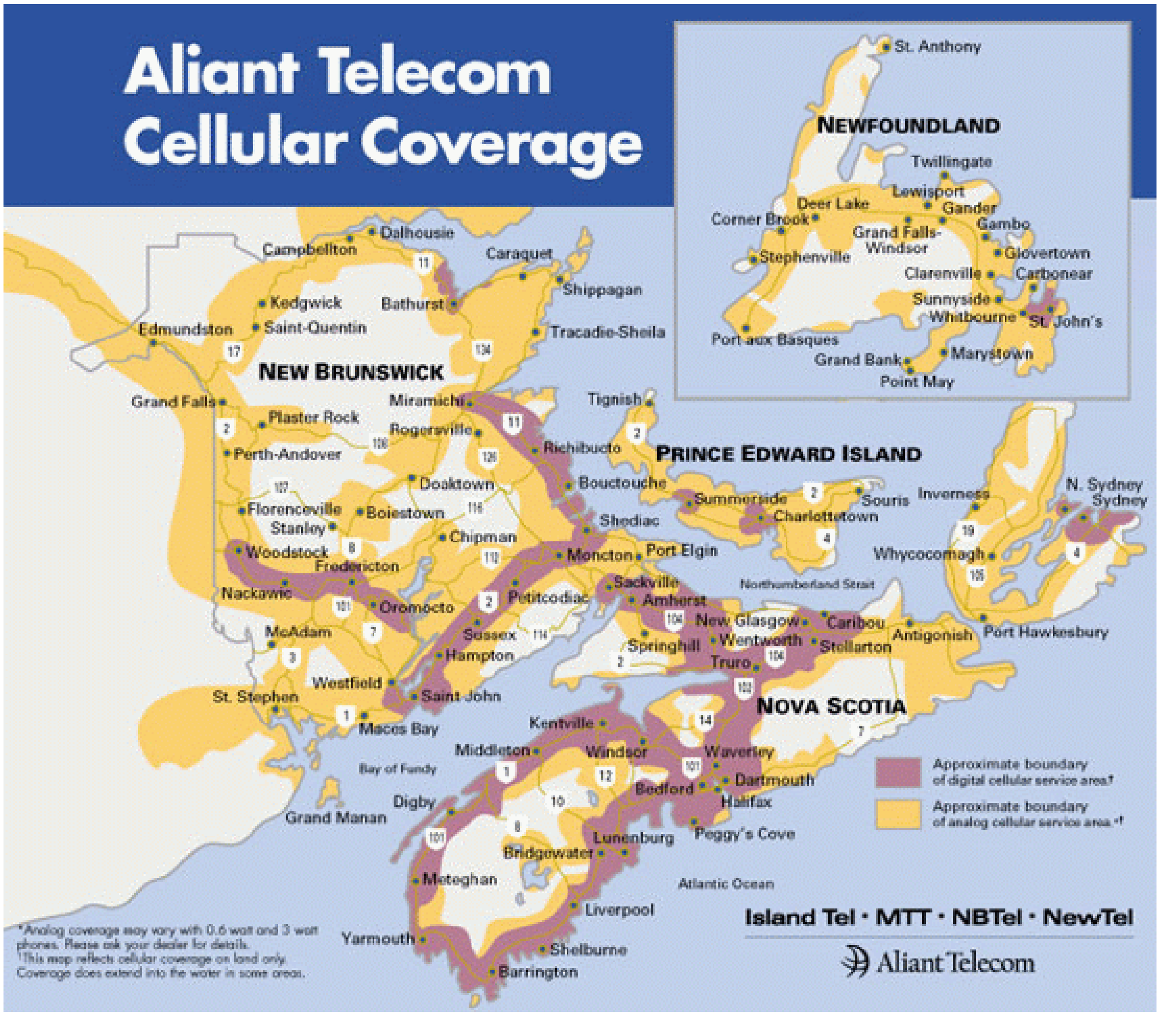
There is no full set of native digital data capabilities in the CDMA network, except circuit-switched data and one-directional SMS (receive-only). In order to provide additional data capabilities, such as cost-efficient E-mail and Web browsing, Bell Wireless Alliance has made their existing separate CDPD network available to the public, which has been used in the past by governmental and commercial users, e.g. RCMP Highway Patrol. CDPD is an overlay over the older analog AMPS network. This service is targeted at PDAs and lap-top computers with wireless CDPD modems because no standard cellular phones are readily available with a CDPD plug-in. Although the AMPS coverage is very extensive, its CDPD coverage is not tailored for general business and personal use and is very sporadic. In addition, Bell Wireless Alliance has partnered with the ARDIS data-only network to provide exclusive mobile access for RIM's Blackberry devices.

CDMA coverage extends to all Atlantic provinces, along the highways and the larger cities. CDMA coverage in New Brunswick is limited to three cities, Saint John, Moncton and Fredericton and the highways connecting them. In other areas the telephone sets switch automatically to the analog AMPS system. In the latter case all data capabilities are lost because no CDMA/AMPS devices with CDPD plug-in are available. CDPD coverage in New Brunswick is limited to the southern Fredericton to Saint John to Moncton highway areas and Bathurst, but is being extended.

Roaming is possible without restrictions across Canada in Bell Wireless Alliance's CDMA networks, for both voice and data. Voice roaming is also possible in the US and overseas CDMA networks, provided multi-band CDMA telephones or wireless CDMA modems are used, and agreements with the foreign public carriers exist. Seamless CDPD roaming is available in all Atlantic provinces where CDPD coverage exists, but no

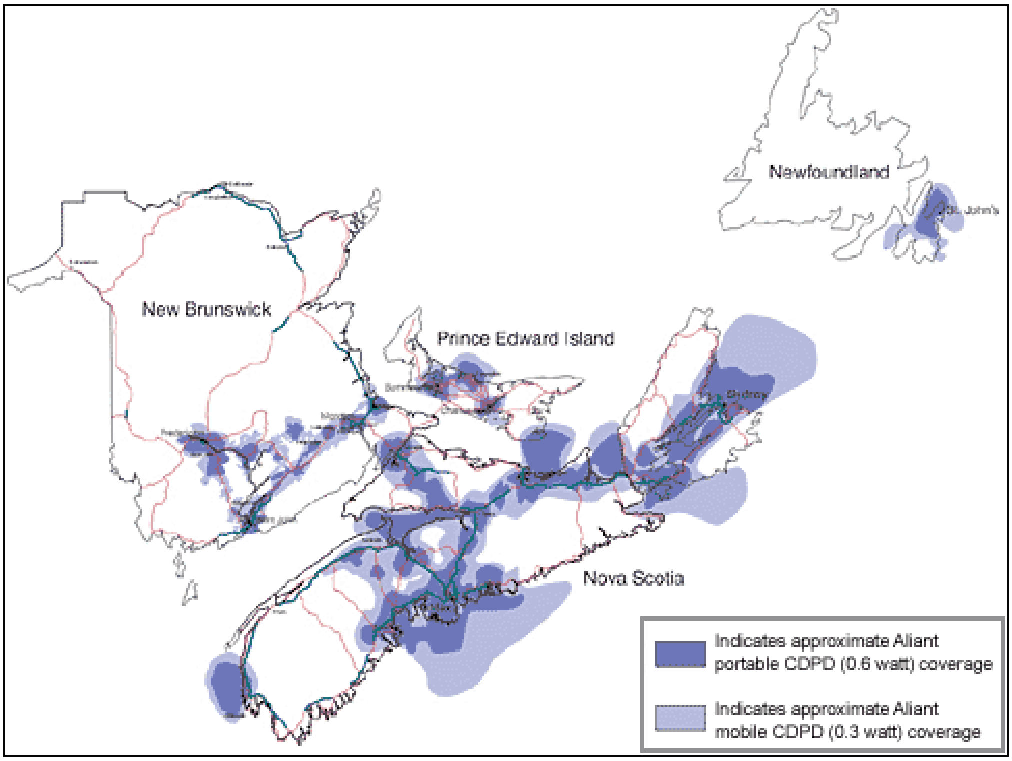


NBTel Mobility Network Architecture (functional)



Source: www.etelesolv.com

Fig. 4.12 NBTel Mobility CDMA Coverage in Atlantic Canada
Purple area indicates digital network coverage



Source: www.sierrawireless.com

Fig. 4.13 NBTel CDPD Coverage in Atlantic Canada.
Blue areas indicate digital network coverage

British Columbia
- Vancouver

Alberta
- Calgary
- Edmonton

Manitoba
- Winnipeg

Saskatchewan
- Regina
- Saskatoon

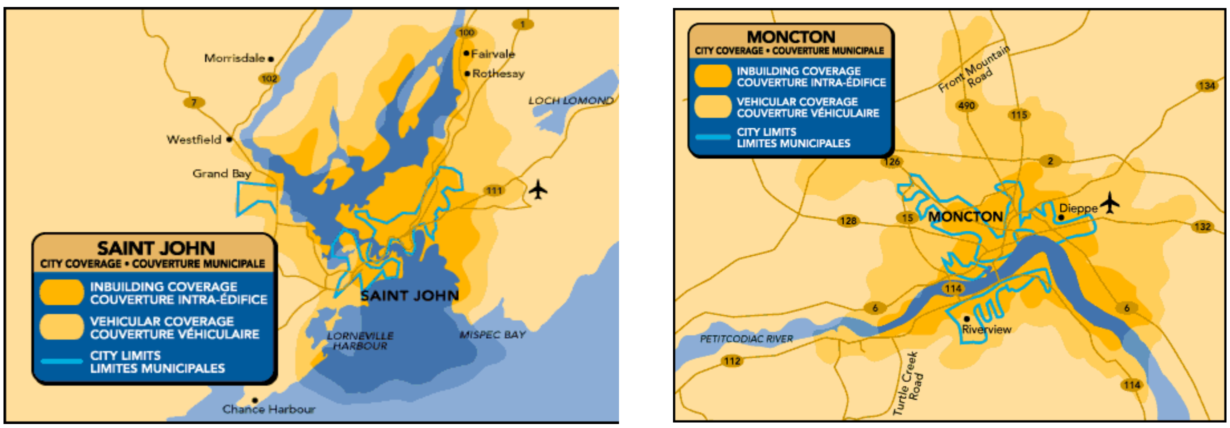
Ontario
- Belleville
- Cornwall
- Kingston
- London
- Ottawa
- Toronto
- Windsor

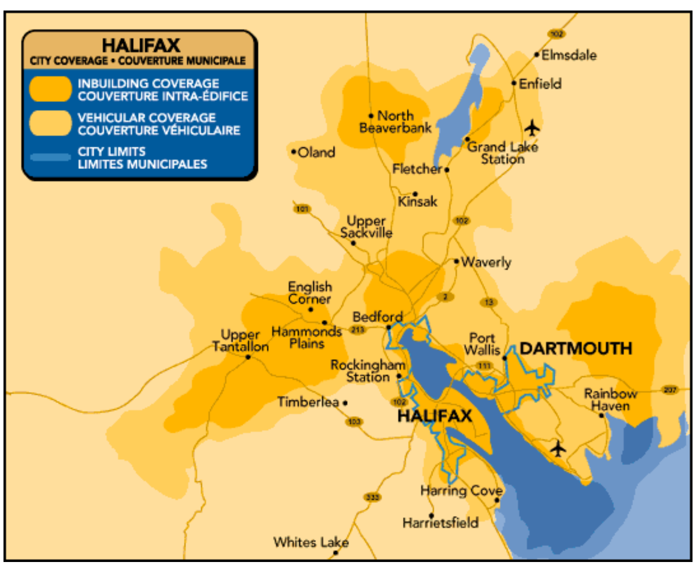
Quebec
- Montreal
- Quebec City
- Trois-Rivieres

New Brunswick
- Moncton
- Saint John

Nova Scotia
- Halifax
- Sydney

Newfoundland
- St. John's





Source: www.data.bellmobility.ca

Fig. 4.14 Bell Mobility Ardis Coverage by Cities and Examples of Area Coverages in the Maritimes. Dark and light orange areas digital network coverage roaming is available in other CDPD areas outside the Atlantic provinces and in the US.

Bell Wireless Alliance has indicated that there is no plan to upgrade from the current IS95a standard to the newer IS95b standard with 64 Kbps general digital packet-switched data capability. Instead, the Alliance focuses on an upgrade of their entire net of networks towards a 3rd generation CDMA2000-based infrastructure in the coming years. The first migration step is expected to take place by 2002/2003 through the introduction of 1xEV technology that offers full data capabilities (circuit and packet-switched) at up to 144 kbps.

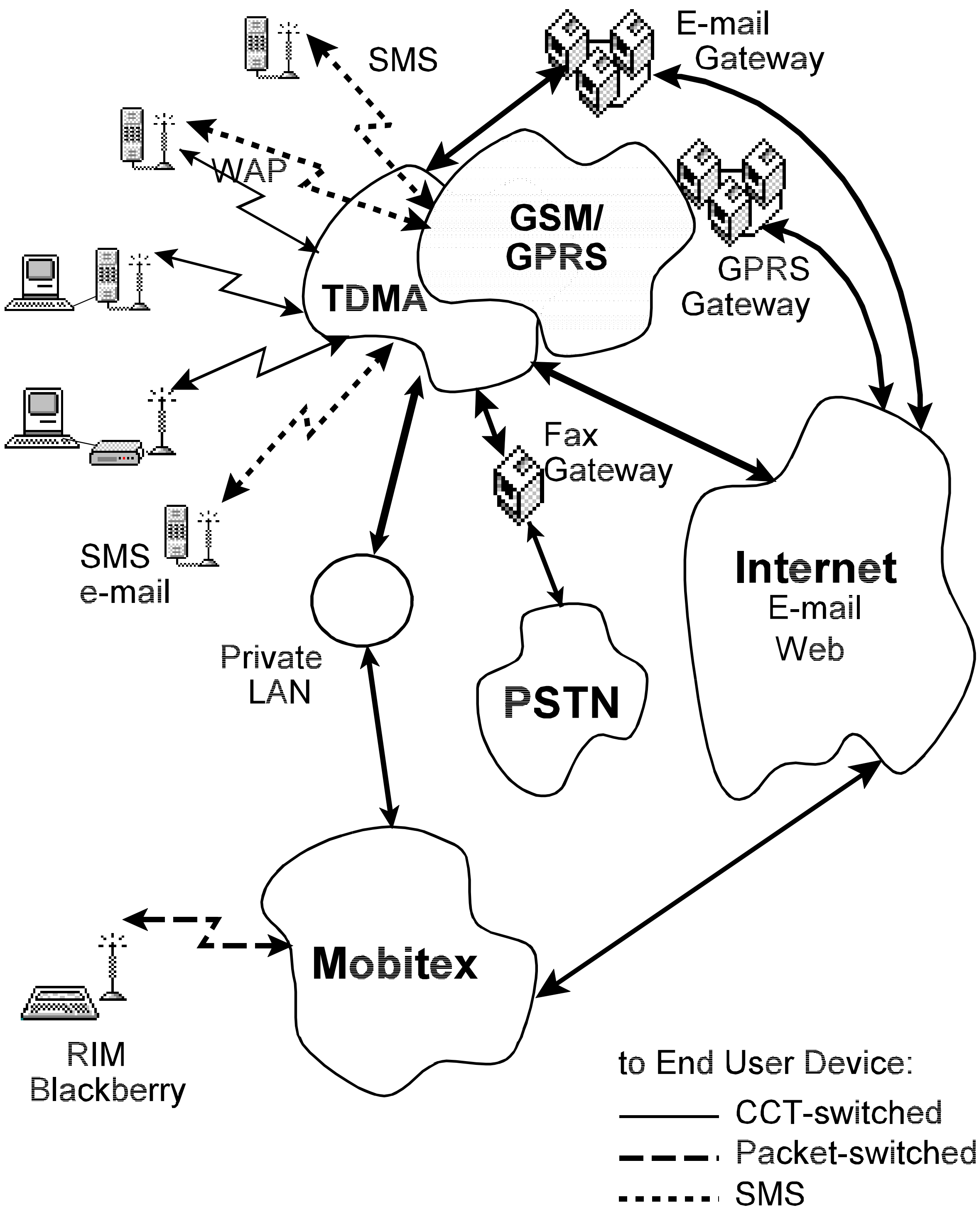
(b) **Rogers AT&T**

Rogers AT&T operates two digital cellular networks, TDMA and GSM. The original Cantel TDMA network operates in the 800/1900 MHz range. Similar to the CDMA (IS95a) network it has no full set of native data capability except circuit-switching and bi-directional SMS (send & receive). In 2001 Rogers AT&T commenced deployment of a GSM overlay with a GPRS extension at 1900 MHz. This network has full data capabilities and a gradual move from TDMA to GSM is anticipated in 2002. In addition, Rogers AT&T has partnered with the Mobitex data-only network to provide exclusive mobile access for RIM's Blackberry devices.

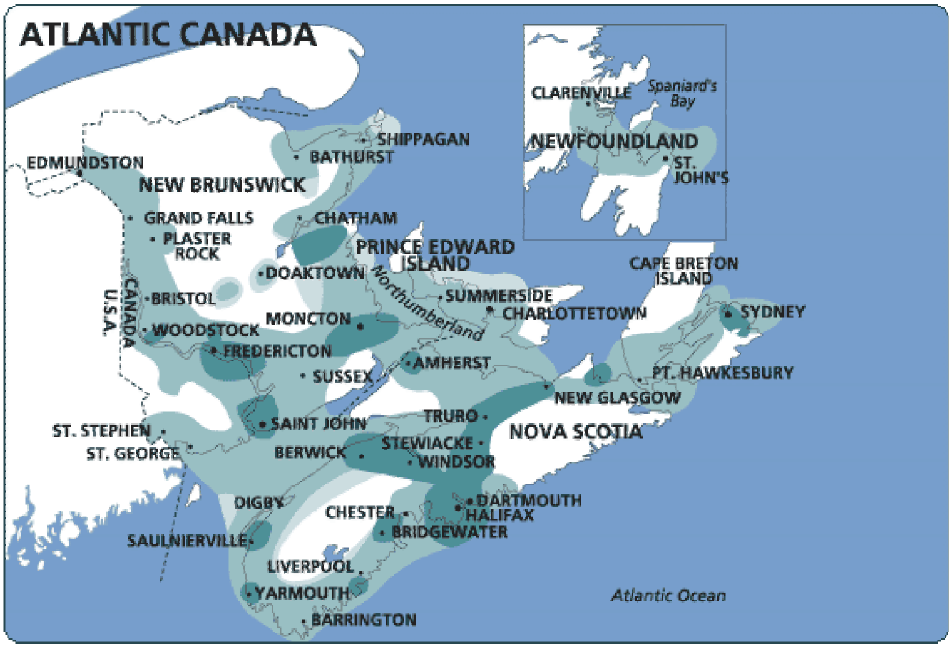
TDMA coverage extends to all provinces, but mainly to the larger cities and highways. TDMA coverage in New Brunswick is limited to three cities, Saint John, Moncton and Fredericton. In other areas the telephones switch automatically to the analog AMPS system and lose all their data capabilities. The TDMA coverage will not be extended in favour of the new GSM network.

The GSM/GPRS network is available in all provinces. In the Atlantic provinces, the Halifax to New Glasgow corridor received coverage in Summer 2001, followed by Saint John in December 2001 and Fredericton and Moncton with interconnecting highways by January 2002. This coverage is in the process of extension and by Summer 2002 all areas covered by Rogers AT&T analog AMPS system are expected to have GSM coverage. In areas not covered by GSM no fall-back to AMPS is possible, either for voice or data, because of the lack of multi-mode telephone sets.

Roaming is possible without restrictions across Canada in Rogers AT&T networks, for both voice and data in all three networks. Voice and data roaming is also possible in the US and overseas TDMA networks, provided multi-band TDMA telephones or wireless TDMA modems are used, and agreements with the foreign public carriers exist. The GSM/GPRS service offers extended voice and data roaming across Canada, North America and worldwide in participating GSM/GPRS networks, provided that multi-band phones and world-wide subscriber plans are used. In the US, all three major GSM providers, Voicestream, Cingular and AT&T, have entered a roaming agreement with Rogers AT&T. Owing to the use of a SIM card, which carries the profile of the subscriber, GSM services in Canada can also be accessed worldwide from any GSM phone where the SIM card is installed.

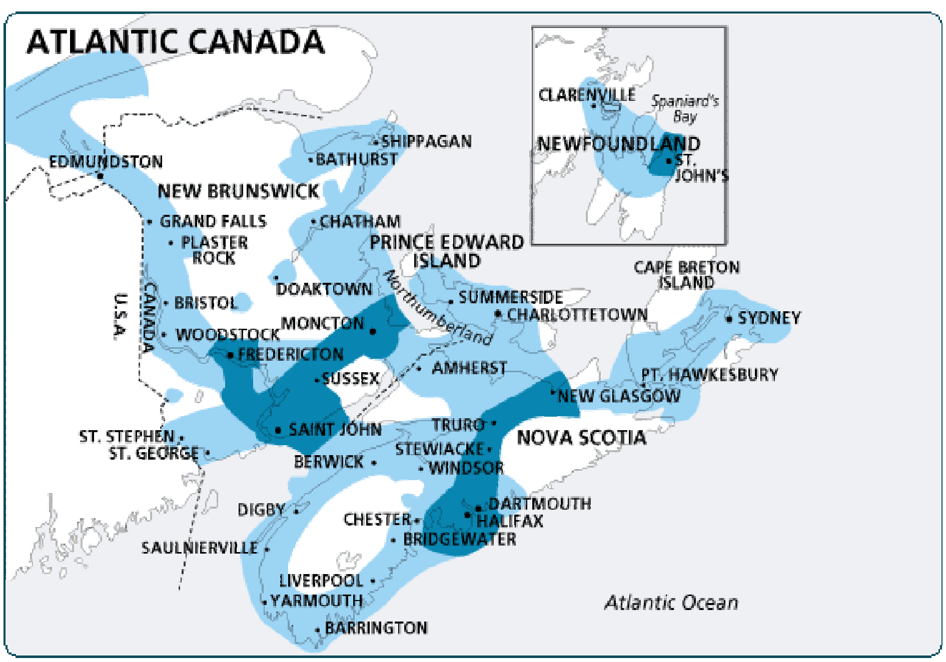


Rogers AT&T Network Architecture (functional)



Source: www.rogers.ca

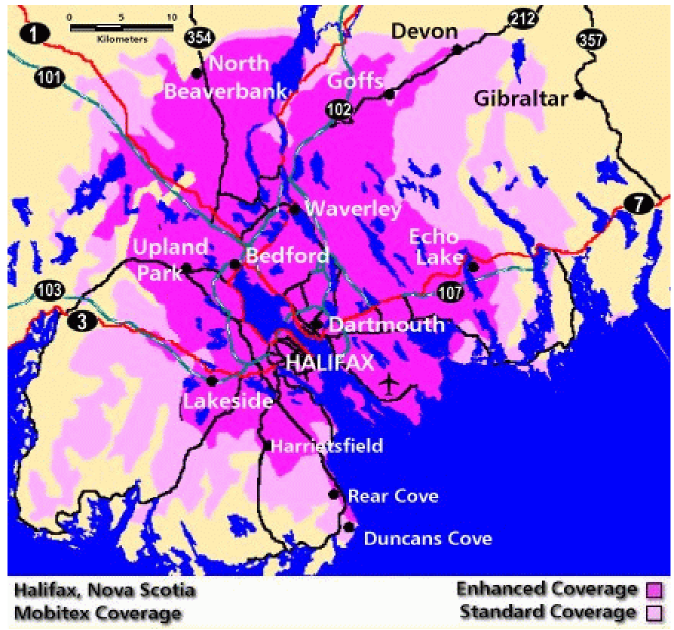
Fig. 4.15 Rogers AT&T TDMA Coverage in Atlantic Canada. Dark blue area indicates digital network coverage



Source: www.rogers.ca

Fig. 4.16 Rogers AT&T GSM/GPRS Coverage in Atlantic Canada. Dark blue area indicates digital network coverage

- Vancouver
- Victoria
- Calgary
- Edmonton
- Saskatoon
- Regina
- Winnipeg
- Greater Toronto Area (includes Welland, Barrie, Peterborough)
- Southwestern Ontario
- Ottawa
- Montreal



Source: www.rogers.com

Fig. 4.17 Rogers AT&T Mobitex Coverage by Cities and Example of Halifax Coverage. Purple areas indicate digital network coverage

(c) **Microcell Connexion**

Microcell is one of the original licensees of Industry Canada for PCS services. It sells services under the names Fido, Cityfone, SIMpro and Connectel. Microcell Connexion is operating a GSM network at 1900 MHz (PCS1900). Since 2001 the GPRS packet-switching enhancement is available to provide superior digital data communications for circuit-switched, packet-switched and native SMS capabilities without the need to partner with other data-only network providers. Due to the wide-spread use of PCS1900 in the US a large number of GSM telephones and wireless GSM modems are available for phone-only use or connection to a PDA/Lap-top computer, respectively.

GSM coverage extends to the larger cities and highways in the western and central provinces, and to St. John’s Newfoundland. There is no GSM coverage by Microcell Connexion in New Brunswick. Subscribers of Microcell have to use Bell Wireless Alliance’s analog AMPS network where GSM is not available using multi-band/multi-mode phones with automatic switch-over. In the latter case all data capabilities are lost.

Roaming is possible in Microcell Connexion’s GSM networks across Canada. In addition, GSM offers unrestricted roaming in the US and worldwide in GSM networks with multi-band GSM phones and GSM wireless modems, provided that a world-wide subscriber plan is used. Owing to the use of a SIM card, which carries the profile of the subscriber, GSM services in Canada can also be accessed worldwide from any GSM phone where the SIM card is installed.

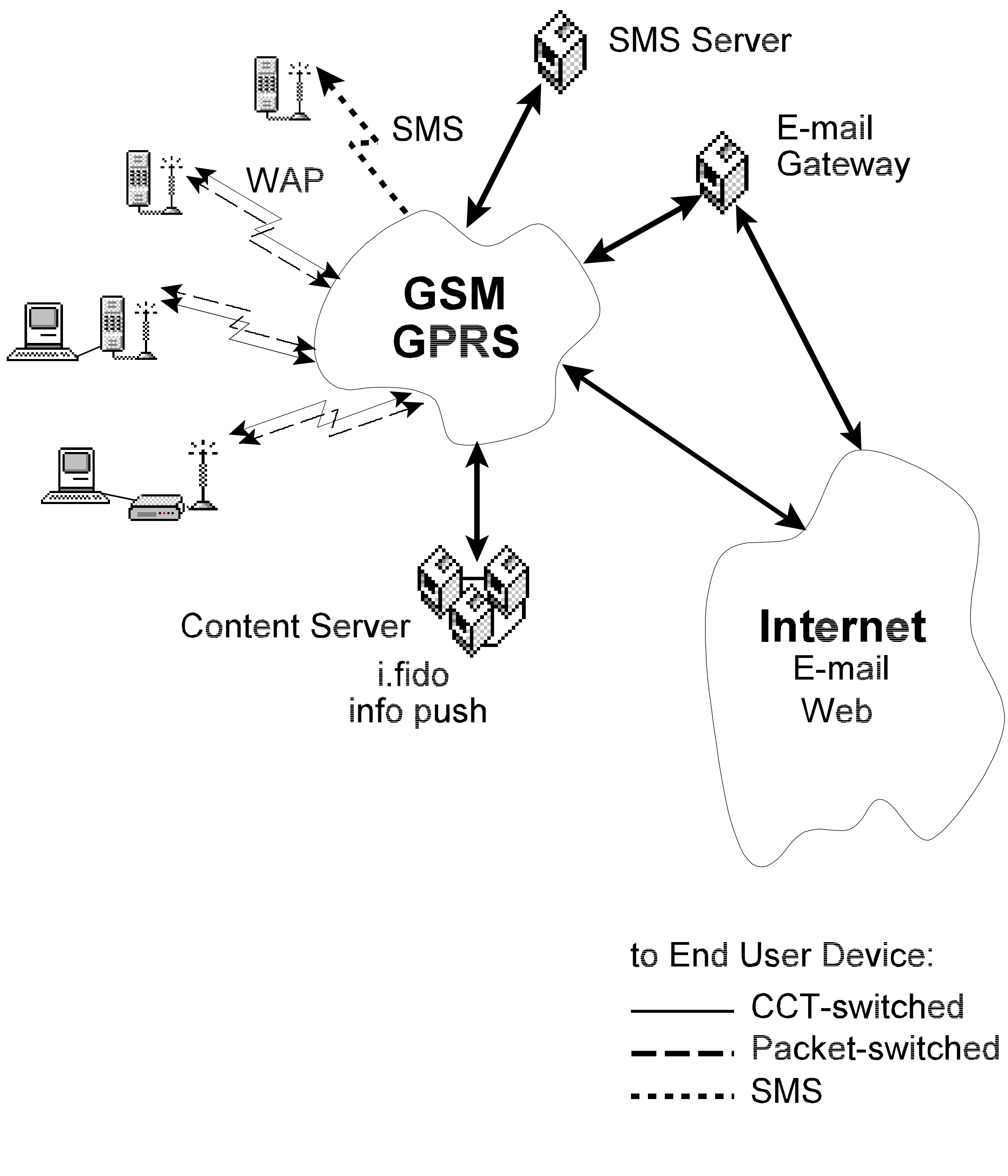
(d) **Telus**

Telus operates two separate wireless telecommunications networks in Canada. Both cellular networks employ incompatible voice networks, but identical data networks.

Telus Mobility uses the CDMA technology at 1900 MHz and is available in the western and central provinces, as well as Nova Scotia. Since no full set of data capabilities are offered by CDMA, Telus Mobility offers packet-switched CDPD services over the older analog AMPS networks in British Columbia and Alberta.

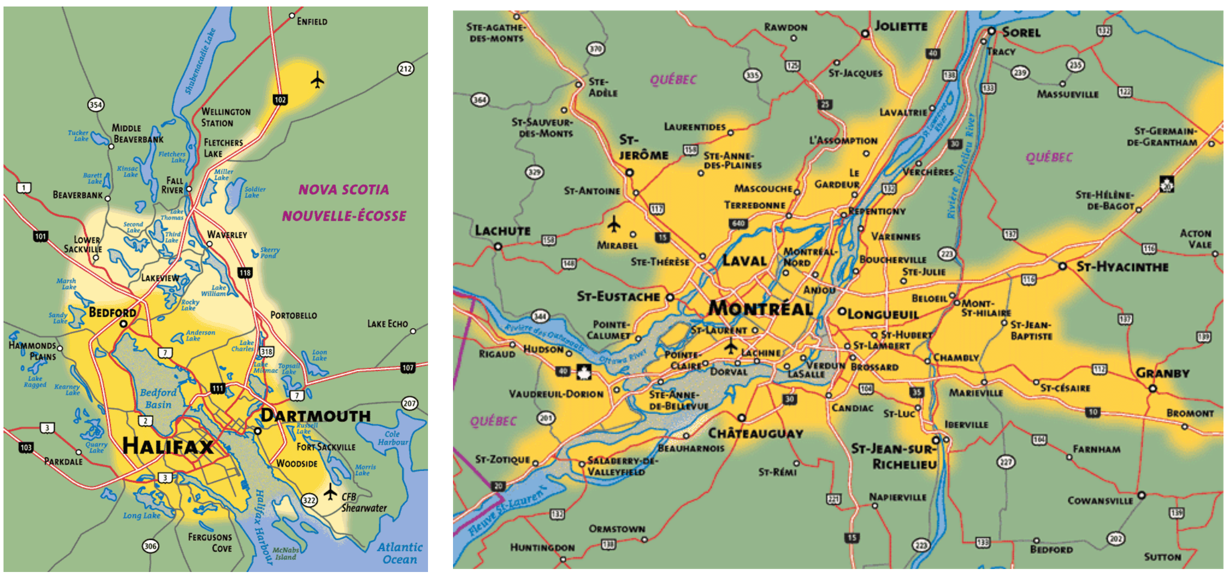
Telus Mike is the only iDEN operator in Canada and extends to the western provinces and Ontario and Quebec. iDEN uses the 800 MHz range. Telus Mike offers the same CDPD access to data communications as Telus Mobility.

Roaming is possible without restrictions across Canada in each of the two respective networks, CDMA or iDEN, but not in-between them. Voice roaming is also possible in the US CDMA areas for Telus Mobility subscribers where agreements with the public carriers exist, and in partnership with Nextel in the iDEN networks in the US.



Microcell/FidoNetwork Architecture (functional)

British Columbia	Vancouver Area
Alberta	Edmonton to Calgary corridor
Saskatchewan	Saskatoon to Regina corridor (future)
Manitoba	Winnipeg area
Ontario and Quebec	Large coverage
Nova Scotia	Halifax area
Newfoundland	Saint John's area



Source: www.canadagsm.com

Fig. 4.18 Microcell/Fido GSM Coverage by Cities and Example of Halifax and Montreal Coverage**.** Yellow area indicates digital network coverage

A brief summary of the Canadian digital wireless network providers is presented in Table 3.1

Provider	Bell Wireless Alliance	Rogers AT&T	Telus Mobility	Telus Mike	Microcell Connexion
Service Reseller	NBTel Mobility, NewTel Mobility , ...			previously Clearnet	Fido, Cityfone, SIMpro, Connectel
Voice/Data Technology	CDMA 800 – 1900 MHz	TDMA 800 – 1900 MHz GSM 1900 MHz	CDMA 800 – 1900 MHz	**iDEN/TDMA** **800 MHz**	**GSM** **1900 MHz**
Packet Data technology	Ardis CDPD	Mobitex GPRS	CDPD (BC, Alberta)		GPRS
New Brunswick Coverage	Saint John, Moncton, Fredericton	Saint John, Moncton, Fredericton	None	None	None
National Coverage	Present in all Provinces	Present in all Provinces	BC, Alta., Man., Ont., Que., NS	BC, Alberta, Ont.,Quebec	BC, Alta, Man., Ont., Que., Nfld, NS
Voice Roaming	US CDMA coverage	US TDMA and GSM coverage	US CDMA coverage	Nextel iDEN network in the US	Worldwide agreements with GSM operators

Table 4.2 Canadian Digital Wireless Network Providers

4.6 Interoperability and Roaming

PCS users must subscribe to a user plan with their Home network services provider. Roaming takes place when a subscriber uses the services of another provider outside of the Home network. The capability of roaming depends on three factors, compatibility of the network technologies, compatibility of the end user device and inter-roaming agreements between the Home provider and the provider of the network to be roamed in, mainly for billing purposes.

If the network technologies of the two networks involved differ, multi-band/multi-mode end user devices are required. Because of the many different technologies deployed around the globe, only a limited combination of technologies is implemented in any one device. It is common to have end user devices that can switch from the analog system AMPS to one of the 2nd generation digital systems, such as TDMA, CDMA or GSM. This allows subscribers to use the more sporadically available digital networks with all their facilities and fall back to the analog system of their Home provider where no digital coverage exists. Unfortunately no devices are available that permit roaming in networks of different digital standards.

The GSM standard has a provision that permits unrestricted worldwide roaming. This is made possible by a single standard for GSM in all countries and the use of the subscriber's personal profile contained in the SIM card installed in the end user device (phone). This profile is used to identify the user to the network being roaming, and any billing is automatically transferred to the Home network provider. Normally, the subscriber must include a worldwide roaming option, at an extra charge, in the subscription to do so. Alternatively, a SIM card can be purchased in the visited country and installed in the traveller's home phone. This transfers the new foreign user profile, including foreign telephone number, into the phone and allows unrestricted use of the visited country's GSM/GPRS network.

5. Digital Data Communications Services

Data communications services comprise two kinds of services, phone-centric and computer-centric services. For the phone-centric service the phone is the end user device that both sends and receives digital data via the wireless network. Typical examples are SMS and E-mail displayed on the phone's screen and entered in on the phone's keypad. For this purpose the phone device must have a suitable client and server installed. For the computer-centric data services the data terminates at a computer end device (e.g. a PDA or lap-top computer) connected to the phone by a data cable. Here the phone device acts as a RF transceiver/modem which relays the digital data between the computer device and the network. Typical examples are GPRS and data over a circuit-switched connection (dial-up). Normally, the IP protocol is used over PPP (Point-to-Point protocol) services. The computer must have the proper software installed to both originate and receive and interpret the data. A hybrid approach is the use of a computer device with a built-in or attached wireless modem, such as a Blackberry device or a Palm organizer with piggy-back modem.

The network provider's data service offerings depend on the standard used and the upgrade level of the network components. The following sections list the data services offered by the four major Canadian wireless service providers.

5.1 NBTel Mobility

The various data services are spread over three different networks, CDMA, CDPD and Ardis.

(a) **Phone-centric** data services are offered on the **CDMA** network as follows.

SMS is available for receive-only of simple text messages that are posted to an E-mail gateway, which is part of the CDMA network's Content Server (InforMe service). These messages are limited to 160 characters and no binary files, such as images or sounds are acceptable, i.e the service is not EMS compliant. It is not possible to send SMS or E-mail from a phone device, i.e. there is no support for responsive phone-to-phone messaging. It may take several minutes until a posted message is forwarded to an active cellular phone.

Web surfing is possible using a WAP-enabled phone device. A circuit-switched connection is established by dialling up the WAP gateway, followed by a PPP session establishment. A Content Server can be accessed which has portals to partner web site providers, or any WAP-enabled web server on the Internet can be reached by entering its URL. The data rate is up to 14,400 bps over the reserved circuit. Usage fee is based on connect time.

(b) **Computer-centric** data services are offered on the **CDMA** network by connecting the end user device (PDA, Palm, lap-top computer, etc.) to either a data-enabled phone with data port or a CDMA modem. These services are offered under the name 'WireFree'.

All data functionalities are enabled by accessing the Internet. E-mail accounts can be accessed through their servers, and any web site can be accessed by connecting to a web server. The circuit-switched connection establishment is identical to that for the phone-centric dial up except that it can be originated from the computer end device. The data rate is up to 14,400 bps over the reserved circuit. Usage fee is based on connect time.

Roaming outside of Canada is currently not available.

(c) **Computer-centric** data services are offered over the **CDPD** network via a CDPD modem connected to an end user device (PDA, lap-top computer, etc.).These services are also offered under the name 'WireFree'.

Through the CDPD network an 'always-on' connection is established to the Internet. E-mail servers and any web site can be accessed by connecting to a web server. This is a packet-switched connection, with a variable data rate up to 19,200 bps and the usage charge depends on the amount of data transferred.

CDPD also offers access to corporate LANs by connecting to their LAN gateway. This feature provides an anytime-anywhere virtual access to business resources with enhanced security and offers many benefits to corporate staff members on the move.

The CDPD network can normally not be accessed by a phone device alone since there are no CDPD-enabled phones readily available (Ericsson and Mitsubishi are said to have produced a multi-mode AMPS/CDPD/TDMA cellular phone exclusively for AT&T subscribers in the US, but with no CDMA-compliance). Roaming outside of Atlantic Canada is not available.

(d) **Computer-centric** data services are available on the **Ardis** network. This separate packet-switched network is accessible by RIM's Blackberry devices and computer devices with a proprietary Ardis-capable RF modem. It provides 'always-on' Internet access with connectivity to all E-mail and web servers and a large selection of business-oriented information services.

Neither one of the three separate NBTel Mobility data networks support all of the desirable personal communications functions, such as voice calls, bi-directional short messaging (SMS, E-mail) and bi-directional data streaming for Web browsing, plus connectivity to a private LAN. The Ardis network has the most comprehensive data communications features but no voice support. It is also not possible to roam between the CDMA and CDPD networks because no compatible multi-band/multi-mode devices exist, and two different user fee plans would be necessary. Since NBTel Mobility does not plan to upgrade CDMA IS95a to IS95b, the complete set of the above data functionalities will likely not be available in a single network until a new 3rd generation CDMA2000-based network will be installed, sometime in late 2002 or 2003.

5.2 Rogers AT&T

The data services are offered via three separate networks, TDMA, GSM/GPRS and Mobitex.

(a) **Phone-centric** data services are offered on the **TDMA** network as follows:

Bi-directional EMS (enhanced SMS) is supported as is bi-directional E-mail service with short messages up to 160 characters. The dispatch of E-mail is a batch process with can take several minutes to be completed.

Web surfing is available using a WAP-enabled phone device. A circuit-switched connection is established by dialling up the WAP gateway. Any web server on the Internet can be reached by entering its URL. The data rate is 9,600 bps over the reserved circuit, and usage is charged on a connect time basis..

(b) **Phone-centric** data services are offered on the **GSM/GPRS** network as follows:

All data services use the packet-switched GPRS system extension, which is an ‘always-on’ data service and is charged on one of several per-volume based fee structures. Bi-directional native EMS (enhanced SMS) is supported with an almost immediate response, as is bi-directional E-mail service with a slower processing time up to several minutes (batch process). Messaging is charged by the number of sent messages.

Web surfing is available using a WAP-enabled phone device via the network’s WAP gateway. A Content Server can be accessed which has portals to partner web site providers, or any WAP-enabled web server on the Internet can be reached by entering its URL. The data rate is theoretically up to 171 kbps, but an estimated rate of 30 to 40 kbps is more realistic. Due to the short deployment of a few months and ongoing tuning of the GSM/GPRS network, conclusive effective data rates could not be established yet. Usage is charged on a data volume basis.

(c) **Computer-centric** data services are offered on the **TDMA** network by connecting the end user device (PDA, Palm, lap-top computer, etc.) to either a data-enabled phone set with data port or a TDMA modem (called Portage Service).

All data functionalities are enabled by accessing the Internet. E-mail accounts can be accessed through their servers, and any web site can be accessed either by connecting to a web server. The circuit-switched connection establishment is identical to that for the phone-centric dial up except that it can be originated from the computer end device. In addition, a provision is available to send faxes to the land-line Public Switched Telephone Network (PSTN) by connecting to a fax gateway. The data rate is 9,600 bps over the reserved circuit. Usage fee is based on connect time.

The TDMA network also supports access to corporate LANs by connecting to their LAN gateway. This feature provides an anytime-anywhere secure virtual access to business resources and offers many benefits to corporate staff members on the move.

No data roaming outside of Canada is possible. No computer-centric data services are currently available on the **GSM/GPRS** network, but are announced for summer 2002. When available, they are expected to provide similar Internet access at similar performance levels as the phone-centric GSM/GPRS services.

(d) **Computer-centric** data services are available on the **Mobitex** network. This separate packet-switched network is accessible by RIM's Blackberry devices and computer devices with a proprietary Mobitex-capable RF modem.. It provides 'always-on' Internet access with connectivity to all E-mail and web servers and a wide selection of specialized services for business and private use. Roaming in the US is possible on the Cingular Mobitex network covering all major US cities.

Rogers AT&T's TDMA network combines most desirable personal communications functions, such as voice calls, bi-directional short messaging (SMS, E-mail) and bi-directional data streaming for Web browsing, plus connectivity to a private LAN. Because no packet-switching support for data-streaming exists, Internet access and Web browsing are relatively costly due to the required reserved circuit connection. TDMA is currently being migrated to GSM.

Rogers AT&T's GSM/GPRS network has the potential to offer all desirable communications services, each most cost-effectively. It is a public wireless network that comes closest to the one-network one-device vision. GSM/GPRS currently lacks all computer-centric services, but this is expected to be remedied by summer 2002. North America wide roaming is available through the roaming agreements of Voicestream, Cingular and AT&T. Global roaming with multi-band devices is readily available due to the high proliferation of GSM networks around the globe, where roaming agreements exist. The GSM network allows the use of different end user devices on the same subscriber plan (one device at a time) by simply moving the SIM card from one device to the other.

5.3 Microcell Connexion

All data services are offered through a single GSM network with GPRS extension.

(a) **Phone-centric** data services are offered on the GSM network as follows:

Native bi-directional SMS is supported with a maximum text length of 160 characters. E-mail support is available over the SMS service. The text of E-mails is embedded into an SMS message and the E-mail address, subject and actual text must not exceed 160 characters. E-mail messages are directed to an E-mail server which forwards them to any destination on the Internet.

Web surfing is available using a WAP-enabled phone device. A circuit-switched connection is established by dialling up the WAP gateway. Any web server on the Internet can be reached by entering its URL. The GSM network has a Content Server which offers specialized information services (i.fido) upon subscription, such as news and stock quotes at regular intervals (push method).

(b) **Computer-centric** data services are offered on the GSM network by connecting the end user device (PDA, Palm, lap-top computer, etc.) to either a data-enabled phone set with data port or a GSM modem. Both circuit-switched and packet-switched communications sessions are supported.

All data functionalities are enabled by accessing the Internet. E-mail accounts can be accessed through their servers, and any web site can be accessed either by connecting to a WAP gateway or another web server, depending on the capabilities of the computer end device. The circuit-switched connection establishment is identical to that for the phone-centric dial up except that it can be originated from the computer end device. In addition, an 'always-on' packet-switched data service is available over GPRS at a data rate up to 56 Kbps. This service is a cost-efficient data transfer method for bursty traffic, such as Web browsing. All GPRS services are enabled by accessing the Internet. Currently, the GPRS service is only available for lap-top computers with installed GSM/GPRS modem and not yet for PDAs. Usage fee for the circuit-switched method is based on the connect time, whereas it is based on the amount of data sent for the packet-switched method.

Data roaming is possible in the worldwide cellular GSM network with multi-band GSM phone devices or modems.

Microcell Connexion's GSM network offers an almost full-featured set of all desirable data communications functionalities in a single network. However, connectivity to a private LAN must travel through the Internet and requires additional security features. It provides optimal communications services for both data streaming applications (circuit-switched) and bursty data traffic, such as experienced in Internet E-mail processing, Web browsing and data base request/reply applications. Currently the cost-efficient GPRS packet-switching service is only available for lap-top computers and PDAs must use the more costly circuit-switched connections. This will likely be remedied in the near future with GPS/GPRS modems becoming available and more computation power in the PDAs. The GSM network allows the use of different end user devices on the same subscriber plan (one device at a time) by simply moving the SIM card from one device to the other.

5.4 Telus

Telus operates two networks, Telus Mobility (CDMA) and Telus Mike (iDEN). The data services are identical in both networks with the addition of enhanced features in iDEN.
All data services are offered through either one of the above networks and an additional CDPD network.

(a) **Phone-centric** data services are offered on either Telus network as follows:

Bi-directional SMS is supported. It is unclear if a SMS server exists for responsive phone-to-phone text messaging. Send and receive E-mail support is available through an E-mail server on the Internet.

Web surfing is available using a WAP-enabled phone device (PocketWeb). A circuit-switched connection is established by dialling up the WAP gateway. Telus permits access only to its own web server (Contents Server) with web site offerings by its partners. The PocketInfo service is an information service that uses the push method to send subscribed-to information, such as news or stock quotes to an active cellular phone at regular intervals.

A special feature available only in the iDEN network is the ability to establish multi-party communications to all members of a closed group (DirectConnect) at the touch of a button.

(b) **Computer-centric** data services are offered on the Telus network by connecting the end user device (PDA, lap-top computer, etc.) to either a data-enabled phone set with data port or a network-compatible modem (not available for iDEN).

The data functionalities are identical to those for the phone-centric connection. The circuit-switched connection establishment is identical to that for the phone-centric dial up except that it can be originated from the computer end device. Usage fee is based on the connect time. Roaming for data services outside of Telus's network is not available.

(c) **Computer-centric** data services are offered over Telus's CDPD network via a CDPD modem connected to a end user device (PDA, lap-top computer, etc.).

Through the CDPD network an 'always-on' connection is established to the Internet. E-mail servers and any web site can be accessed either by connecting to a WAP gateway or another web server, depending on the capabilities of the computer end device. This is a packet-switched connection, so the usage charge depends on the amount of data transferred. Province-wide roaming is available as well as to the US on partnering CDPD networks.

Neither one of the three separate Telus data networks support all of the desirable personal communications functions, such as voice calls, bi-directional short messaging (SMS, E-mail) and bi-directional data streaming for Web browsing, plus connectivity to a private LAN. In all cases, connectivity to a private LAN must travel through the Internet and requires additional security features. It is also not possible to roam between the CDMA, iDEN and CDPD networks because no compatible multi-band/multi-mode devices exist, and different user fee plans would be necessary.

Table 5.1 illustrates a summary of the digital data services available from Canadian network providers.

	NBTel Mobility			**Rogers AT&T**		**Microcell Connexion**	**Telus**		
	CDMA	**CDPD**	**Ardis**	**TDMA /GSM-GPRS**	**Mobitex**	**GSM**	**Mobility**	**Mike**	**CDPD**
Phone									
PDA + pone				TDMA only					
PDA + modem				TDMA only					
Blackberry									
SMS				GSM only					
SMS-email	R			S+R		S+R	S+R	S+R	
Web	CCT	PKT		CCT/PKT		CCT+PKT GPRS	CCT own server	CCT own server	PKT
E-mail	CCT	PKT		CCT/PKT		CCT+PKT	CCT	CCT	PKT
LAN direct									
Fax direct									
Data rate	9.6 k	<14.4k		9.6 k/30....40k estim.		9.6/56 k			
Roaming US									
Roaming int'l				GSM only					
Other						info push	info push	info push	

PDA also includes lap-top computers
CCT = circuit-switched, PKT = packet-switched
S = send, R = receive

Table 5.1 Digital Data Services offered by Canadian Network Providers

6. End User Devices

Digital end user devices are grouped into three groups, phone-centric, computer-centric and Smart or Hybrid devices. Devices in the latter group have special capabilities which serve new markets and which don't fit into any of the first classical groups.

6.1 Phone-Centric Devices

This group comprises exclusively digital telephone sets, such as used for cellular telephone networks, which are primarily designed for voice communication. In addition, these phones are also data-enabled to an extent that is limited by the technology standard used and the features implemented by the manufacturer.

Most phone devices are multi-band and or multi-mode devices. 'Multi-band' means that the device can communicate over several frequency bands (e.g. 800 MHz and 1900 MHz), and 'multi-mode' means that it supports multiple technology standards in any of the accessible bands (e.g. AMPS and TDMA). The above definition of the two 'multi-' terms is the one used in this document. Occasionally the term 'multi-mode' is used more loosely and ambiguously to identify a phone that supports either multiple frequency bands and/or multiple air interfaces; this meaning is not used here. Except for GSM phones used in regions with 100% GSM coverage, such as Europe or the Middle East, phones for digital cellular networks need to be multi-mode because of today's sporadic deployment of digital networks. In addition to the network's digital standard, the companion analog network standard is supported, such as AMPS in the Americas, so the communications can fall back to the wide-spread analog system when no digital coverage is available. Owing to the splintered deployment of varying digital networks, the selection of phones is severely limited for each wireless communications market segment. In addition, support for combinations of digital technologies in one telephone does not exist. This unfortunate fact detrimentally affects both the availability of universal phones and, the roaming capability across digital networks.

Except for GSM-only phones, most phones are approved by, and available from, the Home network provider upon subscription to a user plan. This limits the choice of desirable phones significantly. GSM network services allow subscribers to purchase their own phones from a very large international selection and use this phone in their networks. This is possible by the use of a SIM card which transfers the user's personal profile (Home provider, subscription services, accounting information, etc.) into the phone set once installed in it.

Phone-centric devices have the poorest user interface for data communications due to their small display screen size and 12-key keypad for alphanumeric input. Alphabetic characters are mapped onto the 8 digit keys 2...9, three to four characters per key. One of the characters is selected using a multi-tap input process on each key. Because this is an awkward and time-consuming input method, more efficient ways were developed. Tegic's T9 (Text by 9 keys) input method is widely deployed in cellular phones and allows the entry of words by pressing one key per letter. A predictive method selects the most frequently used word from many combinations from a built-in data base, with the possibility to search for other meaningful words or create and store new words in the database. The T9 methods works surprisingly well and significantly speeds up the entry of alphanumeric text on phone-type keypads. A variant of T9 is Motorola's predictive iTap entry method.

A selected list of available phone devices for the Canadian market is listed below, grouped by network standards, along with the network where the phone is approved for.

(a) **TDMA**

TDMA phones are normally service provider locked (SP locked) and useful only for the network they were purchased for (except roaming under agreements). Each phone needs to be programmed by a representative of the network provider.

Ericsson R278d, AMPS&TDMA, 800 & 1900 MHz (Rogers AT&T)
includes SMS-email, WAP Web browsing capability, CSD, optional chat-board

Nokia 8260, AMPS & TDMA,800 & 1900 MHz (Rogers AT&T)

Motorola StarTac 7897, AMPS & TDMA,800 & 1900 MHz (Rogers AT&T)

Panasonic TX220, AMPS & TDMA,800 & 1900 MHz (Rogers AT&T)

(b) **CDMA**

As with TDMA, CDMA phones are normally service provider locked (SP locked) and useful only for the network they were purchased for (except roaming under agreements). Each phone needs to be programmed by a representative of the network provider.

Audiovox CDM 9100, AMPS&CDMA, 800 & 1900 MHz (NBTel Mobility)
SMS-email, WAP, CSD, T9

Motorola V2267, AMPS&CDMA, 800 & 1900 MHz (Telus Mobility)
includes WAP Web browsing capability

Samsung M100, AMPS&CDMA, 800 & 1900 MHz (Telus Mobility)
includes WAP Web browsing and MP3 player capability

(c) **GSM**

GSM phones do not carry the user and network profile in their hardware, but read it from a SIM card which is inserted into the phone. GSM phones are available both SIM-locked and SIM-unlocked (or SIM-free). Phones which are acquired under a subsidized user plan are normally locked, whereas phones purchased on the open worldwide market are SIM-free. Both types accept SIM cards and can be used at any GSM network, provided the proper bands (900, 1800 and 1900 MHz) are supported by the phone hardware. The use of a SIM cards permits the use of multiple wireless devices (one at a time), such as phone,

Source: audiovox.com

Source: ericsson.com

Source: motorola.com

Source: nokia.com

Fig. 6.1 Examples of Phone-centric End User Devices

From top left to bottom right: Audiovox CDM9100 (CDMA), Ericsson R278d with chat board (TDMA), Motorola P280 (GSM), Nokia 5510 (GSM)

RF modem or PDA with built-in RF modem, under the same user plan by simply moving the SIM card from one device to the other.

Ericsson T39m, GSM, GPRS, HSCD, 900, 1800 &1900 MHz (Rogers AT&T)
tri-band single-mode phone for worldwide coverage, SMS, SMS-email, WAP, data modem, ASR, T9, PIM, Bluetooth

Motorola T193, GSM, GPRS, 1900 MHz (Rogers AT&T)
exclusively for the American region with SMS, SMS-email and WAP web browsing capability, ASR, iTap.

Motorola P280, GSM, GPRS, 900 &1800 &1900 MHz (Rogers AT&T)
tri-band single-mode phone for worldwide GSM compatibility, SMS, SMS-email, WAP, CSD, data modem, ASR, iTap, PIM

Nokia 5510, GSM, GPRS, 900 &1800 MHz, fashion phone for teens
dual-band phone for the Americas and part of overseas countries, SMS, SMS-email, WAP, built-in chat keyboard, FM radio, MP3 music player, games

Nokia 7190, GSM, 1900 MHz (Microcell/Fido)
exclusively for the American market with WAP Web browsing capability

Nokia 8890, GSM, 900 &1900 MHz (Microcell/Fido)
dual-band single-mode phone for the American (1900 MHz) and part of the overseas GSM region (900 MHz)

(d) **iDEN**

Motorola i85s, iDEN, 1900 MHz (Telus Mike)
includes WAP Web browsing capability

6.2 Computer-Centric Devices

Computer-centric end user devices have computers with an operating system built-in. They accept programs to tailor their operations to specific needs. Normally, all devices support Internet access with E-mail and WAP and/or HTML Web browsing. These devices communicate with the wireless telecommunications network either by a serial connection to the data port of a regular phone device (which acts as a RF modem), accept a wireless RF modem, or have one built-in. These computer devices are normally independent of the network standards and compatibility with a particular network is the determined by the phone or modem used and the software to support the network functionalities. An exception to this network standard-independence is the case where the modem is built-in. This group of devices comprises PDAs, Pocket PCs, Handheld PCs, lap-top computers, desktop computers and Blackberry devices.

Source: compaq.com

S
ource: hp.com

Source: palm.com

Source: blackberry.net

Fig. 6.2 Examples of Computer-centric End User Devices

From top left to bottom right: Compaq iPaq 3650, Hewlett-Packard HP720, Palm M505, RIM Blackberry 850

A selected list of available computer-centric devices is shown below. Where needed, the network provider which offers support, such as software and additional interconnection hardware to their approved phone devices, is included. The listing is grouped by manufacturers.

Computer-Based End User Devices:

(a) **Hewlett Packard**
HP Jornada 700 Series, Handheld PC, Windows CE3.0
half-size VGA color screen 640x240, full keyboard, PC-card & CF-card ports, Smartcard reader, multi-media capable, sound recorder
HP Jornada 560 Series, PDA-type, Windows for Pocket PC2002
240x320 color screen, Soft keyboard, CF card port, expansion pack for PC cards, multi-media capable, sound recorder

(b) **Compaq**
iPaq H3600, Pocket PC, Windows for Pocket PC2000
iPaq H3800, Pocket PC, Windows for Pocket PC2002, SD card port, optional Bluetooth
240x320 color screen, Soft keyboard, multi-media capable, sound recorder, expansion packs for PC-cards and CF-cards

(c) **Casio**
Cassiopeia EM500, Pocket PC, Windows for Pocket PC
Cassiopeia A22T, Pocket PC, Windows CE

(d) **Handspring**
Visor, PDA, Palm OS

(e) **Palm**
Palm, M500 Series, Palm OS 4.0
160x160 gray-level or color screen, Soft keyboard, character recognition, SD-card port, accepts expansion sleds with add-on peripherals

(f) **Research in Motion, (RIM)**
Blackberry devices have the RF modem built-in and are dedicated to a particular network standard and network services provider.

Blackberry 950, PDA (Mobitex, Ardis and GSM/GPRS)
Blackberry 957, PDA (Mobitex, Ardis and GSM/GPRS)

RF Modems:

Almost all RF modems are single-mode and dedicated to operate with a specific wireless network technology. Except for the PC (PCMCIA) and CF card-format modems they are built for mechanical and electrical compatibility with a certain PDA or Pocket PC, and normally are

Source: novatelwireless

Source: sierrawireless.com

Source: compaq.com

Source: hp.com

Fig. 6.3 Examples of RF Modems

From top left to bottom right: Novatel Merlin PC-Card (CDPD), Sierra Aircard 750 (GSM/GPRS), Compaq Wireless Pack GSM for iPaq 3600..3800 series Pocket PCs (GSM/GPRS), Hewlett-Packard CDPD for H540 series Pocket PC (CDPD) attached piggy-back to the computer device. Most RF modems employ standard V.42 error control and V.42bis data compression. They are connected via an emulated serial port to the computer device and support Hayes' AT command set for control purposes. As such, they can readily be accessed by any standard dial-up software with PPP support. The Compaq Wireless Pack for GSM deserves a particular mention because it is the first RF modem-like add-on module that integrates the Compaq iPaq Pocket PC with cellular phone capabilities. This combination permits voice and data telecommunication over circuit-switched and packet-switched GSM/GPRS connections. Though bulky in size, it is a first step towards the elusive all-in-one end user device.

(a) **Novatel Wireless**
Minstrel m500, Palm 500 Series, CDPD
Minstrel 540, HP Jornada 540 Series, CDPD
Minstrel V, Palm V, CDPD
Minstrel III, Palm III, CDPD
Minstrel Handspring Visor, CDPD
Merlin G100, PC card, GSM, GPRS
Merlin CDPD, PC card, CDPD

(b) **Sierra Wireless**
AirPath 300, Handspring Visor, CDPD
Aircard 210, PC card for lap-top computers, AMPS and CDPD
Aircard 300, PC card for lap-top computers, CDPD
Aircard 510, PC card for lap-top computers, CDMA
Aircard 750, PC card for lap-top and Pocket PC computers, GSM/GPRS, triple-band 800, 1800 & 1900 MHz for worldwide use (Rogers AT&T)

(c) **Compaq**
Wireless Pack GSM for iPaq 3600/3700/3800 family
GSM and GPRS, 800 & 1800 & 1900 MHz for worldwide coverage,
accepts standard SIM card, adds voice and data over GPRS
Integrates cellular phone and Pocket PC capabilities

(d) **Enfora**
PocketSpider, Casio Cassiopeia, CDPD

(e) **Xircom**
Palm M500 modem, CDPD
Bluetooth modem, PC card

6.3 Hybrid Devices - Smart Devices

Innovation, trend and fashion are the catalysts for the introduction of new Smart hybrid devices, combining many of the features of various wireless end user devices. At the current time a convergence of phone and computer-centric devices is evident. This consolidation is taking place at an accelerated pace since early 2002. The most popular newest devices are those that marry wireless phones and PDAs. The thrust of this development promotes the vision of one device for all telecommunications applications, such as voice communication, general data communications, Personal Information Manager, paging, web browsing and e-mail. In addition, all of these activities can now be integrated, for instance using the PIM's phonebook to dial voice calls, and establishing a unified messaging centre with voice messages, pager alerts, e-mail, fax, and web push-information. These Smart devices serve an emerging market segment and lead the way to future integrated communications devices for 3rd generation telecommunications networks, which eventually also will also include video. At this time all of the new Smart devices are available exclusively for the GSM and UMTS market sections.

(a) **GSM**

Ericsson T68m,GSM, GPRS, HSCD, Bluetooth, 900 &1800 &1900 MHz

this is one of the most advanced tri-band phones for 2.5th generation networks around the globe. It has worldwide GSM compatibility, also supporting Bluetooth networking. SMS, SMS-email, WAP web browsing. It has a color screen, a GUI, ASR, and a full-fledged PIM with compatibility with Microsoft Outlook and ready synchronization capability through IrDA or Bluetooth.

Handspring Treo 180 Communicator, GSM, GPRS 900 & 1900 MHz (Rogers AT&T, Cingular, Voicestream, Microcell/Fido)

keyboard, voice and data capabilities, full Internet access, SMS, SMS-email, WAP/ HTML/ cHTML, full PDA and PIM capability using Palm OS 3.5.

Motorola Accompli 8/9, GSM, GPRS, 800 &1800 &1900 MHZ

keyboard, voice and data capabilities, full Internet access, full PIM is MS and Lotus compatible for synchronization, uses proprietary Wisdom OS

Nokia 6310, GSM, GPRS, Bluetooth, 900 &1800 MHz

dual-band phone for 2.5th generation networking. It has compatibility with GSM networks outside the Americas, and supports GPRS data packet-switching and Bluetooth networking

Nokia Communicator 9890, GSM, 1900 MHz

includes a large display screen and PDA capabilities. Operates exclusively in the American GSM region.

SAGEM WA 3050, GSM, 900 MHz & 1800 MHz

this is a phone device with a Windows CE3.0 operating system. It accepts programs written for any conceivable telecommunications purpose, which makes it one of the most universal phones /computer devices available. It is operational only outside the Americas.

SAGEM, GSM, DECT

this 2nd generation dual-mode network phone supports two tiers of networking. It can act as a local cordless phone in a DECT network and as a standard GSM phone. Manual and automatic roaming between the two network tiers is supported.

NEC and Matsushita, UMTS (NTT DoCoMo)

Prototype phones for the 3rd generation FOMA service in Japan. Services include full data capabilities and videophone in addition to classical voice communications.

Source: sonyericsson.com

Source: foma.nttdocomo.co.jp

Source: sagem.com

Source: handspring.com

Source: motorola.com

Fig. 6.4 Examples of Smart Hybrid Devices
From top left to bottom right: Ericsson T68m (GSM) with wireless Bluetooth headset, NEC 3G Phone for FOMA (UMTS), Sagem WA3050 (GSM), Handspring Treo 180 Communicator, Motorola Accompli 8 and 9 (GSM)

7. Field Tests and Evaluation

An extensive set of field tests and a subsequent analysis and evaluation of the results were carried out in order to gain a thorough working knowledge of existing public digital wireless networks, their services and end user devices. In addition a brief evaluation of the services rendered by general wireless local area networks and personal area networks is included..

7.1 Objectives

The field tests focused on selected criteria of the wireless infrastructures:

- the availability and usability of network services;
- the quality of wireless data connections and the effective data throughput;
- the usability and user-friendliness of end user devices.

In the context of this research work, ‘service’ means a communication service offered directly by the network provider to the end user, such as short messaging and Internet access. Services do not include user applications that ride on top of network services, such as corporate data base access via a secure Internet connection or synchronization applications for cellular phones or PDAs with their home base PC computers.

The field test focused mainly on wireless network services provided in New Brunswick, with some select tests done in the Maritimes while traveling, particularly in Nova Scotia and Prince Edward Island. The testing process considers wireless services as package offerings, from the network service sources to the end user devices. This implies that all aspects of data delivery from source to device were considered as an entity, without breaking down the performance into ratings of individual delivery steps, such as server response, link data rate and device properties. This approach is believed to result in the most meaningful evaluation for a standard subscriber using public wireless services for business or pleasure on the go.

7.2 Testing and Evaluation Procedures

The procedures for the wireless networks, services and devices testing were established to follow accepted practices, to form a backdrop for everyday use of wireless services, and to provide reproducible results for a later follow-up when technologies evolve.

During the overall test period from October 2001 to March 2002 the public wireless technologies deployed by public carriers and the offered data services evolved significantly. In order to capture the latest technologies, two rounds of tests were carried out, from October to mid December 2001 and from mid January to the end of March 2002. The tests were carried out at major locations in New Brunswick and selected locations in Nova Scotia (Halifax - Truro- Amherst corridor) and Prince Edward Island (Charlottetown-Borden corridor).

A group of research assistants helped in gathering field results. A total of 7 research assistants were hired on a part-time basis, 6 males and one female. Of those assistants, 5 were English-speaking and 2 were bi-lingual, with a varying educational background (3 in Computer Science, 3 in Electrical and Computer Engineering and one in Business Administration).

Prior to participating in the filed tests, all research assistants received common directives on the procedures, evaluations and rankings of the test objectives:

- availability of services in the networks under consideration;
- usability of the services;
- responsiveness of the services;
- effective data throughput (speed) of the services;
- usability of end user devices for a particular service;
- content of services, where applicable (e.g. Content providers partnering with network providers), in both official languages English and French.

Throughout the field tests all relevant information was logged, such as date, time, location, network, service, signal field strength (where available) and equipment used. This extensive set of information allowed for a breakdown of performance ratings during the analysis work.

The performance results and rankings of networks, services and devices were arrived at using a mix of subjective and objective methods. Usability testing and ranking of services and devices were done subjectively, whereas the measurements leading to the responsiveness and effective throughput (speed) were carried out objectively. For the speed measurements, file transfers of large-size compressed binary files or web access to sites with large-size binary compressed graphs were used. The use of large-size files assures confidence in the average of the effective data rate without being excessively affected by sporadic temporary connection variations. The use of already compressed binary files avoids artificial increases of the data rate due to secondary compression effects over the wireless link served by RF modems with built-in data compression (V.42). The use of web sites with large-size graphs reduces the artifacts otherwise introduced by an excessive number of object requests through the HTTP-based connection, which are difficult to estimate. Samples of date speed tests over the wireless links were followed by an identical test (same source and device) over a different fast medium (wired and wireless LAN or Vibe) to detect temporary server and/or Internet congestions which might have falsified the test result for the wireless end-to-end connection. Results obtained during excessive Internet congestion periods were discarded to retain a true picture of the wireless network service performance.

7.3 Public Wireless Network Services under Test

The following commercial networks and their services were included in the field tests:

- NBTel Mobility CDMA network: circuit-switched data connections for general Internet access, WAP browsing, E-mail and SMS
- NBTel Mobility CDPD network: packet-switched data connections for

			general Internet access and general E-mail
•	Rogers AT&T	TDMA network:	circuit-switched data connections for general Internet access, WAP browsing, E-mail and SMS
•	Rogers AT&T	GSM/GPRS network:	packet-switched data connections (GPRS) for WAP browsing, SMS and SMS-Email

Rogers AT&T GSM/GPRS network was being set up and configured at the time when the field tests of the GSM network were conducted. Therefore, the results should be treated as preliminary as they may not represent the performance of the network once completed.

7.4 Wireless End User Devices under Test

One of the objectives of the field tests is the evaluation of the suitability of end user devices for particular services, and the identification of certain services tailored to certain devices. Because of the wide variety of end user devices available today, at least one device from the 5 device categories phone, Personal Digital Assistant (PDA), Pocket PC (PPC) , Handheld PC (HHPC) and Laptop PC was acquired for testing. These 5 categories represent the most frequently used end user devices today with distinct input and display capabilities.

Phone-centric device

- phone set — 12-key keypad plus extra keys (9 keys for alphanumeric)
  3..5 line text display with limited graphics, 60x40 ... 120x160 pels, mostly black/white

Computer-centric devices

- Palm-like (PDA) — character recognition or soft keyboard
  160x160 pels, black/white and color
- Pocket PC (PPC) — character recognition or soft keyboard
  320x240 pels, color
- Handheld PC — miniaturized full keyboard
  640x240 pels (½ VGA size)
- Laptop PC — full keyboard
  640x480 (VGA) ... 800x600 pels or better, color

The following list shows the end user devices acquired, configured and used for the field tests along with the network services for which connectivity was available through built-in or externally fitted RF modems. The network services accessible are also indicated.

•	Audiovox 4500 phone stand-alone	CDMA:	WAP and SMS-Email
•	Audiovox 4500 phone to laptop PC	CDMA	circuit-switched general Internet

		access, Web, E-mail (Data-to-Go)
• Ericsson R278d phone with chatboard stand-alone	TDMA	WAP, SMS and SMS-Email
• Nokia 6161 phone stand-alone	TDMA	WAP, SMS and SMS-Email
• Nokia 6161 phone to lap-top PC	TDMA	circuit-switched general Internet access, Web, E-mail (Portage)
• Motorola T193 phone stand-alone	GSM/GPRS	WAP, SMS and SMS-Email
• Palm M505 with Novatel Minstrel m500 modem	CDPD	packet-switched general Internet access, Web, E-mail
• Compaq iPaq 3650 &3870 PPC with Sierra Aircard 300 modem and Novatel Merlin modem	CDPD	packet-switched general Internet access, Web, E-mail
• Hewlett-Packard H720 (WinCE3) with Novatel Merlin modem	CDPD	packet-switched general Internet access, Web, E-mail

7.5 Test Results: Availability of Service

The tests for the availability of services indicate the success of connecting to a service at the first attempt. The ranking of the test results are illustrated in Fig. 7.1.

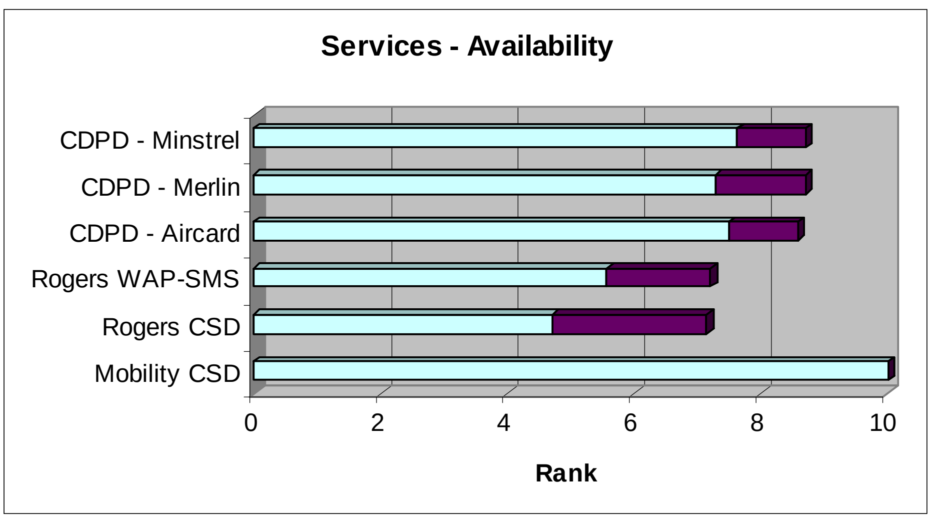


Fig. 7.1 Rankings of Availability of Service

Fig. 7.1 indicates that, in general, the circuit-switched connection of Mobility's CDMA offers the best availability. Rogers AT&T network was busy more frequently or could not connect due to low signal strength. This low-signal strength occurrence was detected relatively many times at many locations, which is indicative of a poorer RF coverage of Rogers AT&T digital TDMA network than that of Mobility's CDMA network.

7.6 Test Results: Usability of Service

Once an end user device is connected to a service, the ability to remain connected and continue to receive acceptable service is indicated by the usability of service. The ranking of the test results are illustrated in Fig. 7.2.

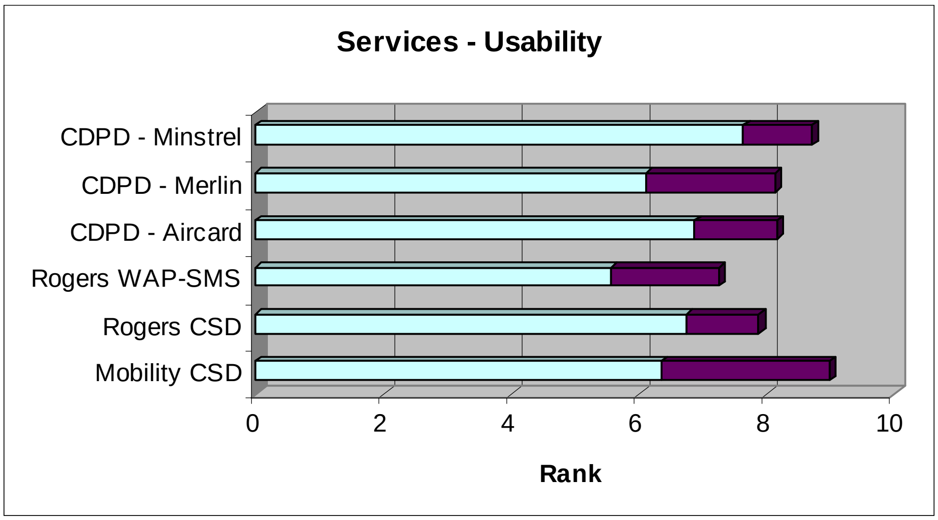


Fig. 7.2 Rankings of Usability of Service

Circuit-switched connections, both of Mobility and Rogers AT&T, offer the overall best service usability. This is true for both phone-centric connections, where the phone is the recipient of WAP services and message services, and for computer-centric services where a laptop computer is connected through the phone as RF modem. The wireless service through Rogers AT&T suffered occasional disconnection at lower field strengths, which is attributable to the poorer RF coverage as already indicated in Sect. 7.5

CDPD service sessions are subject to more frequent disconnections. This is understandable as only one channel is dedicated to data connections in Mobility's CDPD network. This channel is shared with other priority services, such as the RCMP Highway Patrol. If other voice channels are grabbed by data services, then the data service is pre-emptible by voice connections when needed. This renders CDPD a data medium with theoretically wide variability. However, during the test periods in this research work, the usability of CDPD compared well to dedicated circuit-switched connections.

During the testing periods is was noticed that some end user devices were disconnected much more frequently than others. This was traced to the RF modem in use at the time of disconnection. The Novatel Merlin Platinum RF modem performs poorly in medium to low signal strength situations. Only at signal strengths above -60dBm an acceptable usability is achieved. In contrast, the Sierra Aircard 300 performs well even at low signal strengths down to -90dBm. The performances of these two modem cards are nearly inversely proportional to their cost (Aircard 300 $800, Merlin $450 in October 2001). The Novatel Minstrel m500 CDPD modem, used with the Palm M505 PDA, impressed with excellent performance. It connected quickly and maintained connection even in low RF signal strength areas. It also has the most user-friendly program interface with automatic installation of the driver software once connected to the Palm PDA.

An extended CDPD RF coverage test on Mobility's data-only network was performed during three trips by car to Saint John, N.B., Halifax, N.S. and Charlottetown, PEI.

(a) Car travel Fredericton to Saint John along Highway 7 on 2 December 2002.
Two identical Compaq iPaq 3570 PPCs were fitted with a Sierra Aircard 300 and Novatel Merlin Platinum modem, respectively. After logging on to the CDPD network, the received signal strength and the connectivity was monitored continuously. Coverage was found to be almost contiguous, except for spotty coverage around the Eagle pass. The speed of the moving car did not affect the connectivity, where coverage exists. The Aircard 300 maintained connectivity throughout the trip, except at the above-mentioned location. Web browsing was possible with acceptable web page load times. In contrast, the Novatel Merlin RF card lost connectivity frequently in low to medium signal strength regions and kept attempting unsuccessfully to re-register. Using the Merlin modem, web browsing in the moving car was not possible, except in the vicinity of Fredericton, Saint John and nearby cell towers.

(b) Car travel Fredericton to Charlottetown along TCH on 25 January 2002.
A Palm M505 with Novatel Minstrel m500 CDPD modem was used to continuously monitor the RF coverage and occasionally download e-mail and chat on ICQ. An almost contiguous coverage at good signal strength is available on the entire route, except for sporadic coverage along the new part of the TCH between Jemseg and Petitcodiac. However, marginal reception was possible even along this stretch where the new TCH run close to the old TC 2 highway. Another area of poor connectivity was found prior to reaching the Confederation Bridge at the New Brunswick side. Excellent coverage resumes at the Confederation Bridge. Successful web browsing, e-mail service and chatting from inside the moving car is possible everywhere except in the above two areas. ICQ chatting with a partner in Germany from the top of the Confederation Bridge highlighted the good connectivity of the CDPD network

(c) Car travel Fredericton to Halifax along TCH on 17 February 2002.
As in (b) above, a Palm M505 with Novatel Minstrel m500 CDPD modem was used to continuously monitor the RF coverage and use various Internet services. An almost contiguous coverage at good signal strength is available on this route, except for sporadic coverage along the new part of the TCH between Jemseg and Petitcodiac. Successful e-mail service and chatting from inside the moving car is possible everywhere except in the above area.

7.7 Test Results: Responsiveness of Service

Two metrics determine the dynamic behavior of data traveling between the end user device and a server, the responsiveness and the data speed. The responsive of service is indicative of the immediacy of a reply after a request to a server. It is unrelated to the data speed and depends mainly on propagation delays encountered along a request/reply round trip in a client/server environment. The rankings of the responsiveness tests are illustrated in Fig. 7.3.

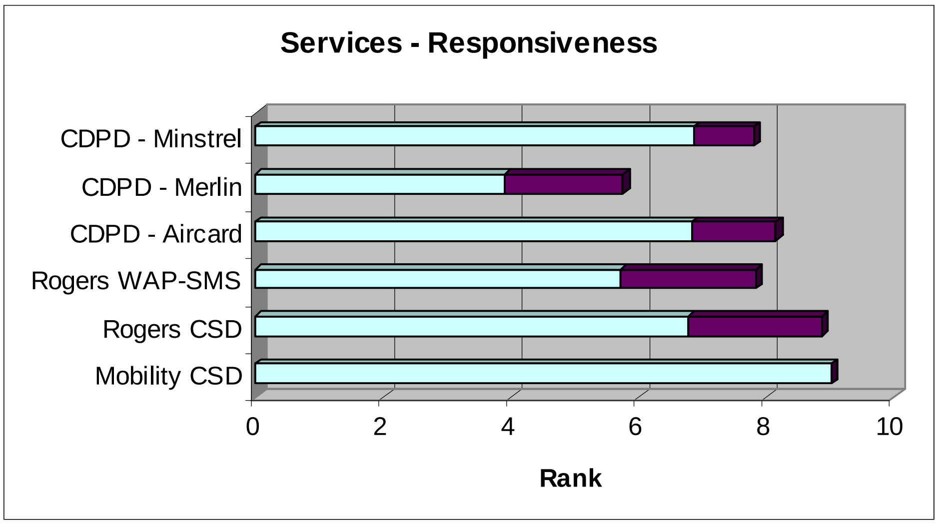


Fig. 7.3 Rankings of Responsiveness of Service

The circuit-switched network services are superior with regard to their responsiveness due to their dedicated reserved connections. A very consistent responsiveness is exhibited by Mobility's CDMA network, whereas the responsiveness varied much more for Rogers AT&T TDMA network. This unexpected deficiency is attributable to the lower signal strengths of the TDM network and a subsequent frequent error recovery which manifests itself as extra overhead and delay.

Mobility's packet-switched CDPD network is less responsive due to its resource sharing on the single data channel and pre-emptible voice channels. The poor performance of Novatel's Merlin RF card is clearly noticeably again, as outlined in Section 7.5 above. Compared with any of the two circuit-switched networks, the CDPD-Merlin combination caused an increase in delay by a factor of approximately 2.

7.8 Test Results: Speed of Service

The throughput of data is evaluated subjectively by the operators of the end user devices and their perceived speediness of data transfer, such as web page loading, and objectively by performing measurements of the effective data rate in controlled environments. The subjective ranking of the service speed is shown in Fig. 7.4, and the measured effective data rates are illustrated in Fig. 7.5.

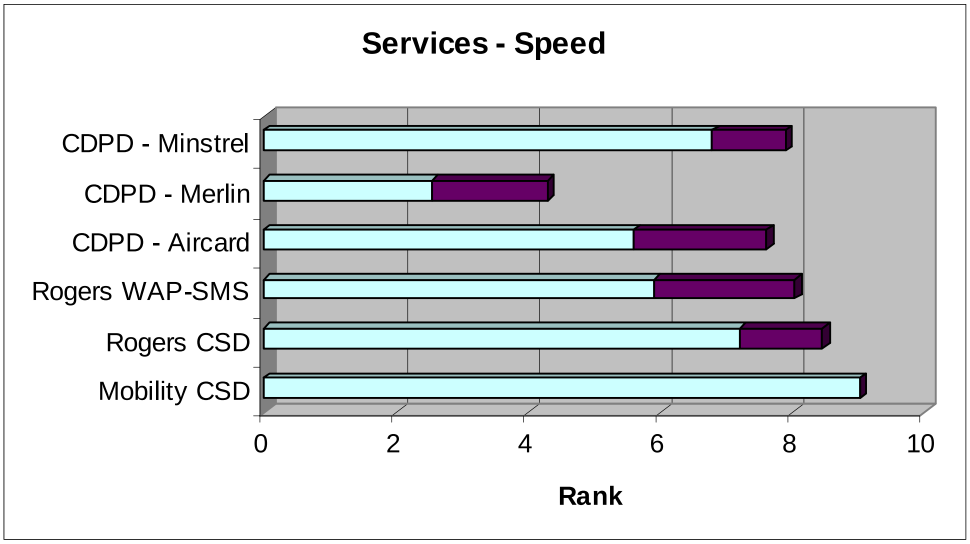


Fig. 7.4 Rankings of Speed of Service

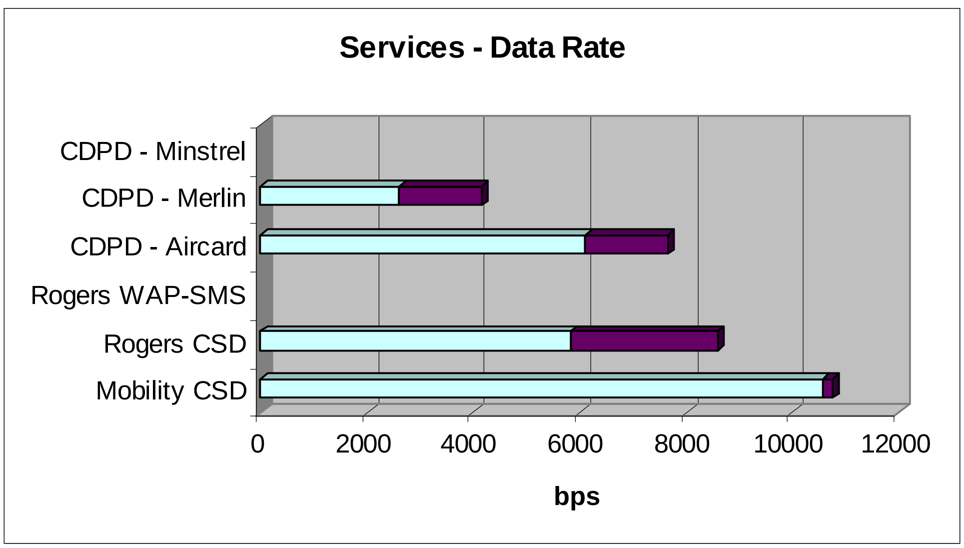


Fig. 7.5 Measurement of effective Data Rates

The data rates of phone-centric applications, such as WAP browsing and SMS on cellular phones could not be measured conclusively due to the lack of test tools in the closed firmware/software systems of cellular telephones. The patterns of the two figures reveal a good match of the subjective and objective test results.

The effective data rates were measured for large binary files and are illustrated in Fig. 7.5. The circuit-switched services exhibit superior performances owing their reserved and consistent bandwidths. However, the data rates are well below the advertised maximum rates. Mobility's

CDMA network supports data rates just above 10 kbps, below the possible 14.4 kbps. Rogers AT&T TDMA services support nominally 8 kbps with a wide variation, well below the possible 9.6 kbps. This variation is due to lower signal strengths and the associated overhead in error recovery. It appears that the advertised maximum data rates are raw data rates which drop significantly due to protocol overhead and error recovery in practical communication scenarios.

Mobility's CDPD rates are advertised as achieving up to 19.2 kbps. In our tests the measured data rates were very much lower. An average of 7 kbps was measured for the Sierra Aircard 300 and a very low 3.5 kbps for the Novatel Merlin modem card. The latter disappointing rate is due to the poor performance of this modem card at low signal strengths. Due to the lack of a suitable full-fledged Web browser and file transfer utility for the Palm M505 PDA, the achievable data rates of the Novatel Minstrel m500 RF CDPD modem could not be measured objectively. However, subjective evaluations suggest an excellent performance at the level of the Sierra Aircard 300.

7.9 Test Results: Usability of Devices

The usability of end user devices was tested and ranked in a subjective manner for specific data communication services, such as web browsing, e-mail reception and transmission, and short messaging. Particular attention was paid to ergonomics and user-friendly user interfaces for both novice and expert users. Phone-centric devices and computer-centric devices are compared separately.

Fig. 7.6 End User Devices under Test
For device identification see text (Sources: respective manufacturers web pages)

The end user devices under consideration are depicted in Figure 7.6. From left to right the following devices are shown: Audiovox 4500, Ericsson R278d with chatboard, Nokia 6161, Motorola T193, Compaq iPaq 3650, Palm M505, Hewlett-Packard H720, generic laptop PC. The test rankings are shown in Fig. 7.7.

Phone-centric Devices

The preferred choice is the Audiovox 4500, connected to a laptop PC. An excellent user interface and intuitive menu structure are noteworthy. In addition, the ease of the laptop connection via the dial-up networking Windows interface made browsing the Internet an uncomplicated procedure.

The Ericsson R278d was noted for its non-intuitive and difficult to use user interface. The phone also freezes up occasionally during web browsing and can be reset only be removing and reinserting the battery. However, the chatboard was found to be a useful addition for short messaging and web browsing.

Computer-centric Devices

Among the handheld and pocket devices, several units stand out for a particular purpose. The Hewlett-Packard H720 handheld PC was the overall preferred choice. This device can be used like a standard laptop computer at a much smaller size. Its full keyboard and ½ size color display provide excellent input and display properties. Several built-in expansion slots allow the use of add-on cards, such as WLAN and Bluetooth, without additional sleeves and cradles. The wide color screen (640x240 pels) permitted the viewing of web pages by scrolling in only the vertical direction. The WinCE 3.0 operating systems offers the feel of a full Windows OS with Microsoft Office compatibility, good Internet Explorer web browser and E-mail client. The draw-back of this device is its relative bulkiness, compared to Pocket PCs, its short battery life and its slow operation due to a large OS overhead.

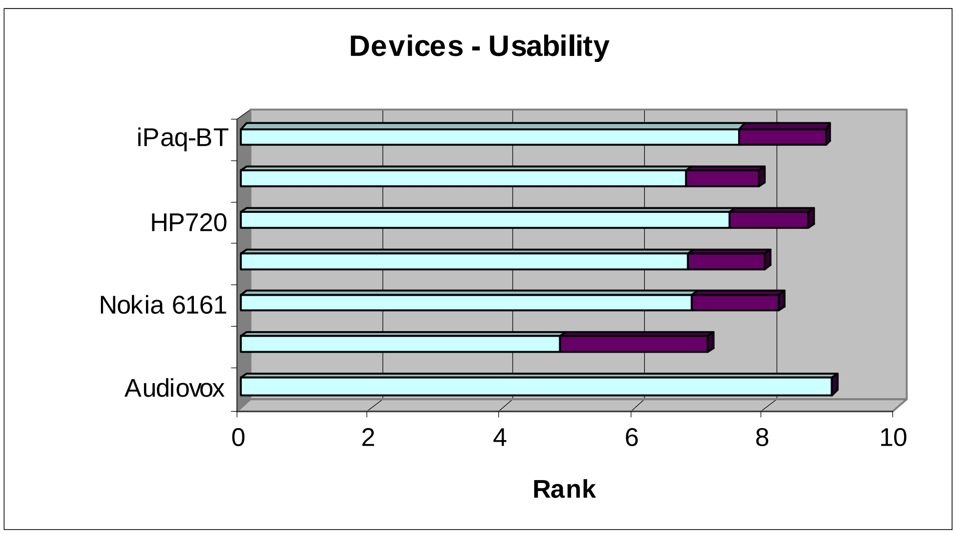


Fig. 7.7 Rankings of Usability of Devices

The Compaq iPaq (both models H3650 with WinPC 2000 and H3870 with WinPC 2002) feature the best display properties. However, the small screen size of 320x240 pels made web browsing difficult, and even awkward for web pages with multiple frames, leading to a loss of navigation in busy web pages. The WinPC operating system is more restrictive in multi-windows based operation than the WinCE OS, and thus less intuitive. Similar to the WinCE OS, compatibility with Microsoft Office products is offered. The Bluetooth connectivity of the newer model H3870 is appreciated, even though currently few companion devices are available that could benefit from it. On the negative side, the required use of expansion packs make this unit bulky. A serious flaw is the lack of a memory backup battery which causes a complete loss of all stored data and program information in volatile RAM in the case of a depleted main battery.

The Palm M505 PDA is the best choice for on-the-road use with wireless RF modem adapters. This device is the smallest, lightest and easiest to use PDA with a very long battery life of several weeks (without additional wireless modems). The Palm operating system OS4.0 supports the widest choice of application programs available. Despite its relatively slow processor (33 MHz clock) the applications run typically faster than on other Windows-based handheld and pocket computers due to the OS's low overhead and efficiency. On the negative side, the Palm does not offer sound capabilities and the application software, such as web browsers, e-mail clients are much simpler and less powerful than for the Windows-based devices.

7.10 Test Results: Contents of Services

The usefulness and value of services accessible through Public Telecommunications network's gateways and Content Server were evaluated in view of the interests of the testers. Both English and French content was considered.

The small messaging system (SMS and its derivatives) is the most popular service. Its immediacy of communication from mobile device-to-mobile device was found very effective for both quick information exchange and chatting. True two-way SMS is only available within Rogers AT&T TDMA and GSM networks. In order to communicate with devices in other networks, such as the Internet, SMS-email is useful although it lacks the immediacy of the native SMS service. In wireless telecommunications networks where native SMS is not available, such as in Mobility's CDMA network, the SMS-email version was found partially useful, though suffering severely from a one-way only communication path from an Internet-connected device to a mobile device.

Web browsing services over the CDPD network were evaluated on end user devices of varying display capabilities. Standard HTML-based web browsing on laptop computers provides identical services as on office-based desktop computers. However, standard web browsing on PDAs was judged ineffective because of the small-size display screens and the trend towards excessive use of frames and graphics in today's web pages. The true information content of web pages is lost in the additional 'decorations', and navigation through the frames of large web pages is very difficult and often frustrating. Only very few web sites were found that are designed exclusively to fit the screens of by PDAs. When available, these web pages loaded quickly and provided an effective perception of the information provided. Most of these PDA-friendly web sites are offered by manufacturers of PDA-type end user devices, such as Palm, Handspring, Hewlett-Packard and Compaq.

Web browsing on phone-centric end user devices, such as cellular phones, were evaluate over the circuit-switched connections of TDMA and CDMA networks. Web browsing proceeds under the WAP format, which provides and efficient way of downloading information with local caching (decks) to reduce excessive requests for WAP pages over low-bandwidth links. Most WAP information sites are available via the wireless network providers' local Content servers.

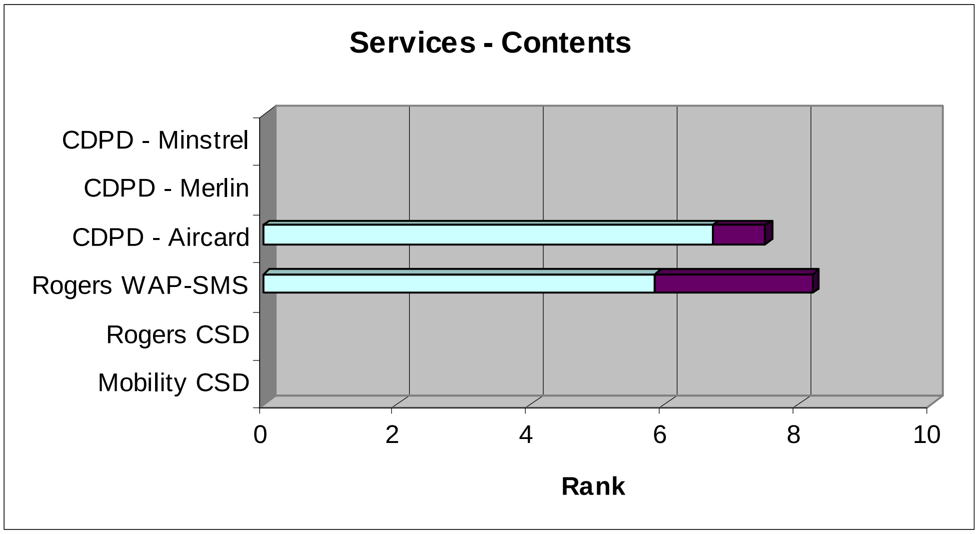


Fig. 7.8 Rankings of Contents of Services

Both Mobility and Rogers AT&T offer access to an excellent selection of information providers with contents and compact presentation of information tailored to the small display screen sizes of phone devices. The most popular information services are news, sports, weather, stock quotes, air line schedules and entertainment information. Some of the WAP services are interactive, such as banking services (most major banks) and Air Canada's airline reservation and scheduling system. As an example, to receive information about an air flight time, and possible delay, the date and flight number is entered from the phone's keypad. A set time before departure a SMS message is sent to the phone informing of the departure on time or a delay. It is evident that much effort is expended by companies to provide just-in-time information to the public at large, but at this time these useful services are much undervalued in North America, due to the still widely existing belief that a phone system is for voice only, and due to the current poor regional coverage of digital wireless networks.

The search for French content providers of WAP-based services within New Brunswick and Canada lead to only a few sites that offer their information in both English and French. Among those sporadically available services are canada.com for news services, banking services from most banks and Air Canada's interactive information system.

7.11 General Wireless Local and Personal Area Networks

Although the emphasis of the network and service evaluation of this investigation lies in public digital telecommunications arena, two local area networks were also considered because of their current and future importance. The IEEE802.11b wireless LAN (Wi-Fi) and the Bluetooth wireless PAN were used in conjunction with suitable end user devices. A brief survey of the findings is presented.

WLAN 802.11b (Wi-Fi)

This standard wireless computer network serves as a replacement of 10 Mbps wired networks and has found widespread acceptance. It has been in use in UNB's ITC building since August 2000. IEEE 802.11b is a mature technology that works with essentially all applications that support regular wired Ethernet networking. Due to its tight standard, excellent vendor interoperability is assured, both for PC Adapters and PDA adapter cards, and for use with centralized access points to wired backbone Ethernet networks to establish a corporate infrastructure network with wireless access for mobile devices. The convenience of mobility for PDAs and laptops is invaluable. The roaming capability among access points is seamless, uncritical and unnoticeable.

IEEE 802.11b network components are supported by all operating systems for desktop PCs, Handheld PCs, Pocket PCs and Palm PDAs, along with excellent application software integration.

On the negative side, the performance of the WLAN degrades more than linearly with the number of connections established at any given time. A maximum throughput of approximately 6 to 8 Mbps half-duplex can be expected for a single sustained data stream. Five simultaneous sustained data streams reduce the throughput of each one to less than 1 Mbps half-duplex. The interleaving nature of the transmissions in the single collision domain makes the IEEE 802.11b wireless network more suitable to bursty traffic when many connections are required. It is recommended that no more than 20 to 30 simultaneous bursty connections should be attempted at any given time. The coverage of the IEEE 802.11b network is disappointing indoors. The RF propagation is fully absorbed after passing through three typical building walls. In-building coverage is limited to about 30 to 50 ft, or 2 to 3 offices. Even for shorter RF links the data rate quickly falls back to 5.5, 2 or 1 Mbps to combat interferences that are relatively more disturbing at low RF signal strengths. The poor scalability of only three channels that can be used in the same region makes for a difficult site planning for varying traffic density areas.

The IEEE 802.11b standard provides for three levels of access and data security. The DSSS spread-spectrum technology makes eavesdropping the RF signal difficult but not impossible. The Wired Equivalent Privacy (WEP) is an encryption facility that can be used to scramble the data sent over the wireless link. Either a 64 bit or 128 bit strong encryption is available (even though only 40 bits or 104 bits are utilized for the actual encryption key). Both stations of an encrypted wireless data link need to know the common encryption key, which must be exchanged via a trusted channel. The third level of security is offered by an access authentication for clients at the access point modules (AP) that provides a mechanism to lock out undesired client modules from accessing the network resources to which the WLAN AP modules are connected. Despite this 3-level security hierarchy, many breaks in security have been reported recently and caution needs to be exercised if data is confidential or vulnerable to loss of service.

WPAN Bluetooth (IEEE802.15)

Bluetooth technology has only recently become widely available in the market place. The experiences reported here were gained during the January to February 2002 period. Bluetooth is a workable wireless solution which has been proven in specialized phone-centric applications in the past. These applications include PIM synchronization between cellular phones and desktop/laptop PCs, and for convenient wirefree headset operation with a cellular phone. Currently, the deployment of Bluetooth networking is extended to the personal sector of computing, in particular to Pocket PCs and PDAs, such as Compaq iPaq and Palm PDAs. Wireless services include dial-up networking through cellular phones, file transfers and printing.

In the computer-centric field, Bluetooth technology still suffers from a serious lack of vendor interoperability, mostly due to the lack of profile implementations, and immature user interfaces on computing devices. Very little application software has been integrated with Bluetooth and a lack of OS support is evident at this time. Bluetooth devices are rather difficult to configure and operate, requiring several manual steps and the know-how of the operational intricacies.

Bluetooth networking solutions are best acquired as a package through renowned vendors in order to guarantee success. This deficiency, however, also offers the opportunity for software developers and third-party service providers to penetrate the market quickly with more user-friendly application software.

8. Comparative Cost Analysis

The cost of owning and operating wireless communications devices involves investment cost and operating cost. End user devices are either purchased or leased, and the operation of them includes one or both of air-time cost and data volume cost.

8.1 Cost Models

A wide variety of cost models is used by different wireless telecommunications providers around the globe, based on criteria such as data air time usage, data volume usage, pay-as-you-go, semi-flat and flat subscriber plans.

Circuit-switched data connections are normally charged by air time because a reserved connection is used regardless of the amount of data and idle time. Data air time can includes both send and receive time, or send time only. In North American both send and receive air time are charged which provides a revenue stream from both ends of a wireless connection. This model is appropriate in a telecommunications infrastructure where local land-line telephone calls are free and the mobile telephone numbers are indistinguishable from land-line telephone numbers, otherwise a land-to-mobile call will not attract any revenue stream. Overseas telecommunications providers, such as in Europe, use a model whereby only send time is charged whereas receive time is free. This is suitable in telecommunications systems where all land-line calls are subject to a fee, with calls made to mobile devices carrying a higher cost, so that at least one revenue stream exist for a wireless telephone call. In this environment the telephone numbers of mobile devices must be distinguishable from the land-line telephone numbers so that a caller is aware of the incurred higher cost**.** It is customary that data air time is in addition to regular connection air time for circuit-switched connections.

Packet-switched data connections are normally charged by data volume. Connect time is irrelevant because all connections are shared and any idle time in one data stream can be used by another data stream of another connection.

In order to lessen the impact of linear cost increase with usage, an overwhelming range of subscriber plans exist which are optimum for varying usage scenarios. Most plans are based on a monthly usage. A semi-flat subscriber plan allows air-time and/or data volume up to a limit, then charges per connect time and/or data usage. In order for a semi-flat plan to be used efficiently, it is necessary to estimate the expected usage per month. The higher the limit, the higher the flat part of the fee and the smaller the per-usage fee thereafter. A flat subscriber plan offers unlimited usage of air time and/or data volume and carries a higher monthly fee.

Public cellular systems that use Subscriber Identity Modules (SIM), such as the GSM system, offer flexible user-administered charging systems. The SIM card contains an account which can be pre-loaded with a certain amount of usage credit (e.g. $50) and the card is automatically debited via the telecommunications centers as connections are made and air time/data volume is used. In many cases these SIM accounts are rechargeable, either over the phone, at banks or special kiosks. In addition to retaining full control over the running wireless operating expenditures, the SIM cards are movable between various end user devices, such as phones, RF modems and data-enabled PDAs, that can be used alternatively on the same wireless telecommunication network as the need arises.

Equipment cost is represented mainly by the cost of end user devices. Because of the high cost of end user devices, such as a cellular phone in the range of $200 to $1000, and the short expected useful life-span until obsolescence of 1 to 3 years, these devices are often leased rather than purchased as an investment. Wireless Telecommunications providers subsidize the end user devices and offer them to their subscribers at a much reduced cost, such as $0 to $200 subject to the subscriber entering into a long-term commitment for service at a monthly fee plan, typically of the semi-flat type, until the cost of the user device is amortized. This marketing approach keeps subscribers locked into service and technology of a single network provider. It also leads to a very small selection of end user devices. In order to discourage subscribers to move their subsidized user devices to other service providers, even in the case of identical network technologies, wireless network providers lock their phones so they are unusable in other networks (Service Provider lock, SP lock). In case of GSM networks, phones are often SIM-locked and do not accept competitor’s SIM cards. The Canadian Telecommunications Act requires that lock codes are released after 6 months into a plan period to a competitor network.

The predominant practice of packaging end user devices and long-term usage plans, in combination with SP-locking and SIM-locking of subsidized end user devices offers an affordable usage of wireless telecommunications services. However, it creates an immobile pool of subscribers, a poor selection of up-to-date end user devices and a stagnant upgradability path of end user devices for business use during the term of the subscriber plan. This practice also discourages the offering of a wide range of the latest end user devices for sale in the open market, or to tailor end user devices to changing user requirements. At the current time only multi-band GSM end user devices are available at the open world market and can be purchased in a SIM-unlocked (SIM-free) version for all GSM networks.

8.2 Optimizing Cost Strategies

Considering the North American cost model, an analysis of typical data operations over a wireless telecommunications network was conducted and guidelines are given that optimize the monthly cost. Three subscriber plans are considered, pay-as-used, semi-flat and flat rate plans. In order to optimize the cost, the expected data traffic volume and connect time, where applicable, must be known or must be estimated. In addition, the type of traffic pattern must be known, such as bursty traffic or sustained traffic. Packet-switched connections are suitable for bursty traffic as created by interactive user operations, such as wireless web browsing, information retrieval (news, weather) and e-mail reading and writing. Circuit-switched connections lend themselves for continuous traffic without idle times, such as Personal Information Manager (PIM) synchronization between a mobile end user device (PDA) and a business PC, and file downloads for inventory and accounting purposes.

The following examples reflect typical data communications scenarios and illustrate the optimizing guidelines. A typical web browsing activity over a wireless link is analyzed, which employs three different end user devices with varying web size display capabilities:

- a typical web session is defined by
  load and view 20 web pages;
  view each page for 0 to 2 minutes;
  run 1/3 to 8 sessions a day for a month;
- use of a WAP-enabled phone for web browsing with
  2 Kytes/page at 10 kbps effective data rate;
- use of a PDA with built-in RF modem for web browsing with
  10 Kytes/page at 10 kbps effective data rate;
- use of a laptop PC connected via a RF modem with
  100 Kytes/page at 10 kbps effective data rate.

Five different subscriber plans (for data only) are considered, which are representative of plans offered by wireless service providers in New Brunswick. Plan 2 through Plan 5 are based on data volume and are applicable to packet-switched connections, such as NBTel Mobility's CDPD network and Rogers AT&T's GPRS network. Plan 1 is based on connect time and is applicable to circuit-switched connections, such as for Mobility's CDMA and Rogers AT&T's TDMA networks:

- Plan1: pay-as-connected data air time, $0.15/minute or $9/hour
- Plan2: semi-flat rate, up to 1.5 Mbytes, then pay-as-used, $20/month + $0.02/Kbyte
- Plan3: semi-flat rate, up to 500 Kbytes, then pay-as-used, $10/month + $0.03/Kbyte
- Plan4: semi-flat rate, up to 150 Kbytes, then pay-as-used, $5/month + $0.04/Kbyte
- Plan2: flat rate, unlimited use of air time and data volume, $50/month.

The charts in Fig. 8.1 and 8.2 illustrate the total cost per month, broken down by subscriber plan, web page size (or device, e.g. 2K for WAP device), and number of sessions per month (e.g. 30 sessions/month equals 1 session per day). The charts in Fig. 8.1 assume a zero-viewing time of web pages and are representative of costs incurred in file transfer activities. The charts in Fig. 8.2 assume a viewing time of 2 min per web page and are representative of a web browsing session or an e-mail session with intermediate read and write periods.

Fig. 8.1 and 8.2 show the monthly costs in dollars per subscriber plan in increasing order of data volume usage from top to bottom and left to right.

The cost patterns in Fig. 8.1 pertain to file-transfer operations (viewing time =0). It is evident that for all end user devices (2 KB...100 KB file lengths) the circuit-switched connection with Plan 1 is cost-effective for monthly low-volume usage only. For higher monthly data usage the packet-switched connections with Plan 2 through Plan 5 offer a lowest cost optimum solution. For WAP-based applications the most cost-effective plans are Plan 2 and Plan 3 because of the small page sizes (2 KB). For PDA and laptop use with their larger page sizes (10 KB and 100

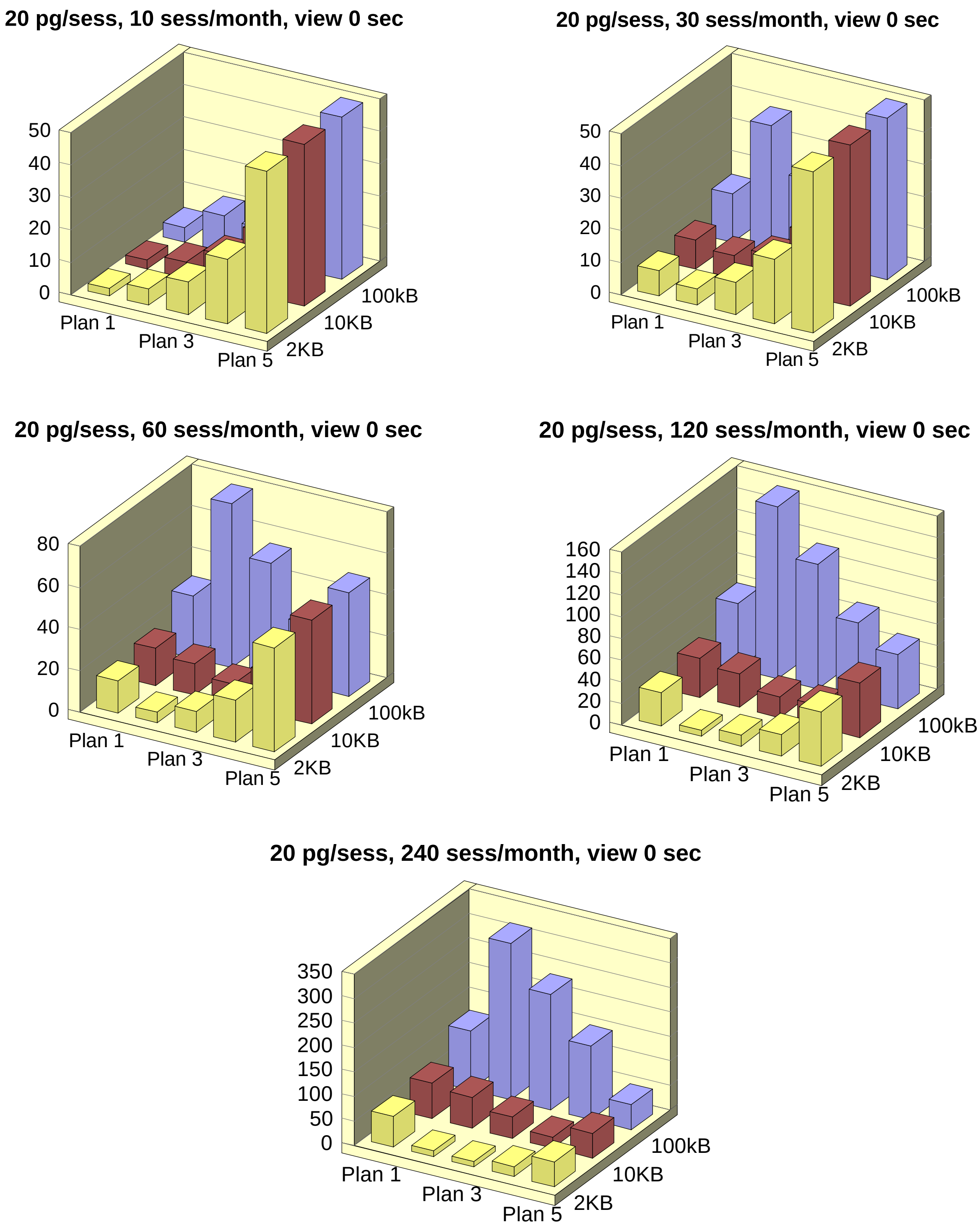


Fig. 8.1 Monthly Telecommunications Cost in $ by Plan
Viewing time 0 minutes (e.g. file transfer)

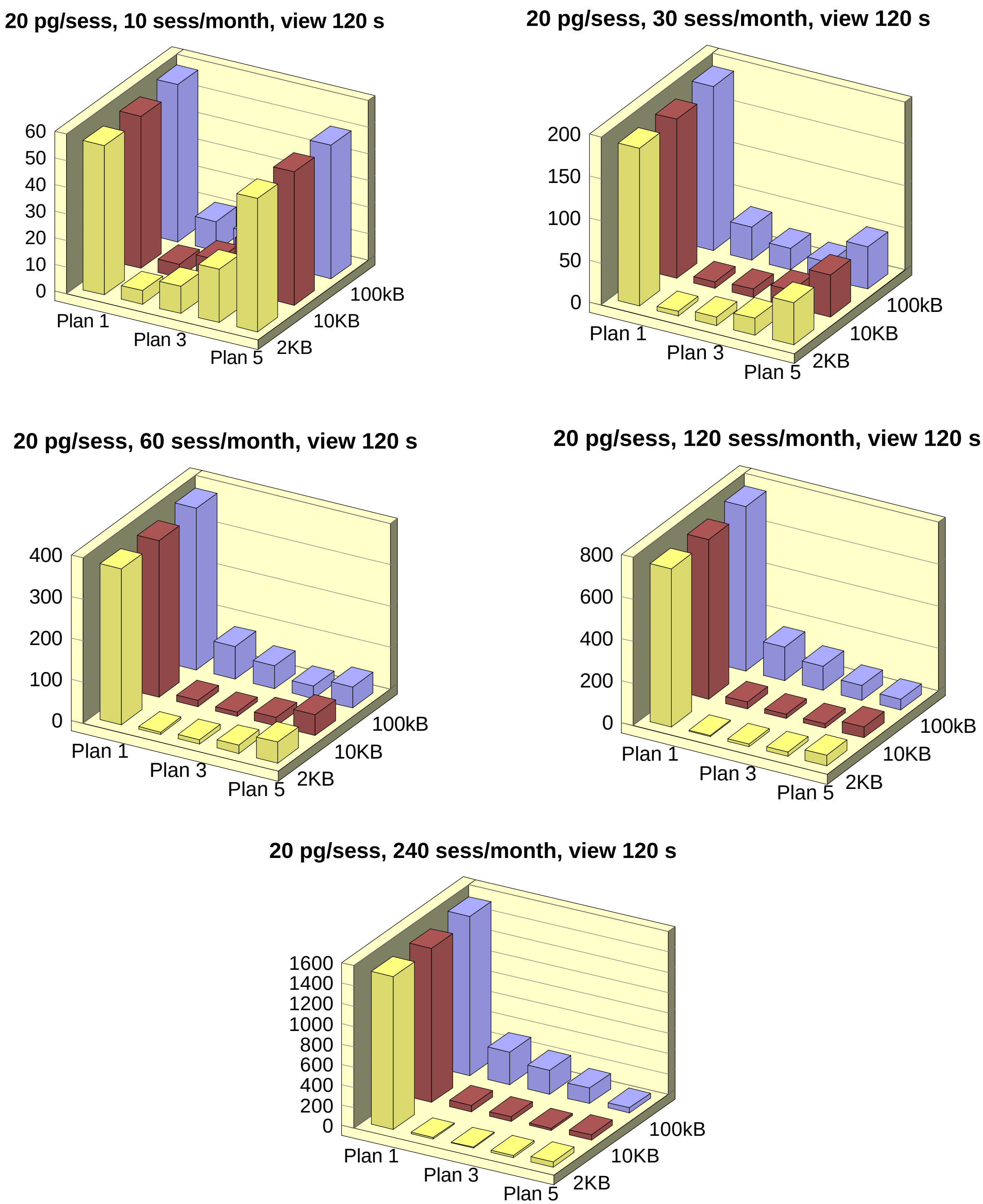


Fig 8.2 Monthly Telecommunications Costs in $ by Plan
Viewing time 2 minutes (e.g. web browsing)

KB) optimized cost plans are Plan 4 for PDAs and Plan 5 for laptop PCs.

Fig 8.2 illustrates the cost patterns for web browsing applications with idle viewing times of 2 minutes between successive web page requests. It is obvious that circuit-switched connections with their pay-as-connected pay Plan 1 lead to a prohibitively expensive solution, up to $1,600/month for any type of end user devices and 8 sessions of web browsing per day. Packet-switched connections with their semi-flat or flat fee plans are ideally suited for these interactive applications. The optimum plan for each end user device is indicated by the minimum monthly cost, e.g. Plan 4 for a PDA (10 KB) and Plan 5 for laptop PC use (100 KB pages).

The preceding analysis of telecommunications costs establishes the following guidelines for a cost-effective solution:

- circuit-switched connections with pay-as-connected fee plans are suitable only for low-volume file transfer type applications (synchronization, file downloads). For all other services and applications the cost becomes prohibitive;
- packet-switched connections with semi-flat and flat fee plans based on data volume are suitable for interactive applications with substantial idle times between data bursts, such as web browsing, data base inquiries and e-mail;
- the optimal fee plan of the semi-flat type is suitable for medium usage. The data volume limit (for the flat cost component) needs to be selected so that it is equal or slightly above the expected monthly data throughput;
- for heavy data usage the flat fee plan is the most suitable one despite its higher monthly cost.

9. Summary, Conclusions and Recommendations

This chapter is written as an extended summary for those readers who wish to quickly gain insight into the topics of this investigation into wireless telecommunications, without first, or at all, reading through the comprehensive text chapters of this document. Conclusions and recommendations are interlaced with the extended summary, and are highlighted in italics.

Personal digital wireless telecommunications evolved during the 1990 decade from analog wireless telecommunications, and initially was dedicated to offer voice services, e.g. by cellular telephone networks and services. Over the last 10-year period wireless data services have emerged as a catalyst for new mobile computer-centric applications and have grown in importance exponentially. As of the end of the year 2000, the monthly number of short data messages has exceeded the number of voice calls made in some technology-aware regions of the world. Wireless telecommunications offers mobility, and with its advent the office-on-the-move is becoming increasingly indispensable for business. Contrary to analog wireless services, that enjoyed a quick public acceptance and explosion in subscriber numbers in the form of cellular phone services, in North America the growth of regional coverage and market penetration of its digital counterpart has been slow, painful and shrouded in mystery.

Objectives

The objectives of this research project are to shed light onto the current state of personal digital wireless telecommunications, with a focus on data communications rather then voice services. Both, public carrier networks and services, such as cellular networks with its data extensions and general purpose wireless computer networks are covered. Additionally, familiarity with, and a working knowledge of available wireless services were gained in order to identify the benefits for business users, opportunities for hardware and software developers, and service opportunities for network service providers. These objectives were achieved by creating an up-to-date inventory of existing digital wireless technologies, networks and their services, developing an understanding of the underlying technologies by appreciating the historical evolution, and by a look into the future to next generation systems. Applicable technology standards were emphasized along with their thrust on global network deployments. Field tests were conducted involving a wide range of existing public and general purpose wireless services and end user devices. This hands-on experience helped to develop an awareness of the advantages and limitations of today's technologies, that is needed to make informed business decisions on the use of these wireless data services, and helped to discover 'Killer' applications.

The investigations for this research project focus mainly on the state of public digital wireless telecommunications in New Brunswick, with a close look at the Atlantic Provinces and Canada. An overview is given of related developments in the United States and overseas in Europe and Japan.

Wireless Technologies

The evolution of public wireless wide area networking (WWAN) has proven that cellular network architectures with their RD spectrum reusability are the key to successful and affordable public wireless telecommunications. The early era of 1st generation (1G) cellular systems, from 1984-1994, with AMPS as the North American Standard, saw networks exclusively dedicated to voice communications. Data capabilities, such as by packet-switched CDPD were retrofitted later in 1994-1997. Although this has become a workable solution for mostly business use, it is a terminal technology in view of the decommissioning of analog services around the world. The early digital technologies of the 2nd generation (2G) were introduced during the period 1994-1996 and included TDMA, GSM I, CDMA and derivatives. These technologies also lacked full data services, except for circuit-switched data over voice channels. Only in 1998 (GSM II) and 2000 (TDMA, CDMA) data extensions were standardized for 2.5th generation (2.5G) networks for cost-effective packet-switching services and fast circuit-switched services (HSCSD for GSM), but only GSM/GPRS and its Japanese counterpart, PDC/PDC-P were fully deployed. These data services suffer from low data rates in the range 9.6 to approximately 50 kbps. All cellular digital networks started to offer SMS or equivalent short messaging services and SMS-email starting in 1998 to 2000. As of today, TDMA and CDMA networks do not offer widespread packet-switching data services.

The future will see TDMA migrate to the enhanced TDMA-based GSM technology. A that time better high-speed data services, such as EDGE will be deployed for GSM, and 1xEV for CDMA to establish transient 2.75G networks before moving on to next-generation 3G networks. Despite its superior technology and best bandwidth efficiency, CDMA trails GSM in worldwide acceptance and deployment. It is predicted that both technologies, GSM and CDMA, continue to coexist and evolve in parallel towards 3G standards, and that both technologies will eventually use similar, but incompatible wide-band CDMA-based RF interfaces.

Digital cellular telecommunications networks are naturally suited for the provision of digital data transport. Yet the service has been very slow in coming. This is mostly due to the legacy voice-centric nature of classical telephony systems and their providers and has impeded the growth of modern wireless wide-are data networking significantly. The closed nature of legacy telephony systems has also contributed to stifle the early success of digital data services.

Complementing public cellular wide area networks are wireless computer networks which are also based on cellular technology, however with smaller foot print cells. The wireless local area network (WLAN) standard IEEE 802.11b has enjoyed an explosive growth over the past 3 years and has become a medium-speed (11 Mbps) commodity network, ubiquitously employed by most computer hardware and software and quickly displacing 10 Mbps wired Ethernet where mobility is desirable. In early 2002 the high-speed (54 Mbps) ETSI Hiperlan/ IEEE 802.11a WLAN appeared in the market place. With its better scalability for connection density, it is seen to start challenging 100 Mbps wired Ethernet where mobility is an asset. Complementing WLANs are wireless personal-are networks (WPAN) based on the industry-standard Bluetooth technology. Although of low speed (1 Mpbs) and with short range (10 m), in early 2002 these networks have started to replace cabling in the personal area surrounding computers, supporting tetherless connectivity to printers, scanners and other peripherals. In the recent past, Bluetooth has proven its capabilities in niche areas, such as allowing cellular phones communicate wirelessly with headsets and PDAs. But the full deployment for general purpose computer devices is still in its infancy due to the lack of support software and applications.

In the future we will see a further penetration of wireless computer networking of both the WLAN and WPAN type and a vertical integration of both types, typically and readily via IP gateways/access points or IP routers. Although today's applications make WLAN use ubiquitous, much more development needs to be targeted at user-friendly software for Bluetooth's WPAN networking in order to make it a success.

Until the advent of computer WLANs, all wireless telecommunications operated under the centralized mode, allowing full control of all transactions from a single point. Although ideal for management and billing purposes, this creates a bottleneck in the networks for both performance and reliability. Starting with the general-purpose computer WLAN/WPAN technologies the peer-to-peer operating mode is supported and widely used, particular for the personal Bluetooth networks. Peer-to-peer networking offers desirable properties, such as capacity increase with the number of participating end user devices, distributed and redundant control and robustness to link failures.

The superior characteristics of peer-to-peer networking will make this networking paradigm the choice of the future. Peer-to-peer networks have been identified as one of the architectures for next-generation 4G networking frameworks. However, more research and development is needed to resolve aspects such as routing, billing and authentication/security.

All public and general-purpose wireless network technologies are co-existing successfully today, but are operated independently in a horizontally isolated manner. Connectivity between these networks is occasionally possible in a very loose fashion where gateways exist. To exploit the synergy of all levels of wireless networks fully and permit mobile service availability anywhere, anytime and with any device, it is mandatory to vertically integrate them tightly for seamless communications from any network to any network. This vertically integrated network structure and its 'always best connected' (ABC) and 'virtual home environment' (VHE) paradigms are two of the visions of IMTS-2000.

Next-generation networks of the 3G and 4G will be more aligned with the vison of ITU's IMT-2000 framework for future global networking. Today's loose horizontal integration will be replaced by a tight vertical integration of wired and wireless networks and their services. The ABC and VHE paradigms will make unrestricted mobility possible and affordable, achieving mobility of users, terminals and services. The first attempts towards this vertical integration were made by GSM/DECT integration (1999) and have been announced for GSM/802.11 and CDMA/802.11 and 802.11/Bluetooth (2002). The incorporation of WLANs (802.11) as lower tiers of public cellular networks offer their operators an interesting possibility to deliver more capacity and higher data rates to end users without depleting the capacity of their current *cellular systems.*

Evolution of Wireless Technologies

The historical evolution of public wireless telecommunications proceeded differently in different regions of the world. Factors, such as population density, technology-awareness, monopolies of public service providers and subsequent deregulation of the telecommunications sectors shaped the avenues and pace of evolution.

In the Americas the introduction of a uniform single-standard 1G analog cellular telephone system (AMPS) was conducive to an adequate geographic coverage, common provider infrastructure and subscriber end user devices, and lead to an unprecedented growth in subscriber numbers during the first 10 years from 1984 to 1994. By virtue of scale of deployment, AMPS created a popular, successful and affordable public wireless telecommunications environment. Following the earlier US example, in 1995 Industry Canada licensed 4 different 2G technologies for digital wireless telecommunications (PCS) to 4 different public providers. Unfortunately, these 4 technologies were incompatible, leading to a duplication of different network resources and affording no roaming capabilities between the networks. The benefits of mere scale, as for the early analog systems, failed to manifest themselves again. This splintering of networks and services is responsible for a reduced profitability of providers, a policy of offering services to mainly major urban areas for increased revenues, and neglecting services to rural areas. It also lead to a very slow penetration of digital services and to isolated subscriber pools. Starting in 2000, digital data extensions were added, such as CDPD to AMPS, circuit-switched data and SMS-email to CDMA and TDMA and GPRS and SMS to GSM. Unfortunately, no single network, except GSM, can provide all cost-effective data services such as packet- and circuit-switching and SMS, leaving most subscribers with multi-network data service solutions. It was predictable that this patchy approach to digital voice and data-based wireless services could not be sustained for long. By 2001, the emerging collapse of this jungle of incompatible technologies became evident, eventually resulting in two provider camps offering either CDMA or GSM based network services, but still leaving many geographical regions without adequate data services. Currently, trials of 3G technologies (CDMA2000 and UMTS) are under way and are expected to be commercially available by 2003/2004.

In Europe the historical evolution followed a path almost opposite to that in the Americas. Early 1G analog cellular networks were proprietary to each country, incompatible with each other and no cross-border roaming was possible. This monopolistic policy is responsible for a very slow market penetration, unaffordable services and eventually leading to the failure of these wireless networks as a public commodity. In 1988 an overhaul of Europe’s legacy telecommunications infrastructure began its pace, which brought uniformity of technologies and services regardless of national borders. ISDN and GSM were specified as single-standard wireline and 2G wireless digital technologies, respectively, and were closely integrated. This telecommunications infrastructure has the benefit of scale and better prospects for profitability for providers. It resulted in a quick and exhaustive geographical coverage of wireless services of almost 100%, both in urban and rural areas. It also permitted Europe-wide roaming with a single universal end user device. The coherent offering of any-where services at affordable cost caused an explosion of subscribers within 5 years, with countries like Finland leading the use of cellular communications services by 70% of the population. The single-standard GSM technology proved so successful that it quickly spread to the Middle East, Africa and Asia Pacific and developed into a leading global standard. In 1990, an upgrade to GSM II with limited data services took place, which was followed in the 1998 to 2000 period by a further upgrade to a 2.5G system with comprehensive digital data services, viz. GPRS and HSCSD. The resulting data services permit cost-effective support of both bursty data (Internet) and streaming data (file transfer, music, video) at increased speeds up to approximately 56 kbps in a single network environment. These services were conducive to an accelerated use of digital data, so that by the end of 2000 the number of data calls exceeded the number of voice calls. The first 3G UMTS installations started to operate on a trial basis in 2001.

Japan followed a similar path as Europe did. A particular challenge is faced by Japan by its high population density and demanding technology-aware population. A proprietary 1G AMPS-derived analog system was introduced in 1979, followed by the proprietary 2G PDC digital network, based on TDMA and GSM principles and tailored to the highest call densities. In 1999 enhanced digital data services were added to build the 2.5G PDC-P packet-switching enabled network. This network hosts the highly successful wireless i-Mode Internet services offered to subscribers. Japan was the first country to offer 3G networks and services on a commercial basis through its UMTS-compliant FOMA telecommunications infrastructure in September 2001.

As of February 2002, global deployment statistics show GSM as the dominant global standard with a 72% subscriber ratio, followed by CDMA with 11%, TDMA with 9% and PDC (in Japan only) with 8%. Currently, many TDMA-based networks are in the process, or plan, to migrate to GSM, eventually increasing its market penetration to 81% in the near future.

Europe has learned its lesson from the failure of the early cellular analog systems as a public commodity, which were proprietary and isolated by country. The subsequent single-standard GSM public telecommunications infrastructure has become dominant in the world, not by superior technology but by its universality. It has also given European countries an edge in export-leading technology. The coherent approach has also made possible an early adoption of cost-effective digital data services available in a single network everywhere and to everyone. After the unprecedented success of its early 1G single-standard analog system AMPS, the Americas still suffer from the splintered deployment of up to 7 incompatible 2G digital network standards. This is particularly true in Canada where the generally low population density cannot support this mix of technologies. Poor area coverage, isolated subscriber pools, no inter-network roaming, and a late adoption of digital data services caused the telecommunications industry to fall behind the rest of the world. A quick and drastic change to a single-standard - or perhaps two competing -standards is necessary to bring sustainability back into this industry and afford subscribers a reasonable geographic coverage, better digital data services and adequate roaming across the continent. The competition by technology needs to be replaced by a competition by service, and a more tighter co-operation among public providers, preferably with sharing of infrastructure, is needed.

The United States is served by six major public digital wireless network providers, AT&T Wireless, Cingular, Sprint PC, Voicestream and Nextel. Similar to the Canadian scenario, the deployment of technologies is fragmented into 7 different technologies. By the middle of 2000, all TDMA network operators announced an accelerated move to the GSM/GPRS technology. This decision suggests that a collapse of this jungle of technologies is near, eventually leaving two major technologies in operation, CDMA and GSM, offered by the major network operators. In early 2002, for the first time the three major GSM proponents, AT&T Wireless, Cingular and Voicestream entered into an agreements for closer co-operation and continent-wide roaming (Rogers AT&T in Canada is a partner in this agreement). This vision creates a powerful lobby group and leads the way towards a single-standard network with more extensive geographic coverage and better services for their subscribers.

Although the United States suffer from the same splintered deployment of technologies and its ensuing problems as Canada does, the major network operators acted faster to implement a closer co-operation to provide together a better geographic coverage, unrestricted roaming and better access to their clients' home services everywhere and every time.

Canadian Deployment Scenario

Taking inventory of the current digital wireless telecommunications infrastructures in Canada, and particularly in New Brunswick, shed light on the difficulties the network providers face. The population density is small on average, yet highly clustered in metropolitan areas, a fact which counteracts the uniform service coverage when the deployment patterns of networks are dictated by business plans rather than by the universality of services to all. A mix of 6 different incompatible technologies is offered by 4 major wireless service providers.

Bell Alliance offers wireless digital data services via 3 separate networks across Canada, CDPD, CDMA and Ardis. In New Brunswick, services are sporadic in major cities and along the interconnecting highways. CDPD provides good packet-switched data services (no voice) for full Internet access for a cost-efficient monthly flat rate, CDMA offers only circuit-switched data which is costly for interactive services (web browsing), and one-way messaging. The Ardis network is dedicated to Blackberry users in 3 cities in the Maritime provinces. No inter-operability exists between any of the 3 networks, thus a desirable single-network solution is not achievable. Rogers AT&T currently operates 3 different networks across Canada, TDMA, GSM and Mobitex. TDMA is currently being migrated to GSM and it is expected that TDMA will be phased out over time. In New Brunswick, services are sporadic in major cities and along the interconnecting highways. TDMA supports circuit-switched data services and two-way messaging. Mobitex is dedicated to Blackberry and available only in Halifax in the Maritime provinces. The GSM/GPRS network started operation in 2001 across Canada and has become available in major cities in Atlantic Canada by early 2002. It provides a full range of data services and can be considered as a single-network solution for all wireless applications, each offered cost-effectively. Its GPRS packet-switching service operates at higher data rates (30...40 kbps expected) and permits continent and worldwide roaming. Microcell Connexions operates a single GSM/GPRS network in Canada, but without presence in Atlantic Canada. It provides all digital wireles data services cost-effectively over a single-standard network. Telus bases its data offerings on 3 separate networks with no inter-operability between them, CDPD, CDMA and iDEN. CDPD is targeted at business use of packet-switched services with no voice capability, CDMA offers limited circuit-switched data services and messaging. Telus operates the only iDEN network in Canada with advanced call management features. Telus's services are available from British Columbia through Quebec, with a single CDPD presence east of Quebec, in Halifax.

The Canadian digital wireless telecommunications arena exhibits the splintered deployment of too many technologies, as is indicative of the North American region. In addition, the digital data offerings within a provider's portfolio of services are mostly distributed over several incompatible networks, which leads to an undesirable multi-network solution that compounds even more the fragmentation problems of networks and services. Currently only Microcell Connexion and Rogers AT&T offer single-network solutions for all data activities, from circuit-switching over packet-switching to short messaging, each optimized for a particular data activity's traffic patterns. These networks are GSM/GPRS based and also offer higher speed (GPRS, 30...40 kbps) and extensive roaming capabilities continent wide and world wide. In order to serve today's data needs of their subscribers, Bell Wireless Alliance and Telus need to accelerate the migration of their CDMA networks to 2.75 or 3G-Phase1 CDMA2000 networks with adequate digital data services at higher speed. All Canadian providers need to extend their geographic coverage of digital services or partner with same-technology providers to facilitate seamless roaming across the North American continent.

End User Devices

In a classical sense, end user devices are categorized into phone-centric and computer-centric devices. Phone-centric devices, such as cellular phones, provide voice and data interfaces to the human end user, whereas computer-centric devices are programmable terminals that process data either for storage or rendering on a display screen .

Data-enabled phone-centric devices are the answer of telephony network providers to offer data services to subscribers. Due to their classical design they provide a limited user interface both for display and data entry and, thus, require special services to render data-borne text and low-resolution graphical information to users. Advanced devices support more efficient predictive text input via the keypad using T9 or iTap procedures, via a small attachable mechanical chatboard or through limited automated speech recognition (ASR). Phone-centric devices are most useful for SMS, short e-mail and WAP-based web browsing using built-in client software. Because of the large number of existing wireless technologies, network-dependent multi- band multi-mode devices are in use to allow for connectivity to a single digital network with fall back to the single-standard analog network, e.g. CDMA and AMPS. No phones for combinations of multiple digital services are readily available, thus no universal phone-centric device exists. Most phone devices are offered exclusively by the network providers for their particular network technology upon subscription to a user plan and cannot be moved to a competitor network. An exception to this rule are multi-band GSM end user devices which are available on the open national and international market with a very large selection of devices with varying capabilities. This is made possible by the use of SIM cards which hold the user personal profile and transfer it into the phone once installed in it.

Mobile computer-centric devices are connected to the wireless network via a RF modem or a data-enabled cellular phone, thus they are network-independent. They are not subject to the phone-centric form factor and offer much better user interfaces, including larger displays and full hard or soft keyboards, with extensible functionality through peripheral ports. Handheld PCs are distinguished by ½-size VGA color screens and a full keyboard, while Pocket PCs and PDAs offer 1/4-size VGA screens and a soft keyboard. Pocket PCs and PDAs are currently the most popular form of computer-centric devices combining a reasonable user interface with programmability under an operating system that supports a wide range of applications for both personal and business use. Among them, Palm devices lead the PDA category in number and availability of programs, although Pocket PCs, such as Compaq iPaq, have increased in popularity among business users due to their superior display screens, the familiar Microsoft Windows feel and compatibility with business-strength software, such as Microsoft Office. They also support full HTML web browsing and powerful E-mail clients for Internet access, and accept standard peripheral cards of the PCMCIA and CF formats for expansion of their connectivity to LANs and wireless networking.

At the current time a convergence of phone-centric devices and computer-centric devices to so-called Smart devices is evident. The latter combine the advantages of phones for inherent network connectivity and computer-devices for programmability and superior user interface. A large range of innovative, trendy and fashionable Smart devices are now available on the market. Because of their built-in network connectivity, these devices are network technology dependent and are currently available exclusively for the single-standard GSM because of its global dominance. Smart devices lead the way to the vision of one-device-for-all telecommunications needs. The most popular applications integrated into Smart devices are currently voice communication, fax, paging, PIM, SMS, e-mail, web browsing and entertainment. Smart devices come in both phone-type form factor, such as Ericsson's T68 or DoCoMo's FOMA 3G phone, and PDA form factor, such as the Handspring Treo 180 and Motorola Accompli 8.

RF modems are peripherals which enable computer-centric devices to connect to wireless networks. They are the only network-dependent hardware in this combination, allowing the more costly computer device to be retained when changing network technologies. Modems are either customized to fit 'piggy-back' onto small-size PDAs, such as Palm devices, or are available as PCMCIA or CF peripherals to install in the expansion ports of Handheld and Pocket PCs. Data-enabled phones with built-in RF modems can also be used to act as connecting interfaces to wireless networks. RF modems appear to the computer device as a regular modem, supporting standard serial communication, the Hayes AT command set and V.42bis error control and data compression. As such they can readily be accessed by most standard dial-up network-aware application software.

We see a consolidation of legacy end user devices, such as phones and PDAs, into Smart devices, using both phone form-factors and PDA form factors. Phone-type Smart devices will *evolve into integrated PIM devices with voice and limited text and graphics capabilities, appealing to the highly mobile user. PDA-type Smart devices benefit from their superior user interface, and with their integrated high-end computational and voice communication capabilities they will appeal to the business person on the move. Smart devices open new wireless markets where voice communication, instantaneous messaging, paging, information push, Internet access, corporate intranet access and entertainment play equal roles, facilitated and encouraged by a tightly integrated operating environment and well-designed single end user device. Due to their small sizes, the user interface is among the most critical aspects to their success in the future. Currently, there is still much room for improvement and an opportunity for both hardware and software developers to contribute integrated hardware and user-friendly client software solutions.*

Field Tests

Extensive field tests were conducted from October 2001 to March 2002 to gain a thorough working knowledge of public digital wireless networks, their services and end user devices. The venue of the tests was mainly New Brunswick, with some mobility tests done also in Nova Scotia and Prince Edward Island.

The practical investigations focused on the availability, usability and quality of network services including data rates, the usability of end user devices and the contents of network services. The tests were carried out by a group of 7 research assistants, students with different cultural and educational background. The targets of the tests were the two public digital cellular network providers in New Brunswick, NBTel Mobility (CDMA and CDPD) and Rogers AT&T (TDMA and GSM), both for circuit-switched data connections (CSD) and packet-switched data connections (PSD), where available. A wide range of end user devices with different form factors and varying user interfaces (phone, PDA, Pocket and Handheld PC, laptop and modem) were acquired and tested. The procedures of the tests and the subsequent analysis followed accepted practices, using subjective and objective evaluation of the test targets in different scenarios.

Service availability indicates the success of connecting at the first attempt. The test results ranked CSD of both providers higher than PSD, despite the need for a dial-up initiation of CSD. NBTEl Mobility's CDMA CSD offered overall best service availability of close to 100%. The second place of Rogers AT&T TDMA CSD was attributed to more frequent busy periods and lower signal strength due to poorer RF coverage range. NBTel Mobility's CDPD trailed in this test due to frequent registration problems due to busy periods, despite its 'always-on' connection mode.

The *service usability* indicates the ability to remain connected with acceptable service, even with end user devices in motion. The CSD connections of both network providers ranked ahead of PSD, as expected because CSD uses reserved links once successfully connected, whereas PSD is a shared network resource without bandwidth guarantee. Rogers AT&T TDMA CSD trailed Mobility's CDMA CSD slightly due to generally lower signal strength that caused connections to be lost during motion. This test revealed a significant performance discrepance between the two CDPD modems under test using the same PSD network. While Sierra's Aircard 300 modem readily registered into the network and maintained connection even at low RF signal strength (less than -100dbm), Novatel's Merlin CDPD modem failed to register at low to medium signal strengths (less than approximately -80dbm) and lost connections frequently in this situation. In high signal strength areas (-60db and better), however, the Merlin modem performed equally well as the Aircard 300.

During two inter-province car trips from Fredericton, N.B. to Charlottetown, PEI and Halifax, N.S., respectively, the CDPD coverage and connectivity was monitored from the moving vehicle. An almost contiguous RF coverage along the Trans Canada highway was detected, with some patchy coverage along the new highway portion between Jemseg and Petitcodiac. Satisfactory use of the CDPD service was reported for web browsing, file transfer and text chats. A similar result was found for the Fredericton to Saint John highway, except for spotty low-signal areas near the Eagle Pass. The above two field tests confirmed the earlier findings that the Aircard 300 CDPD modem offers superior connectivity compared to the Merlin CDPD modem, which lost registration frequently at lower RF signal strength.

Two tests were carried out that investigate the dynamic behavior of the wireless data transport. The test for *service responsiveness* evaluates the latency of a reply after a data request. CSD connections of both network providers offer best immediacy of replies compared to PSD. This is attributable to the dedicated nature of a circuit (CDMA, TDMA) as opposed to the resource sharing of a packet-switched connection (CDPD). The latter connection is also subject to occasional preemption during periods of voice call congestions. The *service data rate* was measured objectively as the effective throughput while receiving large-size binary files. CSD connections of both network providers proved much superior to PSD connections. In either case, the data rates were much below their advertised maximum rates. NBTel's Mobility CDMA CSD reached 10kbps (below the advertised 14.4 kbps), Rogers AT&T TDMA CSD achieved 8 kbps (below the advertised 9.6 kbps), and Mobility CDPD PSD performed at a low 7 kbps data rate with the Aircard 300 modem and at a disappointing 3.5 kbps with the Novatel Merlin modem (significantly below the advertised 19.2 kbps). All data rate measurements were done either at a laptop computer for CSD or Compaq iPaq for PSD, both of which are capable of sustaining much higher data rates so as not to create an artificial data speed bottleneck.

The *usability of end user devices* was evaluated in a subjective manner for services suitable to particular devices, and included aspects of ergonomics, user-friendliness and robustness of operation. Among the phone-centric devices the Audiovox 4500 was ranked ahead of the Ericsson 278d because of a more intuitive operation via menus and a more robust operation with no system hang-ups. However, the latter device's chatboard was found useful for short messaging and WAP web browsing. Among the computer-centric devices the Hewlett Packard H720 hand-held PC (running Windows CE3) was the overall preferred device due to its full keyboard, ½-VGA size screen and built-in expansion ports. In addition a good choice of Microsoft Office application programs and a full-fledged web browser (IE) and E-mail client are available for an efficient office-on-the-move implementation. Particular mention deserves the good web browsing capability on the larger screen with easy navigation of frame-based web pages. The Compaq iPaq Pocket PC ranked second because of its smaller, though excellent quality, screen size and the lack of a hard keyboard and expansion slots. Web browsing is awkward with typical frame-based web pages due to the necessity of two-dimensional scrolling and the potential loss of navigation. The Palm M505 ranked lowest in usability due to its overall less powerful applications and lower display quality. However, it does provide the widest choice of application programs, and it was voted as the best choice for on-the-road limited telecommunication due to unobtrusiveness, small size and low weight.

The *Contents of Services* test evaluated and ranked the usefulness and value of services and applications accessible via the Content Server and portals of the public networks. Among the services, the short messaging system (SMS) is the popularity winner, owing to its immediacy of personal communication from phone to phone, closely followed by SMS e-mail. This confirms the world-wide success of SMS as one of the Killer services over public cellular networks. So far, the North American market has seen little exposure to this service because of the late and incomplete provision of digital wireless data services (market penetration of 7% in North America and 23% in Europe by the end of 2000). Web browsing was ranked as the next popular service. HTML web browsing with PDAs was found interesting but cumbersome due to the small-size displays of portable devices in combination with frame-based web pages and the excessive use of graphics in today's web designs. Only web pages properly formatted for PDA screen sizes loaded quickly and were easy to navigate, but few web sites dedicated to this service exist. WAP based web services were found very useful for their just-in-time information content and quick accessibility. Although sparse and simple in presentation on small phone displays, WAP pages are well designed and tailored for mobile use. Among those services, news, sports, stocks, entertainment, interactive airline information were ranked highest. From the pool of mobile applications, the PIM synchronization either via a dedicated web server, such as AvantGo, or via corporate servers ranks at the top.

The majority of WAP sites are available only in English. Few sporadic services are available in French through the network providers' Content server, such as canada.com news service, most online banking services and Air Canada's interactive information service.

Cost Analysis

The cost of owning and operating wireless telecommunications devices involves investment cost and operating cost. The cost to subscribers was analyzed on the basis of cost models which allows for the development of an optimizing cost strategy for various data traffic patterns. Different cost models are in use around the globe, depending upon the governmental telecommunications policies and regulations. For circuit-switched data (CSD) connections the basic user fee is based on connection time. In North America, where local calls incur no charge and where telephone numbers for public wireless telephones and for land-line phones are indistinguishable, both send and receive data air time are charged, thus providing a revenue stream from both ends of a wireless connection. This data air time is normally in addition to the regular air connect time. Packet-switched (PSD) connections are normally charged by data volume regardless of the connect time, because of the sharing of connections.

A wide range of subscriber plans exist in order to lessen the impact of linear cost increase with time and/or data usage, such as semi-flat and flat plans. Semi-flat plans allow for data activities and data volume up to a limit, then charge per usage, whereas flat plans offer unlimited usage of data air-time and volume. To be beneficial to subscribers, these subscriber plans require a good a-priori estimate of the monthly expected data usage. A more flexible and user-administered charging method is offered by public wireless networks that permit so-called ‘pay-as-you-go’ plans for data usage. GSM networks generally support a fee system using an account on the SIM card. This account is pre-loaded with a certain amount of usage credit, is automatically debited when connections are made, and can be re-charged over the phone itself, at banks or kiosks. The SIM card can also be used with different end user devices, thus providing the most flexible method available to monitor and control a subscriber’s cost.

He cost of end user devices represents a large investment in the range of $200 to $1000. In order to reduce the impact of this high cost, devices are subsidized and then leased from the network service providers by entering into a long-term commitment for service on a monthly subscription plan. This market approach locks subscribers into the provider’s technology and services and counteracts competitiveness and upgrade with technology. Network providers lock their subsidized end user devices (SP lock, SIM lock) so as to discourage the move to another providers services. Currently only multi-band GSM end user devices are available on the open market for purchase in SIM-unlocked versions that accept SIM cards for use in all GSM networks worldwide.

An optimizing cost strategy was developed which allows the selection of the best subscriber plan for a given telecommunications application from among five typical plans and for two typical user applications. Both, CSD and PSD connections are considered with their subscriber plans, and web browsing and file-transfer data activities are considered as applications. Web browsing is representative of an interactive communications activity creating bursty data traffic with idle times between bursts, whereas file-transfer is representative of PIM synchronization where the connection is used close to 100% of time. The 5 subscriber plans under consideration are typical monthly data plans offered in New Brunswick. They are: pay-as-connected at $0.15/minute (CSD), 3 flat rate plans with increasing monthly usage limit (all for PSD, 150 kB at $5.00+$0.04/ kB, 500 kB at $10+$0.03/ kB, 1.5 MB at $20+0.02/kB), and a flat rate plan at $50. The analysis of the monthly projected cost for the two applications at hand gives rise to guidelines for a cost-effective solution: (1) CSD connections are suitable only for low-volume file-transfer type applications (e.g. PIM synchronization, account/inventory downloads), they become prohibitively expensive for interactive applications; (2) PSD connections are suitable for interactive applications (e.g. web browsing, data base enquiries) that have long idle times between data activities; (3) the monthly expected data volume usage needs to be known in order to select the optimum semi-flat or flat subscriber plan; (4) semi-flat plans are suitable for medium monthly usage whereas flat plans are the best choice for heavy usage, despite the higher monthly cost.

The existing practice of charging public wireless data services by a long-term package subscription (end user device and fee plan) is an inheritance of archaic Telco services of the past. It creates an immobile pool of subscribers, poor selection of end user devices, a stagnant *upgradability path to new technologies and a barrier for subscribers to benefit from competition among network services providers. This marketing approach needs to be changed to an open pricing policy, separated by services and end user devices. Data-oriented fee structures need to be made available to subscribers that fit their particular data activities, rather than general purpose type charge plans. End user devices need to be available on the open market for unrestricted upgradability to the latest technology as needed by business, or may continue to be subsidized by network providers for personal use. This move will also allow access of subscribers to a much wider range of end user devices most suitable for their particular telecommunications needs. The implementation of better user-administered charging systems is required to render wireless data services more cost-effective to occasional users. GSM's SIM card based rechargeable accounting system is a technically mature and user-friendly example of a user-controllable means to cost management. It has been made available to China's demanding CDMA customer base in order to increase CDMA's acceptance after the established use of GSM. Circuit-switched data connections with their as-connected fee structure carry a prohibitive high operating cost for any data-born wireless application, except for low-volume occasional non-interactive usage, yet they are the only data connections available today for NBTel Mobility CDMA and Rogers AT&T TDMA digital networks. A quick upgrade, or migration, to appropriate packet-switched services, such as available by NBTel Mobility CDPD and Rogers AT&T GSM/GPRS digital networks is needed to offer reasonable and cost-effective services to subscribers of CDMA and TDMA networks.*

Bibliography

Reference Books

Halsal, F.: Data Communications, Computer Networks and Open Systems, Addison-Wesley, 1992

Lautenschlaeger G., Schmidtke B., Handy - SMS, E-Mail, WAP, Data Becker Publications, Duesseldorf, 2000

Lee, W.: Mobile Cellular Telecommunications Systems, McGraw-Hill Book Co., 1989

O'Hara B., Petric A., IEEE 802.11 Handbook - A Designer's Companion, IEEE Press, 1999

Stallings, W.: Local and Metropolitan Area Networks, MacMillan Publishing Co., 1993

Wenz C., Hauser T., WAP - Architecture, Programming, Reference (in German), Carl Hanser Publications, Munich, Vienna, 2001

Journals

Cox D., Wireless Personal Communications: What is it ?, IEEE Personal Communications, Vol.2, No.2, April 1995, pp. 20-35

Kobb, B.: Personal Wireless, IEEE Spectrum, June 1993, pp.20-25

Mouly M. and Pautet M.-B., Current Evolution of the GSM System, IEEE Personal Communications, Vol.2, No.5, October 1995, pp. 9-19

Noerpel A. et. al., PACS: Personal Access Communication System - A Tutorial, IEEE Personal Communications, Vol.3, No.3, June 1996, pp. 32-43

Steele R., The Evolution of Personal Communications, IEEE Personal Communications, Vol.1., No.2, 2nd Q. 1994, pp. 6-11

IEEE Personal Communications (now: IEEE Wireless),each issue covers relevant aspects of wireless communication networks and services, IEEE publications.

IEEE Pervasive Computing, each issue covers relevant aspects of mobile computing over wireless network infrastructures, IEEE publications.

Reports

Brown, Kenryn Communications, PCS and the Big Picture, Industry Canada - Inform. Technology Industry Branch, PCS Seminar IT Canada, Moncton NB, December 1996, 35 pages

CDPD Forum, Cellular Digital Packet Data System Specifications Rel. 1.1, 1995

IEEE Standards Dept, Draft Std. IEEE 802.11 Wireless LANS (P802.11D3), 1996

Telesat Corp.: MSAT - Reaching All Canadians, Dept. of Supply and Services, Government of Canada, Ottawa, 1988

Vision 2000 Inc.: Networking the Global Village, Dept. of Communications, Government of Canada, Ottawa, 1990

WWW Pages

Aliant, www.aliant.com, www.etelesolv.com

Ardis/Aliant, www.data.bellmobility.ca

Atheros Communications Inc., www.atheros.com

Audiovox Corp., www.audiovox.com

CDMA Development Group and international consortium (CDMA), www.cdg.org

Compaq, www.conpaq.cm

EMC World Cellular, www.emc-database.com

Ericsson S.A., www.ericsson.com

Extended Systems, www.extendedsystems.com

Globalstar Satellite Communications, www.globalstar.com

GSM Association (GSM), www.gsmworld.com

Handspring, www.handspring.com

Hewlett Packard Invent, www.hp.com

International Telecommunications Union (ITU), IMT-2000 site, www.imt-2000.org

Microcell Connexions, www.canadagsm.com

Motorola, www.motorola.com

Nokia, www.nokia.com

Novatel Wireless, www.novatelwireless.com

NTT DoCoMo, foma.nttdocomo.co.jp

Palm Inc., www.palm.com

Research in Motion Ltd. (RIM), www.rim.com, www.blackberry.com

Rogers AT&T, www.rogers.ca

Sagem SA, www.sagem.com

Sierra Wireless Inc., www.sierrawireless.com

Sony Ericsson, www.sonyericsson.com

Spectrix Corp., www.spectrixcorp.com

Universal Wireless Communications Consortium (TDMA), www.uwcc.org, now: www.3GAmericas.com

Appendix A

Progress Seminar

As part of the deliverables of this research project a Half-day Progress Seminar entitled 'Personal Digital Wireless Telecommunication - An Investigation of Technologies and Services' was presented on 8 August 2002 to invited representatives of business, government and academia. The objective of this seminar was the dissemination of the collected information on the state of digital wireless telecommunications and invite feedback for the work to be done during the upcoming field tests. In addition to a presentation of the results of the reconnaissance phase of this project, talks on the public wireless services were given by NBTel Mobility and made available for presentation by Rogers AT&T.

Contact:

Dr. Bernd Kurz
Faculty of Computer Science
University of New Brunswick
540 Windsor Street
Fredericton, N.B.
E3B 5A3

Tel: (506) 453-4566
E-mail: bjkurz@unb.ca

UNB

Abstract

The Information Technology Centre at the Faculty of Computer Science, University of New Brunswick, is conducting an investigation into the current state of personal digital wireless communications in New Brunswick (PCS). This study is directed at wireless technologies and services for economic development in New Brunswick.

The first part of this work is an up-to-date inventory of available technologies and services, a survey of the current use of these services by New Brunswick industry, and an analysis of the collected data. This seminar presents the findings of the first part of this study, a reconnaissance of available technologies and services and of the current use of these services by New Brunswick industry. Although the focus is on New Brunswick and Canada, other regions, such as the US, Europe and the Far East, are briefly covered. The evolution to today's wireless technologies is reviewed and an outlook to the next-generation wireless telecommunications systems is given. Current digital data services and the use of suitable data-enabled phones, PDAs and lap-top computers are presented and the current limitations are outlined.

It is planned to have presentations by the two major PCS providers in New Brunswick, NBTel Mobility and Rogers AT&T on their offerings. The seminar concludes with a brief common discussion session highlighting the benefits for business with the hope to direct future developments in the PCS area. A light lunch is provided with opportunities for mingling and one-to-one exchanges of views and ideas.

UNB

Information Technology Centre
Faculty of Computer Science
University of New Brunswick
Fredericton, N.B.

You are invited to attend a presentation:

Personal Digital Wireless Telecommunications

An Investigation of Technologies and Services (Phase 1)

by

Bernd Kurz

Thursday, 9 August 2001
10:00am-1:00pm
light lunch included
Information Technology Centre
Room IT-C317
550 Windsor Street, Fredericton, N.B.

You are personally invited to attend a presentation on the current state of personal digital wireless communications in New Brunswick, with a view towards business applications.

Agenda

10:00 am	Welcome
10:05 am	Background
10:15 am	Presentation of the results of the Reconnaissance task
11:15 am	NBTel-Mobility offerings *)
11:35 am	Rogers AT&T offerings *)
12:00 noon	Common discussion session and feedback
12:15 pm	Light lunch served and opportunity to mingle and exchange ideas
1:00 pm	Closing

*) subject to confirmation

Parking is available next to the ITC building off Windsor Street

Appendix B

Final Seminar

As part of the deliverables of this research project a full-day Final Seminar entitled ‘Personal Digital Wireless Telecommunication - An Investigation and Evaluation of Technologies and Services’ was presented on 28 February 2002 to invited representatives of business, government and academia. academia. The objective of this seminar was the dissemination of the final results on the state of digital wireless telecommunications and the practical evaluation of public networks , services and end user devices. In addition to two presentations on the results of this research project, representatives of NBTel Mobility, Rogers AT&T and Globalstar Satellite systems gave talks on their wireless services in New Brunswick and Canada. A workshop was conducted with demonstrations of a wide range of available digital wireless connectivities

Contact:

Dr. Bernd Kurz
Faculty of Computer Science
University of New Brunswick
PO Box 4400
540 Windsor Street
Fredericton, N.B.
E3B 5A3

Tel: (506) 451-6973
E-mail: bjkurz@unb.ca

UNB

Abstract

The Information Technology Centre at the Faculty of Computer Science, University of New Brunswick, is conducting an investigation into the current state of personal digital wireless communications in New Brunswick (PCS). This study is directed at wireless technologies and services for data communications for economic development in New Brunswick.

The final part of this work deals with the practical evaluation of public networks, data services and devices, on the basis of a 3-month long field experimentation. This seminar is a follow-up on our first presentation in August 2001, which covered the available technologies and existing services in general terms, and is a conclusion of our investigations. An in-depth outline of the existing and future wireless networking technologies is presented along with roaming and mobility issues. Data services, which are relevant to New Brunswick business, are discussed along with achievable quality of service, data throughput and comparative cost over a variety of networks. A range of suitable devices, from data-enabled phones over popular PDAs to laptop computers are considered and their suitability for particular wireless data services is evaluated, including ergonomics and limitations. Although the focus is on New Brunswick and Canada, other regions, such as the US, Europe and the Far East, are briefly covered. The evolution to today's wireless technologies is reviewed and an outlook to the next-generation wireless telecommunications systems is given.

An afternoon workshop is part of this seminar where many devices for wireless connectivity are demonstrated, and are available for personal hands-on trials on networks such as public PCS, WLAN (802.11) and WPAN (Bluetooth). It is planned to have presentations by the two major PCS providers in New Brunswick, NBTel Mobility and Rogers AT&T, on their offerings.

A light lunch is provided with opportunities for mingling and exchanges of views and ideas.

UNB

Information Technology Centre
Faculty of Computer Science
University of New Brunswick
Fredericton, N.B.

You are invited to attend a presentation
on

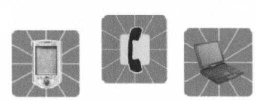
Personal Digital Wireless Telecommunications

An Investigation and Evaluation of
Technologies and Services
(Phase 1)

by

Bernd Kurz

Thursday, 28 February 2002
9:00 am - 3:30 pm
light lunch included
Information Technology Centre
Room IT-C317
550 Windsor Street, Fredericton, N.B.



You are personally invited to attend a presentation on the current state of personal digital wireless communications in New Brunswick, with a view towards business applications.

Agenda

9:00 am	Welcome
9:15 am	Wireless Technology: present and future
10:00 am	NBTel-Mobility presentation
10:25 am	Refreshment Break
10:45 am	Rogers AT&T presentation
11:10 am	Networks, Services, Devices: field test evaluations
12:00 noon	Light lunch served and opportunity to mingle and exchange ideas
1:00 pm	Showcase by Public Carriers and ITC
3:15 p.m.	Closing remarks

Parking is available next to the ITC building off Windsor Street

Appendix C

IT Awareness Week

The New Brunswick Information Technology (IT) Awareness week was held from 3 to 12 May 2002. As part of this event the Information Technology Centre (ITC) participated in publicity events that showcased IT related activities and technologies to raise the awareness of IT to both public and business. The demonstrations of IT technology by the ITC benefitted from the knowledge gained in this research project by showcasing several end user devices and their wireless connectivity in action, and by presenting posters on the available technologies in New Brunswick and Canada.

INFORMATION TECHNOLOGY WEEK – 2002

Events to raise awareness of IT

BY HEATHER MACCALLUM
for The Daily Gleaner

Recognized last year as the best in Canada, organizers of the second annual New Brunswick IT Week have been striving to maintain the spot at the top.

IT Week, a tribute to everyone who makes information and communication technologies more accessible and appealing, will be held May 3-12.

Sponsored jointly by Industry Canada and the Information Technology Association of Canada, more than 35 events were held by partner associations across the province last year. That allowed New Brunswick to boast it did more than any other province in Canada to celebrate and explore information technology.

Jeff McGuigan, co-chair of the Fredericton regional IT Week committee, said he and the other organizers are pleased with last year's achievement and are anxiously anticipating activities planned for this year. He said this year the aim of IT Week is to focus on the public and illustrate to them the significance of the industry in areas they probably don't realize are related to the information-technology sector.

"Traditionally when people think of a computer programmer, they imagine someone, who may be a little geeky, sitting behind a terminal," he said, "when really there are many innovative uses in our every day lives. We are trying to get this awareness out to the public."

The IT sector has grown substantially in Fredericton in the past five years, McGuigan said, due to a joint effort by the province and the municipality to provide the proper framework and make it easier to do business here. Qualified, trained workers are available, and the bilingual work force is recognized as cost competitive and effective, he said.

Fredericton may also be booming as advances in technology break down geographical barriers.

"It doesn't matter if you are located in Toronto to do business there, with the technology we have today those barriers are broken down," he said. "The infrastructure we have here in terms of telecommunications and our knowledge park make it easy to do business anywhere."

He said IT Week provides the vehicle to take the organization to the community level where he hopes to increase awareness about what information technology is all about, as well as encourage children to think about choosing a career in IT.

A large event will be held Saturday, May 4, at Science East to demonstrate to families about how IT affects their everyday lives. This dynamic, interactive IT experience includes top-notch demonstrations from various companies.

During the final weekend of IT Week, Regent Mall will present It's All About IT! Fifteen exhibitors from Fredericton and surrounding areas will showcase their IT-related products and services to over 60,000 Regent Mall customers during this two-day event.

McGuigan said he hopes these activities will provide a chance for families to pair tangible technology they may be using every day with the broad concept of information technology. These demonstrations may also encourage students to consider a career in the IT industry, he said.

"Maybe children will see something at these displays and consider information technology as a great place for them to get a good quality job and an interesting career," he said. "With the training that is offered right in the Fredericton area, companies are able to embrace them, grow their business and make a larger contribution."

He said he is particularly excited about the fact that it is going to be hard for the public to avoid IT this year.

— THE DAILY GLEANER/HEATHER MACCALLUM PHOTO

IN THE PALM OF THEIR HANDS: UNB computer science masters students Elijah Bitting, left, and Jonathan Carter demonstrate how to use a personal digital assistant or PDA. It's just one of the samples of technology they'll be helping to spotlight during upcoming IT Week events.

Mall exhibitors ready for showcase

BY HEATHER MACCALLUM
for The Daily Gleaner

Exhibitors at the It's all about IT! demonstration at the Regent Mall are looking forward to reaching out to the public.

Fifteen exhibitors from Fredericton and surrounding areas will showcase their information-technology related products and services to over 60,000 customers at the mall on May 10 and 11. As part of IT Week events, exhibitors are anxious to not only present customers with information about their own organization and services, but to also help them feel more familiar with the concept of information technology.

Sandra Abbott is program co-ordinator for Computers for Schools, which collects surplus computer equipment from provincial government, private companies and individual donors and then rebuilds them into desktop-ready computers to donate to First Nations and public schools, as well as libraries.

This program has led to the creation of a high school course called Tech Support 110, which teaches students to do basic computer repair and upgrading. Students enrolled in this course assist the central workshop in Fredericton and volunteer sessions, in completing computers to donate to schools.

Computers for Schools will have two booths at the Regent Mall and will hold a "build-a-thon." Six teams of two students will compete against each other to win donate prizes, Abbott said.

As most households now have at least one computer and depend on the Internet and other services in their day-to-day lifestyle, she said this display may help people to be more aware of how to maintain their computers.

"Years ago you had to know how to put oil in your car and change a tire. Now if you have a computer you have to have some knowledge in how to fix problems that may crop up," she said. "Knowing how to fix computer problems is going to be a basic skill you're going to need if you have a computer at home to keep yourself connected."

Abbott said this demonstration is a great opportunity for students involved to talk to people to explain how they refurbish the computers. She said it also showcases how computers are being used in the public school system.

Source: Daily Gleaner 4 May 2002