A Guide to Improving Internet Access in Africa with Wireless Technologies

IDRC Study
August 31st 1996
Mike Jensen (mikej@wn.apc.org)

1.0) Preface

The use of radio frequencies for wireless communications has advanced extremely rapidly over the past few years resulting in an explosion of possibilities for improving communications infrastructures worldwide. In Africa in particular, wireless technologies are seen as one of the most important ways of addressing the needs of a continent with the least developed telecommunication system in the world.

Wireless systems also have a special role to play in meeting data communication needs and the spread of the Internet has placed further demands for widely accessible and reliable high-bandwidth circuits on a generally overburdened and unstable infrastructure. However radio based solutions are being considered so frequently for improving basic telecommunication infrastructure that wireless access to the Internet should also be looked at in a wider context of the provision of systems to assist the public network in providing access to both voice and data.

This report attempts to identify the opportunities for using wireless technologies for Internet access in this context and should be of interest to international agencies planning development assistance projects in the region as well as Telecommunication Operators, Internet Service Providers and end-users. In the developed countries many wireless technologies are being developed to meet the demand for mobile computing. Although many of the systems discussed can also provide mobile Internet connections, in Africa these needs are far lower and so less attention is given to this area in the report.

Wireless solutions usually rely on proprietary hardware and software platforms developed by a particular company - the development of open standards is still at a very early stage and so in most cases it is mandatory to use the same company's products at each end of a link. With this sort of limitation in the competitive environment between suppliers and the great variety in types of connections, equipment and protocols, choosing a system can be difficult and there are few ongoing forii to improve information exchange. As a result there is a strong thread of product information in this report and an extensive list of contact addresses and information resources on the Internet dealing with wireless technologies are included in the Appendix.

2.0) Introduction

The combined effects of plummeting equipment costs, the internationalisation of communications, liberalisation of the telecommunications sectors in many countries and the expanding array of technologies able to exploit new areas of the radio frequency spectrum have produced a dynamic but relatively immature field where clear answers are often not yet available. The rapidity of developments has resulted in many differing schools of thought who have not yet reached agreement on the most appropriate way to make use of these new communications systems.

The explosive growth of cellular telephones is just one example of the pace of these new developments, but is this soon to be eclipsed by new technologies such as personal satellite communications and Personal Handyphone Systems? And will wireless local loops replace copper as the chosen way to expand basic subscriber services? Many such questions bear special relevance in developing countries in general, and Africa in particular, where the existing network penetration is so low that new infrastructure-building initiatives can afford to take full advantage of the latest technologies.

But wireless systems are not a panacea. Although they can offer far more rapid roll out times, greater reliability, lower maintenance costs and better security, wireless systems are still significantly more expensive than cable based systems. Wireless Internet connections are also not inherently more viable than wired networks - they are more appropriate in applications where traditional solutions are for some reason not feasible or cost effective. Aside from the additional equipment which makes wireless systems more costly, they often require skilled technicians to install and they are generally unable to provide the same bandwidth as cable-based systems. The TCP/IP protocol was designed for a relatively error-free environment and many wireless networks are inherently prone to errors. Some wavebands are particularly susceptible to weather conditions (rain, temperature, solar interference etc.) and they also generally require a much greater level of co-ordination to avoid interfering with the activities of others.

3.0) The Radio Spectrum

The frequencies of the electromagnetic impulses called radio waves have been divided into bands along a scale which vary all the way from below audible sounds, up through the conventional radio and television bands into infrared, visible, ultraviolet, X-rays, Gamma rays and finally Cosmic rays. The scale ranges from 0 Hertz (oscillations per second) which is relatively close to where the audible bands start at about 10Hertz, and up to 1035 Hertz of the Cosmic Rays. The section of the spectrum that can be used for wireless communications varies from about 3KHz, which is still in the audible range, up to the visible light range at about 10^{15} Hertz where some laser-based systems operate. These frequencies all vary in their propagation characteristics and susceptibility to interference, which determines their value for a particular purpose. For most applications the usable spectrum stops about 300GHz, at the beginning of the infrared band.

The major distinctions between much of the spectrum is in a particular waveband's value for fixed or mobile communications and long distance or short distance. The broad categories of use are: Radionavigation, Aeronautics, Amateur, Fixed, Broadcasting, Maritime, Satellite, Meteorological, Mobile, Space Research and Astronomy. The most well known wavelengths are those used for radio broadcasts - MF, HF and VHF (medium, high and very high frequencies), but these are also used for other types of point-to-point and multi-point data and voice communications.

The HF band is particularly suited to international communications because it is not restricted to line-of-sight, but is reflected back to earth by the ionosphere and so can travel for thousands of kilometres, providing a long-range but highly variable narrowband service. HF users need to consider the constantly-changing nature of the ionosphere, high levels of ambient noise, crowding and interference, and the need for relatively large antennas. Nevertheless, because of the long-range capability using relatively inexpensive equipment, HF is uniquely valuable for many long-range applications and aside from the international radio broadcasters, is used by many government and relief agencies after hurricanes, earthquakes, or other natural disasters that have disrupted the existing communications infrastructure.

At VHF and UHF frequencies (30-1000 MHz), narrowband fixed services can be used over short ranges (up to 60 km), often sharing frequencies in mobile bands by using directional antennas. These services include the point-to-multipoint multiple address services (MAS). The last group of the most common fixed services uses microwave frequencies (above 1 GHz) for point-to-point wideband communications over line-of-sight paths which include transmissions from communications satellites. Tropospheric scatter systems can also provide point-to-point service over paths up to 200 km, using highly directional antennas and high-power transmitters.

Infra Red wavebands (300GHz-1014 Hertz) are used for very short distance communications between computer devices in an office for cordless printing, file transfer etc.

Beginning at about 10 GHz, absorption, scattering and refraction by atmospheric gases and hydrometeors (the name for the various forms of precipitated water vapor such as rain, fog, sleet and snow) become important limiting factors in transmission distance (see Appendix).

The capacity of a wireless link is determined by the encoding or modulation technique used and the amount of the spectrum that is occupied, measured in Hertz. In the 4-11GHz range, a 1Mhz circuit corresponds to about 1.2Mbps. The higher frequency signals are capable of transmitting more data, resulting in a general tendency to use the lower frequencies for lower band-width or last mile applications, leaving the higher frequencies for broadband systems.

4.0) Regulating the Use of Radio Frequencies

Although radio spectrum is not strictly a consumable resource it is a finite one - the use of a frequency at a particular location usually excludes that part of the spectrum from being used by others in the same area. This need for exclusive geographic use has resulted in regulations to ensure optimal benefits to society by clearly defining rights of use, through granting licenses and allocating areas of the spectrum for particular applications. In some cases the regulator will provide part of an already allocated waveband for a 'secondary' purpose as long as it doesn't interfere with the primary use.

One of the major issues facing regulators at present is to rationalise the current allocations in the light of new technological developments which can make more efficient use of the spectrum already allocated to some other use. This is not an easy task given the pace of technological change and the inertia resulting from the vested interests of those already occupying the spectrum. In Southern Africa, a project known as SABRE, co-ordinated by the Southern African Transport and Communications Commission (SATCC), is currently attempting this process of rationalisation for the sub-region.

The form of the regulatory authority varies from country to country, and there is a worldwide tendency toward the establishment of autonomous government departments. In Africa few countries have so far established independent regulators and it is most often the state operated PTTs who are delegated this responsibility by the Ministry concerned.

For frequencies that can travel across national borders, (most bands above 1Ghz) the International Telecommunication Union (ITU) is responsible for assisting with negotiations between countries through its World Radiocommunications Conferences (WRC) every two years which result in modifications to the treaty known as the 'Radio Regulations'. The conferences are comprised of delegations from roughly 180 countries around the world and adoption of allocations and regulations is done by majority vote, with each country getting one vote. The needs for international co-ordination were identified in the last century, shortly after the invention of radio communications, resulting in the ITU being the world's oldest international body.

The use of the 30-960 Mhz band (VHF/UHF) is essentially up to the country, as long as activities don't interfere with neighbouring nations. Most local telecommunication systems use these particular bands. In some cases, such as in North America, Europe and Southern Africa, countries have established a voluntary mechanism for coordination with neighbouring countries on cross-border use of frequencies. The ITU has a Master Frequency Register of frequencies allocated for different usage, mostly in the bands that require coordination because registering is voluntary in other bands.

The ITU's activities in the area of radio regulation have steadily increased - the rapid development of long distance radio-based technologies and the internationalization of telecommunications development has substantially increased the need for an international decision-making process. The increased use of satellite systems has also focused attention on the role of the ITU who is responsible for the process of negotiation for orbital positions above the earth - there are only 120 positions available around the equator for geostationary satellites, and the ITU has received over 400 applications for their use, mostly from developed nations.

In developing the regulations for international frequencies, the world has been divided into three Regions. Region 1 includes Europe, the Former Soviet Union, Africa and parts of the Middle East. Region 2 includes the entire Western Hemisphere. Region 3 includes Asia and Oceana. As a result regulations in Africa are generally more aligned with those in Europe than in north America or Asia. The regulations usually prescribe the frequencies at which certain services can operate, the maximum power at which they may transmit, the maximum interference they are allowed to cause to other users, and the minimum amount of interference they are obliged to endure.

Although a significant part of the spectrum is not subject to international agreement, spectrum allocations are relatively uniform worldwide, largely because of the dominance of the US in wireless technologies which means that it often sets de-facto national standards for other countries, most of which depend on wireless products which originate from US companies. This isn't always the case however, especially in Africa where spectrum allocations may be made with less awareness of developments in the US, especially since the demand for the latest systems is likely to be much smaller. Also, the US allocated the 900Mhz band before the advent of GSM cellular telephones which use these bands. As a result, where GSM is used in Europe and Africa, some wireless technologies which use the 900MHz band are not useable in Europe or Africa.

Although the spectrum used by the various types of wireless technology may be relatively uniform worldwide, the rules about who can use them are not. In the US, telecommunication liberalisation has resulted in rapidly increasing numbers of companies providing wireless communications services. In Africa access to the airwaves is much more restricted - security concerns often still prevail over the control of information channels, many of the markets are serviced by legally constituted monopolies, and the state often does not have the skills or the resources to monitor spectrum use.

While cellular telephone services have been opened to the public in more than half the Sub-Saharan African countries, much of the rest of the spectrum, aside from radio and television broadcast frequencies, is usually allocated to the military. Security is a major concern in many countries and if armed forces are suspected of opposing the government, wireless communications are likely to be severely restricted. On the other hand, demand for many of the wireless services is so small in these countries that governments have most likely not been offered large sums by companies willing to pay big license fees for access to the market.

Some exceptions are made for development organisations and for the country's biggest corporations which often have special access to government, and for the state itself. All of the UN organisations are also immune to national regulations, having been recognised by the ITU as an independent telecommunications operator. There are also amateur radio bands which are set aside for experimentation, emergency preparedness and private use of a 'non-pecuniary nature' - no third party traffic can be carried and they cannot be automatically connected to the public network.

Less controlled are the ISM bands (2.4GHz) for industrial, scientific, and medical applications. These bands have been opened worldwide for general purpose data communications without requirement for a license if restrictions on the power and transmission characteristics of equipment used are adhered to. This limits the operational range of the equipment to a few hundred metres unless a license can be obtained to use high gain antennas and higher powered transmitters. Also, common appliances such as microwave ovens cause interference in these bands which can result in the need for higher cost equipment where this is a problem.

Because of the lack of radio spectrum monitoring facilities and skills in many African countries (in some cases the regulatory agencies may exist only on paper, with virtually no resources to enforce a country's decisions about spectrum use) quite a few organisations and individuals have simply gone ahead and installed wireless technologies without seeking permission. But telecom operators are becoming more aware of these abuses and either committing resources to developing monitoring capacities, or enlisting the help of amateur operators in the country to identify unregulated use.

Also, limited resources for spectrum allocation planning in many African countries means that some of the rules are not yet clearly defined because many wireless technologies are so new. So national policy is often only set when the technology is introduced by an influential company, creating ad-hoc decisions which can cause problems later.

Of course it is possible to apply for a license to operate communications equipment on the wavelengths designated for their use, but since most of the telecom operators (PTTs) in Africa have a monopoly over telecommunication services of all types, it is almost essential to involve them in some way if the license application is to be successful. The PTT would probably need to be convinced that it cannot reliably provide the service required through its existing infrastructure, it will not be used by third parties or cause interference, and it may also be necessary to give the PTT ownership over equipment and to pay a rental fee for access to the service.

In Southern Africa the procedure is to apply to the PTT to provide a specific service. If it 'declines' then an application for a license is likely to be accepted. Alternatively, the user can very often offer to pay for the additional equipment costs needed to establish the link. In South Africa, Telkom is able to provide financing arrangements to spread the user's cost over a period of up to 7 years. In some cases the PTT will offer to provide the service, but at a higher installation cost than the user believes is necessary. There have been some precedents where a license has still been granted despite the PTTs willingness to provide the service, albeit at high cost.

Nevertheless, probably the biggest barrier to widespread use of wireless technologies for accessing the Internet are the entrenched models used by the PTTs in providing service. They generally plan for the provision of the full range of telecom related services over *all* of their infrastructure using sophisticated equipment that will carry multiple voice/data/ISDN/TV channels etc. As a result they are generally unwilling to consider small-scale approaches which only involve the transport of data/Internet traffic, although if a social improvement dimension is present in a project involving wireless technologies it may be easier to obtain approval.

5.0) Wireless Applications

Wireless systems can be grouped in many ways - fixed or mobile, broadcast or point-to-point, single frequency or spread spectrum or even frequency hopping. But for our purposes, looking at the alternatives according to applications which use particular frequencies, is probably the most useful approach.

5.1) Fixed Microwave Multi-Channel Trunk Carrier Services

Aside from traditional radio and television broadcasting, the most extensive use of the radio spectrum has been made by telecom company networks for medium distance point-to-point microwave links for providing trunk routes between urban areas and within large cities. Microwave towers operating over line of site paths in the 4-GHz and 6-GHz bands and short-range links in the 11-GHz band have been built since the 1950s to carry long-distance voice and data circuits and also radio and TV signals for re-broadcasting locally.

In developed countries many public telecom operations also provide a variety of "distribution" services. These include the multipoint distribution service (MDS, 2 GHz), the multiband multipoint distribution service (MMDS, 2.5 GHz), digital electronic message service (DEMS, 10.5 GHz) or digital termination service (DTS), and there are also proposed local multipoint distribution services (LMDS) operating at 28 GHz. While uncommon in Africa, these services are intended to provide one or two-way services for digital messaging, but they have been used mainly to distribute TV signals. These systems use a star topology with a master station and omnidirectional antenna communicating with several slave stations which have directional antennas aimed at the master station. The same bands and services are often used by private operators.

If well maintained, analogue microwave circuits, carrying leased data circuits for applications such as the Internet, can operate smoothly up to 9.6Kbps and new modems manage to push this to 24-28Kbps in many cases. Over long distances where the signal must travel many hops through microwave repeaters to reach its destination, quite regular outages can occur on poorly resourced networks due to failures at one of the towers along the way.

In developed countries, most of the early analog microwave towers have now been converted to digital systems and many of the links have been replaced by optical fibre, leaving the microwave systems for backup purposes. This is only now beginning to take place on a wider scale in Africa for the largest trunk routes. However, the limited and widely spread demand outside the major urban areas in Africa along with the theft, maintenance and lightning problems of using copper means that small line-of-site microwave systems are increasingly being used to replace copper on the 'thin' routes, even for a few dozen telephones.

The poor quality of the old copper trunking systems in Africa is generally the biggest deficiency in the national network, often causing more problems than the last mile/local loop, so thin route microwave systems are vital in Africa for improving capacity. Using narrowband channels in the 600MHz, 2GHz, 15GHz and 38GHz range, these systems can provide multi-channel trunk routes for copper based local loop dialup voice and data access like any other cable based voice telephone trunk. As a result they are an extremely important method of increasing connectivity in outlying areas. Working with the telecom operator to establish these systems is probably one of the most viable ways of improving domestic access and often the only cost effective one in the long term. Individual point to point data links may be a quick and simple solution but they don't make efficient use of the available spectrum and the per-link costs are significantly higher.

A South African company, NZ Telecoms, which has been active in supplying small microwave trunk systems to national PTTs in Malawi, South Africa and its neighbours, advises that equipment can be cost effective at $900 per user for 120 users. Although 'low-end' equipment is restricted to analogue data rates (28800bps uncompressed), individual dialup users can access the wireless hub through their normal copper voice telephone lines which can be up to 12 kilometres away. Where there is no copper, a 'cable-extender' system developed by Exicom can be installed to provide a single point to point voice/data up to 60km away for about $10000. Operating with tunable frequencies between 68Mhz and 512MHz, the Exicom system is also available in a dual channel model for about $8000 per channel.

More sophisticated digital microwave systems are being supplied by companies such as NZ Telecoms which provide voice services along with high bandwidth leased data circuits, frame relay and ISDN services to small points where demand is concentrated. These systems are also beginning to be used in larger African population centres to provide dedicated digital data services where demand for these services is still small. Some of the cheaper systems require high bandwidth data users to be co-located with the microwave unit, but generally, individual subscribers in a 6km radius from the station can access the frame-relay, digital leased line and ISDN services over normal copper local loops at speeds of up to 2Mbps, and lower bandwidth services (dial-up or analogue leased lines) are available over copper up to 12km from the station.

Small scale digital microwave trunking systems are usually available in different sizes - small capacity units for about 5-30 users, and higher capacity systems for 5-120 users. The DXR-200 system which can service up to 30 users costs about $90 000 for an entire system including two antennas, 2 radios with integrated multiplexors, and all the line cards to provide 30 telephone, fax, coinbox or dial-up services via the copper local loop. Installation typically requires two days.

For medium capacity requirements (5-120 links to the local loop) an 8Mbps microwave system paired with a flexible multiplexor called UMUX is a popular solution. The system can also be upgraded to 480 users by adding 3 more multiplexors and bringing up the link capacity to 32Mbps. This solution becomes cost effective on a per subscriber basis when there are more than 30 users. For example when 120 telephone/dial-up services are required a total system including mulitplexors and microwave system can be deployed for about $100 000.

In addition to providing basic telephone services, advanced data services can be simultaneously provided from a UMUX system equipped with different modules, such as an NTU (Network Terminating Unit) at the remote end, to provide leased line data, frame-relay or ISDN services. As an indication of the cost, NZ Telecoms recently quoted about $200 000 to an African PTT for establishing a start-up public frame-relay network with one Frame Relay node (switch) in each of 2 cities with all the equipment necessary for a total of 60 access circuits, each capable of 128Kbps, in the two cities. This works out at about $3500 per access circuit , but because of the initial cost for the base equipment, the cost per subscriber will drop considerably as more are added. Each UMUX multiplexor can accommodate up to 93 NTUs. These systems can also use HDSL technology (either 2B1Q or the new CAP technology) over the local copper loop to supply up to 2Mbps links, a considerably cheaper way of supplying service than the traditional method of laying fibre, z-screen cable or radio to the premises.

Development of HDSL technology is ongoing and with further developments speeds of up 8Mbps should be possible shortly. Where cable is in short supply HDSL techniques known as 'pair-gain' dramatically improve the capacity of the available cable infrastructure so that as many as 10 voice telephone services or 4 ISDN BRI (2B+D) links can be provided using a single pair of telephone wires.

5.2) Long Distance Terrestrial HF Radio Networks

One of the earliest uses of the radio spectrum results from the characteristic behaviour of HF frequencies to bounce off the ionosphere, allowing them to travel around the globe, making it possible to communicate with virtually any part of the planet. Using HF fixed and mobile radios, diligent amateurs in Southern Africa can converse with fellow amateurs in over 160 other countries. These systems are almost never used by third parties for point-to-point communications, except in emergencies - bandwidth is very low, partly because of problems with interference in these wavebands, and also because they are used extensively for international radio broadcasting. Time-of-day and sunspot activity are particularly important factors in the ability of the HF bands to support long distance communications and a good selection of frequencies, spread throughout the HF bands is critical to maintaining reliable communications.

The data transmission rates available on HF frequencies are only really useful for relatively small messages - equipment capable of 75-300 baud using the SITOR protocol has been available for many years but is now being overtaken by systems able to transmit up to 2400 baud. However HF based systems are far more expensive than cable modems and very long distance (>1000km) transmissions with these higher speed systems are not yet very reliable. As a result many companies are still selling 300 baud systems and even these have a high cost. For example, Motorola in Kinshasa supplies its MICOM range for about $15 000 for a hub and $8 000 for a leaf node. Antennae and installation costs are another $1500.

Much of the developments in this area for data networking have come from amateurs and the relief organisations. The International Federation of the Red Cross (IFRC), World Food Programme (WFP), UN Department of Humanitarian Affairs (DHA), VITA, HealthNet, Mission Aviation Fellowship (MAF) and Worldcom (a Dutch NGO) have all developed a variety of HF data networks to support their projects in Africa.

Among the more popular systems in use is the Australian developed Codan 9002 which has been adopted by MAF and WFP to communicate throughout the central African region. The Codan 9002 provides a close-to-standard Hayes-compatible modem command set to connect to remote units, which allows mainstream email software such as Pegasus Mail and cc:Mail to be used at each end of the system. With assistance from USAID, WFP have developed their own gateway software to route traffic into and out of the Internet.

Originally the system connected directly to Rome, but now a regional hub has been established in Kampala, Uganda, which relays traffic from Burundi, Rwanda, Sudan, Tanzania and Zaire in what will shortly be about 40 locations. Because the number of separate channels is limited, a synchronized polling system is being used to guarantee an average mail delivery time of about 1 hour. The system uses the Windows (3.1/NT/95) operating systems and is completely automatic, handling binary files as well as text, and also allows routing of messages and files through multiple Codan links. In addition it is able to conduct route failure recovery and reroute messages through an alternative working link when the primary one fails.

The price of a Codan 9002 is about $7000 but it can be used in a hub arrangement with a radio modem (TNC) connected to a more standard HF radio such as Kenwood TS50 which costs $1200.

MAF have developed a similar system based on cc:Mail which plans to connect 20 points with 2 hubs, 1 in Kinshasa and the other in Lubumbashi. At least 9 sites are already operational and the infrastructure will be opened to NGOs at some stage.

IFRC has been focusing on longer distance communications from its field offices to its head office in Geneva and have found the Codan deficient for these purposes. In an evaluation of the Codan, IFRC's Field Support & Telecom Unit found it to work well on shorter paths where interference is lower, but that on longer distances where the signal is weaker, the Pactor system supplied by Schuemperlin AG provides superior throughput and is able to negotiate down to low speeds when link quality is poor. A new model of the Codan is in development which aims to provide improved performance over long distances and IFRC may change their strategy if it proves successful.

IFRC currently uses a simple text file management system to transfer messages using DOS batch files, but a new gateway is under development using cc:Mail. DHA is also working on a similar system. To provide local wireless connectivity from the PACTOR hub, IFRC is testing a VHF based packet radio (see below) system, also supplied by Schemperlin.

Worldcom, has a adopted a rather different approach and believes the solution it has identified offers some advantages over both the IFRC and WFP/MAF systems. Worldcom says cc:Mail and other such products are not designed for the minimal bandwidth of HF radio communications where overheads must be reduced as much as possible. So purpose built software is required to optimise the use of the frequency. In addition, the Codan solution is based on a single hardware product, using its own proprietary protocol to communicate and Worldcom believes that a system which can operate with most standard HF radios and communicate with more than one protocol is necessary to ensure flexibility and maximise the use of existing radio equipment. As a result Worldcom has decided to use specially designed software that has been optimised for HF communications, rather than using traditional email software 'bolted' on to the radio. Called DTS (Digital Transmission System) it has been developed by EURAF which is based in Cotonou, Benin.

DTS can be used within a wide range of HF frequencies between 3 and 30 MHz and multiple frequencies can be assigned for use during day and night to ensure automatic link establishment. Distances depend on propagation and frequency, but Worldcom has established links from Bukavu in Zaire to DTS' email server in Benin, a distance of more than 4000 kilometers and there is also a UHF version of the product to provide short distance communications.

DTS uses standard POP and SMTP protocols to receive and send mail from the radio link to the Internet. The result of all this functionality is a high price - about $4000 for the software package (recently negotiated down from $8000 by UNHCR). Worldcom believes that if enough organisations adopt DTS it will be possible for it to obtain an OEM license which would reduce the price to about $900 a copy.

5.3) Geostationary Satellites

5.3.1) Satellite Equipment and Services

Satellites orbiting at about 36 000 kilometres above the earth can remain stationary with respect to its surface and have provided the backbone for international telecommunications for decades with large satellite antennas and high frequency focused spot beams. Because there are delays in transmission as the signal travels the 72 000 km round trip which are noticeable in telephone conversations, the use of satellites for voice communications has decreased where international and transcontinental fibre optic links have become available. There are numerous proposals to ring Africa in optic fibre but currently there are no international fibre links outside of South Africa, Djibouti and the North African countries, so virtually every PTT on the continent still operates a large satellite groundstation for all international voice communications. Some African countries, such as Mozambique, which have a limited domestic terrestrial telecommunication infrastructure also use geostationary satellites to provide links for their secondary cities.

Worldwide, the most popular application of domestic and international satellites is video communications, mainly involving programming for television broadcasters, but also for distance learning and teleconferencing. Until recently this traffic was all routed via large terrestrial transceivers located in urban centres, beyond the reach of all except those who could afford large TVRO antennas (where they were allowed), which still left the bulk of the rural population out of reach. But the advent of Direct to Home (DTH) satellite TV broadcasting is now taking place on a wide scale following the launch of satellites capable of transmitting a more powerful signal and the development of ever more sensitive reception equipment. A worldwide DTH satellite audio broadcasting service for a new digital hand-held radio will be launched next year (see below).

For two-way traffic, the cost of equipment capable of transmission to the satellite has in the past put this technology beyond the reach of all but the national PTTs and other large organisations with sufficient volumes of traffic to justify the cost. More recently, hub-based systems using high powered satellites and shared 'mother ground stations' known as hubs have reduced the size and cost of the equipment required at one end of the link, resulting in the growing popularity of these Very Small Aperture Terminal (VSAT) based systems, even for low traffic applications such as connecting an individual branch of a bank in a small town to its head office. These star topology systems contrast with the alternative mesh topology where larger antennae are used at every station, increasing the cost, but allowing direct peer-to-peer communication without the necessity to go through the hub.

A satellite used for telecommunications is equipped with a number of radio transceivers usually known as 'transponders'. The greater the number of transponders the greater the bandwidth available on the satellite which is usually between 36 MHz and 54 MHz. The orientation of different transponders on the satellite determines 'footprint' pattern on the earth in which the satellite can provide a usable service. Some transponder beams can be focused more tightly, which decreases the area of the footprint but results in reducing the power and antenna size requirements on the ground. There are four types of transponder 'beams' responsible for the size of the footprint - the 'global beam' which covers 40% of the earth's surface, the 'hemispheric' beam covering 20%, the 'zone' beam which covers about 10% and the 'spot' beam which covers less than 10%.

Footprints do not have precise borders but exhibit a gradual loss in signal strength from the centre to the periphery of the footprint where larger antennae and higher powered equipment are required. It is not necessary for the hub and remote terminals to be in the same footprint - traffic can be switched through from one transponder aimed at one region, to another aimed at a different region.

Spot and zone beams usually transmit in the KU band (11-14 Ghz) which allow antennae to be as small 90cm in diameter. Receive-only KU band systems can cost less than $500 for analogue models and less than $1500 for digital systems. Send/receive units (which are all digital) cost about $10 000. The wider global and hemispheric beams usually transmit in the C-Band (4-7 Ghz) and require antennae between 1.8m and 10m in size. A 1.8m C-Band send/receive unit usually starts at about $20 000. Hughes Network Systems (HNS) dominates the market for C-band equipment with about 70% of the installed base.

The waveband between 20 and 30GHz is now being proposed for a number of 'broadband' satellite transmission systems. Seven systems proposing global coverage and seven systems proposing regional coverage were submitted to the regulatory bodies last year. These systems will have bandwidth and channel capacities far in excess of any systems currently in orbit. For instance, the capacity the AT&T and Hughes systems are 100,000 simultaneous 384 kbps circuits which can support roughly 2.4 million phone calls. Such capacity will permit interactive multi-channel video, video phone service, broadband computer connectivity and other services.

Ka-Band Broadband Satellite proposals:

Applicant	# of Sats.	Cost	System Capacity
AT&T (VoiceSpan)	12	confidential	100,000 386 kbps channels
Lockheed Martin Astrolink	9	$3.75 billion	90,000 386 kbps channels
GE American (GE*Star)	9	confidential	not provided
Motorola (Millenium)	4	$2.3 billion	1 million 16 kbps channels
Hughes Spaceway/Galaxy	17	$6.2 billion	100,000 384 kbps channels/2.4 million phone calls
Morningstar	4	$847 million	600 compressed video channels
Teledesic	840	$9 billion	2 million phone calls
SS/Loral (Cyberstar)	3	$1.05 billion	6.75 GHz of effective bandwidth
Echostar	2	$340 million	not provided
KaStar	2	$645 million	12 GHz of effective bandwidth

NetSat 28	1	$250 million	500,000 1.544 Mbps channels
Orion F-7, 8, 9	3	$757 million	not provided
PanAmSat 10, 11	2	$409 million	not provided
VisionStar	1	$207.5 million	100 video channels

End users will access these systems over small ground terminals similar to the inexpensive 33 to 100cm dishes currently used to receive DTH signals.

VSATs are subject to interference from hydrometeors, especially in the KU band where water droplets are similar in size to the wavelength, resulting in regular disruptions of service during storms. As a result C-Band is the preferred band for most data communications requiring reliability. However the C-Band is very close to the frequencies used by some terrestrial microwave systems which can cause problems when such equipment is sited in close proximity.

Transponders can be leased in full or in part from the owner of a satellite system, or from a reseller who has leased a large number of transponders at wholesale rates. Because of the long lead times required in planning for capacity, satellite operators usually offer considerable discounts for long term contracts (See the Appendix for an example of Intelsat's tariffs). Also, the power requirements for the satellite to deliver a signal to larger more sensitive earthstations can be much lower so tariffs for circuits can vary by 500% depending on the type of antenna used. (see Appendix).

There are two channels to be leased: the outroute - a channel from a groundstation hub to the satellite - and the inroute - a channel from a satellite terminal to a satellite. The bandwidth of these two channels does not need to be the same, which is a particularly valuable facility for Internet traffic which is usually asymmetric - there is usually substantially more traffic coming in from the rest of the Internet than going out.

In VSAT systems, the hub groundstation is usually responsible for management of the network, monitoring terminals, assigning channels and routing. It would normally have a very large antenna (up to 20m although 10m is more common) and the entire setup usually costs about $1 million to build, but can cost as much as $10 million for high capacity systems with redundancy capacity and intelligent switching.

In the past the protocols used in communication between the hub and the VSATs were proprietary, resulting in the need to purchase equipment for both ends of the link from the same supplier. As a result the VSAT equipment supplier has been known to donate the groundstation hub in the expectation of increased sales of terminals that would be able to connect to it. This has happened in Egypt where both NEC and Hughes are building groundstation hubs for the Government. However many different hubs and VSATs are now being developed which use the International Business Systems (IBS) standard which allows equipment from different suppliers to interoperate.

In most cases it is not necessary to build a hub to establish a VSAT network - existing hubs in foreign countries can be used. Aside from various hubs in North America and most European countries and in South Africa, Gabon and Gambia already have such facilities and shortly Uganda and Egypt will also be able to provide service. However to provide a viable solution for connecting to the Internet the hub must have access to a local high-bandwidth Internet service which currently eliminates most of the African hubs except for those in South Africa and soon in Egypt. Most hubs usually have a maximum uplink capacity of 512K while some such as those manufactured by STM Wireless can allocate channels of up to 8Mbps.

The three main components of a satellite groundstation are the parabolic antenna (or dish), the outdoor unit and the indoor unit. The dish and the outdoor unit perform the transmission and reception of the signal, and the indoor unit provides the interface with the users' equipment and does the digital conversion to a suitable radio signal.

VSAT terminals are versatile units among the most popular being the Hughes Network Systems' Personal Earth Station (PES) which can be configured with most common data interfaces including RS232, X.21, V.35 and G 703 as well as 10-Base-T Ethernet sockets. Additional cards can usually be added to provide more channels when needed and most VSATs can carry multiple voice and data channels at the same time.

VSAT units are typically installed by trained technicians but the skills are not hard to acquire and simply require a compass and GPS unit to orient the antennae and a db voltmeter to fine-tune the system.

The two most common protocols in use between the groundstation and the satellite are Time Division Multiple Access (TDMA) and Single Channel Per Carrier (SCPC). TDMA based networks are very cost effective but not particularly suited to Internet type traffic - it is a statistical multiplexing demand contention based system where the assigned bandwidth of the hub is shared between all of the VSATs resulting in reduced throughput when all of the groundstations are creating traffic. In addition, added to the double satellite hop delay are further delays caused by the connection setup time required and in the overheads in conversing with the network management system (NMS). This results in minimum delays of 2 seconds and often as much as 4 seconds. As a result TDMA is best suited to transaction oriented data transfers such as credit card verification. Nevertheless, USAID is operating a TDMA based network to connect all of its field offices in Africa to the Internet and although very slow for interactive activities such as browsing the web, the entire network only costs about $5 000 a month to operate.

SCPC based networks offer guaranteed bandwidth and are similar to a terrestrial leased line arrangement. Circuits of up to 8Mps can be provided, but 2Mbps is the most common upper limit of standard VSAT equipment. SCPC Demand Assigned Multiple Access (DAMA) is a relatively new service which allows the user to specify the bandwidth required for the connection. However if the application is for an Internet service then there are some further limitations on bandwidth imposed by the "lossless" design of the TCP/IP protocol.

Since a data packet may be lost in transmission, a copy is kept in a buffer on the sending computer until receipt of an acknowledgment from the computer at the other end that the packet has arrived successfully. As the data packet's trip over a geostationary connection takes at least 250 milliseconds, and the acknowledgment packet takes another 250 milliseconds to return, the copy of the data packet cannot be removed from the buffer for at least 500 milliseconds. Since packets cannot be transmitted unless they are stored in the buffer, and the buffer can only hold a limited number of packets, no new packets can be transmitted until old ones are removed when their acknowledgments are received. The default buffer size in the standard implementation of TCP/IP is 32Kb and this means that at any given moment, only 32Kb can be in transit and awaiting acknowledgment. As a result, irrespective of the channel capacity it still takes at least a half a second for any 32Kb to be acknowledged. So, the maximum data throughput rate is 32Kb per half second, or 64Kbps unless modifications to the defaults of the TCP/IP protocol are made.

Another aspect related to the provision of Internet services in Africa is the lack of shared facilities. Ideally there should be an Internet router on the satellite itself, which would allow the lease of a single high capacity uplink which could then be shared amongst all the ISPs on the downlink. This is not currently available, but the same principle can be applied to the groundstation hub. If a high bandwidth Internet link to a hub is made available, then costs for ISPs in Africa can be substantially reduced because each ISP would not have to lease independent circuits from the hub to the nearest ISP. The only service currently providing this facility is the Colorado based NSN Network Services, but it only provides this as a turnkey service involving the provision of all equipment and satellite circuits.

In remote areas the concept of a shared facility could be extended further. Because a VSAT can carry a number of different data or voice channels, it is possible to spread the capital and operating costs over voice telephone, television and radio services, as well as the Internet service. The television and radio services would require some additional re-broadcasting equipment at the VSAT end and the groundstation hub would need to have access to the required television and radio services.

5.3.2) Geostationary Satellite Operators in Africa

Intelsat (International Telecommunications Satellite Organization) is the largest satellite network, created in 1964 by treaty. Currently Intelsat has 139 member countries. It provides international voice, data, and video services as well as domestic services for many smaller countries. It has announced plans for development of a full range of high bandwidth Internet and multimedia services bundled in to the cost of a satellite circuit. SCPC circuits range in size from 64Kbps all the way up to the recently announced 155Mbps service.

As an indication of current prices, a one year contract for a 64Kbps half-circuit costs $370/month for an 11m antenna and $2470/month for a 3.5m antenna. A 2Mbps half-circuit would cost $9975/month for an 11m antenna and $66500 a month for a 3.5m dish. The discounts for large antenna clearly make it far cheaper for the national PTTs in Africa (who already have the equipment pointing to an Intelsat satellite) to provide the service. In many cases however there are still no digital links between the groundstation and the downtown exchange, which results in some additional equipment cost. If another agency can obtain permission to operate the link, then the PTT usually adds a markup on the cost of the bandwidth - in the case of Telkom SA it is about 30%, in Zaire the PTT charges about 5%.

Under Article XIV of the Intelsat agreement, members can establish international public satellite telecommunication services separate from Intelsat as long as they are technically compatible with existing and planned components of the Intelsat space segment and must not cause "significant economic harm" to the Intelsat system. As a result many countries have launched their own domestic and regional satellites such as ArabSat, Eutelsat, IndoSat and CHINASAT. RASCOM, the African satellite consortium owned largely by the African PTTs, has raised most of the finance to launch a geostationary satellite over Africa in 1997.

The first large private sector satellite system to be established was in 1988 when Pan American Satellite (PanAmSat) launched its PAS-1 satellite into geostationary orbit over the Atlantic Ocean. Since then it has launched a number of additional satellites to complete its network which now provides global coverage reaching about 98 percent of the world's population. Although television programming accounts for most of PanAmSat's revenues, it also provides data services and voice services to businesses in areas where the regulatory climate allows it.

PAS-4 was launched over Africa last year, providing C-Band coverage to most of Europe and Africa except for the extreme west of the continent (Gambia, Senegal, Mauritania, Guinea Bissau, Guinea and Sierra Leone are excluded). The satellite also provides a KU-Band spot beam aimed at South Africa but also covering the southern parts of Namibia, Botswana, Zimbabwe and Mozambique). The South African parastatal Transtel's subsidiary, Transtel, is the agent for PanamSat in Africa and also operates a groundstation hub in Johannesburg.

Transtel is currently excluded from bringing public traffic into its groundstation hub in South Africa due to the monopoly of the national PTT, Telkom SA. It can, however, bring the traffic down in Europe or the US, for which it is quoting about $5000/month for a 64Kbps full circuit on a standard 1.8m C-band dish.

Inmarsat (The International Mobile Satellite Organization) is an international co-operative set up in 1979 to provide mobile satellite communications world-wide for the maritime community. It now has 79 member countries and its systems are also used by a growing number of subscribers on land, at sea and in the air which use it primarily for voice services but also for low bandwidth (2400 baud) data and fax services.

Specially designed terminals are required to access Inmarsat's satellite network, known as A, B, M and C terminals, costing between $45 000 for the A series and $4 000 for the C series, which only transmits data in a store-and-forward arrangement for small messages. Use of the satellite costs $3 to $9 a minute - often competitive with the IDD rates in many African countries. This, combined with the poor infrastructure has meant that Africa has been a major market for Inmarsat although other satellite service providers such as Panamsat and ArabSat will also be providing these facilities shortly. Fleet management and vehicle tracking have been the other major uses for these facilities but the technology is now spinning off into other areas such as environmental and weather monitoring.

Russian satellites with African coverage are now also available from Intersputnik with very low prices for large quantities of bandwidth, but many are aging and have developed wobble and inclined orbits, requiring larger antennae and more sophisticated tracking equipment to operate. Nevertheless, they have provided the first VSAT based Internet connections in Africa - to the Ugandan ISPs Starcom and IMUL, via NSN Network Services groundstation hub in Colorado linking to the Express 14 satellite.

Eutelsat also provides some coverage in North Africa, as does Gulfsat, which is the only other major satellite provider with coverage over Africa, in the Horn and as far south as Tanzania.

5.3.3) Non-Geostationary Orbit (NGSO) Satellites

Small satellites which rapidly circle the earth in polar or inclined orbits at lower altitudes than geo-stationary satellites are rapidly gaining popularity in providing wireless access solutions worldwide. In Africa, radio connections to low earth orbiting satellites (LEOs) have been in use for a number of years by organisations such as VITA and Satellife. The low altitude of the orbit - 780 km - of the micro-satellites (which are essentially solar powered PCs with a transceiver) makes it possible to use a small transmitter and lightweight tracking aerial to connect with the satellite when overhead. Also, the propagation delay to these satellites is much smaller than to a geostationary satellite - about 12 msec vs 0.25 sec.

Acting as a store-and-forward host, messages are stored on the satellite for download when the satellite passes over the recipient's location, or where there is a gateway on the groundstation to the Internet. The storage capacity and bandwidth of these systems is not high (9.6K for a maximum of 20-40 minutes a day when the satellite is in view) but the increased cost of the radio equipment can be justified where there is no telephonic link to the outside world.

Because the satellites are relatively low altitude and employ sophisticated modulation and coding techniques, the connections to ground stations are strong and virtually error-free, despite the relatively low effective radiated power.

SatelLife has purchased two LEO satellites, built by Surrey Satellite Technology Ltd. (SSTL) of the UK. The first of the two, HealthSat 1, was launched in 1991 and HealthSat 2 was launched in 1993. The two HealthSats are members of a family of twelve micosatellites designed and constructed by Surrey. SatelLife's current satellite, HealthSat-2, is capable of store and forward full-duplex communication at 9600 bits per second. The satellite was launched in a polar orbit which means that the satellite has passes (crossings of the sky) in any location around the globe. Locations close to equator have four passes a day, and each pass lasts for about 13 minutes. Due to the sun-synchronous orbit, the satellite passes occur around the same time every day--two passes around 10 a.m. and two passes around 10 p.m. local time. At any given time, the satellite is visible to goundstations within a diameter of 6000 kilometers.

The ground equipment needed to contact the satellite consists of a IBM-PC compatible computer, a Terminal Node Controller (TNC), a satellite radio and antennas. HealthNet groundstations use the WiSP (Windows Satellite Program) developed by Chris Jackson at SSTL and it is currently developing a gateway software package that will operate under Linux OS. SatelLife is testing a new radio design that merges the satellite radio and the TNC in one single box that can be portable. This has been successfully tested in the field.

VITASAT is VITA's low-earth-orbiting (LEO) satellite system. VITASAT satellites circle the planet at an altitude of 800 km. They have a 5,000 km footprint that also passes over every spot on Earth at least four times daily.

There are two types of ground stations: fixed (in production) and portable (still being developed). Both use the same software and are capable of communicating automatically with the satellite. However, the fixed station is designed to operate with standard electrical power and uses steerable, permanent antennas and a desktop personal computer. The portable station uses non-steerable antennas and a lap-top computer and can be powered by alternative power sources. While the fixed station has greater capacity, the portable station is less expensive and can be carried anywhere in the world in a suitcase and set up immediately for use. VITASAT has installed 7 such systems in Africa.

In 1992 the ITU's World Radio Conference allocated slots in very high frequency (VHF) bands and ultra high frequency (UHF) bands for LEO "Non-Voice, Non-Geostationary Mobile Satellite Services," As a result VITA entered into a joint venture with a U.S.-based satellite construction and launch company, CTA, to build and launch a commercial-grade satellite in exchange for access to VITA's license over the United States. This satellite was launched on 15 August 1995 but unfortunately failed to reach orbit after a malfunction in the Lockheed-Martin rocket and its subsequent destruction by ground crew.

VITA now has a new arrangement with another U.S.-based company, Final Analysis, an aerospace engineering and telecommunications company, to develop a satellite containing the VITA communications payload, known both as FAISAT-2v and VITASAT-1R, which will start service near the end of the year. After a second satellite is launched into a similar orbit, Final Analysis plans to launch 24 subsequent satellites in four 67 degree inclination orbital planes of 1000 kilometer altitudes each.

Costs are expected to be as low as $1,000 for mass-produced mobile terminals and $50 for 100K of monthly message transfers, with lower costs in bulk transfers exceeding this amount.

Recently, constellations of satellites have been proposed to provide voice and data communications to fixed and mobile users world-wide. These systems are divided into "Little LEO's" and "Big LEO's and MEO's" (medium earth orbit). The USA's Federal Communications Commission (FCC) currently has filings for 280 LEO satellites - 77 from Iridium, 48 from Loral Systems Globalstar and 24 from Italspazio's LEOCOM project. These, along with the MEOs, will offer real time mobile voice communication systems from hand held telephones which will probably be useful for travelers in isolated areas, but the cost of these services is likely to be high - $3 /min and the density will be fairly low - a few million subscribers. The "little LEOs," such as OrbComm, are the satellite equivalent of paging. Operating below 1 GHz, they will provide simple store-and-forward messaging similar to the VITA and HealthNet systems.

Iridium aims at the high purchase capacity travelers market, and has designed a system which will provide links between satellites to forward traffic to the appropriate satellite for downlinking to the customer. Globalstar's target is the complementary market near the big cities. It foresees that 90% of the whole market will be in the vicinity of such big centers. A Brazilian project - ECO-8, aims to place various satellites in the same equatorial orbit, to guarantee that there is always one satellite visible by a user in the equatorial belt covered. The initial configuration foresees eight satellites plus two for backup placed at an altitude of 2000 km of altitude. The coverage encompasses most of the Brazilian territory and parts of Australia, Africa and India, among others. The orbit altitude is sufficiently low to permit the use of portable communications terminals.

Inmarsat's recently formed subsidiary, ICO, is the most advanced MEO project with its plans to launch 12 satellites orbiting at 10 335km above the earth. Being a subsidiary of Inmarsat, ICO's indirect investors include all of the national Signatory investors of Inmarsat and then a number of direct investors, which in Africa include Telkom SA (the South African PTT), ARENTO (the Egyptian PTT), Nigerian Telecommunications Limited, Sonatel (the Senegalese PTT), and the Liberian Bureau of Maritime Affairs. Full service is expected to be operational by the year 2000.

While still under debate, Teledesic's LEO proposal referred to earlier, is the first "broadband LEO" and may offer the most potential for increasing connectivity in Africa. Teledesic argues that in the absence of high levels of economic development, many developing countries such as those in Africa are unlikely to attract the investment required for an advanced information infrastructure, but that systems like Teledesic could help developing countries overcome this "chicken and egg" problem in telecommunications development.

In a presentation to the Internet Society's 1996 conference, Teledesic's Daniel Kohn states: "Once you come out of a geostationary orbit, then by definition, satellites move in relation to Earth. With an NGSO system, continuous coverage of any point requires, in effect, global coverage. In order to provide service to the advanced markets, the same quality and quantity of capacity has to be provided to the developing markets, including those areas to which no one would provide that kind of capacity for its own sake. In this sense, NGSO satellite systems represent an inherently egalitarian technology that promises to radically transform the economics of telecommunications infrastructure. It is a form of cross-subsidy from the advanced markets to the developing world, but one that does not have to be enforced by regulation but rather is inherent in the technology."

Teledesic plans to launch 840 satellites starting in 1998 which will be capable of carrying high bandwidth services directly to the end user. To date, Teledesic has received most of its funding from Bill Gates--the founder of Microsoft and Craig McCaw--who founded McCaw Cellular, the world's largest cellular communications service provider before its sale to AT&T in 1994.

The concept of a network consisting of hundreds of satellites appears a radical concept when compared to traditional geostationary satellites but it is less radical when compared with the evolution of networks on the ground. Computer networks have evolved from centralized systems built around a single mainframe computer to distributed networks of interconnected PCs. Similarly, satellite networks (for switched network connections) are evolving from centralized systems built around a single geostationary satellite to distributed networks of interconnected LEO satellites. The evolution in both cases is being driven by some of the same forces.

Also, because a LEO satellite has a smaller footprint within which frequencies can be re-used, it is inherently more efficient in its use of spectrum resources. Geostationary satellites will continue to have an important role to play, particularly for broadcast applications where their large footprint is advantageous. But increasingly, geostationary satellites are expected to co-exist with NGSO satellite networks.

The real concern is how African nations will license and regulate LEO satellite operations and wireless technologies in general since the traditional monitoring required when security concerns are paramount is largely rendered meaningless. Liberalizing the regulatory apparatus will probably require willingness to consider the advantages addressed by these new technologies. The ITU will convene the First World Telecommunication Policy Forum in Geneva in October 1996, which will set out policy principles for global satellite systems.

5.4) Short Distance Local Loop Technologies

Wireless systems are now being seen as one of the most important ways of increasing telecommunications access over short distances to the end user (the local loop), and there are an increasing array of technologies able to do this.

5.4.1) Cellular Telephony (point-to-multipoint systems)

Wireless systems based on cellular technologies are already the most popular method of addressing the needs of mobile users and even fixed users where the local infrastructure is poor. As a result over half the African countries have a cellular telephone service. South Africa was at one stage the fastest growing cellular market in the world and now has about 700 000 users. While the US was until very recently 'stuck' with its early entry and primarily uses analogue systems such as TACS, Africa has generally adopted the European developed TDMA based digital cellular standard known as GSM.

Cellular services are generally concentrated in the major cities but due to their installation along major transport trunk routes, rural areas along the way are also benefiting from the service.

Both analogue and digital systems can carry data, although the current systems are only rated for about 9.6Kb/sec. Also, the voice coding techniques used in GSM phones preclude the direct use of modems on the system. Data services are not yet widely available in Africa, partly because the network operators also require additional software to manage the data traffic on the network which has been optimised for voice traffic.

Some cell phone manufacturers have provided a data port on their more expensive GSM handsets and an adaptor link in the form of a card is needed, but this costs at least $250 and requires a computer to have a PCMCIA slot. It is in theory possible to obtain higher capacity links than 9.6Kbits/sec by combining channels together, but as yet this new technology has not been widely tested.

Cellular phones also offer a solution to the problems ISPs in Africa often have with obtaining additional land lines for users to access their service. In Tanzania for example the ISP uses cell phones for all of its dial-in connections. This is only feasible where the tariffs for accessing the cellular network from the terrestrial one are low - in Tanzania it costs the same as a normal local call to dial a cellular phone number. When using a cellular phone it appears that the distance from the centre of the cell affects data connections more than voice connections - from the periphery of Dar es Salaam it is possible to make voice calls but data connections are unreliable.

South Africa's GSM network was the first GSM based system in the world to offer a data service starting in June 1994. Since then the Small Messaging Service (SMS) was launched, which allows cellular phones to receive small messages directly onto the LCD of the handset and this has now been linked to the Internet, so that anyone with an email account can send a small message to a cellular subscriber.

TDMA based wireless systems such as cellular phones are still quite expensive to install (about $5 000 per line) but prices are expected to fall substantially as wireless applications penetrate further. The most recent development in this area is the Personal Handyphone System (PHS) developed by a consortium of Japanese companies. Now with over a million subscribers in Japan, the PHS system makes use of more intelligence in the handset so that it can switch between different access methods. In the home or office, the handset uses the conventional copper telephone network via a small base station. When users are mobile it uses the conventional cellular network and when two people using PHS phones are in close proximity (a few hundred metres) then the handsets directly connect with each other in 'walkie-talkie' mode.

A new communication standard based on Code Division Multiple Access (CDMA) techniques provide even more promise for increasing the bandwidth and lowering the cost of mobile and fixed local loop communications. Equipment can be much more densely packed around a single repeater station and bandwidth is even more efficiently used. Although large scale implementations of CDMA have yet to occur, the technology is superior to the current TDMA based cellular systems such as GSM. TDMA systems are still quite expensive and require a minimum subscriber base of at least 15 000, which makes them inappropriate for small towns. In these situations, much cheaper analogue or CDMA systems are likely to be used.

UK based DSC Communications is one of the first to develop a commercial fixed CDMA telephony system. Called the Airspan Digital Data Subscriber Terminal it provides a 128Kbps channel for voice and data communications. The system can be used to provide high-quality lease line data services, such as ISDN, V.35 and X.21 and operates in cell sizes from 30m to 20km. It is currently being tested by the Government of Botswana Computer Bureau.

Granger Telecommunications, also of the UK, provides a very similar system and South Africa's Council for Scientific and Industrial Research (CSIR) has developed the specifications for a range of very cheap point to multipoint rural radio systems using CDMA which have a range of up to 30 km. The entire installation cost per 'line' is expected to be less than $300 for the 10 km version.

5.4.2) Packet Radio

Originally developed by amateur radio enthusiasts, packet radio has steadily grown in sophistication, bandwidth and popularity, and now offers a wide range of data-only service for unobstructed line of site distances plus 10-15%.

Line of site is not always easy to define - high towers can improve the distances reached and small contour changes can cause diffraction, reducing the distance in some areas and increasing it in others. The transmission range is also influenced by the transmitter power and the type and location of the antenna, as well as the actual frequency used and the length of the antenna feed line (the cable connecting the radio to the antenna). Thus, for two-meter packet (144 - 148Mhz), the range could be 15 to 150km, depending on the specific combination of the variables mentioned above. In addition, any packet TNC can be used as a packet relay station, sometimes called a digipeater which allows for greater range by stringing several packet stations together.

Both narrowband and wideband packet radio technologies are available; the former, whether deployed in the amateur radio bands or in commercial bands, usually require that radio licenses be obtained although there are a few exceptions for very low-power systems. Wideband systems can be operated without licenses in many instances, and offer higher data rates, but there is also greater risk of interference problems and distances are shorter, unless special antennas are used, which then results in licensing requirements.

Wideband systems are best for applications involving high mobility and relatively short distances, such as users inside a building who wish to roam the office with notebook computers. They also are used as wireless bridges, for example, to link the LANs in widely separated buildings on a campus. Their use in longer distance situations is less proven.

The major barrier to using packet radio technology in applications is the knowledge and effort required to establish the initial infrastructure. It is substantially more complex than connecting a modem to a telephone line. Experience is needed to properly site antennas, test radio link performance, install networking software etc.

However operating a packet station is usually transparent to the end user, to whom the network should simply appear as a slow LAN connection. A terminal Node Controller (TNC) automatically divides the message into packets, keys the transmitter, and then sends the packets. While receiving packets, the TNC decodes, checks for errors, and displays the received messages.

A particular advantage of packet over other modes is the ability for many users to be able to use the same frequency channel simultaneously.

5.4.2.1) Narrowband Packet Radio

While most amateurs currently use 1200 bps for local VHF and UHF packet, and 300 bps for longer distance with HF communication, higher speeds are now being developed for use in the VHF, UHF, and especially microwave region. For 1200/2400 bps UHF/VHF packet, commonly available narrow band FM voice radios can be used.

Many packet stations use the AX.25 (Amateur X.25) protocol which was developed in the 1970's and based on the wired network protocol X.25. Because of the difference in the transport medium (radios vs wires) and because of different addressing schemes, X.25 was modified to suit amateur radio's needs. AX.25 includes a digipeater field to allow other stations to automatically repeat packets to extend the range of transmitters.

AX.25 is considered the de facto standard protocol for amateur radio use and is even recognized by many countries as a legal operation mode. Other formats including TCP/IP are also used in some cases. Often special packet radio protocols are encapsulated within AX.25 packet frames. This is done to insure compliance with regulations requiring packet radio transmissions to be in the form of AX.25. However, details of AX.25 encapsulation rules vary from country to country.

The KA9Q NOS program (also called NET) is the most commonly used version of TCP/IP in packet radio. NOS was originally written for the PC compatible. However, NOS has been ported to many different computers such as the Amiga, Macintosh, Unix, and others.

A TNC unit costs only about $300, and an entire station, including the computer, costs between $4,000 and $10,000 plus installation and training. VITA has installed solar-powered VITAPac stations in Sudan for the United Nations Development Programme.

The Centre for Policy Research on Science and Technology and the Telematics Lab, Simon Fraser University, the Canadian Communications Research Centre with the Ottawa amateur radio group have been engaged in a number of projects focusing on packet radio. They have both developed prototypes which incorporate a new modem operating at 56 Kbps with a capability to upgrade to a point-to-point system running at 1.5 Mbps and upwardly compatible systems as higher speed capabilities are reached. The equipment uses the TCP/IP protocols and can provide a link between stations over 100 Km apart and support point-to-point as well as point-multi-point paths, and can be used while mobile.

Designed for low cost and flexibility, the costs per station (including Linux server for routing) is about $1400. A newer version is expected to lower costs even more and the 1.5Mbps versions will be in the same price range. Aside from design considerations, all of the main electronics are off-the-shelf components which could be assembled virtually anywhere.

Nevertheless, there are a number of barriers to extend the use of HF/VHF narrowband packet radio beyond the amateur field. The frequencies are notoriously subject to interference and propagation variations, making them less practical for unsophisticated users.

There are regulatory difficulties as well - to operate at 56Kbps and above, a broad section of radio spectrum is required (85Khz is common) and it can be very difficult to convince the regulator that such a broad slot is required, especially when the VHF & UHF bands have been broken into 12.5KHz wide channels. Also, the commercial VHF & UHF bands are highly populated with paging, cellular phones and other applications. Amateurs don't have this problem because large segments of the VHF & UHF bands are reserved for their use.

5.4.2.2) Wideband/Spread Spectrum Packet Radio and Wireless LANs

Because of the practical limits to data transfer rates with narrowband modulation imposed by distortion of the radio signal, wideband "spread spectrum" systems have become much more popular in the commercial environment, largely for "wireless LAN" applications. These systems overcome distortion by virtue of their wide bandwidth, which provides "frequency diversity".

Spread spectrum technology was originally developed for use by U.S. military to overcome problems of intentional interference from hostile jamming and to reduce the ability for unauthorised monitoring. The US de-classified spread spectrum technology in the mid-1980s. The term "spread spectrum" arose from the characteristic broad spectral shape of the transmitted signal. The spreading techniques normally used can be divided into two families: Frequency Hopping Spread Spectrum (FHSS) and Direct Sequence Spread Spectrum (DSSS).

One of the reasons for the popularity of many of the WLAN products is that in most countries they can be used without the need for a radio license as long as they do not cross public property, in which case the PTT will also need to be approached. In order to qualify for license exemption, however, they must meet various requirements with regard to power output, antenna gain which results in greater potential for interference from other users of the same radio spectrum than is the case with the licensed narrowband systems, since the license carries with it some degree of exclusivity in the frequency allocation.

The present situation in most of Europe and Africa is that 2.4-2.4835GHz band use needs no license with ETSI (European Telecommunications Standards Institute) certified equipment. According to the ETSI standard, the effective radiated power from the antenna must not exceed 100mW which effectively limits the distance to a few hundred metres. The 902-928MHz band generally is not permitted, because 890-915MHz band in Europe and Africa has been allocated for GSM mobile telephony.

However in some cases it is possible to obtain a secondary license for use of the desired frequency with a stipulation that it will not interfere with the primary license holder's transmissions. An example of this situation is in Latvia, where LATNET has a secondary license for 902-928MHz band, while primary license for 890-915MHz band belongs to the GSM operator. Practice shows that low power spread spectrum wireless LAN adapters at 902-928MHz band do not interfere with GSM.

Nevertheless, spread spectrum systems have a number of negatives attached to them that should be borne in mind before using them. In the first place governments, especially in Africa, are not keen on these technologies because of the designed-in impossibility of monitoring the contents of the transmissions. They are also not particularly efficient in use of the available spectrum, contributing to the general level of radio frequency 'noise' in the area that may cause interference to other devices. High densities of the same devices in any one area may reduce their performance significantly.

As with the narrowband packet radio systems described above, a wireless LAN (WLAN) unit consists of a PC interface, modem, radio hardware and antenna. However, these functions tend to be more tightly integrated and in some cases, such as the Xircom product, the entire unit, including antenna, is on a PCMCIA card. It provides very short range and is intended for use within buildings, but there are other WLAN products which can be used with directional antennas to span distances of a few kilometres or more if good line-of-sight paths exist.

There are a wide range of data rates available, with the high end units providing rates of 2 Mbps or more. Prices also span a large range, from about $400 for the Xircom unit to $5000 for a system intended for long-range wireless bridge applications. However, there are a variety of interesting products in the $700-$800 range which offer 1-2 Mbps data rates. Most of these are ISA bus or PCMCIA plug-in cards, and come with software drivers that make them appear like ethernet cards to the network software.

Probably the most popular WLAN product worldwide and also in Africa is the AT&T WaveLAN series of equipment. It provides ISA, MCA, and PCMCIA adapters for the PC and also Access Points for interconnecting wired and wireless LANs, wireless LAN bridges. Models are available for 902-928MHz and 2.4-2.4835GHz bands. The speed is 2Mb/s and distances up to 6km (with direct line of sight and appropriate antennas) can be reached reliably. Security in WaveLAN network is provided by network-id selection (16 thousand combinations) and optional DES chip. The list price for ISA adapter is around 600USD, Access Point around 1800USD, Wireless LAN bridge around 2500USD.

South Africa's CSIR Mikomtek department has developed a complete networking system based on the WaveLAN product known as the Community Information Delivery System (CiDS). It integrates a wireless Internet service access point using FreeBSD and a variety of freely available software utilities to create a complete Web/Email/Nameserver on a Pentium PC. The 6 port CiDS base station combines routing, security, firewalling and Information Services. The base station operates as intelligent wireless router using the RIP protocol to route between wireless 'cells' and management is done via the industry standard SNMP protocol. With an external amplifier the system has been tested to a range of 100km.

Another very popular product is Aironet Communications' ARLAN series of wireless LAN equipment. They are available for the ISA bus in PCs and PCMCIA adapters, Access points for interconnecting wired and wireless LANs, and multipoint wireless LAN bridges. Modifications for license free operation in other countries are available. ARLAN is capable of speeds of up to 1Mb/s and distances up to 10km and an important feature is that it incorporates a link level protocol for error correction, wireless inter-repeater routing, and roaming functionality. This protocol ensures that ARLAN network is as reliable as ordinary wired network and does not introduce any packet loss even at maximum distances. The Access Point models can be managed remotely via telnet protocol. The list price for the ISA adapter is about $900, the Access Point is $1900, and the Wireless LAN bridge about $2600.

A similar product currently being marketed to Internet Service Providers, is provided by Tetherless Access Limited (TAL) who the provide 2.4GHz SubSpace Wireless Router System for $3,695. It is only capable of 160Kbps which is relatively slow, but has a range of up to 30km.

Cylink Corporation is one of the pioneers in the ISM band spread spectrum device manufacturing and still is considered to be the best in this area. SITA, the airline communications group use Cylink equipment in the Congo and elsewhere to provide connectivity where the copper infrastructure is non-existent or too unreliable. Cylink manufactures the Airlink series of wireless modems for 902-928MHz (L-band) and 2.450-2.485GHz (S-band). Distances up to 45km can be reached and the modems typically have synchronous V.35 interface and operate at speeds up to 512kb/s. The list price for different models is in the range $3000-5000.

A Russian product called the RadioHub-1, developed in a joint venture between Elvis+ and Sun Microsystems is also available. With a range of up to 2km and a throughput of 1Mbps it is priced at about $2700.

Wi-LAN of Canada has developed a range of high speed wireless bridges and modems aimed at Internet Service Providers. The Hopper Plus ethernet bridge approaches 1.5Mbps speeds at up to 3km in urban areas and 10km with line of sight antennas and rural conditions. A new version is being developed which is expected to reach speeds of 20Mbps. The Hopper wireless modems transmit up 38.8 Kbits/sec with similar lengths of transmission. The Hopper Plus can be used in a repeater situation where line of sight between antennas is not possible but the capacity is reduced to approximately 750Kbits/sec for repeated links.

With so many alternatives on offer, choosing the most appropriate product is not an easy matter for an end user. Aside from bandwidth and cost criteria, it is also very important to evaluate how well routing is implemented, the quality of security (encryption), ease of management, and the availability of firewalling and other server support on the same unit.

Some WLAN products use infrared wavebands instead of the ISM bands. For speed, infrared is superior to most other wavebands used as it delivers throughput at or near Ethernet or token ring wire speed. But infrared requires a clear line of sight between devices that are no more than 10 to 20 metres apart.

In WLAN systems, antennas are key components which can vary greatly for different needs. The manufacturers of radio cards generally include a small omni-directional antennas which can easily be mounted on walls. To cover large distances, it is necessary to install external high-gain omni and directional antennas. When using directional antennas, reflections off buildings and roofs can assist with a short connection where no line of sight installation is possible. Antenna location depends not only on line of sight but also possible interference. Generally tall buildings are an attractive site for many types of wireless systems and it is possible to burn out the amp/pre-amp system if antennae are mounted too close together. Usually moving antennas at least five meters apart corrects such problems and allows all parties to use the same antenna tower.

To calculate the possible line of sight for longer distances (more than 10km) it is necessary to take into account also curvature of the earth. If h1 and h2 are heights of the antennas (in meters), the maximum distance (in kilometres) for line of sight between the antennas in unobstructed terrain can be calculated according to the formula: 3.55*(sqrt(h1)+sqrt(h2)). For example, an elevation of two antennas, one at 5m and the other at 40m gives a line of sight distance of 30.30km - 3.55 *(SQRT (5m) + SQRT(40m)). This does not take into account the need for a minimum vertical distance between the top of the antennae and the nearest obstruction, known as the Fresnel zone. At 2 km the Fresnel zone must be at least 13m, at 10 km it must be at least 28m.

5.4.3) Microwave Data Systems

While the microwave systems described in section 5.1 overcome the limitations of packet radio and spread spectrum, they are generally too expensive for end users, being designed for general purpose multi-channel voice and data telecommunications.

As yet no one has built a small scale microwave system aimed primarily at the end-user of a data connection. However the idea exists on paper and appears feasible. IO Systems, a South African company, has designed such a microwave transceiver with an expected end user price of about $1000 which can plug directly into an IP router, giving speeds in the region of 1 - 10 Mb/s using Microwave Associates' cheap "gunnplexer" technology. But due to the regulatory concerns of potential users, it has not been taken to completion.

5.5) Fibreless Optical Systems

Free space optical systems, usually based on infra-red lasers, have a range of 1 km and a bandwidth up to 155Mb/sec. These are cheaper than short haul microwave systems and can be suited to local situations where very high bandwidth links are required and cost is not critical (this uncommon technology is not cheap). These systems have the added advantage of not using radio spectrum, so no frequency management is required. One of the few installations of a laser system in sub-Saharan Africa is between two units of the Government Computer Bureau in Maseru, Lesotho.

Laser Communications is the major supplier of these high speed wireless LAN and telecommunications solutions. But since 1983, LCI has only supplied about 1000 systems sold worldwide

Optical point to multipoint local loop telephone systems are under development by CSIR. Aimed at high density settlements such as informal housing, a high tower with a laser is erected in the middle of the settlement and the subscriber can be installed by the user. The estimated cost is just $20 per subscriber station.

5.6) Digital Radio Trunking Systems

Digital Trunking Systems are not really suitable for Internet applications. They are currently limited to 228byte messages, most suitable for truck fleet monitoring. Although their capacity will be expanded to 8k blocks they do not provide a continuous flow of data.

5.7) Data Broadcasting

In many Internet applications large quantities of data are received by the user but little data is sent. In addition, many different users receive exactly the same data through newsgroups, mailing lists and file mirrors. This opens up the possibility for using traditional broadcasting infrastructures for broadcasting of data, commonly called datacasting. Existing radio and television broadcasts can carry substantial amounts of data encoded in their transmissions and in the excess capacity on many broadcast satellite transponders. Users require additional equipment to receive these broadcasts and they use the normal connection via telephone to send their data.

Services providing datacasting of the Internet are already available in the US, Europe and Asia (such as PageSat and DirecPC), but not yet in Africa due to the low level of potential demand which does not warrant the dedication of an entire satellite circuit. But the advent of DTH television broadcasting over the entire African continent by South African based Orbicom raises this potential very significantly. This is because the cumulative bandwidth of the television channels being broadcast (about 3Mbps each) do not fit exactly into the available bandwidth on the satellite transponders that have been leased from PanamSat. This leaves an average of about 1.5Mbps of unused capacity on each of the four transponders currently in use.

The Internet datacasting protocols that have already been developed for the existing systems in other parts of the world are readily available, making it a trivial matter to transfer them to Orbicom's setup and to produce a simple programme for users to transfer the data from the $1000 digital TVROs to their PCs. The 100 000 receivers currently in the field already have serial ports capable of 38Kbps, which, with compression could yield the same throughput as a 64Kbps link. The newer decoders, such as the Nokia, also come with a SCSI port for higher speed transfers.

The only major barrier to the almost immediate establishment of this service is that the digital satellite broadcasting software company employed by Orbicom to develop its DTH service (Irdeto) is not planning to release the new version of its software capable of addressing the serial port because of a perceived lack of demand for datacasting services. However it is believed that if Orbicom can be made aware of the potential demand, it will in turn put pressure on Irdeto to release the software.

While a UseNet newsfeed is the simplest Internet data-set to broadcast, in the US even the subscribers private email can be received through the broadcast by using encryption techniques and more sophisticated software on the user side. In the future it will be desirable to be able use an Internet broadcast protocol such as the Mbone, but this would require more substantial development work.

While establishing a dedicated datacasting channel will provide the most bandwidth, the possibility also exists to encode data inside existing satellite and terrestrial television and radio broadcasts. The most well known application of this technique is to use the vertical blanking interval (VBI) in existing television broadcasts to carry the data. Teletext services are an unsophisticated application of this technology which has since advanced substantially. Philips and Olivetti have both developed systems which are capable of 30-60Kbps transmissions over the VBI which can be security encoded for the individual user.

To establish a VBI datacast, the information provider installs the data broadcast software on the server which schedules when which files should be broadcast and translates the content into a format suitable for insertion in the TV signal. A teletext-inserter combines the content with the TV signal and the new signal is broadcast as normal. The user requires a decoder to separate the information packets from the TV signal. The Philips data broadcast decoder is a set-top box or a PC add-on board.

Intel has also released a similar system it calls Intercast. Based on the growing popularity of TV tuner cards for the PC, the software allows television programmers to include web pages in the VBI with their broadcasts, which are then browsable with the user's standard web browser.

In radio broadcasts, the same principles apply except that the side-band on the carrier signal is used instead of the

VBI. In the future, when Digital Audio Broadcasting (DAB) becomes widespread (such as through WorldSpace's plans to launch a satellite next year to broadcast 18 digital radio channels to Africa), further opportunities for datacasting will become available.

5.8) New 'Information Highway' Wireless Local Loop Proposals

To meet perceived demands for future universal broadband multimedia access, two different wireless communications systems using microwave frequencies in the 5-60GHz range have been proposed and there are number of other emerging high bandwidth wireless technologies under development.

In the US, Apple Computer has championed its High Performance Radio Local Area Network (HIPERLAN) under the banner of Apple's general proposals to the US' FCC for the allocation of a license-free 'National Information Infrastructure' (NII) waveband in the 5GHz range aimed at improving access for community users. Optimised for packet protocols such as TCP/IP, HIPERLAN provides short distance, high speed radio links between computers systems using the 5.2 GHz and the17.1 GHz frequency bands.

HIPERLAN is designed to provide asynchronous data services at rates of 1 to 20 Mbit/s and time bounded services at rates of 64kbit/s up to 2048 kbit/s. Terminals will be designed to communicate while in motion at speeds of up to 36 km/h and the typical range will be 50 m at 20 Mbit/s and 800 m at 1 Mbit/s.

The FCC has not yet made its decision on the allocation of the 5GHz band but it has declared the 59GHz-64GHz band available for unlicensed use. These frequencies happen to be the same as those proposed by Europe's EU funded RACE project to develop a Mobile Broadband System (MBS) operating at 60GHz. MBS focusses more strongly on extending mobile access to broadband services than HIPERLAN, but it also provides for higher bandwidths. It aims to offer capacities of up to 155 Mbit/s to users and will based on the Asynchronous Transfer Mode (ATM).

Two US companies, WinStar Communications and Advanced Radio Telecommunicatons are using the 38GHz band to provide multi-megabit transmisson services using small (30-60cm) dish antennae. Inficom is planning a 25Mbps service and Canon has a 10Mbps service in development.

Wireless Contact List

Appendix 1

Internet Resources on Wireless Technologies

There is an associated HTML file for the data below which can be loaded into your web browser for easy access.

1. ACTS Home Page http://kronos.lerc.nasa.gov/acts/acts.html. The Advanced Communications Technology Satellite (ACTS) Development of high-risk, advanced communications satellite technology.
2. Advanced Research Projects Agency (ARPA) http://www.arpa.mil
3. Advanced Satellite Consulting http://dspace.dial.pipex.com/adsc. The home page of Alex da Silva Curiel, independent consultant on mobile satellite communication, and until recently Director of Operations at Inmarsat, the International Mobile Satellite Organisation in London.
4. Aegis http://www.demon.co.uk/aegis. Aegis Systems Ltd offers expertise in radio frequency spectrum engineering, including interference analysis, propagation modelling, etc.
5. Aerospace Consulting http://www.aeroconsult.com
6. Air Communications http://www.aircomm.com
7. AIRplex Cordless Modems http://www.kme.com
8. AirTouch Cellular's Data Hut http://datahut.airtouch.net
9. Alice WorldView http://www.alice.com
10. Allied Access, Inc http://www.intrnet.net
11. AMT Home Page http://haagar.jpl.nasa.gov/sec339/3392/amt.html. The ACTS Mobile Terminal (AMT) is a proof of concept breadboard designed to incorporate the system and subsystem solutions devised to overcome the challenges of Ka-band land mobile.
12. Andrew Satellite Communication Systems http://www.andrew.com/esag0001.htm. A leader in ground segment equipment manufacturing.
13. Apple/ HIPERLAN http://www.apple.com/documents/fcc.html
14. ARDIS http://www.ardis.com
15. AstroComPage http://infoweb.magi.com/~bcblevis/astrocom.html
16. Atec, Inc http://www.sccsi.com/Atec/rflink.html
17. Atlantic Communications Enterprises http://www.newcomm.net/webpage/ace. ATLANTIC COMMUNICATIONS Ltd. offers unlimited flexibility in the design of a comprehensive turnkey communications projects.
18. Aurastar Satellite Communications Analysis Software http://www.aurastar.com/satcom.html. Software Tools & Services for Telecommunications Regulators, Voice and Data Carriers, Broadcasters and Satellite System Operators.
19. Aviator http://www.mmicro.com/momentum
20. Belcom http://www.belcom.net:80
21. BellSouth Cellular Corp http://www.com/bscc
22. BellSouth Mobile Data http://www.data-mobile.com
23. Breeze Wireless Communications http://www.breezecom.com
24. British National Space Centre http://www.open.gov.uk/bnsc/bnschome.htm. Involved in some mobile satellite communications research.
25. Cable and Wireless http://cwix.com/cwplc. Company that owns mobile satellite service providers.
26. Cal Company Profile http://www.calcorp.com/aboutcal.htm. Manufacturer of mobile satellite communications terminals .
27. Canadian Centre for Marine Communications (CCMC) http://www.ifmt.nf.ca/~ccmc
28. Canadian Communications Research Centre (CRC) http://www.crc.doc.ca/crc/rsatcom.html. Satcoms page.
Canadian Space News http://www.conveyor.com/space/news.html
29. Canadian Wireless Home Page: Wireless Digest http://www.wirelessinc.ca/digest.html
30. Cancom http://www.cancom.net.Canadian Satellite Service Provider.
31. Cellular Telecommunications Industry Association (CTIA) http://www.cityscape.co.uk/cgi-

bin/dat2html?file=8616. The membership of the association has been expanded to cover all Commercial Mobile Radio Service providers, including cellular, personal communications services, enhanced specialized mobile radio, and mobile satellite services.
32. Cincinnati Microwave http://www.cnmw.com
33. CIT Research http://www.citresearch.com/about.htm. CIT is a market research company specializing in the international communications industry. Our work principally covers Europe and the Asia-Pacific region.
34. Comms Research Lab for the Ministry of Posts and Telecommunications, Japanhttp://largo.crl.go.jp/welcome_eng.html. Broadband mobile communications section.
35. Communications Standards http://www.csrstds.com
36. Comsat http://www.comsat.com. Providers of mobile satcom services and systems.
37. ComSym http://www.wp.com/comsym_uk/home.html. ComSym Limited is a UK registered Consultancy, offering a wide range of satellite communications services to the world's communications and space industries.
38. CTA Space Systems http://lois.space.cta.com/index.html. GEMStar (non-profit email satellite) via GEMnet, CTA's little LEO system.
39. CWI Online http://techweb.cmp.com/techweb/cwi/current. Communications Week International
40. Cylink AirLink http://www.cylink.com/radio.html
41. Cylink Corporation http://www.teleport.com/~nts/cylink/cytop.html
42. Data TeleMark http://www.mnsinc.com/datatelemark/dtm.html
43. Deutsche Telecom http://www.dtag.de/dtag. Mobile satellite service provider.
44. Digital http://www.digital.com/info/mobile
45. DLI Datalink International http://www.axionet.com/dli
46. Electromagnetic Sciences Inc. (ELMG) http://www.elmg.com. Electromagnetic Sciences Inc. now includes three subsidiaries that work in wireless data and mobile satcoms systems.
47. ELIRIS Inc http://www.soonet.ca/eliris/eliris.htm. Involved in the fields of GPS, GIS, and vehicle tracking. Currently using UHF/VHF packet radio modems - soon to be satellite based.
48. Ericsson http://www.ericsson.nl. Mobile satellite communications equipment manufacturers.
49. ERWIN http://cabernet.esprit.ec.org/esp-syn/text/5650.html. The objective of the ERWIN exploratory action was to investigate the domain of fixed-to-mobile communications with particular emphasis on ground-to-train communications.
50. ESA http://www.esrin.esa.it
51. etiGATE http://starbase.NeoSoft.com/~eti. Provides consulting and systems integration for distance-insensitive and seamless connections between remote sites and home offices.
52. European Telecommunications Satellite Organisation http://www.eutelsat.org
53. European Telecommunications Standards Institute http://www.etsi.fr/etsi/tc-stc/tor-95/ses.htm. SATELLITE EARTH STATIONS AND SYSTEMS technical committee.
54. Ex Machina, Inc. http://exmachina.com
55. Federal Communications Commission http://www.fcc.gov
56. Ficus http://ficus-www.cs.ucla.edu/ficus-members/geoff/seer.html
57. Freespace Interbuilding Links http://www.silcomtech.com
58. FreeWave Technologies http://www.teleport.com/~nts/freewave/freetop.html
59. French Space Agency (CNES) http://www.cnes.fr
60. Frost & Sullivan Home Page http://www.frost.com. We help our clients become more market-focused by providing the critical market measurements and information they need to be proactive in the marketplace.
61. Glenayre Electronics http://www.synernet.com/glenayre
62. GLENTEL/AIRTEL http://www.wp.com/mcintosh_page_o_stuff/msat.html. MSAT service providers for Canada.
63. Globalstar http://www.wp.com/mcintosh_page_o_stuff/globals.html.Globalstar is a low-earth-orbiting (LEO) satellite-based digital telecommunications system that will offer wireless.
64. GlobeSat Inc. Home Page http://www.globesat.com. Manufacturer of Inmarsat satellite terminals.
65. Gonets http://www.wp.com/mcintosh_page_o_stuff/gonets.html
66. Granite http://home.navisoft.com/granite/index.htm
67. GRE America http://www.greamerica.com/~gre
68. GTE Mobilenet http://www.wireless-gte.com
69. GTE Wireless Data Services http://www.datalife.gtem.com

70. Harris http://www.semi.harris.com/feature_product
71. Harris Allied Broadcast Equipment http://www.broadcast.harris.com
72. HHCA, Inc http://bertha.chattanooga.net/HHCA
73. HIPERLAN http://www.atg.apple.com/areas/wireless/default.html
74. Hiperlan/Netplan http://www.netplan.dk/netplan
75. Hughes Electronics Corporation http://www.hughes.com. General link to a number of Hughes sites .
76. Hughes Network Systems http://www.hns.com
77. Hummingbird http://www.xetron.com/900xcvr.htm
78. IBM Mobile http://www.raleigh.ibm.com/wir/wirehdqt.html
79. ICO Global Communications http://www.i-co.co.uk
80. IEEE Communications Magazine http://www.ieee.org/comsoc/commag.html
81. IETF http://www.ietf.cnri.reston.va.us/home.html
82. Industry Canada - Emergency Telecommunications http://hoshi.cic.sfu.ca/ic
83. Inet, Inc http://www.inetinc.com
84. InfoManager Service http://www.infoexpress.com
85. INFOSAT Telecommunications http://www.nav.ca. Canada's wireless communications experts. Infosat provides remote voice, fax, data, and video services using SkyCom, MSAT, DirecPC, VSAT, INMARSAT, and digital radio.
86. InfoWave http://www.gdt.com/Product.Info/infowave.html
87. INMARSAT http://www.worldserver.pipex.com/inmarsat
88. INMARSAT http://www.inmarsat.org/inmarsat
89. Inmarsat http://www.worldserver.pipex.com/inmarsat
90. Intelsat http://www.intelsat.int:8080
91. International Rescue Corps (IRC) http://www.demon.co.uk/irc/irc1.html. A unique organisation, and is one of the few non-government funded disaster rescue services in the world registered with the United Nations. Users of mobile satellite communications.
92. International Satellite Integration Services, Inc http://www.intr.net/isis. Telecommunication Consultants specializing in satellite solutions to organizational communications problems worldwide, including mobile applications.
93. iPost Services http://www.ipost.net
94. ITC Home Page http://www.telematrix.com. ITC - International Telecommunications Center - is the only Internet site devoted exclusively to telecommunications, data communications and networking. Has some mobile satellite communications info.
95. ITR Home Page http://www.itr.unisa.edu.au/home1.html. ITR's mission is to be Australia's premier organisation for world class research and postgraduate studies of the applications of coding, signal processing and systems engineering.
96. ITU Home Page http://www.itu.ch. The ITU, headquartered in Geneva, Switzerland is an international organization within which governments and the private sector coordinate global Telecom networks and services.
97. KDD Labs http://w3.lab.kdd.co.jp. KDD owns various mobile satellite stations and systems.
98. KPMG Space & Emerging Technologies Practice http://www.lcp2.com:80/kpmg. This group has almost 10 years of direct experience working with the commercial space industry and all major companies involved in that arena.Ç
99. Kyler Laird http://pasture.ecn.purdue.edu/~laird/Kyler/info.html
100. Laser Communications http://www.lasercomm.com/lasercomm
101. LATNET http://www.latnet.lv/LATNET
102. Leslie Taylor Associates, Inc http://www.lta.com. A telecommunications legal and consulting firm which specializes in satellite communications, spectrum management, U.S. and international regulation and ITU matters.
103. LinCom Corporation http://www.lincom.com
104. Linux http://sunsite.unc.edu/mdw/linux.html
105. Linux Mobile-IP http://anchor.cs.binghamton.edu/~mobileip
106. Los Angeles http://www.iepsnet.com/lacelldirect
107. Lyman Bros http://www.lymanbros.com . Lyman Brothers is an international satellite telecommunications contracting and consulting firm headquartered in Salt Lake City, Utah. Lyman Brothers specializes in emergency response, disaster recovery and transportable satellite systems for data, voice and video transmission.
108. Lynn-Arthur Associates, Inc http://www.laa.com

109. Magic Number http://www.magicnumber.com
110. Magic WAND (Wireless ATM Network Demonstrator) http://www.tik.ee.ethz.ch/~wand
111. McCaw Cellular http://www.cellular.com
112. Memorial University of Newfoundland http://alta.ucs.mun.ca
113. Metricom http://www.metricom.com
114. Metricom http://ResComp.Stanford.EDU/~cheshire/Metricom.html
115. Metricom Canada http://www.metricom.bc.ca/index.html
116. MIVS http://www.igd.fhg.de/www/zgdv-mmivs/index.html
117. Mobidata http://rags.rutgers.edu/journal/cover.html
118. MOBILE ANTENNA SYSTEMS HANDBOOK http://www.opampbooks.com/ELE_CELL/14.html
119. Mobile Communication Research http://www.tde.lth.se/pcnh/ancor1.html. Research being done at the department of applied electronics. - Lund University, Lund Institute of Technology.
120. Mobile Communications http://www.ibmpcug.co.uk/~scrfin/screen/others/mobile/mobbie.htm. Mobile Communications is produced twice monthly by the X25 Partnership and published by Financial Times Business Information - the same team that puts together Screen Finance.
121. Mobile Communications http://www.sf.co.kr/t.telecom/mobile.html
122. Mobile Communications Newsletter http://www.ibmpcug.co.uk/~scrfin/screen/others/mobile/mobbie.htm
123. Mobile Computing Lab http://www.mcl.cs.columbia.edu
124. Mobile Datacom Corporation http://www.rdss.com. Mobile Datacom Corporation provides satellite-based data communication services and systems to mobile platforms, remote, fixed site assets and people on the move.
125. Mobile Office on the Web http://www.mobileoffice.com
126. Mobile Planet Online Catalog http://www.mplanet.com
127. Mobile Telesystems, Inc http://mti-usa.com. A provider of Satellite Telephones designed to operate under the INMARSAT Satellite system.
128. MobileSat Home Page http://www.mobilesat.com. This link is to the home page for Mobile Satellite Products Corp. They are a division of California Microwave. Manufacturers of the Lynxx portable Inmarsat B satellite terminal.
129. MosquitoNet http://plastique.stanford.edu/mosquito.html
130. Motorola http://www.mot.com
131. MSAT http://www.wp.com/mcintosh_page_o_stuff/msat.html
132. Multipoint http://www.multipoint.com/website
133. NASA http://www.nasa.gov
134. NASA New Products Development Group http://newproducts.jpl.nasa.gov/npd/projdesc.html#msat_x. Provided RF analysis and equipment recommendations for 1.5 GHz SATCOM installation in helicopters.
135. National Oceanic and Atmospheric Administration (NOAA, USA) http://www.noaa.gov
136. National Telecommunications and Information Agency http://www.ntia.doc.gov
137. Navisoft http://home.navisoft.com/nspi/bzk.htm
138. New Space Network http://www.newspace.com. The New Space Network is an information clearinghouse for anyone interested in small and low cost space programs.
139. NewEast Group of Companies http://www.neweast.ca/profiles.html. In conjunction with IDB Mobile Communications, NewEast Wireless Telecom operates an Inmarsat-C Virtual Earth Station.
140. NOCOM's http://www.nocom.se/noweb/produkt/wrq
141. Nomadic Research Labs http://microship.ucsd.edu
142. Nomadic'96 http://www.tticom.com/nomadic
143. Novacom Home Page http://www.clark.net/pub/novacom/homepage.htm. Expert and experienced satellite communications systems consulting on business development, implementation, spectrum and regulatory issues, technological advances and engineering analyses/designs.
144. Omnes http://www.omnes.net. A joint venture between Schlumberger and Cable & Wireless, was created to provide global communications solutions to the energy business sector - including some mobile comms.
145. On The Move http://www.sics.se/~onthemove
146. OPTUS Communications http://cwix.com/cwplc/fedoz.htm. Mobile satcoms service

provider in Australia.
147. ORA Electronics http://www.orausa.com
148. ORBCOMM http://www.orbcomm.net
149. Pacific Communication http://www.pcsi.com
150. Packet Radio http://www.tapr.org/tapr/html/pkthome.html
151. PaySatTelecom http://www.PaySatTelecom.com. Satellite Payphone project for Local and World Wide Communication.
152. Pepper & Corazzini L.L.P http://www.commlaw.com/p-and-c. The law firm specializes in communications, telecommunications, Internet and on-line services law.
153. Phil Karn's, KA9Q http://www.qualcomm.com/people/pkarn
154. Philips homepage http://www.philips.com
155. Pinpoint Communications Inc http://www.avl.com
156. Portable Products http://www.portableproducts.com
157. Principles of Spread Spectrum Communication http://olt.et.tudelft.nl/~glas/ssc/techn/techniques.html
158. Proxim http://www.proxim.com
159. Qualcomm http://lorien.qualcomm.com/QualHome.html
160. QUEST TELECOM INTERNATIONAL http://www.hypernet.com/quest.html. Quest Telecom International, an Inmarsat Partnership Company, provides consultation on mobile satcom equipment and services by assisting prospective users and operators planning to purchase Inmarsat A, B, C, and M satellite telephone systems in making their satcom purchase decision and assisting in arranging for service contracts with service providers and Inmarsat satcom commissioning through appropriate Routing Organizations (ROs).
161. RadioMail Corporation http://www.radiomail.net
162. Radiometrix http://www.radiometrix.co.uk
163. Radiosat http://www.radiosat.com/radiostar. Test drive the car radio of the future with this on-line simulation. Shows how mobile satellite telecommunications can revolutionize consumer car radios.
164. RAM Mobile Data http://www.ram.co.uk
165. RAM Mobile Data http://www.ram-wireless.com
166. Remote Satellite Systems International http://www.remotesatellite.com. Specializing in Remote Connectivity, systems integration, sales, and engineering support.
167. Ricochet http://www.metricom.com/info/ricochet.html
168. Riza Akturan, Research Page http://ccwf.cc.utexas.edu/~akturan/research.html#ONGRESEARCH. Photogrammetric Mobile Satellite Service Prediction.
169. RoamAbout Wireless-to-Wired Access Point http://www.digital.com/info/infosheet/EC-F2666-42.txt.html
170. SatCorp Communications Inc http://www.satcorp.com. Through satellite and radio links, SatCorp equipment connects groups of mobile, or isolated rural, or fixed location users to the information superhighway.
171. SATELLITE COMMUNICATIONS RESEARCH CENTRE (SCRC)http://audrey.levels.unisa.edu.au/dcg/scrc/scrc.html. The charter of the SCRC is to provide highly specialized support in the field of communications technology to Australian industry - some mobile related research described here. (NOTE - This server is a bit slow - but worth the wait).
172. Satellite Communications Systems and Technology Group.http://144.126.176.213/AnnRprt93_94/SCST.htm. The National Aeronautics and Space Administration (NASA) and the National Science Foundation (NSF) commissioned a panel of U.S. experts to study the international status of satellite communications systems and technology.
173. Satellite Journal International - SJI http://www.nmia.com/~roberts/sji/sj.html
174. Satellite Systems and Technologies http://rosa.vpcs.doc.ca
175. Scientific-Atlanta Home Page http://www.sciatl.com
176. Seanet http://vislab-www.nps.navy.mil/~seanet
177. Sierra Wireless http://www.sierrawireless.com
178. Signal Processors Ltd http://www.cityscape.co.uk/cgi-bin/dat2html?file=10716. Manufacturers of satellite modems and other related equipment.
179. SINTEF DELAB Research - Satellite Systems http://ofelia.er.sintef.no/www/welcome/research-satellite-systems.html. SINTEF DELAB has

long experience in the field of satellite communications and broadcasting. The R&D activity in this area is application oriented aiming to develop new technologies for both high performance and consumer products. Research projects and topics covered include mobile satellite communications.
ÇÇ
m. Skysite is a telephone service provider on the MSAT 1 Satellite. The company will be focused on government and industry customers primarily in the United States.
181. Small Satellites Home Page http://www.ee.surrey.ac.uk/EE/CSER/UOSAT/SSHP/sshp_intro.html. A number of the new systems are using 'small satellites'.
182. Socket Communications, Inc http://www.socketcom.com
183. Sosoft http://ourworld.compuserve.com/homepages/SOSOFT. Specialist designers of satellite voice and data multiplexers for permanent, mobile or transportable systems, order wire and talkback codecs.
184. Spectrum - Shuken http://www.iwe.com/spectrum. A global network of satcom system and equipment engineers and marketing professionals.
185. Spectrum Guide http://home.navisoft.com/nspi
186. SpectrumWare http://www.tns.lcs.mit.edu/SpectrumWare/home.html
187. Speedycom International http://www.iinet.com.au/~speedy
188. Spread Spectrum Communications http://yamuna.eas.asu.edu/areas/spread.html
189. Spread Spectrum Research http://ee.oulu.fi/~tipe/ann.rep/res.list.html
190. Steinbrecher Corporation http://steinbrecher.com
191. http://www.wp.com/mcintosh_page_o_stuff/iir1.html
192. TAPR http://www.tapr.org
193. TD Communications http://canam.dgsys.com/cg/tdcom.html. Wireless and satellite engineering firm which installs & operates fixed and mobile systems in Northern Canada and worldwide.
194. TDK Systems http://www.tdksystems.com
195. TECHLOCK DISTRIBUTING http://www.erinet.com/kenny. Microwave and RF component supplier.
196. TekNow, Inc http://www.teknow.com
197. TELE-Satellite Journal http://xan.esrin.esa.it:2602/TELE-Satellite.html. Some mobile satcoms news on occasion.
198. Telecom International http://www.telkom.co.za/international.html Mobile satellite service provider.
199. Telecommunication Laboratoryhttp://ee.oulu.fi/EE/Telecommunication.Laboratory/Telecommunication.Laboratory.html
200. Telecommunications Research Center (TRC) Communications Group http://emelc1.eas.asu.edu
201. Teleconsult Limited http://www.teleconsult.com/index.html
202. Teleglobe Canada http://www.Teleglobe.CA:80/en. Providers of mobile satcom services.
203. Telenor http://www.telenor.no. Norwegian Mobile Satellite Service Provider.
204. Telstra Corporation: {Tele}Communications Information Sourceshttp://www.telstra.com.au/info/communications.html. A very good list of communications resources, including some mobile satellite stuff.
205. Telular Corporation http://www.telular.com
206. Tetherless Access Ltd. (TAL) http://www.tetherless.net/home.html
207. The Ellipso Mobile Communications Satellite System http://www.universe.digex.net/~prism/ellipsat.html
208. The MCS Group, Inc http://www.themcsgroup.com
209. The Mobile Office Outfitter http://www.themoo.com
210. The Telecommunications Glossary http://www.wiltel.com/glossary/glossary.html
211. The WAMIS Program http://esto.sysplan.com/ESTO/WAMIS. The goal of the WAMIS program is to achieve revolutionary improvements in mobile communications technology.
212. The Wireless Dealers http://wirelessdealers.com
213. The World-Wide Web Virtual Library: Communications & Telecommunicationshttp://www.analysys.co.uk/commslib.htm
214. Transferable European Space Technology

http://esapub.esrin.esa.it/pointtotest/test0.html. The European Space Agency is offering a range of technologies that have been developed by European and Canadian firms while taking part in the European space programmes. Some mobile satcoms technologies.
215. Traveling Software http://www.travsoft.com
216. Tucson Amateur Packet Radio http://www.tapr.org/tapr
217. UK trials of a fishing vessel tracking system http://www.smithsys.co.uk/smithsys/techp/maff/maff.html
218. UMASS Wireless http://www.ecs.umass.edu/ece/wireless
219. Uo-Sat http://www.ee.surrey.ac.uk:80/EE/CSER/csertext.html
220. Utilicom LongRanger 2000 http://www.utilicom.com/std_products/LongRanger_2000.html
221. VE7PSA Home Page http://echo.rfnet.sfu.ca
222. VEGA Group PLC http://www.vega.co.uk/public/index.html. Consulting services related to space and satellite comms.
223. Veritas Electronics Ltd. UK http://dspace.dial.pipex.com/town/plaza/jm73. UK Suppliers of the WORLDWIDE PHONE Inmarsat-M Satellite Telephone (manufactured by Thrane and Thrane in Denmark).
224. VITA: Volunteers In Technical Assistance http://www.vita.org/whovita.html
225. Vodafone Web http://www.vodafone.co.uk
226. Voice Notepad http://www.cnj.digex.net/~rhogan
227. W.L. PRITCHARD & COMPANY, INC http://www.wlpco.com. Provides technical, economic, and market analysis for new and established telecommunications ventures.
228. WaveLAN http://www.ncr.com:80/pub/products/wavelan
229. WaveLAN International PC Network Interface Card http://www.digital.com/info/Customer-Update/930712026.txt.html
230.
Wavelets/Subbands: Fundamentals and Applicationshttp://www.ecse.rpi.edu/Homepages/abbate/ShortCourses.html. Course available.
231. Westinghouse Wireless Solutions http://www.wireless.westinghouse.com
232. Wi-Lan Inc http://ntg-inter.com/wilan
233. WINLAB http://winwww.rutgers.edu
234. Wireless http://litwww.epfl.ch/~wireless/.html
235. Wireless and Satellite ISDN http://www.NeoSoft.com/~eti
236. Wireless Andrew http://www.ini.cmu.edu/wireless/Wireless.html
237. Wireless Communications http://www.wirelessinc.ca
238. Wireless Computing Lab http://www.pitt.edu/~ppd/wclpp
239. Wireless Information Network Laboratory http://winwww.rutgers.edu/pub/Index.html
240. Wireless LAN Group http://www.ecs.umass.edu/ece/wireless
241. Wireless LAN Modem Product Directory http://hydra.carleton.ca/info/wlan.html
242. Wireless Modems http://pasture.ecn.purdue.edu/~laird/Electronics/wireless-modems/FreeWave.html
243. Wireless Modems http://pasture.ecn.purdue.edu/~laird/Electronics/wireless-modems
244. Wireless RF & Satellite ISDN http://www.neosoft.com/~eti
245. WirelessNOW http://www.commnow.com
246. Worldcomm Systems http://www.worldcomm.com/text/solution.htm. Company Products.
247. WorldSpace http://www.worldspace.com Digital satellite radio for the world.
248. Wynd Communications http://www.callamer.com/wynd.html
249. Xetron Corporation http://www.xetron.com
250. Xircom Road Warrior Central http://www.xircom.com
251. Xtend Micro Products-Notebook http://www.xmpi.com
252. Xybernaut Corporation http://www.xybernaut.com

compiled by Mike Jensen
August 1996
mikej@wn.apc.org

John Tully
Aizkraukles 23-514, Riga LV1006, LATVIA
Tel: +371 9204836
Fax: +371 7 820467,
E-mail: tully@mii.lu.lv

Advanced Systems Consultants, Inc.
Consultant, custom software for Motorola/UDS radio modem
1516 Marsetta Dr.
Dayton, OH 45432
Tel: (513) 429-1428
Fax: (513) 429-8575

Aerotron-Repco Sales, Inc.
RS-232 wireless modems
2400 Sand Lake Road
Orlando, FL 32809-7666
Tel: 800-950-5633/ 407-856-1953
Fax: 407-856-1960

Aerotron-Repco Sales, Inc.
spread spectrum 1 watt unlicensed, wireless modem
2400 Sand Lake Road
Orlando, FL 32809
Tel: (800) 950-5633

AfricaLink
Jeff Cochrane
Tel: 1-703-235-5415
Fax: 1-703-235-3805
Email: jeffc@info.usaid.gov
URL: http://www.info.usaid.gov/alnk

Apple Computer, Inc.
Securing Radio Spectrum for Wireless Internet Access
Email: Steve Cisler <sac@apple.com>

AstroCom Associates Inc.
Aerospace and Telecommunications
1997 Neepawa Avenue
Ottawa, Ontario K2A 3L4
CANADA
Tel: (613) 722-4412
Fax: (613) 722-8324
Email: bcblevis@magi.com

Bass, Inc.
portable wireless batteries
2211 Arbor Boulevard
Dayton, OH 45439
Tel: (513) 293-5732
Fax: (513) 293-9756

Center for Satellite Engineering Research
R.A.da Silva Curiel
University of Surrey, Guildford, Surrey GU2 5XH
United Kingdom
Email: A.da-Silva-Curiel@ee.surrey.ac.uk

Centre for Policy Research on Science and Technology School
Simon Fraser University
Peter S. Anderson, Communication Director
Harbour Centre Campus 515 West
Hastings Street, V6B 5K3
Vancouver, B.C. Canada
Tel: +1-604-291-4921/3687
Fax: +1-604-291-4024
Email: anderson@sfu.ca
URL:http://hoshi.cic.sfu.ca/epix/
Gopher: hoshi.cic.sfu.ca 5555
Telnet hoshi.cic.sfu.ca
User ID: epix

Communications R&D Corp.
full duplex, 200 foot range, wireless modem
Indianapolis, IN
Tel: (317) 290-9107

Data Radio Corp.
wireless modem
6160 Peachtree Dunwoody Road
Suite C-200
Atlanta, GA 30328
Tel: 404-392-0002
Fax: 404-392-9199

Communications Research Centre
Ottawa, Canada
Mobile and Personal Communications -
Jack Rigley (613)991-9309
Satellite Systems and Technologies -
Dr. Edward J. Hayes (613)998-2467
Satcom Applications and Projects -
John Butterworth (613)998-2559
Applications Programs -
Allan MacLatchy (613)990-0008

Community Information Delivery System (CiDS)
Nic Swart
MikomTek
CSIR
Pretoria
South Africa
Email: nic.swart@csir.co.za

Compu-Mech, Inc.
wireless modem
2375 Dorr Street
Toledo, OH 43607
Tel: 419-535-6702
Fax: 419-535-0805

COMtrix Systems Inc.
DOS device drivers for Data Radio Corp. and Motorola RNet radio modems

4760 Walnut St.
Bldg 102
Boulder, CO 80301
Tel: (303) 440-7868
Fax: (303) 938-9439

Cylink
spread spectrum, unlicensed, wireless modem
310 N. Mary Avenue
Sunnyvale, CA 94086
Tel: 408-735-5800
Fax: 408-735-6643

Data Comm Test Lab
Kevin Tolly, Director Tolly Group (Manasquan, N.J.).
Email: ktolly@tolly.com.

Data Communications
David Newman, Testing Editor
Email: dnewman@data.com.

Data Control
UUNET Internet Africa, Zimbabwe
Rob Nursten
Tel: 758194
Fax: 758197
Email: rob@harare.iafrica.com

Data Radio, Inc.
5500 Royalmount Avenue, Suite 200
Mount Royal, Quebec, Canada H4P 1H7
Tel: 514-737-0020
Fax: 514-737-7883

DSC Communications
CDMA-Based Fixed Access Radio System
TERRY ADAMS
Tel: +1-214-519-4358

E. F. Johnson Canada, Inc.
633 Granite Court
Pickering, Ontario L1W 3K1
Tel: 800-263-4634

E. F. Johnson Corporate Headquarters
11095 Viking Drive
Minneapolis, MN 55344-7292
Tel: 800-328-3911 ext. 380

Electronic Systems Technology (EST)
licensed, wireless modem
415 N. Qua
YKennewick, WA 99336
Tel: 509-735-9092
Fax: 509-783-5475

ELVIS+
103460, RUSSIA, Moscow
Centralny prospect 11
Tel: +7 (095) 531-46-33 / 536-95-51
Fax: +7 (095) 531-24-03
Email(Internet):sasha@elvis.msk.su
URL: http://www.elvis.ru
ELVIS+ is represented in the USA by RCR,Inc.
Tel: 415 974 0381

EURAF / DTS
B.P.06-2535 Cotonou
Benin
Tel.:+229-313779
Fax:+229-313879
E-mail:dts@bow.intnet.bj
URL: http://dts.intnet.bj

Frank-Uwe Andersen
RADIO-LINK V1.0, low cost wireless modem, RS232, 1200 bps, 20m
Baroper Bergstr. 16
44227 Dortmund
Tel: 0049 231 773756/ 0049 5201 9314
Fax: 0049 5201 9300 fax
Email: uch024@ux2.hrz.uni-dortmund.de

G. Campbell & Associates Inc.
Telecoms Consultants
1273 Dieppe Road
P.O. Box 101
Sorrento
British Columbia
Canada
V0E 2W0
Tel: +1 604 675 4836
Fax +1 604 675 4837
Email: 104067.1504@compuserve.com

GRE America, Inc.
spread spectrum, wireless modem
425 Harbor Blvd.
Belmont, CA 94002
Tel: (415) 591-1400
Fax: (415) 591-2001

GRE Japan, Inc.
6-2-15 Roppongi, Minato-Ku
Toyko, JAPAN 106
Tel: 03-3404-3636
Fax: 03-3405-5387

Institute of Mathematics and Computer Science, UL
Guntis Barzdins (main contact person)
Rainis blvd.29, Riga LV1459, LATVIA
Tel: +371 9206943
Fax: +371 7 820153,
E-mail: guntis@mii.lu.lv

Joe Seward
Consultant, custom software for Motorola/UDS radio modem

Huntsville, AL
Tel: (205) 882-3924

JOLT Ltd.
125Mbps wireless or fiberlaser link
P.O. Box 53354
Jeruselem, Israel 91533

K and M Electronics, Inc.
Diffuse IR, RS-232, 19.2kbps or voice, wireless modem
11 Interstate Drive
West Springfield, MA 01089
Tel: 413-781-1350
Fax: 413-737-0608

Laser Communications, Inc.
laser wireless inter-building communications, short range laser wireless video, T1, ethernet,etc links
1848 Charter Lane Suite. F
Lancaster, PA 17605-0066
Tel: 717-394-8634
Fax: 717-396-9831

Linux Mobile-IP
Email: mobileip@anchor.cs.binghamton.edu

Megadata Corp.
wireless modem
35 Orville Drive
Bohemia, NY 11716-2598
Tel: 516-589-6800
Fax: 516-589-6858

Metric Systems Corp.
Consultant, custom software for Data Radio Corp. and Motorola RNet radio modems
2052 Sequoia St.
San Marcos, CA 92069
Tel: (619) 727-0780, Bill Brown
Fax: (619) 727-1674

Monicor Electronics Corp.
licensed, wireless modem
2964 N.W. 60 Street
Fort Lauderdale, FL 33309
Tel: (305) 979-1907
Fax: (305) 979-2611

MosquitoNet
Email: cheshire@CS.Stanford.EDU

Motorola
wireless modem
Wireless Data Group
50 East Commerce Drive
Suite M-4
Schaumburg, IL 60173
Tel: 708-576-8213
Fax: 708-576-8940

New Era Microsystems Ltd
24 Cargate Ave
Aldershot, Hamshire
GU11 3EW UK
Tel: 44-252-345426
Fax: 44-252-317699

Northern California International Teleport, Inc.
2311 Lincoln Avenue
Hayward, CA 94545
Tel: 510.782.9301
Fax: 510.782.9401

NZ Telecoms (Pty) Ltd
Peter Lochner
Telecoms House
Edison Crescent
Hennops Park Extension 15, South Pretoria
South Africa
Email: plochner@icon.co.za
PO Box 12611
Clubview 0014
Tel: 27 (12) 660 2833
Fax: 27 (12) 660 2839
E-Mail: nz_telecoms@infodoor.co.za

O'Neill Connectivities, Inc.
wireless LAN, wireless modem
607 Horsham Road
Horsham, PA 19044
Tel: 215-957-5408
Fax: 215-957-6633

Pacific Crest Instruments
licensed, wireless modem
1190 Miraloma Wa
YSuite W
Sunnyvale CA 94086-4607
Tel: (800) 795-1001 USA & Canada
Fax: (408) 730-5640
Fax: (408) 730-5789 outside USA

Philips Data Broadcast Systems
Philips New Business & Special Projects
Professor Holstlaan 4
5656 AA Eindhoven
The Netherlands
ir. D. Santilli
Tel: +31 -40 -2742817
Fax: +31 -40 -2744522
E-mail: santilli@natlab.research.philips.com

Proxim, Inc.
RangeLAN, wireless LAN
295 North Bernardo Ave.
Mountain View, CA 94043
Tel: 415-960-1630
Fax: 415-964-5181

Worldcom Foundation

Rene Roemersma
Paulus Potterstraat 20 1071 DA
Amsterdam
rene@worldcom.nl

Seaboard Electronics (East Coast)
wireless modem
70 Church Street
New Rochelle, NY 10805-3204
Tel: (914) 235-8073
Fax: (914) 235-8369

Seaboard Electronics (West Coast)
wireless modem
6986 El Camino Real, #B-205
Calsbad, CA 92009-4110
Tel: (619) 438-1205
Fax: (619) 438-8660

SunTek Systems Group, USA
licensed, wireless modem
101 Grays Lane
Lansdale, PA 19446
Tel: 215-832-5037
Fax: 215-368-1933

Swintek Communications
RS-232, portable w/batteries
Tel: 408-727-4889
Fax: 408-727-3025

Teledesign Systems, Inc.
450MHz-470MHz 2watt, licensed, wireless modem
1710 Zanker Road
San Jose, CA 95112-4215
Tel: 408-436-1024
Fax: 408-436-0321

Telepoint, Inc. Canada
Fax: 514-648-0578 east
Fax: 403-250-8643 west

Telepoint, Inc. U.S.A Headquarters
1022 S. La Cienega Blvd.
Los Angeles, CA 90035
Tel: 310-652-3666
Fax: 310-652-0777

Traveling Software, Inc.
Laplink Wireless, 30 foot range, package includes Laplink software and radios
Bothell, WA
Tel: (206) 483-8088

UDS Motorola
wireless modem
5000 Bradford Drive
Huntsville, AL 35805-1993
Tel: (205) 430-8000
Fax: (205) 830-5657

Volunteers in Technical Assistance
Gary L. Garriott, Director, Informatics
1600 Wilson Boulevard, Suite 500
Arlington, VA 22209
Email: garyg@vita.org

Wi-LAN Inc.
Tel: (403) 273-9133
Fax: (403) 273-5100
Email: zaghloul@Wi-LAN.com

World Food Programme (WFP)
Gianluca Bruni, Information Systems Officer
Transport Coordination Unit WFP
Kampala
Uganda
Tel. (256 41) 241565
Email: bruni@wfp.or.ug

Appendix 2

INTELSAT Satellite Equipment Standards

Earth Station Standard	Antenna Size in Meters	G/T (dB/K)	Type of Service	Frequency Band (GHz)
A	15-18	35.0	All Services	6/4
B	10-13	31.7	All Services	6/4
C	11-14	37.0	All Services	14/11
D1	4.5-6	22.7	Vista	6/4
D2	11	31.7	Vista	6/4
E1	3.5-4.5	25.0	IBS	14/11 & 14/12
E2	5.5-7	29.0	IBS and IDR	14/11 & 14/12
E3	8-10	34.0	IBS and IDR	14/11 & 14/12
F1*	4.5-5	22.7	IBS and IDR	6/4
F2	7-8	27.0	IBS and IDR	6/4
F3	9-10	29.0	International voice and data, including IBS and IDR	6/4
G	All sizes	Not Defined	International and Domestic Lease Services	6/4 & 14/11 & 14/12

Intelsat Tarrifs

TABLE 1. IDR CARRIER TARIFFS C-BAND HEMI/ZONE & KU-BAND SPOT - RATE 3/4 FEC (US$/month) (one end of a two-way service)

EARTH STATION TYPE SERVICE CATEGORIES

		A	B	F3	F2	F1	C	E3	E2	E1
64 kb/s	1-Yr	370	465	615	820	1,425	370	505	1,100	2,470
	5-Yr	320	400	525	705	1,235	320	435	945	2,120
	10-Yr	275	345	455	615	1,045	275	375	820	1,835
	15-Yr	240	300	395	525	910	240	325	705	1,585
512 kb/s	1-Yr	2,850	3,610	4,750	6,270	10,925	2,850	3,895	8,475	19,000
	5-Yr	2,375	2,945	3,895	5,225	9,120	2,375	3,230	7,065	15,835
	10-Yr	2,090	2,565	3,420	4,655	7,980	2,090	2,850	6,215	13,935
	15-Yr	1,805	2,280	2,945	3,990	6,935	1,805	2,470	5,370	12,035
1.024 Mb/s	1-Yr	5,225	6,555	8,645	11,590	20,045	5,225	7,125	15,540	34,835
	5-Yr	4,275	5,415	7,030	9,405	16,340	4,275	5,795	12,715	28,500
	10-Yr	3,800	4,750	6,270	8,360	14,535	3,800	5,130	11,305	25,335
	15-Yr	3,325	4,180	5,510	7,315	12,730	3,325	4,560	9,890	22,165
1.544 Mb/s	1-Yr	7,980	10,070	13,205	17,670	30,590	7,980	10,830	23,735	53,200
	5-Yr	6,270	7,885	10,355	13,870	24,035	6,270	8,550	18,650	41,800
	10-Yr	5,510	6,935	9,120	12,160	21,090	5,510	7,505	16,390	36,735
	15-Yr	4,750	5,985	7,885	10,545	18,240	4,750	6,460	14,130	31,665
2.048 Mb/s	1-Yr	9,975	12,635	16,435	22,040	38,190	9,975	13,585	29,670	66,500
	5-Yr	7,790	9,880	12,825	17,290	29,830	7,790	10,640	23,170	51,935
	10-Yr	6,840	8,645	11,305	15,105	26,220	6,840	9,310	20,345	45,600
	15-Yr	5,985	7,600	9,880	13,205	22,895	5,985	8,170	17,800	39,900
6.312 Mb/s	1-Yr	28,880	36,235	47,750	63,875	111,090	28,880	39,335	85,900	192,535
	5-Yr	22,500	28,525	37,120	49,700	86,550	22,500	30,565	66,930	150,010
	10-Yr	19,580	24,805	32,335	43,230	75,300	19,580	26,665	58,230	130,520
	15-Yr	17,010	21,525	28,085	37,560	65,380	17,010	23,120	50,590	113,395
8.448 Mb/s	1-Yr	38,760	48,925	63,935	85,690	149,055	38,760	52,725	115,285	258,400
	5-Yr	30,210	38,285	49,875	66,785	116,185	30,210	41,135	89,855	201,400
	10-Yr	26,220	33,250	43,225	57,950	100,890	26,220	35,625	77,990	174,800
	15-Yr	22,800	28,880	37,620	50,350	87,685	22,800	30,970	67,815	152,000

Appendix 3

FIGURE 1. Wireless Internet Hub

FIGURE 2. Aironet ArLAN Internal and External Adapters

FIGURE 3. High Gain Antenna

FIGURE 4. Weather Impacts on Radio Transmissions