

INNOVATIVE WAYS TO DELIVER INTERNET IN LEAST DEVELOPED NATIONS.

Gideon Hayford Chonia
University of Zurich
Switzerland

ABSTRACT

This paper describes the experiences accumulated by the Chonia Informatica in Ghana where wireless solutions for connecting to the Internet, is been used routinely since September 1997.

The transmission technology used in Ghana by Chonia Informatica is based on spread spectrum wireless LAN adapters adjusted for Internet interconnection - the original antennas are replaced with high gain antennas installed on tall buildings around the city and PC based IP routing software is used to provide efficient point-to-multipoint connections and error correction.

Besides describing Chonia Informatica's experiences, this paper also contains a brief introduction to the underlying wireless technology project report used in the project Ghana SchoolNET for providing a direct Internet access to various Universities, Schools, NGO's, departments and other establishments scattered around the city of Accra with a diameter of approximately 25km.

A packet-based 2Mb/s Wireless Metropolitan Area Network solutions for Internet Access to link point-to-multipoint access servers.

The paper should be of interest to networkers of developing countries where communications infrastructure is weak and wireless communications are not over-regulated. Wireless IP networking might be a cost effective solution also in industrial areas of the world.

INTRODUCTION

Sending data over the wireless links has been a dream for many networkers over the years, especially in the countries where appropriate communications infrastructure is not available. Until recent time wireless data links really were only a dream for most of us, because available radio transmission technology was:

- Very expensive (high speed microwave links cost well above 10,000 USD),
- Individual frequency licence required for operation,

- Required lot of knowledge to assemble a working link (modulators, transceivers, antennas, etc.)

Only a few years ago a completely new wireless data link technology arrived which has made building private wireless data links as simple as plugging a radio adapter card into PC and connecting this card to an antenna. The new technology operates at LAN speeds (up to 2Mb/s) at distances up to 45km (with direct line of sight), and costs around 800 USD for the necessary PC card and high gain antenna. And what is most attractive about the new technology - in many countries (USA, most European countries) it is that it does

not require a licence for operation at low power and short distances (5 -10 km). What is this miracle technology? It is called simply "spread spectrum radio".

Since its introduction to the market in early 1990's, the popularity of spread spectrum wireless data transmission has growing dynamically. Today wireless LANs are used in many university campuses to interconnect distant buildings, in banks, hospitals, warehouses, shops etc. In these places it has become as common as cordless telephones.

In this paper we will describe in detail the usage of wireless technology for providing Internet access. The description is based on the experience gained in GhanaNet while setting up a big wireless Internet access network in Accra, the capital city of Ghana. The network started in September 1997 when Legon University, Academic Computing Center, and ISP's scattered all around the city were connected by wireless links to the Internet.

Since then the network has evolved significantly: now it provides Internet connectivity at aggregate speed of 2Mb/s to other buildings in Accra and its suburbs. A backbone network antennas are installed on a high buildings in the central part of city, each antenna capable to serve more than 20 connections in the radius of 15km.

The distinct property of the Accra network is that radio links are set up in the point-to-multipoint mode which significantly reduces the cost of individual connections. The remarkable feature of the network is that it has been built using only standard wireless LAN equipment operating at 2.4GHz frequency. This means that the solutions used in Accra can easily be repeated anywhere else.

Spread Spectrum Radio

Spread spectrum technology was developed for use by U.S. military to

overcome the problem of intentional interference by hostile jamming and eavesdropping (espionage). 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)

Direct Sequence Spread Spectrum (DSSS).

The first approach resists interference by jumping rapidly from frequency to frequency in a pseudorandom way.

The receiving system has the same pseudorandom algorithm as the sender, and jumps simultaneously.

The second approach (most famous) resists interference by mixing the data signal with a Pseudo Random Noise Code (PN-code). A PN-code is a noise-like sequence of chips valued 0 and 1. The number of chips within one code is called the period of code. In the most simple case a complete PN-code is multiplied with a single data bit and thus the resulting signal bandwidth becomes much larger. Receiving system applies to coded signal the same PN-code and retrieves the data signal.

The total signal power doesn't change during spreading, the Power Spectral Density decreases.

The result is a signal that is essentially "buried" in the noise floor of the radio band, is extremely hard to detect, does not interfere with other services (like conventional AM and FM radios), and still passes a great bandwidth of data (due to much higher than usual bandwidth occupancy). However the Gaussian Noise level is increasing.

The receiver examines the bandwidth of the spread signal, and correlates the data (despreads it). The process of correlation is

symmetric to spreading and causes any other signals received to be spread as the wanted signal is de-spread. This causes unwanted signals to be reduced to noise - allowing the same frequency to be reused many times within a given area.

The possibility to multiplex users in the same frequency band by assigning them different spreading keys is called Code Division Multiple Access (CDMA).

The U.S. military de-classified spread spectrum technology in the mid-1980s. The FCC in 1985 approved (47 Sec.15.257) three so called Industry, Medical & Science (ISM) bands for licence free use:

**902-928MHz,
2.400-2.4835GHz,
5.725-5.850GHz.**

These bands are used by microwave ovens, garage door openers, and also spread spectrum radios.

FCC allows maximum 1 Watt of radio power, with up to 6 dB antenna for spread spectrum devices operating at ISM bands. Higher gain antennas may be used, with a corresponding reduction in transmit power. With appropriate outdoor antennas, and line of sight conditions, 40 mile paths are possible, with some types of spread spectrum radios. As these devices do use radio signal the devices themselves must be approved by the US Federal Communications Commission.

The present situation in most of Europe is that 2.4-2.4835GHz use needs no license with ETSI (European Telecommunications Standards Institute) certified equipment. According to ETSI standard ETS 300 328, the effective radiated power from the antenna must not exceed 100mW which is significantly lower than allowed by FCC in U.S. The 902-928MHz band generally is not permitted, because 890-915MHz band

in Europe has been allocated for GSM mobile telephony.

In the developing world the situation will go country by country. Our experience has been that one way is to obtain a secondary license for use of the spectrum you desire to use (2.4GHz will be the easiest), with a stipulation that you will not interfere with the primary license holders transmissions. Those who would like to learn more about spread spectrum radio, can check Spread spectrum home page on

<http://www.tapr.org/ss/other.html>

ARLAN Network Setup

Setting up IP router network using ARLAN wireless LAN is very simple: ARLAN completely hides the radio "visibility/invisibility" and packet loss problems from the user, therefore regardless of the actual topology of radio links, the whole wireless network to the user appears as one long Ethernet cable. This property is achieved by employing already in the ARLAN hardware the link level cell routing between repeaters, and cell acknowledging and retransmission. **Antennas, cables, connectors, amplifiers** The distance a connection can be established at is a factor of the antenna gain, signal loss in cable and connectors, line of sight, transmitter output power, amplification of the signal going to the antenna, and re-amplification of the signal going to the radio receiver.

Basic concepts:

attenuation - power loss during transmission over a medium (cable, air, connectors),

gain - signal collecting (and radiating) ability of the antenna, omni directional antenna has the same gain in all directions in horizontal plane, directional antenna has increased gain in the direction at which it is pointed, dB or decibel is simply an expression of ratio.

The formulae for power is $10\log(P_2/P_1)$ and for voltage $20\log(V_2/V_1)$.

The dB for a voltage is twice that of a power ratio because power varies with the square of the voltage. Thus ohms law is preserved.

dBm - the signal is referenced to one milliwatt.

Therefore 0dBm is 1 milliwatt and 20dBm is 100 milliwatts.

dB - the signal collecting ability in decibels of the specific antenna relative to a theoretical antenna with equal gain to all points on isotropic sphere.

dBd - the signal collecting ability in decibels of the specific antenna relative to the actual signal collecting ability of a dipole antenna.

Antennas are key components which can vary greatly for different needs. The manufacturers of radio cards generally include a small omni-directional antenna which can easily be mounted on walls. To cover large distances, it is necessary to install external high-gain omni and directional antennas.

Directional Antennas are used at the client sites or on very long point to point links.

Antenna Cables

It has happened many times that when installing a system people will find no connection or a bad connection. The simple culprit in many cases is bad or poorly constructed (or planned) antenna cabling.

Although for short distances you may use ordinary Ethernet cable with BNC connectors, for quality installations it is generally good to use at least Belden 9913 or similar type high quality low loss cable with "N-connectors" on both ends. If you have access to it, 2.5cm hardline (low loss rigid coax) is the perfect cabling (often available from cable TV and microwave

companies.) Cable runs should generally be no more than 50 feet. If it is necessary for longer runs then an amplifier should be considered for replacing the power lost in the cable attenuation.

Here is some typical loss information for coax cables for 915MHz signals:

Belden 9913	-4.2dB/100ft
RG-59	-11dB/100ft
RG-8	-7.5dB/100ft
Copper Heliac 1 5/8"	-0.7dB/100ft
Copper Heliac 7/8"	-1.3dB/100ft
Copper Heliac 1/2"	-1.7dB/100ft

Line of Sight and Antenna Location

When attempting a connection beyond 200 meters, a line of sight between the antennas is necessary. When using directional antennas, reflections off of 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 a magnet for all wireless systems. Usually moving antennas at least five meters apart corrects such problems and allow all parties to use the same antenna tower.

The communications at 915MHz and 2.4GHz are not substantially affected by the weather conditions (rain, snow). Meanwhile the performance of antenna itself might deteriorate if it is covered by ice or snow. Therefore in very hard climate it is a good idea to mount antenna inside plastic tube of sufficient size (so called "radom".)

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 h_1 and h_2 are heights of the antennas (in meters), the maximum distance (in kilometres) for line of sight between the antennas in plain area

can be calculated according to the formulae $3.55(\sqrt{h1} + \sqrt{h2})$.

For example, elevation of antennas 5m and 40m give line of sight 30.30km = $3.55 (\sqrt{5m} + \sqrt{40m})$.

Amplifier and Pre-amplifier

The transmit power of wireless LAN adapters is very low (100mW for 2.4GHz models, 250mW and 1W for 915MHz WaveLAN and ARLAN models respectively). For longer distances, bilateral amplifiers - which include transmit and receive amplification - are being used by Chonia Informatica. The Hyperamp 5 watt 915MHz has shown positive results extending range up to 40 km with high gain directional antennas at each end.

Wireless Internet for Education – Project

Since modems don't have anywhere near sufficient bandwidth to allow entire schools to access the Internet at instructionally useful speeds, our goal of wireless Internet access network set up in capital of Ghana, Accra by Chonia Informatica is to provide Internet connectivity to various University, Institutions and departments and other establishments scattered around the city with a diameter of approximately 25km. We used these solutions over a two-month test period to connect a ACC office with the University of Ghana, Legon.

Since international Internet connection for Ghana is over 128kb/s line, then 64kb/s to individual sites is considered sufficient.

We chose to use wireless LAN, because:

Wireless LAN adapters inherently deliver high speed (around 1Mb/s),

In case of wireless LAN, one central node can "talk" to numerous "client" nodes simultaneously, thus requiring only one wireless adapter per connected client site, Distances up to 10km (from the centre of the city to perimeter) can be covered using available wireless LAN adapters with high gain omni-directional antennas in the centre and directional antennas at client sites,

Using wireless bridges it is not possible to provide sufficient isolation between the LANs of connected organisations; most of them will want an IP router on the border of their network.

The least expensive IP router "on the market" is PC running some IP routing software. With LAN adapters such a router can deliver up to 2Mb/s throughput and simultaneously act as a gateway between wired and wireless network.

The wireless network for Internet access in Accra has just been in operation.

The ARLAN 2.4GHz network installation was chosen because of two reasons:

ARLAN 2.4GHz is ETSI compliant and therefore will not cause licensing problems in long term, and ARLAN has built-in link level error correction, thus avoiding the need for error correction done by routers. ARLAN also has more sophisticated management and security features.

Requirements for a Wireless WAN Network

The intended WAN imposes that the following requirements be satisfied with the following characteristics.

- Licensing Frequency license for 2.4 GHz transmission
- Highest Visible Point. Territory survey to install Base Station
- Farthest Access point (Uni-Ghana, Legon)

The first requirement is particularly important if the country need frequency license before operation.

Wireless - Basic Functionality

The FCC in 1985 approved (47 Sec.15.257) three so called Industry, Medical & Science (ISM) bands for licence free use:

- 902-928MHz,
- 2.400-2.4835GHz,
- 5.725-5.850GHz.

These bands are used by microwave ovens, garage door openers, and also spread spectrum radios.

Current FCC regulations limit spread-spectrum radios to a meager 1 watt of power and confine their transmissions to so-called ISM bands.

Yet despite these regulatory limitations, the inherent superiority of the technology allows the radios to cover 15km distances at speeds up to 2 Mbps.

The radios can reach as far as 45km (with direct line of sight) and with the use of additional radios as relays, the range can be extended even farther.

In part because spread-spectrum radios cause less interference, the FCC requires no license for their operation.

Configuration Overview:

PC based router software the PC on which you run JNOS preferably must be dedicated for that, you may remove keyboard and screen from this PC when it is configured. No hard disk required in this PC - DOS, JNOS and configuration file will fit on floppy disk.

To set up the ARLAN network, we used ARLAN 630 Access Point for the central

site (Access Point is a "transparent" device that connects two medias: wireless LAN and wired Ethernet), and ARLAN 655 ISA adapters mounted in PC routers for the client sites. ARLAN 655 ISA adapters normally do not communicate directly, but allcommunication between ISA adapters goes through the central ARLAN 630 Access Point.

The distinct property of ARLAN is that several Access Points can be used to cover larger area; the Access Points themselves can be interconnected through wired Ethernet interfaces, or over radio, if one Access Point can "see" another Access Point.

In this way it is possible to use an Access Point as a radio repeater to extend the range of wireless communication.

Point-to-Multipoint usable bandwidth measurements

In case of wireless LAN, one central node can "talk" to numerous "client" nodes simultaneously, thus requiring only one wireless adapter per connected client site.

The project implies the exchange of large amount of data over the network. It is therefore necessary to ensure that the network - and the supporting applications- is providing the performance required. Several services have therefore been evaluated:

- Ordinary TCP/IP links
- File transfer FTP
- WEB Browsing

The Client - Server Wireless Link

A series of measures have been performed to evaluate the behaviour of these applications, comparing their respective performances.

In all cases, the tests were performed between a Unix Server (ACC) and 14 PC's

workstations networked at the University. The workstations are linked to the server through a wireless network 15km away from the Base Station

The Server machine

The server machine stored small, medium and large files for FTP tests and gave access to files through a WWW server and through the simplified file-sharing protocol. The server machines used is a UNIX server. This choice was made considering all functions it has to fulfil: WWW server, file server, etc. Such a machine is versatile enough to cope with all functions at the same time.

Communication Performance of Wireless and Ethernet LANs

The TCP/IP basic tests showed quite promising performances for the wireless link: up to 200kbps over TCP was reached in this configuration, which is fairly good considering that the additional bytes due to TCP/IP headers that are not counted in. The file transfers also benefited from the increase of bandwidth. Small, medium and large files were transferred across Ethernet and wireless, either one at a time or 4 at a time.

After these promising results, we looked at one of the most used services between workstations: web browsing. Again the test was performed with files on a server at the ACC.

To summarize

We have seen that a high speed Wireless network delivers the expected bandwidth. However, depending on how the applications transferring data are conceived, this improvement can be counterbalanced by protocols not designed for higher speed networks. According to our measurements direct TCP/IP have an adequate behaviour while the current

Browser versions doesn't bring the expected performance increase. It is clear that due to the different nature of the information transfers, the problems are not the same.

Future direction

The system is still running and gaining acceptance in most Africa Countries, but some directions for future can be already be drawn up. There is a clear demand for an increased bandwidth, in order to allow multimedia applications like videoconferencing, access to multimedia data, etc. to be really usable.

The most important development will address the support for a Backbone system to remove backlog...

CONCLUSION

We have tried to describe in this paper all the basic things about wireless Internet access network.

Finally, we want to stress that wireless Internet connections are not a replacement for wired solutions – they should be used in applications where more traditional wired solutions are not possible or cost effective for the throughput required. Compared to wired connections, wireless network involves more components (PCrouters, radio adapters, cables, antennas) which all have to be properly installed and maintained to avoid network failures.

Wireless is also subject to weather conditions - icing, lightning, extreme temperatures, etc. Wireless requires careful access configuration to protect your communications from intruders. And finally, the wireless solutions described here are not mobile solutions - mobility would require much higher transmission power to ensure stable communication also without direct line of sight, as well as roaming support between the radio cells.

Despite above mentioned limitations, wireless IP networking is here and it has proved to work reliably in Ghana and elsewhere. It has become a viable and cost effective alternative to wired IP networking.

As the successful completion of our project has shown, wireless network will transmit signals with any bandwidth required, file transfer protocols will deliver requested data where needed.

There are political decisions that will shape the future. An example will be ISM frequency licensing.

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