The Road to Broadband Fixed Wireless Access

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Abstract:

Broadband Fixed Wireless Access (BFWA) provides a viable alternative for a range of narrowband, wideband and broadband access media and services that allows effective sharing of scarce frequency spectrum resources among subscribers. Both ETSI and IEEE have recently issued BFWA draft standards. Saudi Telecom Company (STC) conducted a multivendor field trial of four such BFWA products.

This paper presents the findings of the field trial and, in light of the available IEEE and ETSI standards, it describes the main factors for evaluation of such BFWA systems. The paper also compares merits of BFWA with other access technologies such as Optical Fibers and xDSL in terms of their applications and capabilities (e.g. services, security, speed, performance, deployment time).

1. Introduction

Advanced telecommunications capabilities are becoming ever more important and crucial to countries' economy and all aspects of life, as businesses and consumers increasingly rely on the Internet and associated applications incorporating audio and video which require sustained high information rates. Most countries are now setting aggressive plans to construct the necessary infrastructure for such advanced capabilities.

One important part of the Telecommunication infrastructure is the Access Network (AN), often denoted as "the last mile", and it represents a major "Bottleneck" for offering Broadband services. The other two parts of the infrastructure are the Core Network (CN) and Customer Premises Equipment (CPE). Up to the early 1990's, the AN's were almost totally copper based and represented about 70% of the total network cost.

In order to take advantage of the large investment already made in the existing copper, modems were used to transmit data at rates which increased from 2.4 kb/s at the early 80's to 56 kb/s at present. Integrated Services Digital Network ISDN transmit data at rates up to 128 kb/s. For higher bit-rates (e.g. 200 kb/s – tens of Mb/s), a new generation of digital modems are being introduced (xDSL: x Digital Subscriber Line, where x= A, S, H, .., or V to correspond to different types of such modems).

For areas not yet served by copper, or where existing copper loops are not suitable to fulfill the service requirements, alternative "broadband" access technologies are being considered, namely: Fiber Optics, BFWA (or more commonly called Broadband Wireless Access **BWA**), Satellite and Power Line Telecommunications (PLT).

During the year 2000, BWA has attracted much interest due to its several advantages. However, there has been a great deal of debate about BWA viability for deployment into the access network. The confusion arises from the combined effects of the plethora of access technologies as mentioned above with their unclear future of adoption by different markets, and the performance of BWA systems in different networks. The case is further blurred due to incomplete BWA standards that clearly specify performance, functionality and interoperability parameters. In addition, the fact that new "Air Interface" International standards are expected to be released during the year 2001 adds a concern as to whether the current proprietary BWA products would be upgradeable, else their technology lifetime would be sharply shortened.

Following a brief description of the network trends in which BWA is emerging, as well as an overview of BWA systems, we present the main findings of small scale field trial of 4 BWA products. We compare BWA with other access technologies and, in the light of the draft and planned IEEE and ETSI standards, we conclude with our assessment of the potential of BWA deployment.

2. Telecommunication Network Trends

2.1 Market Trends

The dominating telecommunication service today, next to telephony, is the Internet. The estimate for the number of Internet subscribers in 2004 is 0ne Billion [1]. Most future services and applications will be implemented over IP based networks. These include Virtual Private Networks VPN, Media streaming service, video on demand, Telemedicine, Digital Libraries, Digital Museums, E-Commerce, E-Business, E-Government, E-Learning. Depending on the specific requirements, access to such applications may vary from as low as 64kb/s up to 155 Mb/s or more. In Europe, "Broadband Service" is defined when the bit rate exceeds 2 Mb/s, "Wide-band" when between 256 kb/s and 2Mb/s. In USA, the FCC defines Broadband Service as > 200 kb/s [2]. In USA, it is forecasted that the number of broadband users will increase from 1% in 2000 to 66% by 2008. The market decides what applications get off the ground and what remain as dormant innovations with no practical use. A key driver to success for most applications, however, is High-bit-rate Access when obtained at affordable cost.

2.2 Technology Trends

In order to meet market demands as mentioned above, telecom networks are moving towards convergence from multiple narrow-band service-specific networks to one broad-band packet-based "master" network (Next Generation Network NGN), where voice, data and video applications are supported efficiently and cost effectively.

One dilemma with NGN is that, while building network infrastructure to cope with data traffic doubling every year (or every 6 months in some countries), attention has to be paid to the quick turnaround rate of technology replacement [3]. The other major concern is that, while technology of the core is achieving terabits/s through the fiber and router elements, the access network is not growing as high and fast as such, in order to satisfy the hundreds of million s of "Internet" users.

Access network constitutes a major bottleneck between core network and CPE networks such as high speed LANs (e.g. 100 Mb/s, 1000Mb/s, 10Gb/s). Fiber Optics represent the best performing access choice. However, it is often not a viable alternative due to its long deployment time, interface complexity and high installation cost (e.g. 150-250 k$/mile). The other promising access technologies are xDSL which make use of the existing copper plant, Satellites which are more expensive but have large coverage, and BWA which is a mixture of WLL, Cable-modems, GSM, Satellite and Microwave access technologies. PLT that makes use of the existing power distribution plants to achieve few Mb/s is in an early stage of demonstrating viability.

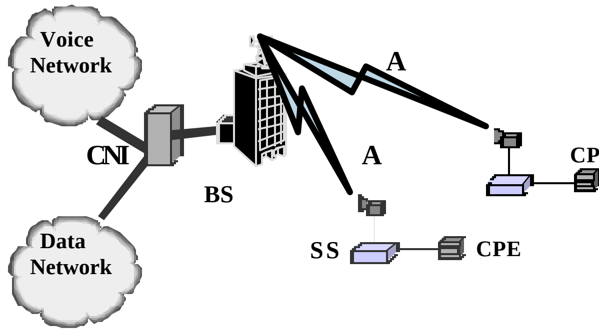
2.3 Regulations Trends

The introduction of new systems in the wireless world always creates the problem of frequency availability, and of frequency licensing processes. This is of special importance for broadband systems requiring associated bandwidths in order to fulfil multi service and high capacity requirements

Recognizing the value of Broadband services to the national economy and welfare, Regulators take the necessary measure to support or to imply measures to be undertaken by both incumbents and new entrants such as to empower BB capabilities. A good example is the government in Sweden which attempted to set a strategy to ensure the basic right of individuals in Sweden for access to 5 Mb/s. Another example, is the USA government who has recently conducted a study aiming at identifying the necessary means to provide > 200kb/s access capability to Rural areas in USA..

3. An Overview of BWA Systems

3.1 BWA Description



BS : Base Station
SS : Subscriber Station
A : Air Interface
UNI: User Network Interface
CNI: Core Network Interface
CPE: Customer Premesis Equipment

Fig.1 BWA Conceptual Model

In its simplest form, BWA is composed of a multi-sector base station communicating with a number of customer units. Figure.1 demonstrates the generic make up of the system.

There are two main BWA systems in common use today, namely: LMDS (Local Multi-point Distribution System) and MMDS (Multi-channel Multi-point Distribution System). LMDS is a millimeter-wave broadband access system generally operating above 20 GHz. BWA became practical at such high frequencies due to advances in DSP's, modulation and Gallium Arsenide IC's. The technology offers several advantages such as the availability of a wide bandwidth (e.g. 1.3 GHz in USA). LMDS is based on a cellular architecture. However, it differs in that it uses fixed links between a multidirectional hub, called Base Station (BS) and a number of dispersed fixed subscriber stations. It also requires line-of-sight (LOS) communications since the millimeter waves form pencil-like beams that can easily be reflected and/or attenuated by the physical obstructions along their paths. An LMDS network typically comprises multiple overlapping cells of 2–6 km radius each [4], [5]. Each cell basically consists of a BS with sectorized antennas and a number of subscriber stations , each with a directional antenna. Capacities and coverage generaly depend on a number of factors, mainly: frequency band, transmitted popwer, bandwidth, number of sectors, frequency reuse factor, polarization, modulation scheme (e.g. QPSK, 4QAM, 16QAM, 64QAM), Multiple Access scheme (e.g. TDMA, FDMA and CDMA), Duplexing method (e.g. TDD, FDD) and QoS. QoS depends on a number of factors such as the coding scheme and availability requirements (e.g. 99.995%). The total capacity of BS can reach more than 155 Mb/s. LMDS is usually deployed in high density high bit rate subscribers in business areas.

MMDS differs from LMDS mainly in that it works at 2 – 4 GHz and requiers Near-Line Of Sight. Radius of a sector may range between 15 – 50 Km. It is more fitted to rural and residential subscribers.

3.2 World View

Many field trials started 3 years ago and many are currently in early stages of deployment by several Operators. The take up is rather slow but expectations are high (see explanation in sec.6).

In US there are 493 Basic Trading Areas (BTA) each with two licenses: A=1150 MHz & B=150 MHz (in 28 – 31 GHz). 104 companies won 397 "A" licenses and 485 "B" licenses.

In Europe, most countries either started or in the process of licensing frequencies both for LMDS and MMDS at 26 GHz and 3.5 GHz, respectively, where 32 bands of 28 MHz in each of the up and down links are specified for LMDS.

3.3 BWA Main Applications

Generally, for sites not yet served by copper, or when distance/bit-rate does not fulfill the service requirements, or when Satellite is also too expensive for a dense cluster of subscribers over a small area, then BWA will be the best candidate for applications such as:

- Internet Broadband Access (10/100-base T),
- Voice PABX E1 Access,
- Leased lines (LAN-LAN, ISP to Internet Core, SME to ISP, GSM BS/BSC ,...) ,
- Videoconferencing & Video streaming,
- Virtual Private Networks VPNs,
- Other high-speed data applications

3.4 Main Merits of BWA

BWA systems enjoy the following advantages:

- High speed of deployment and fast realization of revenue, as it requires no digging, no right of way constraints, ..
- Low initial investment (copper costs around 15 000 $/mile per x-pairs)
- Low cost of relocation,
- Capacity per subscriber can reach higher than other access technologies (except fiber),
- Dynamic sharing of the frequency spectrum,
- Serving large areas and bridging coverage gaps of other access systems, and
- Flexibility of provisioning of wide range of bit rates (from 64 kb/s to 150 Mb/s).
- Licencing of frequency for BWA can be a tadious process or very expensive.
- More complex to install and more expensive when compared to xDSL.

4. Comparison of Access Technologies

Table-1 below shows a Comparison of BWA with Other access technologies [2], [6].

Table-1 Access Technology Data Rates & Range

Access Type	Upstream data rate (kb/s)	Downstream data rate (kb/s)	Range (km)	Deployment (in US)
Analog Modem	14.4-34	14.4-53	9	Millions
ISDN	128 kb/s	128 kb/s	7	100000's
ADSL	256 kb/s 640 kb/s	2 Mb/s 8 Mb/s	5 2	>½ million
VDSL	640 kb/s 2 Mb/s	13 Mb/s 25 Mb/s	1.4 0.6	?
Cable modems	200 – 10000	30 k (shared)	4.5	>1.5 million
Satellite DVB	2 Mb/s	36 k (shared)	Not limited	10000's
Fiber to the Home	millions	millions	100's	1000's
MMDS	100's – 1000's	100's – 1000's	50	10000's
LMDS	8 Mb/s (up to 155 Mb/s)	36 Mb/s (shared) (up to 155 Mb/s)	5 - 7	10000's

5. BWA Field Trial

5.1 Objectives of the Trial

Because of the merits of BWA explained above and, as a result of the ongoing debate about BWA viability for deployment into the access network. The following trial objective were defined [7]:

- Assess BWA technology suitability for its introduction in STC network.
- Enhance development of project specification.
- Facilitate development of effective test procedures for subsequent acceptance testing.
- Bring about technology awareness. This will help to pinpoint problem areas, standardize serving processes, assess customers needs and gauge their satisfaction, and ultimately avoid surprises that may arise during or after implementation of new technologies.
- Serves as means for relaying requirements to vendors in such a way as to promote better understanding of specific needs.
- Establish an environment to develop the necessary O&M procedures.

5.2 Field Trial Set Up

Four Vendors (Netro, Nortel, Newbridge/Alcatel, and Ericsson) took part in the field trial. Four base stations were installed in 3 sites (2 in Murabba, 1 in Ulaya, and 1 in Mursalat). CPE's of ISP's and Banks Customers were connected. Each Base station radiated power in 2-4 sectors. Services ranged from 64 Kb/s to E1 and 10BaseT. Base stations acted as hub centers connecting customers to the public ATM network. BS's interfaced to the ATM network via STM-1 (155 Mb/s) links [8].

Each system is composed of BS antenna subsystem at STC site, Subscriber Stations at customers' sites, and a network management NMS that manages, supervises and configures the system. Several networking scenarios were established including leased lines, LAN to LAN and connections of ISP's to the Internet ATM network.

Frequency spectrum in the 26 and 28 GHz were used. The systems support interfaces to ATM, FR, and PSTN networks in such a way as to demonstrate video, data, and voice traffic.

5.3 Test Senarios and Evaluation

Special emphasis was given to those issues that may raise economic, service and/or operations and maintenance concerns. Evaluation was organized around five main categories of tests consisting of:

1- Subjective systems inspection.
2- Assessment of traffic handling capabilities
3- Evaluation of NMS capability.
4- Field measurements of performance
5- Evaluation of service performance based on Field trial customers' assessment of Quality of Service as compared with wire line accesses.

Fig.2 and Fig.3 show samples of two common configurations that were tested.

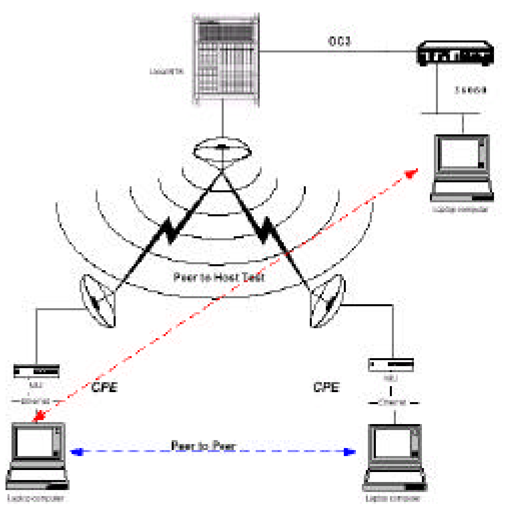


Fig.2 LAN-to-LAN

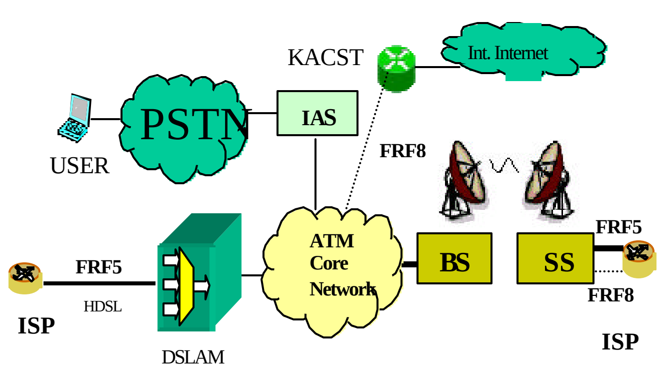


Fig.3 ISP-to-ISP & ISP-to-Internet

5.5 Main Findings of the Trial

In view of the trial objectives mentioned above, the following summarizes the main findings of the trial:

1- **Bit rates** per sector for the 4 vendors were measured, where capacities of equipment could be compared (see appendix-1).
2- **Bit Error Rates** (BER) were measured before Forward Error Correction (FEC) as $< 10^{-6}$, while $< 10^{-11}$ was obtained with FEC.
3- **Distances** from 70 meters to 7 km were tested with no service degradation.
4- The tested systems were stable with no unplanned failures during the 3 months of the trial. **Maturity of the BWA** technology was assessed for small scale deployment.
5- **The different service configurations** tested (e.g. LAN to LAN, Frame Relay FRF5 ISP-to-ISP, Frame Relay FRF8 ISP-to-ATM (KACST), Video Streaming,... etc. indicated the potential of BWA as a practical means of filling the gaps in providing Broadband access to customers who cannot be served otherwise.

6. BWA Standards

Further to the regulation and performance aspects of standards for BWA, their importance mainly stems from defining interoperability. This allows operators and customers to select some system components and CPE's from a variety of vendors, thereby getting best technology at the lowest cost.

6.1 Classification of BWA Standards

The main standards supporting BWA systems may be grouped according to five categories:

1. Core Network Interfaces,
2. Customer Equipment Interface,
3. Environmental & EMC,
4. Radio Frequency bands and Parameters [9],
5. Air Interface: Physical & Data Link layers

The first two categories of standards are not unique to BWA and apply to all alternative access systems. They are very important to qualify any system, as they determine the capability for connection to different core networks such as ATM, IP, and PSTN/ISDN (e.g. E1 on G703/G704, STM-1 electrical, STM-n optical, V5.2 on G703, ATM/FR, ATM/NNI, …). Interface standards to CPE's can be E1 G.703/G.704, ISDN/BRI, 10BaseT, 100BaseT, USB, POTS. Such interfaces determine the scope of services to be offered and the purpose for which the system is intended. Being as such, interface standards are implicitly mandatory in any specification.
The 3rd and 4th categories of standards are usually subject of regulatory concern and type approval.

The 5th set of standards (Air Interface) is in fact the most important factor in differentiating BWA systems and in characterizing their merits [10], and driving their evolution as described below .

6.2 Status of BWA Air Interface Standards

The two candidates of BWA (MMDS and LMDS) are very similar technologies. Both are initially designed for providing wireless distribution of video, as complement of and rival to the Cable Television CATV systems. In1998, CATV networks started to compete with Telco's in the area of Internet access by the use of cable modems. This was made possible through development of new standards, namely: DOCSIS (Data Over Cable Service Interface Specifications) in North America, and DVB/DAVIC (Digital Video Broadcasting/ Digital Audio-VIdeo Council) in Europe. These two standards define OSI layers 1 & 2 that allow two-way interactive data transmission.

Naturally, the standards of BWA for internet access and two-way (data) communication followed the standards readily developed for cable modems and, therefore, BWA are sometimes called "Wireless Cables". Existing BWA systems are subject to the following shortcomings:

1. Because no complete BWA Air Interface standard is yet available, all existing BWA systems are proprietary based on combinations and variations of the two cable modem standards mentioned above. Being proprietary as such makes the price reduction due to economies of scale a rather slow process.

2. Being originated from cable modem standards which assumes asymmetric traffic, their design is not optimal in the handling of symmetric traffic or the asymmetric traffic with dynamic change over the uplink and down link.

3. No adequate provision is made to serve more than a single customer from the same SS.

6.3 The Coming BWA Standards

The coming ETSI (HIPERACCESS) and IEEE (802.16.1 & 802.16.3) standards of Air Interface are expected to be released during the second half of year 2001 [11], [12], [13], [14].

According to their preliminary drafts, BWA designs will enjoy the following merits [12], [15], [16]:

1. Protocols of Media Access Control MAC and Physical PHY layers will allow interoperability of multi vendors BS and SS equipment.
2. They allow multiple CPEs per SS.
3. They are optimized for IP and ATM traffic.
4. MAC and PHY protocols will allow data rates to scale beyond 10 Mb/s, as well as multi rate adapted by transmission power, modulation and others based on distance and interference.
5. MAC and PHY protocols allow adaptive Time Division Duplexing TDD operation that will optimize system traffic capability under varying asymmetry in Up and Down stream directions
6. Improve system security in terms of Privacy, Authentication and Authorization.

7. Conclusion

The trial of LMDS systems from four vendors demonstrated the viability of BWA technology in terms of performance, services, coverage and O&M. However, the MAC and PHY layers of the different systems are not interoperable. When standard and interoperable systems will emerge by the end of year 2001, operators will demand systems that conform to those standards, which are expected to provide far better performance at lower cost. It is advisable, therefore, only to implement the smallest scope of BWA system that would fulfill the priority broadband demands. Further, a special weight will be given to existing BWA equipment that may be software/firmware upgradeable to the coming standards.

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Appendix1: Performances of Vendors' Equipments

Performance Parameters	Vendor W	Vendor X	Vendor Y	Vendor Z
Operating Frequencies (GHz)	24.549 – 26.453	24.00 - 31.30	24.549 – 26.453	24.549 – 26.453
Channel Bandwidth (MHz)	14	36	28	28
System	Cellular	Cellular	Cellular	Cellular
Down Link	TDM	TDM	TDM	TDM
Up Link	TDMA	TDMA	TDMA	TDMA
Operation Characteristic	Symmetric	Asymmetric	Symmetric	Asymmetric
Downstram Base Modem Data Rate @ BER= 10^{-6} (Mbps)	23.712, 4 QAM	41.68, QPSK	37.5, C-QPSK	72.8, 16 QAM
BS Modulation Efficiency (bits/Hz)	1.694	1.158	1.339	2.6
CPE Modem Data Rate @ BER= 10^{-6} (Mbps)	23.712, 4 QAM	10.2, DC-QPSK	37.5, C-QPSK	36.4, 4 QAM
CPE Modulation Efficiency (bits/Hz)	1.694	1.133	1.339	1.3
Min. Sector Size (Degrees)	45	30	90	30
Maximum download data rate per Cell (Mbps) @ Cel. = 5 Km, BER = 10^{-6}	189.696	500.16	150.00	873.6
Bits per second, per Hertz, per Cell (BHC)	13.549	13.893	5.357	31.2
Bits per second, per Hertz, per Square kilometer (BHS)	0.173	0.177	0.068	0.397