Broadband Wireless Access
Trends and Challenges

A.P.S. Khanna
WSD, Hewlett Packard, Santa Clara, CA. USA
(Paul_Khanna@hp.com)

I. INTRODUCTION

We are approaching the next millenium at a juncture when huge opportunities in the field of high-speed communications are knocking at the door and challenging us to develop innovative solutions with desired performance and cost. Wireless will play a key role in the forthcoming rollout of infrastructure, due to its inherent advantages of quick time to install and mobility.

The first phase of wireless era dealing with telephony has been an enormous success. Greater than 400 million wireless phone subscribers in the world and increasing at a rate greater than a million a month is a testimony to the importance of the wireless communication for mankind. Recent explosive growth of the Internet has clearly exposed the bandwidth limitations of the telecommunication infrastructures. The new challenges are taking us into a different battleground of data communications. Broadly wireless applications have multi dimensions. While one dimension is voice, data and video applications, the other dimension deals with mobility versus fixed. Wireless cellular phones' success is undoubtedly based on the need for mobility while communicating. These cellular infrastructures are presently being used for data applications providing tens of kbps capacity to the end user. Next generation cellular systems commonly known, as 3G systems will move this capacity to 128kbps mobile access speeds. These systems are expected to have capability of providing up to 2Mbps under stationary conditions. However, these systems are being primarily designed for mobility and may have limited application in extremely cost competitive fixed end -user market.

Fixed Wireless Access (FWA) is an excellent option for broadband wireless access to fill the gap of so called "Last Mile" application for business and residential data consumers. This paper is focussed on the trends and challenges in the field of Fixed Broadband Wireless Access (FBWA). FWA itself falls under three parts: Narrowband, Wideband and Broadband. There are no universally accepted definitions of these terms. One of the options is to define narrowband as data rates up to 64kbps, wideband as data rates from 64kbps to 1.5Mbps and Broadband as applications requiring data rates greater than 1.5Mbps. The broadband definition matches with the recent definition set by ITU.

II. OPTIONS FOR BROADBAND ACCESS

A number of options are presently available to relieve the bottleneck between the end-user and their Internet service provider. The leading options include:

ADSL

This asymmetric service uses single pair standard copper wiring and permits simultaneous voice use of the line. Upstream and downstream data rates of 128 kbps and 384kbps+ are presently available in many parts of the US at a nominal price. ADSL is limited to 18,000 feet from the Central Office and requires loop upgrading on the part of Local Exchange Carriers. This service also relies significantly on the strength of the incumbent exchange carriers. ADSL standards are already in place and over 100 equipment vendors are in second or third generation development cycle.

Cable Modem

Full two-way data communication services are now available to many parts of the US at competitive rates. This option can use existing coaxial cable but it does require an expensive upgrade of the plant equipment. In a typical urban environment customers can expect down stream data rates up to 1Mb/s. Statistically multiplexed data in the dedicated channels serving the single segment can run out of steam once the market demand takes off. Other challenges of this technology include lack of existing cable infrastructure in the business areas and very highly asymmetrical characteristics. Standards for cable modems are in place and over 15 vendors are already supplying the cable modem equipment.

Fixed Broadband Wireless Access

A terrestrial wireless alternative to wired techniques has a number of advantages including:
Wireless Infrastructure can be installed quickly and with much less expense than wireline infrastructure. Radios give network design engineers flexibility in how they deploy their infrastructure. A network engineer can isolate and repair a radio link much faster than isolating and repairing a break in a cable link. High reliability, immunity to cuts, floods, and earthquakes makes wireless an attractive option. Wireless circumvents need for right-of-ways for in-ground installation. Wireless alternatives not only provide independence to the service providers, it also offers low cost of ownership compared

to leased option. Wireless hardware is also redeployable. Faster time to market provided by wireless alternatives, an important competitive edge can turn into increased business profitability, particularly when demand evolution is not known precisely, or when difficulties exist for undertaking civil works. Wireless Access Systems represent the fastest way to reach end-users controlled growth by demand, and the provision of full wireless access to end customers.

III. BROADBAND WIRELESS ACCESS TRENDS AND FEATURES

With the worldwide deregulation of the telecommunications industry, and the rapid growth of voice telephony and high-speed data networks, wireless networking is becoming the technology of choice for many applications. Wireless networks can be installed in a fraction of the time required for wired (fiber or coax) networks. The initial costs (equipment and installation) of wireless networks are generally far lower than the costs of a wired network, and recurring costs of operations and maintenance are lower as well. It is not surprising that in wireline infrastructure 90 percent of costs are related to the installation of cable -usually fiber- while in fixed wireless solution, installation makes up less than 20 percent.

Large enterprises with 1,000+ employees, representing the highest profit potential for wireless communications vendors in the initial phase. It is expected they will maintain their weighty position into the next millennium. Medium size firms with 100- 999 employees, also represent substantial market opportunities for wireless vendors. Residential and SOHO customers may need to wait in order to reap the benefits of the BWA infrastructure being put in place and technology being developed for their elder brothers.

A number of different frequency bands are presently being used or deployed for FBWA. Some of those are shown below:

Table 1 FBWA LICENSED BANDS

Frequency Range	Bandwidth	Description
2.1 - 2.7 GHz	78 MHz	MMDS
3.4 - 3.6 GHz		Europe
10.15-10.65GHz		Europe
24.5 – 25.5 GHz	400 MHz	Teligent
27.5 – 31.3 GHz	1150 MHz	LMDS
24.5 – 29.5 GHz	Various	Many Countries
38.6 – 40 GHz	1400 MHz	Winstar/ART
40.5 – 43.5 GHz		Europe MWS

Millimeter Waves in BWA:

Millimeter-wave radio typically ranges from 21 GHz to 60 GHz on the frequency spectrum. As frequency increases, propagation distance decreases. In the millimeter-wave end of the spectrum, the propagation distance of the transmission is short, ranging from approximately 10 miles at 21 GHz to as little as 0.5 miles at 60 GHz using permissible and achievable transmitter powers. Since the transmission signal dies out over a short distance, these carriers can reuse the same frequency beyond a certain range. This concept of "frequency reuse," together with the low cost of the radios relative to long-haul microwave links and leased lines, are key reasons for a strong growth in the point-to-point millimeter-wave radio market in the last 5 years. Major application of these radios has been interconnection of base stations in the cellular phone infrastructure. The technology developed for these radios has provided a helpful start in the newer Point-to-Multipoint BWA market applications.

Higher frequencies naturally offer wide bandwidths. For example, in the US the 38 GHz band has 1.4 GHz of bandwidth which translates to higher number of channels in a given band, and more bandwidth per channel for higher data rate, compared to spectrum available at lower frequencies. Higher frequencies also offer less frequency congestion compared to lower frequencies. The high directivity of the antennas, in the order of 1° to 3°, together with the choice of vertical, horizontal or circular polarization, allow reuse of the same frequency at different directions and close locations. A large number of radios therefore might be placed in a single metropolitan area without interference.

Smaller antenna size for a given gain represents flexibility in mounting the equipment and improved aesthetics compared to lower frequency equipment. Significant reduction of the multipath fading is another important characteristic of the mmw frequencies.

IV. BWA SYSTEM SOLUTIONS

A number of BWA systems are already in operation in the USA. Service providers include WinStar Communications Inc., Advanced Radio Telecommunications Corp., Teligent and more recently Formus and Nextlink. These fixed wireless service providers, have ambitious plans and are predicting a prosperous life for the technology. Point-to-point as well as point-to-multi-point microwave technology in the licensed 38 GHz, 28 GHz and 24 GHz band is being used for these Broadband Wireless Access services. Some of the specific system examples are:

LMDS

LMDS and LMCS are BWA cellular systems in USA and Canada respectively which operate at frequencies between 27.5 GHz and 31.3 GHz and provide multiple users a variable rate of demand based access to voice and data services via a shared wireless access medium. More than a Gigahertz of spectrum available in this band makes it a very attractive option. Many other countries in the world have already established or are in the process of defining frequency bands in the frequency range of 23 to 43 GHz for similar applications.

MMDS

Multichannel Multipoint Distribution Service (MMDS) started in the USA as one way video distribution service in the seventies. With FCC's ruling in 1998, MMDS can now be a two-way service using frequencies in the range of 2 to 2.7 GHz. Frequency spectrum in this band is available in many other countries in the world. 78 MHz of frequency bandwidth is available in the US. This band has the advantages of low cost and high coverage but faces multipath and interference issues. Two-way wireless access systems using MMDS have started to roll out to provide hundreds of Kbps data rates to end users. Each hub in a typical MMDS system can cover 30 to 50 km radius. Recent investments by major service providers Sprint and MCI Worldcom in this market are expected to inject new vigor in MMDS.

Satellites and Stratospheric Systems

Role of satellite for two-way data communications and Internet services has been debated for some time. A number of systems based on GEO and LEO satellites are presently in development. Satellites offer great value in global coverage but will have hard time competing in cost with the alternate technologies in the urban metropolitan areas where most of the customers happen to be.

One of the recent options proposed by Angel Technologies Corporation plans to use a high altitude aircraft as a hub in the air. This aircraft will fly above the civil air traffic and adverse weather. This system is expected to provide 1 to 5 Mbps capacity to end-users within a circular footprint of about 100 km diameter. Height of the Hub airplane clears a large part of the obstructions by Foliage, buildings and local terrain. Aircraft being 10 to 100 times closer to the end user compared to the satellite systems, a lower performance and hence lower cost subscriber equipment can be used. The challenges include managing the crew and airplane in the air on continuous basis.

Backbone

BWA systems need large capacity backbone delivery systems. Fiber where ever available is a logical choice for the backbone applications. Point-to-point radio links and optical wireless links are the options when wireless connection is necessary. Optical wireless links do not perform satisfactorily under fog and smog conditions. Till recently it was prohibitively expensive to use radios with capacity greater than DS-3 or E3. Radios to carry 100Mb/s and 155Mb/s using licensed and unlicensed bands are now available for use in these short haul applications. The trend for even higher data rate point-point links for backbone connections fueled by the increasing need for speed is expected to continue. While wireless may not have the bandwidth muscle of fiber infrastructure, the technology can be a valuable add-on to existing services, reaching customers outside the wired coverage area quickly and economically.

Licensed Vs. License Exempt Bands

License exempt wireless access is a relatively new application of an existing technology. Main challenge for using a license exempt band is its vulnerability to undesired interference. However, license exempt bands do make a valuable case for residential and SOHO wireless access applications. Advantages of using license exempt bands include:

a) Lower cost due to use of lower frequencies
b) No hassle or fees for licensing.
c) Extremely wide customer base and
d) Flexibility in choosing among bands.

There are limited number of license exempt bands available internationally. In the US the unlicensed bands which are being used or bands that can be used for wireless access are shown in the table below:

Table 2: LICENSE EXEMPT BANDS IN US

Frequency	EIRP	Range
902-928 MHz	1W	
2.4-2.483 GHz	1W	3-10Km
5.25-5.35 GHz	1W	2-5Km
5.725-5.825 GHz	4W	2-5Km
24-24.25 GHz	2W	1-2Km
59-64 GHz	10W	0.5Km

Presently a number of wireless ISPs in the US are providing wireless access using the 2.4GHz equipment originally designed for 802.11 applications. A number of service providers are now looking at the 200 MHz UNII bandwidth at 5.25 and 5.725 GHz for the same purpose.

60 GHz band offers an attractive option for providing very-high-capacity short haul point-to-point links for backbone applications in BWA. 5 GHz of available bandwidth can potentially carry information at a Gbps speed and beyond. This frequency range being in the oxygen absorption part of the spectrum, limits the effective range to less than one kilometer.

V. BWA SYSTEM ISSUES

A number of trade off are necessary at the system level to provide a cost effective solution for the emerging need for high bandwidth. From the viewpoint of a service provider the critical aspects are Capacity, Coverage and Cost. For the infrastructure suppliers important aspects include Regulations, Co-existence/Interoperability, bandwidth flexibility and service integration. From the perspective of the hardware suppliers (Radio, network, computer) the important issues include Technology Cost and Choice, and Time To Market under constantly changing conditions and environment. As an example in the initial phases of the roll out it will be more important for an ISP to have more emphasis on coverage than capacity. As the demand in certain sector increases, higher capacity solutions can be added. A model combining the low frequency/ low capacity system in the beginning followed by high capacity/high frequency is one of the possible solutions.

FDD Vs TDD

For any wireless system transmit/receive signal duplexing can be achieved in two ways: frequency division duplexing (FDD) and time division duplexing (TDD). Both FDD and TDD have their merits and demerits. FDD needs paired spectrum while TDD offers some advantages in terms of time and frequency flexibility as well as capacity assignment. TDD offers lower cost radio implementation, as it does not require expensive RF filters and Transmitter/Receiver isolation techniques. TDD is more suitable for asymmetric applications. FDD requires a simpler and lower cost network management system compared to TDD. Microwave and millimeter wave radios have traditionally used FDD so far. Recently a number of companies are experimenting with TDD option for the advantages mentioned above. It is very likely that both FDD and TDD will be used in the future for BWA depending upon the application and available frequency spectrum.

Mesh Vs Cellular

Cellular point-to-multipoint configuration is the most commonly used technique in the present day voice and data communication system. This approach represents hub and spoke architecture to provide shared services to end-users. Communication between any two points always passes through the Hub. Other options include Mesh and Ring configurations. These are characterized by the absence of Hub and the information is passed from one point to the next in a mesh (one to many) or ring (one to next) form. Most BWA systems presently use or plan to use cellular configuration. Some applications however may be more suitable to use Mesh or Ring Configuration to overcome LOS, range and scalability issues at the cost of network complexity.

Multiple Access and Modulation

Spectrum resource access approach represents another design variance for BWA systems. FDMA is more suitable for high capacity symmetrical applications. TDMA allows for bandwidth on demand and can provide statistical bandwidth gain. QPSK and 16/64 QAM modulations are the key candidates for BWA. QPSK systems have lower spectrum efficiency (1.7b/s/hz) compared to higher level QAM systems, but require radio hardware which is significantly lower in cost due to lower amplifier linearity and LO phase noise requirements. FDMA/QAM and TDMA/QPSK combinations can be one of the solutions. Certain applications may require accommodating both options from the same base station at the cost of increased system complexity and reduced coverage.

Co-existence, Interoperability and Interference

Number of other system issues need to be resolved including co-existence and interoperability of various point-to-point as well as point-to-multipoint systems in BWA systems. Availability of international standards can help resolve these critical issues. Co-channel and adjacent channel interference can be controlled by careful design of the system parameters including frequency and polarization reuse, antenna directivity, hub and subscriber placement and RF filter design.

Propagation Issues:

Higher frequency systems have to deal with the increased propagation losses and the fade impact of natural events like heavy rain and fog. Losses through trees and walls is a major concern at frequencies greater than 10 GHz. Systems need to be designed with enough link margins to overcome these impediments, reducing thus the coverage area of the cell sites. A systematic study of high resolution GIS databases as well as heavy rain statistics will need to be part of the radio planning to accurately determine the coverage.

Standards

Lack of standards for broadband wireless systems has undoubtedly contributed to the delay in rolling out of the necessary infrastructure. Recent efforts at various levels are now under way to help resolve the critical issues. Recently IEEE has approved a working group IEEE802.16 to develop standards and recommended practices to support the development and deployment of fixed broadband wireless access systems. (http://grouper.ieee.org/groups/802/16/). In Europe, ETSI has a standardization project BRAN – HIPERACCESS in process to generate standards for BWA (http://www.etsi.org/BRAN/). ITU's Wireless Access Systems Study Group JRG8A/9B study group JRG8A/9B has also been chartered to work on the FWA systems (http://www.itu.int/was/). All these groups are working on resolving the issues discussed above in order to make right choice of critical options. Timely and coordinated efforts between these groups can help generate global standards for the long term success of the BWA systems. In addition to the immense time pressure, the challenge will be to strike the right balance between providing flexibility for innovation and speed on one hand and over standardization on the other.

VI. CONCLUSION

Broadband Wireless Access systems are a lot more complex than cellular or voice Communications or high speed wired solutions. To implement it effectively, a convergence of complex, hardware, software and networks is required. Trends towards lower cost, improved user awareness and efforts towards resolution of issues related to technologies and standards are making it easier to justify the investment. It is, however, important to understand that a number of the challenges and issues discussed here need to be dealt with effectively in a timely fashion in order to help BWA take off quickly.