Performance Evaluation of WiMAX and Spectral Efficiency Gains Solutions

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Abstract— No doubt wireless network is an amazing wireless technology which has totally changes means of communication. There is no business, industry, project which can be progressed without needs of wireless networks. Now a wireless network has become significant option of any business because of its salient features like speed, security, mobility.

In this paper first we provided an overview of WiMAX technology in day to day work. The associated implementation challenges faced by WiMAX infrastructure developers are performance, cost, flexibility, etc. We investigate some performance measure parameters of WiMAX system with Spectral Efficiency Gains solutions. By deploying WiMAX spectral efficiency gain solutions, service providers gain a significant advantage; both in the performance of their network and their ability to cost effectively deliver high value services and applications.

Index Terms—- WiMAX, spectral efficiency, optimized challenges, Higher Order Modulation, XPIC, protocol conversion, Bandwidth Optimization

1 Introduction

THE lackluster performance of Broadband (BB) market, primarily attributable to technical and economic non feasibility of fixed line infrastructure in India, indicates that solution for mass proliferation of broadband in India has to be wireless. Government had announced its Broadband Policy (2004) and Broadband Wireless Access (BWA) auctions (2008) to accelerate BB adoption in India. Adoption of any new wireless technology would hinge on affordability, spectral efficiency, scalability, robustness, range of devices available, evolution roadmap and meeting BWA policy requirements.

WiMAX emerges as a strong platform for mass adoption of BB in India as well as emerging fourth-generation (4G) technologies—presents significant lawful intercept challenges. It gives superior performance and lower cost as compare to existing 3G technologies and futuristic LTE equipments. WiMAX was developed for high speed wireless BB data access and is a 4G technology available today at 3G prices.

WiMAX networks will bring new challenges to operators. WiMAX (IEEE 802.16 standard) comes from IEEE family of protocols and extends wireless access from LAN to MAN and WAN. It uses OFDMA (Orthogonal Frequency Division Multiple Access), physical layer radio access technology for uplink and downlink.

Initial version 802.16d (2004) focused on fixed and nomadic access and is referred as Fixed WiMAX.

Later version 802.16e(2005) includes many new features and functionalities needed to support enhanced QoS and high mobility broadband services at speeds greater than 120km/h and is referred as Mobile WiMAX. The following Objectives are used for WiMAX Networks:

- Broadband
- Backhaul
- Triple-play
- Rapiddeployment

Mobile WiMAX defines an all-Internet protocol (IP) end-to-end network architecture, which is an integrated telecommunications network architecture that uses IP for end-to-end transport of all user data and signaling data. Core networks based on IP routers and switches are easily scalable and easier to install and operate than a circuit switched network.

The current WiMAX revision is based upon IEEE Standard 802.16e-2005 IEEE 802.16e-2005 improves upon IEEE 802.16-2004 by:

- Advanced antenna diversity schemes and hybrid automatic repeat-request (HARQ)
- Adaptive Antenna Systems (AAS) and MIMO technology
- Denser sub-channelization, thereby improving indoor penetration
- Introducing Turbo Coding and Low-Density Parity Check (LDPC)
- Introducing downlink sub-channelization, allowing administrators to trade coverage for capacity or vice versa.[6]

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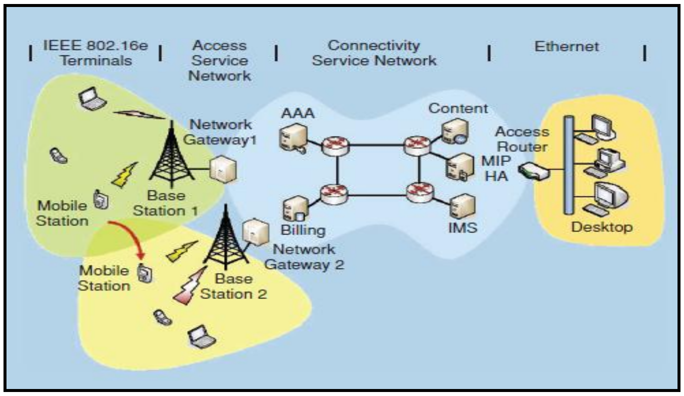

Figure1: IP based WiMAX Network Architecture [9]

2 WIMAX-OPTIMIZED CHALLENGES

Designers of WiMAX systems need to meet a number of critical requirements such as processing speed, flexibility and time-to-market, and it is these stringent requirements that ultimately drive choice of hardware platform. Some of major challenges are further described below.

2.1 Processing speed

Broadband wireless systems such as WiMAX have throughput and data rate requirements that are significantly higher than those in cellular systems such as WCDMA and cdma2000. In order to be able to support such high data rates, underlying hardware platform must have significant processing capabilities. In addition, several advanced signal processing techniques such as Turbo coding/decoding, and front end functions such as FFT/IFFT, beam forming, MIMO, CFR and DPD are very computationally intensive and require several billion multiply and accumulate (MAC) operations per second.

2.2 Flexibility

WiMAX is a relatively new market and is currently going through initial development and deployment process. 802.16Rev d has just been standardized while the 802.16e mobile version is still in works. Under this current scenario, having hardware flexibility/reprogram ability in end WiMAX compliant product is very important. This ensures that in-field programmability is possible, alleviating the risks posed by constantly evolving standards.

2.3 Packet based architecture

The growing dominance of data traffic has established a clear direction to mobile WiMAX networks. Packet based mobile network architectures enable operators to deliver IP-based services much more efficiently and at much lower cost points than alternative backhaul options by taking advantage of statistical multiplexing. Packet microwave solutions also eliminate overhead associated with traditional SONET/SDH systems.

2.4 High capacity and scalability

While capacity and scalability are important, these are not only areas where traditional backhaul networks will fail to measure up; legacy backhaul infrastructure also lacks the latency, availability, and advanced QoS performance demanded by emerging WiMax applications. With throughput levels reaching up to 2 Gbps per channel, current packet microwave systems have capacity to support a single base station or aggregate traffic from multiple sites today and well into the future.

2.5 Low latency

Native IP packet microwave systems enable ultra-low latency over link. This WiMax optimized capability allows business critical applications such as voice-over-IP, video-over-IP and future time-sensitive applications to perform at high levels. Keeping this priority traffic on the native Ethernet transport layer greatly reduces risk of incurring delays associated with segmentation and re-assembly, or frame adaptation.

2.6 Operational simplicity

Converged packet networks offer several significant operational advantages. Having a single traffic plane and one element management system (EMS) greatly reduces complexity of operating a backhaul network. With WiMax, we have integrated switching in order to reduce number of boxes in network, further simplifying operations.

2.7 High spectral efficiency

Spectrum is a valuable non-renewable resource, and like any other precious commodity, it is must be properly managed. Advanced radio features such as Cross Polarization Interference Cancellation (XPIC) allow operators to essentially double their capacity within their existing spectrum, allowing for greater flexibility and higher throughput per channel.

2.8 Advanced queuing and QoS support

Integrated bandwidth management features are a valuable tool for next generation operators looking to manage multiple service levels, traffic types, and user profiles. These features include multiple levels of prioritization (based on 802.1p/q, MPLS or Differentiated Services Code Point), advanced flow control via 802.3X, expedite queues, VLAN queuing and Weighted Fair Queuing. In order to maintain priority traffic at all times WiMAX backhaul solutions should also support QoS-aware adaptive modulation.

2.9 Intelligent nodal switching, high availability ring and mesh

Integrated Ethernet switching and nodal intelligence, allows packet-based traffic to be interconnected and routed without the need for additional third-party equipment. Eliminating boxes from the network results in lower equipment cost and simplified management and operations. In addition, this integrated functionality can support the active use of working and protection channels by prioritizing traffic in the event of a failure, virtually eliminating any wasted capacity.

2.10 Seamless evolution path for existing services

Service providers will continue to carry legacy services for many years to come. In order to simplify transition to a packet-based architecture, pseudo wire capability allows operators to effectively converge their TDM and IP traffic onto a unified network. Because synchronization is a building block of traditional networks, WiMAX backhaul solutions also support advanced network synchronization including Synchronous Ethernet, which locks the timing of the Ethernet physical layer, and 1588v2 which is used to carry synchronization data.

2.11 Lowest total cost of ownership (TCO)

Combining several of above mentioned elements produces a solution that achieves much greater operational efficiency. Adaptive modulation means smaller antennas and longer link spans for reduced site leasing costs; zero footprint deployment options further minimize this expense. High spectral efficiency maximizes spectrum investment and greatly reduces need for new spectrum licenses. Additional operational savings are gained through remote management, remote scalability and lowest power per bit. Lastly, high-capacity packet microwave solutions generally offer lowest CAPEX per bit of any backhaul solution alternative.

2.12 Time to Market

Because WiMAX is an emerging technology; time-to-market is a key differentiator for OEMs looking for early success in gaining market share. This has a direct effect on the development cycle and choice of hardware platform, with designers requiring easy-to-use development tools, software, boards, and off--shelf IP and reference designs in order to accelerate the system design.

2.13 Cost Reduction Path

Another important requirement to keep in mind while choosing hardware platform is the availability of a long term cost reduction path. Evolving WiMAX standard/market is expected to stabilize after initial uncertainty surrounding it, leading to a situation where cost of final product becomes much more important than retaining flexibility. A hardware platform that has such a clear cost reduction path and enables a seamless flexibility/cost tradeoff is the need of hour.

3 WIMAX TECHNOLOGY PERFORMANCE MEASURE PARAMETERS

3.1 Spectral Efficiency and Sector throughput

BWA technology adoption decisions hinge on spectral efficiency in business model. Spectral efficiency has prosperous impact on business case as; it lowers deployment cost per megabit and enables higher network capacity to support services. Uplink and downlink performance is also important as it directly impacts on equipments. WiMAX with all-IP end-to-end network has lower operating cost as compare to higher cost circuits switched network for HSPA/HSPA+ (High Speed Packet Access). This translates to higher data transfer capacity in same quantum of spectrum and lesser number of base stations.

High data throughput results in better data multiplexing and low data latency, which is essential to enable broadband data services and VoIP with high quality of service. Performance will enable transparency of quality of service between Mobile WiMAX and broadband wired services such as Cable and DSL, an important requirement for successful delivery of broadband mobile services ranging from real-time interactive sing

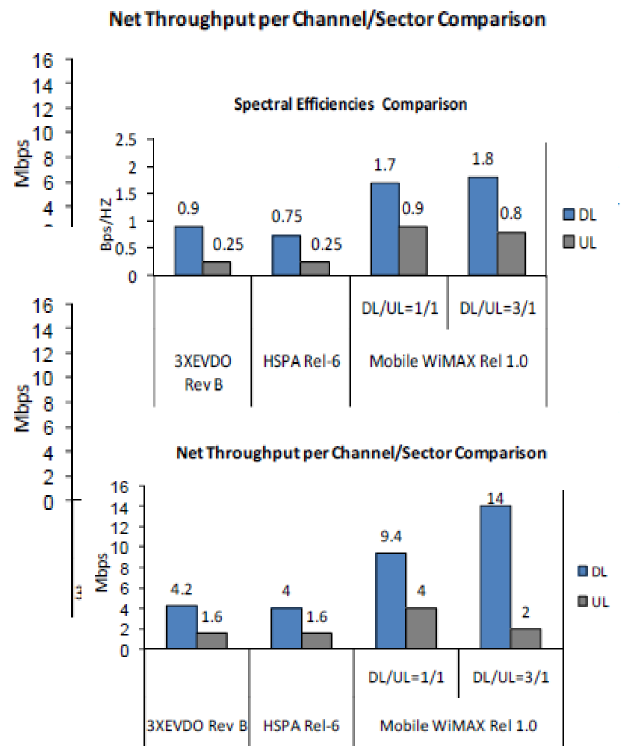

***Figure2**: Spectral Efficiency and Spectral throughput Comparison [3]*

To quantify technology differences, a throughput and spectral efficiency performance comparison is provided based on simulations using a common set of parameters for systems: Mobile WiMAX and HSPA.

Comparison between Mobile WiMAX with 3GPP like HSPA/HSPA+,

- Mobile WiMAX has higher peak rate.
- Two to three times greater DL sector throughput for same modulation, Coding and channel BW than HSPA.
- WiMAX supports channel BWs up to 20MHz, FDD and TDD.
- WiMAX support 1000 subscribers per base transceiver stations (BTS), the oversubscription.
- Factor for WiMAX is 38 while for HSPA+, it is 85.[1]

TABLE: PERFORMANCE PARAMETERS OF WIMAX OVER HSPA/HSPA+ [1]

DATA NETWORK	WiMAX	HSPA+	HSPA
Total Amount of Spectrum	30MHz	30MHz	30MHz
Spectral Efficiency per BTS	3.3bps/Hz	2.0 bps/Hz	1.2 bps/Hz
Base Station Total Throughput(Mbps)	99	59	36
Uplink and Downlink	66.7%	50.0%	50.0%
Network Loading %	80.0%	80.0%	80.0%
Available Downlink Throughput(Mbps)	52.8	23.4	14.4
QoS requirement per subscribers(Mbps)	2.0	2.0	2.0
Number of simultaneous subs	26.4	11.7	7.2
Total subscribers per BTS	1000	1000	1000
Over Subscription	38	85	139
Average kbps per subscriber	53	23	14

Source: WiMAX Forum

Based on 2008 IEEE 802.16m SRD specifications defining 802.16e spectral efficiency

3.2 Voice vs. Packet Traffic Forecast

WiMAX access technologies are viewed as solution to massive traffic increases that mobile network operator. Throughput rates of 100 Mbps or higher are regularly quoted, yet there is a larger challenge that is rarely given much thought; real bottleneck for WiMAX networks is current backhaul infrastructure.

WiMAX infrastructure was put in place for a very different service mix – one that was dominated by TDM voice and where bandwidth requirements were measured in kbps. With networks shifting rapidly to a data and packet domain (as shown in figure3), and demanding much higher levels of throughput to deal with unpredictable applications bandwidth consumption, lack of scalability of existing systems will start to be a major impediment to introduction of new services.

Packet end to end delay and traffic received are some issues related to Packet Scheduling in WiMAX Network. In case of various applications like voice, ftp and video conferencing average traffic received using Weighted Fair Queue (WFQ) scheduler is more than by using Priority Queue (PQ) scheduler. So in terms of overall performance WFQ performs marginally well than PQ. [5]

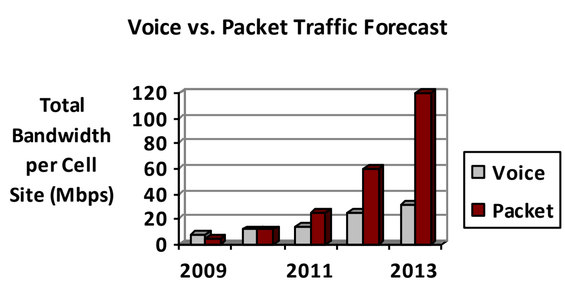

Figure3: Data is growing three times faster than voice, reaching 80% of total traffic by 2013 [4]

3.3 Data Usage and Revenue per bit (GB) Trends

With emergence of mobile data services, a valuable new revenue stream has arisen for operators. Growing importance of data services has prompted MNOs to design strategies to maximize the revenue-earning potential of these services. However, mobile data revenue is not growing as fast as mobile data traffic. What started as a small gap between revenue and capacity growth with 3G networks, threatens to be become an opening for WiMAX network operators. Data services currently account for 30% of mobile revenue, yet they consume almost 50% of the wireless capacity (as shown in figure 3). As data services increases continue, decline in revenue per bit delivered will see an equivalent decrease.

Traditional response by mobile operators has been to add additional T1/E1 leased lines or move to higher capacity circuits. WiMAX would drive backhaul costs to unsustainable levels, where bandwidth per base station will exceed 100 Mbps is follow this approach. Service providers operating traditional microwave backhaul networks struggle with high site leasing costs driven by large antennas and a substantial equipment footprint. Inefficient use of spectrum is another growing concern as spectrum leasing costs rise in response to decreasing availability.

Faced with these challenges and a need to evolve their current business model, mobile operators will look to monetize new high-value services. But in order to make this possible, they need to transform their network to one that is designed for next generation of mobile applications. Other critical element to their evolution strategy is to reduce cost per bit delivered – and since backhaul typically represents largest cost in a mobile network, implementing a lowest total cost of ownership backhaul solution will be a high priority.

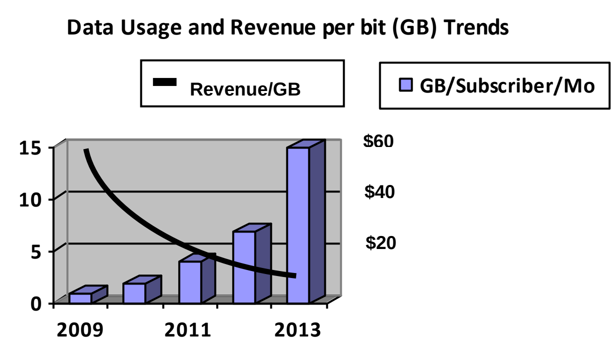

Figure4: Relationship between subscriber data usage and service provider revenue/GB. [4]

4. WIMAX: SPECTRAL EFFICIENCY GAINS SOLUTIONS

4.1 Integrated Solution for Wimax Operators

We can developed an innovative approach to LI that targets the specific requirements of WiMAX operators which intercept traffic from WiMAX operator and transmit it to Law Enforcement Agencies (LEA). LI allows LEAs to intercept voice and data traffic generated by or directed to a subscriber, regardless of the access technology used. It provides robust LI for all types of traffic and applications in any IP environment that supports mobility.

The challenges that WiMAX operators face in combining affordable service with a high-quality subscriber experience. Solution allows operators to meet all of their LI requirements by ensuring that LEAs can intercept all IP streams—voice, data, multimedia—at a point in network where they can be uniquely associated with subscriber. Depending on traffic type, core network components, and regulation, the network locations where IP streams can be assigned to the subscriber may differ. [7]

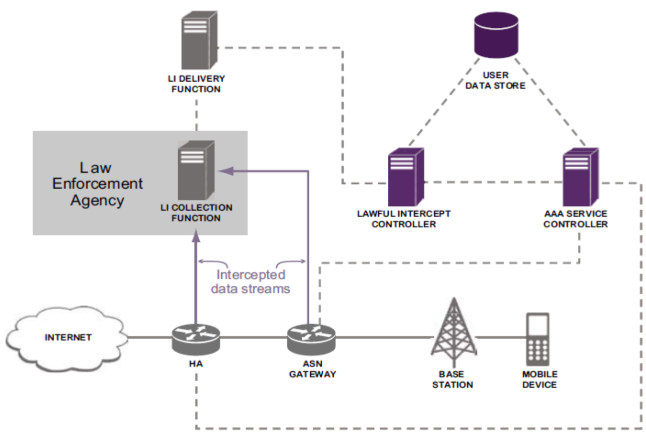

***Figure5**: Lawful Intercept Architecture for WiMAX [7]*

The solution employs three core product elements for performing these functions: the Service Controller (AAA), the LI Controller, and Subscriber Data Broker.

Service Controller translates subscriber's pseudo identity, which is used by WiMAX to identify subscriber, to real identity of subscriber contained in LI requests. When Service Controller receives accounting records from ASN gateway, it performs this translation before passing records on to the LI Controller.

LI Controller is a scalable and robust server that securely stores and maintains all of information on surveillance targets for on-network subscribers and inbound roaming users. When LI Controller is notified of a new subpoena, it first queries Subscriber Data Broker state database to determine if targeted subscriber is currently online. State database keeps a record of every authenticated subscriber for duration of subscriber's session. If there is an entry in database for targeted subscriber, LI controller sends subscriber's IP address and IP address of ASN gateway and/or home agent to Delivery Function.

If LI Controller does not locate an entry for subscriber in Subscriber Data Broker, it means that subscriber is not currently online. In this case, LI Controller continuously monitors subscriber authentications to determine when targeted subscriber starts a new session on network and then sends relevant information to Delivery Function.

4.2 Higher Order Modulation

WiMAX utilizes an adaptive modulation and coding scheme together with BPSK (Binary phase-shift keying), QPSK (Quadrature Phase Shift Keying) and QAM (Quadrature amplitude modulation) modulation schemes. The adaptive modulation allows highest order modulation to be chosen according to channel conditions. Higher modulation rates have provided a dramatic boost to spectral efficiency; moving from QPSK to 256QAM has driven a 4-fold increase in throughput. Additional complexity associated with these higher modulations does however translate into a reduction in system gain, which can affect performance during periods of heavy rain. Fortunately, techniques such as adaptive modulation, which automatically shift to higher or lower modulation rates depending on weather conditions, greatly enhance utility of higher order modulations by optimizing throughput for different classes of service.

When comparing microwave solutions, it is important to note that many of systems available today do not support higher modulation levels in small channel sizes. This is a very important consideration for operators looking for maximum efficiency across all available channel options.

Future advances in modulation depth are possible but this is a case of diminishing returns. For example, going from 256QAM to 512QAM adds significant cost and complexity, yet provides only a 12% increase in throughput. In addition, higher modulations entail greater export controls which will complicate procurement of these systems. Consequently, higher modulations alone will not deliver capacity and spectral efficiency needed to support advanced WiMAX services. [1]

4.3 Cross Polarization Interference Cancellation (XPIC)

One approach used to effectively double capacity within existing spectrum allocations is to transmit on both vertical and horizon polarization of RF channel (as shown in Figure 6). XPIC filtering of cross-polarized signal allows two separate data streams to be transmitted over same channel. This technique does require additional hardware but this capital expenditure is typically minimal in comparison to long term operations savings generated. XPIC is a less attractive option in countries, where wireless operators must pay for equivalent of an additional channel to operate a cross-polarized system.

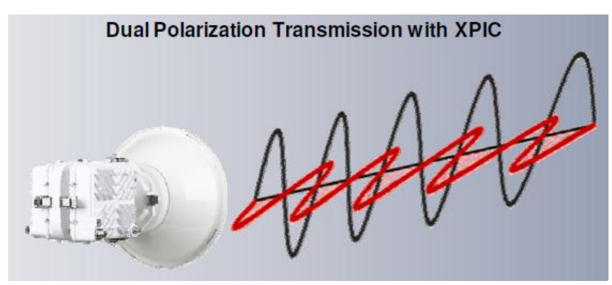

***Figure 6:** Dual Polarization transmission with an XPIC filter, doubling spectral efficiency. [1]*

4.4 ELIMINATING PROTOCOL CONVERSION

As mobile WiMAX networks move to a much more data-centric traffic profile, traditional SONET/SHD backhaul systems introduce significant protocol conversion inefficiencies and latency. Packet-based microwave systems are designed to transport IP natively, eliminating this conversion overhead. In addition, statistical multiplexing results in improved link utilization, enabling WiMAX network operators to deliver emerging services much more efficiently. WiMAX-optimized packet based backhaul networks not only allow for greater efficiency but they also enable advanced signal processing and bandwidth optimization designed to further augment the efficiency of backhaul networks. [1]

The Access Point (AP) need protocol converter/bridge to convey data from access to backhaul. Figure7 shows proposed protocol converter, which is comprises of traffic classifier, scheduler and protocol encapsulation/de-encapsulation. Local traffic is traffic from/to access network under same local community. The external traffic is the traffic from/to internet. First traffic is classified; then traffic is scheduled in to two queues based on traffic types. Finally, internet traffic needs protocol encapsulation due to different interfaces. [8]

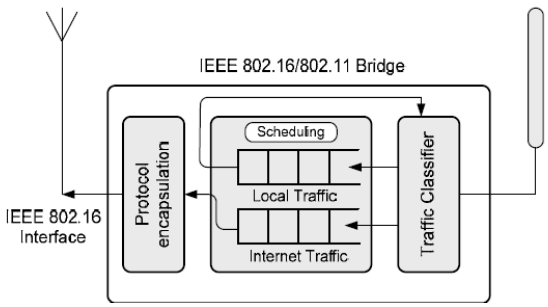

Figure 7: The proposed protocol converter/bridge between WiMAX and WiFi [8]

4.5 Bandwidth Optimization

One of most significant advances in WiMAX, and perhaps most effective means of cost effectively increasing spectral efficiency, is to implement bandwidth optimization technology. These base band techniques leverage white space suppression, header and bulk optimization, and lossless compression to eliminate transmission of redundant information. This leading edge capability drives a 2 times or greater throughput improvement. To provide higher capacity using limited bandwidth, it would be desirable to select more efficient schemes. However, these schemes are more vulnerable to interference and thus require a higher signal-to-noise ratio to ensure a fixed bit error ratio. [10]

When contrasted to alternative approaches, such as moving to higher modulations, advantages of bandwidth optimization are clear: going beyond 256QAM introduces additional complexity, increased interference sensitivity and a further reduction in dynamic range-all for small incremental increases in spectral efficiency. Bandwidth optimization techniques on other hand can yield well over a 100% improvement in spectral efficiency with no impact to system gain and little impact to system delay. By augmenting existing microwave solutions with bandwidth optimization technologies, WiMAX systems deliver a new level of spectral efficiency. For example: these advanced systems could allow an operator to backhaul over 200 Mbps of capacity in a cost effective 7 MHz channel an ideal solution for WiMAX base stations. [1]

WiMAX has a theoretical maximum bandwidth of 75Mbps. This bandwidth can be achieved using 64QAM 3/4 modulation. 64QAM can only be utilized under optimal transmission conditions. WiMAX supports use of a wide range of modulation algorithms to enable most bandwidth to be realized under all conditions. WiMAX has a theoretical maximum range of 31 miles with a direct line of sight. Near-line-of-sight (NLOS) conditions will seriously limit potential range. In addition, some of the frequencies utilized by WiMAX are subject to interference from rainfade. Rainfade may also refer to extensive cloud cover, strong winds, or any other environmental effect that distorts a satellite broadcast. The unlicensed WiMAX frequencies are subject to RF interference from competing technologies and competing WiMAX networks. [10]

5. CONCLUSION

WiMAX networks, and applications they enable, are demanding new levels of performance that will quickly drive many existing backhaul implementations to obsolescence. Engineered to meet the requirements of tomorrow's networks, WiMAX -optimized microwave backhaul solutions address technical and business challenges faced by next generation mobile operators. As a result, service providers can focus on offering new high-value services to their rapidly expanding subscriber base – and they can do so with the full confidence that their backhaul network will meet their evolving needs well into the future.

Spectral Efficiency and Sector throughput, Voice vs. Packet Traffic Forecast, Data Usage and Revenue per bit (GB) Trends are some of performance measure parameters of WiMAX technology.

In order to optimize issues, Powerful integrated LI solutions are based on its in-depth understanding of interworking of WiMAX core network elements, and of LI and business model requirements of WiMAX operators. LI solution allows WiMAX operators to meet both requirements and retain their focus on revenue-generating services. WiMAX are leveraging a suite of technologies including higher order modulation, XPIC, packet-based architectures, and new bandwidth optimization techniques to boost spectral efficiency to new levels. This is enabling operators to provide much more capacity in smaller spectrum allocations, which is a key requirement for WiMAX networks.

Looking forward, backhaul networks will continue to evolve in order to deliver higher levels of spectral efficiency, staying ahead of bandwidth demands of future mobile networks. By deploying WiMAX spectral efficiency gain solutions, service providers gain a significant advantage; both in the performance of their network and their ability to cost effectively deliver high value services and applications without running into a spectrum barrier.

ISSN 2229-5518

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ABRIVATIONS

AAA - Authentication, authorization, accounting servers

AAS - Adaptive Antenna Systems

BB- Broadband

BPSK - Binary phase-shift keying

BTS - Base transceiver stations

BWA - Broadband Wireless Access

EMS - Element management system

HARQ - Hybrid automatic repeat-request

HSPA - High Speed Packet Access

IEEE - Electrical and Electronics Engineers

IMS - IP Multimedia subsystems

IP - Internet Protocol

LAN -Local area network

LDPC - Low-Density Parity Check

LEA - Law Enforcement Agencies

LI – Lawful Intercept

MIP - Mobile IP agents

MIP HA- mobile IP home agents

MAN – Metropolitan area network

NLOS - Non-Line of Site

OFDM - Orthogonal frequency division multiplexing

OFDMA - Orthogonal Frequency Division Multiple Access

PAN – Personal area network

PQ - Priority Queue

QAM - Quadrature amplitude modulation

QoS - Quality of service

QPSK - Quadrature Phase Shift Keying

TCO - Total cost of ownership

VoIP – Voice over Internet Protocol

WAN – Wide area network

WCDMA - Wideband Code Division Multiple Access

WFQ - Weighted Fair Queue

WiMAX- Worldwide Interoperability for Microwave Access

XPIC - Cross Polarization Interference Cancellation