The Progression of WiMAX Toward a Peer-to-Peer Paradigm Shift

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Abstract

The standardization of worldwide interoperability for microwave access (WiMAX) represents an opportunity for a radical shift in viewing the Internet and its access systems. Considering the current constellation of the Internet service providers (ISPs), WiMAX can both improve its presence (by offering broadband connectivity where previously unavailable) and trim down its authority (if used as an instrument for ad hoc peer-to-peer networking). Therefore, the deployment of WiMAX is important for several stakeholders. It can be a source of substantial revenue for the equipment manufacturers and the ISPs, an alternative way of offering service for the content providers, and an opportunity for increased use of wireless commons in the broader society. In this paper, we look at a progressive model of WiMAX, starting from a wireless ISP (WISP) perspective, through social learning of the commons, and ending with a shift toward the peer-to-peer paradigm as applied to a network of interconnected wireless fidelity (Wi-Fi) users.

Introduction

Since the commercial deployment of the World Wide Web, the ways in which information is viewed, gathered, shared, and analyzed has changed drastically. As a result, many business models (if not most of them) rely on or incorporate the Internet strategic service component into their plans. The Internet has thus become a widely used common resource, just like water, oil, or public highways. In addition, the emergence of Wi-Fi has enabled wireless connectivity to the Internet, thus improving and increasing its availability and presence among customers [1]. With the emergence of WiMAX, there is an opportunity to establish wireless networking as a potentially new paradigm of Internet computing. WiMAX represents a technology that can enable customers to create their own manifestation of the Internet. By connecting individual (or corporate) Wi-Fi networks, it can go beyond the initial idea of extending the reach of wireless local-area networks (WLANs). It can create a notion of parallel Internet while still providing the conventional Internet connection as we now it.

WiMAX can alter current business models by enabling Wi-Fi owners to enter the circle of ISPs and mobile providers. The astounding success and acceptance rate of the peer-to-peer (PTP) Internet platforms (among Internet users) can be used as a case in point when providing an analogy to the potential use of WiMAX [2, 3]. Information is not only valued, but also shared among people like never before. With the emergence of WiMAX, the information shared in PTP networks can potentially evolve into a wireless network itself, providing access to various resources such as local databases, storage capacity, high bandwidth, etc. Learning from the lessons of the Wi-Fi deployment, it is necessary to explicitly evaluate the WiMAX environment (ISPs, mobile operators, content providers, current regulations in the telecommunications, social and economic trends, user needs and abilities, etc.) and the possible business models that can accompany it [26, 6]. The emergence of Wi-Fi hot spots clearly conveys the trend toward the idea of wireless commons as the center of the new style of collaboration. We use WiMAX technology as a possible enabler of the PTP paradigm shift in the broader society interactions. In addition, to address the current Internet and social developments, we describe an evolutionary model for WiMAX deployment with the premise of PTP networking as the foundation of its mature state.

Background and Current Trends

WiMAX represents a technology based on an evolving standard for point-to-multipoint wireless networking. It is being promoted by the WiMAX Forum, a wireless industry consortium with more than 100 members, including major vendors AT&T, British Telecommunications, France Telecom, Fujitsu, Intel, and Siemens Mobile [4]. Even though broadband wireless access has been used by enterprises and operators for several years, the standard developed by the Institute of Electrical and Electronics Engineers (IEEE), 802.16, is likely to accelerate the adoption of the technology and expand the scope of usage [5]. Basically, WiMAX is the common name associated to the IEEE 802.16 suite of standards. The first standard was officially published in late 2001 by the IEEE and was followed up by the 802.16a standard in early 2003. Both standards support peak data rates up to 75 Mbps and have a maximum range of 50 km. The frequency range is 10 to 66 GHz for line of sight and 2 to 11 GHz for non-line-of-sight standards. The WiMAX Forum expects to begin certifying equipment in early 2005 in the 3.4 to 3.6 GHz and 5.7 to 5.8 GHz ranges for both time division duplex (TDD) and frequency division duplex (FDD) systems [6]. For the time being, WiMAX has developed a single system profile with regards to the 5.8 GHz license exempt band and the 2.5 and 3.5 GHz licensed bands.

The Subtle Link between WiMAX and Wi-Fi

WiMAX has been referred to by many as an extension of Wi-Fi [7]. The main reason for such a relationship is the increase in range and bandwidth that WiMAX provides. Even though the technology behind WiMAX is not a result of incremental improvement of Wi-Fi [5], its emergence and market acceptance are based on the older standard, 802.11. Introduced in 1997 (when IEEE formally developed the 802.11 standard), Wi-Fi represents a technology that enables broadband Internet access via unlicensed spectrum in the 2.4 GHz and 5 GHz bands. In addition, the technology can also be used to wirelessly connect Internet protocol (IP)–based devices to each other or to a wireline network [8]. Wi-Fi can provide data rates up to 54 Mbps within a range of 20 to 100 meters. There are various applications of this technology, among which enterprise and campus networking, ad hoc networking, public access in “hot spots,” home networking, and others. Wi-Fi has a number of 802.11 standards (also known as the “alphabet soup”), which also was one of the primary problems in its commercial acceptance. Among the major issues concerning Wi-Fi, the most important were (and, in many cases, still are) the security of the wireless networks, quality of service (QoS), total cost of ownership (TCO),

compatibility of standards, and architecture of the networks [9]. Similar issues are at stake with WiMAX deployment, if we consider it to be the next stage of Wi-Fi evolution.

Market Trends

According to a report from In-Stat/MDR, the fixed wireless broadband (FWB) market will grow from $558.7 million in 2003 to more than $1.2 billion by the end of 2007 [10]. One of the primary reasons for such an increase is the introduction of standardized WiMAX technology. Similarly, ABI Research predicts that the combined equipment market for 802.16 and 802.20 (a standard that provides wireless broadband mobility) will reach $1.5 billion by 2008 [11]. The impact of WiMAX can be profound considering the broadband constellation in the United Sates. According to the research firm The Yankee Group, just 21 percent of homes and 51 percent of businesses in the United States had broadband access in 2003. Among the businesses, almost 90 percent of large enterprises and only 35 percent of small and medium-size businesses have broadband access [11]. This clearly identifies the small-to-medium enterprises (SMEs) as a near-term opportunity for WiMAX.

When considering these trends, it is inevitable to emphasize how truly ubiquitous the Internet has become as a means of global communication. Today, the total amount of packet-based network traffic surpasses traditional voice network traffic, and it is growing 125 percent per year, while voice is increasing at less than 10 percent. According to forecasts by market researcher Technology Futures Inc., at the given rate, voice traffic will be less than 1 percent of total traffic by 2007 [12]. Also, PTP file-sharing traffic volumes are at least double that of hypertext transfer protocol (HTTP) during the peak evening periods and as much as tenfold at other times [13]. More important, in the last mile, PTP makes up 80 percent or more of the traffic on the network. In October 2004, content provision became the leading on-line activity in the United States. More than 40 percent of the time spent on-line in the U.S. can be attributed to content distribution and acquisition activities [29]. As far as the nature of the content is considered, WinterGreen Research expects a $359.1 million worldwide on-line music market in 2003 to be $14.7 billion by 2009 [29]. In addition, emphasizing the social inclination toward the PTP collaboration platform, at any given instant, more than 7 million people are using PTP networks in the United States [29]. We use these developments as a case in point when trying to argue that PTP can be viewed as a dominating configuration in the future evolution of the communication and business models. If we add the recent trends and success of the IP telephony, particularly the case of Skype [14], it is clear that the WiMAX has a broad range of deployment opportunities leading toward possible success.

WISP as a Starting Point for WMAX

WISP can be considered as the starting point in the WiMAX evolution. Fixed wireless broadband is most likely to be the initial WiMAX target application. It appears that WiMAX is probably the most viable broadband alternative in markets where wired infrastructure is lacking [6]. The cost and complexity associated with traditional wired broadband infrastructure makes WiMAX the optimal solution for the significant broadband coverage gaps in the United States and the rest of the world (underserved areas). Even though market opportunities for fixed access in developed markets seem limited, newcomers in the ISP world can use the low deployment cost of WiMAX (as anticipated) to take market share of the incumbent broadband service providers such as digital subscriber line (DSL) and cable. Some estimates claim that WiMAX is likely to cost about one-fifth of a third-generation (3G) mobile network, but it is still unclear what volume levels are required to achieve this low pricing [6, 28]. According to *Wireless Watch*, it would cost $3 billion in equipment, towers, sites, labor, and setup costs to build a national U.S. WiMAX network

reaching more than 90 percent of the mainland population [27]. Since WiMAX can operate both in unlicensed and licensed bands, it opens the possibility of independent companies deploying regional or nationwide wireless networks that will compete with the established cable and wireline service providers. However, to provide and guarantee QoS, it is necessary to operate in the licensed spectrum. Therefore, wireless service providers with available spectrum but without broadband service offerings, such as Sprint PCS and Nextel in the United States, can be among the first to successfully deploy and commercialize the technology [6]. In addition, WiMAX has enormous potential to lead the technological leapfrog in areas of the world with a less developed telecommunications infrastructure.

To support a profitable business model, ISPs and operators have to sustain a mix of business customers (for high-revenue services) and residential subscribers (high-volume users with lower QoS) [15, 16]. The advantages of the broadband wireless access when considering WiMAX can be summarized as follows [17]:

- Lower TCO than traditional leased lines and faster time to market
- Higher flexibility in service delivery using shared or dedicated bandwidth
- Scalability in handling rural and urban subscriber densities on the same infrastructure
- Standardization that creates a volume opportunity for chipset vendors/silicon suppliers
- Standards-based, common platform that fosters rapid innovation and the addition of new components and services
- Security, performance, and reliability at or above the standards for leased line networks

WiMAX Integration Phases

It has been generally accepted that WiMAX applications will have to transition through the following three major phases [8, 18]:

- Fixed location private line service or hot spot backhaul (providing services to fixed private locations and/or backhaul between the mesh/Wi-Fi networks and the points of presence)
- Broadband wireless access, including WiMAX as inter-cell transport (combination of Wi-Fi and WiMAX for optimal end-to-end performance)
- Mobile/nomadic client connection (with the emergence of the 802.16e standard)

In addition to these phases, we propose a PTP complementary integration process (where the peers are Wi-Fi networks) throughout each of the phases. At the beginning of this process, WiMAX will serve as a backbone for 802.11 WLAN hot spots, where roaming users can access carriers' Wi-Fi services [4]. According to the International Data Corporation (IDC), the number of Wi-Fi hot spots worldwide is set to grow from about 50,000 to about 190,000 by 2008 [6]. Through price adjustment and social integration of Wi-Fi commons [19], WiMAX can interconnect Wi-Fi owners' private networks (corporate or individual) and create a PTP-based network architecture. In this case, we will refer to the Wi-Fi network itself as a peer.

Since PTP has become popular through file-sharing platforms such as Kazaa and BitTorrent, WiMAX is supposed to provide similar capabilities, but in a more general sense. This means that users can chose their own path to a particular location (Wi-Fi network) through optimizing their peer relations. In addition, content providers can introduce their services in a more localized (and more secure) manner by personally selecting the networks of presence. The shift toward a PTP–driven paradigm lies in the power of the commons and its willingness to share resources.

An Untethered View of the WiMAX Integration

The previously mentioned integration phases of WiMAX are developed according to the "tethered" operator-centric–driven model of the telecommunications process. In addition, they do not explicitly account for the emerging PTP trends in the technological and social (business) constellation of interactions. As depicted in *Figure 1*, we consider a shift toward an untethered view of the wireless commons based on the promising PTP paradigm.

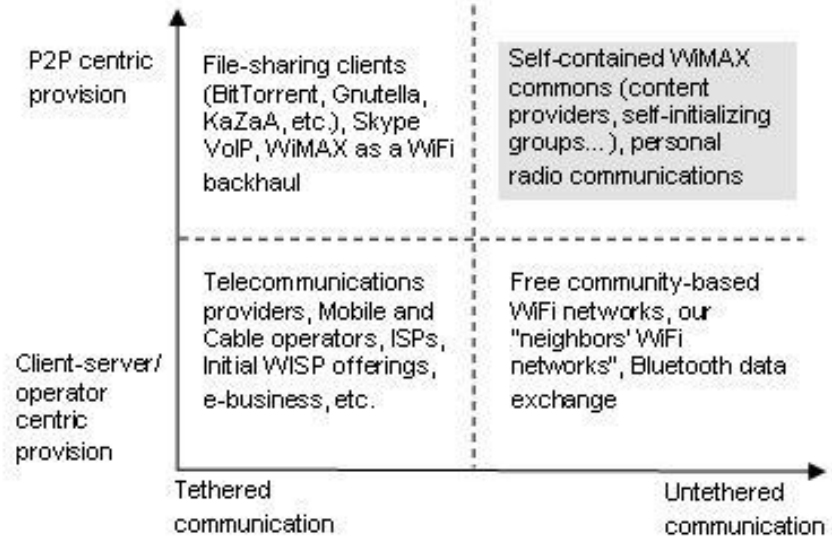

Figure 1: *The Untethered Positioning of WiMAX*

Basically, we see a transition from the current peer-to-peer client platforms toward an untethered collaborative effort of the wireless commons. Even though the first WISPs are supposed to provide services according to the conventional operators' view of telecommunications, the increased use of WiMAX as a Wi-Fi backhaul, along with the continuous proliferation of the community-based hot spots, is likely to have a profound influence on moving WiMAX toward enabling self-contained and self-initializing WiMAX commons.

Wireless Commons and the Peer-to-Peer Paradigm

The emergence of WLAN infrastructure has allowed entrepreneurial organizations to engage in a dynamic process of clustering private and public WLANs to create pervasive wireless broadband networks [20]. Some of these initiatives have evolved into a community-oriented wireless commons, in which participants share their Wi-Fi networks with others. At the same time, through peer-to-peer networking, Internet users exhibited unprecedented willingness for information sharing (collaboration). They have allowed people from around the world access to their own files, and by borrowing their resources (bandwidth, processing power, storage), they facilitated the global effort toward the PTP paradigm shift. On the other hand, this initiative for information sharing comes in times when "new" knowledge is the essential builder of competitive advantage and the major driver of innovation [21]. Both individuals and corporations have hoisted the value of readily accessible information and PTP may seem to be not only the new technology paradigm, but the social and business one.

PTP represents a paradigmatic shift from the client-server model (both in the computing and business worlds) and assumes a dynamic interchange of goods and services, actively involving all participants. This PTP mechanism was formally defined as the action of mutually exchanging information and services directly between the producer and the consumer to achieve purposeful results [22]. A more precise definition was provided by the PTP Research Group, Internet Engineering Task Force (IETF)/ Internet Research Task Force (IRTF) [23]: "(PTP) is a way of structuring distributed applications such that the individual nodes have symmetric roles. Rather than being divided into clients and servers each with distinct roles, in PTP applications a node may act as both a client and a server."

This definition underlies our evolutionary model of WiMAX. Once the technology is accepted and commercially deployed, the Internet will no longer be the only access system for information servers. Instead, the Wi-Fi owners, both individual and corporate, will engage in a dynamic PTP participation, creating, offering, and sharing their own resources and services. This means that the need for a third-party enabler of the information (or resource) transfer (such as operators or ISPs) will be reduced to a minimum. In the new architectural paradigm, the traditional operators and telecommunications providers will have to adapt to the user-shaped and user-driven world of communications.

Peer-to-Peer WiMAX Commons

The evolutionary process of WiMAX is not going to be swift. It depends on many factors, both technological and social. The first step is acceptance from the current incumbents in the broadband arena and the new service operators. In addition, by resolving the mobility issues (advancement of 802.16e), WiMAX will create the opportunity to successfully penetrate the commercial barrier. Another important factor for our premise is the establishment of the wireless commons. Rao and Parikh [19] consider the bandwidth crunch, network integration, and group dynamics to be the major technological and social challenges regarding the future of the community-based Wi-Fi networks. Since WiMAX may upgrade the position of the users to the current level of ISPs and content providers, individual actions and regulations play a focal point in the establishment of the Wi-Fi PTP paradigm.

Since the foundation for our view of PTP WiMAX commons is the process of hot-spot interconnection and integration, we argue that instead of global Internet connectivity, many current applications and businesses can be better utilized if using the localized Wi-Fi constellation. *Figure 2* illustrates the possible integration of Wi-Fi commons using WiMAX. Each Wi-Fi network (hot spot) can be owned by individuals, corporations, or community institutions. In addition, each hot spot represents a peer entity that aggregates the genuine attributes of the local environment. Using WiMAX, these peers can be interconnected in such manner that their preferences are met most optimally. Generally, peers can be both individual users and groups of users or corporations.

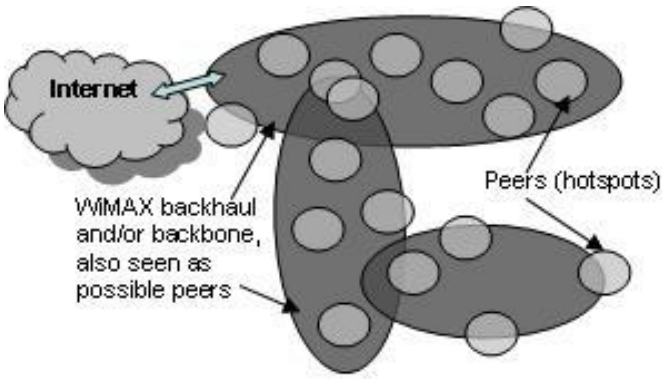

Figure 2: *Wi-Fi Integration Using WiMAX*

It is important to notice that even though WiMAX networks are supposed to provide Wi-Fi interconnection, their initial deployment will be as an Internet backhaul. We argue that the WiMAX progression will lead toward increased use of inter–hot spot communication, thus virtually creating a parallel Internet. In addition, the WiMAX networks themselves can be considered as peers in the new architectural setup.

The peer networks enabled by WiMAX will differ in their needs and organizational structure. Since they will be characterized by high peer-selectiveness (meaning they/peers will participate based on their genuine properties and localized attributes), the WiMAX commons will range from family/friends type of peer relationships to business-to-business content distribution networks. In addition, it is our belief that separate WiMAX PTP networks will appear as new peers (integrated peers resulting into one aggregative peer) when dealing with larger, content-oriented business peers. For example, if all universities in New York are considered to be peers, and their local Wi-Fi commons are integrated via WiMAX, their aggregation can be considered as one peer. Furthermore, universities in New York and Pennsylvania universities can be seen as one peer when dealing with institutions such as NSF, ETC, and other similar to them.

Considering the wide range of possible WiMAX communities, we have selected the following structures as the most evident representatives of the previous:

- Informal, local groups—These groups consist of family members, friends, neighborhood members, and smaller, local service providers. The main purpose of these wireless commons is to share personal information and computer resources, such as bandwidth and storage. In addition, they may consolidate with each other and represent a single peer when dealing with other content-providing peers.
- Scientific research communities—These groups can use WiMAX technology to optimize their resources and level of collaboration. They can also integrate their research effort and allow secure content distribution.
- Education and local government communities—As in the previous example, one possible WiMAX community can be consisted of various educational institutions. In addition, local authorities can deploy their own WiMAX network and interconnect to other communities in the same environment.
- Professional and business communities—These communities refer to a specific group of users that share similar characteristics and needs (such as finance, stock news, entertainment, politics, sports, etc.).

- Local ISPs and mobile operators—Along with the previous communities, telecommunication providers can also use WiMAX to better utilize their resources (increase the mutual collaboration), and acquire and distribute user-specific content. They are supposed to be the first group to introduce WiMAX, mainly as a last-mile broadband access to underserved areas.
- Corporate communities—The enhanced QoS capabilities of WiMAX, along with the high security and bandwidth, can be used by corporations to build a very effective means of inter- and/or intra-collaboration with other corporations and stakeholders. They can further utilize their peer networks for high-quality voice applications and connection to the content providers.
- Professional content distributors—Content distributors can use the PTP design of the WiMAX communities to provide secure, timely, and localized access to various types of content (video on demand, financial information, etc.)

Conclusion

The latest developments in WiMAX technology may prove to be an important driver of overall wireless broadband evolution. After the introduction of Wi-Fi and its successful commercial adoption, WiMAX can also be viewed as its integrator and aggregator, and a potential bridge across the digital divide [5]. Because of competitive equipment prices and low operation costs, the scope of WiMAX deployment will broaden to cover markets where the low plain old telephone service (POTS) penetration, high DSL unbundling costs, or poor quality of conventional telephony lines have acted as a brake on extensive high-speed Internet and voice over broadband (VoB). In addition, the forecasts predict that WiMAX will reach its peak by introducing the portable Internet (WiMAX with embedded mobility). Such an outcome is possible when low-cost WiMAX chipsets are going to be integrated into laptops and other portable devices. The technology is supposed to provide high-speed data services on the move, extending the current limited coverage of public WLANs to metropolitan areas. The combination of these capabilities makes WiMAX an interesting technology for a wide diversity of stakeholders, such as fixed operators, mobile operators (2.5G, 3G, and 4G), WISPs, various vertical markets, and local authorities.

In this paper, we have tried to look beyond the technical capabilities of WiMAX and integrate the emerging technology with other existing business, technology and social trends. As PTP seems to be an inevitable paradigm of our current networking constellation—both from business and social perspectives—we argue that the same PTP architecture can be overlaid on Wi-Fi networks using WiMAX technology. In this case, peers are not just the individual users, but also the Wi-Fi networks themselves. This architecture is basically an evolution of the emerging wireless commons [19]. For wireless commons to survive and flourish, the society (businesses and individuals) has to accept and capitalize on the premise of communities of practice [24, 25]. In addition, there has to be a shift in the business practice allowing users (literally the Wi-Fi owners) to dynamically participate in the value creation. Such a shift assumes that instead of client-server–based business relations, the current Internet users need to evolve into entities that will actively participate in the configuration of the wireless networks (powered by WiMAX) and the trade of their resources and content. In a way, the users will have the authority (and responsibility) that now lies in the hands of the operators and ISPs. If the evolution is successfully realized, it should provide higher connection speed, increased reliability, lower operation costs, optimized interconnectivity, higher content control, and enhanced adaptability to the local environment. Basically, the PTP WiMAX architecture may prove to be the “natural” cure for the immense problem of regulating the digital content distribution.

We consider WiMAX to possess the capability to change the current communications paradigm and give users the power to shape and control the processes of accessing and utilizing the communication networks. The time has come for an integrating technology that simplifies wireless broadband.

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