Business Opportunities and Considerations on Wireless Mesh Networks

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Abstract

Wireless broadband and Metro WiFi are sweeping through municipalities, campuses, enterprises and public safety organizations creating a buzz of excitement and anticipation unseen in the communications arena since the advent of the Internet. In this networking landscape Mesh Networks are emerging as the wireless technology of choice, offering a cost-effective solution for providing low cost, reliable network access. Even as the potential of wireless mesh networks has already been well documented, it still remains to be seen whether this promising technology can achieve high market penetration in diverse application areas. In this paper we explore some well known success stories of wireless mesh solutions and identify market trends with regards to wireless communication and opportunities for business exploitation.

1. Introduction

The architecture of Wireless Mesh Networks (WMNs) [1], [2], [3] is a first step towards providing high-bandwidth network access over a specific coverage area. The WMN architecture is built of peer radio devices that don't have to be cabled to a wired port like traditional WLAN access points (AP) do. The mesh architecture sustains signal strength by breaking long distances into a series of shorter hops. Intermediate nodes not only boost the signal, but cooperatively make forwarding decisions based on their knowledge of the network. In essence, each device (cell phone, traffic light, laptop, car, etc.) serves as a mini-cell tower, wirelessly routing and repeating signals received. Each device added contributes to the size, reach, and bandwidth of the network, making it robust, decentralized, redundant and highly scalable. Such architecture may, with careful design, provide high bandwidth, spectral efficiency, and economic advantage over the coverage area.

WMNs can extend the reach of Wireless LANs securely and cost-effectively for enterprises and end users and offer service providers new opportunities to drive increased revenue generation. The associated technology has undergone significant evolution in the past few years. As the cost of radios plummeted, mesh nodes evolved to support more radios [4], increasing the potential capacity of the network but also the modularity of the architecture, as each radio at a node operates at a different frequency.

WMN solutions are trying to address the market requirements for networks that are highly scalable and cost effective, offering end users secure, seamless roaming beyond traditional WLAN boundaries, and provide easy deployment in areas that do not (or cannot) support a wired backhaul. These solutions are well-suited for providing broadband wireless access in areas that traditional wireless systems are unable to cover. They make outdoor WiFi viable and are designed to enable a new revenue opportunity for service providers and to enable enterprises to extend their private wireless networks to outdoor areas.

The main features of WMNs are summarized below:

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- A cost-effective method for extending wireless coverage more broadly into business and end user markets.
- A platform for WLAN access that is highly flexible in terms of capacity, coverage, and availability.
- Self-organization and auto-configuration capability, as well as the ability to increase capacity, coverage, and/or availability by simply deploying more Wireless Access Points.
- The most cost-effective way to deploy wireless broadband services without investing in expensive radio spectrum.
- The ability to leverage consumer devices (wireless handsets, personal communications devices, etc.) that are inexpensive, readily available, and already exist in large numbers in the market.
- The use of wireless links for backhaul, which keeps the amount of new or additional Ethernet cabling or other necessary backhaul facilities to a minimum. In the case of service providers, this translates to faster network deployment and reduction in the costs of leasing facilities for data transport.

The rest of the paper is organized as follows. In section two, we describe market trends with regards to the Internet and wireless broadband in particular. Next, we discuss some well known business initiatives that explore the feasibility and the use of wireless mesh networks. In section four, we identify elements of successful implementation strategies and business models for the deployment of wireless mesh networks. We then describe the benefits of some of the latest developments in mesh networking, and discuss their impact on the commercial exploitation of such solutions. In the last section we provide some concluding remarks.

2. Market trends

One of the risks that an organization adopting wireless mesh technology is exposed to, is the fact that wireless networking facets such as technology, business, standards and market trends, are changing rapidly. To minimize this risk, continuing verification of market needs, technical validity of solutions and their applicability to the selected context is necessary.

A determining factor for the successful exploitation of wireless mesh technology lies in the future proliferation of the Internet, and of mobile and wireless broadband, in particular.

There are numerous factors that are driving the growth of the Internet. Some key driving forces are summarized in Table 1. The table shows important factors that have been recently significant and will continue to add growth to the Internet.

Table 1. Internet driving forces

DSL & broadband connections
Handsets with Internet access
Home LANs for Internet access devices
Wireless Internet access points
Web Content for wireless devices
Multifunction handheld devices
Un-metered Internet access fees
Internet entertainment content
$50 handsets with Internet access
Wireless broadband

The growth of wireless access points providing broadband Internet access to mobile devices is exceptionally strong, while low cost Internet access devices are expected to be a leading Internet user growth factor. Internet-enabled consumer electronic devices also have an increasing impact on Internet usage. We are currently witnessing an increasing number of 2.5G and 3G cell phones that have Internet access capabilities which will extend the time and place of Internet access. According to a recent study by IDC [5], one of the key drivers for the expected growth of these *converged mobile devices* (CMDs), or smartphones, lies in the power to use them, beyond basic telephony, to access email, the Internet, and to securely link to corporate databases. CMDs will also extend the number of Internet users—especially in developing countries where fixed phone lines are limited. We can therefore expect mobile and wireless Internet, and wireless broadband in particular, to have an increasing impact on the Internet growth in the years to come.

According to a recent study by Telecom and IT research firm Juniper Research [6], the number of worldwide subscribers using mobile Internet services will rise from 577 million in 2008, to more than 1.7 billion by 2013. This rapid growth can be explained by demand for collaborative applications known collectively as *web 2.0*, and greater 2.5/3G penetration, according to the same report. Based on the study's results, the importance of mobile and wireless Internet is steadily growing and revenue from mobile and wireless services will experience strong growth in the

following years despite the widespread economic gloom.

Another big driver for mobile revenue over the past year has been the growth in mobile data services. With more carriers subsidizing smart-phones such as the iPhone and the BlackBerry Storm, mobile data revenues are expected to see continued strong growth throughout the following years. According to a study by IDC [7], converged mobile devices, will demonstrate solid growth and will help keep the overall mobile phone market out of the recent economic crisis.

The growth on all fronts is creating a virtuous circle in which mobile and wireless broadband are achieving greater economies of scale, driving down the cost of devices and attracting even more users.

As voice communication and wireline broadband services become commoditized, telecoms must look for opportunities in untapped markets, i.e. offering mobile/wireless data services. For operators, a big concern is capacity, both in mobile networks and backhaul. Capacity demand is also likely to force carriers to look for other ways of building mobile and wireless networks. Wireless mesh networks are well positioned to play an important role in this context, addressing capacity aggregation and enhanced coverage.

3. Wireless mesh business initiatives

Wireless Mesh Networking is pushing wireless communication into a new era. Identifying market needs is crucial for a company in understanding the opportunities and acquiring a competitive advantage. Looking at some well known business initiatives, one can gain a lot of insight by understanding the factors that drove them to success or failure. In this section we take a close look in some selected business stories of WMN solutions which can help derive best practices but also to understand what is the gap in the communication technologies arena that WMN will be able to fill.

The first example involves California based start-up firm Meraki [8] which in early 2007 started delivering hardware and firmware to connect people through a community wide WiFi network in the area of San Francisco. What the offered solution provided was the hardware and software to manage a network. Free ad-supported Internet connection was also provided. At the heart of the business we find a $50 mini wireless mesh router which is neither the fastest nor the most powerful on the market.

Earlier similar attempts to provide citywide WiFi installations in cities such as Philadelphia and San Francisco were almost universally panned as failures; so it is interesting to identify the success factors that sustained the solution in the very same geographical context. We can identify two factors: the first is related to the technology used to implement the solution, while the second concerns the got-to-market strategy employed.

It is easy to see that both these aspects have attributed to the success of this business case. Compared with the offerings of other major players in municipal WiFi, which at the time were abandoning their large wireless projects, the key attributes that supported the viability of the solution were its relative low cost and the simplicity of network deployment and management.

Typical alternatives require high-end network access points and a controller to manage the wireless service, which quickly becomes expensive. Instead, providing the controller hardware as well as an intuitive, Web-based software package to configure and manage the network at a very low cost, lowers costs for partners and their customers, and streamlines the acquisition and training process for new resellers.

An even more aggressive approach can be followed by offering the WiFi equipment for free to residents who volunteer to deploy the equipment on their rooftops. In exchange for mounting the gear, free access through the wireless network could also be provided without advertising. Such a targeted approach focuses on smaller communities, neighborhoods, business districts and apartment complexes within a large city in order to slowly expand the network's presence and allow the provider to gain growth.

Through such a strategy there are several important things to be gained. First, the network provider has the opportunity to evaluate the deployments around the city area and stress test the network. Second, the test bed also provides the means to help resellers increase their revenue in municipal WiFi, a market which seemed unlikely only a few years ago, and cash in some of that growth by competing on price and using a simple *software-as-a-service* (SAAS) [9] based system. Another gain is the acquired knowledge on the economics of ad-supported Internet access and on the tools that resellers will need to serve their customers. What all this adds up to is information on market needs, which is invaluable for a company in adjusting and refining its business model to gain a competitive advantage.

From the perspective of the end-user the incentive to use the network solution is also important. In neighborhoods where the network has been deployed people can access the Internet while walking down the street, or they can get a repeater for in-home coverage. As the WiFi network is faster than the available 3G

networks, users would be inclined to jump on the WiFi network when there is coverage. Once users explore such "always-on" broadband access, their mentality towards the necessity of such a feature is likely to prevent them from switching back to a fixed DSL connection in the future.

Even the introduction of such an innovative service, however, is not able, on its own, to guarantee a steady, disciplined pattern of growth for the company offering the service. Careful business planning is required, ensuring that the market's needs are respected and addressed by subsequent offerings. A year and a half after going into business, Meraki severely changed its pricing policy and downgraded the features available on its wireless routers – e.g. billing, user authentication and access control, were only included in their high-end solutions. This apparently did not strengthen the company's position in the market sector it helped to create.

The second example we will focus on involves Open-Mesh [10], which went into business in 2008 providing inexpensive mesh WiFi routers and offering ad free service, trying to fill the void left by Meraki. The management software used is open source and is deployed on top of OpenWRT.

In this case, the business model is even more aggressive, offering a web based management system which is free and fully customizable. Furthermore, the devices support auto-configuration making it straight-forward to create a neighborhood or apartment network. The small mini-routers that are provided come pre-flashed with open-source mesh firmware. They are ready to plug in and use with no configuration being necessary. A customer need only plug the router into a DSL or other Internet connection and put additional mini-routers where Internet access is required to extend the WiFi range.

The business model is focused on supporting simple, cheap, open source, do-it-yourself wireless mesh networking. Rather than trying to provide a wide-ranging, citywide access area, a more targeted, neighborhood approach is followed, which also involves closely working with local chambers of commerce to develop opportunities.

It is easy to see that this approach is essentially building on the flourishing reseller community, taking advantage of this existing environment. The low-cost, high-performance mesh network technology employed uses easily available, cost-efficient, off-the-shelf components. Backed by a hosted software-as-a-service back-end architecture the offered solution simplifies network management and reduces operational expenses.

Furthermore, using commodity components and off-the-shelf hardware can help resellers compete on price with vendors such as Cisco Systems. Using a software-as-a-service model not only eases the learning curve for wireless solution providers, but can also give partners the opportunity to generate recurring services revenue.

In our last example we look into the wireless network of Ozone [11], a 2003 French start-up company. Ozone went into business trying to deploy a pervasive network over Paris, offering cheap and flexible connectivity operating on unlicensed frequency bands. The network has been deployed using multi-radio antennas on local rooftops to provide local coverage. Access on the rooftops of buildings is acquired by offering free access to services to the individual owners.

Following the well established model of free access offerings to the public, the company was able to ascertain the technical feasibility of the initiative and slowly expand its client base. Adopting a careful pricing strategy it explored the economical viability of the initiative and a steady growth lead to its 2007 buyout by Neuf Cegetel, the second major telecom company in France.

Besides looking at the business strategy that has been employed, which is not much different from that in other similar WiFi solutions, it is interesting to look also at the network architecture in order to identify key features which are necessary in deploying a successful city-wide installation, but also to identify limitations and areas of concern.

A first key feature of a WiFi installation is the ability of the network to provide sufficient coverage. In a typical architecture each rooftop installation is equipped with omni-directional, sector, and directional antennas to provide enhanced coverage. Each roof is connected to a concentration sector antenna located on a high building in the city. Each of these buildings uses several concentration sectors and is connected to the Internet through fiber. For example, according to Ozone, 1000 rooftop installations are able to provide a first mapping of the city area of Paris (105 square kilometers), with each rooftop antenna covering a 200m radius area.

Full city coverage, however, can only be provided through additional deployments. Tried examples of such deployments mainly involve lamppost deployments in which a network of multi-radio access points provides seamless mobility to clients moving within the effective coverage area. The majority of the lampposts can be backhauled by wireless network, but some can also be backhauled by DSL or WiMAX links.

Other important challenges that need to be addressed in deployments of wireless networks involve interference management and Quality of Service (QoS)

provisioning. Supporting QoS is vital in enabling a rich set of applications and scenarios but currently this is accomplished by over-provisioning of bandwidth and other resources, which is clearly not an ideal solution. Latest developments in wireless mesh networking [12] address these issues, enhancing the infrastructure of wireless networks by providing efficient resource utilization, reducing operational and management costs, and supporting secure routing and wireless communications.

Successful examples such as those described here by Meraki, Open-Mesh, and Ozone, have driven major vendors such as Nortel, Cisco and Motorola to take the plunge and start offering their own WMN solutions. In table 2, we describe the key features of the described business initiatives.

Table 2. Key features of reviewed business initiatives

Feature	***Meraki***	***Open-Mesh***	***Ozone***
Target market sector	Wireless network & equipment provider	Wireless network & equipment provider	Wireless ISP
Target user community	ISPs	ISPs	End-users
Initial free wireless access offering	Ad-supported	no	yes
Wireless solution	Wireless mesh	Wireless mesh	WiFi
Router auto-configuration support	yes	yes	no
Deployment type	City-wide, Ad hoc	Ad hoc	City-wide

4. Identifying successful implementation strategies

Wireless communication has grown significantly over the past few years and telecom companies are utilizing associated technologies to extend their reach in areas where there is no network infrastructure or where the cost to build it is high. However, addressing technical as well as economic issues needs careful consideration as wireless solutions gain ground in urban deployments and users get acquainted with the benefits of permanent seamless connections.

Through the business initiatives explored in the previous section we can identify several aspects of successful business strategies but also pinpoint specific failures associated with go-to-market planning of wireless mesh solutions.

The first point we can identify in a successful strategy is a pragmatic approach. In all of the networks we described it is evident that one needs to closely study the concrete constraints imposed by the construction of a WiFi based metropolitan network, and the supply of a direct wireless access to the end-user. Analysis must be further carried out in the light of users' real behavior and spending patterns, on the performance of WiFi and available equipment and the actual quality of reception obtained by the users. This is fundamental in understanding the technical viability of the solution, especially with regards to a city-wide installation.

This evaluation is crucial as it determines the performance of the network in real usage situations, which is likely to affect the user's acceptance of future pricing policies. It also provides an opportunity to review the changing WiFi specifications and take advantage of the richness of existing technical solutions. At this point, a set of concrete issues are likely to surface, such as coverage, interference, etc., and it will be very important to work on developing solutions before moving to a large-scale deployment or a change in the pricing policy.

The second point network operators must deal with is an evaluation of the users' interest on a wireless connection. Due to the fast growing base of wireless equipment in the market, the penetration of the technology is also proportionally increasing. But network operators need also understand the critical factors that affect the acceptance of wireless networks and wireless technology by the users. According to a recent study [13], the factors that influence the current and future intentions of users with regards to the use of wireless networks include (but are not limited to) the following:

- Relative advantage;
- Ease of use;
- Facilitating conditions;
- Wireless trust;
- Personal innovativeness in the domain of information technology.

Relative advantage refers to the degree to which an individual believes that using a particular system would enhance his or her job performance. Obviously, systems that are perceived to be easier to use and less complex have a high likelihood of being accepted and

used by potential users. Facilitating conditions are defined as the degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system.

Wireless trust can be defined as the extent of a user's belief that privacy protection, security assurance, and system reliability are achieved within a wireless technology. It is impossible to implement business applications in a public wireless environment without first setting up a trustworthy on-line environment. Therefore, all communications and transactions require an element of trust; especially those conducted in the uncertain environment of wireless technology. Finally, personal innovativeness is important because it has been argued that individuals with a higher-level of innovativeness are more likely to adopt an innovation.

A distinction between the initial decision to use the system and the sustained use of the innovation needs also to be made. Initial use does not necessarily indicate that the user will continue to use the target system.

According to the same research [13], the WiFi acceptance is mainly influenced by the relative advantage factor. Interestingly, this is the only factor found to have direct and positive influence on both current and future usage of the technology – all other factors have only indirect influence. The findings clearly suggest that the momentum generated by current use of wireless networks can be relied upon to prompt continued future use. Consequently, the favorable experience of current users of WiFi is instrumental in predicting future use. Therefore, operators of wireless networks must ensure a satisfying experience by meeting the benefit expectation of the initial users, with hope of retaining them as permanent users.

This last point can be exploited by operators through initial free offerings. The rationale of initially offering a free service (offered in the cases of both Meraki and Ozone) is that users accustomed to a wireless connection no longer wish to be restrained in terms of where they get network access. Such expectations are absolutely not addressed by utilizing wireless HotSpots. In this respect, content is also the key to increase market penetration. It's not enough just to have the infrastructure; people also need a reason to use the technology.

The willingness of users to pay for the service should be carefully calculated when deciding to change the pricing policy. Clearly, there are trade-offs involved in migrating to new business models. Customers must be convinced of the tangible benefits in making a change. As the example of Meraki has shown, the inability to understand what is the added value of the service to the users, and what can actually be charged, may lead to a loss of the competitive advantage. Furthermore, not all user communities are likely to respond in the same way to the service being offered. Adaptation of the marketing plan is therefore required, according to the context in which the solution is implemented.

Finally, understanding how to compete in the market is vital. Building the network with lightweight, cheap hardware that's easy to install, will keep deployment costs to a minimum and also provide the necessary flexibility to expand as necessary. Furthermore, employing a *Utility Computing* [14, 15] model would maximize the efficient use of resources and minimize the associated costs, while also help increase strategic focus by selectively outsourcing non essential technical skills and retaining the required business skills. Savings can be passed on to the users with an offer for mobile wireless broadband connections for a fraction of what mobile telecom operators charge. Use of technology that's less aggressive in terms of radio frequency emissions will also help reassure users using the service.

In table 3, we summarize the elements of a successful implementation strategy for the deployment of wireless mesh networks.

Table 3. Elements of successful implementation strategies

Adopt a pragmatic approach, analyzing the associated implementation and market constraints.
Evaluate the solution in real usage conditions to acquire reliable statistics regarding user needs.
Carefully identify and address ease-of-use and technical requirements.
Realistically measure the added value perceived by the users to determine an agreeable pricing policy.
Invest on an outsourcing strategy to enhance flexibility and minimize risk.
Closely follow technological developments to improve service and reduce operational and management costs.

5. Commercial exploitation of latest developments in mesh networking

Telecommunication service providers are always looking for solutions towards expanding their broadband network capabilities and coverage. Wireless mesh networking is currently one of the most

promising proposals in this field, providing connectivity in areas where wiring is not existent or is saturated. Existing wireless mesh networks, however, lack comprehensive QoS support and efficient resource utilization, which prohibit their large-scale deployment by network providers. Another concern, in the case of Ozone, who is not currently using a mesh solution, has been to enhance the resilience of the network and provide auto-configuration mechanisms.

Latest developments in mesh networking [11] address these shortcomings and provide network providers with a low-cost infrastructure which can easily adapt to changing demands in capacity and provide service to both fixed and mobile users. Providers can thus expand the wireless broadband market with innovative services, which can include real-time interactive and streaming services (e.g., VoIP, Video-on-Demand), mission critical and public safety applications (e.g., video surveillance), and future pervasive services. The added value for end users involves seamless mobility and QoS guarantees.

Mesh networks are clearly not expected to replace standard internet access options but to supplement them. For a network operator, formulating a successful business model to uptake these developments presents the possibility to differentiate itself from other operators by providing its customers with innovative services that offer a convenient and affordable way to access the Internet with a consistent quality of service while at home, at the office, or on the move. Providers can thus reduce time-to-market and reach superior operational status and competitive advantage in terms of cost-efficiency and coverage.

The introduction of such innovative services in an opportune environment is expected to both expand existing markets and create new ones, and offer an affordable and convenient way for customers to access the Internet from a fixed or wireless line.

6. Concluding remarks

In the past few years we have witnessed new needs in terms of mobility, communications, fluidity, permanent access to user data and free choice of content. Services must be redesigned so as to be accessible and usable wherever the subscriber may be, and not just where the ISP is. Our increasingly mobile society means that a large percentage of users will access the Internet through mobile and wireless Internet devices. People want access to the methods of communication and volumes of information now available on the Internet, at a cost they can afford, and in such a way that they aren't confined to a living room or office desk.

The upcoming changes will transform how business is conducted, how services are delivered, and how our limited resources and the built infrastructure are managed. Communities and companies that embrace the changes and realize the new opportunities will reap huge rewards. To be proactive and remain competitive it is imperative for businesses to provide the community with a convenient and affordable way to access the Internet from everywhere. The enabling technology that will drive this revolution is wireless mesh networking.

In this paper we have presented some business initiatives that realize and promote this new technology, in an effort to identify successful applications and market strategies. As is the case for every new technology, careful consideration of success stories and lessons learned are valuable in understanding its potential and ensuring its proliferation in relevant market sectors.

Large cities such as San Francisco, London and Taipei, have already undertaken successful wireless city infrastructure projects. Investigation of success factors in the deployment of such networks is thus becoming ever more crucial as other major cities around the globe are also expected to eagerly pursue their own wireless network projects, in order to raise their international competitiveness and acquire a more business-friendly profile.

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