Building Wireless Metropolitan Networks

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Abstract

This paper describes the main aspects of building wireless networks, as described by the e-City idea of municipal networks owned and controlled by a central authority versus the anarchic design of open communities using as a case study Patras Wireless Metropolitan Network. The paper points out the important economic aspects that lead to the rigorous development and notates the main issues when using commercial equipment, as in the hot-city project driven by Cisco and the City of Luxemburg. Some discussion is done to point out the main differences among the two case studies, in terms of offered services, network coverage and the impact to the local societies. The important criteria into characterizing each approach is a discussion on the vision, objectives, and the expected benefits to each of the involved parties. Finally, it is evaluated if such an investment is profitable and whether a wISP should deploy such an infrastructure even if the economic criteria propose otherwise. Finally, the paper concludes on how these could lead to further local business development, improving the value of the offered services.

Keywords: wireless – network – communications – network planning

1. Introduction

Current wireless and wired networks serve on bigger cause; the broadband networking. Broadband usually means fast connectivity, enabling people to quickly and easily send or receive large amounts of data. The exact speed of broadband varies depending on who is defining the term. Last mile mobile (wireless) or fixed (wireless or wired) access is the key to such development. One of the main advantages among wireless and wired networks is the fact that wireless networks have no setup fees for the end user and as long as the network operator has planned ahead, the extra cost for adding equipment should be expected within some boundaries. Furthermore, the client of the Wireless Internet Service Providers (wISP) can afford moving away from its present location without losing connectivity. What is being pointed out here is that wireless technologies in general has major advantages compared to the wired ones as long as they are used for last mile intra-connection between the end user and the intranet / internet operator. Another important aspect of wireless infrastructure is the subscribing business model. In wireless networks, no labour work is needed to make cabling connections and therefore it is easier to create business models that do not need contracts and one prepaid card should be sufficient to gain more customers in the market. This is crucial for people who do not have enough time to experience the whole cabling route like visitors, tourists etc. In addition, less amount of revenue is spent in infrastructure building, since no contracts with local authorities are needed and no labour effort is spent. Wireless networking in conjuncture with geolocation mechanism may provide the user with personified information in accordance with his habits and his special needs using some higher layer services.

2. The main wireless networking technologies

The main wireless networking technologies comprises of three main technology platforms; Wi-Fi, WiMax and GSM based.

2.1 Wi-Fi

Wi-Fi is short for wireless fidelity and is the term used commonly when referring of any type of 802.11 [Ra2] based network, which is the most widespread technology being used to provide wireless access today. There are four production protocols that are widely deployed namely

802.11a, *802.11b*, *802.11g*, and *802.11n*. The *802.11a* transmits at 5GHz and can move up to 54 megabits of data per second. It uses orthogonal frequency-division multiplexing (OFDM), an efficient coding technique that splits that radio signal into several sub-signals before they reach a receiver. This greatly reduces interference making radio transmissions more robust. The IEEE *802.11b protocol* is considered the oldest, though the least expensive standard. For a while, when the first open wireless communities evolved, its low cost made it popular, but now it's becoming less common as better standards become less expensive. *802.11b* transmits in the 2.4 GHz frequency band of the radio spectrum. It can handle up to 11 megabits of data per second, and it uses complimentary code keying (CCK) coding. Its importance arises from the fact that it is the mostly used standard from the Wi-Fi family and can be found even on legacy equipment. The *802.11g* operates at 2.4 GHz and is considered the successor of *802.11b*. It may transmit in rates of up to 54 megabits of data per second. *802.11g* is considered as the successor of the 802.11b protocol even though its main success comes from the fact that it is backward compatible with the *802.11b* protocol. The backward compatibility implies that any operating 802.11b device in every mode can inter-operate with every *802.11g* as part of the standard functionality. Finally *802.11n* is the latest standard and thus not so widely deployed. IEEE *802.11n* significantly improves speed and range. For instance, *802.11g* theoretically achieves a speed of 54Mbps, but in practice only 40Mbps due to network congestion. *802.11n*, however, reportedly can achieve speeds as high as 140Mbps with a maximum of 300Mbps (240Mbps at laboratory tests).

2.2 WiMax

Also known as the IEEE 802.16 [Ra1][Ra2] group of standards, WiMax defines a packet-based wireless technology that provides high-throughput broadband connections over long distances. WiMax can be used for a number of applications, including last mile broadband connections, hotspots and high-speed connections for businesses. The mobile standard 802.11e was just ratified by the Institute of Electrical and Electronics Engineers (IEEE), in January 2006. WiMax is similar to Wi-Fi in concept, but it has certain features aimed at improving performance and that should permit usage over much greater distances. The IEEE 802.16 supports continuous peak data speeds of about 70Mbps, with average user (subscriber to base station) data rates between 1Mbps and 10Mbps. It uses a combination of licensed and unlicensed bandwidth. Intel, along with several corporate sponsors, is working with the wireless industry to drive deployment of WiMax networks. The official name of the 802.16 suite of protocols is WirelessMAN, which also is the name trademarked by the IEEE 802.16 Working Group on Broadband Wireless Access Standards for its wireless metropolitan area network standard. In WiMax, subscriber stations communicate with base-stations that are connected to a core network. This is an alternative to fixed line networks that is simple to build and relatively inexpensive because no cabling needs to be implemented on customers premises.

2.3 GSM/cellular based

The GSM technologies considered in this paper are *EDGE, GPRS, UMTS,* and *HSDPA-HSUPA* [Rc1]*.* The *EDGE* (Enhanced Data for GSM Environment) is a digital mobile-phone technology that acts as a bolt-on enhancement to 2G (second-generation) and 2.5G General Packet Radio Service (*GPRS*) networks. This technology works in TDMA and GSM networks. *EDGE* (also known as *EGPRS*) can function on any network with *GPRS* deployed on it, provided the carrier implements the necessary upgrades. The *WCDMA* (wideband code division multiple access) is another name for *UMTS* (Universal Mobile Telecommunications System), which is defined as a cellular network. As the name suggests, *WCDMA* is based on CDMA technology and was envisioned for the next generation of GSM. It's a European standard designed to support data transmission rates of 144kbps for use in vehicles, 384kbps for pedestrian use and up to 2mbps for use indoors. The *GPRS* (General Packet Radio Service) defines a mobile data service available to users of GSM mobile phones. It is often described as 2.5G “that is, a technology between the second generation (2G) and third generation (3G) of mobile telephony. It provides moderate-speed data transfer by using unused TDMA channels in the GSM network. *HSDPA* (High-Speed Downlink Packet Access) on the other hand is a new mobile-telephony protocol that's often called 3.5G or 4G Internet. Its purpose is to increase the

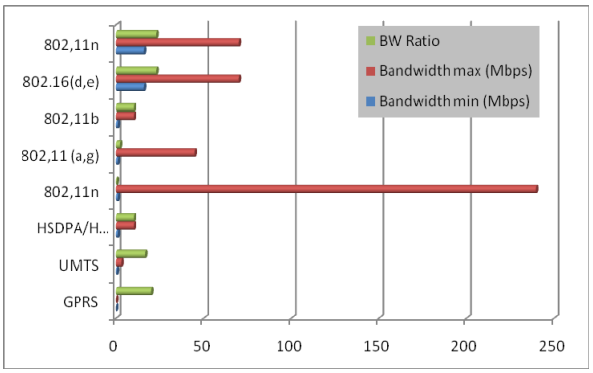


Figure 1: The bandwidth capabilities at a glance

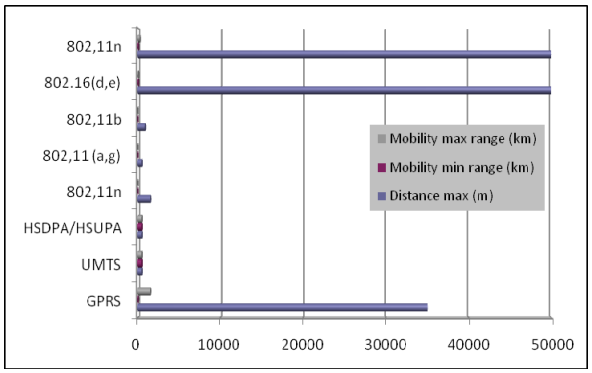


Figure 2: The protocol's range capabilities at a glance

download speeds of the WCDMA networks. In contrast *HSUPA* (High-Speed Uplink Packet Access) is an under development new data access protocol for mobile-phone networks that aims to increase upload speeds of WCDMA networks. As it is done with HSDPA, some people refer to HSUPA as 3.5G or 4G mobile Internet. While most Internet applications, such as Web surfing, music and video downloads, and e-mail, rely heavily on downlink speeds, applications such as video conferencing, telemetry services high definition audio also, require fast upload speeds. It is expected to hit the market around 2011. Figure 1 and 2 summarize bandwidth and range capabilities of all the wireless networking technologies discussed above.

3. Comparison with other broadband technologies

An organization interested creating a metropolitan area network has many benefits using wireless links than traditional wire line infrastructure. Firstly, by design cable based services have to terminate in a local office (BBRAS for DSL), then enter the IP routing core and again pushed down to the local core and routed back to the destination. This data path is much longer and computationally more "expensive", thus creating extra complexity and delay to the packets. Furthermore, the bandwidth that such an overhaul may provide is by far inferior to that a wireless network can offer. For example using DSL in order to create a local LAN (using tunnelling techniques e.g. VPN) means extra delay of one order of magnitude and lower bandwidth of two orders of magnitude compared to the slowest WLAN technology still in use. Table 1 clarifies these statements in such a setup with average values concerning network performance of each technology. The setup in this figure concerns a standard 1 hop private network (using varying underlying infrastructure) located in the geographically dispersed locations of the same municipal.

4. Economic key aspects

In order to empower our evaluation, we tried to analyze some of the most important aspects of the wireless technologies available for ISPs. The first economic estimation based on [TES1][TES2] is the cost per installation matrix (Figure 3). We considered current/real market prices for equipment and further that all technologies are license-free (which is not the case in most countries). The labor costs are sophisticated estimations, in accordance to the previously mentioned economic studies. One key characteristic of every network operator is the bulk bandwidth. According to the cost matrix, we calculated in Figure 4 the bandwidth cost per technology. According to our measurements the most cost efficient technology for deployment in terms of bulk bandwidth is the 802.11n technology followed by the WiMax technology and the 802.11 family of standards. GSM based technologies do not provide adequate results in this index metric. This reveals the main disadvantage of GSM and the main advantage of the IEEE protocols. GSM was not designed to cope with bursty data traffic while IEEE protocols were. In addition, GSM expansion packs do not cope with the efficiency neither of the WiMax nor of the Wi-Fi. The verdict of this comparison is that GSM is not sufficient for high capacity data transfers and is not an economic solution for such a scenario. The second economic consideration was about the number of subscribers in contrast to the cost. In this index metric

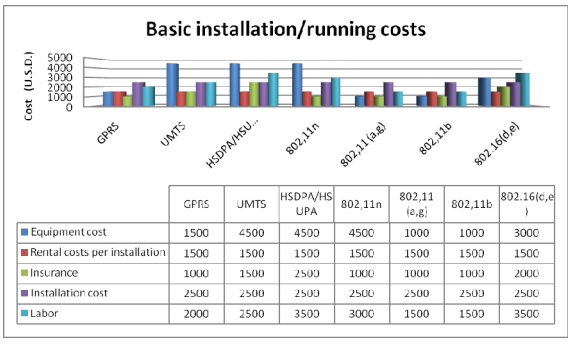
Type	Capacity	Latency	Max PPS	Jitter
DialUp 56k	4kbyte/s	34 ms	150	20%
DialUp 128k	7kbyte/s	25 ms	150	10%
ADSL 2mbps/256kbps	25kbyte/s	90 ms	300	20%
ADSL 24mbps/2mbps	200kbyte/s	90 ms	300	20%
802.11b	200kbyte/s	3 ms	1,5k	10%
802.11a	3Mbyte/s	3 ms	3k	10%
802.16	6Mbyte/s	3 ms	10k	10%

Table 1: the average network characteristics of major broadband infrastructure for (virtual) LAN usage

(Figure 5), we analyze the expenditure the carrier has to compensate for the actual maximum number of users per installation. In this assessment the GPRS has a good performance, followed by WiMax technology and the 802.11n set of standards. The other GSM technologies cannot satisfy many users at the same installation at the same time, whereas the same case holds for the 802.11{a,g} protocol suite. This is due to the design of the protocols. GPRS has the best performance thanks to the small bandwidth allocation per user it makes (at the same time it has the worst index metric in the previous evaluation), while the other GSM expansion packs cannot satisfy the same amount of clients as GPRS does. On the other hand, 802.11{a,b,g} protocols albeit they theoretically support an unlimited number of concurrent users, practically there are some limitations. Cisco suggests the usage of one channel to be spanned up to 15 people, whereas other suppliers suggest equally low numbers (i.e. 3COM). WiMax behaves better because it was designed to support large amounts of individuals while sustaining high data rates. Based on these two economic dimensions, there is a strong indication that the newest set of technologies, WiMax and 802.11n, are the technologies of the future. In addition, it is clear that GSM based networking access is overpriced especially for the grown-up technologies like GPRS.

5. Network Planning

Network planning [NP1] is a placing problem of network equipment in some (geographical) area, in order to serve networking demands better and it roots back to the electrical power distribution by civil engineers. *Network planning* [NP1][NP2] today is realized as an recursive analytical process, encompassing topological design, network-synthesis, and network-realization, and is aimed at ensuring that a new network meets the needs of the subscriber and operator. Literature proposes various heuristic schemes in order to validate and create under some conditions a suitable network overlay though no deterministic algorithms exist. Many parameters may alter the results of such algorithms, especially unpredictable incidents that have no direct connection with the technology itself. For instance in Greece in many occasions cellular operators were forced to changed their network planning (after deployment) under aggressive public demand, or under changes of law status quo. In general most textbooks analyze the problem in four steps; the business plan, the long term planning, the short term planning and finally the operation and maintenance phase. The actual planning though is split in



	GPRS	UMTS	HSDPA/HSUPA	802.11n	802.11 (a,g)	802.11b	802.16(c,e)
Equipment cost	1500	4500	4500	4500	1000	1000	3000
Rental costs per installation	1500	1500	1500	1500	1500	1500	1500
Insurance	1000	1500	2500	1000	1000	1000	2000
Installation cost	2500	2500	2500	2500	2500	2500	2500
Labor	2000	2500	3500	3000	1500	1500	3500

Figure 3: Basic installation cost per installation

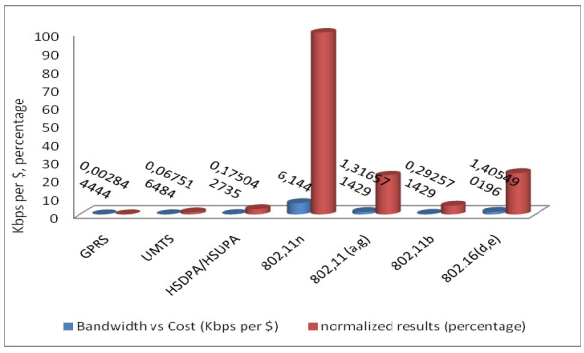


Figure 4: Bandwidth cost per technology

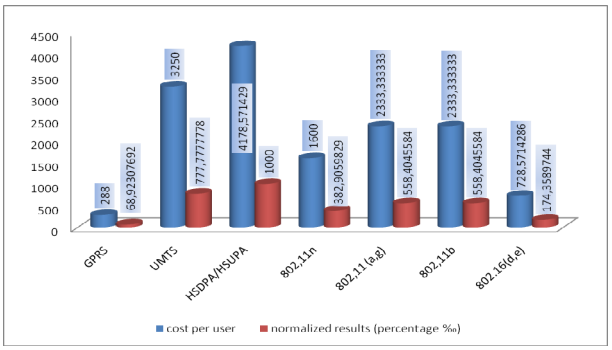


Figure 5: Cost per user

3 phases; the *topological design*, the *network synthesis*, and the *network realization*. In *topological design* decisions are taken using as parameters the GIS information of the area, and the expected customers in that area. At the *network synthesis* phase the process dimensioning the needs, while in the *network realization* the *multi-commodity flow problem* is approximated in order to cover the demand raised by the subscribers for different kind of services. While the above seem trivial, they aren't, and much of ISP's software [NP3] is focused on optimizing the network outlay. Well known platforms for such tasks are Cisco's NPS, and OPNET's SP Guru NP.

6. Netwide Services

Different organizations when building their own infrastructure have different service offers and business plans. These services may be available on one of the following fields; government to citizen, business to customer, business to business, or user to user services. The three first categories are the ones that can be charged, thus offering revenue to the service owner while the fourth provides the user the flexibility to create his own services. The last spot is equally important due to very popular peer to peer services. The user to user services also help growing the community aspect of the network, while creating and sustaining a strong relation between end- users, thus creating a core of "loyal" customers. Key role in a success story should be the agreements with local authorities offering public services. Such services include online tax payment, certificate authoring etc. Business to customer services concern the (paid) services offered to users by other private companies, like digital entertainment, IPTV, etc. Advertisement is another popular service offering high revenues. Finally, the business to business services cover all the services a private business may require in terms of outsourcing. Such services are IT design and support, communications and other custom relayed services that may be important throughout the business lifecycle. It is considered that almost 20% of the revenues of a high tech company come from the business to business support.

7. The case studies

Based on the previous analysis, two case studies will be presented as paradigms on how individuals (PWMN) or private companies (HotCity initiative) developed their own wireless metropolitan infrastructure. The common ground for both examples is the choice of the networking standard. Both used IEEE 802.11 protocol suites either for client access, backhaul connections or both. The choice seems to follow up with the abovementioned economic analysis and obviously it is logical and profound given the justification in paragraph 4. The first case study is Hotcity [HC1] that is an initiative of the City of Luxembourg to build a municipal wireless Internet infrastructure. Until the end of 2009, a seamless mesh network of 400 access points will be deployed to allow access anywhere in the boundary of the City of Luxemburg. Hotcity is part of the e-City vision, whose aim is to create a virtual city allowing the citizens to access or benefit from a wealth of public and private services via fixed or mobile infrastructure. Hotcity is an open project inviting public services, businesses, retailers, application editors and independent stakeholders to join in with offering added value services to all types of users. Hotcity uses the Wi-Fi technology to connect computers or PDAs to the network, instead of connecting your appliances with a cable. It is a confined environment in which one can move freely and use the services put at his disposal. Private also means that user's equipment has to be connected to one of the Hotcity antennas. Hotcity applications are not visible on the global Internet network. Hotcity is a centrally managed network driven by open market policies and a strict business plan designed by the city of Luxemburg. In fact as described in the [HC1] the plan goes beyond 2009 and so does the economic planning. According to the [HC2] the profits have already covered the initial investment and at the present time the business are booming.

In addition to that the management has already decided the new coverage map wrapping bigger areas. HotCity at the present time offers e-gov services in addition to VoIP, internet and private business services such as e-banking.

The second case study concerns Patras Wireless Metropolitan Network [PW1] (PWMN), which is a public, free, open Wi-Fi network is based on a community of individuals who all share the same hobby; building and managing wireless networks. Currently PWMN is the dominant wireless network community in Patras, Greece. It has about 150 active members who are the individual node owners of this metropolitan network and spans over 5 Greek provinces (Achaia, Ilea, Etoloakarnania and Fokida) with backbone links up to 65km. PWMN is an anarchic network, in terms of no central managing authority. The development is done in an ad-hoc manner by individuals who cover the expenses on their own. In addition there are no paid services over the network in order to have ROI for each individual, though one may provide such services. Networking access in the network though is free, and open for everyone interested.

It is obvious throughout this analysis that the PWMN doesn't fit any business model since it is a non-profitable organization, and it doesn't have a firm development plan. Its main advantage though is its ease of development and the people involvement in the development process. In a managed network the development is guided firmly by some business plan. In an anarchic network the development is managed by the people's needs and that's the value of such networks. For instance in order for the HotCity to create a hotspot may require some pre-planning, designing, carrying out techno economic studies and so on. In order for the PWMN to expand in that area the only necessary mean is the will for the people to connect and of course create their local access node and its backhaul connections. The major drawback in PWMN is fault recovery. The fault recovery depends solely on the individuals administering the node and their capability (in money and time) to fix the problem. The response in such cases is best effort, in the sense that the faults may persist for arbitrary periods of times. In managed networks such problems do not hold since there are SLAs to be met and fault recovery is guaranteed. The services is another major problem for unmanaged networks. Since no central authority exists no planned service overlay may occur. Every user though may provide other users with his personal services either paid or not, with guarantees or not. This is not the case where central management is employed. The services follow the business plan and the services, usually, arrange the network. It is clear that HotCity has a strict business plan being wISP and service provider, whereas PWMN is a more enthousiast's network with emphasis in interoperability and quick expansion.

8. Conclusion

In this paper, we have presented the main aspects, when building wireless metropolitan area networks. Technology options are presented and compared, while economical issues and service offerings are also discussed. Two case studies are presented namely the Hotcity that is an initiative of the City of Luxembourg and uses commercial equipment and the Patras Wireless Metropolitan Network that is an open ad-hoc community of individual users.

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