Wireless Community Networks:
Motivations, Design and Business Models

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ABSTRACT

In this paper we provide an integrated presentation of applications, technologies and business models for wireless community network together with design considerations and examples. An overview is given of the state-of-the-affairs of wireless community networks. Driving forces and stakeholders of the projects and the applications and services will be presented for some carefully selected cases. We suggest a design methodology and illustrate its application to an ongoing digital city project in Hungary. Relevant business models are also analyzed.

Categories and Subject Descriptors

C.2.1 [**Computer Communication Networks**]: Network Architecture and Design - *Wireless communication*

General Terms

Performance, Design, Economics, Experimentation, Security, Verification.

Keywords

Community networks, digital communities, digital cities, Wi-Fi Mesh, WiMAX, network planning, business models.

1. INTRODUCTION

Providing broadband access to citizens, communities, public institutions and developing businesses has become a strategic objective for governments and international organizations worldwide. In particular, serious problems related to the "digital divide" have been widely recognized by public administrations. However, the solution to these problems is not straightforward.

A large number of initiatives, under the collecting name

community networks have been launched in North America as well as in Europe. By creating telecom infrastructure in underserved regions, local governments can prevent remote communities from digital divide, and are able to create a healthy climate for economic development, help startups grow, bring new businesses into the region. Community networks can be created also by non-government organizations, schools etc. A note on terminology: "community network" is also, and has been originally, a social science term; and in fact, the first community networks were created by social groups in order to improve communication among their members. Free or cheap Internet access has always been an important objective. In this paper, we use this term in a technological-economical sense: by "community network" we mean the combination of the telecommunication infrastructure, the services provided upon it and the specific business model to operate the infrastructure and provide services.

As for technologies for community networks, all infrastructure options that are common in telcos' networks are in principle suitable for building community network infrastructures. Fiber has been an attractive solution for many cities, first of all in North America, terms like "municipal fiber" or "condominium fiber" refer to fiber infrastructure built by a municipality or an association of users such as school boards. While building a fiber network is technically viable where a local government or some of its utility companies own ducts and support structures which are "free" assets, for economical feasibility it is necessary to have a few large customers (e.g. ISPs) which buy the lion share of the fiber capacity from the local government.

Wireless technologies, on the other hand, are almost always suitable for building community networks for several reasons: ease of installation and expandability, usually low costs, and the availability of a range of technologies, starting from the ubiquitous Wi-Fi through WiMAX and 3G mobile.

Planning, deployment and operation of community networks have been challenging tasks. As opposed to telco networks, there is a specific set of services that the cities or

regions want to implement, the applications and services have to be made accessible by a wide range of geographically diverse users, no matter where the user is located. Intel Corporation suggests a list of technical requirements that must be met by digital cities [3]. As opposed to telco networks, cities can more freely choose communication technologies, including emerging ones as they do not have the stringent business requirements the telcos have to meet: e.g. short ROI (Return Of Investment) or totally risk-free adaptation of new technologies. And last but not least, suitable business models have to be defined with clever constructions of involving both the public and private sectors, while satisfying legal and regulatory requirements.

The objective of this paper is to provide an integrated presentation of applications, technologies and business models for wireless community network together with design considerations and examples. This integrated approach has been rarely found in the technical literature. A recently edited book [1] attempts to bring together the most important aspects – technical, legal, regulatory and economic – into one book. Within the framework of an ongoing European Network of Excellence project – OPAALS – the social side, information technologies and economic models are being investigated by a large inter-disciplinary international team [2], also putting community networks in a wider context of digital ecosystems and digital business ecosystems.

The rest of the paper is organized as follows. Section 2 provides an overview of the state-of-the-affairs of wireless community networks. In some carefully selected cases, we present the driving forces and stakeholders of the projects and the applications and services. In Section 3 we suggest a design methodology and illustrate its application to an ongoing digital city project in Hungary. In Section 4 we analyze the relevant business models and include a sample economic calculation. Finally, Section 4 gives a short summary.

2. COMMUNITY NETWORKS

In this section, first we are going to look at the set of applications usually considered for community networks, then briefly present the available wireless technologies and finally introduce three case studies.

2.1 Stakeholders, initiators and applications of community networks

As mentioned in the Introduction, by "community network" we mean the combination of the telecommunication infrastructure created by the participation of the local government, the services provided upon it and the specific business model to operate the infrastructure and provide services. In this paper, we will be focusing on wireless community networks, where at

least the access part but in many cases also the distribution and backbone part is implemented using a wireless and/or mobile technology.

The stakeholders of community networks include (i) public agencies (local governments, local development agencies); (ii) users (citizens, SMEs, associations etc.); (iii) private sector services providers (e.g. telcos; ISPs); (iv) local and global facilitating agencies such as research and consulting centers, associations of community networks. One of the above stakeholders is usually the "initiator" of the project. While classic community networks were initiated by the communities themselves (a.k.a. grass root initiatives), most of the today's community networks are planned and implemented by some form of the participation of local and/or regional governments.

Applications that drive the development of community networks can be grouped as follows:

A) Access to public information and services

B) Public safety

C) Traffic control and transportation

D) Health care

E) Business services

F) Educational

G) Utility companies (electricity, water, gas, etc.)

In most cases, there is usually one or two applications that are the main motivations for the implementation of a given community network. Below we list some wireless community network initiatives together with their primary applications [3]:

Chaska, MN – Digital divide for schools, businesses and residents;

Cheyenne, WY – Traffic signal management;

Corpus Christi, TX – Automated meter reading for city-owned utilities;

Lewis&Clark County, MT – leased line replacement; access to remote county buildings;

Medford, OR – public safety;

Ocean City, MD – Integrated digital, voice and video for city buildings;

Piraí, Brazil – Municipal field-force productivity;

Portsmouth, UK – Bus passenger information dissemination;

San Mateo, CA – Police field-force productivity improvement;

Shanghai, China – Police field-force productivity improvement;

Spokane, WA – Municipal applications and e-Government initiatives;

Westminster, UK – Video surveillance and enhanced security.

2.2 Available wireless technologies

2.2.1 Wi-Fi mesh

Wi-Fi (Wireless Fidelity) mesh networks are peer-to-peer multi-hop networks, where the nodes cooperate with each other to route information packets through the network. They present an alternative to "infrastructure based" networks. Mesh networks have some attractive features. They are "organic"; nodes may be added and deleted freely; the mesh principle means also fault tolerance: nodes may fail and packets will still be routed; mesh networks are manageable in a distributed way. However, mesh networks also pose challenges. If there are too many nodes, the need for routing other nodes' traffic decreases the access throughput of a given node. On the other hand, if there are too few nodes then routing could be a problem. Security is also an issue. A practical problem is that presently there are no interoperable products as the WLAN (Wireless Local Access Network) mesh standard (IEEE 802.11s) is relatively new. In spite of the aforementioned shortcomings, the majority of wireless community networks are Wi-Fi mesh and it is the most likely option to consider when someone is planning to create such an infrastructure. Current products feature dual and multiple radios to significantly compensate the throughput decrease when traffic is routed through a chain of nodes. Most recently combined products have been developed that feature WiMAX capabilities to use the latter technology as a backbone.

2.2.2 WiMAX

WiMAX's (Worldwide Interoperability for Microwave Access) flexible architecture is based on the family of IEEE 802.16 standards. The topology can be point-to-point, point-multipoint or mesh. The area coverage is up to tens of km in LOS (Line Of Site) environment, at limited data rates. An attractive feature is operation in NLOS (Non Line Of Site) conditions. High capacity and data rates up to 100 Mbps makes WiMAX a viable option for backbone and distribution network segments. It provides a high level of security due to AES and 3DES encryption standards. Quality of service is an inherent feature of WiMAX. It has several service classes including support for real-time data streams. The mobile version is based on the IEEE 802.16e standard, approved at the end of the 2005, and products have already been available based on this standard. Its deployment is easy, quick and relatively inexpensive. Different spectrum allocation possibilities exist in licensed and license-free frequency bands. Implementors of wireless community network infrastructures are cautious regarding WiMAX, mainly due to the currently high costs of WiMAX subscriber stations. However, a WiMAX-based backbone for Wi-Fi mesh networks seems to be an attractive option. And mobile WiMAX will be definitely the solution when mobility is of key importance.

2.2.3 3G cellular mobile

3G cellular systems together with enhancements like HSDPA/HSUPA, also due to the smaller cell sizes, offer per-customer data rates that would satisfy the requirements of most of the applications. Nevertheless, there are no community networks, at least to the best of the authors' knowledge, that are based on cellular mobile service. The reason might be a simple one: municipalities did not take this option into account, but on the other hand cellular operators might be also reluctant to work out a specific offer for a city, with very special pricing, and specific solutions in addition to cellular coverage to support large institutional users (e.g. a combination with WiMAX). So this option is included here for completeness only.

2.3 Case studies

According to Muniwireless.com, one of the well-known portals of wireless community networks, there were 92 regional and city-wide networks, 68 city hotzones and 40 public safety and municipal use networks, alone in the US (status of August 1, 2007). There are further 215 ongoing city and country-wide projects. The number of existing networks plus ongoing projects totals to 415, and shows an exponential growth from 122, the figure two years ago. There are similar initiatives around the globe, and, although Europe, at least the continental part, seems to be lagging behind the US, a similar growth is expected to happen in the next few years, to meet the objectives of ambitious European plans to penetrate broadband services to citizens and institutions and foster regional development.

In this section, we present three case studies that represent different objectives, target applications, stakeholders and business models. Although all three projects aim at providing various services and applications, in each case there is one primary application that is in the center of the business model. *T.Net* in Italy aims at creating a telecommunication infrastructure in a province that is sparsely populated and geographically challenged. The main goal of *Wireless Philadelphia* in the US is to provide Internet access in a city where the Internet penetration is quite low, while the *Corpus Christi, US* project's primary objective was to implement city-wide remote data collection for utility companies.

2.3.1 T-Net, Trentino, Italy

T.Net is a community network project under implementation in Trentino, a province in Northern Italy. It is part of the eSociety project of the local government, whose strategic aims are: (i) the innovation of the local economy, (ii) the improvement of Public Administration efficacy, and (iii) the reduction of the gap which keeps many citizens from participating in the Information and Knowledge Society. Its management model involves publicly controlled companies for the implementation and

management of the broadband infrastructure, supplying of transport services, connectivity and IT services for public administration and renting infrastructure to market operators under fair and non-discriminatory conditions. The network consists of a fiber optic backbone and a pre-WiMAX-based (HiperLAN-2) wireless access network. The number of backbone nodes will be 78 with the total length of optical cable over 750 km. The network will connect in total 223 municipalities. Until the fiber infrastructure will be built, the province is leasing Gbit Ethernet facilities from Telecom Italia, the Italian incumbent telecom service provider. By the end of 2007, wireless access will be provided for 150 municipalities [4].

2.3.2 Wireless Philadelphia, US

The Wireless Philadelphia initiative started with a pilot, covering the central districts and is currently being expanded to cover the entire metropolitan area with a total 20 million USD investment. The project is financed and implemented by Earthlink. The business model is based on providing Internet access in the city, as the level of broadband penetration is very low (below 25%) and is mainly dial-up access. Earthlink is also planning to sell bandwidth both to retail and wholesale customers. The city is planning to subsidize Internet access for low-income residents. Mobile workers that constitute half of the city workforce will communicate using this network infrastructure, supported by an already implemented Geo-spatial Information System (GIS). Other applications include video surveillance to reduce crime in the city [5].

2.3.3 Corpus Christi, US

The city, which has about 250,000 inhabitants and an area of about 150 sq. miles, has decided to implement an Automated Meter Reading (AMR) system for water and gas customers. The underlying network is an optical fiber backbone plus a Wi-Fi mesh network by Tropos Networks. Overall, the city spent $20M on the AMR system and on the wireless network, which yields a saving of $30M over the estimated $50M costs within the next 20 years without AMR. In addition to savings, the project resulted in higher level of customer service and support to citizens. After the rollout of the project, it was realized that the AMR application uses only a fraction of the bandwidth of the wireless network, therefore the city is planning to implement other applications including the support for public safety, health inspection, animal control, public works and utilities personnel [6].

3. DESIGN CONSIDERATIONS

In this section, we deal with issues related to network planning. First, we are going to look at the process of the design methodology. We discuss the key points of technology selection as well as the topology planning based on QoS and coverage requirements.

3.1 Overview of our design methodology

In general, there are significant differences between planning of CNs and ISPs' and other service providers' design methodology. Key differences include the following requirements for the planning of CNs: (i) ubiquitous Wi-Fi access covering the whole territory of the community (e.g. a city, a county or a province), no matter if some parts are sparsely populated and/or geographically challenged; (ii) users should be provided with other forms of access as well, depending on the application and the users' needs and economic possibilities. Thus, on one hand, the services must be made accessible via cheap communication services such as 2.5G (GPRS), and, on the other hand, bandwidth-demanding customers have to be served too; (iii) mobility or at least nomadic access across the covered area must be supported; (iv) support of a multiplicity of user devices from simple mobile phones through PDAs and laptops to video conferencing equipment; (v) the network should support a specific set of government, business and society-related applications. For the latter, a specific general service platform is needed like the Intel's Government Federated Service Bus (GFSB) [7].

The whole design process consists of the following steps:

1. Identifying applications and services. First, we should select the key applications and services which raise requirements toward the network.

2. Identifying network technology requirements, based on applications. We should analyze the requirements of the applications and services selected in the first step. This analysis should contain QoS (delay, jitter) and bandwidth parameters.

3. Identifying coverage requirements and the possibilities and limitations of the environment. Preparing the network technology selection, we should determine the area which is supposed to be covered by the network, with its topography, natural obstacles such as hills or trees as well as buildings, availability of support structures, towers etc.

4. Choosing network technology. Selecting the right technology is one of the key parts of network planning. This decision should be based on identified requirements and conditions of the environment. We should choose optimal solutions both for the access and the backbone network. This step of the design process is explained in detail in Section 3.2.

5. Planning of network topology. This complex part of the methodology uses the results of the coverage requirement analysis as well as the network technology selection. We should plan the network topology according to the topography and the optimal station placement strategies.

6. Verifying original requirements. Last, but not least, this step stands for verifying the results of planning. We should recognize the differences between the original requirements and the capabilities provided by the planned network.
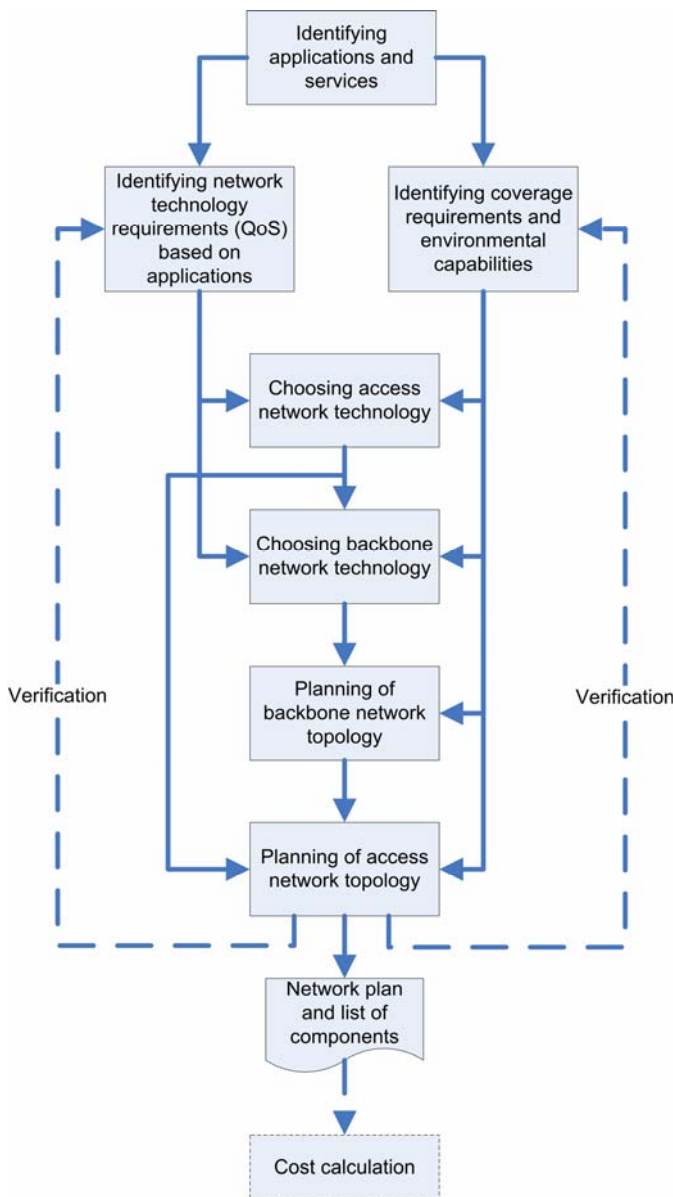
These steps are illustrated in Figure 1.

Figure 1. The design process

3.2 Technology selection

As mentioned earlier, there are differences between CNs and telcos' networks from the viewpoint of technology selection, too. For CNs, cost minimization may not be the primary objective and implementors of CNs can also experiment with new and advanced technologies. Another difference is that interoperability is of critical importance for CNs. As opposed to some big telcos that rely on a long-term business relationship with a selected major network system vendor, cities have to be open to extensions of their initial network by any standard-based equipment. A CN should be open also in the sense of its connectability to ISPs and telcos as it cannot operate in an isolated way.

Specifically, we should choose the technology by considering the requirements of the applications and expected coverage which has been identified in the previous step. A summary of our analysis of the state-of-the-art wireless technologies are shown in Tables 1 and 2.

Data in the tables are based on our measurements and calculations using the following assumptions:

- Microcell is an area covered by one access point or mesh node in the access network. Macrocell is a union of well-connected microcells. Macrocell connects to the backbone with one or more backbone access points.
- There is no sectorization in the multimode network topology scenarios, we use only omni-directional antennas.
- Each mesh node has 4 mesh neighbors.
- WiMAX nodes use 28 MHz bandwidth.
- Soft QoS means IEEE 802.11e standard in Wi-Fi. Managing QoS is one of the inherent features in WiMAX.
- The delay and jitter parameters are one-way latency measures.
- Distances and cell size parameters are based on transmission power limited by EU-conform regulation at high data transfer rates for high cell efficiency.
- The values are mostly maximum values at optimal coverage. We can increase maximum bandwidth density by decreasing the cell radius.
- We can define backbone access point (BAP) density in number of BAP/km^2 which can help estimate the initial and operational costs. We can do this in two ways:
    - Each of the macrocells connects only one BAP, but this BAP serves only that macrocell. In this case, the measure is the reciprocal value of maximum coverage.
    - Each of the macrocells connects more BAPs. The number of BAPs should be calculated as the ratio of aggregated traffic in macrocell and BAP capacity.

One of the most important issues in technology selection is finding the most suitable solution for application requirements. Table 1 helps choose the right technology and configuration by the coverage, bandwidth and density parameters. Table 2 focuses on QoS measures.

Table 1. Technology selection for capacity and coverage planning

ID	Technology	Configuration	Maximum microcell capacity	Number of microcells in macrocell	Maximum macrocell capacity	Maximum microcell radius	Maximum AP distance	Maximum coverage (macrocell size in 0.01 km^2)	Maximum bandwidth density (Mbps/0.01 km^2)	Typical usage
1	Wi-Fi	NLOS	20 Mbps	1	20 Mbps	100 m	160 m	3	7	hotspot
2	Wi-Fi mesh	Max. 2 hops NLOS	7 Mbps	24	170 Mbps	100 m	150 m	50	3.5	high density coverage (optimal)
3	Wi-Fi mesh	Max. 4 hops NLOS	2 Mbps	80	160 Mbps	100 m	140 m	150	1	high density coverage with few BAP
4	WiMAX	LOS	100 Mbps	1	100 Mbps	3 km	3 km	1000	0.1	rural, backhaul, special req's
5	WiMAX	NLOS	50 Mbps	1	50 Mbps	1 km	1 km	100	0.5	urban, suburban
6	WiMAX mesh	Max. 2 hops NLOS	16 Mbps	24	380 Mbps	1 km	1 km	2500	0.15	rural, urban, suburban

Table 2. Technology selection for QoS planning

ID	Technology	Configuration	Maximum microcell capacity	Average delay per hop (low utilization)	Average delay per (high utilization) without QoS	Average delay per (high utilization) with QoS	Bandwidth allocation capability	Voice transmission capability w/o soft QoS
1	Wi-Fi	NLOS	20 Mbps	5 ms	400 ms	100 ms	no	yes / no
2	Wi-Fi mesh	Max. 2 hops NLOS	7 Mbps	10 ms	1000 ms	200 ms	no	yes / no
3	Wi-Fi mesh	Max. 4 hops NLOS	2 Mbps	25 ms	2000 ms	400 ms	no	no / no
4	WiMAX	LOS	100 Mbps	20 ms	100 ms	50 ms	yes	yes
5	WiMAX	NLOS	50 Mbps	30 ms	150 ms	50 ms	yes	yes
6	WiMAX mesh	Max. 2 hops NLOS	16 Mbps	80 ms	300 ms	100 ms	yes	yes

The following points are recommended to take into account for the technology and configuration selection based on the Tables 1 and 2.

If some not frequently connected spots should be covered by a wireless network, standalone Wi-Fi access points as hotspots should be used. It can be used in LOS and, to a limited extent, in NLOS conditions. IEEE 802.11e capable devices should be used to support QoS requirements to real-time services such as voice communication (Table 1, 1st row).

If a larger area has to be covered by a limited number of backbone access points, Wi-Fi mesh network with only a few hops should be used. The benefits of a mesh network are simple installation and using nodes as access points for users and as retransmission points of the backbone network. More than 2-3 hops to the BAP cause degradation in effective bandwidth and in QoS parameters, too. Real-time applications can tolerate this relapse up to 2 or 3 hops with 802.11e support (Table 1, 2nd and 3rd rows).

Wide areas with low density of users should be covered by WiMAX. It can be used not only in access networks but in backbone networks in point-to-point or point-to-multipoint configuration as well. Robustness and high data rate of the WiMAX guarantees the QoS and sufficient capacity in LOS and in NLOS environment, too (Table 1, 4th and 5th rows).

WiMAX can operate in mesh mode, too. In this case, advantages of Wi-Fi mesh and WiMAX are combined. This solution is not widely implemented yet (Table 1, 6th row).

To summarize our possibilities we can say that, for a number of applications, Wi-Fi mesh could be the solution, but for applications that require QoS and high bandwidth, WiMAX is the best choice. However, because of the low penetration of WiMAX devices, we have to use today a widely preferred access technology, such as Wi-Fi. On the other hand, the backbone or distribution network should be robust and should have sufficient capacity. The combination of WiMAX and Wi-Fi technology, and the combination of mesh, ordinary access and transfer can be the optimal solution for every wireless community network. Wi-Fi will remain the only feasible customer access solution for the next 2-3 years (until mobile WiMAX cards will be as ubiquitous and cheap as expected by major market players).

There are some key points to select the right technology:

A) Application requirements

We have discussed above in detail.

B) Timeframe

Wi-Fi mesh is available now, however we should keep in mind that currently there is no interoperability between different vendors' mesh products, standard is only coming. Fixed WiMAX is on the market, but prices will go down. Mobile WiMAX is not yet on the market.

C) Frequency issue

In many countries or regions, mainly in Europe, it is difficult to obtain licenses required for WiMAX. Using unlicensed ISM band can result in weak QoS and low bandwidth because of disturbance of other devices and providers.

D) Costs

A careful calculation is needed for each individual project. Equipment price is not enough to take into account (a Wi-Fi node is much less expensive than a WIMAX station). Required density of Wi-Fi mesh nodes should be considered vs. number of WiMAX base stations. These calculations can be based on the data in Table 1.

3.3 Network design for Digital Győr

Győr is a major industrial and cultural center, a capital of the region of Western Hungary. Digital Győr is the municipality's project to implement a city-wide network infrastructure and services. At the time of writing this paper, a feasibility study has been prepared by the authors and their colleagues. The pilot phase of this network is currently under implementation which covers the university campus together with a part of the city along with a complete bus line to test a traffic supervision application.

3.3.1. Services for the municipality of Győr

The planned wireless infrastructure will serve several important goals: (i) it will carry the internal data and voice traffic among public institutions and publicly controlled companies, thus saving costs of bills currently being paid to telecom service providers; (ii) it will improve the efficiency of work processes by using advanced communication means, improve the quality and amount of information available over the Internet, and introduce electronic customer services via an e-government initiative; (iii) it will improve services for citizens and facilitate citizens' participation in public processes. Some specific applications based on interviews with potential large users are as follows [8].

A) Public safety system

The objective is to improve public safety and reducing crime in the city of Győr by establishing a network of surveillance cameras throughout the city and equip police and fire brigade personnel with wireless enabled devices for improved management and intervention.

B) Telemetrics for the local utility company Pannon-Viz

The objective is to use the wireless network to implement automated meter reading (AMR) for the local water company. AMR will allow Pannon-Víz to optimize water usage based on real-time consumption conditions and also reduce fuel and personnel cost by eliminating the need for meter reader personnel.

C) Parking management for the local parking company Komszol

The wireless community network is planned to support parking services in several ways: communication with the parking ticket dispensers to ensure that they are functioning properly, providing enforcement staff with handheld devices that communicate over the network with a parking management system. Additional services include online payment, SMS warnings of expiring parking tickets, reminders of unpaid parking dues, automated payment using RFID technology linked by the wireless network.

D) Services for the public bus company Kisalföld-Volán

The objective is to improve the efficiency of the company's operations and the quality of passenger service. The planned wireless CN will collect and transmit real-time data related to departure and arrival times, delays, technical problems, road and traffic conditions. Some kind of positioning system will be installed on the buses. Using this information the company will be able to optimize routes, the utilization of vehicles and manpower and improve controlling of business processes which is presently paper-based and off-line.

E) Advanced tourism information system

The objective is to implement a tourist and cultural information portal based on geospatial information system, and install several kiosks supporting free or low-cost Internet access to this portal.

3.3.2 Network design scenarios

In this sub-section, we summarize an example of designing a CN according to the proposed design process. The case study is based on project Digital Győr. First, we identified the services (detailed above) and analyzed their requirements (Table 3). The required overall microcell capacity was calculated as the aggregate of average bandwidth for each service, and the maximum value of delay in the network must be not greater than the minimum of the maximum tolerated delay of the services.

Table 3. Services requirements

Service ID	Bandwidth per user per microcell	Probability of activity per user	Average number of user per microcell	Average bandwidth per microcell	Max. tolerated delay
A	1 Mbps	1	2	2 Mbps	500 ms
B	1 kbps	<0.0001	50	< 1 kbps	2000 ms
C	10 kbps	<0.001	50	< 1 kbps	500 ms
D	10 kbps	0.1	5	< 5 kbps	1000 ms
E	1 Mbps	0.2	5	1 Mbps	500 ms
Minimum required capacity and delay limit				3 Mbps	500 ms

Technology and topology selection should be based on the result above, the pilot service area, which contains the campus of University of West Hungary, Győr and a bus line close to the campus.

We have studied two different scenarios according to the above and considering the aspects given in Section 3.2 (A, B, C and D points):

Scenario 1: Fixed WiMAX as backbone network and Wi-Fi access from WiMAX subscriber stations

In this scenario the user connects to a Wi-Fi access point, which is connected to a WiMAX BAP through WiMAX by its secondary interface. WiMAX BAPs connected to each other are the main points of the backbone network.

Scenario 2: Wi-Fi mesh with WiMAX backbone and interconnection network

In this scenario the user connects to a Wi-Fi mesh access point, which can forward the traffic to another one in mesh mode. Finally it reaches one of the mesh nodes which has a WiMAX interface to connect to the main WiMAX base station.

Numerical results calculated by using the previous considerations and tables are given in Table 4 to illustrate the above scenarios. The detailed planning process could not be included here due to space limitations.

Table 4. Comparison of Scenario 1 and 2

Scenario	*1*	*2*
Number of WiMAX nodes in backbone	4	1
Number of Wi-Fi access points with a secondary WiMAX interface	21	0
Number of Wi-Fi mesh nodes	0	18
Number of Wi-Fi mesh nodes with secondary WiMAX interface	0	3
Average cell capacity	15 Mbps	5 Mbps
Overall capacity of the network	200 Mbps	100 Mbps
Worst case estimated delay	250 ms	300 ms
Worst case estimated jitter	100 ms	200 ms

Regarding all of the technical parameters Scenario 1 is the better choice, but it uses plenty of Wi-Fi access points with WiMAX interface. Therefore if one should keep the costs low Scenario 2 is preferable.

3. BUSINESS MODELS

In this section, we deal with issues related to business planning. We discuss the business constructions for planning, implementation and operation and maintenance of CNs.

3.1 General considerations

The interesting feature of business models for a public entity is that getting the invested money back in short term is not of primary importance. Thus, longer ROIs are acceptable, and maximizing the profit is not the primary objective as, there are important indirect benefits which result from aiding new service providers, ISPs, telecom companies, value added service providers to enter the market and grow. Hence, the public entity can obtain additional revenues from the company taxes. Second, the public sector can significantly decrease its expenses for telecom services using the public entity's own infrastructure.

It does not exist an easy and straightforward business model to deploy and operate community networks. In the following, we discuss some possibilities according to the involvement of the public entity.

Figure 2 shows three basic models and a fourth one called 'demand aggregation' which represents the lowest possible level of public participation [1]. The next one is when a public entity provides a passive infrastructure. The highest level is when the public entity acts as a service provider; it should be applied carefully since it creates a conflict of interest situation. The local government may provide

services only for internal purposes, i.e. for public institutions, thus avoiding competition with service providers in the marketplace. The model in between is a pure wholesale model when the CN operator acts as a "carrier's carrier".
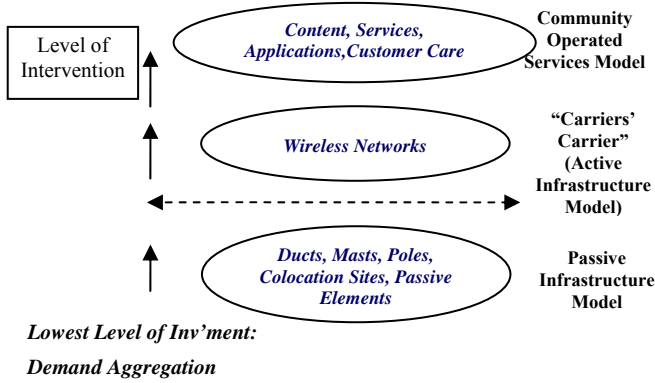

Figure 2. Basic models of public involvement

The aforementioned models differ in terms of ROI, too. Figure 3 illustrates the approximate ROI values for different levels of public involvement [1].
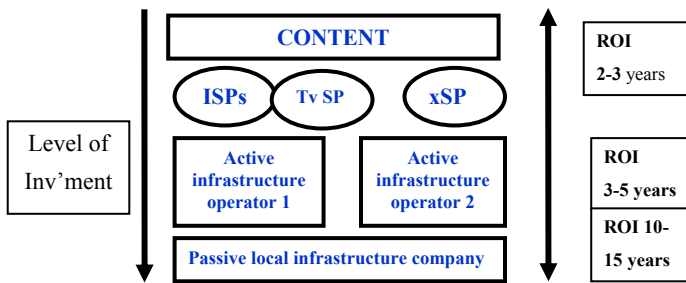

Figure 3. ROI for different basic models

The participation of a public entity in creating and operating a CN is often accomplished in a kind of public-private partnership (PPP). The typical models according to the structure of public-private cooperation are as follows:

- Publicly owned and operated
- Privately owned and operated
- Non-profit owned and operated
- Publicly owned, privately operated
- Owned and operated by a public utility
- Privately owned and operated jointly with the municipality

The choice of the appropriate model is also influenced by regulations that may allow or restrict the different ways and levels of how a public entity can participate in providing telecommunication services. Moreover, the selection among the possible models can be based on costs and/or complexity of management for the public entity.

3.2 Business structure

The business structure can be based on the following strategic alternatives: (i) building the CN by the LG (Local Government); (ii) teaming up with a local company and build the CN together. In the rest of the section, we analyse the second option as an 'incarnation' of a public-private cooperation. We consider the following business structure:

a) *Infrastructure* company: set up by the LG and the selected local company. It makes the investment in the wireless infrastructure, owns the wireless network and offers the use of the native wireless infrastructure as a product to the *internal customers* within the community and to the *external market*. Internal needs and requirements are channeled through the *Services* company.

b) *Services* company: is to be set up to take care of the *internal* services, including Internet access, voice, data and others, for the public sector. The Services company operates on business terms but does not sell its services in the open market.

The ownership structure is that the Services company is majority-owned by the Infrastructure company, but it can also have minority interests from partners, see Figure 4.

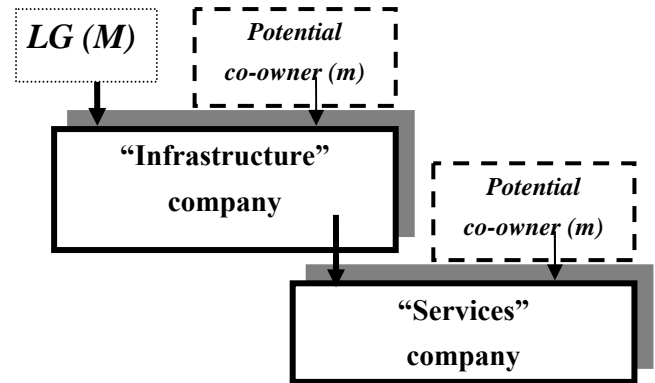**Figure 4. Ownership structure**

3.3 Creating the business model

The most important part of building a business model is to work out the set of assumptions for the calculations. The assumptions can be summarized as follows.

Voice traffic, internal needs: It can be usually assumed that 40% of the traffic is internal (and can be totally carried by the CN) and that a 20% cost cut can be achieved on the external traffic by using the community network before reaching the external world.

Data traffic, internal needs: On the data and information related traffic, it is reasonable to assume a conservative

scenario, where the bandwidth growth and the price reductions will compensate each other.

Wholesale of excess capacity: Scenarios are to be drawn up for two different types of customers: (i) telecom operators; and (ii) business customers. It can be usually assumed that 1-2 out of the potential telecom operators and ISPs will be customers of the CN for the near future.

Investments: Here we need a total investment figure, the total length of the investment period and the division of investments over that period. The model should also include depreciation calculation for different periods.

Financial assumptions: Include the total needed equity and its division into own equity and external financing. The repayment conditions of external financing have to be taken into account, too.

Operational costs: The operational costs can be split into three main groups: *Operation & Maintenance, Personnel costs* and *Other costs*.
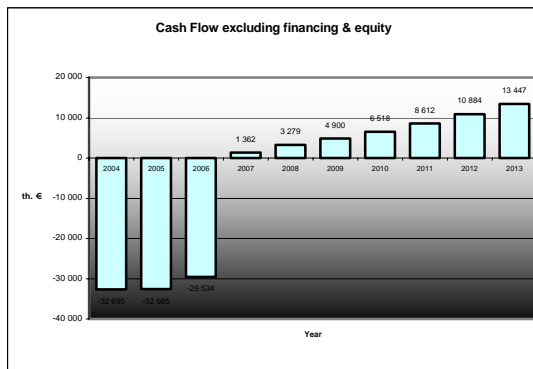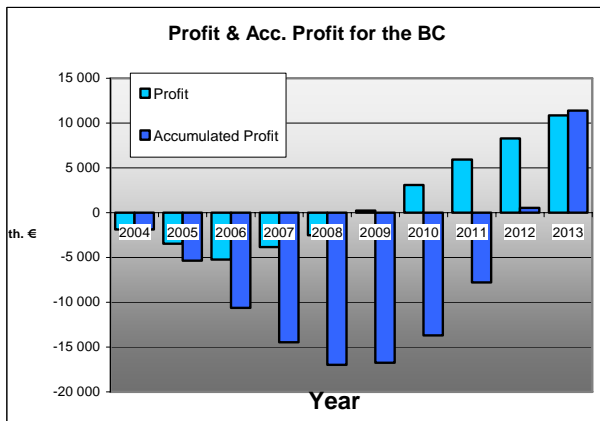

Figure 5. Cash-flow

Figure 6. Profit and accumulated profit

In Figures 5 and 6 we illustrate the above methodology by sample results for a particular set of assumptions we used in one of our earlier CN planning projects.

4. SUMMARY

This paper has presented an integrated view of applications, technologies and business models of wireless community networks. We have proposed a design methodology and illustrated it by the example of an ongoing digital city project in Hungary. There are interesting research areas of great practical significance, related to novel design methods for Wi-Fi mesh and WiMAX networks including mobile WiMAX, and the authors intend to pursue some of the related research opportunities.

5. ACKNOWLEDGMENTS

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