Design Aspects of Open Municipal Broadband Networks "(Invited Paper)"

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ABSTRACT
This paper presents the design principles that cover the implementation of broadband infrastructure in the region of Western Greece, by examining all the necessary parameters that arise while implementing such a critical developmental project. Furthermore, we present as a case study, all issues of the designing of the Metropolitan Area Network of Patras, the third biggest city of Greece. The major target of the MAN of Patras is to interconnect the buildings of the public sector in the city and also deploy fibers that will create conditions of competition in providing both access and content services in advantage of the end consumer. The usage of the broadband infrastructure by service providers will be based on the open availability of the fiber optics infrastructure in a cost effective way. Finally, we present the main characteristics of a proposed business plan that ensures financial viability of the broadband infrastructure.

Categories and Subject Descriptors
C.2.1 [**Computer-Communication Networks**]: Network Architecture and Design – *Network topology, packet-switching networks, network communications.*

General Terms
Design, Economics, Verification.

Keywords
Metropolitan area networks, Business models

1. INTRODUCTION
This paper presents the design principles that cover the implementation of broadband infrastructure in the region of Western Greece, by examining all the necessary parameters and studying all the issues that arise while implementing such a critical developmental project. In particular, we present the main principles that should be followed while developing such Metropolitan Area Networks. Regarding the design guidelines, in this paper, we cover issues such as architecture of the broadband network, topology selection, requirements of the passive and active equipment, and requirements of the fiber and ducting infrastructure. Furthermore, we present as a case study, critical issues regarding the design of the Metropolitan Area Network of Patras, the third biggest city of Greece. The main target of the MAN of Patras is to interconnect the buildings of the public sector in the city. The organizations that are going to be connected in the MAN are organizations of the sectors of public administration, education, health, culture etc. The usage of the broadband infrastructure by service providers will be based on the open availability of the fiber optics infrastructure in a cost effective way. Finally, we present the main characteristics of a proposed business plan that ensures financial viability of the broadband infrastructure and guarantees the administration, growth and exploitation of infrastructure.

Several related projects that implement neutral broadband infrastructure in cities are running across the world. For example, Ireland, Sweden and New Zealand run such programs, where the local authorities design and fund the major part of the projects aiming to increase the broadband penetration with benefits to the end users [12][13][14].

This paper is structured as follows. Section 2 presents the general guidelines for the design of municipal broadband networks. Following this, section 3, presents the methodology of work regarding the designing of the MANs. Furthermore, in the same section the overall architecture and topology of the MAN of Patras is briefly described. Section 4 presents the main characteristics of a business plan that ensures the financial viability of broadband infrastructure. Finally some concluding remarks and planned next steps are presented in Section 5.

2. ISSUES ON DESIGNING BROADBAND INFRASTRUCTURE
This section presents the main principles that should be followed while designing such metropolitan area networks. In Western

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Greece (our case) the networks belong to cities, where in most of the cases the municipalities do not have the proper know how of designing such networks. Therefore, a specialized technical consultant (the Research Academic Computer Technology Institute) has been selected in order to provide its know how. In particular, the consultant works on conducting the studies of network's design and architecture, supervising the technical part of the construction of the networks and also designing the business plan that will be applied and will ensure the network's viability. The business plan proposes the scheme that will be responsible for the operation of the networks, according to the criteria and the guidelines of the EU [1][2].

The expected results of these projects are the creation of broadband infrastructure, and the existence of a business plan that will guarantee their financial viability. A common strategic design and implementation in a regional level is highly desirable. At the first stage, the main target of these networks, as Metropolitan Area Networks, is to interconnect the buildings of the public sector of the cities in which they will be developed. The organizations that are going to be connected are those belonging on the education, health, culture sectors etc. On second stage, this infrastructure will be available on network and content providers in a cost effective way. The latter will create conditions of competition in broadband infrastructure and services that will have benefits on end users. The plan for deployment of the infrastructure encourages the public exploitation, through the leasing of pairs of fiber optics. This fact provides revenue in a cost effective way in order to cover all operating and maintenance costs.

The projects mainly consist of manholes, ducts, channels, fiber optics, points of interconnection, together with the installation of the passive and active equipment in order to provide the basic broadband access in the public sector buildings. In particular, a broadband infrastructure based on optic fibres will be installed across the cities and several public collocations points will be created. The projects also fund some additional access infrastructure from public sector's buildings to the collocation and aggregation points. This access infrastructure along with a small part of the cities' broadband infrastructure will be used in order to provide network connectivity to the public sector. The remaining broadband infrastructure (optic fibres and collocation points) will be available for the content and service providers to use it and provide broadband services to the citizens.

The major characteristics of the mentioned broadband infrastructure according to [3] should be the following:

- Open access: The funded projects must be consistent with the new regulatory framework of electronic telecommunications and the rules of competition (public funding and antitrust). The appliance of these rules is a commitment in order to have a clearly defined open access. In particular, the construction of the networks, as already mentioned, should be limited in the construction of infrastructure and equipment that will be open to any telecommunication carrier and service provider [3][4].
- Neutral Operator: The main principles in the deployment of the broadband infrastructure assign the network operator the obligation to retain the neutral character of the infrastructure. The network should be an open access installation to all the organizations that provide electronic networks and services with absolutely no discriminations against them [6].
- Infrastructure Owner: The Municipality constructs the broadband infrastructure and obviously has specific benefits from these networks. Therefore, is also responsible for planning the expansion of the current infrastructure in a controlled and a rational way. Also its role is to solve all issues of the installed infrastructure and declare the rules of usage of the infrastructure by the providers. Additionally, the property owner should cover all costs for the expansion of the infrastructure.

3. METROPOLITAN AREA NETWORKS

This section is dedicated to describing the methodology that we followed in order to design the MAN of Patras. Furthermore, it presents the main characteristics of the MAN of Patras in terms of the topology, architecture and technology selection.

3.1 Designing Aspects

The overall architecture [9] of the MAN is shown in Figure 1. The topology is based on a three levels model: main network – distribution network – access network. There are three types of nodes in the system. These are: Main Nodes, Distribution Nodes and Access Nodes.

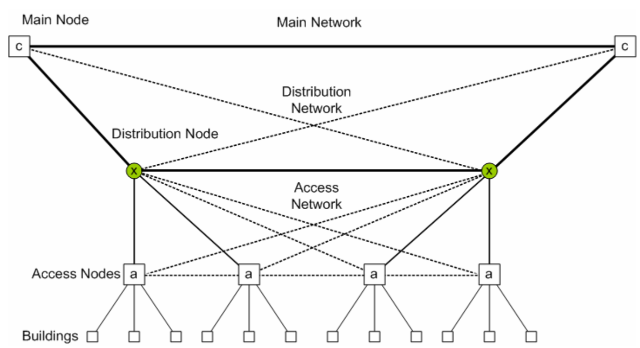

Figure 1: General Architecture

The main network consists of a number of main nodes that are connected directly between each other. In the main network, there must be some direct redundancy between main nodes which are close together. This means that it must be possible from one main node to reach the main nodes next to it without passing through the active equipment of another node. The optical cables should be laid without a break between the main nodes, so as to achieve high operational dependability. The main network's optical cables that connect different main nodes are to be separately ducted. The number of fibers between the main nodes in the main network in a municipality ought to be not less than 72 per optical cable. This number results as following: Each distribution node usually collects traffic from 8 access nodes approximately, as designed in the technical studies for the development of the networks. Each access node gathers 2 pairs of fibers (1 uplink and 1 backup), thus each optical cable should have at least 4 x 8 = 32 fibers, plus 32 for alternative routes in the distribution network. The available cables usually provide 48, 72 and 96 fibers, so 72 is the lower acceptable optical cable. If main nodes in different municipalities are long distances apart, with a smaller number of distribution nodes, the number of fibers may possibly be smaller if this is justified by great differences of fiber cost.

As far as the distribution network is concerned, it consists of the distribution nodes. A distribution node shall connect to a main node and shall be planned to have a redundant connection to another main node. The optical cables should be laid without a break from each main node to any distribution node. Alternatively, an optical cable loop is laid with two or three distribution nodes where the need for each distribution node is hived off. Over long distances this will be a cheaper but more vulnerable option. The number of fibers in the distribution network is affected by the following parameters:

- Number of access nodes connecting with each distribution node.
- Number of operators needing connections in the distribution network.
- Leasing of dark fiber to other actors.

The number of fibers to each distribution node ought not to be less than 72 per optical cable, as already described.

The access network consists of the access nodes. A number of buildings are connected to an access node through a fiber cable with at least 4 fibers (2 pairs of fibers, 1 uplink and 1 backup).

Regarding the fiber infrastructure, the additional optical cable will be installed, in order to handle situations the possible or anticipated penetration in the area, a large number of Internet operators active in the area, the positioning of active equipment and the degree of redundancy in the networks. As a general rule, if existing ducting is to be used, a careful assessment must be made of the best way to use it. If the number of existing optical pipes is small, an optical cable with many fibers will have to be laid so as to make maximum use of the ducting.

For the part of the network that will provide connectivity to the public sector's buildings, the Ethernet technology has been selected [10]. Ethernet switches are used on access nodes and aggregate the traffic from the buildings. Each building has a 100Mbps or 1Gbps connectivity through Base-LX SFPs. The distribution nodes do not have any active equipment but only passive. The main nodes have Gigabit Ethernet switches with advanced features. Those switches connect the Ethernet switches of access nodes as well as the buildings that have dedicated fiber connections. This choice has been done due to the fact that the public sector's buildings should use various service providers. In particular, the traffic from the connected schools in the MAN should be forwarded to the Greek School Network, the traffic from universities on Greek Research and Technology Network etc. Therefore, the designing approach is to configure the equipment in such a way that will provide Transparent LAN services [11], connecting the building to their service provider transparently and friendly. The latter means that the limitations for to the network and the service providers will be eliminated.

3.2 Methodology of Work

In order to handle the project work and secure the correctness and quality of the design, a specific methodology was followed. In particular the steps were the following:

- Several visits on municipalities took place, in order to finalize the location of the building, the points that those building will connect to the network and the final maping out of the ducts.
- Design of the network according to the 3 distinct levels (access, distribution and main network).
- Design the requirements of network's nodes and the equipment (passive and active).
- Writing the first version of the analytical design study of the network.
- Writing the specific requirements of the network's components according to each municipality's needs.
- Indicative cost accounting of the requirements and the overall design in order to ensure that it is compliant to the allocated budget.
- Final optimization of network's design and equipments' requirements.

The above mentioned methodology was used efficiently for 8 different municipality networks in Western Greece. The case of MAN of Patras was the biggest one and therefore the most complex.

Table 1: Telecommunications fees in the Municipality of Patras (in K€)

	ORGANIZATION		SUM
Education - Research	Universities	2	880,41
	Technical Universities	1	73,37
	Research Institutes	6	117,39
	Elementary Schools	76	102,72
	High Schools	44	108,58
	Public occupational centres	2	5,57
Health	Hospitals	4	622,16
Government	Region	1	158,48
	Prefecture	1	70,43
	Municipalities	2	76,30
	Libraries	1	3,22
	Sum	**140**	**2218,63**

3.3 The MAN of Patras

The city of Patras is the biggest municipality in the Region of Western Greece, the third biggest city of Greece (its metropolitan area has a population of over 200,000) and is an important commercial center and a busy port, the second biggest in Greece. Patras' MAN connects 210 public buildings in the city, among them 3 university institutes, 6 research centers, 4 hospitals and 120 schools (primary and secondary).

Immediately benefiting from this network will be all the employees of institutions of Education, Research, Health and Public Administration in the region of Patras, while in effect profited will be all the citizens of wider region of the city of Patras. Additionally, all major Greek content and service providers can use (cost effectively) this infrastructure to provide broadband services to the citizens. Their interest is quite big as the local 'Patras' market is very attractive.

The MAN of Patras consists of five rings while the total length of the ducts is 48 Km. The used fiber cables (various types, 24/36/48/72 fibers) are approximately 230Km. Among the rings, a star topology is used for the connections of the buildings to the access nodes. Additionally, 100% redundancy has been designed for the distribution and main network. More specifically the Patras MAN will consist of:

- Four (4) Main Nodes
- Eight (8) Distribution Nodes
- Twenty two (22) Access Nodes
- Nine (9) Wireless Access Nodes

Regarding the cost of the total investment, the Patras infrastructure cost approaches the value of 3 M€ which is absolutely comparable to the cost of the telecommunication services of the municipality of Patras.

As shown in Table 1, this cost is approximately 2.2 M€ according to a recent research for the municipality of Patras. Consequently, the depreciation of the cost of the whole investment in the municipality of Patras will take no more than two years.

4. BUSINESS MODEL

In order to secure the financial viability of the broadband infrastructure of Western Greece, it has to be supported by a business plan. Such business models have been proposed by several researchers and are used on other broadband municipal networks.

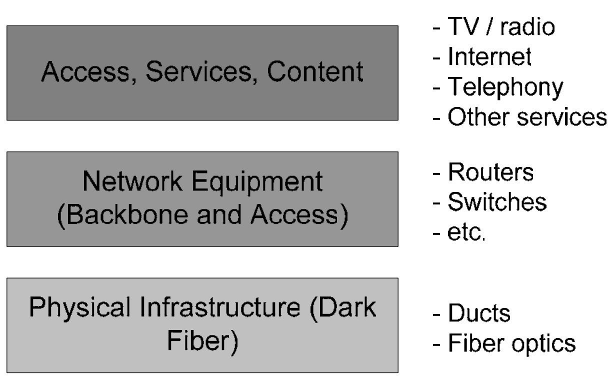

Figure 2: Basic business model's levels

A business model defines the way a metropolitan public network should be exploited. It defines the role of the municipality or the public authorities, the handling of competition issues, the involvement of private companies, etc. Its intention is to provide the citizens with a viable metropolitan fiber optics network, including the proper resources for the maintenance and the expansion of the network [5][6]. The main goal is the provision of better and less expensive services to the public [7]. Figure 2 presents the 3 basic levels of a business model.

- The first level refers to the physical infrastructure of the network (ducts, dark fiber, etc.) and to the organization that provides and exploits this broadband network infrastructure.
- The second level refers to the active equipment of the network, e.g. routers, switches, etc.
- The third level refers to who has access to the network, its services and the provided content.

By assigning each of the above mentioned levels to different organizations, consortiums or companies, different business model cases can be proposed:

- Equal Access Model: In this model the broadband infrastructure is built by the city or state and then it is being leased or sold to an operating company or a consortium. The operating company adds the active equipment to the network and sells access to the operating broadband network to any service provider. The service providers pay to the operating company a monthly fee per customer, while independent content providers are able to sell their content to the public or to business customers. This process is done through the operating company's portal, which is responsible for keeping billing records and having a direct billing relationship with the customer.

  The role of the public authorities (municipality or government) in this model is to stimulate competition at the level of content and services. The government in this model has already invested in passive infrastructure, thus the cost for a service or content provider to enter the market is much lower. Through the operating company the government ensures an equal confrontation of all the service and content providers. In this model the roles and responsibilities of all the involved organizations must be clearly defined, because it may lead to complex structures and processes [8].

  The equal access model is followed by a number of international and EU countries. Examples of this model can be found in the Netherlands (Enschede) with the Dutch/German Internet Exchange (NDIX), in Canada (Alberta) with Axia and in the US (Grant County) with the Zipp Network. Variations of this model can also be found in the case of the city of Amsterdam, where the physical infrastructure already existed and in Spain (region of Catalonia) and Italy (Infratel), where local government also set up the active infrastructure of the network.
- Sole Private Provider Model: This model is applicable for cases where no service and content providers preexist, and the broadband market has not create a critical mass of customers that would be able to generate sufficient revenue to a large number of involved companies. In this model the operating company is also the service provider. In this way, the development of broadband infrastructure can become more easily a viable project, but the customers experience a less wide range of services at a price which is not benefited by the competition of companies. For this reason, the monopoly of the operating company should be maintained temporarily, in order to lead to an equal access model in a

fixed period of time. This model requires a lower management complexity and is also more attractive to service providers as it becomes commercially viable much more quickly [8]. Examples of this model can be found in Sweden (Stokab – Stockholm) and the Netherlands with the Fiber Pilot program in Almere.

- Full Public Control Model: In this model, all the layers are managed by one or more public organizations, including the development of passive and active infrastructure and the provision of services. Private sector can also get involved in a variation of this model, by the creation of public-owned companies with private capital investment. This model is suitable in cases where the involvement of an operating company is not feasible and no service providers are activated. Most of the times, this is the case of rural or remote communities, with no prior broadband infrastructure [8].

  The main problem of this model, like the previous one, is that no competition is evolved between service and content providers. Moreover, the lack of technical expertise of the local government most of the times has as an effect less innovation in the deployment of the network and its provided services. Finally, the cost of the total investment in building the network and providing the services is quite high for the local government. Examples of this model can be found in Italy with Terrecablate in Siena and Acantho in the region of Emilia-Romagna, and in Austria with the Wienstrom in Vienna.

4.1 Proposed Business Model

The selection of the proper business model is essential for the viability and the success of the project. Regarding the Metropolitan Area Networks, the use of the equal access business model based on a national level is the one that seems to fit most in the case of Greece. In this business model, the public sector is only the owner of the passive infrastructure (level 1 in the model presented in Figure 2) while in the upper two levels (Figure 2), competition is delivered between both telecommunications carriers that operate the networks and content and service providers.

The public sector's organization (who will operate on level 1) will provide the fiber optics infrastructure, in a cost-effective way, to the telecommunication companies. The mission of this organization will be the establishment of competition conditions between the providers, the maintenance and the expansion of the network, where this will be necessary. In particular, it should have certain responsibilities, such as the information of the citizens, the recording of the needs during the use of the network infrastructures, in order to be able to maintain the networks and conduct the studies for their expansion. The requested revenue for the expansion of the network will come by the leasing of the existing infrastructure to telecommunication and service providers. Thus, the service and content providers will focus on their role by providing their competitive services in a cost efficient way. The consumer will be able to choose among the competition a great variety of different services.

All in all, this model has some certain advantages regarding the design and the deployment of an overall broadband network in Greece. In this way, the service and content providers will provide their services at a low cost and in a continuously developing way. The service providers will also gain from this situation, as they will have access to national infrastructure through one organization and network operating schema. Additionally, there will be competition in the network level between telecommunication companies as it is shown in Figure 2 and competition in the access, services and content level among the service and content providers.

5. CONCLUSIONS AND FUTURE WORK

In this paper is being presented the basic design aspects for the broadband municipal infrastructure networks in the region of Western Greece. The proposed broadband networks will cover the needs of the 8 major cities within the region of Western Greece and other 61 networks in other regions of Greece. These networks will interconnect the organizations of education, research, health, culture and the sum of the buildings of public administration through high speed connections, and will also establish public collocation points and exceeding fiber cables that can be used cost effectively by service and content providers. Additionally, the case of city of Patras, the biggest case on the designed MANs, is described. Finally, paper discusses the proposed business models for the operation of those broadband networks and the one that we believe that suites better in Greek case.

For future work, we have already plans that contain the supervision of the deployment and the full description of the appropriate business model that covers all technical and political aspects for the operation of those broadband infrastructure networks.

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