Applied Architectures to Brazilian´s Open Access MANs

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Abstract

Currently in Brazil, we are seeing an increasing development of Open Access Metropolitan Area Networks. Many cities have implemented this architecture with the aim of providing free Internet access and other services to citizens. Open Access Metropolitan Area Networks (Open Access MAN) are built to allow universal access to a single digital multimedia communication network. The aim of this paper is to discuss our experience in developing Open Access Metropolitan Networks, focusing on technologies and cost-benefit considerations. We present the results we had in the development of a Open Access MAN for the city of Pedreira, Brazil. This city has implemented many services to the citizens including free Internet access. The logical structure for this network is based on TCP/IP and the infrastructure is based on fiber optic and wireless networks.

Key words:

Convergent Networks; Free Internet Access, Digital Cities; Multimedia Networks; Open Access Metropolitan Networks; Universal Access Networks, Open Mans

1. Introduction

We can define an Open Access MAN as a convergent multimedia network offering universal access for the whole population of a city [1][2][3][4]. Open Access MANs are part of an information distribution environment that allows digital inclusion and universalization of the information [5][6]. The universal access to information is a prerequisite to the evolution of the Information Society.

Many network solutions may fall in the category of this broad definition. However, the state of the art development of TCP/IP networks powered by optical and wireless Ethernet solutions (Gigabit Ethernet, 10G Ethernet, IEEE802.11x, IEEE802.16x, etc) offer a single generic environment that may be considered the best candidate to become the solution of choice for a single and universal convergent network.

Open Access MAN has been studied in different countries as an alternative to provide broadband services to citizens. Troulos and Maglaris [7] present a survey with 74 cases of broadband networks developed with municipal intervention in European countries, discussing their strategies and affecting factors. On the other hand, Hudson [8] presents lessons learned from open access MAN development in San Francisco and Silicon Valey, USA.

The complexity to develop an Open Access MAN has to consider a lot of parameters that are responsible to provide services with quality for all public institutions and citizens. In order to develop a MAN, we can use more than one media, and this choice for each POP (Point of Presence) is an important point that will make the difference in all aspects for entire network project. Considerations as cost-benefit, location of the POPs, their demands, and many other characteristics should be taken in an important study for the total feasibility of a MAN, that probably will grow up with new citizens being added year by year.

In this paper, we seek to practically illustrate the results measured in a real project implementation for a Brazilian city that have adopted the Open Access MAN structure. We also illustrate the choice for two main network topologies and the relationship between them. However, the main contribution of this paper is to present possible answers about choices that have to be made for the implementation of certain technologies over others, the concept of the cost-effectiveness of services, maintenance of these infrastructures, and what are the important steps and concepts to be considered when a Digital City is being designed.

This work is organized as follows. Section 2 brings background concepts about Open Access MAN. Section 3 presents how the infrastructure of Open Access MAN is designed and developed, discussing costs and presenting a case study performed in Pedreira, Brazil. Finally, the conclusion is presented in section 4.

2. Open Access Metropolitan Networks

On the physical point of view, we can describe the Open Access MAN as divided into three layers: Access Layer, Distribution Layer, and Network Core.

The network core, normally built using a fiber optic backbone, forms the central part of the network. Being capable to transport hundreds of gigabits per second of information, the core is what guarantees that the Open Access MAN will support the full traffic demand of the city. It is built to support the largest bit rates generators of the city. The core must also offer the points for the interconnection of the distribution layer network. All these connections link themselves to the core through specific points: the points-of-presence (POP). Because of the high speed nature of the network core, we shall call these POPs as GPOPs (from Gigabit POPs).

The Distribution Layer is responsible to centralize the data flow in and out of the access points. This layer is composed of several distribution centers connected

Manuscript received September 5, 2011
Manuscript revised September 20, 2011

directly to the network core through a GPOP. Because of its function, the distribution center must be capable of handling from tenths of megabits per second up to a gigabit per second of data flow. A point of connection in this layer is called a DPOP. The DPOP can be constructed using several different technologies, from wireless technology to twisted pairs or even fiber links.

Figure 1, presents the conceptual physical architecture of an Open Access MAN.

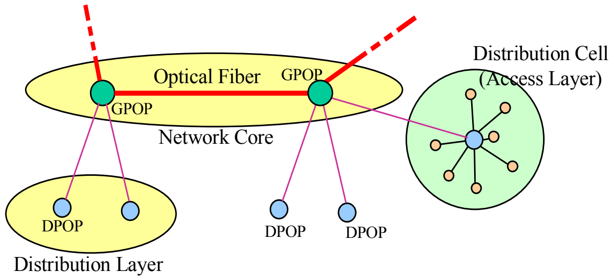

Figure 1. Physical description of an Open Access MAN

Finally, the Access Layer is responsible for handling the generic point of presence of the Open Access MANs. These points are aimed at connecting homes and small businesses. They derive from the DPOP forming distribution cells.

2.1 Logical Architeture

On the logical point of view, the Open Access MAN, at least in the form we are now practicing it, is built upon the Ethernet and TCP/IP protocols.

Ethernet is not more only a LAN technology. Its evolution enables the application of Ethernet in the construction of MAN and WAN. In 2010, it was released the standard IEEE 802.3ba with the fastest Ethernet version, which is able to send frames at 100 gigabits per second. Since 2001, the Metro Ethernet Forum has worked to make Ethernet a suitable technology to carrier-class networks.

TCP/IP protocols are the core of Internet. The most of networking applications in the world are executed over TCP/IP, what makes this protocol suite a mature and well tested option.

2.2 Benefits of Deploying Open Access MANs

Within available technologies, the most promising is an infrastructure of transmission using a fiber optic network as physical environment. In the future, we foresee that the Open Access MANs may provide citizens the most different services (high speed Internet access, VoIP, videoconference, video over demand, Web TVs, Web Radios, citizen access to public services, e-business, e-learning, etc).

3. Open Access MAN Infrastructure

The initial goal of a Digital City is to interconnect the public institutions and buildings, such as: municipal schools, city hall, health centers, hospitals, courts etc. [9]. This section shows how important is to consider some parameters about the choice of the communications media.

The Open Access MAN of the city of Pedreira, São Paulo, was developed in 2006 and was the first Brazilian municipality to be called as a Digital City. This project and its infrastructure's characteristics will be deal in this chapter. The network is hybrid, with optical and wireless topologies, where the main infrastructure is composed by an optical backbone Gigabit Ethernet complemented by Wireless Access links and cells based on the standards IEEE802.11 *a* and *g*.

Considering the calculations to be made for the connection services of POPs, the following active devices and their facilities were considered on a connection between only two POPs using these two technologies:

- *Fiber Optic:* 2x Switchs – Layer 2 (with SFP Gigabit-Ports *feature*), 4x GBIC-Gigabit-Ethernet Ports 1000BaseLX, 2x I.O.D. (12 fibers - Internal Optical Distributor), 4x Duplex Optical Extensions, 4x SM Duplex Cord, and the cable of Single-Mode Fibers.
- *Wireless Links (IEEE 802.*11a/g): 2x Standard Routerboards, 2x MiniPCI IEEE802.11 5.8GHz Adapters, 2x Outdoor Antennas and Accessories, 2x Switchs, Installation and Configuration Service, and a Self-supporting Tower (15 meters).

So, the main issue of a Digital City's Project is to decide exactly when a connection must be made by fiber or radio. This decision is often made by terrain characteristics, location of the POP and the cost-effective for connecting every building. However, these parameters may not be enough.

3.1 Cost-benefit

As we have already mentioned, this is an item of extreme relevance to all Digital City's elaboration project. Every POP holds a cost benefit to be put into the development. It is from the analysis over data demand, the amount of users (citizens), employees, computers, telephones and the importance of that area to the city, which the benefit of the service to the building can be defined. But, these are not the only factors in the definition of the importance of the area. In the cost-benefit, the analysis of insertion of a POP in the project is considered. For example, if a POP has not a demand to be served by fiber optic infrastructure, being unfeasible to be connected by this media, but, from it, other points can be achieved by fiber optic or wireless links, then its significance will be increase, and the benefits to achieve this POP in the operation will be changed.

3.2 Costs for Deploying the Topologies

It is commonly believed that high costs are associated with the deployment of fiber optic infrastructure for communications network. Our goal here is also to show that, in the case of Open Access MANs, fiber optic infrastructure is the only way to match affordability with the high-speed connection necessary for the convergence of services we are looking for.

Here, the results of the investments are presented regarding the two different types of common infrastructures applied on metropolitan networks. These data were related for the current network of Pedreira. The variables of implantation in this project and the basis of values can allow us to choose the better type of media to be used for each transmission between the POPs: fiber optic or wireless links.

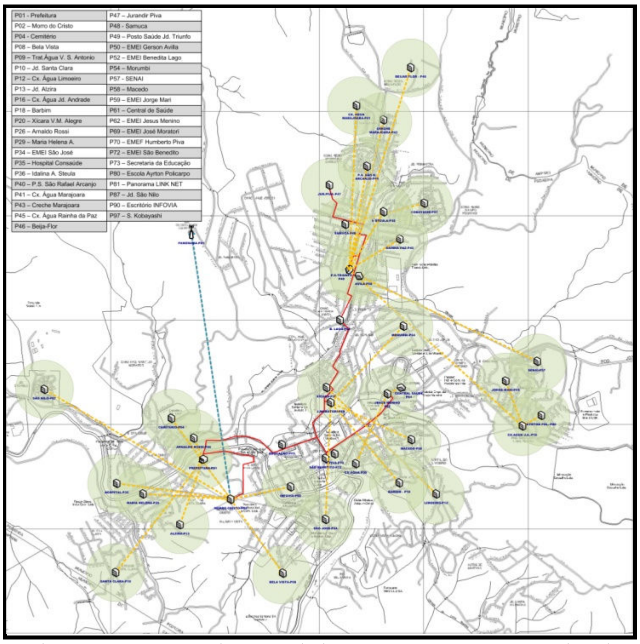

Figure 2. Interconnections – Pedreira's Open Access MAN Deployed

3.3 Discussion-Case of Pedreira's Open Access MAN

Figure 2 presents the conceptual project of the Open Access MAN of Pedreira.

The simplest approach considers the covering of the city with sets of wireless cells. These are based on the construction of a network of distribution nodes which are connected to the main backbone by fiber optic or wireless IEEE802.11a standard links.

The Open Access MAN of Pedreira was bid in September/2006 and deployed in November of that same year. The optical infrastructure is distributed over 10 *km* of electric energy poles of the city and a total of 13 buildings are interconnected to the main backbone through optical links of 1Gbps. The central network node is located on the City Hall, where traffic is commuted among the other network nodes, with the Internet, and with public switching telephone network.

Tables I and II present the main items involved in an optical connection and in a wireless link between two buildings. These data are used to the comparison of the media. All the prices were exchanged for dollars to a project developed in Brazil (R$).

The values for the optical devices and for the area of meters of cable were given by three possible conditions used in wireless communications being deployed for the same amount of investment. These three combinations of wireless communications and the relationship with the measurement of optical cabling are presented in Figure 3. From these three possible ways of wireless, we consider that they can communicate by their own structure, or by using a midsize steel tower (approximately 15 meters).Table I presents the values of the equipment and the basic quantities of the devices used only for the establishment of a simple wireless data link. The opening of cells was not considered in this paper because we only want to demonstrate the service provider of a POP. Table II presents to the same values of the wireless conditions, the distances (in meters) achieved between two adjacent POPs interconnected by fiber.

TABLE I
COSTS TO BUILD A WIRELESS COMMUNICATION LINK

Equipments	Price[1] (Unit.)	Qty.	Sub-Total
5.8GHz MiniPCI Adapters	$89.96	2	$ 179.92
Digital Routerboard Radio (IEEE 802.11a/b/g)	$551.36	2	$ 1102.72
POE Source (for Digital Radio)	$23.22	2	$ 46.44
Switch Layer 2 (*feature:* 2 SFP)	$500.00	2	$ 1,000.00
Outdoor Case and Mounting Bracket (with No-Break)	$377.78	2	$ 755.56
Directive Antenna (Gain: 28dB)	$87.06	2	$ 174.12
Pig-Tail (one for each antenna)	$13.89	2	$ 27.78
Service Installation & Configuration (per POP)	$870.57	2	$ 1,741.14
Installed Freestanding Tower – 15 meters	$11,400.00	*T*	*T* . $11,400.00
Costs for Condition #1 (Best-Case: without towers, T = 0)			***$ 5,027.68***
Costs for Condition #2 (Only one Tower, T = 1)			***$ 16,427.68***
Costs for Condition #3 (Two towers, T = 2)			***$ 27,827.68***

T = quantity of towers to be used: $0 \leq T \leq 2$
[1]Prices in Reais (R$) exchanged for Dollars (US$) – 2010 - September, 09 (US$ 1.00 = R $ 1.7230)

Thus, the investment for each optical point (without the passage of fiber) is equivalent to US$2,471.17. With respect to the value of radio *Condition 1*, by the optical infrastructure we can consider only the equipment used for the transmission because we cannot connect two buildings by 10 meters of optical cable.

We observed that the difference in hardware deployed for operation between two points for the simplest condition (#1) is different only on US$85.34. For the other two conditions, using steel towers for the wireless infrastructure we can obtain big differences for the installation of optical cables. This comparison may show us how important is to know all POP individually. This is because we can develop MAN's projects where connections made by radio links can be made by fiber optic for the same cost, or even less, especially when the POP needs a tower. Moreover, the opposite can happen when one POP does not have demand or characteristics to be connected by fiber being attended by a cheaper radio link (e.g. nursery school). The relationship for the investments for these two media is illustrated in the Figure 3.

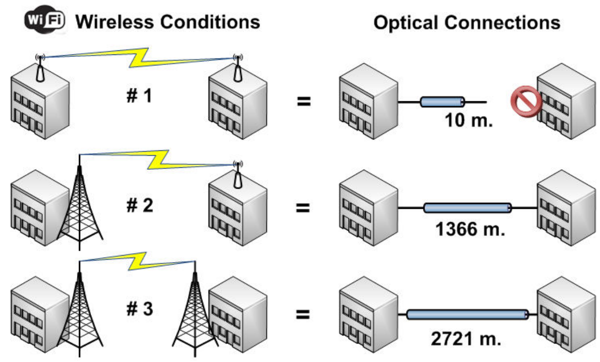

Figure 3. Considerations between the two medias for a Metropolitan Area Network infrastructure

Currently, the optical laser ports are able to generate pulses for transmission to a 10 and up to 100Gbps. This article has considered the speed of 1Gbps, the same bandwidth applied on the city of Pedreira. For wireless communications, the average transmission rate adopted in the links was 54 Mbps. This is the maximum operating rates for radios in standard configurations, according to the types of the directive antennas [15].

TABLE II
ADJACENT POINTS CONNECTED BY FIBER OPTIC

Equipments	Price[1] (Unit.)	Qty.	Sub-Total
Single-Mode Fiber Optic Cabling (6 fibers) - per meter	$3.13	*F*	*F* . $3.13
Internal Optical Distribuitor - 6 fibers (three pairs)	$128.14	2	$256.28
Duplex Optical Extensions	$28.11	4	$112.44
Cord Singlemode Duplex	$54.33	4	$217.32
8U Rack's	$188.55	2	$377.10
Service Pass: Optical Cabling installation in the eletrical poles - per meter	$5.28	*F*	*F* . $5.28
Switch Layer 2 (*feature:* 2 SFP)	$500.00	2	$1,000.00
SFP Port – G-Ethernet 1000BaseLX	$569.80	4	$2,279.20
Service Installation & Configuration (per POP)	$350.00	2	$700.00
Price (Only Equipments, F = 0)			***$ 4,942.34***
By the Costs for Wireless Condition #1, F = 10 meters			***$ 5,027.68***
By the Costs for Wireless Condition #2, F = 1366 meters			***$ 16,427.68***
By the Costs for Wireless Condition #3, F = 2721 meters			***$ 27,827.68***

F = meters of fiber optic cabling has gotten for the same values in the three wireless possible infrastructures. F is also the only variable that determines the costs for the passing service in the electrical poles and for the cost of all cable to be acquired.

We observed the usage of 28 links involving 35 POPs that are distributed in these three conditions mentioned above and which comply with these distances by applying coherent directive antennas. Thus, considering the individual analysis of each point, we have for the Pedreira's Open MAN, eight links for *Condition 1*, thirteen links for *Condition 2* and six links for *Condition 3*. Figure 4 illustrates how necessary is the infrastructure of steel towers in the creation of a wireless transmission system in a Digital City, and how they can increase the costs for this topology. However, once we established a link between two buildings that fall in *Condition 3* (requiring the deployment of towers in both POPs), any other condition of communication with one of the buildings created from this case will be changed for the *Condition 2*. The same process happens to this second condition, where a new connection with a POP that has already deployed a tower will be considered in the first condition. This occurs by the infrastructure that has already been considered in establishing the first link. In the wireless topology of Pedreiras's Open Access MAN, 21 POPs are using steel towers in a total of 35.

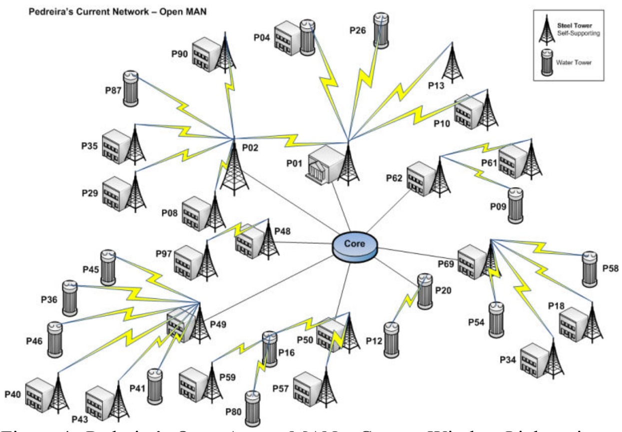

Figure 4. Pedreira's Open Access MAN – Current Wireless Links using steel towers connected to the Optical Backbone

4. Conclusion

In this paper we describe our experience in designing and deploying Open Access Metropolitan Area Networks (Open Access MANs) as Digital Cities in some Brazilian municipalities. Our best experience with the construction of Open Access MANs happened in the deployment of the community network of Pedreira, a 45,000 inhabitants located in the southeast of Brazil. In Pedreira, a hybrid optical-wireless network was deployed.

This article sought to present through experience in developing projects that in the most of the cases the distance should not be the only topic to be taken into consideration in the choice of means of transmission to meet the point of an Open Access MAN. Even with well-known quality and reliability, fiber optic cannot be the best option for service providing, since several other parameters must be taken into account in the analysis of individual attendance of all POP and for the entire MAN network. However, optical technologies for physical access are being year by year more affordable, what will make it the most probable choice for these projects on few years.

Thus, the Open Access MAN will be well known in both parties as a whole, growing hierarchically and being developed with flexibility, quality and organized manner. The result is better cost of any feasibility study involving the broadcast media in attendance at each POP and for all the Open Access MAN. The knowledge of all the spread points to be attended in the city is what determines the choice for better conditions for infrastructures. In these networks, one point can be treated by various different topologies, so the determination of the most economical and efficient way to the communication according to its demand is very important.

Different from LANs, every POP in a metropolitan network has its own characteristic and feasibility for the choice of a specific media service. Moreover, this choice for the physical environment can promote the appropriate project in transmission quality, redundancy, scalability and cost optimization. All considerations and analysis of service providing should be taken individually. But, more important than the condition of individual communication is the result of broadening out the network, which should take into account all the points that have already selected to be a member of the project done, seeking to create a core from them to get all other new POP or to achieve last-mile buildings.

The goal is to establish a better quality of transmission with the highest rate possible and with a considerable cost according to the POP's demand and its location. It involves the important consideration that is extremely necessary to guarantee the demand of transmission by the media chosen. As we could observe, in the designing of an Open Access MAN not only this transmission rate decides the media to be deployed for the connection of a POP.

There are several feasibility studies which should be taken into account to stimulate and encourage the development of better economic topologies of networks used to meet the demand of each POPs and to be applied on whole projects of Open Access MANs. We expect that this discussion case can improve the development of projects for metropolitan networks in Brazil and around the world. These techniques are already being applied in new conceptions, as in the city of Itatiba, Paulínia, São Bernardo do Campo and Vinhedo, cities of São Paulo, Brazil.

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