CORFUNET: A MESH NETWORK PROVIDING WIRELESS SERVICES AT METROPOLITAN LEVEL

Adamantia Pateli
Ionian University
7 Tsirigoti Sq., 49 100, Corfu, Greece, E-mail: pateli@ionio.gr

Andreas Floros
Ionian University
7 Tsirigoti Sq., 49 100, Corfu, Greece, E-mail: floros@ionio.gr

Konstantinos Oikonomou
Ionian University
7 Tsirigoti Sq., 49 100, Corfu, Greece, E-mail: okon@ionio.gr

Emmanouil Magkos
Ionian University
7 Tsirigoti Sq., 49 100, Corfu, Greece, E-mail: emagos@ionio.gr

ABSTRACT

This paper discusses the technology and commercialization challenges of a research initiative intended to establish a wireless metropolitan network for the city of Corfu. Key wireless mesh networking issues are discussed and value for the potential service providers and users of the network is specified. The network development builds on advanced features of wireless mesh networks, like multi-channel and multi-radio operation, connectivity to a fixed network infrastructure through multiple links and general purpose applications support, which overcome many of the limitations that are currently imposed by wireless ad-hoc networks. The proposed network is designed to provide apart from broadband Internet access a number of sophisticated services to the citizens, tourists and business visitors of the island. To assure viability and expansion for the CorfuNet initiative, the present study discusses scenarios on two alternative business models, namely the collaborative and the single provider models, differentiated on the basis of the network's owner.

KEYWORDS

Mesh networks, metropolitan, wireless, ad hoc, Corfu

1. INTRODUCTION

The CorfuNet project envisions the construction of a wireless mesh network for broadband information access in the metropolitan area of Corfu. Corfu comprises one of the highest inhabited, with over 40,000 permanent habitants in its city, Greek islands. The city of Corfu is full of monuments of historical significance. Corfu is also the home of the first University of Greece, the Ionian Academy. Apart from its cultural nature, Corfu is world-wide known as a tourist destination of incomparable beauty hosting annually thousands of tourists, thus making Corfu one of the dominant islands in the Greek tourist industry.

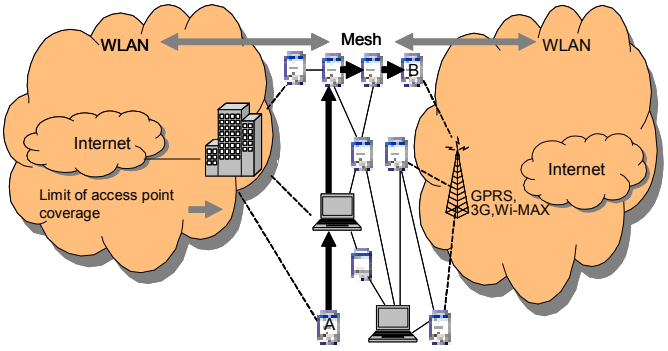
In this paper, we describe a research initiative towards the implementation of a Wireless Mesh Network (WMN) in the city of Corfu, based on the experience of several testbeds that have been established to carry out research and development of WMNs (Maltz et al., 2001; Aguayo et al., 2003). This particular research aims at employing a number of fixed and mobile nodes to provide open and free wireless local access for citizens and visitors of Corfu. The services will be offered to fixed or portable devices with wireless

capabilities, such as PDAs, cellular phones and laptops. The wireless services to be provided through the network will offer cultural, historical, as well as other related information (news, highlights, guides, city maps, recreation opportunities) in an interactive way.

2. RESEARCH BACKGROUND AND CHALLENGES

A WMN is a mesh of networks, intended to deliver wireless services over different types of networks like Sensor Networks, Wi-Fi, Wi-Max, Ultra Wide Band (UWB) and the newly emerging area of cognitive radios. More specifically, a WMN is a mix of fixed mesh nodes (routers) and mobile mesh nodes (clients) that are interconnected via wireless links to form multi-hop ad hoc networks (Figure 1). The mesh routers usually employ multiple radio interfaces and form a multi-hop wireless backbone, while some of them may have a fixed connection to the Internet. Hence, WMNs are not isolated. Instead, they operate as self-configured, flexible and low-cost extensions of the wired infrastructure, offering data transport services between clients connected to the mesh network, or between these clients and the Internet.

Figure 1. Configuration of a Wireless Mesh Network



From the architecture point of view, WMNs can be subdivided into two major categories: Infrastructure WMNs and Hybrid WMNs. An infrastructure WMN is a structured mesh network with two types of nodes being considered:

1) Backhaul Nodes: These nodes are (usually) fixed nodes and can be considered the equivalent of a network core, namely the backhaul network, which interconnects WMN clients and handles traffic between nodes. The backhaul network can also provide integration of the WMN with other networks (e.g. Internet, cellular networks, IEEE 802.11 WLANs, IEEE 802.16 WMANs). The WMN backhaul nodes offer basic access point and routing services for WMN clients and usually have multiple radio interfaces with full duplex capabilities. For example, one radio interface talks to the WMN client, and the other to its peer.

2) Mesh clients: Mesh clients can be either fixed or mobile. In a basic service set, mesh clients are expected to have single radio capabilities with half duplex connections. In contrast with fixed backhaul nodes, power consumption may be an issue for mesh clients, since it has a major impact on the nodes' lifetime and eventually on the offered network services.

When compared to infrastructure WMNs, hybrid WMNs offer several additional services to their end users. A mesh client may also house routing functionalities to allow other client nodes to access a backhaul node that is out of range, thus extending the network coverage, while allowing more users to enter the network from areas that the infrastructure cannot or may be not easily established. Thus, mesh clients can access the network either through the backhaul network or by directly meshing with other clients. Furthermore, mesh clients in a hybrid WMN can also establish temporal networks to communicate in an ad hoc manner.

Clearly, the WMN concept relaxes the main constraint of a classic MANET (Mobile Ad-Hoc Network) that the network consists only from user devices and no infrastructure exists. Compared with the Wi-Fi (IEEE 802.11) hot spots, WMN networks can offer increased reliability and flexibility, with redundant paths being

available for each connection. MANETs are often referred to as a subset of WMNs. Furthermore, in contrast with Wi-Fi hotspots, where one-hop connection is available for clients and high bandwidth wires connect the Wi-Fi access points, WMNs have huge potential for supporting broadband access for mobile users at the local (home and organisation) and the wider (public and metropolitan) area level, even when no prior infrastructure exists, and in cases where deployment is for a limited time period (i.e. during the high-season tourist periods). Moreover, as an alternative broadband access technology, wireless mesh networks can, through increased competition, enable generalized and affordable access in less developed and rural areas.

Although mesh networks can employ some of the techniques developed in ad hoc networks (i.e. self-configurability and multi-hop forwarding), they have important differences that require different design principles, control and management procedures. These differences typically include multi-channel and multi-radio operation, heterogeneous wireless technologies, limited mobility of mesh routers, interconnection to a fixed network through multiple links, and general purpose applications support (Akyildiz et al., 2005). Moreover, high research attention has been recently devoted to solve the difficult problem of providing basic security services like key management and authentication for the ad hoc networking paradigm (Molva & Michiardi, 2003).

The interest in wireless mesh networks has given rise to experimental and non-commercial mesh testbeds funded and operated by government agencies, non-profit organizations, municipalities and research institutions. Representative examples include the Seattle Wireless Network, the Champaign-Urbana Community Wireless Network (CUWiN) (Lad et al., 2005), the San Francisco BAWUG, the Roofnet system at MIT (Bicket et al., 2005), the Wireless London and the Berlin Roof networks. Finally, related initiatives in Greece include the Athens Wireless Metropolitan Network, the Thessaloniki Wireless Metropolitan Network and the Heraklion Students Wireless Network.

3. THE CORFUNET PROPOSAL

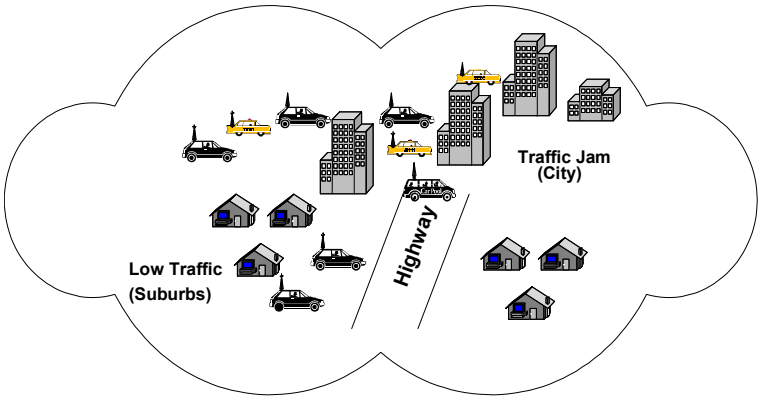
3.1 Infrastructure

In order for the CorfuNet to be able to provide services in the whole city of Corfu, it is considered important to cover the metropolitan area with an appropriate Wireless Mesh Network "infrastructure". The idea is to deploy a backhaul network by using the roofs of some centrally-situated buildings in the city as fixed backhaul nodes. For the beginning, it will be enough to use the buildings that belong to the Ionian University, since they will allow for the coverage of the most (almost the entire) city area. Actually, the campus of the Ionian University consists of several historical buildings in the main (and touristic area) of the city of Corfu (e.g., Ionian Academy, Palace of St. George and St. Michael, Old Fortress), hence allowing for large coverage of the CorfuNet.

At the first stage, the CorfuNet is planned to operate as infrastructure WMN. However, depending on the success of its operation and the users' demand for future services, the research team plans its transformation to a hybrid WMN. In this case, the deployment of a wireless vehicular network in parallel and in cooperation with the existing WMN is planned. Such a network will allow for use of network facilities in distance places as proposed in Marfia *et. al.* (2007), but mainly it will allow for the existence of a complementary network available in cases of emergency (e.g., fire, flooding, earthquakes).

Figure 2 depicts a hybrid example of a WMN and a wireless vehicular network. Base stations are located on the buildings and on the cars. In urban areas, connectivity is highly available. However, in the suburbs, connectivity is spontaneous and network availability sporadic depending on the particular (and most likely delay tolerant) application. For example, utilization of the local suburbs bus schedule may allow for downloading large files (e.g., video). Eventually, the proposed CorfuNet may be seen as a WMN infrastructure over which different technologies may be adapted due to its flexible structure.

Figure 2. Configuration of a Vehicular Mesh Network



3.2 Content and Services

The CorfuNet network is intended to provide its target groups with broadband access to Internet. Nevertheless, its purpose is also to deliver a set of advanced wireless services for three target groups: a) tourists; b) business visitors; and c) citizens. The application design and implementation process is going to be conducted in two stages. At the first stage, a basic set of applications including provision of tourist and local information will be provided. At the second stage, we plan to provide a set of value-added services for all the above target groups. Such services are planned for a later stage as they require for a reliable network infrastructure to be successfully implemented and a critical mass of users to be already connected to the network. As illustrated in Table 1, the CorfuNet services have been defined to create value for three target groups (tourists, business visitors, citizens) and encourage synergies with local content and service providers.

Table 1. Description of Services provided for each Target Group

SERVICE	CONTENT/SERVICE PROVIDERS	TARGET GROUPS
Basic CorfuNet Services		
Local News	▪ Local News Channels (e.g. local TV channels, publishers of local newspapers)	Citizens, Tourists Business visitors
Public Transport Itinerary	▪ Local Transport Parties ▪ Airline/Shipping Companies	Citizens, Tourists Business visitors
Agenda of Social Events	▪ Municipality of the Corfu city ▪ Perfecture of the Ionian Islands ▪ Other local parties (i.e. Ionian University)	Citizens, Tourists Business visitors
Commercial/Tourist Catalogue	▪ Association/Union of Traders	Citizens, Tourists Business visitors
Digital Map	▪ Municipality of the Corfu City ▪ Development Company of the Corfu Municipality	Tourists Business Visitors
Value-Added CorfuNet Services		
Electronic Local Newspaper	▪ Local Channels (e.g. local TV channels, local newspapers) ▪ Local enterprises and free-lancers	Citizens Business Visitors
Reservations	▪ Cultural Parties ▪ Local commercial/tourist enterpises	Citizens, Tourists Business visitors
Multimedia Touring Services	▪ Cultural Parties	Tourists Business visitors
Navigation Services	▪ Policy Authority ▪ Municipality of the Corfu City	Citizens, Tourists Business Visitors
Discussion Forums	▪ Application provider	Citizens, Tourists Business Visitors

3.3 Scenarios for the CorfuNet Business Model

Using a method that identifies scenarios and generates contingencies for developing business models (Pateli & Giaglis, 2005), we extract two primary scenarios for the business model that could support the CorfuNet's operation and viability. Each of them is then analyzed using description of its core elements; the value network including the actors and the roles that they assume in order to provide the CorfuNet's services, the basic value-creating exchanges between them, the revenue model and the value creation potential for the CorfuNet provider(s) and customer(s).

The *Collaborative* scenario. This scenario concerns the formation of a partnership between a local authority (e.g. the municipality), a research body (e.g. the Ionian University) and a number of ICT actors. The last ones may be firms having contributed to the CorfuNet's development, such as the wireless network equipment provider, the Internet Service Provider and one or more applications/service providers. The above bodies may form a consortium or an alliance to jointly support the network's further development and operation. In its extreme form, the scenario comprises the establishment of a joint venture. In this case, a new legal entity, based on equity of all bodies, will be established to take on operation of the network and its services.

The *Single Provider* scenario. According to this scenario, the overall responsibility for both the network infrastructure and the service provision is assigned to a single party, keeping the ownership rights of the CorfuNet network. This provider could be a local non-commercial body having some type of power and control over the metropolitan area, such as the Development Company of the Corfu Municipality, the Union of Local Traders, the Prefecture of Ionian Islands, or the Ionian University. Of course, it is not possible for the local body to have all the resources and knowledge required for the network's growth and exploitation. For that reason, a number of partnerships in the form of outsourcing and service-level agreements are going to be implemented between the owner and several other private ICT companies.

REFERENCES

Aguayo, D. et al, 2003. MIT Roofnet Implementation. [Available online at: http://pdos.csail.mit.edu/roofnet/design/, last accessed on: 05/02/2008]

Akyildiz, I.F. et al, 2005. Wireless Mesh Networks: A Survey. *In Computer Networks Journal*, Vol. 47, No. 4, pp. 445-487.

Bicket, J. et al, 2005. Architecture and Evaluation of an Unplanned 802.11b Mesh Network. *In Proceedings of the 11th annual international conference on Mobile computing and networking*. Cologne, Germany, pp. 31-42.

Lad, M. et al, 2005. Enabling Coalition-Based Community Networking. *In Proceedings of the London Communications Symposium*, London, UK.

Maltz, D.A. et al, 2001. Lessons from a fullscale multihop wireless ad hoc network testbed. *In IEEE Personal Communications*, Vol. 8, No.1, pp. 8-15.

Marfia, G. et al, 2007. Evaluating Vehicle Network Strategies for Downtown Portland: Opportunistic Infrastructure and the Importance of Realistic Mobility Models. *In Proceedings of MobiOpp'07*, Puerto Rico, USA.

Molva, R. and Michiardi, P., 2003. Security in Ad hoc Networks. *In Proceedings of Personal Wireless Communication (PWC 2003)*, Venice, Italy.

Pateli, A., and Giaglis, G. 2005. Technology Innovation-Induced Business Model Change: A Contingency Approach. *In Journal of Organizational Change and Management*, Vol. 8, No. 2, pp. 167-183.

Raniwala, A. et al, 2004. Centralized Channel Assignment and Routing Algorithms for Multi-Channel Wireless Mesh Networks. *In ACM SIGMOBILE Mobile Computing and Communications Review*, Vol. 8 , No. 2, pp. 50-65.

Royer, E.M., 2003. Multi-level hierarchies for scalable ad hoc routing. *In ACM/Kluwer Wireless Networks*, Vol. 9, No. 5, pp. 461-478.

Yuen, W.H. et al, 2002. A Simple and Effective Cross Layer Networking System for Mobile Ad Hoc Networks. *In Proceedings of the 13th IEEE International Symposium on Personal, Indoor and Mobile Radio Communications*, Lisbon, Portugal, pp. 1952–1956.