The RURALMAYA project, *(Comunidad Valenciana*, Spain)[1]

Strengthening Internet support in rural environments through wireless technologies in the Comunidad Valenciana, Spain.

RURALMAYA began in 2005 as a research project of the Technical University of Valencia in Spain. The project intended to develop new information and communication technology to offer low-bandwidth Internet access to isolated rural areas. With this purpose we developed Ruralmaya, an experimental wireless platform which combines the promising paradigm of wireless Mesh networks and cheap off-the-shelf wireless devices to offer a wide range of Internet-based communication services and applications. RURALMAYA has targeted rural areas of the *Comunidad Valenciana*, in Spain, with increasing demand for Internet connectivity to support the emerging industrial activity and population demands. To date, we deploy the proposed system in a small-scale project on a rural area located on the south of the *Comunidad Valenciana* which encompasses about 50 subscribers including local industry and villagers.

1. Project description

It is widely accepted that new information and telecommunication technologies are needed to alleviate a wide range of obstacles for economic and social development in rural areas. This is particularity true for Internet accessibility, since it offers a global platform for retrieving and sharing information. During the past few years there has been a remarkable progress in the most developed countries in terms of telecommunication facilities. However, outside the main urban areas, there are still important handicaps that make Internet connectivity a complex and costly task. In rural areas and small towns the Internet Service Providers (ISPs) do not assume the high-cost of technologies designed for the urban market. Moreover, low population density and high deployment costs discourage ISP investments since the estimated return on investment (ROI) is unattractive.

In this scenario we observe that Wireless local area network (WLAN) technologies have emerged as a promising networking technology to extend network connectivity outside private networks. Wireless technologies offer a very effective and inexpensive solution to bring wireless Internet at public venues. This synergy has been driven by wireless standards ratified by the IEEE, namely the IEEE 802.11 [IEEE80211] standard for wireless local area networking, also known as WiFi, and the IEEE 802.16 [IEEE80216] standard for long distance point-to-point and point-to-multipoint connectivity, also known as WiMax.

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We developed an experimental wireless system, called RURALMAYA, which extends the capabilities of hotspots to provide wireless connectivity at distant areas and at a low cost. The system combines the promising paradigm of Wireless Mesh Networks (WMNs) [MeshNet] with the Captive Portal technology, and it is based on the use of commercial off-the-shelf wireless devices. WMNs represent a good solution to provide Internet connectivity in a sizeable geographic area, and allow us to increase the coverage area of hotspots at a much lower cost than with classical Wifi networks.

Every client within the coverage area of RURALMAYA can access all the services offered, which does not mean free access or uncontrolled access. Our system is implemented under a captive portal solution based on the use of wireless access points to provide both an effective user authentication and physical connectivity to the backbone. RURALMAYA runs upon the a modified version of the OpenWRT [OpenWrt] project firmware, which allow us to implement access control into the AP while increasing the hotspot coverage by implementing a multi hop wireless mesh network. The OpenWRT firmware offers us all the functionality of the usual GNU/Linux tools for monitoring, bandwidth shaping, firewalling, and so forth. Our proposed system offers wireless Internet connectivity to rural areas located out of hotspots centers at a low cost. Users only need an Internet navigator to access RURALMAYA. When they access the system they are automatically redirected through the captive portal system to the main web page where they are authenticated for security purposes; further knowledge about wireless networks is not required, neither is it necessary to use special software.

Aims of the project

The general purpose of RURALMAYA is to strengthen Internet support in rural environments through wireless technologies in the Comunidad Valenciana, Spain. The system should empower mobile users with the ability to access Internet applications on the move.

Rather than creating a new wireless technology, the major challenge has been to demonstrate the practicality of designing and building a system that, by combing existing wireless networks paradigms, is able to reach distant areas at a low cost, while offering a wide range of telecommunication services and applications.

RURALMAYA scope and selected approach

The system has been designed to be scalable, and easily upgradeable to cover a wide area at a low cost. With this purpose we selected a multi-tier approach where all the subscribers are connected to the Internet through a main server which acts as a gateway to the Internet. RURALMAYA combines three different interconnected tiers (a) a wireless mesh distribution network, (b) a backbone wireless/wired network, and (c) a top level management system. This approach allows creating a scalable network which is able to cover a vast area, connecting the main server with all the clients within range of any of the APs deployed. We base our solution on Linksys WRT54G [Wrt54G] wireless routers, which operate using IEEE 802.11 technology on the 2.4 GHz frequency. Figure 1 shows the overall system architecture.

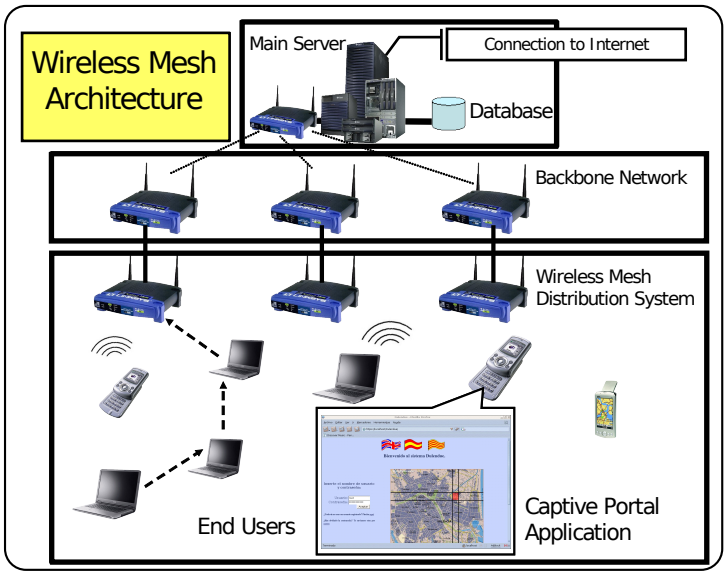

Figure 1. The RURALMAYA System Architecture.

- **Top level management system.** The top level management system is composed by a server that controls user authentication, and where all the software required supporting the system is stored. The main software components are a web server to interact with the subscribers, a database used to store system information, and a control unit that converts management decisions into traffic rules. Besides, the server has also a high-speed connection to the Internet, along with a wireless or an Ethernet connection to the backbone network.

- **Backbone network.** This second level is composed by a group of nodes distributed in the operative area, composing a mesh network. These nodes are connected to the main server and to other nodes through either Ethernet or IEEE 802.11 technology. Wireless connections are preferred since they can benefit of antennas to achieve increased range at little cost. The main purpose of this level is to work as a bridge, connecting subscribers to the main server.

- **Distribution network.** The distribution network is composed by several wireless routers representing neighboring rural areas, which are hierarchically grouped to form a mesh network. To implement the mesh network each WRT54G router at the distribution level activates the Ad hoc On-Demand Distance Vector (AODV) Routing protocol [AODV]. AODV is a simple and efficient routing protocol designed specifically for use in multi-hop mobile wireless ad hoc networks. By using AODV the coverage area can be easily extended since the network is completely self-organizing and self-configuring. Moreover, since the route used to reach any destination may change over time, the resulting network topology is frequently changing.

RURALMAYA interacts with clients through Captive Portal technology. Therefore, when one client first connects to the system and opens a web browser, he is automatically redirected to the main page of the portal; this process is completely transparent to the user. The management server controls

client access depending on whether he is a registered user or not. Depending on the client's access level, different services will be provided. The first time a client accesses the system he is asked to register himself with the Captive Portal. After a login process the user can use any of the freely available services, like Internet access. Concerning the Internet access service, the system allows to choose among multiple connection speeds.

2. Involved countries, organization, and people

RURALMAYA is part of a research project of the Computer Networks Group (GRC) of the Technical University of Valencia in Spain (http://www.grc.upv.es). RURALMAYA has been supported by the *Generalitat Valenciana,* Spain under grant GV05/245 and by the IMPIVA under Grant IMIDTD/2006/551. GRC members involved in RURALMAYA are Pietro Manzoni, Juan-Carlos Cano, Carlos T. Calafate, and Jorge Hortelano.

3. Project results and further work

We develop a small test bed in our laboratory to do a preliminary evaluation of the feasibility and performance of our architecture, including testing the capability of the hardware devices used and documenting all the software packages required to tune system. After that, we deploy RURALMAYA in a small-scale project over a rural area of the *Comunidad Valenciana* in Spain. We assess the viability of our system by providing a set of subscribers with Internet connectivity. A performance evaluation was made focusing on the throughput achieved and on the overhead imposed on the Linksys routers used. We find that the service offered to clients is the one we expected, while the system can be gradually scaled up as the number of subscribers increases.

The system is currently implemented using several programming languages and tools as applications running in user-space, and is a proof-of-concept to demonstrate the feasibility of the RURALMAYA architecture through extensive operation. We studied the system performance and also acquired experimental data, allowing us to evaluate the capabilities of the Linksys routers and the captive portal functionality.

The experience acquired during this project made evident that, by combining both wireless and web technologies, we are able to offer a cheap and efficient solution to provide Internet services to rural areas where users are sparsely located. Nevertheless, further work must be done to make an in-depth study of deployment and management of mesh networks to find the most appropriate strategy to scale the RURALMAYA infrastructure in a transparent manner.

All the developed software as part of the RURALMAYA project is free software, and it can be downloaded at http://www.grc.upv.es/software/index.html.

4. Contact person and links

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[IEEE80211] IEEE/IEC Std 802.11, Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications}, The Institute of Electrical and Electronics Engineers, Inc., August, 1999.

[IEEE80216] IEEE Std 802.16, IEEE Standard for Local and Metropolitan Area Networks — Part 16: Air Interface for Fixed Broadband Wireless Access Systems, The Institute of Electrical and Electronics Engineers, Inc., 2002.

[MeshNet] I.F. Akyildiz and X. Wang and W. Wang, Wireless mesh networks: a survey, Computer Networks and ISDN Systems, 2005, 47.

[OpenWrt] OpenWRT Project, Openwrt, Available at http://openwrt.org/.

[Wrt54G] Cisco~Systems.,Wrt54g Lynksys Router, Available at http://www.linksys.com.

[AODV] C.E. Perkins, E. M. Belding-Royer, S.R. Das, Ad Hoc On-Demand Distance Vector (AODV) Routing, Request for Comments: 3561, July, 2003.