An IEEE 802.11 static mesh network design for isolated rural areas in developing regions

Javier Simó[1], Pablo Osuna[2], Joaquín Seoane[3], Andrés Martínez[1]

[1]Department of Signal Theory and Communications. Universidad Rey Juan Carlos. andres.martinez@urjc.es

[2]Rafael Escolá Foundation and EHAS Foundation. posuna@ehas.org .

[3]Department of Telematic Systems Engineering. Universidad Politécnica de Madrid. jsp@dit.upm.es

Abstract

Isolated rural areas often lack of any terrestrial telecommunication networks, specially in developing countries, which supposes an important obstacle for many professional and comunitary activities requiring PSTN and Internet access. On the other hand, the low density and low concentration of population, the lack of electricity in many points and accessibility problems make it difficult to propose realistic solutions based on conventional technologies. This poster presents the development of an autonomous solar-powered wireless node for low-cost static mesh networks. The network is QoS-aware at the IP level so that VoIP services may be used reliably. Nodes contain a software PBX so that any two nodes in the network can establish a multihop VoIP communication.

1. Introduction

More than a half of world population live in isolated rural areas out of the scope of any terrestrial telecommunication networks. This is particularly true in developing countries, where very often rural areas lack of any access to telephone network or electricity. The low density and low concentration of population make it difficult to afford the installation of permanent infrastructures that would be expensive due to tipical restrictions in power servicing, accessibility, mainainability and security. Additionally, in developing countries rural communities use to be poor and cannot afford the cost of services if it is too high [1].

In our group - the EHAS program [12] – we have applied successfully radio networks in the HF/VHF bands for distributing access to the PSTN and giving e-mail services in these scenarios. Nonetheless, this solution presents some important restrictions like the extremely low data speed, the relatively high cost of installations, the high power consumption of equipments (so that solar powered system have important restrictions in the duration of communications), voice communications are half-duplex and licensed bands must be used.

In this project we are instead applying IEEE 802.11 for distributing voice and data communications in rural areas.

Mesh networks don't need any communication infrastructure, nodes connect to neigbours as they discover them, and can communicate with non-contiguous nodes or with other networks using other nodes as routers. Several aspects must be taken into consideration for applying IEEE 802.11 and the mesh networks paradigm in this project:

– IEEE 802.11 is a well-known technology and extremely cheap. Nonetheless, the existing research cannot be applied to long-distance WiFi links because of the universal asumption that a node can listen to another transmiting node within a slot time (20 µs). In a paralel research we are working on a model for long-distance WiFi links up to 100 kms.

– WiFi systems can work in ad-hoc mode, which makes the technology appropiated for mesh networks. This reduces even more the price of communication infrastructures because user terminals permit themselves to extend the network scope.

– IP autoconfiguration is desirable to avoid the need of network administration. The same reason forces to use multihop ad-hoc dynamic routing protocols, so that nodes can attribute themselves unique IP addresses and then constitute with other nodes an IP network. Routing protocols must use a cross-layer approach in order to use phisical level information for taking the right decisions in the choice of routes.

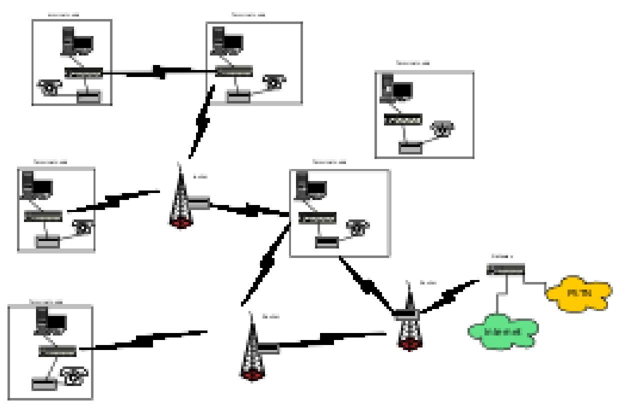
– Minimal power consumption is a must, nodes will be solar powered, so the size and the cost well be strongly related to consumption. Hardware must be optimized for low power consumption, and the network must collaborate in order to avoid useless transmissions when users don't need the network to be available.

All these considerations guide our design of an autonomous wireless mesh node; some units of the designed system could constitute a network just by putting them on in there places and making sure that each node sees at least a neighbour.

Related projects are developed by the TIER group in the University of Berkeley [2] or the Inveneo group [3], but none of them offers a complete self-configuring QoS-aware solution.

2. Mesh network architecture

The final objective of this project is to enable isolated rural areas to access the PSTN and the Internet. We start by one or several points where those global networks can be accessed locally by gateway nodes. Other nodes can connect to the Internet or to the PSTN if the gateway node can be accessed through one or several hops. Intermediate nodes can be user terminals when available, or we can additionally use dedicated routers when a node must be placed in a desert place in order to have lign of sight among nodes. Actually all those nodes (gateways, routers, user terminals) are exactly the same.



In the basic version, nodes have a high-power WiFi interface connected to an external high-gain omnidirectional antenna. Depending on the local regulations for the 2.4GHz ISM band may vary. In a country that applies FCC's regulations, the distance to neighbour nodes can depass slightly 5Km. For longer distances, an additional WiFi card is installed in the node for a specific link and connected to a directional high-gain antenna. When two nodes connect to each other through a point to point link using directional antennas in both ends, the distance can even depass 80Km.

3. Hardware design

Our autonomous wireless mesh network node has the following material components:

– An embedded computer with extra low power consumption, with the appropiated interfaces. Our first prototype used an x86 Soekris net4521 board, but the consumption of about 3W was still too high. The second version uses a Compulab StrongARM based platform, with a consumption lower than 1W.

– The wireless subsystem has a minimum of one and a maximum of three WiFi cards with pigtails and external antennas. The first adapter always is connected to an omnidirectionnal antenna (12-15dBi) so that any close neighbour around the node can connect to it. Additional adapters are connected to directional antennas (19-24dBi). The first adapter has Intersil Prism 2.5 chipset due to the good support of ad-hoc mode in linux, and the additional adapters have Atheros AR50XX chipsets because of their flexibility for adjusting timeouts and other parameters for long-distance optimization.

– Everything (but the antennas) is installed in a NEMA-4 case with a battery and a current regulator. A solar pannel is attached to the case.

– Several external elements can be connected to each node, depending of its function in the network. A gateway will have a VoIP-to-PSTN converter connected to an ethernet port, and a terminal node will have a PC and an IP phone.

3.1. Software components

Now lets describe the software, which lives in a Compact Flash card. Due to the limited number of writings supported by these memories, the installation is made in such a way that the dynamic parts of the operating system are loaded in RAM upon startup.

– The operating system is a special Linux version based on Debian. The total size with applications is about 77 MB.

– We add a software PBX named Asterisk that supports VoIP-to-PSTN switching. All VoIP components in the networks use SIP, though the Asterisk PBX communicate with peers using the propietary IAX protocol.

– IP address autonfiguration a node needs to attribute itself a unique IP address. This is itself a difficult problem to solve. By the time of presenting this poster we are considering if we must develop our own solution or use a dynamic routing protocol like Pacman [4] that incorporate their own autoconfiguration systems.

– Multihop dynamic routing protocol: initially we tried using conventional protocols like AODV [6] and OLSR [5] as presented in our previous work [8]. Nonetheless, De Couto et al. [9,10] showed that the “shortest path” metrics is not good enough for wireless networks due to the variable quality and performance of links, and they proposed [7] the ETX metrics, which takes into account the retransmissions experimented in each link. By now we have chosen a

QoS adaptation of OLSR that performs cross-layer routing using the ETX metrics [11].

– The QoS is essential because VoIP communication is probably the most important service and its quality must be preserved. IEEE 802.11 cannot support QoS services, and even the new IEEE 802.11e standard is only appropiate for short distances such that the propagation time is less than a slot time. Assuming this limitation, it is possible to get a partial QoS support by managing traffic at the IP level. We have simplified the DiffServ architecture [13], eliminating any differentiation between core nodes and edge nodes, and describing just three types of traffic: VoIP (EF PHB), control (AF1 PHB) and the rest (BE PHB). In our approach we must estimate in advance the performance of links in order to do a conservative configuration of queuing disciplines, further work is required to develop a system that adapts itself dynamically to link quality.

4. Results

We have obtained a first prototype of autonomous wireless mesh node based on x86 boards, running our linux-EHAS version and incorporating a software PBX. This first version was used for deploying a mesh network in Cuzco (Peru). Wireless point to point links go up to 42Km in that network and the longest links are permitting a throughput of 2.5Mbps working in 802.11g at 6Mbps speed. We have also verified experimentally that we can get up to 1.5Mbps in a 84Km long link working in 802.11b at 2Mbps speed. Our first prototype was not really autonomous because the solar pannel and the battery couldn't power the system 24 hours a day.

The second version described is under development now.

5. Discusión y futuro trabajo

In this poster we are presenting the design of an autonomous wireless node for mesh networks using IEEE 802.11. The aim of this project is to obtain a low cost technology that permits to distribute voice and data in isolated rural areas of developing regions.

The project is not concluded, and the following parts are still under development:

– Evaluation of alternatives for IP autoconfiguration and development of the chosen solution.

– Adaptative QoS support at the IP level.

– Optimization of IEEE 802.11 for long distance links.

Referencias

[1] Eric Brewer, Michael Demmer, Bowei Du, Kevin Fall, Melissa Ho, Matthew Kam, Sergiu Nedevschi, Joyojeet Pal, Rabin Patra, and Sonesh Surana. ***The Case for Technology for Developing Regions.*** /IEEE Computer/. Volume 38, Number 6, pp. 25-38, June 2, 2004.

[2] TIER Group web site: http://tier.cs.berkeley.edu.

[3] Inveneo Group web site: http: //www.inveneo.org/.

[4] K. Weniger: PACMAN: Passive Autoconfiguration for Mobile Ad hoc Networks, to appear in *IEEE Journal on Selected Areas in Communications (JSAC) Special Issue 'Wireless Ad hoc Networks'*, March 2005.

[5] Kenichi Mase, Cedric Adjih. No Overhead Autoconfiguration OLSR. Internet draft mase-manet-autoconf-noaolsr-00.txt, 26-May-05.

[6] C. Perkins. E. Belding-Royer. S. Das. Ad hoc On-Demand Distance Vector (AODV) Routing. IETF-RFC3561(experimental), July 2003.

[7] T. Clausen, P. Jacquet Optimized Link State Routing Protocol (OLSR) IETF-RFC3626(experimental), October 2003.

[8] J. Simó, J. Seoane, R. Salazar. A QoS-aware Ad-Hoc Wireless Network for Isolated Rural Environements. In Proc. EUNICE 2005, July 2005.

[9] D. S. J. de Couto et al. Performance of Multihop Wireless Networks: Shortest Path is Not Enough. ACM SIGCOMM Computer Communication Review, Vol. 33, N. 1, January 2003. architecture for sparse sensor networks. In Proceedings of the First IEEE. 2003 IEEE International Workshop on Sensor Network Protocols.

[10] Douglas S.J. De Couto, Daniel Aguayo, John Bicket, Robert Morris. A high-throughput path metric for multi-hop wireless routing. In Proc. ACM/IEEE Mobicom 03. September 2003.

[11] H. Badis, K. Al Agha. QOLSR, QoS routing for Ad Hoc Wireless Networks Using OLSR. European Transactions on Telecommunications, Vol. 15, No. 4, 2005.

[12] A. Martínez, V. Villarroel, J. Seoane, F. del Pozo. Analysis of information and communication needs in rural primary healthcare in developing countries IEEE transactions on Information Technology in Biomedicine, Vol. 9, N. 1, March 2005.

[13] S. Blake, D. Black, M. Carlson, E. Davies, Zh. Wang, W. Weiss. RFC2475: An architecture for Differentiated Services. IETF RFC, 1998.