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

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Abstract

Isolated rural areas often lack for 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, low density and low concentration of population, lack of electricity in many points and accessibility problems make 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 providing reliable VoIP services. Nodes contain a software PBX so that any two nodes in the network can establish a multihop VoIP communication. This project has been proposed by EHAS Group in collaboration with Rafael Escolá Foundation.

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 rural areas very often lack for any access to telephone network or electricity. Low density and low concentration of population make difficult to afford the installation of permanent infrastructures that would be expensive due to tipical restrictions in power service, accessibility, maintainability and security. Additionally, in developing countries rural communities are usually poor and can not afford the cost of services if this is too high [1].

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

In this project instead of radio technology we are applying IEEE 802.11 for distributing voice and data communications in rural areas. And especifically we are focused in mesh networks.

Mesh networks do not need any communication infrastructure. Nodes connect to neighbours 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 very well-known technology and extremely cheap. Nonetheless, existing research can not 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 this technology be 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 physical level information for taking right decisions in the choice of routes.

– Minimal power consumption is a must. Nodes will be solar powered, so size and cost will 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 do not need the system 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 in different places and making sure that each node sees at least one neighbour.

Related projects are developed by TIER group in the University of Berkeley [2] or 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 Internet network. First we need gateways nodes where those global networks can be accessed locally. Other nodes can connect to Internet or to PSTN if at least gateway node can be accessed through one or several hops. Intermediate nodes can be either user terminals when available, or dedicated routers when a node must be placed in a isolated spot in order to have line of sight among nodes. Actually all those nodes (gateways, routers, user terminals) have the same architecture scheme. See Figure 1.

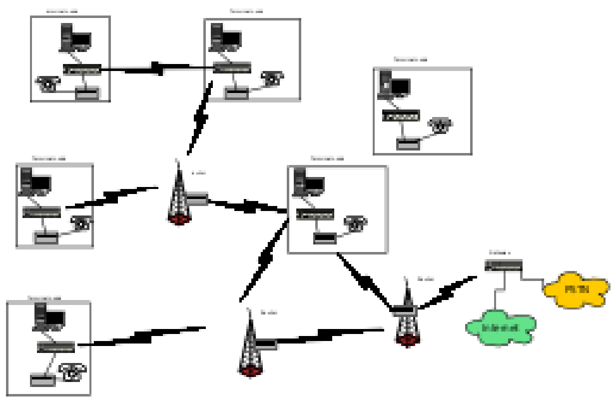

Figure 1:Mesh Network architecture

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, 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 components:

- An embedded computer with extra low power consumption, with the appropiated interfaces. Our first prototype is based on x86 Soekris net4521 board. Its consumption is about 3W, still too high for our requirements. The second version is based on Compulab StrongARM 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. First adapter is always connected to an omnidirectionnal antenna (12-15dBi) so that any close neighbour around the node can easily connect to it. Additional adapters are connected to directional antennas (19-24dBi). First adapter has Intersil Prism 2.5 chipset due to the good support of ad-hoc mode in linux, and 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.

4. Software components

The software used by mesh router resides in a Compact Flash card. Due to the limited number of writings supported by these kind of memories, installation is made in such a way that the dynamic parts of the operating system are loaded in RAM upon startup. Below we will describe some of the most important software features:

- The operating system developed by EHAS, linux-EHAS, is based on Debian. The total size with applications is about 77 MB.
- We have added a software PBX named Asterisk that supports VoIP-to-PSTN switching. All VoIP components in our networks use SIP, though Asterisk PBX communicates with peers using the propietary IAX protocol.
- IP address autoconfiguration: 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 considerating either to develop our own solution or using a dynamic routing protocol like PACMAN [4] that incorporates its own autoconfiguration system.
- 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 are not good enough for wireless networks due to the variable quality and performance of links. They proposed [7] 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 ETX metrics [11].
- QoS is essential because VoIP communication is probably the most important service so its quality must be preserved. IEEE 802.11 can not support QoS services, and even new IEEE 802.11e standard is only appropiate for short distances such that propagation time is less than a slot time. Assuming this limitation, it is possible to get a partial QoS support by managing traffic at IP level. We have

simplified 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.

5. 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 solar pannel and battery could not power the system 24 hours a day.

The second version described before is under development now.

6. Discussion and future work

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.

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