

# Broadband Provision to Underprivileged Rural Communities

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## Abstract

Providing access to remote rural areas presents a unique set of technical and non-technical challenges. These challenges are key issues that arise when deploying wireless networks to remote rural areas in developing countries; long distances between nodes, difficulties in getting line of sight, severe climate conditions, single low-bandwidth gateways to the Internet, high cost of Internet connectivity, lack of proper road infrastructure, and lack of reliable power supply. These severe conditions combine with other socio-economical factors (such as low per capita income) to offer unique sets of challenges that call for non-traditional techniques to provide telecommunication and broadband connectivity of acceptable quality and at affordable price to citizens, especially those in poorly resourced rural areas. Furthermore, the lack of reliable energy supply in remote rural areas requires more innovative ways of reducing the total amount of energy that is needed to operate these wireless communications infrastructures.

This paper highlights the technical details of the Wireless Mesh Network model to indicate how a specific project (Wireless Mesh Network) funded by the Department of Science and Technology (DST) is currently being implemented by the Meraka Institute of the CSIR. This project will be carried out in communities in selected areas (Nkangala, Sekhukhune and John Taolo Gaetsewe) in South Africa. The main focus of this project is the deployment of low-cost broadband connectivity in underprivileged communities.

## 1. Introduction

Providing access to remote rural areas presents a unique set of technical and non-technical challenges. Some of these challenges are captured by Johnson and Roux (2008: 17) as well as Ntlatlapa (2007: 2) as key issues that arise when deploying wireless networks to remote rural areas in developing countries; long distances between nodes, difficulties in getting line of sight, severe climate conditions, single low-bandwidth gateways to the Internet, high cost of Internet connectivity, lack of proper road infrastructure, and lack of reliable power supply. Other non-technical challenges are issues of low per capita income, theft, vandalism and a general lack of technical personnel. These severe conditions combine with other socio-economical factors to offer unique sets of challenges that call for non-traditional techniques to provide telecommunication and broadband connectivity of acceptable quality and at

affordable price to users. This further suggests that communities need to be educated on how best to operate these networks and to take ownership.

Lack of reliable energy supply in remote rural areas requires more innovative ways of reducing the total amount of energy that is needed to operate wireless communications infrastructure such as the wireless mesh networks that are being rolled out in Nkangala, Sekhukhune and John Taolo Gaetsewe.

## **2. Overview of Wireless Mesh Network activities within Meraka Institute**

In response to these challenges of deploying WMNs in harsh rural conditions, the wireless mesh network research group at the Meraka Institute of the CSIR is working on introducing energy efficiency and awareness in the wireless mesh networks. The aim of this group's research in this area according to Ntlatlapa (2007:3-4) is to optimise mesh protocols for energy-efficiency across all network protocol layers. Some of the ways in which this can be achieved is to introduce the "remaining energy" levels as a factor in routing and path selection decision making (Mhlanga *et al*, 2009). Another way is to reduce the total amount of energy needed to operate the infrastructure by introducing node-power saving schemes to preserve battery energy (Masonta, Olwal & Ntlatlapa, 2010). To deal with the difficulty of achieving line-of-sight and the long distances between nodes, high-performance nodes are being developed which are multi-radio antennae capable of both directional and omni-directional radio communications. Research of this nature requires continuous simulation and testing before being implemented in real life situations; for this purpose a 49-node mesh testbed as discussed by Johnson and Lysko (2008) has been commissioned.

The next section describes the technology and the network model used in wireless mesh networks deployed in areas such as Siyabuswa, Moutse, Kwaggafontein, and Kwamhlanga.

## **3. Technology description**

Wireless mesh networks (WMNs) are dynamically self-organised, self-configured and self-healing networks built on a mix of both fixed and mobile nodes interconnected through wireless links to automatically form an *ad hoc* network and maintain mesh connectivity (Akyildiz *et al*, 2005; Akyildiz & Wang, 2005; Bruno, Conti & Gregori, 2005).

This section presents a component-level description of the wireless mesh networking technology that is currently being rolled out as part of the Wireless Mesh Networks Project's Broadband4All initiative. The section is organised as follows: The first device to be described is the high-performance node (HPN) which serves as a mesh router. This is followed by the description of the entire network of HPNs and other helper-devices.

### **High Performance Node (HPN)**

Put simply, the entire CSIR Meraka Institute's deployed wireless mesh networks are networks of HPNs connected through wireless/radio links and communicating with each other using mesh protocols.

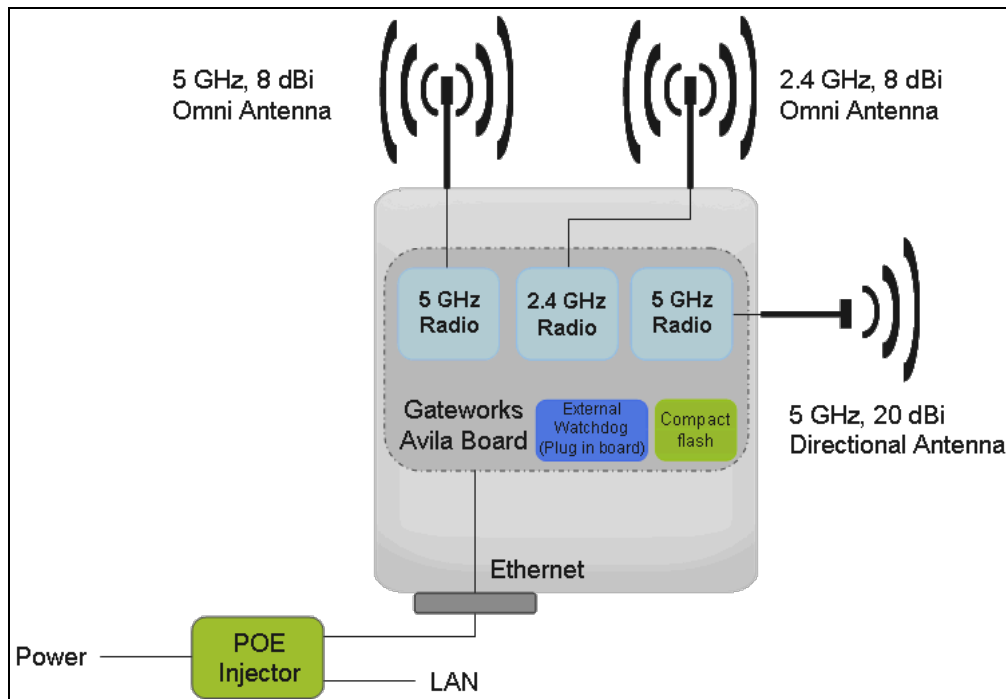
HPN is a multi-radio (3 radios), high-performance, IEEE 802.11-based wireless router. Each HPN has three antennae, one 5.8 GHz directional antenna, one 5.8GHz omni-directional antenna and one 2.4 GHz omni-directional antenna. At the bottom of the router there is a weatherproof unshielded twisted pair (UTP) connector that is used for both Power-over-Ethernet (PoE) and Ethernet connectivity to the router. A mounting bracket is placed at the back of the router making it easy to attach the HPN to a pole or a building. The HPNs is based on embedded microcontroller technology.

Figure 1 shows the high-performance node (HPN)



***Figure 1: High-performance node***

Figure 2 below shows a simplified block diagram of an HPN



**Figure 2: Block diagram of the high-performance node**

These HPNs allow the deployment of a wireless mesh network by aligning each directional antenna to point to a neighbouring omni-directional antenna or another directional antenna.

The HPN that is configured as a gateway connects the mesh network to other networks; these could be school computer laboratories or even clinics' local area network (LAN) and this is also how the mesh network provides Internet backhaul. The gateway node will also become the domain name server (DNS) for the mesh and all the nodes inside the mesh will register their host-names with the DNS server. Another function of the gateway node is to act as a time server for the mesh network and all the nodes inside the mesh will synchronise their time with the gateway node.

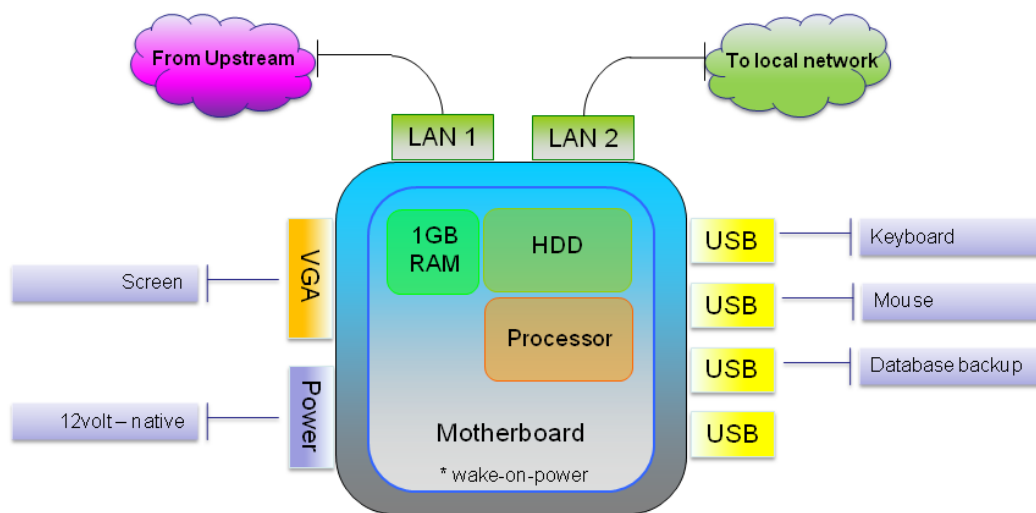
Client connectivity to the mesh network is achieved in two ways. Firstly, the client devices can connect directly using their IEEE 802.11-based wireless cards if the HPN is configured as a hotspot or access point (AP). Secondly, the clients can connect to the mesh using the HPN's Ethernet connectivity as follows; the Ethernet cable is connected from the HPN to the client's LAN hub or network switch, client devices (PCs/laptops) are then connected through this hub or switch.

### **Wireless Internet Service Provider (WISP)-in-a-Box**

The next component described is the wireless Internet service provider (WISP)-in-a-box. To understand this component one needs to capture clearly what a WISP is or what a WISP does. In most shopping centres, malls and business parks, there are a number of hotspots; an area from which it is possible to connect to a nearby AP; it is the AP's radio coverage area. If a person has a Wi-Fi enabled laptop or mobile device, he or she can detect these wireless

hotspots. The APs are owned by wireless Internet service providers (WISPs). They provide Internet connectivity to wirelessly connected client devices through one or more wireless access points. Their Wi-Fi networks are running in infrastructure mode allowing client connections only through their APs. A WISP would therefore need to be able to monitor connections made through their infrastructure Wi-Fi networks, to be able to charge users, to employ some authentication, authorisation and billing mechanisms. To do this a WISP needs a set of tools that can facilitate this, hence the development of a WISP-in-a-box solution package for the Wireless Mesh Network project's village operators, who will take the role of a village WISP.

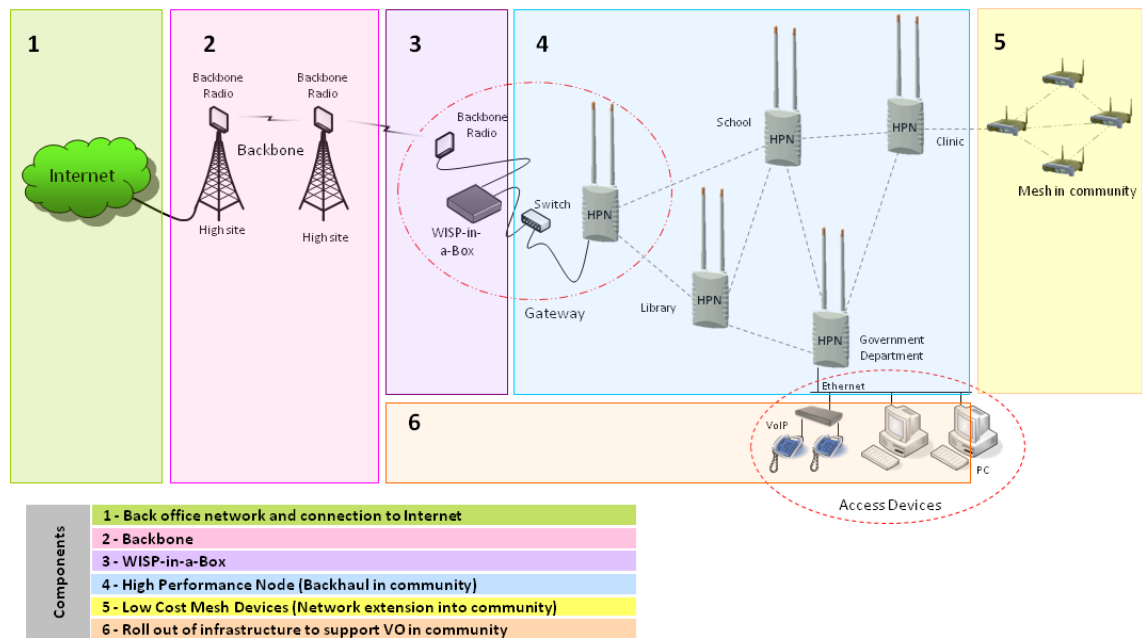
Figure 3 below shows components of a WISP-in-a-box



**Figure 3 Block diagram of hardware components for a WISP-in-a-box system**

The WISP-in-a-box component in the network model on figure 5 shows how the village operators will use the WISP-in-a-box. Essentially, the WISP-in-a-box is connected to the wireless mesh network through the HPN's Ethernet adaptor (see LAN 2 on Figure 4). In this case the HPN serves as an AP to which wireless devices such as Wi-Fi enabled smart phones and computers can connect. To access the Internet, these devices go through the WISP-in-a-box (see LAN 1 on Figure 4), which allows the VO to control who accesses the Internet.

Figure 3 below is a network model that clearly shows the network components described above



**Figure 4: Wireless Mesh Network Project's Network Model**

The network model in Figure 3 adopted by the Wireless Mesh Networks project takes the form of an infrastructure wireless mesh network (Akyildiz et al, 2005), with the HPNs forming an infrastructure for clients to connect to the mesh network. In the survey on wireless mesh networking, Akyildiz *et al* (2005) discuss the types of wireless mesh network such as backbone/infrastructure wireless mesh networks, client wireless mesh networks and hybrid wireless mesh networks.

The shaded regions of the network model shown in Figure 3 are described hereunder:

The first region (1) depicts the Internet backhaul which is provided by the infrastructure mesh network to clients. This is an infrastructure mesh as suggested by the backbone connection (2) to the "back office" network. Region (3) is the wireless Internet service provider (WISP) device that allows the "back office" to monitor and account for bandwidth usage in the network clients. Region (4) shows the mesh overlay, made up of HPNs, which communicate using mesh protocols. These HPNs are able to discover each other to automatically self-organise and form mesh network, and they can also perform self-healing and re-configuration in an event of some HPNs shutting down. Region (5) is an interesting region; it shows off-the-shelf low-cost wireless access points (typically based on IEEE 802.11) which are being re-programmed to support mesh protocols. This is interesting because, from this point a community network extension (client mesh) can be formed, changing the network model into a hybrid wireless mesh (combination of infrastructure and client mesh networks). For instance, four other access devices can be connected to form a network of access devices – this will be a client mesh, and the device in region (5) will be providing backhaul to the mesh overlay and possibly to the Internet. This is how a community network extension is achieved using low-cost off-the-shelf wireless access devices.

#### **4. Relevance to health**

By developing low-cost yet technically advanced communication technologies that can withstand the harsh conditions in most rural areas in South Africa, the Meraka Institute is able to connect previously underserved and un-connected communities and their clinics, schools, care centres and so forth on a shoestring budget.. This section describes two cases of the applications of these community wireless mesh networks, particularly in areas of health. Specifically this section presents reference wireless mesh networks deployed to support health services in rural areas; cases under discussion are Peebles Valley in Mpumalanga Province and the Tsilitwa telehealth project in the Eastern Cape Province.

##### **Possible applications of low-cost wireless mesh networking technologies in health**

Telemedicine and eHealth solutions hitherto undreamt of in these rural areas are now within reach; healthcare centres can be inter-connected, affording the healthcare professionals access to medical information systems and a greater variety of sources of information on diseases such as HIV/AIDS, TB and malaria. Voice over Internet Protocol (VoIP) calls are now possible, affording healthcare professionals the possibility of cost-effective communications, cutting costs on telephone calls so that money can be spent on other priorities to improve healthcare services.

Morris (2007) reported on a number of "First Mile, First Inch" (FMFI) project activities as well as the lessons learned in the project as of writing of the report in 2007. The FMFI project has shown the value, for developing countries with poor telecommunications and Internet infrastructure, of the unlicensed spectrum and low-cost wireless communications technologies that operate on these bands Morris (2007: 5-8). Peebles Valley in Mpumalanga is one such case. The Peebles Valley wireless mesh network, funded by the International Development Research Centre (IDRC), is made up of nine (9) nodes and covers an area of about 15 square kilometres. It connects the local AIDS Care Training and Support (ACTS) clinic which in turn connects to the surrounding schools, homes and nearby farms through this mesh network. Johnson and Roux (2008:18-19) reported on this and some of the social observations that were made. The technical details on the performance of this IEEE 802.11 network are provided in Johnson (2007).

Another case of wireless networking support for health is the Tsilitwa telehealth project in the Eastern Cape (Morris, 2007:6). The Tsilitwa telehealth project connects the rural clinic in Tsilitwa by means of a wireless network to the Nessie Knight Hospital in Sulenkama, thus enabling a clinic sister to interact with doctors at Nessie Knight Hospital through data, video and voice.

## 5. Conclusion

Information and communications technologies (ICT) can improve the lives of millions of citizens, especially those living in remote areas. For this to take place, ICT infrastructure needs to be rolled out to these communities at justifiable costs – this means that access to ICT needs to be increased by addressing infrastructure, access and cost-related issues. The availability of such infrastructure involves some important issues, such as telecommunications regulations, community ownership, technical support and training for recipient communities. It also necessitates research into business models that can flourish in these conditions, including WISPs. The Wireless Mesh Networks project, funded by the DST and spearheaded by the Meraka Institute of the CSIR, seeks to establish a sustainable business model through training local youth as “village operators”. The village operators are to render both technical and business support services to their communities. Potential services include Internet sharing (in the form of a WISP) as well as other services such as printing and video editing.

This paper presented an overview of the wireless networking technology being developed by the Meraka Institute of the CSIR to provide broadband access to remote rural areas on a shoestring budget. Components of such a network model were discussed and applications and relevance of this technology to health was expanded. Research and development efforts are underway to optimise the mesh technology for energy efficiency across all network layers to enhance the survivability of these networks in harsh conditions, such as low energy supply and frequent power outages.

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