MobiMESH: a Complete Solution for Wireless Mesh Networking

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Abstract

Wireless Mesh Networks (WMNs) have raised great interest in both academy and industry thanks to their flexibility, low cost and easy deployment characteristics. MobiMESH is a WMN implementation that provides a complete framework for analyzing, studying and testing the behavior of a mesh network in a real-life environment. MobiMESH includes seamless mobility support for mesh clients, enhanced multi-radio-aware routing, channel assignment, as well as provisioning, management, monitoring and security platforms.

1. The MobiMESH WMN

Wireless Mesh Networks represent the new frontier of wireless networking. In fact, thanks to the flexibility and low cost of the all-wireless approach, WMNs allow the extension of traditional wireless networks, thus creating new networking opportunities. Besides simulations and analytical studies, testbed experimentation is of utmost importance, to assess the behavior and efficiency of the network under the real-life conditions [2] [3]. To this end, MobiMESH [1] is a complete WMN implementation that addresses some specific issues and targets:

- *Broadband Connectivity* - the MobiMESH network offers connectivity and network services to standard clients through broadband backhauling;
- *Mobility* - MobiMESH clients are allowed to seamlessly roam within the radio coverage of the whole network without losing active connections;
- *Transparency* - the MobiMESH network appears to the access client as a standard WLAN, automatically handling all the mobility, tracking and management functions.

The MobiMESH architecture is formed by multi-radio mesh nodes, and it includes provisioning, management and monitoring functionalities as well as security procedures, thus providing a rather complete WMN platform, that can be employed in a wide variety of environments, for the support of a vast range of applications (real-time traffic, Internet access, etc. . .).

The architecture of the MobiMESH network is shown in Figure 1. It features a completely wireless backhaul section, called backbone, which provides the routing and mobility management infrastructure, and an access network section, composed by wireless clients.

The backbone network is a multihop wireless network based on the ad-hoc paradigm, where all nodes are mesh routers and therefore collaborate to routing duties; routing is provided through a modified version of the Unik implementation [4] of the OLSR routing protocol.

Special Mesh Routers, called Gateways, are responsible of the integration of the wireless backbone with other networks, such as wired networks, enabling MobiMESH to access the Internet.

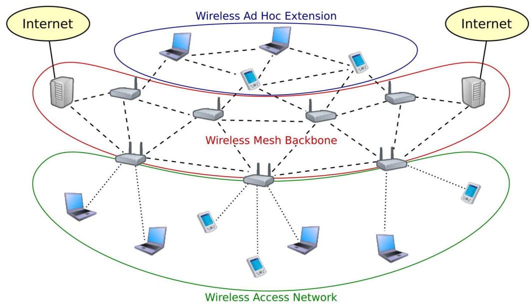

Figure 1. MobiMESH Network Architecture

The access network employs the infrastructure operation mode to allow clients to associate and access to the network services. Access transparency is the main characteristic of the access network, which is designed in such way that clients perceive the network as a standard WLAN; in this way, MobiMESH can be accessed by standard WLAN clients with no specific software installed. The access network is connected to the backbone through Access Routers (ARs), Mesh Routers that also act as access points.

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The IP organization of the network reflects the logical architecture; the backbone is a separate IP subnet, and the whole access networks is another IP subnet. Such structure ensures that when a wireless client moves from an AR to another, it does not have to change its network configuration, exactly as it happens to clients associated to standard WLANs; the backbone has to handle the layer 3 tracking of access clients.

MobiMESH has been implemented employing standard IEEE 802.11 interfaces; in particular, it employs 5 GHz frequencies (IEEE 802.11h) on the backbone and 2.4 GHz frequencies (IEEE 802.11b/g) on the access network. The nodes themselves are self-assembled embedded devices, employing off-the-shelf commercial boards equipped with Atheros-based radio modules. The employed operating system is a customized GNU/Linux embedded distribution.

2. Mobility Procedures

Seamless mobility is a key feature of the MobiMESH architecture; access clients may roam within the coverage area of the network maintaining existing connections alive and without changing their network configuration. In a WMN, a client moving to a new BSS area requires changes in the routing on the backbone, because the client position must be known by the routing protocol in order to correctly deliver packets. In the MobiMESH architecture, since the access network is a single IP subnet, access clients do not change IP subnet as they roam from a BSS area to another. Therefore, MobiMESH features cross layer procedures that map layer 2 movements on layer 3 routing updates; such procedures propagate the information that the access client is now available through the new AR, thus modifying routing on the backbone. The key element of such cross layer procedures is the MAC-IP association, which has to be consulted in order to correctly announce associated clients on the backbone routing.

We have measured the mobility delay as the time a connection remains idle upon moving from an AR to another; this is an important parameter for the quality of the offered service. Figure 2 shows the inter arrival times measured while performing four movements during a VoIP call: the four longer inter arrivals represent the movements, whose average value is less than 100ms. Such a result ensures that movements are almost undetectable for active connections.

3. Multiradio Issues

MobiMESH nodes are equipped with multiple radio interfaces on the backbone network; this is intended to provide a broadband backhaul for access clients. In order to support multiple radio interfaces, the OLSR routing protocol has been modified, introducing a metric that takes into account the intra flow interference and that encourages traffic to get out of the node on an interface set to a frequency that is different from the frequency of the ingress interface. To do this, we have implemented a slightly modified version of the CSC metric described in [5].

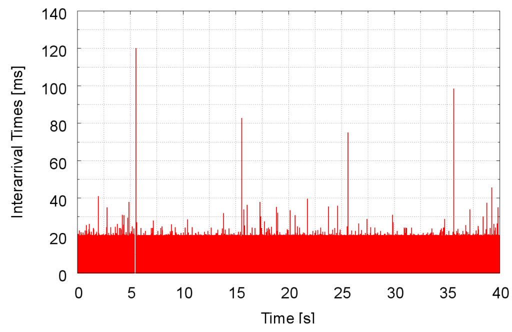

Figure 2. Mobility delay on a VoIP call

Moreover, a channel assignment algorithm is needed, in order to plan the frequencies on the network. We have developed and implemented the CHannel Optimal Channel Assignment (CHOCA) algorithm, to assign frequencies to the various links on the network. We have assumed that most traffic on the mesh network is directed to the Internet, therefore it flows through the gateways. The algorithm considers each link on the routing tree to the gateways and avoids reusing a channel within the two-hop neighborhood. The CHOCA algorithm detects the physical topology of the network once in a while, by tuning all the interfaces on a common channel for a short period of time.

We have measured the performance of the CHOCA algorithm comparing it with the performance of the single channel case, and with a reference, unplanned case where the interfaces of each router are assigned to the first available channels. The results are shown in Figure 3, referred to a three hop line topology: the CHOCA algorithm ensures a data throughput around 20Mbit/s.

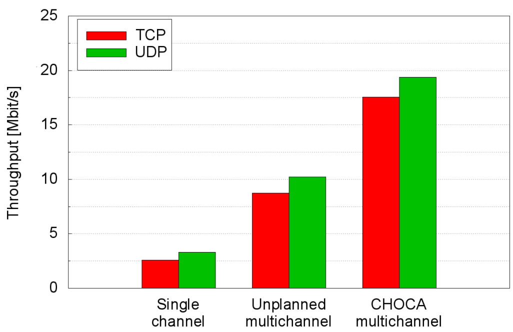

Figure 3. Channel assignments comparison

4. Provisioning, Management and Monitoring

The deployment of a provisioning, management and monitoring solution for a WMN must take into account some additional issues in respect to the traditional approach: for example, due to the multi-hop nature of the backbone network, the configuration provisioning of the nodes must be carried out maintaining the connectivity of the network, employing redundant messages and heavy error control.

The MobiMESH network features an integrated provisioning, management and monitoring system based on the SNMP protocol. In particular, we have realized the Provisioning, Authentication, Configuration, KEy, and Time Server (PACKETS) server that, through a web based interface, allows the configuration of the whole system (i.e. the network, the monitoring tools, the notification procedures).

The PACKETS server also provides a configuration provisioning infrastructure; in fact, during the bootstrap process, every node retrieves its configuration and the latest version of the software from the PACKETS server, thus enabling a centralized network management. During the provisioning process, the node gets a restricted access to the network; as soon as the booting node gets and applies its configuration, it joins the network with full privileges.

Monitoring is carried out through the OpenNMS monitoring system, that has been integrated with the PACKETS system.

5. Security Framework

It is crucial that only authorized Mesh Routers can join a wireless mesh network; moreover, both user and control traffic must be protected through authentication and encryption. The MobiMESH network provides a complete security framework, with particular attention to the backhaul security issues. MobiMESH nodes are in fact authenticated through the use of certificates and the control traffic is signed, so that unauthorized packets will be discarder.

On the access network side, an AAA infrastructure has been set up, so that only authorized clients can join the network, therefore preventing uncontrolled accesses and misuses of the network services.

User traffic is encrypted through the use of Virtual Private Network (VPN) solutions, and layer two solutions (WPA/WPA2) are being implemented, to increase the flexibility of the security provisioning.

6. Conclusions and Current Work

The MobiMESH network is a complete WMN solution featuring broadband backhauling, mobility support, management and configuration procedures and a security framework. Seamless mobility is provided through a cross layer approach, and mobility delays are minimal. Broadband backhauling is granted by the use of multiple radio interfaces, managed by optimized routing and channel assignment algorithms. The security and the management frameworks are designed according to the peculiarity of the mesh environment. The innovation of the MobiMESH architecture compared to other implementations and testbeds resides in the mobility support and in the completeness of the solution.

We are currently working to enhance the MobiMESH network both improving the existing mechanisms and designing and implementing new features and ideas. We are developing an SNMP-based channel assignment framework that will support the interaction between the nodes and the central station performing the channel assignment calculations. On the security side we are focusing on strong encryption for all frames and key rotation mechanisms. We are also enhancing routing by introducing improvements to the scalability of the routing system and load balancing features; we are also enhancing the mobility framework, making it OLSR-independent and even faster. Integration with other technologies is another important issue: we are investigating the possibilities of integrating IEEE 802.16 and IEEE 802.15 interfaces on the MobiMESH nodes.

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