Wireless Mesh Network Testbed

Demo

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***Abstract*— The success of the IEEE 802.11 standard has pushed the research community to put a not negligible effort in the design, analysis, and development of new wireless solutions during the last decade. More recently, the apparition of the wireless mesh technology incited a number of wireless testbeds to be deployed in several countries, in both academic and industrial environments. The LIP6 laboratory of the Université Pierre et Marie Curie is a main actor in the context of wireless mesh networking and has deployed its own testbed. Custom wireless routers built up from off-the-shelf hardware and open source software form this testbed, which is called MeshDVNet. On this platform the LIP6 has designed and implemented the MeshDV demon, an integrated approach for routing and mobility management, which hides to end-users all the complexity of wireless mesh networks. MeshDV allows end-users to easily access the network without the constrain of embedding any kind of additional software (*e.g.* routing demon, protocol stack extensions).**

I. Introduction

Wireless Mesh Networks (WMN) are an emerging two-tier architecture targeting the deployment of large-scale networks in a fast and cheap fashion. Wireless ISPs look at this technology as a way to offer broadband and seamless connectivity to mobile users. A WMN is composed of Wireless Mesh Routers (WMR), which offer connectivity to clients by acting as APs, forming at the same time a self-organized wireless backbone. The two tiers of a WMN consist in a sub-network for clients and a sub-network for mesh routers. The client sub-network has the purpose of offering wireless access to any authorized client, while the mesh sub-network can be a self-standing network, simply offering inter-user connectivity, or a local wireless extension of the Internet, if a connection is available through one or more gateways. Since each WMR covers a region where it offers connectivity by acting as an AP, end-users do not need to embed any routing feature; routing is performed exclusively between WMRs.

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Recently, a number of testbeds have being deployed by the research community, moving the focus of research activities on real implementations. Nevertheless, very few works have a global approach that tackles both main tasks of a WMN: the self-organization of the mesh backbone and the seamless connectivity for end-users ([1], [2], [3]). Testbed activities often just focus on issues related to the mesh backbone, assuming that the extensions to give connectivity to end-users are straightforward, which is not always the case. Another common practice is to have an *"ad hoc"* approach, where end-users need to embed additional software, typically a routing protocol or protocol stack extensions, which limits its possible commercial use.

The LIP6 laboratory of Université Pierre et Marie Curie is actively working in the area of wireless mesh networking and has deployed its own wireless mesh network testbed, called MeshDVNet [4]. This work has mainly concerned: *(i)* an efficient cross-layer routing to increase as much as possible the transport capacity of the mesh backbone; *(ii)* a mechanism able to effectively manage users' mobility. Both tasks have been integrated in MeshDV, a unique framework that leverages on the two-tier architecture of WMNs [5]. At the best of our knowledge, MeshDV is the first proposal that fully exploits the two-tier architecture of WMN, by maintaining routes between WMRs in a pro-active manner, while searching for routes toward clients in an on-demand fashion. The architecture of MeshDV has been strategically designed in order to obtain the following advantages:

- reduced routing table sizes, since there is no need for keeping all routes toward all clients;
- easy management of clients that change WMR association, since related information is maintained only on edge WMRs.

Furthermore, MeshDV is also able to perform the following tasks:

- Address prefix advertisement;
- Gateway advertisement;
- DNS servers list advertisement.

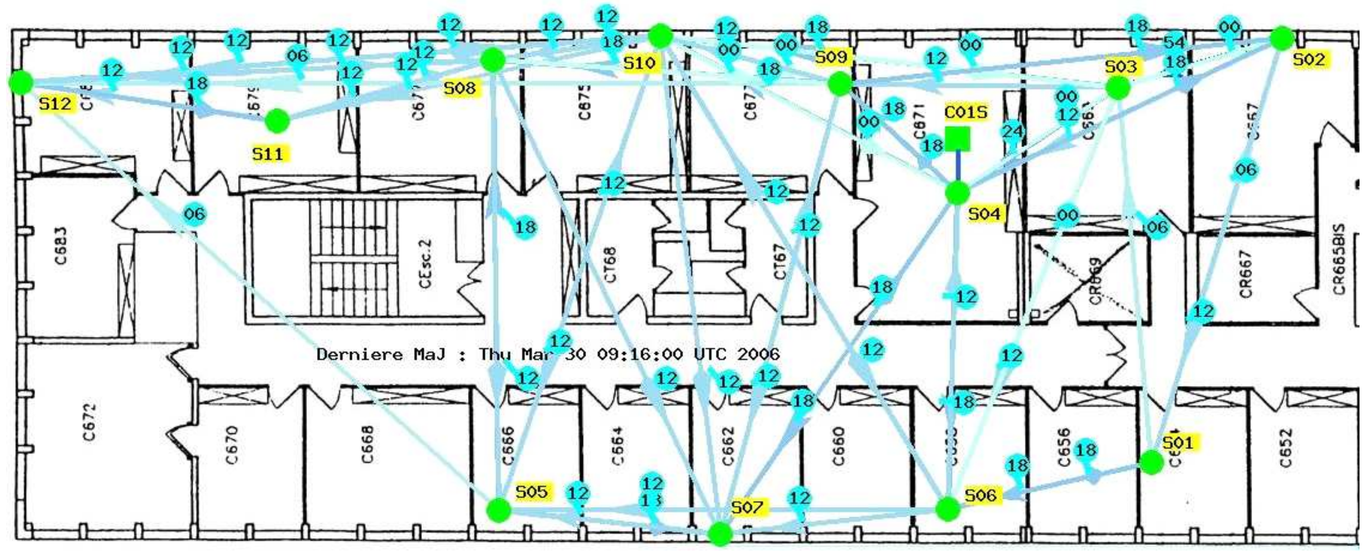

Fig. 1. Snapshot of the MeshDVNet wireless mesh network deployed at the LIP6 laboratory.

MeshDV performs all these tasks in a way that remains totally transparent to end-users. It runs on custom mesh routers called MeshDVBoxes that have been built using commercial components and open source software.

The next section gives a small description of the MeshDVNet testbed, while in section III an overview of the MeshDV demon is proposed. Section IV concludes this short paper with a resume of the main achievements.

II. The MeshDVNet Testbed

MeshDVNet has been deployed in the LIP6 laboratory and is open to be accessed by any member of the laboratory, by any university student, and any other person registered in the LDAP directory of the university. The platform is composed of a dozen of MeshDVBoxes, scattered in the laboratory. Their approximate position is depicted in figure 1. This mesh cloud is connected to the laboratory wired LAN by a gateway. Figure 1 shows also the routes that have been established by the MeshDV routing demon. Balloons associated to each link indicate the raw transmission rate available on the link. Figure 1 is a snapshot of our supervision web page, used to monitor if WMRs are running and reachable. This page is publicly available (IPv6 only) at: *http://www.infradio-jussieu.lip6.fr/supervision/supervision-mesh-scott.html*.

A MeshDVBox wireless mesh router is based on Soekris net4521 box [6]. It is a single board computer (SBC) embedding a 133 MHz AMD ElanSC520 processor, 64 MByte SDRAM and is quipped with a 1 GByte Microdrive. It has also two PC-Card/Cardbus slots and a mini-PCI socket. Figure 2 shows a picture of a MeshDVBox.

Each MeshDVBox uses two wireless cards, one to give access to clients and one to form the mesh backbone with other MeshDVBoxes. The client interface acts as an access point for client connections using the IEEE 802.11 b/g [7] technology. This interface is implemented by a Proxim 8470-WD b/g cardbus card [8] (*cf.*, left hand side of figure 2). The mesh interface works in ad hoc mode in order to form the mesh backbone with the others WMRs' peer interfaces, using the IEEE 802.11a [9] technology. This interface is a mini-PCI NetGate 5354 MP Plus Aries2 4G a/b/g card [10] (*cf.*, right hand side of figure 2). The use of different technologies working in different frequency bands, on the mesh sub-network (802.11 a) and on the client sub-network (802.11 b/g), makes them physically independent. All wireless interfaces are configured exclusively with IPv6. MeshDVBoxes run NetBSD 3.99 current, which is the development branch of the NetBSD Project [11].

III. Overview of MeshDV

MeshDV, the demon running on each MeshDVBox has also been developed in the LIP6 laboratory [5] and has been expressly designed in order to take advantage of the two-tier architecture of WMNs.

The first important task of MeshDV is to form the mesh backbone. This task is performed pro-actively, since WMRs are not mobile. MeshDV maintains pro-actively a route toward any other MeshDVBox present in the backbone sub-network, using an IPv6 version of the DSDV [12] protocol. The MeshDV module dedicated to this purpose has been implemented in two versions: a first one using the traditional hop-count metric and a

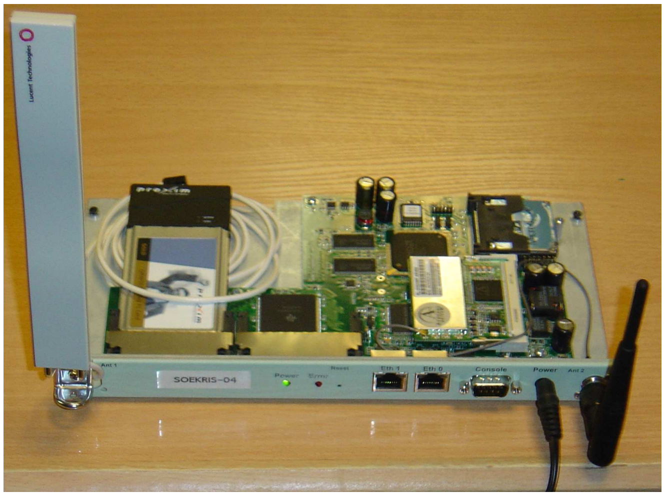

Fig. 2. MeshDVBox: the custom wireless mesh router used to build the MeshDVNet testbed.

second one using the raw transmission rate metric. For the latter, the cost in terms of data rate R of a path can be defined as

$$R\,(Path) = \max\left(\min_{\forall (i,j)\in Path}[R_{i,j}]\right), \tag{1}$$

where $R_{i,j}$ is the raw data transmission rate on the link from i to j and $Path$ is the set of all links from the source to the destination. The second version is the result of the efforts to implement a cross-layer metric aiming to improve the transport capacity of the mesh backbone [13]. Rate-aware routing that chooses links offering high transmission rates is able to increase the average throughput and reduce the end-to-end delay ([14], [15]).

Routing update messages exchanged by WMRs can also embed information other than routes. If a MeshDVBox acts as a gateway, because it has a wireless or wired connection to the Internet, the information can be propagated along with routing information. In this way gateway advertisement is performed and other non-gateway MeshDVBoxes can select the closer gateway to reach the Internet.

Along with the gateway information two other kinds of information are propagated: the address prefix and the DNS servers list. Both parameters, when available, are propagated in the routing updates in association with the entry concerning the gateway.

In order to give addresses to the associated clients, the stateless auto-configuration features of IPv6 are used [16]. All MeshDVBoxes in the mesh cloud send periodically *router advertisement* messages on the client interface, advertising the same sub-network prefix. The announced prefix can be either configured manually or the one received from the gateway through the address prefix advertisement mechanism. The result is three-fold:

- clients are able to build a correct IPv6 address in the correct sub-network;
- clients obtain as default route the address of the MeshDVBox where they are associated to;
- clients changing the MeshDVBox to which they are associated still keep the same IPv6 address, updating at the same time its default route.

The fact that users' devices keep the same address when move and associate to different MeshDVBoxes allows to keep alive all the ongoing sessions and connections. The task of updating routing information in order to make mobile clients always reachable is performed by MeshDV in a totally transparent way.

Since not all the clients wish to communicate to all other clients, but mainly to a subset of them that generally offer a particular service or to gateways in order to access the Internet, MeshDV uses an on-demand approach for clients' communication. As mentioned before, all clients are in the same logical sub-network, no matter to which MeshDVBox they are associated to. The main advantage of this approach is that clients perform the same steps as in a wired LAN in order to communicate to each other, independently of their current association. If the two communicating clients are associated to the same MeshDVBox they really communicate in the same way as in a wired LAN, since the AP interface acts as a bridge. If the two communicating clients are associated to different MeshDVBoxes, MeshDV is able to detect the steps performed to initiate the communication and setup a tunnel between the two edge MeshDVBoxes where the two clients are associated. This tunneling mechanism remains totally transparent to clients.

The tunneling approach has also the nice property of avoiding the need of information about communicating clients on MeshDVBoxes along the path connecting the MeshDVBoxes where clients are associated. MeshDVBoxes in the middle are able to forward packets without any information about communicating clients. While introducing some overhead due to the presence of an additional IP header per packet, this tunneling approach has another main advantage: it allows an easy and efficient management of clients' mobility. Indeed, if a client moves and changes the MeshDVBox where it is associated, only information on the MeshDVBoxes at the edges of the tunnel needs to be updated. This limited update allows continuing to deliver packets to the moving client without any impact on the core network [5].

IV. CONCLUSION

One of the main achievements of the MeshDVNet is that it is not simply an experimental wireless mesh network, but a fully functional network able to give the same services as a common wired LAN can offer. Indeed, MeshDVNet is open to all permanent staff and students of the Université Pierre et Marie Curie.

Nevertheless, several tests have been done on the platform in order to validate the correct behavior of each task performed by MeshDV and to evaluate its general performance.

In particular, in order to evaluate the routing capacity of MeshDV, experiments for both the hop-count and the cross-layer versions were performed. These experiments concerned all possible scenarios of traffic patterns: *(i)* client-to-client associated to the same MeshDVBox; *(ii)* client-to-client associated to different MeshDVBox; *(iii)* client-to-Internet. All the three traffic patterns have been tested with and without mobility.

Results obtained insofar are promising. The limited overhead introduced by the tunneling approach of MeshDV does not compromise either the throughput or the delay. An important difference appears comparing the throughput of the hop-count version to the cross-layer version of our proposal. The latter shows far better throughput [15]. Furthermore, MeshDV succeeds to maintain traffic toward/from clients that move, getting associated to different MeshDVBoxes. All these results are achieved without the deployment of any additional heavy mechanism (*e.g.* Mobile IP, HIP). MeshDV fully exploits current standards, having no impact on the existing protocol stack architecture and with no need for clients to embed any kind of additional software.

Finally, clients are able to correctly configure their wireless interfaces in a totally automatic manner. Indeed, they are able to build a valid global unique address using the prefix received from the MeshDVBox they are associated to. At the same time they are able to obtain a default route and a DNS servers list. In this way associated clients are fully functional and can perform any kind of common network operation.

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