Exploiting DHT's Properties to Improve the Scalability of Mesh Networks

N

Silvio Sampaio
IDMEC, University of Porto, Portugal

Francisco Vasques
University of Porto, Portugal

INTRODUCTION

Over the past few years, the IEEE 802.11 family of standards has become a dominant solution for Wireless Local Area Networks (WLANs) due to its performance, low cost and fast deployment characteristics (Hartmann & Meister, 2008; Sgora, Vergados, & Chatzimisios, 2009). The rapid growth of both Internet and wireless communications, create an increasing demand for wireless broadband access and higher data rates (Jiang et al., 2006).

In this context, Wireless Mesh Network (WMN) concept appears as a promising solution for wireless environments, due to its characteristics, and fields of application (Farkas & Plattner, 2005). Akyildiz et al. (2005) gives numerous application examples for WMNs, which goes from simple communication environments as broadband home networking, community and neighborhood networks, enterprise networking, building automation, to more complex environments as industrial networks, disaster recovery networks, public safety and many others. In order to cope with all requirements from these applications, one of the most important characteristics is the scalability. A WMN that does not scale well has limited usefulness.

This is the case of traditional IEEE 802.11-based mesh networks, which offers limited scalability, caused mostly by the underlying IEEE 802.11 mechanisms and multi-hop communication issues. This characteristic makes it a questionable candidate for large-scale network deployments. In fact, scalability is a well-known issue in multi-hop networking, not only WMNs. Studying the scalability of this type of network is important as WMNs tend to be deployed over large areas and hence the self-organization property may gather a large number of stations whitin the same mesh network. Basically, the lack of network scalability means that when the size of the network increases, its performance behavior may significantly degrade[1]. In such a case, traditional routing protocols may not be able to find paths and MAC protocols may manifest high delays.

Seeking for more scalable solutions, researchers have looked to scalable mechanisms created for Peer-to-Peer (P2P) systems, such as the Distributed Hash Table (DHT). Originally designed to create an overlay network that allow more scalable and faster to search and to recover information over the P2P systems, now its use is proposed to increase the network scalability and speed up the overall network performance.

Galán-Jiménez & Gazo-Cervero (2011) presented an interesting survey on the use of overlay networks. The authors emphasize the following properties of overlay networks:

- They can be built on top of one or more existing networks;
- They can provide an additional layer of indirection/virtualization;
- They can change properties in one or more areas of the underlying networks;
- They can change an existing network layer.

From these definitions it becomes obvious that WMNs may potentially take advantage from the scalable structure provided by DHTs. However, if in one hand, deploying DHTs structures over WMNs represents promising possibilities, in other hand several challenges need to be investigated to make clear the tradeoff resulting from this combination. Therefore, this article aims to points out the benefits as well as the issues related to the deployment of IEEE 802-11-based

DOI: 10.4018/978-1-4666-5888-2.ch609

Mesh Networks by using the distributed characteristics of the DHTs. Moreover, we emphatisize the challenges that must be overcome to create more scalable IEEE 802.11-based WMNs, using DHTs.

BACKGROUND

802.11-Based Wireless Mesh Networks

A WMN is essentially formed by a set of wireless nodes, Mesh Stations (Mesh STA), that work together to create a backhaul for communication between clients, or stations (STA). In a WMN each Mesh STA may operate not only as host (STA) but also as router (Mesh STA), forwarding packets on behalf of other Mesh STAs or STAs that may not be within direct wireless transmission range of their destination or may not have mesh capabilities.

Multiple channels and/or radios can be used to better usage of the entire available frequency spectrum to meet the ever-increasing throughput demands of WMN applications. This way, in a mesh network, different non-overlapping channels can be assigned to adjacent mesh points, thus mitigating the interference between them. However, the absence of a common and shared channel among all mesh nodes brings new challenges to the mesh management. That is the main reason why most of current IEEE 802.11-based WMN are developed using a single-channel and single-channel communication approach. Additionally, new routing mechanisms must be applied in order to enable routing among the multiple channels.

There are several ongoing standardization bodies working to extend wireless communication specifications in order to allow mesh networking (Devi, Praveen & Beg, 2011). For example, the IEEE 802.11s specifies the PHY and MAC requirements to enable network in Wireless Local Area Networks (WLANs), which the proposed amendment was recently included in the last version of the IEEE 802.11-12 standard (LAN/MAN standards Committee, 2012).

Distributed Hash Table (DHT)

The DHT concept arises from the Structured P2P overlay networking's field. In contrast to Unstructured P2P systems, in which the content is placed at random peers, in Structured P2P overlay networks, the content is placed at the specified (by some deterministic calculation) locations. This approach is more efficient to retrieve the content. In this context, a DHT is used as a substrate of the overlay network to provide a number of functionalities such as information distribution, location service, and location-independent identity. DHT overlays have been established as an effective solution for data placement and exact match query routing in scalable network infrastructures.

Briefly, in a P2P system, each node keeps a DHT structure to supply contents and a routing table including the address of some other nodes in the overlay network. The main idea behind DHT is to apply a hash function to distribute content among a group of nodes in a network. The same hash function must be used to locate the node that stores the desired content. This method allows the efficient publication/lookup/retrieval of data, through the association of a key, or identifiers, to each data element. The space of identifiers is divided among the nodes that form the DHT and the pieces of information are mapped into that space, typically using a hash function. Each network node is responsible for all the information pieces mapped to its identifier.

The nodes participating in a DHT use a physical communication network, such as the Internet, to exchange messages. However, they also create a new network, superimposed upon this physical network, called the overlay network. This overlay network has its own topology and routing protocols that are specified by the DHT. Thus, each node has its own neighbors in the DHT, that is, the nodes to which they are directly connected in the DHT, even if the underlying network includes nodes that are are several hops away. In essence, DHTs are multi-hop networks, where each node forwards a message to the neighbor node that is closer to the message's destination.

To manage and maintain a DHT an extra effort is usually required. In a DHT, nodes have to maintain a neighborhood table. As the number of entries in that table increases, the performance of a search operation on the DHT also increases, but so does the cost to maintain the DHT. In order to balance the cost of these operations, the neighborhood table may keep $\log N$ entries, where N is the number of nodes on the network, ensuring that the search cost will be $\log N$.