Light Client Management Protocol for Wireless Mesh Networks

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Abstract

The future of wireless networks evolves toward more simple ways for users to get connected while on the move. In this perspective, Wireless Mesh Networks constitutes one of the key technologies for next generation wireless networks. In this paper we present LCMP, a new protocol for client management in wireless mesh networks. LCMP performs on-demand path setup for clients and supports clients mobility by introducing new light mechanisms that take full advantage of the mesh architecture. The work on LCMP and mesh routing is still in progress at LOR/INT laboratory. In this paper, we highlight some ongoing work.

1. Introduction

Future wireless networks are designed with the objective of providing users with simpler ways to get connected while providing better service quality. Wireless Mesh Networks (WMNs) [1] constitute one of the key technologies for next generation wireless networks. As shown if figure 1, a WMN, composed of Wireless Mesh Routers (WMR) and Wireless Mesh Clients (WMC), is a two tier network architecture. The two architectural levels, client access level and mesh backbone level, can be distinguished according to their provided functionalities. The client access level offers the wireless access to the network; on this level each WMR plays the role of a normal access point with which clients can be associated. The mesh backbone level is a multi-hop wireless network used to route packets between clients associated with different mesh routers.

WMRs are equipped by two wireless interfaces, one to communicate with the mesh routers and the second to communicate with WMCs; it is assumed that these two interfaces operate on non interfering channels. WMCs are equipped with one wireless interface that must be associated with a WMR in order to communicate with other WMCs. WMCs do not need to run any particular routing protocol to get connected. The mesh backbone is totally transparent for WMCs that think all destinations are on the local LAN.

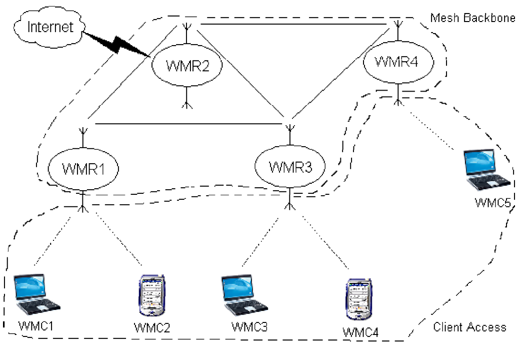

Figure 1. A Simple Wireless Mesh Network

LCMP, our proposed protocol for client management, aims to take full advantage of WMNs. LCMP minimizes the traffic overhead due to mobility support. In fact control packets are only sent when the moving node involved in an active communication, these control packets are either local broadcasts or unicasts; no network wide flooding is required. Moreover, LCMP reduces the processing overhead by minimizing the size of routing tables. WMRs located on an active path have only to keep routes toward the communicating WMCs. This means that if a WMR is not used as an intermediate node for any communication it will not keep any route to WMC nodes.

The remainder of this paper is organized as follows: Section 2 gives an outline on some related work. The description of LCMP is presented in section 3. In section 4 the formal specification of LCMP is presented. In section 5 we conclude the paper and highlight the ongoing work on the specification and implementation issues.

2. Related Work

The concept of combining the properties of cellular and AdHoc based networks has been the topic of many recent studies. One approach consisted of building an overlay over adhoc networks in order to improve the performance and increase the scalability of adhoc networks. Other approaches try to exploit the mesh architecture and proposes interesting technical solutions.

Hierarchical OLSR (HOLSR) [4] is designed for heterogeneous networks where nodes with different communication capabilities coexist. HOLSR dynamically organizes nodes, all running OLSR, into cluster levels. The objectives of HOLSR are to reduce the amount of exchanged topology control information at different levels of the hierarchical network topology and to use efficiently high capacity nodes. LCMP differs from the client management in HOLSR in that it does not require clients to run any particular routing protocol. The communications are transparent for our clients that think destinations are on the local network. Second, in HOLSR higher level nodes need to add routing entries toward all lower level nodes that explode the routing tables with unneeded information. In LCMP, mesh routers stores only routing entries for clients that have active sessions that pass by the mesh router (as a source, destination or intermediate node).

For MIT's Roofnet Project [2] mesh clients are directly connected to WMRs through an Ethernet port. Network Address Translation is used on each WMR to mask client addresses from the rest of the network. Contrarily, for LCMP, clients are mobile and connected to WMRs trough wireless connections. Mobility is supported by using a light message exchange so clients do not loose active connections while on the move.

The MeshDV [5] protocol uses IP-in-IP encapsulation on end WMRs. For the rest of WMRs traffic exchange between clients is transparent and seems to be between the two end WMRs that perform IP encapsulation/decapsulation of clients' sent and received packets. LCMP differs from MeshDV in that it requires no encapsulation mechanism. Only intermediate nodes between the source and destination need to know about the communication. This reduces processing complexity implied by IP encapsulation/decapsulation and allows supporting more efficiently client's mobility. The price is slightly more routing entries on only intermediate nodes.

3. LCMP Description

In a two tier network topology as WMNs, we can divide the routing protocol into two main components:
Route establishment component: This component is responsible of discovering and maintaining routes between the WMRs. from the routing protocol vision the mesh subnetwork is seem as a stable adhoc network.
Client management component: Wireless Mesh Clients are mobile and may move from one WMR's coverage zone to another. A WMR should be aware at any given moment about its attached WMCs. WMCs should be able to initiate and respond to communication requests with other WMCs or any internet destination in the case a global connection exists. These mentioned points are the responsibility of the client management component.

In this paper we present a new client management scheme for wireless mesh networks. We suppose that a routing component is deployed and routes toward all WMRs are proactively available.

3.1. Client Maintenance

Each WMR has to maintain a list of all WMCs that are associated with its client access interface in the Local Client Table (LCT). The LCT contains the IP and the MAC addresses of associated WMCs. This table is updated to reflect local topology change (join and departure of clients). The LCT format is represented in table 1.

Local Client Table	
WMC IP	**WMC MAC**
Associated WMC IP 1	Associated WMC MAC 1
Associated WMC IP 2	Associated WMC MAC 2
...	...
Associated WMC IP N	Associated WMC MAC N

Table 1. Local Client Table Format

In addition to maintaining the list of all associated WMCs, each WMR has to store in the Remote Client Table (RCT) the IP addresses of remote WMCs that are in communication with local WMCs and those that have active communications that use the WMR as intermediate node (on the path from source to destination clients). Moreover, there is a need to store the addresses of WMRs that manage the WMCs mentioned previously. Each entry in the RCT contains the IP address of the remote WMC and the IP of the WMR with which the remote WMC is associated. The last field is either the IP address of the local WMC involved in the communication or "forward" in case the WMR is an intermediate node. The format of RCT is represented in table 2. The last field in RCT is needed to improve mobility support described in section 3.3.

Remote Client Table		
Remote WMC IP	**Remote WMR MAC**	**Local Client IP**
WMC IP 1	WMR IP 1	Local WMC IP
WMC IP 2	WMR IP 1	Forward
WMC IP 3	WMR IP 2	Forward
...	...	...
WMC IP N	WMR IP N'	Local WMC IP

Table 2. Remote Client Table Format

3.2. Communication Handling

In a Wireless Mesh network the communication traffic flow can be classed into three categories:
A. Communication between two WMCs attached to the same WMR.
B. Communication between two WMCs attached to different WMRs and
C. Communication between a WMC and internet destination.

<u>A. WMCs attached to the same WMR.</u>

In this case, the Wireless LAN interface of the WMR bridges automatically packets between the two clients as they are attached to an access point. This is an embedded feature (HostAP mode) of 802.11 wireless card drivers. No further attention is needed here as the communication will not affect the Mesh side.

<u>B. WMCs attached to different WMRs.</u>

To show the connection setup between two WMCs connected to different WMRs, let us take the example of figure1. We suppose WMC1 wants to send data to WMC5, the following steps occur:

1. WMC1 sends an ARP Request [6] for WMC5 IP.
2. WMR1 receives the ARP request. It checks then in the LCT if WMC5 is an associated node (if yes we fall on A. described earlier). If it is not, WMR1 checks the FCT. If it has an entry match it pass directly to step x. if no entry is found, it broadcasts a CLREQ (client location request) message asking for the WMR that manages WMC5.
3. WMR4 receives the CLREQ and checks in its LCT if WMC5 is an associated client and unicasts to WMR1 a CLREP message indicating that WMC5 is an associated client. WMR4 inserts in its RCT an entry indicating that WMC1 associated with WMR1 is in communication with WMC5.
4. When WMR3 receives the CLREP message (path WMR1-WMR3-WMR4) it inserts 2 "forwarding" entries in its RCT for WMC1 and WMC5 (with their corresponding WMRs).
5. When WMR1 receives the CLREP message it adds an entry in its RCT indicating that WMC5 associated with WMR4 is in communication with WMC5.
6. WMR1 sends an ARP Reply message associated with its own MAC address (WMR1 must be an ARP proxy) to WMC1.
7. WMC1 receives the ARP Reply; now it is able to send data packets to WMC5.

In addition to the previously described steps, each WMR has to update its routing table whenever a change occurs in its RCT. For example, when receiving CLREP, WMR1 must add an entry toward WMC5 in its routing table.

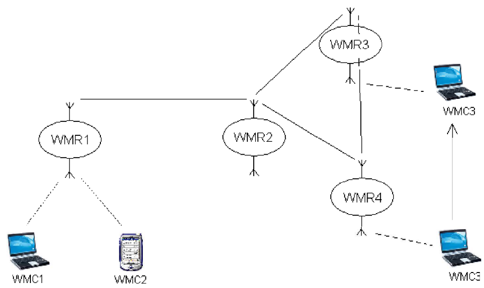

Figure 2. Mobility Support

<u>C. Communication with an internet destination.</u>

When an Internet gateway is available the routing protocol should be able to support gateway discovery in order to allow for distant WMRs to direct their external traffic toward the gateway. Thus no extra attention will be needed in order to forward a packet to the internet.

The problem is when the data traffic is from the internet to an internal client; in this case the same rules described in B (clients attached to different routers) applies in order to discover the location of the destination WMC and build valid routes on intermediate WMRs.

3.3. Mobility Support

In a Mesh network WMCs are mobile and may arbitrary move within the network. With node mobility, the location information and routing entries must be updated to reflect the current location of the WMC. Remember here that in a WMN the Client location is synonymous to the WMR with whom the WMC is associated. Our main objective with the design of LCMP is to minimize the overhead due to mobility support; WMRs are only informed about WMC's mobility if it is involved in an active communication. In this case an update packet is sent from the previous WMR along the communication path to update routing and RCT entries to point to the new location of the WMC. To better understand LCMP mobility support let us take the network scenario presented in figure 2.

We suppose that WMC1 is in communication with WMC3 that moves from WMR4 to WMR3, the following steps occur:

1. WMR3 detects the association of WMC3 and adds it into its LCT table.
2. WMR3 sends a CAInf (Client Association Inform) message to its direct WMR neighbors by setting the TTL field to 1. The message contains the IP address of WMC3.
3. WMR4 receives the CAInf message, it knows by checking the LCT table that WMC3 is an associated client. WMR4 deletes the entry form the LCT table.

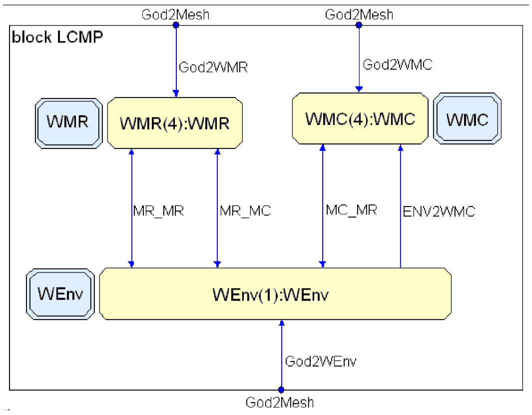

Figure 3. LCMP entities SDL specification

4. WMR4 checks if WMC3 is involved in active communications by looking the RCT table. If not no further action is needed; if yes (this is our case) WMR4 updates its RCT table to point to the new location of WMC3. In this case, WMR4 must unicast a CLUpdate (Client Location Update) message to WMR1 indicating that WMC3 is now associated with WMR3.
5. WMR2 receives the CLUpdate message, it checks if the WMC3 figures in its RCT table and make the update to point to the new location of WMC3.
6. WMR1 receives the CLUpdate message and perform the same action described in step 5.

The LCMP mobility support described above insures that no traffic is generated unless it is required. This is in the only case that the moving WMC is involved in an active session. The new WMR is only responsible for informing its one hope WMR neighbors about the new association. The Previous WMR is responsible for informing the network about the association update in case of client activity. This has two advantages, first it reduces the control overhead and second it allows the previous WMR to forward on-the-fly packets to the new WMR to limit packet loss when a handover occurs.

4. LCMP Specification Description

In the networking field, system complexity as well as high degree of reliability required for global functioning, justify the care provided for formal specification and testing validation.

In our case, we are working on writing LCMP formal specification in order to generate test sequences to validate its characteristics. In this perspective we are using the well known formal specification language SDL [3] (Specification Description Language) that is a well adapted language for the formal specification of interactive systems. For the redaction of this specification, we are using the industrial ObjectGEODE tool that provides a simple graphical interface to specify the system. Figure 3 illustrates the different components of our system with the channels that connect them, information exchange on different channels were not presented for clarity reasons. The system is composed of three "Process Types": WMR, WMC and WEnv that specifies respectively the functionalities of mesh routers, clients and the wireless medium. We represented the WMR and WMC using the "Process Types" formalism that allows creating several instances of the two processes, this permits to easily scale our tested network to generate more realistic scenarios.

No direct message exchange was specified between routers and clients; indeed WEnv (Wireless Environment) plays the role of intermediate between WMR and WMC. In the WEnv entity we can specify the characteristics of the wireless medium like packet loss, interference, and broadcast nature of transmissions. We choose also to specify client's mobility within the WEnv entity that informs WMCs when the handover occurs.

5. Conclusions and Ongoing Work

In this paper, we presented the specification of LCMP, a protocol for client management in wireless mesh networks. We described the main functionalities of LCMP and the work toward formally specifying it. LCMP searches for routes toward mesh clients reactively and reduces the routing tables by adding route entries on only intermediate WMRs. LCMP incorporates a light mobility support component that minimizes control messages.

The work is still ongoing on LCMP with multiple axes: we are implementing the protocol on a testbed of multiple machines in the LOR/INT laboratory in order to prove the performance of LCMP. Feedback from the formal specification will be used to refine the protocol and conformance testing will be used to validate the implementation.

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