A new multicast routing algorithm for the Wireless Mesh Networks

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Abstract—Wireless mesh networks, also known as “community wireless networks”, have been attracting much attention due to its promising technology. It is becoming a major avenue for the fourth generation of wireless mobility. This is due to the revaluation of using basic radio frequency physics to provide a robust, flexible, standard-based architecture that offers instant mobile broadband communications to different communities. Communication in large-scale wireless networks can create bottlenecks for scalable implementations of computationally intensive applications. A class of crucially important communication patterns that have already received considerable attention in this regard are group communication operations, since these inevitably place a high demand on network bandwidth and have a consequent impact on algorithm execution times. Multicast communication has been among the most primitive group capabilities of any message passing network. It is central to many important distributed applications in Science and Engineering and fundamental to the implementation of higher-level communication operations such as gossip, gather, and barrier synchronisation. Existing solutions offered for providing multicast communications in WMN have severe restriction in terms of almost all performance characteristics. Consequently, there is a need for the design and analysis of new efficient multicast communication schemes for this promising network technology. Hence, the aim of this study is to tackle the challenges posed by the continuously growing need for delivering efficient multicast communication over WMN. In particular, this study presents new load balancing aware algorithms with the aim of enhancing the QoS in the multicast communication over WMNs.

Index Terms—Multicast, Routing Algorithms, Wireless Mesh Network, Gateway

I. INTRODUCTION

Recently, it has been reported widely that hundreds of municipalities are recognising that facilitating internet access is part of their responsibility towards citizens. In this context, they are planning to bypass traditional internet access providers, opening access to the net in a more direct and affordable way. As a new cost effective technology, the Wireless Mesh Network (WMN) is a natural candidate for constructing a resilient, locally networked access to communication infrastructure. This is due to its desirable characteristics, including, but not limited to, multi-hop routing, auto-configuration, bandwidth fairness, low cost, easy deployment, self-healing and self-organized, etc. A WMN combines the fixed network (backbone) and mobile network (backhaul). In WMNs, there are internet gateways, mesh routers and mesh clients. Every node in the WMNs acts as a router, forwards the packet to other nodes. A node without access to the network can require connection by route packets from a neighbour node that has a network connection. All the network capable devices can be used in the WMNs. These devices include the traditional desktop PCs, laptop PCs and mobile devices such as Mobile phones, PDAs and Pocket PCs.

In the recent years, the demand for multicast TV, video conference and online multicast based games are hugely increased. More and more internet users like to watch football matches and TV dramas on the internet instead from traditional TV. Therefore, the multicast communication becomes an even more important research topic in the WMNs. The aim of multicasting is to send information from the source sender to multiple receivers. Some researches have already been studied in [1] [2] [3] [6] [7] [17] and some others. In multicast, compared to the mesh based multicast routing, tree based multicast routing is more suitable for the Wireless Mesh Networks, since WMNs topology is less dynamical than MANET. Nodes do not have high mobility requirement in the WMNs. Ruiz et al. [3] have studied efficient multicast routing in wireless mesh networks. Ruiz et al. [8] have studied the problem of computing minimal cost multicast trees in multi-hop wireless mesh networks. Zeng et al. [1] have proposed a Level Channel Assignment (LCA) algorithm and a Multi-Channel Multicast (MCM) algorithm to optimize throughput for multi-channel and multi-interface mesh networks. In all of these papers, the tree-based multicast is chosen as the foundation of their proposals. In [17], multicast routing between shortest path trees and minimum cost trees have been compared.

There are a number of research aspects of multicast such as throughput, QoS and load balancing in the WMNs. In [1] [2] [3], high-throughput and efficiency are the key issues they want to achieve. However, all of the previous researches do not cover the load balancing of multicast in the WMNs. In [4], the problems of the Gateway Loading has been determined which happens there are uneven traffic load in different gateways. In the WMNs, mesh client nodes connect to
been proposed in [12] and it is a typical on demand multicast algorithm. MAODV uses a shared bidirectional multicast tree and the group leader maintains the tree by sending group hello periodically. A RREQ request is broadcasted by a node which tends to join the multicast group or send multicast data to this group. Group members receive RREQ, response RREP to the source node to build the multicast tree.

ODMRP is proposed by Gerla et al. [11]. Compared to MAODV, a mesh topology with source node root is maintained by ODMRP. And as ODMRP’s mesh topology, the source node has multiple routing paths to one receiver. This mechanism allows fast repair of failure links. Either MAODV or ODMRP runs well via the gateway to the backbone internet. A gateway discovery scheme is introduced by Jelger et al. [15] and it uses prefix continuity to attach nodes with a gateway that has the same prefix. Based on this scheme, Ruiz et al. have proposed a multicast routing within the WMN [3]. This multicast routing algorithm builds a Steiner tree and multicast data packet via the prefix continuity gateways. The prefix continuity scheme only works when the ISPs set the prefix for all the gateways and mobile network subscribers. A mesh node without a prefix will not have the authority to register with the gateway.

In [1], the authors have proposed two algorithms Level Channel Assignment algorithm (LCA) and Multi-channel Multicast algorithm (MCM) to improve the throughput of WMNs. They have considered the multi-channel characteristic of WMN and have enabled every node acts with two network interfaces. In addition, the goal of MCM is to minimise number of relay nodes and hop numbers in the multicast tree. In the multicast session, one interface is used to receive packets (RI) and another one is used to send packets (SI). Therefore, RI works with the upper level data flow and SI to transmit the replicated packets to down level nodes. This mechanism can reduce the interference and improve the multicast throughput. However, this paper does not mention how the channel assignment algorithms work with the gateways.

None of the above researches has clearly presented the key role of gateway load balancing in multicast communication of WMN. In an attempt to address this issue, we propose here a multicast algorithm, in which gateways maintain the traffic loading every time a mesh node made a registration request. The gateways are also responsible for recording and forwarding all the multicast information. This mechanism makes the multicast more efficient in the WMN and also enhances the load balancing during the communication phase.

FIG. 1. THE ARCHITECTURE OF A TYPICAL WMN.

II. RELATED WORK

Recently, there are many proposals on multicast in MANET such as MAODV [12], ODMRP [11], ADMR [13] and ADAM [14]. Most of these routing algorithms are demand driven routing due to the mobility and power nature of MANET. There are also some proposed multicast routing protocols in WMN environments. [1], [3] and [7] have discussed the multicast algorithm in WMN. MAODV has been proposed in [12] and it is a typical on demand multicast algorithm. MAODV uses a shared bidirectional multicast tree and the group leader maintains the tree by sending group hello periodically. A RREQ request is broadcasted by a node which tends to join the multicast group or send multicast data to this group. Group members receive RREQ, response RREP to the source node to build the multicast tree.

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gateways relay the message from internet to the mesh clients. Compared to MANET, most of the traffics are expected to flow between the mesh clients and the backbone network via gateways [10]. The gateway loading is not considered in the existing Ad-hoc multicast algorithm such as MAODV [12] and ODMRP [11]. In these algorithms, most multicast data flows are directly hopping between the sources and receivers. However, in WMN, a gateway handles all the traffic flow between mesh clients and internet. Furthermore, in MANET, all the nodes are assumed as mobile nodes moving in the network. Compared to MANET, most of nodes are stationary in a WMN. Only nodes like mobile phone and other portable devices are mobile.

**Algorithm 1:**

When node i wish to join a optimal gateway

{ 
  i sends GRDR to all the reachable nodes.
}

if i receives GRDP

{ 
  i store info of GRDP sender
}

then after i sends GRDR for \( \hat{\delta} \)

{ 
  i sends GRR to best load gateway in the table
}

if i receives GRP

{ 
  registration complete
}

if i receives GRP-E

{ 
  choose the next best load gateway and send GRR
}

for each node j:

if j receives GRDR

{ 
  forward GRDR to all gateways in j's table
}

for each gateway G:

if G receives GRDR

{ 
  reply GRDP to sender
}

if G receives GRR and current load is fine

{ 
  G sends GRP to sender
}

if G receives GRR and current load is bad

{ 
  G sends GRP-E to sender
}

There are three layers in a typical wireless mesh network: Internet Gateway Layer (IGW), Mesh Router Layer (MR) and Mesh Client Layer (MC) [16]. Fig. 1 illustrates the architecture of a WMN. For the simplicity of describing the routing algorithm, we combine the layer 1 and layer 2 as gateway node in this paper. Both IGW and MR are routing devices to connect the mesh clients to internet. For the load balancing of a typical WMN, MRs maintain traffic load of mesh client clusters and an IGW maintains the load of all the traffic from/to MRs to/from internet. In this paper, a gateway node works as the administrator of accessing backbone internet. It takes care of all the traffics in the WMN and maintains the optimal load balancing.

**IV. PROPOSED SOLUTION**

In this paper, we proposed a gateway associated multicast protocol (GAMP) on WMNs. In WMNs, clients connect to the internet and the nodes in other mesh networks via gateway. Therefore, in our proposal, we divide the multicast session for WMN into three steps: A. How mesh clients register with gateway. B. How the gateway nodes act in the multicast routing and C. How GAMP maintains the routes in WMN and routes of multicast tree.

**Algorithm 2**

Input: Gateway i, mesh client n;
Output: optimize the traffic loading of gateway

For each i:

if i's \( \hat{\delta} \)

{ 
  i sends GRP-B to its neighbor j with best \( \hat{\delta} \)
}

if \( \hat{\delta} \) receives GRP-B

{ 
  sends GRR-A to a j \( \hat{\delta} \)
}

if \( \hat{\delta} \) receives GRP-A

{ 
  sends GHR to sender of GRP-B
}

if \( \hat{\delta} \) receives GHR

{ 
  gateway handover session finished, direct request of the handover node to new gateway
}

For each n:

if \( \hat{\delta} \) receives GRR-A

{ 
  \( \hat{\delta} \) sends GRP-A to GRR-A's sender
}

**A. How mesh clients register with gateway**

Algorithm 1 shows the gateway registration of a client node. When a client node intends to send information to the internet, it must first register with a gateway node that has connection to backbone internet. The client node sends out the gateway route discovery request (GRDR) across the network similar to RREQ in AODV. A node receiving the GRDR relays the request to all the gateways in its gateway table, as gateway nodes receive the request, a gateway route discovery reply (GRDP) contains the current gateway load index, is answered to the request node. The request client node may receive
replies for routes to more than one gateway. The client then records the route with the minimum hop number to each gateway in its gateway routing table. After a time $\hat{t}$, it sends gateway register request (GRR) to the gateway with the best available bandwidth. In addition, the GRR request contains the IP addresses of all the potential gateways the client has. The gateway IP addresses are used to calculate the joint nodes of two gateways and to find out whether two gateways are closed neighbours. When the gateway node receives GRR, it detects its current medium usage (the channel bandwidth) see whether it is under a certain usage level. If so, the gateway node records the route path in its routing table and sends gateway reply (GRP) back to the client node. As client node receives the GRP, the registration phase has completed. However, if the gateway’s medium usage is higher than a certain level, the gateway node sends a gateway register error reply (GRP-E) to client node. Upon receiving the GRP-E, the client node marks this route with error flag in the routing table and sends GRR to the gateway with the second best load index.

![Fig. 2. General client-gateway registration.](image)

Algorithm 2 presents operations of gateway load balancing. The gateway nodes exchange load and bandwidth information with their neighbour gateways (who have joint nodes) periodically by sending gateway index packet (GIP). In a gateway node, it maintains the neighbour’s load index ($L_i$) for its gateway balancing purpose. Here we have to mention, we choose a value $u$ which is close to gateway threshold $\lambda$ to ensure handover session happens before the bandwidth excess the gateway threshold.

As algorithm 2 shown, when a gateway node $GA$ finds its bandwidth ($b$) getting lower than load balancing bandwidth factor ($u$) and approach to $\lambda$ or it finds neighbour gateway’s load is better than its threshold, it will start a gateway handover session. It sends out a gateway busy reply (GRP-B) to the neighbour gateway with the best load index, $GB$. In this case, $GA$ checks the gateway routing table for the gateway with best $L_i$. When receiving the GRP-B, $GB$ checks their gateway routing table and sends out an alternate gateway register request (GRR-A) to the joint node it would like to hand over. As $GB$ receives node’s reply, it informs $GA$ to handover the information of its new gateway by sending a gateway handover request (GHR). Upon receiving GHR, $GA$ transfers all the routing responsibility of the handover client node to $GB$. Before the handover session finished, $GA$ still forwards the data packets to this client node. After the handover session finished, all the data flow request for this client node arrives at the old gateway will be redirect to client’s new gateway. Thereafter, the new gateway $GB$ will inform the requested nodes the new routing information of the mesh client. Then $GA$ checks its load index again and generates a $L_i$ exchange. If the medium bandwidth of $GA$ is still low, it will restart the gateway handover session again.

**B. How the gateway nodes act in the multicast routing**

Algorithm 3 presents the description of multicast tree construction procedures. A node (this node can be both gateway and client node) would like to set a multicast session, periodically broadcasts a multicast Hello message with its routing detail and sequence number to all the gateway nodes in the network. When a gateway node receives this message, it records the backward route to the source node in its multicast routing table and ignores the old entry if the sequence number is fresher than an existing one. When a client node would like to join a multicast group, it sends multicast route request (MRQ) with destination IP address to its registered gateway. Once the gateway node receives the MRQ, it checks its multicast routing table. If there is an entry with the same IP address, the gateway node will send a multicast route reply (MRP) combining the routes from request client node to gateway and gateway to the source node. Otherwise, it broadcasts a multicast source request (MSQ). Any gateway receive this request replies a multicast source reply (MSP). The gateway records the routing information with the freshest sequence number in MSP. When source node receives this MRP, it record the route detail and starts to send multicast message to the client node.

![Fig. 3. Construction of multicast tree.](image)
Fig. 3 shows how a multicast tree is built. In another WMN, G2 and C0 are gateway and client node respectively. C0 is also a multicast source. Arrows 1, 2, 3 are multicast Hello, MRQ and MRP respectively. C0 broadcasts multicast Hello message over the internet via gateway G2. All gateways receive this Hello records the route information in its multicast routing table and stop forward it to their downstream client. In this example, G1 receives Hello message and records it. When C4 would like to join this multicast group, C4 sends MRQ to G1. As G1 finds the appropriate entry of this MRQ in its multicast routing table, G1 calculate the route from C0 to C4 and send this routing information back to C0. Finally, C0 receives MRQ and start to multicast data to C4.

Algorithm 3

\[
\text{for} \ S: \\
\begin{cases} 
\text{if} \ \text{wants to start multicast} \\
\text{broadcasts Multicast HELLO message} \\
\text{if} \ \text{receives MRP from M} \\
\text{adds M to its multicast routing table.} \\
\end{cases}
\]

\[
\text{for} \ \text{each} \ G: \\
\begin{cases} 
\text{if} \ \text{receives Multicast HELLO} \\
\text{records message and stops forward to its mesh clients} \\
\text{if} \ \text{receives MRP} \\
\text{if} \ \text{finds the routing entry for S} \\
\text{if} \ \text{cannot find the routing entry for S} \\
\text{if} \ \text{receives MSQ} \\
\text{if} \ \text{there is an entry for S} \\
\text{replies MSP} \\
\text{for} \ M: \\
\text{if} \ M \ \text{wants to join multicast group with the source S} \\
\text{ sends MRQ to its registered G} \\
\end{cases}
\]

C. How GAMP maintains the routes in the WMN and routes of multicast tree.

The client node of a WMN broadcasts periodic Hello message to its one-hop neighbours to detect the link breakage. When a node does not receive any data stream for a certain period, this node sends out GRDR to discover a new route. When this node finds a new route to a gateway node, the gateway will update its routing table. When this node is also a receiver of a multicast group, the gateway will send out the routing detail of the node to its multicast source node. As the source node receives it, the source node updates its multicast routing table, and uses the new route to multicast the message.

V. Conclusion and Future Work

In this paper, we investigate the multicast communication in wireless mesh networks where the mesh gateways have the paramount priorities. In particular, unlike many existing works, this study focuses on the load balancing over the gateways in WMNs. We have proposed a new load balancing aware multicast algorithm. There are two key components of the proposed algorithm: the mechanism to make gateway registration for client nodes by considering the gateway loading and the gateway’s action in the multicast tree construction.

As future directions, there are some works we plan to carry on. First, we will evaluate the algorithms under a wide range of operating conditions and scenarios. Second, based on the experimental results, the further improvement will be made to our algorithms by introducing either multi-channel or multi-path multicast routing algorithms.

REFERENCES


