2009 International Conference on Information Management and Engineering

Multicasting in Wireless Mesh Networks: Challenges and Opportunities

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***Abstract*-Wireless Mesh Network (WMN) is a multi-hop wireless network with partial mesh topology, which can replace wired infrastructure backbone in a traditional wireless network, to wireless. It is an exciting new technology that has applications in defense, metro-area Internet access, and disaster management. WMNs are believed to be a highly promising technology and will play an increasingly important role in future generation wireless mobile networks. This paper presents a survey on multicast protocols in wireless mesh networks and factors to be addressed while designing a multicast protocol for wireless mesh networks, like availability of mesh router infrastructure, effect of multiple channels and channel assignment, load balancing, selection of multicast routing metric, effect of guaranteed Quality of Service, and cross layer optimization.**

Keywords-wireless mesh networks; multicasting; channel assignment; load balancing

I. Introduction

Wireless Mesh Network (WMN) is a radical network form of the ever-evolving wireless networks that marks the divergence from the traditional centralized wireless system such as cellular networks and wireless local area networks (WLANs) [13]. Wireless Mesh Network comprised of two types of nodes: mesh routers and mesh clients. To improve the flexibility of mesh networking, mesh routers are usually equipped with multiple wireless (radio) interfaces built on either same or different wireless access technologies. Mesh routers have minimal mobility and form the mesh backbone for the mesh clients. In addition to mesh networking among mesh routers and mesh clients, the gateway/bridge functionalities in mesh routers enable the integration of WMNs with various other networks such as the Internet and other wireless networks. Although mesh clients can also work as a router for mesh networking, the hardware platform and software for them can be much simpler than those of mesh routers [1]. The primary advantages of a WMN lie in its inherent fault tolerance against network failures, simplicity of setting up a network and broadband capability. Figure 1 shows a typical Wireless Mesh network.

WMNs are dynamically self organized and self configured. WMNs can be deployed incrementally, one at a time, as needed. As more nodes are installed, the reliability and connectivity for the users increase accordingly [1]

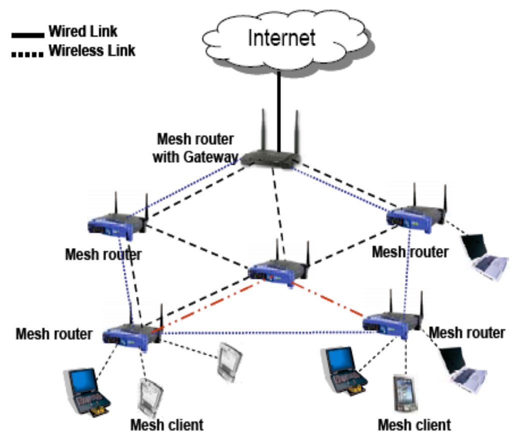

Figure 1: A Typical Multichannel WMN [12]

It is the ideal technology for providing quick and easy network access where network infrastructure is hard to install or has been destroyed and is equally suited to the low cost extension of network access to a wide area. The self-healing capability combined with the mesh topology's inherent redundancy provides wireless mesh networks with a high level of robustness and fault tolerance.

The major features of WMN are listed below [1].

(a) WMNs enhance network performance, because of flexible network architecture, easy deployment and configuration, fault tolerance and mesh connectivity. Due to these features, WMNs have low investment requirement, and network can grow gradually as needed.

(b)Mobility dependence on the type of mesh nodes:-Mesh routers usually have minimal mobility, while mesh clients can be stationary or mobile nodes.

(c) Dependence of power consumption constraints on the type of mesh:-Mesh routers do not have strict constraints on power consumption. However, mesh clients may require power efficient protocols.

(d) Compatibility and interoperability with existing wireless networks:-WMNs are interoperable with Wireless LANs, WiMAX and Cellular networks.

(e) Mesh Routers are equipped with multiple radios and non overlapping channels can be assigned to each of these radios.

978-0-7695-3595-1/09 $25.00 © 2009 IEEE
DOI 10.1109/ICIME.2009.92

This will improve the capacity of the mesh network as control packets for maintaining the connectivity among nodes can be routed through one channel and data packets from client nodes can be routed through different channel in the same node.

Multicasting is a bandwidth-conserving technology that reduces traffic by simultaneously delivering a single stream of packets to a group of recipients. In wired network environments, a host joins a multicast group by informing a local multicast router that in turn contacts other multicast routers; a multicast tree is thus created through a multicast routing protocol. The multicast router periodically sends queries to determine whether any of the hosts in its coverage is still a member of the multicast group. All host- multicast router communication is performed through the Internet Group Management Protocol (IGMP) [14].

The rest of the paper is organized as follows: We initially address the issues associated with multicasting in WMN. Features of some of the recently published multicast protocols are summarized in section III. We conclude this article by giving an insight into the factors to be considered while developing a multicast protocol for Wireless Mesh Network.

II. MULTICASTING IN WMN

Multicasting is a method of delivering information to a group of destinations simultaneously, using the most efficient strategy to deliver the messages over each link of the network only once, creating copies only when the links to the multiple destinations split.Many multicast routing protocols have been proposed for single-radio multi-hop wireless networks. A typical approach to supporting multicast in such an environment is to construct a multicast tree and let each parent node be responsible for multicasting data to its child nodes. This approach works under the assumption that a parent node and its child nodes share a common channel. However, in multichannel WMNs this assumption may not hold. In addition, if the channel assignment is dynamic, extra overhead due to frequent tree reconstruction or retransmissions of multicast packets must be addressed [11]. Applying this method of multicasting in WMN is difficult, since in a WMN a multicast protocol must consider several factors such as availability of static mesh router infrastructure backbone, availability of multiple channels among nodes, load balancing among channels and nodes, selection of multicast routing metric, guaranteed Quality of Service (QoS), cross layer heuristic etc.

A. The Effect of Multiple Channels and Channel Assignment

WMN uses IEEE802.11 family of standards (802.11 a/b/g/n). In the physical layer the frequency band is divided into multiple channels. The number of channels varies from one standard to another. For example in case of IEEE 802.11b the frequency band 2.4GHz to 2.485GHz is divided into 11 channels (US). Two channels are said to be non-overlapping if they are separated by four or more channels. Thus in 802.11b channels 1, 6, and 11 are non-overlapping. In a single channel wireless network like MANET, all nodes are equipped with single radio interface and are assigned a common channel. To communicate each other nodes in the network must share a common channel. This limits the capacity of the network as two nodes can't communicate simultaneously. In the case of WMN, mesh routers are generally equipped with multiple radio interfaces (Multi Radio-WMN) and these interfaces can be assigned non-overlapping channels. This increases the capacity of the network by allowing concurrent transmission over non-overlapping channels. The routing problem (both unicast and multicast) in WMN addresses the issue of determining which nodes to include on the routing path and which channel to use on each link of the path. To fully exploit the availability of multiple channels in WMNs, routing algorithms should account for the existence of channel diversity on a path in the network. The routing problem in multichannel WMNs is made worse by the fact that the network topology is determined by the channel assignment. As an example even though two nodes are located within the transmission range of each other, they cannot communicate with each other directly without a radio tuned to a common channel. Channel assignment can be static, dynamic and hybrid. Detailed study of these channel assignment schemes can be found in [15] and [16].

B. Availability of Static Mesh Router Infrastructure Backbone

Based on how routes are created among the members of the multicast group, multicasting can be classified into tree-based, mesh-based and hybrid. Most schemes for providing multicast in wired networks are tree-based. These protocols construct a shared multicast delivery tree to support multiple senders and receivers in a multicast session. The same principle is also used in MANET for multicasting. Ad Hoc Multicast Routing Protocol Utilizing Increasing ID Numbers (AMRIS), Multicast Ad Hoc On-Demand Distance Vector (MAODV) Protocol, and Lightweight Adaptive Multicast (LAM) are examples of tree based multicast protocol in MANETs. In mesh-based multicast protocols there exist multiple paths between any source and receiver pair. On-Demand Multicast Routing Protocol (ODMRP), Core-Assisted Mesh Protocol (CAMP) and Forwarding Group Multicast Protocol (FGMP) are examples of mesh based multicast protocols in MANET. The tree-based approaches provide high data forwarding efficiency at the expense of low robustness, whereas mesh based approaches provide better robustness (link failure may not trigger a reconfiguration) at the expense of higher forwarding overhead and increased network load. The hybrid approach combines the advantages of both tree based and mesh based approaches. The Ad Hoc Multicast Routing Protocol (AMRoute) and Multicast Core Extraction

Distributed Ad Hoc Routing (MCEDAR) are examples of hybrid multicast protocols in MANET. In a network environment with dynamically changing topology, mesh based multicasting out performs tree based multicasting and hybrid protocols suitable for medium mobility networks taking advantage of both a tree and a mesh structure [2].

In WMN the mesh routers form an infrastructure of mesh backbone for mesh clients. In general, mesh routers have minimal mobility and operate just like a network of fixed routers, except being connected by wireless links through wireless technologies such as IEEE 802.11. [17] Suggests that compared to mesh based multicast routing, tree based approach is more suitable for Wireless Mesh Network (WMN), as the network topology in WMN is less dynamic than MANET. But in a hybrid WMN, where client nodes are not necessarily static, hybrid multicasting is also preferable.

C. *Load Balancing*

Unbalanced load in the network can cause gateway overloading, center overloading or channel overloading [12]. Most of the traffic in a WMN is destined towards gateways, traffic aggregation at gateway nodes creates load imbalance, which in turn results in gateway overloading. The issue of center overloading refers to the nodes located near the geographical center of the network becoming overloaded in comparison to other nodes in the network. The main reasons behind center overloading are: (i) the nodes near the center of the network tend to lie on the shortest path more than other nodes in the network, (ii) the use of multi-hop relaying, and (iii) the relatively static nature of WMNs. Channel overloading in a multi-radio wireless mesh network refers to certain channels becoming overloaded compared to other channels. Thus, for any static network, like a multi-radio mesh network, load balancing is necessary to avoid hot spots and increase network utilization, as bad routes can exist for a long time in a static network and result in congestion and inefficient use of network resources. A multicast protocol for WMN should consider the above three overloading.

D. *Selection of Multicast Routing Metric*

The routing metric is a criterion to judge the goodness of a path in routing algorithms. Important routing metrics used in WMN are Expected Transmission Count (ETX), Expected Transmission Time (ETT), Weighted Cumulative Expected Transmission Time (WCETT), Packet Pair (PP), Success Probability Product (SPP), and Multicast ETX (METX). ETX measures the expected number of MAC transmissions and retransmissions needed to successfully deliver a packet from a sender to receiver. ETT explains the expected MAC transmission time of a packet over certain link. It improves on ETX by making use of data rate in each link. WCETT is based on ETT and aware of loss rate due to ETX and bandwidth of the link. A comparative study of these routing metrics can be found in [10]. There is a fundamental difference in the way the MAC layer handles multicast packets opposed to unicast packets. Typically multicast packets are broadcast at the MAC layer opposed to unicast in order to leverage the wireless multicast advantage (WMA) [3]. Due to the broadcast nature of the wireless channels, by a single transmission of a transmitting node, all nodes that fall in the transmission range of the transmitting node can receive its transmission. This property of wireless media is called Wireless Multicast Advantage. So directly taking the link-quality based routing metrics proposed for unicasting is not appropriate for multicasting in WMN. [4] addressed modification done in ETX, ETT, PP, METX and SPP to adapt Wireless Multicast Advantage.

E. *Effect of Guaranteed Quality of Service(QoS)*

One of the most challenging issues in WMN is how to efficiently support multimedia applications like mobile TV and audio/video conferencing. Multimedia communications have more stringent QoS requirements that must be fulfilled to provide an acceptable service. In particular, multimedia traffic is characterized by strong time sensitivity and inelastic bandwidth requirements. These applications require a guarantee on delay, jitter, packet loss, and throughput in order to give acceptable level of QoS to end users. Although multicasting is an enabling technology for bandwidth management, however, owing to the limited bandwidth and the shared nature of the wireless medium, designing multicast routing algorithms and protocols capable of satisfying a set of QoS constraints for different application services on wireless mesh networks is still a challenging research problem [5].

F. *Cross Layer Optimization*

Traditional network engineering is based on a strict layering approach on the protocol stack. In this modular approach, fundamental functionalities such as access to the medium (link layer), routing (network layer), and congestion control (transport layer) are performed independently. This has proven to be a very powerful and successful paradigm for wired networks, since the infrastructure is based on links with constant capacity and high degree of reliability. A cross-layer design approach on the other hand, is one that utilizes information across different layers of the protocol stack. A number of studies over recent years highlighted that cross-layer designs that support information exchange between layers can yield significant performance gains. The penalty that has to be paid for increasing system performance by deploying cross-layer designs is the complexity and communication overhead. Therefore, these two aspects should be carefully taken into account. Recently, a technique called *network coding* was proposed [9] to implement multicast by information encoding at the relay nodes. Network coding has proven to be effective in increasing the multicast throughput.

III. Related Work on Multicasting in WMN

In [17], Uyen Trang Nguyen and Jin Xu presented a simulation based performance comparison of Minimum Cost Tree (MCT) and Shortest Path Tree (SPT) methods of multicasting in WMN. These SPT algorithms minimize the distance from the sender to each receiver, whereas the MCT algorithms minimize the overall cost of the multicast tree. The simulation results shows that SPT algorithms offer better performance to multicast flows than MCT algorithms. In this study they used average multicast Packet Delivery Ratio (PDR), average end-to-end delay, average throughput and average delay jitter metrics to measure the performance of multicast protocols.

Design of two multicast algorithms, Level Channel Assignment (LCA) and Multi-Channel Multicast (MCM), for multi channel WMN is described in [8]. A multicast backbone – "tree mesh"- is constructed by partitioning the mesh routers into different levels based on Breadth First Search and heuristically assigning channels to different interfaces. Instead of only using non-overlapping channels, partially overlapping channels are also used in this design to reduce channel interference. In this design the channel assignment is based on the multicast structure to exploit broadcast property of wireless nodes. The effect of channel assignment in WMN is clearly addressed in this work. But features that are essential for an efficient multicast protocol in a WMN such as load balancing, QoS, cross layer optimization are not considered in this paper.

A framework for the QoS multicast routing is described in [5]. A proactive/mesh multicast routing protocol is used in the backbone mesh routers and reactive/tree multicast protocol is used between Mesh Access Points (MAP) and client nodes. This helps to eliminate unnecessary delays in setting up routes amongst backbone mesh routers and also minimizes control overhead as paths are only set up on demand in case of MAPs and clients.

A load aware algorithm to improve QoS in multicast communication over WMNs is described in [7]. It considers gateway overloading as the multicast traffic load for a gateway node can be extremely heavy during particular periods because when a gateway relays multicast messages there are also unicast packets through the gateway. The algorithm described in this paper, Gateway Associated Multicast Protocol (GAMP), consists of registration of client nodes to gateway and construction of multicast tree. GAMP is a hybrid multicast protocol as multicast source sends periodic Hello messages to all gateway nodes in active mode and the receiver nodes joins the multicast group by sending request to their gateway nodes on demand. Gateway loading is reduced by detecting the gateway bandwidth every time a new client node requests to register. The issues such as load balancing and QoS are addressed in this paper by considering gateway overloading. But load estimation of nodes other than gateway routers is not considered in this work. Also channel assignment and cross layer optimization are not addressed.

The development of network graph pre-processing approach to provide QoS multicast routing with traffic engineering capability is described in [6]. The main idea of the approach is, when a connection request arrives, the original network graph is preprocessed and a new graph is generated. This new network graph is used as input to a QoS multicast algorithm to find QoS guaranteed tree. In the graph preprocessing stage, prioritized admission control is used to achieve traffic engineering. A cross layer approach that joints power control and routing with random linear network coding to improve throughput in multicast over WMN can be found in [9]. An optimal power algorithm is used to choose the best power level of nodes and network coding technique is used to transmit packets on the network. But factors such as channel assignment and load balancing are not considered in this work.

IV. Conclusion

Efficient multicasting over wireless mesh network is well suited for video dissemination, in crisis management, surveillance, and home entertainment. Multicasting protocols that take into account the presence of multiple channels can simultaneously transmit data and improve efficiency. Avoiding overload can reduce latencies and cross layer optimization can improve throughput in WMN. Multicast routing metric must be carefully chosen to suit WMN. Recent works on multicasting in WMN has taken into account some of these issues but to the best of our knowledge there does not exists a generalized multicast algorithm that addresses all the issues discussed in this paper. Developing an efficient multicast protocol for video dissemination in WMN is a challenging area of research.

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