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Multicasting in Wireless Mesh Networks - Issues and Solutions

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Abstract*—*A wireless mesh network (WMN) is a communication network made up of radio nodes organized in a mesh topology. It is highly being deployed for a wide range of applications such as broadband wireless access, disaster recovery, industrial monitoring and control etc.WMN has gained significant acceptance due to its potential of providing low-cost wireless backhaul service to mobile clients. Multicasting is a method by which a source can send data to multiple receivers using a single transmission, thereby conserving bandwidth. Multicasting can be used as an effective routing method in wireless mesh networks but there are a lot of issues that brings down its efficiency. This article provides a brief analysis on various issues in multicasting protocols and a comparative study on different approaches against few network parameters.

Keywords*— *Wireless Mesh Network, Multicasting, Quality of Service, Performance Analysis, Mesh Topology

I. INTRODUCTION

A wireless mesh network is a communication network of radio nodes organized in the form of a mesh topology [1]. The figure below (Fig 1.) shows architecture of WMN. It is formed of mesh clients, mesh routers and gateways. The mesh clients are the wireless devices such as laptops, cell phones etc. The mesh routers are wireless access points that forwards packets from the clients to the gateways which relays them to the receivers. The IEEE standards used in wireless mesh networks are 802.11a, b and g. The network connection in a wireless mesh network is spread among a large number of nodes which communicate with each other by sharing the network connection across a large area.WMN is a self healing network [2] due to its self-configuring and self-tuning abilities. There are multiple redundant paths eliminating single points of failure. When a link becomes congested or a node fails the mesh automatic redirection of traffic on an alternate route occurs.

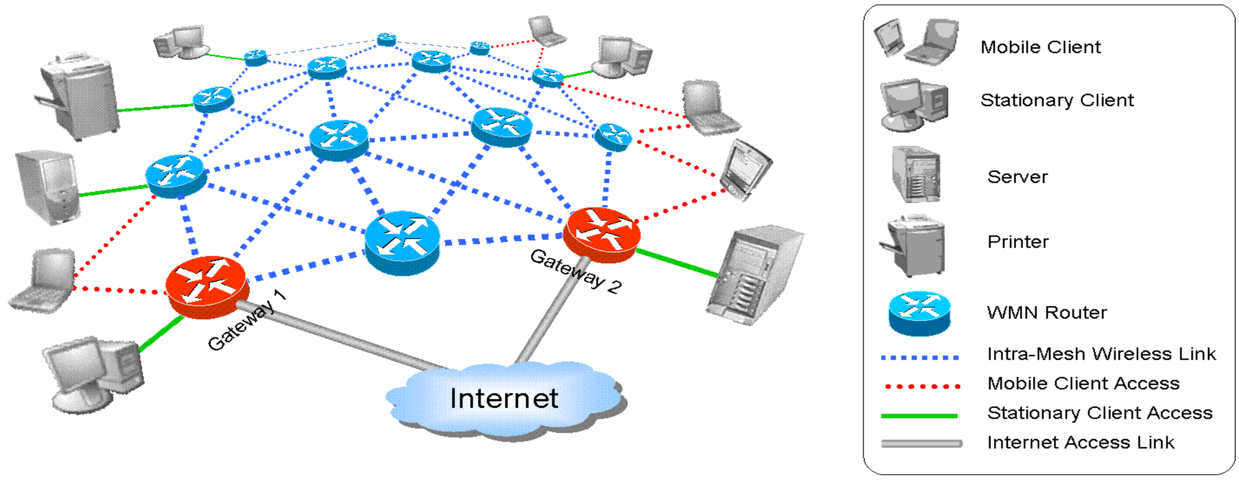

Fig 1. Wireless Mesh Network [11]

Multicasting aids message delivery to a group of destination simultaneously using single transmission by the source. Automatic creations of copies occur in the routers as per the requirement in the transmission. This process eases the applications such as videoconferencing, video serving, news distribution etc., with better quality. It is the cost effective way to communicate with many receivers at the same time [3].

II. ISSUES IN MULTICASTING IN WMN

The process of multicasting in wireless mesh network is prone to various issues. One among that is the interference caused by the radio transmission of neighboring nodes during simultaneous data transmission, reducing overall efficiency of the WMN by blocking the data being communicated[4] .Secondly the unreliability of data caused due to the lack of RTS/CTS and ACK support for multicasting in wireless networks denies QoS for the users [5]. Thirdly the "Crying-Baby" problem [6] that prevents the data reception by the nodes far from the source is to be considered. Security is another major issue occurring mainly when the users are mobile [7].Security measures are important to ensure that only authenticated members in a multicast group have access to the multicast data. High data rate and bandwidth support in multicasting in a WMN is very crucial [8].It should be ensured that communication overhead is less so as to prevent the delay. The section below provides a brief description on the protocols developed to solve these issues along with their performance evaluation.

1. GORby: Interference-Aware Multicast for Wireless Mesh Network [4]

In this method the nodes are grouped into three groups based on their operating states such as transmitting, receiving and stand-by. All the nodes with same operating state at a particular instance of time are considered to be members of a GORby-groups (GG). The nodes change their state in the table shown below (Table I). If a node transmits data in the first timeslot (Green), it will be in receiving mode in the second (Orange) timeslot and in stand-by mode in the third timeslot (Red).

TABLE I
SCHEDULING IN GORBY [5]

Time Slot	Transmitting	Receiving	Standby
First	Green	Orange	Red
Second	Red	Green	Orange
Third	Orange	Green	Red

The nodes with a greater Signal to noise ratio (SINR) value are found to be less affected by interference. The SINR is calculated by each node in a group using the using the following equation.

$$SINR = \frac{P_{ri}}{N + \sum_j I_j} \quad \text{(Eq: 1)}$$

where, *Pr* is the received power of the carrier signal; *N* is the thermal noise; *Ij* is power of interference caused by transmission of other nodes.

The nodes as well as path that can provide maximum SINR i.e. less interference can be found out thereby increasing the efficiency of routing. This value is used to select maximum SINR in the algorithm used to join the multicast group. This is called GORby Interference-Aware (GIA). The Path GIA (PGIA) is defined for the new branch of Multicast distribution tree. This is done when the distance between the node on the existing tree joining new branch and the new receiver is one hop. PGIA is the minimum of GIAs of all the nodes along the path and the receiver selects the path that can provide the maximum PGIA.

An increased packet delivery ratio could be achieved with this approach due to the selection of a node as well as path with least interference. The convergence time is more with increased join requests. It can support only a stable topology with one directional transmission. The maintenance overhead is another disadvantage.

2. A ring-based multicast routing topology with QoS support in wireless mesh networks [5]

This protocol enhances the IEEE 802.11 MAC multicast layer by providing RTS/CTS and ACK support thereby reducing the collision probability and providing QoS support by multicasting over a bidirectional ring based topology (Fig 2.).

A bidirectional ring based topology is constructed using the following steps:

Step1: Group the nearby nodes into cluster.
Step2: Select one router among them as cluster head using the cluster head selection algorithm.
Step3: Connect the cluster heads to form a ring.
Step4: Transmit data to the cluster head.
Step5: Relay the data to the next cluster head with the support of the intermediate routers.
Step6: Send the data to the respective group members.

The special structure of the bidirectional ring based multicast routing topology i.e., the similarity in the way multicast traffic is routed on a ring topology and unicast routing, allows for the simple exchange of RTS/CTS and ACK messages between neighboring nodes on the ring. The router which receives the data sends RTS to its neighbor and sends data to it only after it receives CTS from its neighbor. Half of the data is considered to be sent on both the directions.

All the routers at a particular instance are in any of the operating states which is denoted in Fig 2. by different colors. The operating states are; transmitting multicast traffic to the successor node in clockwise direction of traffic flow (Green),receiving multicast traffic from the predecessor node in the direction of clockwise traffic flow (Orange), stand-by mode in order to prevent collision with the multicast traffic in the clockwise direction i.e. hidden node problem (Red) transmitting multicast traffic to the successor node in anti-clockwise direction of traffic flow(Yellow),receiving multicast traffic from the predecessor node in the direction of anti-clockwise traffic flow(Blue), stand-by in order to prevent collision with the multicast traffic in the clockwise direction i.e. exposed node problem(Purple).The band width utilization is inefficient because of the above said two stand-by states.

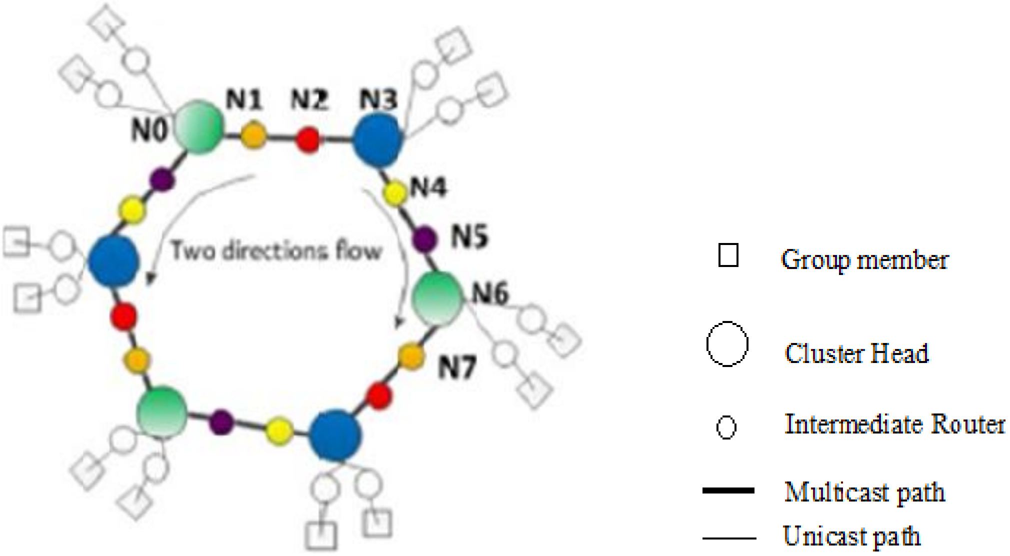

Fig 2. Bidirectional ring based topology [5]

Network Coding is done to increase the bandwidth utilization by avoiding hold time of a node. The intermediate node, instead of just forwarding the packets, combines it with other packets that it has seen so far and sends this combination to both sides. The nodes in the topology has only three MAC operating states colored as Green: when a node is transmitting the encoded traffic (E traffic), Orange: when a node is receiving traffic from the predecessor node in the direction of clockwise traffic flow (RL traffic), Red: when a node is receiving traffic from the predecessor node in the direction of ant-clockwise traffic flow (RR traffic).We can observe that all nodes on the ring are busy all the time and there is no hold times. Each encoded traffic contains information that is useful to neighboring nodes on both directions of the ring. All the nodes on the ring are either receiving or transmitting all the time hence there is no hold time.

This method ensures successful reception of packets due to the RTS/CTS mechanism. The transmission delay is reduced as the hop count is reduced via bi-directional topology. Reduction in the power consumption is seen with reduction in packet loss and hop count. The increased bandwidth utilization is also an advantage. This protocol did not consider the mobility of the group members which curbs the applicability of the WMN.

3. Pacifier: High Throughput, Reliable Multicast without "Crying Babies" in Wireless Mesh Networks [6]

Pacifier is a high throughput reliable multicast protocol aimed at solving the issues in multicasting in a WMN arising out of the lossy nature of the wireless links and the "crying baby" issue where the varying connectivity from a source to different receivers degrades the performance when reliability needs to be ensured for the poorly connected nodes.

It is a combination of four methods. First is the tree-based opportunistic routing, where an efficient traditional multicast tree is built connecting the source to all receivers and the opportunistic routing is carried out. The tree constructed at the source is a shortest-ETX tree formed by combining all the shortest-ETX paths from the source to the receivers. This multicast tree is reconstructed at the source whenever a receiver completes a batch of 32 packets and the source is notified. Second is application of intra-flow, random linear NC to eliminate packet loss thereby avoiding hop-by-hop feedback and coordination requirement at the packet forwarders. Third is source rate limiting so as to reduce the network congestion level. A simple form of backpressure-based rate limiting is applied based on BMCC [10]. The source waits until it overhears its child nodes forward the previous packet it sent before it transmits the next packet. Fourth is the source's round-robin fashion of sending the packets batches, solving the "crying baby" problem. Round-robin fashion of packet transmission occurs and not sequential as in MORE [11]. This is shown in the following figure (Fig 3.).

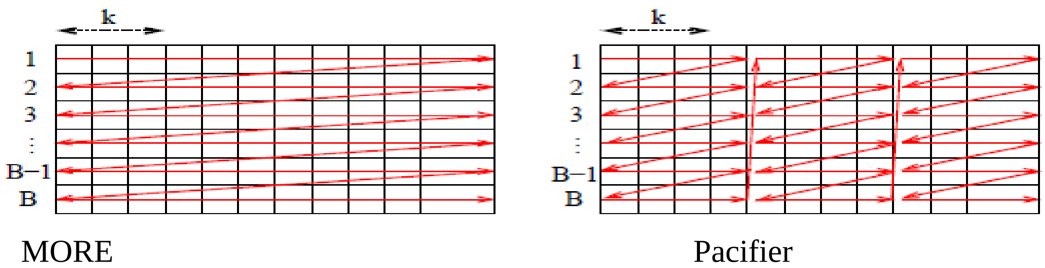

Fig 3. Difference between MORE and Pacifier [3]

The source sends the next batch every time a single receiver acknowledges the current, eliminating the waiting time to wait for ACK from all the receivers. The throughput variance at the receivers is highly reduced and no packet duplication occurs. This approach is not applicable in case of multiple sources.

4. Hierarchical agent-based secure and reliable multicast in wireless mesh networks [7]

This protocol aims at providing security and reliability in multicasting in a mobile WMN using a hierarchical structure. The security measures used here ensures authenticated access and also forward and backward secrecy. Efficient failure handling of links is also done here along with support for user mobility. A pair-wise secret key is shared between the member and the mobile agent (MA) to securely deliver the multicast packets to the member. Upon the join of a mobile agent to the network a new key is generated after discarding the old key. A group key is used by the source to encrypt the packet to be disseminated to the mobile agents. Each mobile agent decrypts this received packet using the group key.

A multicast transmission from source to a group member is a two-stage process involving two pairs of encryption/decryption operations. Re-encryption of the packet is done using the pair-wise key with a group member it serves in its service region. This is sent to this group member. The group member finally decrypts the packet using the pair-wise key shared with its mobile agent.

Packet recovery mechanism in the lower level of hierarchy involves sending a negative acknowledgement to the mobile agent so as to resend the packet. In the higher level this is done by the mobile agent to the source. The overall communication cost is reduced by reliable delivery of packet. The applicability of the mesh network can be extended here for mobility support with secure transmissions. This protocol failed to address the mobility of source. Failure handling of MRs and MAs in addition to packet losses on wireless links is unaddressed.

5. An architecture with QoS support for application layer multicasting over wireless mesh networks [8]

This protocol provides QoS in terms of consumed bandwidth and data rate in multicast applications. This approach uses a ring based topology as shown in Fig 4. The cluster heads are connected in the form of a ring so as to relay the multicast traffic, supporting many to many multicasting.

The high data rate is ensured by selecting senders and cluster heads with high data rate are only. The upper bound bandwidth is reserved at Cluster heads (CH) and mesh routers during the ring construction and shortest distance is selected satisfying the bandwidth. Only disjoint paths and Minimum hop-count between member and CH is selected. This aids in avoiding duplicate packets. This topology-aware overlay multicast routing protocol route the traffic on both directions on the ring ensuring shorter hop distances between group members thereby reducing delay and bandwidth requirement. The traffic distribution in the network is such that the congestion is reduced. This multicast scheme saves bandwidth and reduces link stress. The overhead in processing the sub layer is a disadvantage.

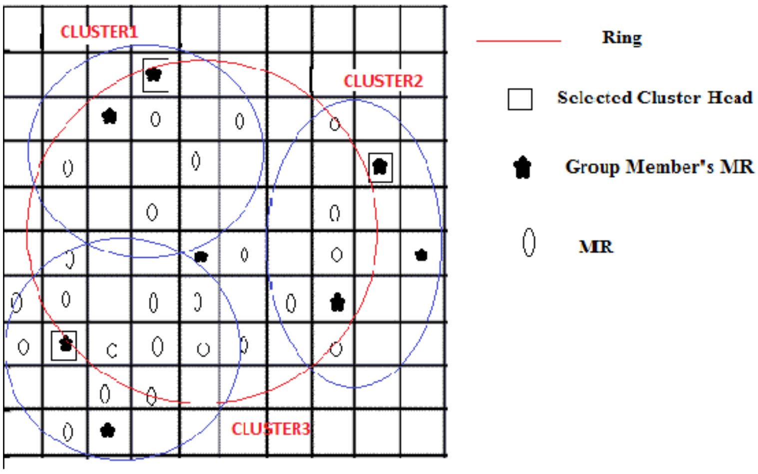

Fig 4. Ring Topology Construction

The following table provides summary a brief protocols described above .

TABLE II: SUMMARY

Method No	Source/ Receiver Initiated	Routing Metrics	Performance Metrics	Advantages	Disadvantages
1	Receiver	Hop-count	1) PDR was 5-10% more than PIM-SM. 2) Delay increases with increase in convergence time in case the topology is not static.	1) Helps in selecting a path with least interference. 2) The packet dropped is less compared to PIM due to less interference. 3) Better performance except in low traffic and packet reception even across long distance.	1) More time for convergence which increases with join requests. 2) Designed only for WMN with fairly stable topology and one directional transmission. 3)Three way handshaking is done where it is two in

					PIM-SM. 4) Hello packet has eight bytes data more than PIM-SM, and nodes send the hello packet every 30 Sec. 5) More overhead for GORby maintenance.
2	Receiver	Hop-count	1) Reduced delay, 2) Reduced power consumption, 3) Reduced bandwidth.	1) Efficient bandwidth utilization and less delay. 2) RTS/CTS and ACK mechanisms increases reliability. 3) Reduced power consumption. 4) Interference Aware process.	Mobility of the users is not considered.
3	Source	Hop-count ETX	Higher throughput compared to MORE. Ranges from 24-199% increase.	1) Congestion reduction. 2) Reduces throughput variance at the receivers. 3)No packet duplication	Applicable only to single source.
4	Receiver	Hop-count	1) Effective stability with change in state of wireless links. 2) Increase in population leads to efficiency, causing cost reduction.	1)Security assurance 2) Support for mobile users.	1)Failure handling of MRs and MAs in addition to packet losses on wireless links is Unaddressed. 2) Source mobility is not considered.
5	Receiver	Hop-count	1) Less bandwidth consumption and link stress. 2) Less delay and control message overhead.	1) Less bandwidth. 2) Shorter hop distances between group members. 3) Less delay and reserved bandwidth at cluster heads. 4) Congestion avoidance. 5)Reduction in overhead (up to 7x) and failed QOS route establishment.(8x)	Extra processing overhead mesh routers to process the sub-layer.

III PERFORMANCE ANALYSIS

GORby [4] outperformed the Protocol Independent Multicasting-Sparse Mode (PIM-SM) in packet drop analysis with a value of 5-10% due to increase in interference in PIM-SM.A major drawback found for GORby is the convergence time required, in case of a dynamic topology due to the time required to download the GMI table to calculate GIA and selecting the best path. A two way handshaking is done in PIM-SM to join the multicasting group while in GORby it is a three way handshaking. The hello packet in GORby has eight data bytes more than PIM-SM. The overhead for GORby maintenance is high. In the second method [5] the bidirectional ring topology out performs the tree topology in terms of throughput because of the network congestion occurring due to large amount of packets being transmitted. In tree based topology every packet is first send to the root and then it transmits to the respective receivers causing congestion at the root nodes. This leads to packet loss. Lack of RTS/CTS mechanism leads to retransmission due to increase in collision probability and additional energy consumption by the whole network. The delay in tree topology is more because of the network congestion also due to the additional time taken to transmit a packet to the root node.

Pacifier [7] out performed MORE in terms of throughput in 80% of the scenarios considered. The throughput gain range is from 20% to 199% with an average of 42% over all 10 scenarios. The higher throughput achieved is due to the fewer forwarding nodes and lower total number of transmissions.

The HARSM [8] incurred less communication cost compared to traditional shortest path tree (SPT) algorithm as multicast efficiency improves with increase in population density. HASRM performed superior to SPT, for moderate values of population and also with changing quality of wireless links.

The bandwidth consumption by the overlay architecture [9] and link stress was found to be less because less wireless transmissions were introduced when members in the same cluster share wireless links. The topology awareness provided shorter hop distances between group members, less delay and reserved bandwidth at cluster heads. The control message overhead was found to be less in this method as construction of a new QoS route every time it gets a packet is not required as in tree topology. Traffic distribution across the network helped in reducing congestion.

IV CONCLUSION

Multicasting in a WMN is a widely accepted technique in the world of communication as it provides an optimized network performance with support to distributed applications in a scalable and resource efficient manner. Multicasting being UDP based faces many issues. The lack of RTS/CTS and ACK support, "Crying Baby" problem, interference caused by simultaneous transmission of neighboring nodes, unauthorized data access in case of mobile users etc. diminish the performance of the network. A thorough knowledge on the issues in multicasting in WMN is required to take maximum advantage of this technique. A brief review on the protocols to solve these issues is done in this article. In addition to it a comparative study of these protocols is done providing a clear depiction on their efficiency and performance..

REFERENCES

[1] http://en.wikipedia.org/wiki/Wireless_mesh_network

[2] http://www.securedgenetworks.com/secure-edge-networks-blog/bid/57702/3-Key-Benefits-of-Wireless-Mesh-Networks

[3] http://en.wikipedia.org/wiki/Multicast

[4] H. Nicanfar, M. Jaseemuddin, N.-W. Ma, & V. C. M. Leung, "GORby: Interference-aware multicast for wireless mesh network", *Accepted for presentation at IEEE ICC WS-SCPA workshop.*

[5] A. Alasaad, H. Nicanfar, S. Gopalakrishnan, V. C. M. Leung, "A ring-based multicast routing topology with QoS support in wireless mesh networks," *Wireless Networks*, DOI 10.1007/s11276-013-0559-z

[6] D. Koutsonikolas, Y. C. Hu, C. Wang, "Pacifier: High Throughput, Reliable Multicast without "Crying Babies" in Wireless Mesh Networks", *IEEE INFOCOM '09*, 2009.

[7] Y. Li, I.-R. Chen, "Hierarchical agent-based secure and reliable multicast in wireless mesh networks", Science Direct, 2013.

[8] A. Alasaad, S. Gopalakrishnan, V. C. M. Leung, "An Architecture with QoS Support for Application Layer Multicasting over Wireless Mesh Networks", *IEEE*, 2009.

[9] B. Scheuermann, M. Transier, C. L. M. Mauve, and W. Effelsberg, "Backpressure multicast congestion control in mobile ad-hoc networks", *in Proc. of ACM CoNEXT*, 2007.

[10] S. Chachulski, M. Jennings, S. Katti, and D. Katabi, "Trading structure for randomness in wireless opportunistic routing", *in Proc. of ACM SIGCOMM*, 2007.

[11] http://www.ece.ncsu.edu/wireless/WMN/intro.html.