Exhaustive Analysis of Multicast Routing Protocols used in Multi Hop Mobile Ad Hoc Networks

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Abstract— A mobile ad hoc network (MANET) is a self-organizing temporary autonomous network with set of mobile nodes. MANET provides a platform to host many applications which in turn require rapid development and dynamic reconfiguration. For example defense industry, rescue sites, classrooms, and conventions. These applications lend themselves into multicasting. Multicasting can improve the efficiency of wireless links which is a limited resource by sending multiple copies rather than sending multiple unicast. Thus, it greatly reduces the bandwidth consumption. Hence, scalable and reliable multicast routing is a challenging task due to inherent characteristics of MANET. In the recent past years, many researchers have proposed many multicast routing strategies and they differ by its features and recovery mechanisms. This paper aims to provide a comprehensive study onsome of the existing multicast approaches proposed by the research community with respect to reliable, energy-aware, QoS –supported and secured multicasting.

Key words: MANET, Multicast, Reliable, Energy, QoS and Security

I. INTRODUCTION

Mobile Ad hoc Networks (MANET) are used in areas which require rapid deployment and dynamic reconfiguration. The general problems of MANETs [1] are the scarcity of bandwidth, short lifetime of the nodes due to power constraints, dynamic topology caused by the mobility of nodes, attacks and satisfying QoS. These problems enforce to design a simple, scalable, robust, secure, QoS constrained and energy efficient protocols for multicast environment.

Multicasting [2] is one of the transmission techniques which transmitpackets to a group by a single destination address. Multicasting is intended for group-oriented communication, where the group membership is dynamic. Multicast over MANETs is an important and challenging goal because several issues must be addressed before many group-oriented applications can be deployed on a large scale.

Multicasting [3] is a more efficient method than multiple unicast and broadcast because of less resource (processing, bandwidth, and memory) consumption and has an ability to transmit and route packets to multiple destinations. In [4], the fast improving capabilities of mobile devices and a widespread deployment of wireless network content and service providers are increasingly interested in supporting multicast communication over wireless networks. Some of the major multicast applications include group-oriented mobile commerce, military command and control, distance education and intelligent transportation systems. A wireless multicast requirement varies from one application to other hence the multicast protocol designed for MANETs should meet all these criteria.

This paper is organized into four sections. Section 2 provides a detailed study of existing multicast work. Section 3 provides drawbacks of existing work. Section 4 provides the future work needed and conclusion.

II. RELATED WORK

We have discussed some of the existing multicast approaches based on reliability, QoS, energy aware and security. This section will provide a detail insight of each protocol operations, its properties, merits and limitations.

A. Reliable multicast approaches

A multicast routing is called as reliable multicasting only if it can provide very few or no chances for link failure which posses rerouting and packet loss which needs packet retransmission. Due to the dynamic topology of MANET, providing such a kind of multicasting is a challenging one. Also, receiving reliable data is very complicated to group members in dynamic topology. By reliable multicast routing, the cost for recovery of links can be minimized. Some of the existing reliable multicast routing protocols are discussed below.

Su et al proposed a Modified AODV Routing [5]using Fuzzy approach. In route discovery process, the lifetime of an active route is determined using fuzzy logic weighted multi-criteria which performs based on the remained energies of the nodes on the routes, the number of hop-counts and the transmitted controlled packages. FMAR allows a source to communicate with its receivers through multiple routes. Thus, it can improve the robust transmission against unreliability and limited bandwidth of wireless links. Since routes are established in mesh topology, the suddenly broken links during transmission can be handled. By applying a set of definitions and rules, a most suitable main route and an alternative route are selected, and they are stored as active routes in the routing table. It achieves reliable packet delivery by maintaining and repairing the route based on route lifetime information. Here, the lifetime information used is static information. By this information, the routes cannot be repaired before they crashed.

Manvi S.S et al proposed a reliable multicast routing using multi agents system. In this approach [6] a set of static and dynamic mobile agents are used to discover the reliable route from a source to destination. It aims to constructs a backbone with reliable nodes for multicasting. Also, it provides backbone and group members management to cope with mobility. Simulation a result shows that it can offer flexible and adaptable multicast services and support component based software development. But, in ABMRS control overhead is high because of using more number of agents to discover a route to reliable node. Thus, control overhead is high in ABMRS.

The authors used a network coding technique to provide a reliable multicast. In [7] the destination will send a feedback when it does not properly receive a packet. The relay takes the responsible of the source node instantly after

receiving the packet properly. In a transmission slot, if a destination does not receive a packet which is received by the relay, then the relay will retransmit this packet in the following transmission slots until this packet is successfully received by all destination nodes. It uses the network coding concept to improve the efficiency i.e. for a packet retransmission, the source and the relay requires a list of lost packets and their corresponding intended destinations. This information can be obtained by feedback received from destination. For each retransmission period, throughput can be improved by using both network coding and relay forwarding.

The reliable multicasting [8] is provided by combining the Recovery Point (RP) and Forward Error Correction (FEC). The combination of these schemes reduces the control overhead. The node mobility problem has been solved by the maintenance scheme. By using virtual backbone, this protocol achieves multicast service with the small number of control messages. This protocol supports scalability also. Therefore, the multicasting protocol with RP and FEC schemes can provide higher multicasting service reliability.

Xiang, X et al proposed a efficient and reliable multicast based on geographical location of the mobile nodes. EGMP [9] supports scalable and reliable membership management and multicast forwarding through a two-tier virtual zone-based structure. At the lower layer, in reference to a predetermined virtual origin, the nodes in the network self-organize themselves into a set of zones and a leader is elected for each zone. At the upper layer, the elected leader guides its zone for joining or leaving a multicast group as needed. It uses location information for the zone construction, group membership management, multicast tree construction and maintenance, and packet forwarding. In EGMP, all the multicast sources of a group can share the zone-based tree, and the bidirectional packet forwarding is provided for reducing the forwarding overhead and delay. When the multicast packets are transmitted through the multicast tree, on-tree zone leader will transmit them to the group members of its local zone. By simulation results, it has been proved that EGMP has high packet delivery ratio and low control overhead and is scalable protocol.

In [10] the protocol does not use state information for establishing the routes. Instead, it uses only a list of the multicast member's addresses that are stored in packet headers. This, RBMulticast protocol uses the knowledge of the geographic locations of the nodes and hence it eliminates the cost of state maintenance.In RBMulticast, "multicast regions" are generated using a quadrants approach. In this approach, one multicast region is generated for one quadrant of the network. When a user wishes to send a packet, it will send a RTS packet to a multicast group. Then the data are forwarded down to the RBMulticast module in the protocol stack. After receiving this packet, the RBMulticast module gets the group list from its group table. This stateless protocol can significantly decrease the overhead. But, whenever a link breakage or packet loss is occurred, the recovery of that specific link breakage or the retransmission of that particular lost packet is very difficult. The comparison of the reliable multicast approaches is shown in Table 1.

Table 1: Comparisons of reliable multicast approaches

S. No	**Name**	**Type**	**Technique used**	**Metrics Measured**	**Drawbacks**
1.	FMAR	Mesh	Fuzzy Logic	Node mobility, Packet delivery ratio, average route acquisition latency delay, the routing overhead andaverage end-to-end delay	To repair the routes before they crashed, the dynamic lifetime information must be used.
2.	ABMRS	Tree	Agent based approach	Packet delivery ratio, Control overhead and Group reliability	high control overhead, because of too much agents
3.	RAWMNC	Tree	Network Coding	Throughput and Average Delay	high overhead and delay in retransmission of error or lost packets
4.	RP Scheme With FEC	Tree	Forward Error Correction (FEC) and Clustering	Delivery Ratio and Multicast Efficiency	Delay is high due to the retransmission process
5.	EGMP	Tree	Geographic Routing technique	Delivery Ratio, Normalized control overhead, Normalized data packet transmission	It consumes high bandwidth.

				overhead and Joining Delay	
6.	RBMulticast	Receiver-based Transmission	Stateless Approach (Location based)	packet deliveryratio, Latency, and Average traffic	Recovery of specific link breakage and retransmission of specific lost packet are very difficult

B. Qos based approaches

Quality of service (QoS) provision is the most important challenge in designing algorithms for MANET multicasting. QoS provisioning in MANETs is most significant process for supporting real-time communications, for example audio and video over MANETs. These applications require strict QoS requirements (such as delay, jitter and throughput) on Internet. But, achieving all QoS requirements together is very complicated task to due to the characteristics of ad hoc networks. Even though all QoS requirements can be achieved, the protocol will be more complex in terms of many routing tables, high control overhead, high energy consumption, etc. Therefore, achieving all QoS requirements together will not be appropriate for MANETs by means of their limited resources. More number of QoS multicasting protocols has been proposed by researchers and some of them are discussed below.

MOEAQ [11] uses the greedy and family competition approaches to speed up the convergence of algorithm and preserve the diversity of population. This approach is based on CBT. Also, it can effectively create multi-objective. Even though it requires less running time and provides fast convergence, it is very complex algorithm to implement for a highly mobile large scale network.

In Modified QPSO [12], the QPSO algorithm is integrated with loop deletion operation to provide the necessary QoS. The modified QPSO routing algorithm encodes the location of each particle as a vector of the number of the path between the source code and each end code in the network, and hence the routing problem has been resolved as an integer programming with the required QoS constraints. By using a loop-deletion process, optimal solution can be achieved. By simulation results, it has proved that the modified QPSO can provide better multicast trees with high convergence speed than PSO- based and GA-based routing algorithm. Also, the modified QPSO consumes less computational time and minimum cost, and provides higher routing request success ratios than PSO-based and GA-based routing algorithms. Even though this method has lot of benefits, there is no guarantee for recovering the packet loss. Hence further investigation is needed on QPSO regarding packet loss recovery.

In most of the QoS multicast routing protocol, the paths between the source and each destination are searched first and then the multicast tree can be created by integrating these paths. This method is slow and complex. The tree is built using an Ant Colony Algorithm proposed in [13]. And Ant Colony Optimization is used to control the tree growth for creating multicast tree. At first, the multicast tree is constructed only with multicast source node. After that, the ant will choose one link and insert it to the existing multicast tree based on the probability to grow the tree persistently. If the tree meets all the multicast members, then the tree constructing process will be stopped. Then, the constructed tree will be pruned, and the connecting links will be eliminated to find the real multicast tree. Also, the pheromones will be updated with respect to the obtained multicast tree. These processes are repeated until the algorithm converges. To improve the quality of optimization, the best combination of various parameters can be selected through orthogonal experiments. By simulation results, it has proved that this algorithm can perform well in searching, converging speed and adaptability scale. However, in this algorithm power consumption is high.

The multicast routing method proposed in [14], employs a Genetic algorithm (GA) to compute optimized route with the help of crossover, mutation, and population size. This approach effectively reduces the search space and avoids the unwanted nodes and links. It also uses an extended ST (Sequence and Topology) to simplify the coding and decoding process. It computes a modified fitness function to reduce the delay and higher residual battery energy. In most of the protocols, the intermediate nodes are used to calculate multiple metrics for each received and rebroadcast connection-request message. Thus, the additional research is required to minimize the work load of the intermediate nodes to enhance the design principle of routing protocols.

[15],the bandwidth requirements of a call can be satisfied by providing dynamic time slot control using a multi-path tree. MQMR uses a decision rule to avoid the hidden terminal problem and inadequate bandwidth in bandwidth reservation process. The reserved time slots on each node in the multi-path QoS multicast tree can be selected using a bandwidth reservation scheme. In bandwidth reservation for wireless networks, the time division multiple access (TDMA) scheme is mostly used. In time-slotted network systems, bandwidth can be evaluated based on the number of free slots. By scheduling the free slots, the bandwidth-constrained paths between source and destination can be selected among all possible paths. Simulation results have proved that MQMR can reduce network blocking and improve the call success ratio. In MQMR, bandwidth only is considered as the main QoS issue. But here, other than the bandwidth QoS metrics are not considered.

Benfattoum et al proposed [16] QoS enabled reliable multcasting using Generation- Based Network coding concept. This approach maintains the delay constantly by adjusting the generation size based on the network variations which includes network size, congestion and losses. An enhanced DYGES with ACK Recovery called RDYGES has been proposed using Network Coding to recover the lost ACK. It provides guarantee for QoS in terms of delay. Using the Generation-Based Network

Coding, the file to be transmitted is split into blocks, called generations, by the source node then it appends the packets belonging to the same generation using coefficients randomly and uniformly selected from a Galois Field (GF) while preventing all-zero coding coefficients. This enhanced DYGES considers only the delay metric and does not consider about other metrics. The comparison of the reliable multicast approaches is shown in Table 2.

Table 2: Comparisons of QoS based approaches.

S. No	**Name**	**Technique used**	**Metrics Measured**	**Drawbacks**
1.	MQMGA	Genetic algorithm	Cost to control information, data transmission rate and success rate	Energy is wasted in path reconstruction
2.	MOEAQ	Genetic algorithm, Greedyand family competition approach	Throughput, Delivery delay, Media access delay and Packet loss ratio.	Very complex protocol
3.	QPSO	Genetic algorithm and Particle Swarm Optimization	Cost, Average delay and Jitter	It needs investigation on packet loss
4.	A tree-growth based ant colony algorithm	Ant Colony Optimization	Cost and Convergence time	Energy consumption is high
5.	MQMR	Bandwidth reservation scheme	Success ratio	Bandwidth reservation may waste the bandwidth, and it is cost consuming process
6.	DYGES	Generation-Based Network Coding	Delay, Throughput and Batch Expiration Rate	It does not satisfy the bandwidth requirement

C. Power-aware approaches

The mobile nodes in MANET have very limited power since they have used battery power for their transmission operations. So the power has to be conserved to provide efficient communication. The energy efficient multicast routing protocol can minimize the total power consumption of all nodes in the multicast group and maximize the multicast life span. This can be done by applying some energy saving techniques and metrics. A lot of multicast protocols which reduce the energy consumption have been proposed by researchers and some of them are discussed here.

In [17],the minimum power multicasting problem in ad-hoc networks is handled. A set covering-based formulation has been considered for the problem and two possible algorithms have been proposed. In the first method, the whole constraint matrix is constructed by iteratively adding the violated constraints. At first, a submatrix is constructed by selecting $n-1$ rows. Then, the submatrix is preprocessed for removing the dominated rows and columns. After that, integer problem can be solved and violated constraints are checked whether they are presented. If all the constraints are best suited, then this method (procedure) is interrupted for discovering the optimal solution. Otherwise at most $n2$ violated rows can be inserted at a time, and then the iterative process will be repeated for the new submatrix until the violated constraints are lost. In the second method, violated constraints are generated iteratively on the basis of the current solution looking at its support. In these algorithms, computation overhead is high, and the matrix format requires large memory space.

This suite [18]employs various techniques to construct the energy efficient route. SS-SPST-E maintains an energy efficient and self healing structure. Enhanced SS-SPST-E decrease the stabilization latency and AMO reduces the energy overhead during the route maintenance process. In the distributed nodes, local autonomous actions are enabled by self-stabilization, and each action has two things: guard and statement. The guard is a boolean variable and the statement updates zero or more protocol variables. The statements can be performed only if the guarding predicates are true. The guarding predicates become true for appropriate nodes if global Legitimacy Condition (LC) is false. A node is assumed as stabilized node at any time if it is true for LC at that instance. However, in this approach the energy consumption is high while achieving higher Packet Delivery Ratio requirements.

Hsiu et al proposed a technique to maximize the minimum remaining energy of nodes after transmitting the packets of a session using a routing metric is known as Maximum-Residual Routing[19]. Using the Maximum-Residual Routing, the first failure time of nodes can be delayed in the network. The algorithm for Maximum-Residual Multicasting, proposed in [20], has shown its optimality when up-to-date topology and energy information are available. It is very simple to implement. Also, it can be used in existing link-state routing protocols for wireless ad hoc networks.

In [20], a single integrated layer can control the tasks of the MAC layer and the network layer. In MANET, for the real-time data multicasting, MC-TRACE provides highly energy efficient and robust tree and mesh structures by integrating and reengineering them.MC-TRACE is a cross-layer design which is derived from the Multi-Hop TRACE (MH-TRACE) architecture. In MH-TRACE, the network is divided into overlapping clusters using a distributed algorithm. Time is set into cyclic constant

duration superframes containing a number of frames. The least noisy frame will be selected by each CH, and it can be operated based on the interference level of the dynamic network. By selecting minimal interference frame, CH can minimize the collisions between the members of different clusters. Since the presence of limited carrier sensing range of the radios, the inter-cluster interference is not fully removed in MH-TRACE.

A new multicasting algorithm for MANETs, presented in [21],considers the residual energy while forwarding the data packets. It extends the lifetimes of the node and the network without degrading the network throughput. In order to perform multicasting, the proposed model allows the nodes with the higher residual battery capacity to participate in the routing. Here, each node maintains the two tables, namely the routing table and the multicasting table. Each column in the routing table contains the destination IP, destination-sequence number, IP address of the next-hop, hop-count to the destination, and time-to-leave. The multicast table keeps the group nodes information. Each column in the multicast table contains the multicast group IP and group-sequence number. The proposed model chooses a node with the maximum remaining power among all the nodes. The simulation results have showed that this proposed algorithm expected to exhibit more lifetimes of the node and network compared to others. The basic mechanism in this model is highly extensible and supports QoS. But, it does not consider packet loss and take any action for recovering the lost packet.

Table 3:

S. No	**Name**	**Technique used**	**Additional Aspect considered**	**Drawbacks**
1.	Minimum power multicasting	Set covering-based formulation	-	Computation overhead is high, and the matrix format requires large memory space
2.	SS-SPST-EFC	Self-stabilization paradigm	Cost, packet delivery ratio	Energy consumption is high
3.	Maximum-Residual Routing	TDMA	Network lifetime and load balance	It is very complex process
4.	MC-TRACE	Integration and reengineering of the tree and mesh structures	Link breakage recovery	It can't create a stable multicast tree where unidirectional links are presented
5.	Power-aware Multicast Algorithm	-	QoS	It doesn't consider packet loss and take any action for recovering the lost packet.

D. Secured multicasting

Providing security in MANET multicasting is a critical issue because of the broadcast character of this type of network, the existence of a wireless medium, and the lack of any centralized infrastructure. By these features, MANETs will be affected by eavesdropping, interference, spoofing, and so on. Mainly in some applications like military (battlefield) operations, national crises, and emergency operations, secure multicasting is very essential. Several security schemes have been proposed and integrated into multicast routing, and some of them are discussed here.

Xingwen Zhao et al [22] proposed a generic key management (DASGKA) features which does not uses any central management for key preparation and key distribution.Itcombines three approaches such as conventional group key agreement, a public key encryption and a multi-signature for the preparation key preparation and key distribution. This generic construction is same as authenticated group key agreement for a dynamic group. After calculating a shared private key, the equivalent public key will be distributed to outsiders. Before distributing the public key, in order for outsiders to trust that public key a multi-signature is inserted with it. In this generic construction, users can be joined or leave the group efficiently without initiating a new key agreement protocol. By doing so, the users can obtain a knowledge about present and future conversation. Thus, this method does not provide any guarantee for secure communication.

In [23],Jin-Hee Cho et al have proposed region-based hierarchical group key management in which voting-based IDS scheme is used to handle both outsider and insider security attacks. Since this region-based integrated scheme integrated with intrusion detection, it can perform better than existing schemes consisting intrusion detection and group key management separately. In a lookup table consisting optimal settings, the tradeoff between security and performance is encapsulated. During runtime for a given set of parameter values (describing the operational and environmental conditions of MANETs in dynamic nature), the GCS can carry out the lookup operation to choose optimal settings. By selecting the optimal settings, the mean time to security failure can be maximized with minimized total communication cost.

Yanji Piao et al [24] have proposed polynomial-based key management for secure intra-group and inter-group communication.The proposed polynomial-based key management approach drastically reduces the amount of broadcast traffic in the inter-group communication. But it has additional number of re-keying messages and communication overhead. When a member leaves the group,

the group controller needs to change the polynomial P and multicast it to the members in the group except the leaving member. When changing the polynomial P, computation overhead will be high.

Table 4:

S. No	**Name**	**Technique used**	**Attack Detection/ Avoidance**	**Authen-tication**	**Metrics Measured**	**Drawbacks**
1.	ECGK	Trust oriented approach	Negative trust values, Collusion attack and malicious node attack	Yes	Mobility	Communication overhead is high due to the communication between clusterheads
2.	DASGKA	Public key encryption and a multi-signature	chosen plaintext attack	Yes	Cost	No guarantee for secure communication
3.	region-based hierarchical group key management	Voting-based IDS	outsider and insider security attacks handled	Yes	Cost	Total communication cost is high
4.	Polynomial-based key management	Polynomial based scheme	overhearing and node capture	No	Communication overhead and storage overhead	Computation overhead is high

III. DRAWBACKS OF EXISTING WORKS

By analyzing the various works in the previous section, the following things are identified as drawbacks of the existing works on multicasting.

Most of the reliable routing protocols did not use artificial intelligence for routing.

Some protocols have limitations such as high control overhead, delay due to retransmission, inaccurate location information and high energy consumption.

Even if some of the existing QoS-based multicasting protocols use artificial intelligence scheme, they did not provide stable routes. Also, they require high energy consumption. Some protocols are not satisfied all the QoS requirements i.e., they leaves any one of the QoS constraints such as delay, bandwidth and packet loss.

Some of the energy-based Multicasting protocols use TDMA scheme which causes slot allocation complexity due to the use of time slots. Most of the energy-based multicasting protocols did not consider energy wastage. Mobility prediction may provide inaccurate predictions.

The existing security-based multicasting protocols did not handle all types of attacks. The key management with authentication scheme is not enough for providing secure communication. The cost of key management and overhead is more in most of the solutions.

IV. FUTURE WORK AND CONCLUSION

— A multicasting routing should be designed with low delay and energy consumption. Control overhead mustkept minimumin multicast routing.
— Accurate mobility prediction techniques need to be designed by using optimization or artificial intelligence techniques. It should meet all QoS requirements and provide stable routes in low cost.
— For providing energy efficient multicasting, energy wastage must be considered. Along with normal energy consumptions, it should consider energy wastage due to failures, retransmissions, frequent route updations etc.
— In security, all types of attacks should be detected and avoided. In particular, attacks pertaining to physical and MAC layer should be addressed. The key management techniques should be robust so that it can consume limited energy and cost.

In this paper, we have studied a broad range of multicasting related work designed for MANETs.And the work done are categorized into reliable multicasting, QoS based multicasting, Energy-aware multicasting and Security-based multicasting. Finally, for each protocol we have also discussed about their operational scenario, properties, and listed the advantages and limitations.

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