Taxonomy of Network Layer Multicast Routing Protocols in Mobile Ad-hoc Networks

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***Abstract*—A MANET consists of self organizing mobile nodes which exhibit dynamic behavior during their multicast operations. Thus, it is imperative to obtain the best way to provide multicast services in this kind of environment. For this purpose investigation and quantification of existing multicast routing protocols is the foremost step. In this article detailed discussion is done regarding basic behaviors of the multicast protocols and the types of services provided by them. Multicast protocols have different layers of operation namely, network layer, application layer and MAC layer. This work presents the coherent survey of existing network layer multicast routing protocols and discusses their routing mechanisms and the application/services. The classification of protocols on the basis of their types of routing mechanism and type of application/services, provide the comprehensive information about the protocols. Thus this paper aims to present a clear view to the MANET researchers and application developers so that they could select the multicast protocol accordingly for their work.**

Keywords—MANET, Multicast, Taxonomy

I. INTRODUCTION

A MANET is a self organized network consisting of mobile nodes. The nodes act as the both host and the router. MANETs have many constraints like channel efficiency, power related problems, security, packet drops and noise errors. So if there are more no of receivers than it is better to use a multicast routing protocol rather than unicasting the data from source to the reciever. A multicast routing protocol sends multiple copies of datagram to the intended receivers. Thus with the help of multicast routing protocols energy consumption, routing and processing delay and cost of communication gets reduced [1].

Apparently, many classification criteria have been proposed for multicast routing protocols. In this work classification criteria have been chosen in such a manner that most of the common mechanisms employed by the well known multicast protocols are covered. The details of the application or services provided by them are also discussed simultaneously. Most of the survey papers classify multicast protocols on the basis of multicast topology or initialization approach only. This paper presents the state-of-the-art review for multicast protocols operating at the network layer by introducing new technical trends and the avenues of the research examples being carried out in this field.

Primary goal of this survey is to provide precise and an up to date useful taxonomy. To achieve this goal the basic properties of the multicast protocols of the network layer are first identified and multicast protocols are then classified according to the routing mechanisms and types of services they provide. Already existing multicast protocol designs are then summarized based on the proposed classification criteria and are referenced for future investigations. As compared to the previous surveys, this research provides the wider view of the different operational features of multicast routing protocols for MANETs. The key contributions of this research are as follows:

1. To classify network layer multicast protocols according to the type of routing mechanism and type of application/service delivered by the protocol simultaneously, to help researchers to analysis and compare the network layer protocols more easily.
2. To granulize routing mechanisms to deeper level, to study the protocols more minutely.
3. To identify and distinguish the main applications/services provided by multicast protocols.
4. To review typical multicast routing protocols according to the proposed classification criteria.

This paper is further organized as follows. In Section II, taxonomy of multicast routing protocols is presented. Further in Section III, comprehensive survey of typical multicast routing protocols based on the proposed taxonomy is discussed. Then later on, in Section IV research work is concluded.

II. TAXONOMY OF MULTICAST ROUTING PROTOCOLS

Apart from the fact that each multicast routing protocol has some distinct characteristics of its own, they exhibit some common features too, on the basis of which they can be categorized and studied readily. So in this work we have classified the protocols primarily according to their routing mechanism types and the type of service/application they provide as shown in Fig. 1. These two chief categories provides the basic features of a multicast protocol, concurrently specifying the main services provided by that protocol.

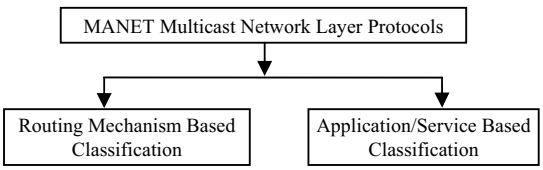

Fig. 1 Principal Classification Criteria

A. Routing Mechanism Based Classification[2]

This classification is basically concerned with the various features exhibited by multicast protocols during their routing operation. The protocols are categorized on the basis of type of network maintenance approach, multicast topology used for multicasting, routing scheme of the protocol, multicast initialization approach followed, type of core mechanism and dependency on any underlying unicast protocol. Fig. 2 presents the overview of this classification. So it covers nearly all the features which a multicast routing protocol can have.

Moreover each category is further divided into sub categories to give the exact and precise information of that particular routing mechanism. So this classification covers a huge no. of multicast protocols providing the inclusive details and discussions of their operational features. The main categories under this classification and the analogous subcategories are explained as follows:

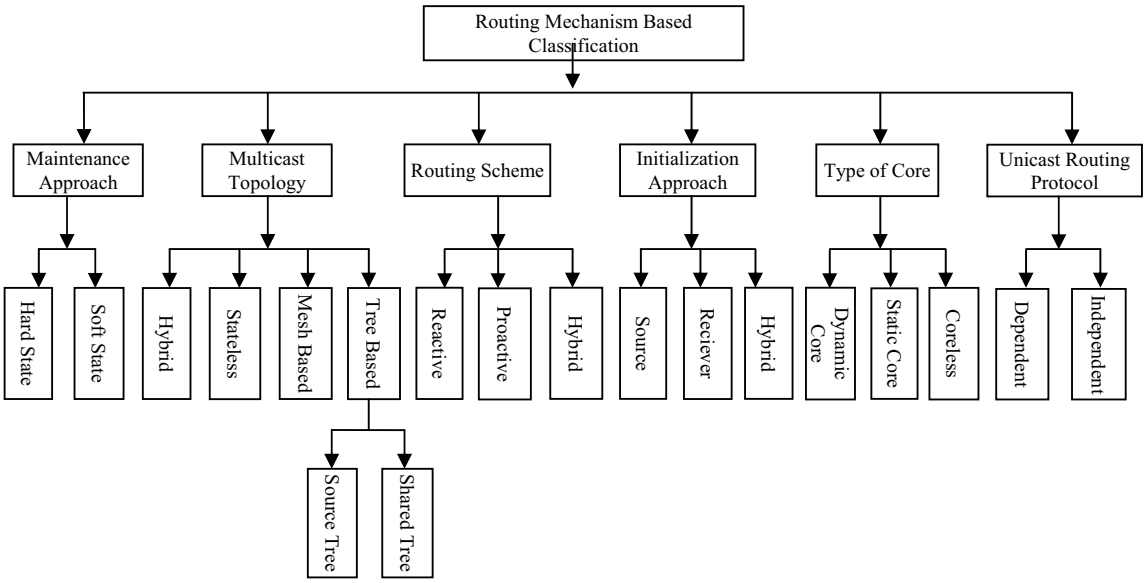

Fig. 2 Routing Mechanism Based Classification

1) Maintainence Approach [2]

As we discussed earlier that MANETs have dynamic environment and frequent topology changes occur due to the frequent link breakages. So updating routing tables and information of the participating nodes promptly, becomes a necessity to keep consistency of multicast routing topology. Maintenance mechanisms can be chiefly of two types–soft state based and hard state based. The details of these two approaches are as follows:

1. Soft-State Approach:In this approach the control packets are flooded periodically to obtain the multicast group membership updates. The state of the connection between the nodes is checked periodically and multicast group information is refreshed. This approach is flexible for use in dynamic wireless communication and provides reliability.
2. Hard-State Approach:In this approach, the information of broken links is delivered by two methods. The implicit control packets are sent reactively in the first method when a link breakage occurs. In the second proactive method the link breakages are predicted through GPS or local prediction mechanisms and routes are repaired or updated accordingly beforehand. The successful implication of this approach involves many crucial factors like on time notification of failure, quick initialization of the repair process and a speedy link repair mechanism. It involves less overhead as compared to soft state approach.

2) Multicast Topology [2]

It is the most common criteria for the classification of multicast protocols. It classifies protocols on the basis of how routes are constructed and how mobile nodes arrange themselves to do the multicast operation. So according to this classification criteria, multicast protocols can be classified into four types – mesh based, tree based, hybrid or stateless. The tree based protocols can be further sub categorized according to the multicast tree formation and operation i.e. source tree based or shared tree based multicast protocol. These types can be further explained in detail as follows:

1. *Tree based Topology:* In this topology, a single and a shortest path exists between a source and a

destination node. It can be further classified into two types:

- *Source Tree based:* A different multicast tree is built for each source node. So a source must have the information of the addresses of the receivers.
- *Shared Tree based:* In this topology, a single multicast tree is created for all source nodes, rooted at a node called as a core node, responsible for the overall management of the topology and multicast group. Shared tree approach is less efficient than source tree approach because the paths constructed between the source and destination node are not the shortest. Moreover it has to keep more routing information so more control overhead is associated with it. Due to the presence of core node, there exists the single point failure threat.

2. *Mesh Based Topology:* In this topology, the packets are forwarded on the set of interconnected nodes forming a mesh structure called as the forwarding group. Route establishments are either done by forwarding the control packets or with the help of core nodes. So redundant paths are available from source to destination and thus give more stability in case of mobile scenarios. Unlike tree based topologies, reconstruction of topology is not required in case of mobile nodes. As there exist a route between a source and destination always due to mesh structure. So provides high robustness but is less efficient than tree based approaches.
3. *Hybrid Topology:* It combines both the features of tree and mesh topologies i.e. robust and efficient. But they can produce non-optimal trees with nodes having mobility so efficient mechanisms for managing group membership information and nodes mobility are required.
4. *Stateless:* Both the tree based and mesh based approach involves huge control overhead. So, stateless topologies are used to minimize control overhead. In this routing information of all forwarding nodes is not maintained rather, source node explicitly specifies the destination nodes list and data is directly sent to those nodes making it suitable for a small multicast group.

3) Routing Scheme[3]

There are principally three ways to update the routing information among the mobile nodes in case of MANETs. So protocols can be classified in following three types on the basis of routing schemes or approaches they follow:

1. *Proactive:* This approach is also known as the table driven approach because each node has a table representing the topology of the network. To update this information in the tables the topology information is exchanged between the nodes from time to time. So in this routing scheme, the information about network is maintained at each node irrespective of the fact that whether the information is needed or not. So this leads to more power consumption and more control overhead.
2. *Reactive:* This approach is also known as On Demand approach. The routes are created only when desired by source node. The group membership information is updated on demand. This routing scheme is more scalable than proactive scheme and does not need maintenance of whole network information thus requires less control packets. Path discovery process is more difficult in this case.
3. *Hybrid:* This combines the features of above two approaches to alleviate the problems in them. Zones are maintained and different routing scheme are deployed at different zones.

4) Initialization Approach [4]

A multicast operation is initiated by a single node. It can be a source node or a receiver node. So on the initialization approach basis, the multicast protocols can be classified into following types:

1. *Source based Initialization [5]:* In this method, the source node offers the data to the interested set of receivers. So this method is sometimes called as pushing. The receiver nodes acknowledge each packet sent by the source node. Thus source takes the responsibility for data delivery and processes feedback from the receivers. This method is more suitable for the dense groups i.e. when no. of receivers are higher. But when no of sources or senders increase, control overhead too increases exponentially.
2. *Receiver based initialization:* In this method, the reciever looks up for the senders of the desired data. So this method is also known as pulling. In this case, it is the responsibility of receiver to detect transmission error and packet loss by checking the gaps in the sequence no. of received data packets. This method is well-suited for sparse groups i.e. when no. of receivers is lesser. When no. of senders increase, the control overhead too increases but linearly.
3. *Hybrid [2]:* Some protocols do not fall strictly in any category. The initialization is sometimes done by source or by the receiver; this is called as the hybrid approach.

5) Type of Core[4]

Two approaches can be used in a multicast group to give the network information: distributed or centralized. The nodes which maintain this network information and

do the membership management are called as the core nodes. So, multicast protocols can be classified on the basis of types of core as follows:

1. *Coreless:* In case of distributed approach there is no particular node which has the complete membership information so this approach is called coreless. But large control overhead is associated with distributed approach, because each node keeps the information and exchanges with the neighbours.
2. *Static Core:* In the centralized approach, the membership information is maintained by a single node called as the core node. When the core node is assigned by an external entity before the multicast session establishment, then it is called as the static core approach. The major drawback of this approach is that if the core node fails, the whole membership information will be lost and multicast group will collapse.
3. *Dynamic Core*: In this approach, the core node is selected dynamically. So if the present core node fails, the new core is selected by the members dynamically. Core based approaches have relatively less control overhead because control packets are sent to the core and then from the core to the members. Moreover, dynamic core approach is more stable in high mobility.

6) Unicast Routing Protocol [4]

Many multicast routing protocols work on some underlying unicast routing protocols while others work independently. So in this context classification can be done in two ways :

1. *Independent multicast protocols*: These protocols do not need a unicast protocol for their operation. They have inbuilt unicast routing protocol and are designed in the manner to support both multicast and unicast simultaneously.
2. *Dependent multicast protocols:* They can be further divided into two subparts. Some multicast protocols can work only with specific unicast routing protocols while some can work with any available unicast routing protocol. It suffers from higher control overhead.

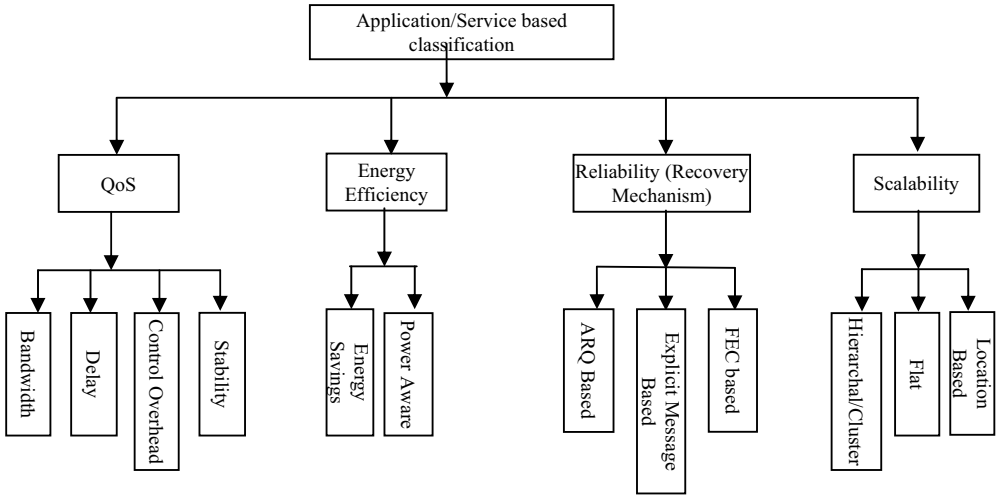

Fig. 3 Application/Service Based Classification

B. Application /Service Based Classification[6]

Each multicast protocol is designed for a specific purpose. So different multicast protocols provide different services and are used in different applications. The protocols are categorized on the basis of type of QoS they provide, whether the focus is on energy savings or protocol is a power aware protocol. Other classification criteria include reliability as a service, which is further categorized on the basis of recovery mechanisms being used and the last classification criteria is scalability. Fig. 3 represents the various classification criteria on the basis of application/service. They can be further explained as follows:

1) Type of QoS

QoS is one of the important elements to evaluate the performance of MANETs because QoS constraints the bounds on delay, jitter, bandwidth and control overhead. QoS routing provides route from source to destination and end to end QoS simultaneously. It further provides the reliable communication by providing the stability in terms of route, link or node stability. But in case of MANETs, it is difficult to provide QoS because of sharing of bandwidth and mobility of nodes. Protocols can be classified on the basis of type of QoS they provide and can be divided chiefly into below four categories. Most of the network layer multicast protocols can be categorized into these subtypes:

1. *Bandwidth:* It is the amount of data transferred per second. Some multicast protocols are designed to utilize the bandwidth properly because real time applications require assured bandwidth for standard and continuous presentation of data. So these protocols provide the better utilization of bandwidth.
2. *Delay:* It is the time taken by the data packet from source to destination. Most of the multicast protocols are designed for multimedia applications where delay boundsare quite critical. So some protocols are designed particularly to keep the end to end delay least. End to end delay includes– packet compression and packetization, transmission, queuing and synchronization, decompression and depacketization at the destination end. So by focusing on delay, these protocols prove to be as a boon for multimedia applications.
3. *Control Overhead:* It is the total control packets used per data packet delivered. If the control overhead will be higher; more bandwidth will be utilized for control packets than data. The protocols which eradicate this problem are included in this category.
4. *Stability:* Stability is mainly in the context of – node, link and route. A node's stability relies on the mobility, life of battery, no. of interfaces currently being used and the data transmission rate. Higher the mobility, lesser is the stability. More is the battery life, higher will be the stability. If no. of interface is more, then energy spent will also be more, resulting in lesser stability.

2) Energy Efficiency[5]

In MANETs nodes have limited energy supply and due to adverse network conditions in MANETs, it becomes difficult to save the energy of batteries. So designing of energy efficient protocols is one of the major issues and many multicast protocols are designed only for this purpose. They can be further classified into following categories:

1. *Energy Savings:* In this approach, the primary goal of protocol is to find a routing path with least energy consumption.
2. *Power Aware:* The primary focus is to consume node energy in a balanced manner using a cost function and keeping track of the node's residual battery capacity. Thus all the links of the nodes and the power consumption of the nodes can be reduced by managing the transmission power of node wisely.

3) Reliabililty[4]

A protocol is considered as a reliable if it has mechanisms for error detection and to indicate the source or destination by sending error messages and availability to retransmit the lost packets again. So, due to frequent link changes in the MANETs it becomes a very challenging task to provide reliability. On the basis of various recovery mechanisms used, the multicast protocols can be divided into following main categories:

1. *ARQ (Automatic Retransmission Request) based:* They are called as the deterministic protocols. They are further of two types- sender initiated and reciever initiated. in case of sender initiated protocol the ACK messages are used and sent back by the receivers for the retransmission of the data packets. NACK messages are sent in receiver initiated based protocols after detecting missing packets.
2. *Explicit Message (Gossip) based:* In this an explicit message, sometimes called as a gossip message is transferred in a peer to peer manner. It consists of the information about the multicast packets received and missing packets. They do not guarantee full delivery of packets.
3. *FEC (Forward error Correction) based :* In this the reliability is provided by repeatedly sending the data. The data is encoded and then split into fragments. The receiver receives the fragments and reassembles the packets. But this approach is more suitable in the scenario where loss rates are predictable which is difficult in MANETs.

4) Scalability

The multicast protocols are scalable with respect to some constraints posed by the MANETs. They can be further categorized into following three types:

1. *Flat:* The homogeneous nodes in terms of network resources and computing power constitute flat network architecture. The protocols having flat network architectures are included in this category.
2. *Hierarchical:* These protocols have physically hierarchical architecture. The multicast structures are built at each level of hierarchy for efficient multicast delivery.
3. *Location Based:* In these protocols, the availability of a Global Positioning System (GPS), Bluetooth or other location systems is required to get the geographical information of the multicast networks. The sender determines the location of the destination by using the location service. Moreover the routing decisions of each forwarding node relies on it's neighbours and destination node.

III. Comprehensive Survey of Typical Multicast Routing Protocols

Multicasting efficiently supports many applications. The multicast protocols are driven by specific goals and needs based on suppositions about the network or application. Each protocol has its own pros and cons. It is difficult to cover all the multicast protocols proposed so far, in a single review. In this section the survey of recent and popular multicast protocols which operate on the network layer is done according to the proposed classification criteria. The Table 6 below lists the various network layer multicast protocols and categorizes them according to the classification criteria proposed.

IV. Conclusion

The purpose of this paper is to propose the classification criteria on the basis of different routing mechanisms and the application/services provided by the multicast protocols simultaneously. The categorization of the routing selection principles can simplify the work of a network designer. This paper aims to provide a useful survey to the researchers or the beginners who are going to embark on MANETs. It can be concluded that each protocol satisfies the maximum possible requirements but one size does not "fit all". To design a multicast protocol which meets all the requirements, is a very complicated task and will be difficult to operate in MANETs environment.

TABLE 1 COMPREHENSIVE SURVEY OF TYPICAL MULTICAST ROUTING PROTOCOLS

	Classification Criterion									
			Routing Mechanism based Classification						***Application/Service based Classification***	
List of Protocols	***S.No***	***Name***	***T***	***M***	***R***	***I***	***C***	***UD***	***Type***	***Sub Type***
	1.	ABAM[2]	SOT	HS	RE	SRC	CL	IND	QoS	ST
	2.	ABMRS[2]	ME	HS	RE	SRC	CL	IND	REL	EM
	3.	ACMRP[2]	ME	SS	RE	SRC	DYC	IND	QoS	ST
	4.	AMRIS[2]	SHT	HS	RE	SRC	CL	IND	REL	ARQ
	5.	DDM[5]	S	SS	RE	REC	STC	IND	QoS	BW
	6.	DQMRP[3]	SHT	SS	PRO	SRC	CL	IND	QoS	D
	7.	EHMRP[3]	THY	SS	RE	SRC	DYC	IND	SC	HL
	8.	EODMRP[3]	ME	SS	RE	SRC	CL	IND	REL	EM
	9.	FGMP[2]	ME	SS	RE	REC	CL	DEP	QoS	CO
	10.	HQMRP[3]	S	SS	PRO	REC	CL	IND	QoS	BW
	11.	HZMAODV[6]	SHT	HS	RE	REC	DYC	DEP	SC	LO
	12.	LAM[3]	SHT	SS	RE	SRC	STC	DEP	SC	FL
	13.	LSMRM[6]	ME	HS	RE	SRC	CL	IND	QoS	ST
	14.	MAMR[5]	THY	HS	RE	IHY	CL	DEP	QoS	D
	15.	MAODV[2]	SHT	HS	RE	REC	DYC	DEP	QoS	ST
	16.	MCEDAR[2]	THY	HS	PRO	IHY	DYC	DEP	QoS	BW
	17.	MMAs[2]	SHT	HS	RE	REC	DYC	DEP	EGY	ES
	18.	NSMP[2]	ME	SS	RE	SRC	CL	IND	QoS	CO
	19.	ODMRP[2]	ME	SS	RE	SRC	CL	IND	QoS	ST
	20.	OGHAM[2]	THY	HS	RE	SRC	CL	IND	QoS	BW
	21.	OPHMR[2]	ME	HS	RHY	REC	CL	DEP	EGY	PA
	22.	PPMA[2]	SOT	SS	RE	SRC	CL	IND	QoS	ST
	23.	P-REMiT[5]	SOT	SS	PRO	SRC	CL	IND	EGY	ES
	24.	QARBE[6]	SOT	SS	RE	REC	CL	IND	QoS	BW
	25.	RDG[4]	S	SS	RE	SRC	CL	DEP	REL	EM
	26.	RMDP[2]	THY	SS	RE	SRC	CL	IND	REL	FEC
	27.	SPBM[3]	SOT	SS	RE	REC	CL	IND	SC	LO
	28.	SRMAODV[6]	SHT	HS	RE	REC	DYC	DEP	REL	EM
	29.	SRMP[2]	ME	HS	RE	REC	CL	DEP	EGY	PA
	30.	WBM[2]	SOT	HS	RE	REC	CL	IND	QoS	BW

T-Multicast Topology M-Maintenance Approach R-Routing Scheme I-Initialization Approach C-Type of Core UD-Dependency on Unicast Routing Protocol THY-Hybrid Topology S-Stateless Topology ME-Mesh Topology T-Source Tree based topology SHT-Shared Tree based Topology Hard State Maintenance SS-Soft State Maintenance RHY-Hybrid Routing RE-Reactive Routing PRO-Proactive Routing IHY-Hybrid Initialization REC-Reciever initialized SRC-Source based initialized DYC-Dynamic Core STC-Static Core CL-Coreless DEP-Dependent on unicast protocol IND-Independent of unicast routing protocol QoS-Quality of Service BW-Bandwidth D-Delay CO-Control Overhead EGY-Energy Efficiency ES-Energy Savings PA-Power Aware REL-Type of Reliability Mechanism ARQ-ARQ based reliability EM-Explicit Message based Reliability FEC-Forward Error Correction Based Reliability SC-Type of Scalability Approach HL-Hierarchical/ Cluster Scalability FL-Flat Scalability LO-Location based scalability ST-Stability

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