A Survey of Multicast Routing Protocols for Ad-Hoc Wireless Networks

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Abstract

Many network applications require transmitting the same single copy of data packets concurrently to many destinations, it is called *multicasting*. Wired and infrastructure-based wireless networks are supported by many multicast routing protocols. But, applying this concept in Mobile Ad hoc wireless NETworks (MANETs) is a big challenge. Ad hoc wireless networks composed of self-organized mobile nodes that can move arbitrarily without any preexisting communication infrastructure base stations. It causes producing dynamic and unpredictable network topology. Many proposals are introduced trying to solve multicast supporting problem in MANETs. In this paper, multicast routing protocols in MANETs that was proposed in recent years will be classified according to different view points such as multicast topology, topology initialization, topology maintenance, core or coreless approach, and dependency on unicast routing protocols.

Keywords: Multicast, Ad Hoc Wireless Networks (MANETs)

I. Introduction

The first wireless network concept refers to a system of wireless nodes that can freely and dynamically communicate with supporting of infrastructure base stations. These base stations have fixed locations and can be connected in wired backbone or wireless techniques. There are some applications [1] (e.g. military applications, mobile conferencing, emergency search and rescue missions, personal area applications (PAAs)), in which using such infrastructure-based wireless networks is very difficult and expensive. At last decade, Mobile Ad hoc wireless NETworks (**MANETs**) concept [2] was established to solve the previous problem. **MANETs** consist of mobile nodes that cooperate with each others to perform a certain task without relaying on any assistance from base stations. So, a node can be used as a source, a receiver, or a relay (i.e. router or transit node between source and receiver) .The salient characteristic of **MANETs** are limited bandwidth due to radio waves, limited energy, and dynamic and unpredictable network topology because of arbitrarily movement of nodes.

Multicasting [2] can be defined as the process of the concurrently transmission of the same single copy of data packets to several destinations which they identified by a single address. The transmitter may be one or multiple nodes. The former is called "one to many" model but the latter is called "many to many" model. There are several multicast routing protocols in wired networks (e.g. Distance Vector Multicast Routing Protocol **(DVMRP)** [3], Multicast Open Shortest Path First **(MOSPF)** [4], Core Based Tree **(CBT)** [5], and Host Based Multicast Routing Protocol **(HBM)** [6]). Many other proposals were surveyed in [7]. They are not suitable for ad hoc wireless networks because of wireless routes existence. Applying multicast idea become essential and have important role in **MANETs**.

In last ten years, many scientists interest in solving that problem so various multicast routing protocols that are suited for **MANETs** are proposed. Some of these proposals were surveyed and classified in [8], where others were evaluated and compared in [9] [10] by using different simulators or emulators. But new protocols are produced recently and no one surveys them.

The remainder of paper is organized as follows. In Section II, we introduce different classification view points (e.g. topology, initialization of multicast session, topology maintenance approaches, core versus coreless approaches, and dependency on unicast routing protocols). Futural open research points and issues of applying multicast over **MANETs** are described in Section III. Finally, we conclude this survey in Section IV.

II. CLASSIFICATION OF MULTICAST ROUTING PROTOCOLS OVER MANETS

In this paper, we will classify the proposals that tried to pose general ideas of how applying multicast concept in **MANETs**. The classification of these proposals will be mentioned under different view points as shown in Figure 1.

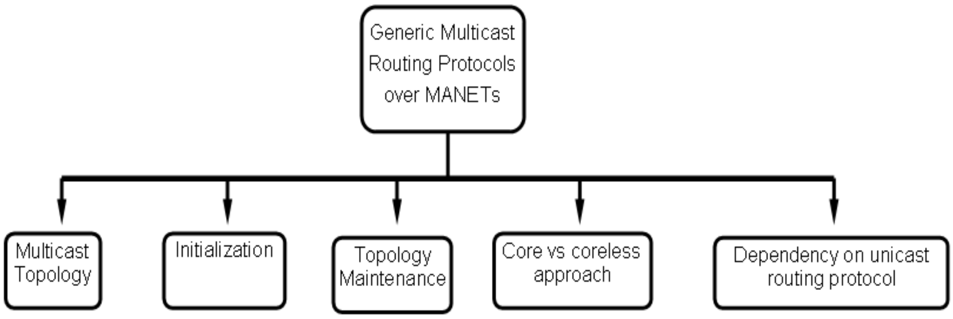

Fig. 1. Multicast Routing Protocols over MANETs

A. Proposals Classification under Topology view point

1) Principle:

Topology is defined as how multicast session's nodes are arranged in a known topology shape. Multicast routing protocols can be divided into two main categories: Tree-based protocols and Mesh-based protocols as shown in Figure 2 and Figure 3. Multicast tree-based concept was appeared firstly in several wired networks. It means that, only a single shortest path (i.e. route) must be established between source-receiver pair. Although multicast tree-based routing protocols are efficient and satisfy scalability issue, they have several drawbacks in ad hoc wireless networks due to mobile nature of nodes that participate during multicast session.

Tree-based proposals are also divided into two subcategories: source-based tree and shared-based tree approaches. In source-based tree approaches, each source builds its single tree. The protocols that follow this type are Bandwidth-Efficient Multicast Routing Protocol **(BEMRP)** [11], Multicast Routing Protocol Based on Zone Routing **(MZRP)** [12], Associativity-Based Ad Hoc Multicast Routing **(ABAM)** [13], Differential Destination Multicast Routing Protocol **(DDM)** [14], Weight-Based Multicast Protocol **(WBM)** [15], and Preferred Link-Based Multicast Protocols **(PLBM)** [16]. In shared-based tree approaches, all sources share only a single tree that is controlled only by one or more specific nodes. Many proposals follow this type of topology like Multicast Ad Hoc On-Demand Distance Vector Routing Protocol **(MAODV)** [17], Ad Hoc Multicast Routing Protocol utilizing Increasing ID Numbers **(AMRIS)** [18], Light Weight Adaptive Multicast **(LAM)** [19], Location Guided Tree Construction Algorithm for Small Group Multicast **(LGT)** [20], and Reservation Based Multicast Routing Protocol **(RBM)** [21].

There are other proposals that try to use source-based and shared-based tree topologies as **Adaptive shared tree multicast routing protocol** [22]. Each source builds its own tree and multiple sources share one that is rooted at a rendezvous point (RP).

There are two basic drawbacks of tree-based protocols. the first drawback is ease of tree structure fragile because of unpredictable topology changes due to mobility of nodes. The second drawback is tree reconstruction delay. So, a new topology concept called *Mesh-based* was established. It has the possibility to provide multiple paths between any source-receiver pair. This category also has many proposals like On-Demand Multicast Routing Protocol **(ODMRP)** [23], Dynamic Core-Based Multicast Routing Protocol **(DCMP)** [24], Forwarding Group Multicast Protocol **(FGMP)** [25], Neighbor supporting Ad Hoc Multicast Routing Protocol **(NSMP)** [26], and Core-Assisted Mesh Protocol **(CAMP)** [27].

Ad Hoc Multicast Routing Protocol **(AMRoute)** [28] and Multicast Core-Extraction Distributed Ad Hoc Routing **(MCEDAR)** [29] try to gather both tree-based and mesh-based advantages in one protocol by constructing shared-based tree topology over mesh topology. These protocols are called *Hybrid topology protocols*.

2) Discussion:

Tree-based protocols generally suffer from fragile tree structure and traffic concentration. Besides the previous problems, source-based tree proposals also suffer from large memory space requirements and wasteful usage of limited bandwidth because each source constructs its own tree. But, it performs better than shared-based tree proposals at heavy loads due to efficient distribution of trees. Although shared-based tree proposals are more scalable, they have the vulnerability of the single core problem. We can deduce that each one has its pros and cons, so this is an invitation to propose protocols that can collect both their advantages as in **Adaptive Shared Tree Multicast Routing Protocol** [22]). Finally, we can say that tree-based proposals are more efficient than mesh-based multicast protocols.

On the other side, mesh-based multicast routing protocols generally are robust due to the penalty of multiple paths between different nodes. But many of these proposals suffer from excessive control overhead which will affect on scalability and utilization of limited bandwidth, while others that apply core-based approach **AMRoute** [28] and **MCEDAR** [29] try to collect both robustness and efficiency from mesh and tree multicast approaches.

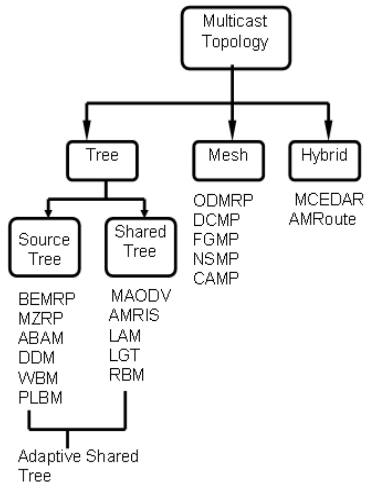

Fig. 2. Multicast routing protocols under topology view point

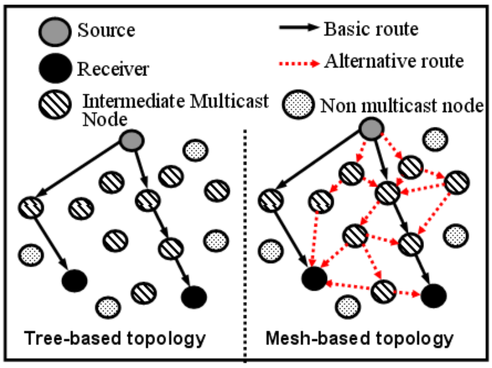

Fig. 3. Tree-based and Mesh-based topologies

B. Proposals classification under multicast session initialization view point

1) Principle:

Another view point of multicast routing protocols' classification is which node will initiate the multicast session. **MZRP** [12], **ABAM** [13], **AMRIS** [18], **LGT** [20], **ODMRP** [23], **DCMP** [24], **FGMP-SA** [25], and **NSMP** [26] give this responsibility to source but other protocols give it to receiver as **BEMRP** [11], **DDM** [14], **WBM** [15], **PLBM** [16], **MAODV** [17], **LAM** [19], **RBM** [21], **Adaptive Shared Tree Multicast Protocol** [22], and **FGMP-RA** [25]. **CAMP** [27], **AMRoute** [28], and **MCEDAR** [29] don't care who will initiate a session. Figure 4 illustrates this classification view point

2) Discussion:

Generally, there are no pros or cons about who have the rights to initiate the multicast sessions except in the case of receiver initialization because this approach has many benefits if number of sources will be greater than number of receivers.

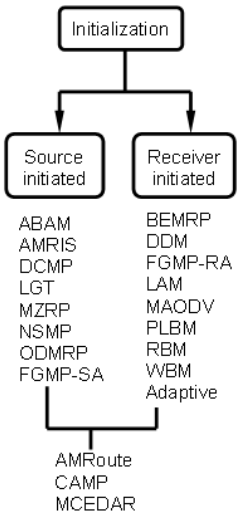

Fig. 4. Multicast routing protocols under initialization view point

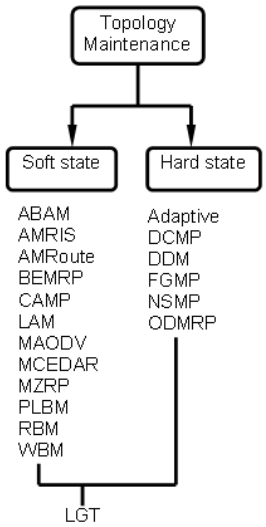

Fig. 5. Multicast routing protocols under topology maintenance view point

C. Proposals classification under topology maintenance view point

1) Principle:

Soft state approach and hard state approach are different in the way of maintaining connectivity between multicast session nodes. In soft state approach, periodic transmission of control packets is used to keep topology connections between nodes. But in hard state approach, control packets will be transmitted only when link's break occur. As shown in figure 5.

2) Discussion:

Although soft state approach causes an inefficient utilization of limited bandwidth due to large number of control packets that flooded over network, it offers a high packet delivery ratio. In the other side, hard state approach saves bandwidth but it suffers from low packet delivery ratio. Soft state approach is found in **DDM** [14], **Adaptive Shared Tree Multicast Protocol** [22]**, ODMRP** [23], **DCMP** [24], **FGMP** [25], and **NSMP** [26]. Others are hard state as **BEMRP** [11], **MZRP** [12], **ABAM** [13], **WBM** [15], **PLBM** [16], **MAODV** [17], **AMRIS** [18], **LAM** [19], **RBM** [21], **CAMP** [27], **AMRoute** [28], and **MCEDAR** [29]. **LGT** [20] tries to use both of them.

D. Proposals classification under core/coreless view point

1) Principle:

Multicast routing protocols in **MANETs** can be classified according to the answer of the following question. Who is responsible of providing network information (e.g. information about nodes, short paths and routes between different nodes). There are two answers. The first answer is that all nodes in multicast session may be cooperate with each others to build an initial topology whether it is mesh based or tree based and also to maintain that constructed topology. the previous description is called *distributed control* or *coreless-based* approach in which not one but many nodes responsible of controlling all the network tasks. The proposals that follow this category are **BEMRP** [11], **MZRP** [12], **ABAM** [13], **DDM** [14], **WBM** [15], **PLBM** [16], **AMRIS** [18], **LGT** [20], **ODMRP** [23], **FGMP** [25], and **NSMP** [26]. Centralized control or core-based approach is the second answer of that question. It means that the responsibility of managing, storing, and controlling all information of multicast session is performed by one or some of multicast nodes. Core-based approach can be divided into two different approaches. they are *dynamic core* and *static core* approaches. Dynamic core approach means that if the current core node is failed, member nodes of a multicast session elect or search for another one to be a new core as **MAODV** [17], **DCMP** [24], and **AMRoute** [28]. Static core approach is the contrast of dynamic core concept. It means that a group of nodes or just one node controls all network tasks. Network will be dropped due to any failure of these core nodes like **LAM** [19], **RBM** [21], **Adaptive Shared Tree Routing Protocol** [22], **CAMP** [27], and **MCEDAR** [29]. Figure 6 illustrates this classification view point

2) Discussion:

Generally, core based routing protocols is used to reduce control overhead messages and to make a best utilization of bandwidth; however, they have a risk of a single node failure. Coreless based protocols solve the last problem but large overheads resulting of periodic announcements.

E. Proposals classification under dependency on unicast routing protocols view point

1) Principle:

One of the key strengths of any multicast routing protocol is its ability to work as a multicast or a unicast protocol as **BEMRP** [11], **MZRP** [12], **ABAM** [13], **WBM** [15],

PLBM [16], **MAODV** [17], **AMRIS** [18], **LGT** [20], **Adaptive Shared Tree Routing Protocol** [22], **ODMRP** [23], **DCMP** [24], **FGMP-SA** [25], and **NSMP** [26]. There are proposals that must be supported with a specific underlying unicast routing protocol like **LAM** [19], **RBM** [21], **CAMP** [27], and **MCEDAR** [29]. Other proposals that can work over any unicast protocol are **DDM** [14]**, FGMP-RA** [25], and **AMRoute**[28]. Figure7 illustrates this classification view point

2) Discussion:

Separation between unicast and multicast approaches has many disadvantages. It increases separated and redundant control overhead packets and it causes consequently wastage of bandwidth and decrease in overall efficiency of all the system. Also, a complex problem is established when a unicast session need to be converted into a multicast session at any time. Above all of these cons, it is a challenge that multicast protocol that relay on unicast one can work in heterogeneous networks.

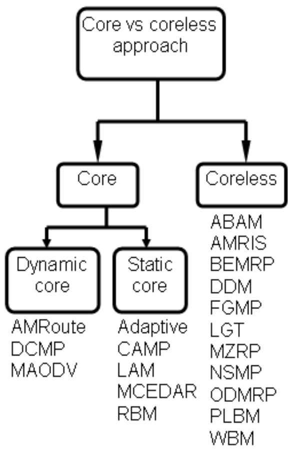

Fig. 6. Multicast routing protocols under core or coreless view point

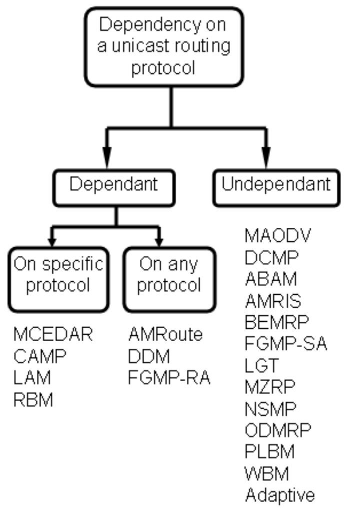

Fig. 7. Multicast routing protocols under dependancy on unicast view point

III. DISCUSSION AND OPEN POINTS

Any multicast routing protocol in **MANETs** tries to overcome some difficult problems which can be categorized under basic issues or considerations. We can say that the semi-optimal multicast routing protocol is the one that can satisfy many issues from all the following issues.

A. Robustness

There are several situations in which link disconnection between node pairs occur causing that data packets that sent by any source may be dropped. This problem results in low packet delivery ratio. So, a new proposal should provide multiple routes between any node pairs (like in mesh based routing protocols) or it should repair link failure quickly (like in tree based protocols). The previous possible solutions will increase packet delivery ratio and consequently high robustness is the final result.

B. Efficiency

Efficiency deals with how limited bandwidth of radio channels in **MANETs** is utilized efficiently in sending the maximum number of data packets with the fewer number of control packets, So destinations will receive all data packets that sent by any source in a smallest time period. Multicast routing protocols that fall under pure Mesh-Based topology (e.g. **ODMRP** [23], **FGMP** [25] and **NSMP** [26]) may be considered inefficient protocols. In such protocols, several routes must be constructed and maintained between any source-receiver pair. Control packets (e.g. join requests and join replays) will be broadcasted by any source (or by any receiver) and will be rebroadcasted by any intermediate node over all these routes. When many sources and receivers join into multicast session, large number of control packets will be produced. They cause inefficient utilization of limited bandwidth of radio channels. Using soft state approach (i.e. periodic transmission of control packets during topology maintenance phase) in these protocols will increase the problem.

On the other side, pure Tree-Based topology and soft state protocols (e.g. **DDM** [14] and **LGT** [20]) may be considered semi efficient protocols. In these protocols, only one shortest route will be constructed and maintained between any source-receiver pair. Control packets will travel only through this route during topology maintenance phase which save limited bandwidth. Applying hard state approach (i.e. control packets will be transmitted only in the case of link disconnection and not periodically) with Tree-Based topology protocols will improve efficiency (e.g. **BEMRP** [11], **MZRP** [12], **ABAM** [13], **WBM** [15], **PLBM** [16] and **AMRIS** [18]).

Generally, efficiency will be improved by applying core techniques with any protocol. Core technique will prevent nodes from sending control packets between each them, but control packets (except data packets headers) will travel only from any node to core node which will reduce large number of these control packets (e.g. **MAODV** [17], **LAM** [19], **RBM** [21], **DCMP** [24], **CAMP** [27], **AMRoute** [28], and **MCEDAR** [29]).

C. Scalability

Scalability and efficiency can be considered as two similar faces for one coin. It means that they affect on each others (i.e. as efficiency is improved, as scalability is improved too and vice versa). Scalability concerns with observing the operation of a multicast routing protocol when number of nodes (sources, destinations or intermediate nodes) in multicast session are increased (i.e. group size is increased) or the number of multicast sessions (i.e. number of groups) are increased. We can say that the more nodes in a multicast session, the more control packets will be produced. Scalable multicast routing protocol should try to reduce number of control packets. **DDM** [14] and **LGT** [20] are basically designed to deal with small groups. The scalability is not their main target. Mesh-based and soft state protocols (e.g. **ODMRP** [23] and **FGMP** [25]) suffer from excessive control packets which affect on scalability and packet delivery ratio. Applying core techniques (described in section II-D) in such protocols will improve scalability. For example, dynamic core technique was used by **DCMP** [24], while static core technique was used by **CAMP** [27] to reduce control packet overhead founded in **ODMRP** [23]. .

D. Security

It is one of the most important issues that many protocols neglect to achieve it. It is related with how to protect multicast session from intruders' joining or to prevent an unauthenticated node (a non member node) from receiving data packets. No one of the previously mentioned proposals try to achieve security issue.

E. Quality of Service (QoS)

In military and real time applications, data packets must reach completely to their destinations. Loss of data packets in such applications is not permitted. The previous concept is called Reliability. Besides reliability, throughput, end to end delay, and available bandwidth are the main parameters for providing **Qos** issue. The previously mentioned protocols don't satisfy **Qos** issue because they are considered as general ideas of applying multicast concept in **MANETs**. Several multicast routing protocols are posed recently to satisfy reliability (e.g. **Adaptive Protocol for Reliable Multicast in Mobile Multihop Radio Networks** [30] and Reliable Multicast Protocol for Wireless Mobile Multihop Ad Hoc Networks

(ReMHoc) [31]). Wireless Ad Hoc Real Time Multicasting Protocol **(WARM)** [32] tries to achieve bandwidth reuse in real time applications. Also, Multicast Priority Scheduling Protocol **(MPSP)** [33] improves multicast delivery ratio with bounded end to end delays.

F. Power control

In ad hoc wireless networks, each mobile host has its own battery power which determines the maximum time that a node is still connected in a multicast session (i.e. lifetime of a node).Several multicast routing protocols suffer from periodic messaging that affect on life time of battery capacity, so the need of using protocols and algorithms that try to save power consumption of any mobile host become the most futural research points. [34], [35], and [36] are trials to overcome power constraints in **MANETs**.

IV. CONCLUSION

Ad hoc wireless networks in which nodes that can move freely become the hottest research points in recent and futural periods. So, this paper introduces and classifies several proposals in the field of constructing multicast concept in ad hoc wireless networks **(MANETs)**. Classification of these proposals performed according to several points of view as underlying topology structure, topology maintenance approaches, initialization of multicast session, core versus coreless approaches, and dependency on unicast routing protocols. We cannot pose an overview about each protocol due to large number of concluded proposals in this article. Also, we try to show the considerations that each existed or futural protocol should achieve some of them as robustness, efficiency, scalability, security, Quality of service (**Qos**), and power control. Futural open points also are discussed

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" معاينة لبرتوكولات النقل المتعدد فى الشبكات اللاسلكية ذات العقد المتحركة والشكل الغير منتظم "

يقدم هذا البحث معاينة (survey) وتصنيف لاكثر من 19 مقترح لتطبيق مفهوم النقل المتعدد (Multicast) (وهو يتعلق بنقل نسخة واحدة من حزم البيانات (Data Packets) مثل الفيديو أو الصوت إلى اكثر من مستقبل فى آن واحد) فى الشبكات اللاسلكية ذات العقد المتحركة والشكل الغير منتظم (Mobile Ad hoc Wireless networks) التى ليس لها شكل محدد نتيجة للحركة المستمرة لأعضائها دون التقيد بمكان ثابت وكذلك يعتمد اعضاء الشبكة على بعضهم البعض لتوفير الإتصال بينهم بدون الإعتماد على نقاط الإتصال الثابتة (Base Stations) . تم تصنيف هذة المقترحات طبقا لخمس نقاط مقارنة.

- **النقطة الأولى** : طبقا للشكل الذى سيقوم الأعضاء بإنشائه.
- **النقطة الثانية** : طبقا لمن يقوم ببدء الإتصال سواء كان المرسل (source) أو المستقبل (Receiver).
- **النقطة الثالثة** : طبقا للنظام المتبع للحفاظ على الشكل الذى تم انشاؤه.
- **النقطة الرابعة** : طبقا لمن يقوم بتوفير معلومات التحكم الخاصة بالشبكة فهى إما مركزية أو موزعة معلومات التحكم.

النقطة الخامسة : اذا كان المقترح يستطيع أن يقوم بالنقل المتعدد أو النقل الفردى (Unicast) اذا تطلب الأمر ذلك أم انه يحتاج للعمل أعلى أحد المقترحات الخاصة بتنفيذ النقل الفردى فقط.