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Glimpses on QOS Routing for Mobile Adhoc Networks

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ABSTRACT

Mobile Ad Hoc Networks (MANETs) are observed to be a class of infrastructure less network architecture that are formed by a collection of mobile nodes, communicate with each other using multihop wireless links. The reason for preferring MANETs is that they eliminate the requirement for central management, so that each node must operate cooperatively to successfully maintain the network. Each node performs as a source, a sink and a router. Wireless ad hoc networks have diverse applications spanning several domains, including military, commercial, medical, and home networks. From the review, it is observed that (i) there are many challenges in the creation of a MANET, such as routing challenges, wireless medium challenges, scalability challenges and portability challenges (ii) large groups of mobile nodes located over a large geographical area belonging to the same network grouping can benefit from this system (iii) MANETs are expected to be based on all-IP architecture, carrying a multitude of real-time multimedia applications such as voice, video and data (iv) MANETs should have an efficient routing and quality of service (QoS) mechanism to support diverse applications and (iv) to cope with the unpredictable nature of this highly dynamic environment, wireless ad hoc networks need to be able to adapt to changes in resource availability (i.e., energy, bandwidth, processing power, network density, and topology changes) and overcome any unanticipated networking problems while satisfying a wide range of application requirements.

1. INTRODUCTION

The innovation in mobile computing technology and the proliferation of communication devices (e.g., cell phones, laptops, personal digital assistants, or wearable computers) are revolutionizing our way of sharing information. We are at the verge of entering the ubiquitous communication era in which a user utilizes numerous devices through which he can access all the required information whenever and wherever needed. The nature of ubiquitous communication advocates wireless networks as the most appropriate solution and as a consequence, the wireless networking realm has undergone exponential growth in the past decade. Wireless networks are becoming more widespread, succeeding as they do to make access "every time, everywhere" possible, through today's IP-based communication system. The main architectures for wireless networks are the wireless local area network (WLAN) and wireless ad hoc networks. The mobile nodes in WLAN directly communicate with the fixed base-station to send their traffic to nodes in the same or different WLAN. It is a single hop communication and routing is not necessary. In a mobile ad hoc network (MANET), routing is indispensable for packet forwarding. Each node acts as router, as well as source and destination node. In principle, a MANET allows an arbitrary collection of mobile nodes to create a network on demand. Numerous scenarios lacking in network infrastructure could benefit from the creation of MANETs. Such scenarios are rescue and emergency operations, natural or environmental disasters, law enforcement activities, tactical and military missions, commercial projects such as conferences, exhibitions, workshops and meetings, and in educational classrooms. It is expected to be a major focus of research for years to come.

The introduction of technologies, namely, Bluetooth, HyperLAN, GPRS (General Packet Radio System [Heissenbuttel et al., 2004], IEEE 802.11 [2], IEEE 802.15 [3], and IEEE 802.16 [4] are also fostering MANET deployments outside the military domain. As per RFC2386 [1998], QOS is defined as a set of service requirements to be met by the network while transporting a packet stream from source to destination. The QOS MAC protocol is an essential component in QOS support in MANETs. All upper-layer QOS components (i.e., QOS routing and QOS signaling) are dependent on the QOS MAC and the ability to provide QOS is dependent on how well the resources are managed at the MAC layer. Although many MAC protocols (e.g.,Karn, 1990; Bharghavan et al., 1994; Fullmer et al., 1995; Talucci et al., 1998) were proposed for wireless networks, they are primarily designed to solve medium contention, hidden/exposed terminal problems but do not incorporate the notion of QOS. Recently, the Group Allocation Multiple Access with Packet-Sensing (GAMA-PS) protocol (Andrew et al., 1998) and the Black-Burst contention mechanism (Sobrinho and Krishnakumar, 1999) were proposed to support QOS guarantees to real-time traffic in a distributed wireless environment. However, their QOS support is valid only in a wireless LAN environment where every host can sense each other's transmission without any hidden terminals.

2.0 Quality of Service Framework for Mobile Ad Hoc Networks

Mobile Ad Hoc networks are autonomous distributed systems that comprise a number of mobile nodes connected by wireless links forming arbitrary time-varying wireless network topologies. Mobile nodes function as hosts and routers. As hosts, they represent source and destination nodes in the network while as routers, they represent intermediate nodes between a source and destination, providing store-and-forward services to neighboring nodes. Nodes that constitute the wireless network infrastructure are free to move randomly and organize themselves in arbitrary fashions. Therefore the wireless topology that interconnects mobile hosts/routers can change rapidly in unpredictable ways or remain relatively static over long periods of time. Typical mobile Ad Hoc network is shown in Fig. 1.

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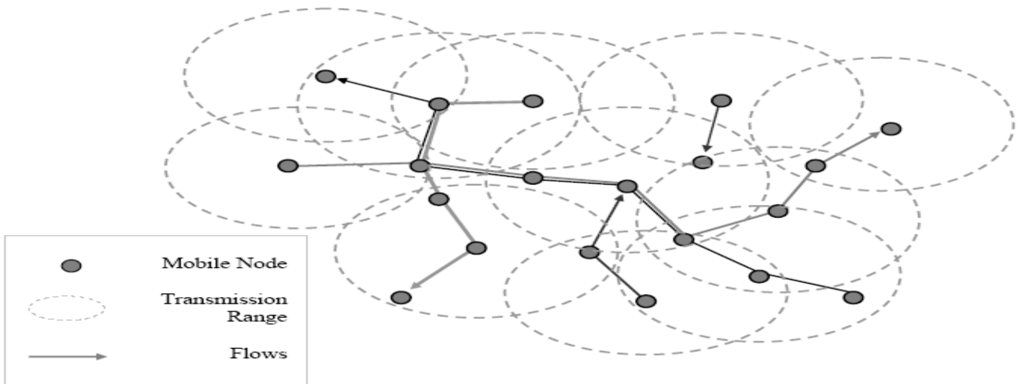

Fig. 1 Typical Mobile Ad Hoc Network (Seoung-Burn, 2006)

3.0 QoS Models for MANETs

The available QoS models can be classified into two types according to their fundamental operation; the Integrated Services (IntServ) framework provides explicit reservations end-to-end and the Differentiated Services (DiffServ) architecture offers hop-by-hop differentiated treatment of packets.

3.1 IntServ

The IntServ (Braden et al., 1994) model merges the advantages of two different paradigms: datagram networks and circuit switched networks. It can provide a circuit-switched service in packet-switched networks. The Resource Reservation Protocol (RSVP) was designed as the primary signaling protocol to setup and maintain the virtual connection. RSVP is also used to propagate the attributes of the data flow and to request resources along the path. Routers finally apply corresponding resource management schemes to support QoS specifications of the connection. Based on these mechanisms, IntServ provides quantitative QoS for every flow.

IntServ has the following salient shortcomings in MANET environments:

Scalability: IntServ provides per-flow granularity, so the amount of state information increases proportionally with the number of flows, which results in a storage and processing overhead on routers, which is the well-known scalability problem of IntServ.

Signaling: Signaling protocols generally contain three phases: connection establishment, connection maintenance and connection teardown. In highly dynamic networks there is no promising approach since routes may change very fast and the adaptation process of protocols using a complex handshaking mechanism would just be too slow.

3.2 DiffServ

DiffServ (Black, 2000) was designed to overcome the difficulty of implementing and deploying IntServ and RSVP in the Internet backbone and differs in the kind of service it provides. While IntServ provides per-flow guarantees, Differentiated Services (DiffServ) follows the philosophy of mapping multiple flows into a few service levels. At the boundary of the network, traffic entering a network is classified, conditioned and assigned to different behaviour aggregates by marking a special

DS (Differentiated Services) field in the IP packet header (TOS field in IPv4 or CLASS field in IPv6). Within the core of the network, packets are forwarded according to the per-hop behaviour (PHB) associated with the DSCP (Differentiated Service Code Point). This eliminates the need to keep any flow state information elsewhere in the network.

The main drawbacks of a DiffServ approach in MANETs are given below:

Soft QoS guarantees: DiffServ uses a relative-priority scheme to map the quality of service requirements to a service level. This aggregation results in a more scalable but also in more approximate service to user flow.

SLA (Service Level Agreement): DiffServ is based on the concept of SLA's. In the Internet an SLA is a kind of contract between a customer and its Internet Service Provider (ISP) that specifies the forwarding service the customer should receive.

Ambiguous core network: The benefit of DiffServ is that traffic classification and conditioning only has to be done at the boundary nodes. This makes quality of service provisioning much easier in the core of the network. In MANETs though there is no clear definition of what is the core network because every node is a potential sender, receiver and router.

4.0 QOS Existing Technologies

4.1 RSVP

RSVP is a classic two-pass protocol using out-of-band signaling. The messages used are the *Path* message, which originates from the traffic sender, and the *Resv* message(Braden, 1997), which originates from the traffic receivers. The roles of the *Path* message are first to install reverse routing state in each router along the path, and second to provide receivers with information about the characteristics of the sender traffic and end-to-end path so that they can make appropriate reservation requests. *Resv* messages finally carry reservation requests to the routers along the distribution tree between receivers and senders.

There are many shortcomings of RSVP when used in MANETs:

- The two-pass reservation model employed by RSVP is not suitable for MANETs, specially in case of local repair.
- RSVP is based on a fixed QoS level approach. As a consequence no mechanism for a fast adaptation to QoS changes can be provided. To solve this problem reservation requests should specify ranges of values instead.
- Due to its out-of-band approach, RSVP produces a significant signaling overhead.
- This may be of importance if the refresh rate high because the message size is not negligible in RSVP. A high refresh rate might occur when no route-change notification service from the routing layer is available. This causes local repair to fail.

Due to the shortcomings of RSVP in Wireless networks, MRSVP and DRSVP, two extension of RSVP to support mobility and dynamic network environments were proposed. MRSVP[24] addresses mobility issues of a mobile node changing the point of attachment to the fixed network and follows a Pro-Active approach whereas DRSVP[16] overcomes the shortcomings of

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RSVP in terms of QoS adaptation. By treating a reservation as a request for service somewhere within such a range, flexibility needed to deal with network dynamics is gained.

4.2 FQMM

FQMM(www.ece-icr.nus.edu.sg/journal1/fqmmhandbook02.pdf.) (Flexible Quality of Service Model for Mobile Ad Hoc Networks) combines the IntServ and the DiffServ model. Three kinds of nodes are defined, exactly as in DiffServ. An ingress node is a mobile node that sends data. Interior nodes are the nodes forwarding data for other nodes. An egress node is a destination node.

FQMM is an interesting attempt at proposing a QoS model for MANETs, however it suffers of major problems:

- FQQM aims to tackle the scalability problem of IntServ. But without an explicit control on the number of services with per-flow granularity, the problem still exists.
- Due to its DiffServ behaviour in ingress nodes, FQMM may not be able to satisfy hard QoS requirements. It could be difficult to code the PHB in the DS field if the PHB includes per-flow granularity, considering the DS field is at most 8 bits without extension.
- How to make a dynamically negotiated traffic profile is a well-known DiffServ problem and FQMM seems not to solve it.

4.3 INSIGNIA

INSIGNIA is a signaling protocol designed explicitly for MANETs. It supports fast flow reservation, restoration and adaptation algorithms that are specifically designed to deliver adaptive real-time service. INSIGNIA implements an in-band approach by encapsulating some control signals in the IP option of every data packet (Figure 2), which is now called INSIGNIA option.

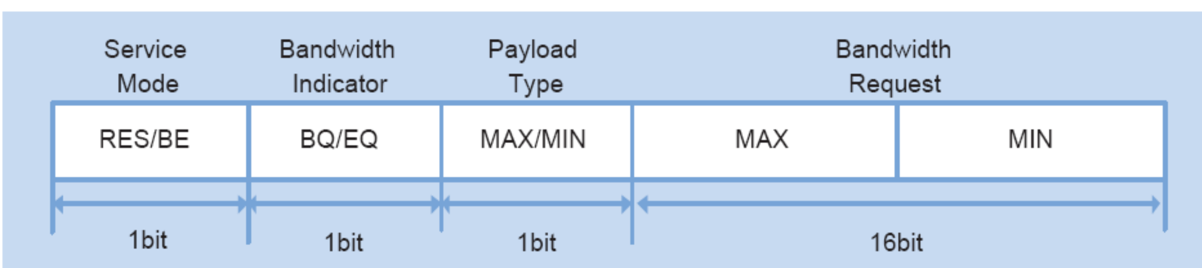

Figure 2: ASAP/ns Insignia Option Field (Patrick, 2003)

iMAQ (http://cairo.cs.uiuc.edu/adhoc/.) is a cross-layer architecture to support the transmission of multimedia data over a MANET. INORA is a QoS support mechanism that makes use of the INSIGNIA in-band signaling and TORA routing protocol for MANETs.

5. Routing Mobile Ad Hoc Network

Routing is the process of *discovery, selecting,* and *maintaining paths* from a source node to destination node to deliver data packets. The goal of every routing algorithm is to direct traffic from source to destination, maximizing network performance whilst minimizing costs. In mobile ad hoc networks, routes are mainly multi hop due to limited propagation range, frequent topology changes since each network host moves randomly. A routing protocol for ad hoc wireless networks should have the following characteristics (Raghavendran, 2013):

- It must be fully distributed.
- It must be adaptive to frequent topology changes caused by the mobility of nodes.
- Route computation and maintenance must involve a minimum number of nodes.
- It must be loop-free and free from stale routes.
- The number of packet collision must be kept to a minimum by limiting the number of broadcasts made by each node.
- It must optimally use scarce resources such as bandwidth, computing power, memory and battery power.
- It should be able to provide a certain level of QoS as demanded by the applications, and should also offer support for time-sensitive traffic.

Routing strategy and network structure are mainly used to classify routing protocols of MANETs. According to the routing strategy the routing protocols can be categorized as *Table-driven* and *Source Initiated*, while depending on the network structure these are classified as *Flat Routing, Hierarchical Routing* and *Geographic Position Assisted Routing*. As shown in the Fig. 3 the Flat routing protocols are divided as Table-driven and Source Initiated protocols (Raghavendran, 2013).

The main requirements for a QoS Model for MANETs are as follows:- *Minimal overhead* –The wireless link capacity, battery and computational resources in a wireless multi-hop network are quite limited. Therefore a QoS model for wireless multi-hop networks should minimize the signaling overhead as well as the computational overhead entailed in provisioning of QoS. *Robustness* – QoS models should be capable of handling frequent route failures and dynamically changing network. The QoS model should have mechanisms to adapt to the changing topology without creating bottlenecks, in a fast and efficient manner. *Fairness* – The QoS resources should be shared in a fair manner among the wireless clients, and misbehaving nodes should not be allowed to make use of the network's resources without relaying packets for other nodes. A fundamental requirement of any QoS mechanism is a measurable performance metric. Typical QoS metrics include *available bandwidth, packet loss rate, estimated delay, packet jitter, hop count and path reliability*.

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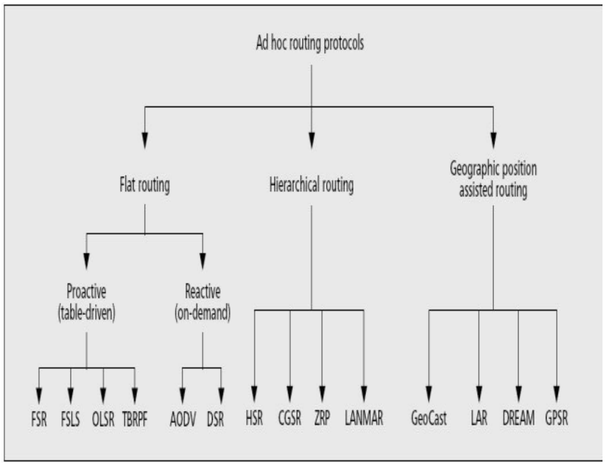

Fig. 3 Classification of Routing Protocols in MANETs (Raghavendran 2013)

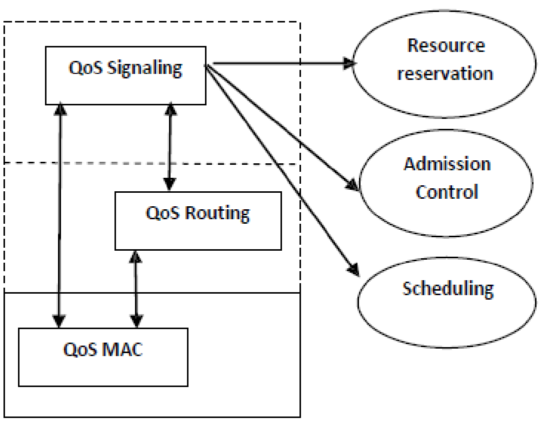

Fig. 4 QoS model (Raghavendran 2013)

Summary and concluding remarks

Mobile ad hoc networks (MANETs) are complex distributed systems comprising wireless mobile nodes that can self-organize dynamically into arbitrary and temporary, ad-hoc network topologies. Since the mobile devices are free to move randomly, the network's wireless topology may change rapidly and unpredictably. It was observed that there are many interesting applications such as multimedia services, disaster recovery etc can be supported if Quality-of-Service (QoS) support can be provided for MANETs. But QoS provisioning in MANETs is a very challenging problem when compared to wired IP networks. This is because of unpredictable node mobility, wireless multi-hop communication, contention for wireless channel access, limited battery power and range of mobile devices as well as the absence of a central coordination authority.

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