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A Survey on Quality of Service in MANET

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Abstract—**This paper presents a short survey of quality of service (QoS) in mobile ad hoc network (MANET) regarding issues and challenges, metrics, routing and architectures in the attempt to provide QoS in such dynamic and unpredictable environment. First we have described the most relevant issues of QoS provisioning in MANET, followed by the classification and description of most important QoS metrics and QoS protocols. After that we have presented different proposals of QoS architectures/models for provisioning of end-to-end QoS in mobile environment.**

Keywords-quality of service, routing, MANET, performance metrics

I. Introduction

A mobile ad hoc network (MANET) consists of mobile nodes organized independently and randomly, with no need of previously established infrastructure or centralized administration. Network topology in MANET usually changes very dynamically. Nodes in such environment communicate with one another by single or/and multi hop paths. When multi path is required nodes act at the same time as hosts (source and destination) and routers.

QoS provisioning in MANET is highly important aspect of research and is still an open issue and not an easy task, due to its dynamic nature, lack of centralized administration, mobility of the nodes and unreliable channel prone to errors. Compared to wired networks, MANET has a built-in problem of changing topology and capacity of established connections.

QoS provisioning in such networks implies provisioning of better network resource utilization and successful delivery of transferred information, and also requires implementation of adaptive routing and signaling protocols used for access control, resource reservation, QoS negotiation and resolving situations of network congestion [1].

QoS provisioning in MANET additionally affects the complexity of mobile nodes and increases power consumption due to data processing, forwarding and storing. QoS needs to be observed taking into account frequent transmission interruptions due to breaking of established paths. In such circumstances QoS needs to be defined as ratio of total time of disrupted communication and total time of established connection, and it should be above some predefined threshold. Since MANET environment is so dynamic, where QoS routes are selected based on the resource metrics, it is almost impossible to provide hard QoS guarantees. Therefore, implementation of dynamic QoS should be considered, where characteristics of guaranteed services are defined by a range of values that will satisfy user's requests. In such circumstances change of resource availability and possibility of resource reallocation does not strictly affect QoS provisioning.

QoS provisioning and efficient utilization of resources are the opposing objectives, since one can provide better QoS with just more resources and resource utilization can be better if there are no QoS guarantees. To provide QoS and to efficiently utilize the resources, a traffic management is needed to deal with both objectives at the same time.

This paper is organized as follows. After introduction, in the second chapter we have presented different aspects of QoS provisioning in MANET. First of all, we gave short descriptions of all the most important issues regarding QoS provisioning, followed by description of most common QoS parameters and performance metrics. We have also present typical classification of QoS routing protocols in MANET and concluded the chapter with presentation of different proposals of QoS architectures/models for provisioning of end-to-end QoS. In the last, third chapter we gave concluding remarks.

II. Quality of Service

A. QoS issues and challenges

The most relevant issues of QoS provisioning in MANET environment are the following [2], [3], [4]:

(1) Unreliable channel. Bit errors are common in wireless networks due to high sensitivity of the channels to interference, thermal noise, multipath fading effects, shadowing. Bit errors lead to low packet delivery ratio. Wireless channels are also prone to leakage of information.

(2) Node Mobility. Nodes in MANET change their position frequently, randomly and independently, in any direction and at any speed, which means that information about the topology must be frequently updated, so the information can be delivered (routed) to final destination. This issues affect QoS metric, such as PDR (packet delivery ratio).

(3) No centralized control. Since nodes in MANET dynamically join and leave the network (willingly or due to battery exhaustion) it is very hard to establish some kind of centralized administration, but there are some proposals from different researchers [5], [6].

(4) Limited resources of the device. Mobile devices or nodes are still constrained by limited power supply (battery), less computational power and less memory space, in

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comparison to devices used in wired networks. QoS provisioning additionally affects the power consumption due to overhead from the mobile nodes.

(5) Maintenance of route. This is a very difficult task in MANET due to frequent topology changes. Established connections (paths) can be disconnected in any time, even in the process of data transfer. Therefore, maintenance and reconstruction of the traffic paths should be carried out with minimal overhead and delay.

(6) Channel Contention. MANET nodes communicate on a common channel to discover network topology, which leads to the problems of interference and channel contention. This can be avoided by the use of a TDMA-based system (each node transmits at predefined time) or by the use of different frequency band for each transmitter. First solution is hard to implement due to lack of centralized control, while the second solution requires a distribution of channel information and mechanism for distributed channel selection.

(7) Security. Increase of number of wireless application introduced a number of numerous security issues, that are not typical in wired networks. MANET is highly vulnerable to the security attacks due to all of the above issues [5]. Implementation of security mechanisms can affect QoS, while malicious activities (different attacks, bandwidth stealth) have severe impact on QoS performance. But even with the implementation of security mechanisms, QoS could still be provisioned, even under attack and QoS of traffic flows not under attack could be preserved. Development of secure systems which can provide quality of service is a very challenging task. QoS and security issues are highly interlaced [7]. Many researcher proposed different management models dealing with both, security and QoS [4], [5], [8].

B. QoS parameters and performance metrics

Quality of service is in packet switched networks described with minimum set of parameters that are common for the largest number of services (applications): traffic flow; packet delay due to transmission through the network, and it can be observed as end-to-end delay (for applications), delay between network border elements (ingress or egress routers) or in specific network elements; jitter or delay variation can be observed also as end-to-end, between network border elements or in specific network elements; packet loss rate describes how many packets were lost during the transmission and is defined as ratio between the number of undelivered and number of delivered packets; scalability represents the software or hardware ability to function well even in the extremely changed network conditions (i.e. increase of traffic flows) [1] [3] [9] [10]. Figure 1 show more comprehensive listing of QoS metrics, but the list can, of course, be expended [11].

QoS requirements usually differ from application to application. For multimedia applications key QoS parameters are delay, bandwidth, power requirement, packet loss rate, jitter, communication overhead and scalability, while military applications additionally set more stringent security requirements. Availability of the network is the key QoS parameter for applications used in emergency search/rescue operations [3], [10].

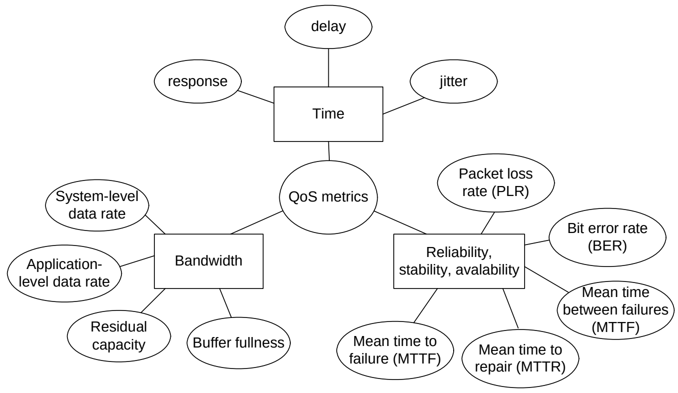

Figure 1. QoS metrics

QoS can have additional attributes regarding QoS architecture characteristics and specific application requirements: (1) end-to-end QoS (between applications) or QoS limited to specific domain or set of domains; (2) QoS that can be applied to all traffic flows or to some specific sessions or set of sessions established between user applications; (3) QoS regarding one- or two-way traffic flows; (4) absolute (guaranteed) or relative (statistical) QoS.

QoS parameters can be represented in a qualitative and/or quantitative fashion. Regarding quality of service, performance metric or performance indicator represents an unambiguous defined and quantitatively expressed value of specific QoS parameter. Performance metrics are used in QoS request specification and for measuring the achieved QoS by measuring the appropriate metric during network operation.

In wireless networks (like MANET) QoS requirements are affected by the node resource limitation, like battery power, buffer space and processing power, therefore there is no hard QoS or any absolute guarantee of QoS.

C. QoS routing

QoS routing implies finding and selecting those path for traffic flows which can provide the requested QoS, taking into account resource availability of the nodes. Basic goals of QoS routing is dynamically determination of the paths, optimization of resource utilization taking into account network condition and improvement of overall network performance [9].

Challenges of routing in MANETs are similar to challenges regarding the provisioning of QoS in such networks: dynamic topology, resource limitations (bandwidth, energy capacity, computing power, etc.), variable link capacity.

There are different classifications of QoS routing protocols, and Figure 2 presents the most common ones:

(1) QoS protocols can be classified into three categories, taking into account routing information update: reactive (on-demand), proactive and hybrid. With proactive protocols routing table is filled with up-to-date information about routing paths from each to every other node. This facilitates a process of packet forwarding, since the source node gets a routing path as soon as it needs it. Typical examples are QOLSR (QoS Optimized Link State Routing), PLBQR (Predictive Location-

Based QoS Routing in Mobile Ad Hoc Networks). Reactive protocols initiate a route discovery only when a path from source to destination is required, which leads to higher delays, but their advantage is much lower overhead traffic. Examples are QoS AODV (QoS Ad-hoc on demand Distance Vector), CQMP (Mesh-based Multicast Routing Protocol with Consolidated Query Packets), ACMP (Adaptive Core based Routing Protocol with Consolidated Query Packets). Hybrid protocols try to exploit strengths of both, proactive and reactive, protocols. EHMRP (Efficient hybrid Multicast Routing Protocol) is one an example of such protocols [3].

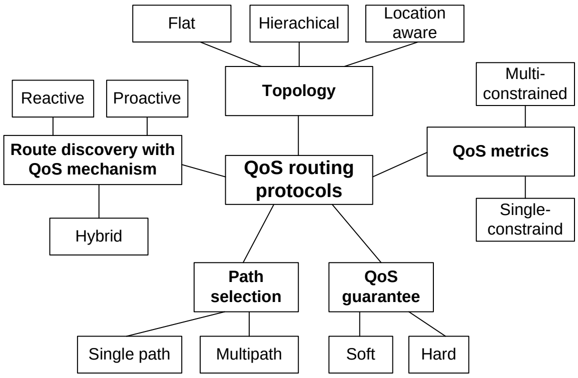

Figure 2. Clasifications of QoS routing protocols in MANET

(2) Single constrained QoS routing protocols use only one QoS parameter for routing. But with the increasing number of multimedia applications, this approach is not suitable, since these applications require satisfying more QoS parameters, i.e. delay, jitter, throughput, at the same time. So, multi constrained QoS routing protocols, needs to find a route that satisfies more QoS requirements. In MANET this is a NP-complete problem, due to its dynamic changes of topology. CEDAR (Core Extraction Distributed Ad Hoc Routing) is a routing protocol that takes into account only one QoS metric (bandwidth), while typical examples of multi constrained protocols are GAMAN (Genetic Algorithm-based routing for MANETs), QMRPD (QoS Multicast Routing Protocol for Dynamic group topology) HMCOP (Heuristic multi Constrained Optimal Path) [3].

(3) Hard QoS requires a connection with guaranteed required QoS during the session. This approach is inefficient in wired network, but even more hard to apply in MANET. There are some examples of such protocols for MANET as well, i.e. SIRCCR (SIR and Channel Capacity based Routing) and NSR. With soft QoS, QoS guaranties are defined within some statistical boundaries and most of the QoS routing protocols provide these kind of guaranties.

(4) Based on the number of the paths in the network, QoS routing protocols can be classified into single and multipath routing. With single path there is only one traffic route for sending the data from source to destination, while multipath routing protocols provide more than one route. Multipath protocols help with the achievement of load balance and fault tolerance. These protocols address different MANET issues, like scalability, security, network lifetime, etc. Examples of multipath QoS routing protocols are Q-AOMDV (QoS Ad-Hoc On Demand Multipath Distance Vector) and HQM (Hybrid QoS aware Multipath routing protocol) [12], [13].

(5) Another classification of QoS routing protocols takes into account how are the paths among group members constructed: flat and hierarchical QoS routing protocols. Many routing protocols assume flat network architecture i.e. all mobile nodes have the same capability in terms of network resources and computing power. Examples of such protocol are QAODV (QoS Ad-Hoc On-Demand Distance Vector) and AQOR (Ad hoc Qos On-demand Routing). Things are usually different in real life, since nodes have different role, capacities and are not all of the same type. Protocols that take into account diversities of mobile nodes are HQMRP (Hierarchical QoS Multicast Routing Protocol), CEDAR (Core-Extraction Distributed Ad hoc Routing algorithm) [3], [14].

D. QoS architectures

QoS models, such as Integrated services (IntServ) and Differentiated services (DiffServ), cannot be used in wireless networks, like MANET, even though they were successfully implemented in wired networks. IntServ is a per flow QoS model, meaning that each node needs enough capacity to store, process and forward data, therefore it cannot be used in wireless networks, due to their particular limited resources. In DiffServ provides easier routing of the packets in the core network, since it is an approach where packets with similar QoS requests are grouped in one class (per service class approach). But this approach is also hard to apply in MANET, because it is hard to define a network core due to dynamic topology of MANET [5].

Achievement of E2E QoS in MANET requires a cross-layer approach, since three protocol stack layers (physical, data link layer and network layer) participate in this process. Cross-layer approach encompasses provisioning of different functions on different layers regarding security, energy saving and quality of service. Many researcher gave their contribution to help solving this issue with proposals of different combined architectures such as CEQMM, INSIGNIA, iMAQ, SWAN, DS-SWAN, 2LQoS and CLQM.

Complete and efficient quality of service model for MANET (CEQMM) is a hybrid scheme, combining per-flow (for traffic with highest priority) and per-class QoS provisioning (traffic with other priorities) [15]. Model consist of priority classifier, active queue management, packet scheduler and congestion avoidance mechanisms.

INSIGNIA [16] represents a specific in-band signaling protocol that can be used in MANET. It introduces a support for adaptable services that can satisfy basic level of QoS for sending real time data.

iMAQ (Integrated Mobile Ad hoc QoS) framework is a cross-layer architecture for transport of multimedia data in MANET [17]. Middleware communicates with network layer and applications for higher QoS level of the whole system. Middleware uses information of nodes' location provided by the network layer to predict partitioning of the network. After predicted portioning, data is replicated and diverted depending on the location and mutual arrangement of the nodes.

SWAN model assigns TCP (*Transmission Control Protocol*) traffic in the network as *best effort*, while UDP (*User Datagram Protocol*) *real-time* traffic is assigned with appropriate QoS level [18]. This model uses build-in algorithms for provisioning of required delay and bandwidth with resource access control for *real-time* UDP traffic.

DS-SWAN (*Differentiated Services-Stateless Wireless Ad Hoc Networks*) is a model developed for E2E QoS provisioning in wireless ad hoc networks connected to fixed IP infrastructure. It's a combination of SWAN and DiffServ models, for wireless and wired networks, respectively. Parameters in SWAN model are dynamically adjusted to conditions in wireless and wired network. If the delay is larger than some predefined value, the model aggressively shaping of *best effort* traffic [19].

2LQoS (*Two-Layered Quality of Service*) is actually a QoS routing algorithm with the differentiation and shaping of ingress traffic. Path discovery is done based on parameters regarding power consumption (number of hops energy level, storing possibilities) and mobility (network stability), while selection of the oath is done based on delay and bandwidth. This model suppose three service classes [20].

CLQM (*Cross-Layer QoS Mapping*) model provides service differentiation in MANET environment where QoS parameters are mapped, to four proposed service classes, between three layers of protocol stack [21].

QoSMMANET (QoS Management in Mobile Ad Hoc Networks) represents a QoS support for real-time traffic in highly mobile and ad hoc environments. The proposed framework consists of the three building entities regarding routing, traffic differentiation and bandwidth allocation [6].

III. CONCLUSION

Compared to wired networks, provisioning of QoS is in a dynamic environment with no centralized control and unreliable channels, like MANET, a very challenging task. MANET can be rapidly deployed anytime and/or anywhere, since there is no need of preexisted infrastructure or any kind of network administration, but these networks need to be able to provide required QoS imposed by real-time communications. Such network have to provide good network resource utilization, while successfully delivering sent data through the network. So, there is a need for implementation of adaptive QoS routing and signaling protocols used for access control, resource reservation, and resolving situations of network congestion. Development of automated and scalable architectures, that address simultaneously different issues typical for MANET (E2E QoS, security, efficient resource management, etc.), is also very important.

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