QoS Routing Models in Mobile Applications that Implement Ad-Hoc Networking

Trajche Kocev[1], Pece Mitrevski[2] and Tome Dimovski[3]

Abstract – **It is much more difficult to guarantee QoS in MANETs than in other types of networks – the topology changes as the nodes dynamically move and network state information is generally imprecise. This requires extensive collaboration between the nodes, both to establish the route and to allocate resources necessary to provide the required QoS conditions. This article addresses some of the QoS models that can be used for data transmission between mobile apps that use ad-hoc networking. The focus is on QoS routing, as well as issues like: limited availability of resources, insecure transmission medium, QoS provisioning, security features, etc.**

Keywords – **MANET, Routing Protocols, QoS models, Mobile Communications, QoS Provisioning.**

I. Introduction

Mobile networking is one of the most important technologies supporting pervasive computing. Taking into account that, in the past 10 years, advances in both hardware and software have resulted in mobile hosts and wireless networking, created the need of distinction between the approaches that are taken in order to consider valuable advantages and disadvantages of different aspects on the wireless communication, together with QoS issues [2, 12] that affect this area of mobile networking.

As an *infrastructureless* approach [3], MANET (*Mobile Ad-hoc NETwork*) [1] is a type of network that can change locations and configure itself "on-the-fly". It can also be defined as a collection of independent wireless nodes that can dynamically form a network in order to exchange data without using any pre-existing *fixed* network infrastructure [4].

MANET is a distributed network that does not require centralized control, and every host works not only as a source but also as a router. This type of dynamic network is very useful for e.g. military communications or emergency search and rescue operations, where the rescue teams do not have access to an infrastructure-based network. The nodes that make up the network at any given time communicate through each other in order to exchange packets of information. In this way every node can establish a connection to every other node. The available bandwidth depends on the neighboring traffic status, as does the delay. Due to this characteristic, supporting QoS cannot be done by the host itself and cooperation from the hosts within a node's interference range is needed. This requires an innovative design to coordinate the communication among the neighbors in order to support QoS in MANETs.

In this paper, the fundamental problems of QoS models in ad-hoc networking are described by giving related research background, including the concepts, features, status, and applications of MANETs in different situations. Special attention is paid to QoS routing, which includes the network layer routing strategy of MANET. The paper covers the main challenges of supporting QoS in ad-hoc networks together with reservation of network bandwidth in order to guarantee the specified delay for real-time application data flows. Furthermore, QoS models are tested on a couple of commercial Windows Phone applications that support ad-hoc networking in order to define the main issues that concern QoS in this kind of networking.

Finally, the paper concludes with the main characteristics and properties of existing QoS models in ad-hoc networks, i.e. their behavior and applicability in real life scenarios.

II. Background

A. Main concept of QoS in MANET

The notion of QoS, as mentioned before, is a guarantee by the network to satisfy a set of predefined service performance constraints for the user in terms of end-to-end delay statistics, available bandwidth, probability of packet loss etc. This means that enough network resources must be available during the service invocation to honor the guarantee. The first essential task is to find a suitable path or *route* [5], through the network between the source and destination(s) that will have the necessary resources available to meet the QoS constraints for the desired service. The task of resource (request, identification) and reservation is the other required ingredient of QoS. By QoS routing, we mean both these tasks together. Let us assume a situation like the one presented in Fig. 1, where the numbers next to the links represent their respective bandwidth (Mbps). In order to minimize the delay and better use network resources, minimizing the number of intermediate hops is one of the principal objectives in determining suitable routes. However, we suppose that the packet flow from A to E requires a bandwidth guarantee of 3 Mbps. QoS routing will then select route A–B–C–E over route A–D–E, although the latter has fewer hops.

Different types of service (e.g., voice, live video, document transfer) have significantly different objectives for delay, bandwidth and packet loss. Determining the QoS capability of

[1]Trajche Kocev is a student at the Faculty of Technical Sciences, St. Clement Ohridski University, Ivo Lola Ribar bb, 7000 Bitola, Republic of Macedonia, E-mail: trajce90@yahoo.com.

[2]Pece Mitrevski is with the Faculty of Technical Sciences, St. Clement Ohridski University, Ivo Lola Ribar bb, 7000 Bitola, Republic of Macedonia, E-mail: pece.mitrevski@uklo.edu.mk.

[3]Tome Dimovski is with the Faculty of Technical Sciences, St. Clement Ohridski University, Ivo Lola Ribar bb, 7000 Bitola, Republic of Macedonia, E-mail: tome.dimovski@uklo.edu.mk.

candidate links is not simple for such scenarios, and for multicast services the difficulties are even larger. We have already noted that the route computation cannot take "too long." Consequently, the computational complexity of route selection criteria must also be taken into account. More than one QoS constraint often make the QoS routing problem *NP complete* [6]. Suboptimal algorithms such as *sequential filtering* are often used, especially for large networks, where an optimal path based on a single primary metric (e.g., bandwidth) is selected first, and a subset of them are eliminated by optimizing over the secondary metric (e.g., delay), and so on, until all the metrics have been taken into account. A random selection is made if there is still more than one choice after considering the network throughput as the last metric. All remaining the same, as long as the QoS constraints are satisfied, the same route is used for all packets in the flow. Once a route has been selected for a specific flow, the necessary resources, (bandwidth, buffer space in routers, etc.) must be reserved for the flow. These resources will not available to other flows until the end of this flow.

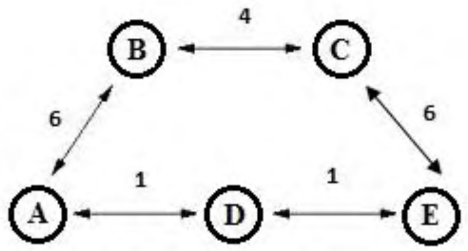

Fig. 1. Basic concept of QoS in Mobile Ad-Hoc Network

Consequently, the amount of remaining network resources available to accommodate the QoS requests of other flows will have to be recalculated and propagated to all other pertinent nodes as part of the topology update information. Minimization of routing updates is a principal objective of network engineering, because routing updates consume network bandwidth and router CPU capacity. The frequently changing of routes could increase the delay gap experienced by the users. This objective is extremely difficult to attain in ad-hoc wireless networks because of involuntary network state changes as nodes join or depart, traffic often vary, and link quality swings dramatically. To accommodate real-time traffic needs such as voice or live video, both the overall delay and delay variance must be kept under a certain bound which is accomplished primarily by minimizing as far as possible the number of hops, or intermediate routers, in the path. With potentially unpredictable topology changes in an ad-hoc network, this objective is difficult to attain. QoS routing being dependent on the accurate availability of the current network state, we briefly consider the nature of such information. The first is the *local state* information maintained at each node, which includes queuing delay and the residual CPU capacity for the node, as well as the propagation delay, bandwidth, and some form of cost metric for each of its outgoing links.

The totality of local state information for all nodes constitutes the *global state* of the network which is also maintained at each node. The instantaneous network connectivity is part of the global state information. While the local state information may be assumed to be always available at any particular node, the global state information is constructed by exchanging the local state information for every node among all the network nodes at appropriate moments. The process of updating the global state information is also loosely called *topology updates* [7], and as we have seen already, may significantly affect the QoS performance of the network. The global state update may be done by broadcasting the local state of each node to every other node (*link-state protocol*), or by exchanging suitable *distance vector* information among adjacent nodes only (*distance-vector protocol*). Since topology updates throughout the network cannot happen instantaneously, the global state information may only be an approximation of the true current network state. For ad-hoc networks with highly mobile nodes, the global state information may never be accurate.

B. QoS Routing

Three distinct route-finding techniques are used for determining an optimal path satisfying the QoS constraints. These are *source routing*, *destination routing*, and *hierarchical routing*. In *source routing*, a feasible path is locally computed at the source node using the locally stored global state information, and then all the other nodes along this feasible path are notified by the source of their adjacent preceding and successor nodes. In *destination* or *hop-by-hop routing*, the source and the other nodes are involved in path computation by identifying the adjacent router to which the source must forward the packet associated with the flow. *Hierarchical routing*, as the name suggests, uses the aggregated partial global state information to determine a feasible path using *source routing* where the intermediate nodes are actually logical nodes representing a *cluster* [8].

Flooding is not an option for QoS routing, except for broadcasting control packets under appropriate circumstances (e.g., at the start of a route discovery process).The exchange of control packets should receive higher priority than user data packets in a network designed for QoS. Except for instances of "thin" low-traffic (relative to the network capacity) networks, control packets should receive preemptive priority over user data packets. Second, the QoS policy may allow different priorities to exist even among different flows of user packets. Clearly, in accommodating packets with preemptive priorities, the network may not be able to preserve the QoS guarantee for ordinary flows.

Handling of user data with multiple priorities presents difficulties as well. When a user requests QoS with a certain priority, the network first needs to authenticate such a request by exchanging appropriate control packets (too many authentication requests, by themselves, may degrade the operational performance of a large QoS network). Next, the network must find a route with the requested QoS for a higher priority against all other flows with lesser priority, even if they are allocated identical QoS parameters in all other respects. In heavy traffic situations, guaranteeing QoS for lesser priority traffic may be extremely difficult or impossible. The development of QoS routing policies, algorithms, and protocols for handling user data with multiple priorities is also an open area.

III. QoS ROUTING IN AD-HOC NETWORKS

The basic concepts of QoS routing discussed in the previous section constitute the foundation for QoS routing for ad hoc networks as presented in Fig. 1. We assume that each node carries a unique identity recognizable within the network. Then we assume that we have the existence of all necessary basic capabilities, such as suitable protocols for medium access control and resource reservation, resource tracking, and state updates. Each node periodically broadcasts a *beacon* packet [9] identifying the QoS characteristics, allowing each node to learn of its adjacent neighbors (i.e., with which it can communicate directly). The beaconing mechanism lies at the heart of ad-hoc networking, for otherwise a node will not even know its adjacent neighbors which change dynamically in an ad-hoc network. The knowledge of adjacent neighbors is, of course, indispensable for routing in MANETs.

Two routing techniques are used in both limited to combinatorial stable QoS-preserving networks. One is based on the availability of only local state information, and the other assumes possibly inaccurate knowledge of global states. When an existing feasible route becomes unavailable, a new feasible path is determined, and the flow is rerouted to the new feasible path. During the interval immediately following the disappearance of the existing path and the establishment of the new route, data packets are sent as best-effort traffic. For QoS routing using only the local state information, there are two different distributed routing algorithms, the so-called *source-initiated routing* and *destination-initiated routing*. Both rely on the use of *probe* packets [10] with appropriate nodal identity and QoS information in identifying a feasible route with the desired QoS characteristics. The probe packets are sent by the source and intermediate routers using a form of flooding. Various workarounds are considered in order to avoid the penalties of flooding, and the advantages of destination-initiated routing over the other methods established under certain conditions.

Multiple mechanisms are considered for QoS-preserving QoS routing by detecting broken routes and then either repairing the broken route or rerouting the flow on an alternate route with the desired QoS. The likelihood of QoS violation is reduced further by using redundant routes of various kinds. A broken route is detected by using the beaconing protocol for detecting adjacent neighbors. Consider Fig. 3. If node B determines that C is no longer its neighbor because the link between B and C (in red) is broken, it may attempt to repair the route by finding another node E such that by replacing segment B–C with segment B–E–C, the QoS requirement is satisfied between the source *S* and the destination *D*. If no such route segment can be found, B notifies the source that the route is broken. Depending on the network policy, B may send the notification of route unavailability to *S* without attempting to repair the route.

When the source receives the notification of route unavailability, it seeks an alternate route with the same QoS characteristics, as shown in Fig. 3. The unusable route is shown in red, and the new alternate route is shown in blue. If such a route can be found, the flow is rerouted to it after the necessary route updates among the pertinent nodes.

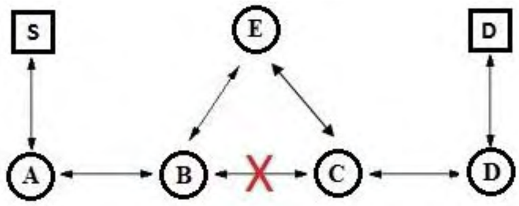

Fig. 2. Route repair

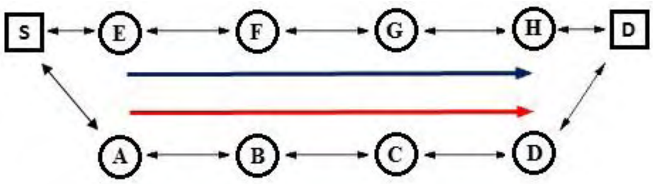

Fig. 3. Alternate routing

The existence of the QoS route between a source-routing with imprecise information by sending suitably constructed control packets, called *refresher* packets [11] from the destination back to the source. If such a packet fails to arrive within a predetermined timeout interval, the QoS route is changing. This also accommodates the failure declared unavailable and the associated resources released. In order to reach various unavailability notifications to their intended recipients additional timeout mechanisms are used. Multiple redundant routing mechanisms are also considered for minimizing the likelihood of QoS violation due to route failures (Fig. 4).

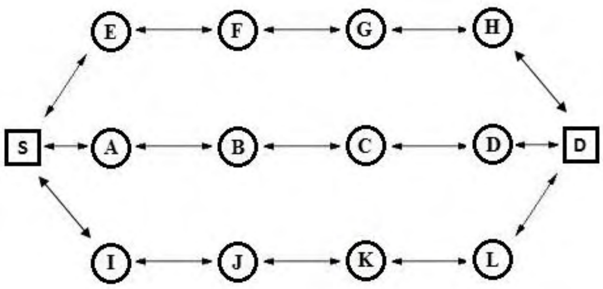

Fig. 4. Redundant routing

At the highest level of redundancy, multiple alternate routes with the same QoS guarantee are established for the flow, and are used simultaneously. The alternate routes should be preferably disjoint, although this may not always be possible. Duplicate packets are discarded at the destination. At the next lower level of redundancy, the routes and associated resources are reserved and rank ordered, but not used unless the primary route fails, or the first choice for the alternate route fails while the primary is unavailable, and so forth. When not in use for the QoS-guaranteed flow, the alternate route is used to carry best efforts packets. At the lowest level of redundancy, only the route is identified; no resource is reserved. When the primary path fails, the alternate paths are checked to determine whether the necessary resources are still available. Rerouting is initiated if none of the alternate routes are found to be able to support the desired QoS.

IV. Real-world applications – “Splendor” vs. “Skye Bank”

The project called “Splendor” is a Global Natural Disaster Center which is used to share *geolocation* information of the people that are experiencing a Global Natural Disaster. The “Skye Bank” project, on the other hand, is used for accessing the bank accounts of the users and making transactions from one account to another. Both solutions are mobile applications that use ad-hoc networking and implement QoS routing protocols mentioned above. These apps are written for the *Windows Phone* platform and they implement *source-initiated* routing and *destination-initiated* routing in order to achieve communication in changing mobile ad-hoc environment. Fig. 5 shows the main concept of Ad Hoc networking in “Splendor”, while Fig. 6 shows the concept on which the “Skye bank” mobile application is based. When the user starts the Splendor mobile application he/she gets the current position on a map, together with the latitude and longitude. This Windows Phone mobile application is able to establish ad-hoc communication with other Windows Phone mobile devices that have the same app. It also uses *infrastructureless concept* and *hierarchical routing* in order to send a short “SOS” message for help over other mobile applications/ devices that are in the vicinity of the disaster area in order to save people that are located nearby. The data are shown on a *website* [11] (on a map) and the rescue teams can react on-time in order to save as many human lives as possible.

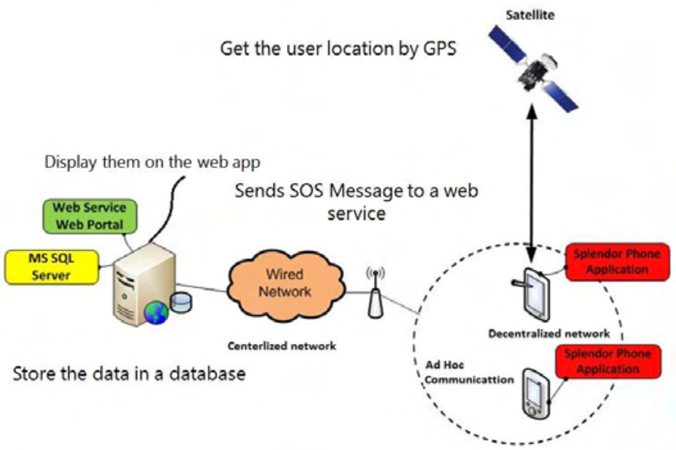

Fig. 5. The main concept of ad-hoc networking in “Splendor”

“Skye Bank” is an app that enables to the user to check bank accounts’ balance and make transaction in situation where there is no centralized network. It uses redundant routing and advanced algorithms for enabling security in order to enable high level of QoS. The concept is shown on Fig. 6.

Fig. 6. The main concept of ad-hoc networking in “Skye Bank”

V. Conclusion

In this research paper we tried to give an overview and to analyze the fundamental issues and key problems that affect QoS and routing models in MANETs. Then, some real-world applications that use ad-hoc communication, which we implemented for the Windows Phone platform, were presented together with centralized and decentralized infrastructure.

Mobile ad-hoc networking alongside QoS routing are one of the most important and essential technologies that support the future pervasive computing paradigm. Much work remains to be done on cost-effective implementation issues to bring the promise of ad hoc networks within the reach of the public.

References

[1] ETF Working Group: Mobile Adhoc Networks (MANET) http://www.ietf.org/html.charters/manet-charter.html
[2] M. Kumar et al., Issues and Challenges of Quality of Service in Mobile Ad Hoc Network, Int J of Computer Science & Engineering Technology (IJCSET)
[3] B. Awerbuch, A. Mishra, Introduction to Ad hoc Networks: Advanced Topics in Wireless Networks, Johns Hopkins University, 2008.
[4] B. A. Peacock, Connecting the edge: Mobile Ad-Hoc Networks (MANETs) for Network Centric Warfare, USAF ,2009.
[5] A. Koliousis, .J. Sventek, Proactive vs reactive routing for wireless sensor networks, University of Glasgow, 2010.
[6] S. Chen, Routing Support for Providing Guaranteed End-To-End QoS, PhD thesis, Univ. of IL at Urbana-Champaign, 1999.
[7] R. Sivakumar, P. Sinha, V. Bharghavan, “CEDAR: A Core Extraction Distributed Ad Hoc Routing Algorithm, *IEEE JSAC*, 17(8), pp. 1454–65, 1999.
[8] E. Crawley et al., A Framework for QoS-Based Routing in the Internet, RFC 2386, IETF, 1998.
[9] A. Iwata et al., Scalable Routing Strategies for Ad Hoc Wireless Networks, *IEEE JSAC*, 17(8), pp. 1369–79, 1999.
[10] T. Dimovski, P. Mitrevski, Connection Fault-Tolerant Model for distributed transaction processing in mobile computing environment, Proc. of the 33rd Int. Conf. on Information Technology Interfaces, pp. 145-150, Dubrovnik, Croatia, 2011.
[11] URL<(http://splendor.somee.com/)>
[12] T. Kocev, P. Mitrevski, T. Dimovski, Mobile Ad Hoc Communication – the Ability of Networking Without Network, 10th CiiT Conf. on Informatics and Information Technology, Bitola, 2013.