Meeting Data Specific Quality of Service Requirements in Mobile Ad-Hoc Networks with High Network Load

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Abstract. In the military sector, radio communication is vital during a mission. The information exchange is provided using a Mobile Ad-Hoc Network. In order to reach specific participants and to transmit data in the awareness of restricted resources, multicast is the common communication technique. Within the network, the armed forces send different data types with appropriate transmission technologies. Hence, the forwarding of video and audio streams over several nodes increases the network load. Different Quality of Service requirements exist for specific data types. Voice has the highest priority and should be delivered in real time. Quality of Service is compromised by overload situations, limited bandwidth, arising bottlenecks or active attacks. These situations can result in higher delay, congestion, insufficient packet delivery and, in the worst case, a Denial of Service. Therefore, the objective of this PhD research is to adapt the transmission of various data types to the current utilization of the Mobile Ad-Hoc Network, to ensure Quality of Service and resilience. For instance, in order to meet the requirements, certain routes within the network that are compromised by limited bandwidth will prioritize transmission of voice over video.

Keywords: MANET, Multicast, QoS, Streaming, Bandwidth Limitation

1 Introduction

The communication via radios between soldiers during a mission is essential and indispensable. The tactical forces have a continuous information exchange within the troop, as well as with other troops. They inform about their current status or exchange mission information. With the Software Defined Radio (SDR) [1], the armed forces have the possibility of transmitting information via the TCP/IP-Stack. Now, the necessary group communication is established via multicast routing, which is an appropriate method to share information between several participants. The soldiers therefore build a Mobile Ad-Hoc Network (MANET). This network structure is well-suited, because a group of soldiers communicating in the field cannot rely on a centralized infrastructure during a mission [2]. The SDR technology also enables the transmission of different data types like video/audio streams, pictures of observations or general file transfer, depending on the applications running on the radios. With the exchange of different information material, situations can be described more specific.

2 Problem Description

In the military sector it is particularly important to meet the transmission requirements with Quality of Service (QoS) compared to the civil environment. Troops in combat depend on a robust network architecture that is available at any time, even when the participants are constantly on the move and communication flow is high. Every data type mentioned above has individual QoS requirements to provide their services. They differ in delay, throughput, loss rate and quality. Voice over IP (VoIP) relies on a delay less than $250ms$. Video streaming at least needs a bandwidth over $1Mbps$. Transferring for instance a video stream with a resolution of 640x480 pixels needs a bandwidth between 600-700$Kbps$ [6]. Providing these services increases the network load. The narrowband, used in the military, reaches a bandwidth of $64Kbps$ [3]. With broadband communication the radio can reach a bandwidth up to $2Mbps$. The resources of MANETs vary depending on the continuously changing environmental conditions. It is a common situation, that only a single, long-distance route is available to a multicast receiver or that a specific node acts as forwarder for several multicast sessions. In case of high network load, these constellations result in higher delay, congestions, bottlenecks, insufficient packet delivery ratio and, in the worst case, a Denial-of-Service. Consequently, all QoS requirements can no longer be achieved with current technologies. The scenario in figure 1 illustrates a behavior, where

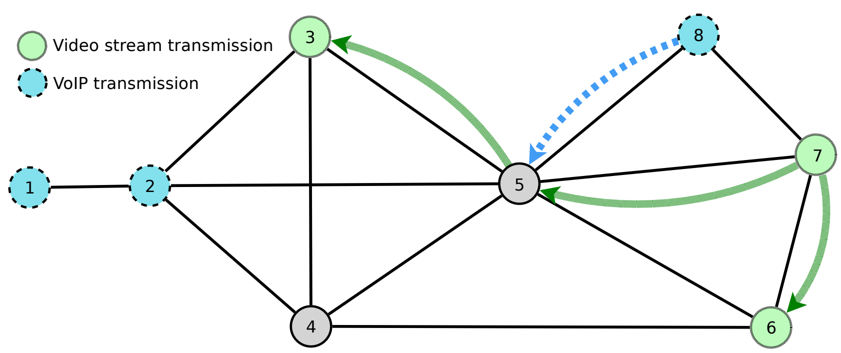

Fig. 1. Example of an arising transmission problem

a capacity problem can occur and could be solved with QoS extended routing. Node 7 transmits a video stream at time t to the Nodes 3 and 6. At time $t+1$, Node 8 tries to communicate via VoIP with Nodes 2 and 1. The intermediate Node 5 already forwards the bandwidth-consuming video stream and now has to serve two routes.

3 The Idea

As mentioned in section 1, the data types have individual specifications, like e.g. available throughput. Furthermore, every data type has a certain priority. Keeping that in mind, the general objective is to reach the most optimal QoS with respect to the available network resources and the individual performance specifications of the data types. To achieve this, every node in this MANET is, apart from the common routing, equipped with additional QoS information. Figure 2 shows the architecture of a node with such a QoS routing extension.
Before a node starts transmitting payload, the network capacities have to be compared to the QoS requirements of the payload. This is achieved with transmission request. This transmission requests can either be received from a participating node of the network (*External Transmission Request*) or from a node itself (*Internal Transmission Request*). Both requests contain the QoS requirements of the data type and the priority. QoS requirements specify delay, loss rate and necessary bandwidth of the payload. The *Internal Transmission Request* is

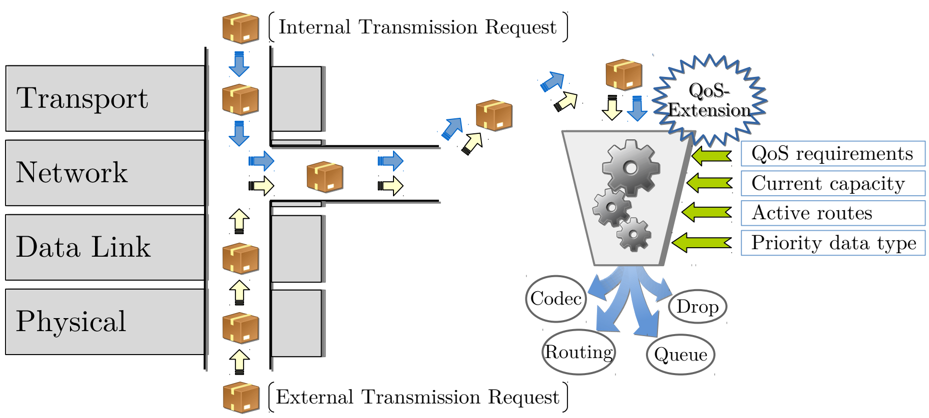

Fig. 2. Structure of QoS aware Node in a MANET

triggered from an application running on the radio. Such requests cross the upper layer till they arrive at the QoS extension. There are several factors which influence the treatment of the received request. First, the QoS requirements of the received data type are determined. Then, additional information such as utilization, available bandwidth or active routes of the network has to be examined in order to get an overview of the available resources. Based on this information and depending on the priority of the data type, the request will be treated accordingly. If the node has minimal capacities and low bandwidth because it relays packets of several routes, it might inform the other senders to reduce their sending interval or to drop their packets. If voice has to be transfered under these network conditions, the necessary capacities have to be provided. This can result in the multicast origin having to change the codec of e.g. a video stream

to save bandwidth or having to reroute the packets. A picture could be queued and distributed to the multicast receiver when the network load has decreased. The procedure of an *External Transmission Request* is very similar to the internal transmission request. The node which receives the external request determines the QoS requirements of the received request. Then, factors like available capacity, bandwidth and the number of routes are examined. Again, the node determines the treatment of the request with respect to the priority of the data type, its own possibilities and the QoS requirements of the request. Depending on the results, the request is treated accordingly. If the data type of the request has compared to the other active routes the highest priority and the bandwidth is not sufficient, the origins of resource-consuming routes must be informed to change their transmissions or drop them.
It turns out, that a management process which affects the network has to be triggered if necessary resources are not available and the QoS requirements can not be met.

4 Scientific Questions

An important characteristic of MANETs is the self organization. This has a fundamental impact on the routing. Basically, routing protocols will determine the fastest route to every multicast receiver with respect to the network load at runtime. Not only time critical requirements, but also data loss rate, throughput, necessary bandwidth and quality have to be taken into account in order to meet the QoS. Accordingly, the following scientific questions have to be investigated:

- How can the current transmissions in the MANET be distributed best in order to fulfill the QoS requirements?
- How can areas with high network utilization be identified?
- In case of a sender with higher-priority data determining the best path towards all multicast receivers, how can other senders be informed about changing the behavior of their current transmissions, in order to provide the necessary capacity for the delivery of higher-priority data?
- If a multicast route meets the QoS requirements, how can quality be maintained during transmission?
- What impact does the QoS management overhead have on the network when the mobility of the nodes is high?

5 Related Work

In the paper by Kumar et al. [7] a QoS routing protocol is introduced which uses a neighbor reliability pair factor to assign a route for a multicast session. This factor is based on the battery level, distance and mobility of the node. The algorithm tries to increase the robustness of active routes. In doing so, the algorithm performs well, compared to the multicast routing protocols MAODV [5] and EMAODV [4].

The work of Lu et al. [8] proposes a unicast routing protocol designed for hybrid wireless mesh networks [9]. The algorithm provides a multi-criteria routing functionality with the goal to achieve the utilization of clients. Here, the data is divided in urgent and non-urgent QoS requirements. End-to-End delay is determined when transmitting urgent data, hop count and link load are measured when non-urgent data has to be delivered. Simulation results indicate, that the route selection with respect to the data type can effectively reduce the average end-to-end delay when transmitting urgent data. In addition, the utilization of the network is more balanced while guaranteeing the capability when transmitting non-urgent data.
A further approach to achieve QoS is to manage the network resources of multicast sessions according to the feedback received by multicast members [10]. The approach tries to adjust the sending rate and the codec of video streams regarding to the received feedback of multicast receivers. The feedback is classified with fuzzy logic [11][12]. The evaluation results show, that with resource adjustment techniques, the packet delivery ratio and the delay can be improved.

6 Early Results

Before thinking about solving the mentioned research questions, it has to be analyzed which effect it has, when payload is split over several nodes in the MANET. It is expected, that generating a balanced utilization provides better results with respect to delay and loss rate. To investigate this assumption, we created a scenario shown in figure 3 where two different source nodes transmit data to the same destination. There, the behavior transmitting video and VoIP streams ($Video_1, VoIP_1$) using the same path is compared with using different routes towards destination ($Video_2, VoIP_2$). It is not uncommon that different

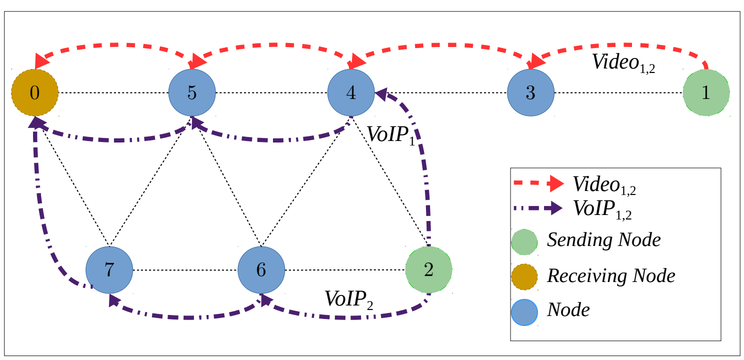

Fig. 3. test

traffics stream share one path towards the same destination. The routing algorithms AODV [13] and DSR [14] for instance chose the stressed path towards the destination because node 3 with respect to the introduced scenario would reply with an active route to node 0. It has to be mentioned, that the data rates of $Video_{1,2}$ provoke a utilized route. As a side note, with a configured video data rate of $205Kb/s$, the packets of all streams are delivered to the destination. All simulation parameters are described in Table 1.

Table 1. Configured Simulation parameters

Type	**Value**
Simulation time	$65sec$
Bandwidth of node	$2Mb/s$
Overhead $Video_1$	$227Kb/s$
Overhead $Video_2$	$240Kb/s$
Overhead $VoIP_{1,2}$	$40Kb/s$

The plots in Figure 1 illustrate the delivered packets and the delay of the described scenario. Results of the left plot show, that more packets are delivered in total using different paths towards destination. This becomes clear with a re-

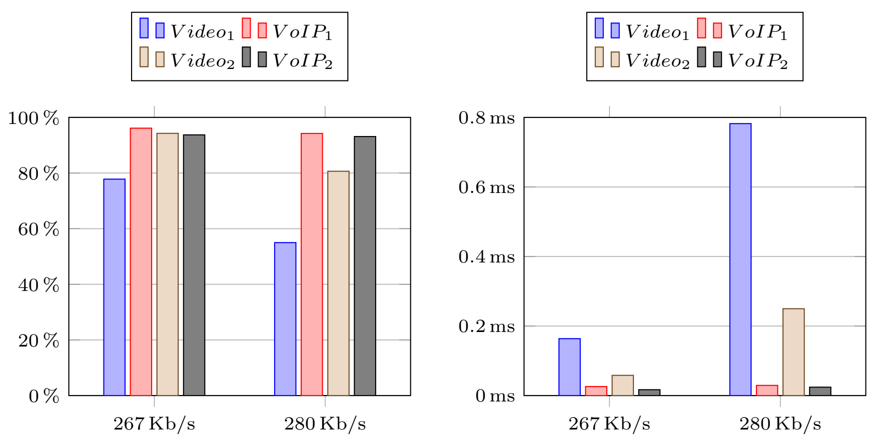

Fig. 4. Received packets in percent and associated delay with respect to video and VoIP streams

quired bandwidth fo $280Kb/s$. There, $Video_1$ delivers 54.994% of the sent packets and the $VoIP_1$ stream loses 5.7737% of the transmitted payload whereas $Video_2$ reaches a delivery rate over 80% and $VoIP_2$ loses 6.8772%. The high loss rate of $Video_1$ may be due to an arising congestion. The end to end delay in the left plot reinforce this assumption. Here, $Video_1$ produces a noticeable high delay with a required bandwidth of $280Kb/s$. This is because the intermediate nodes do not have enough capacities to forward packets of two routes. In general, using the same path to the destination creates a higher delay and the results shows that less packets are lost when using different paths.

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