Service Differentiation in Mobile Ad hoc Networks

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Abstract

Mobile Ad hoc Network (MANET), a collection of nodes that form a multi-hop wireless network, is emerging as an important technology in the present and near future. MANETs are being used in a variety of applications from emergency rescue to sensor networks. With the expansion of real-time applications for this type of networks, the need for quality of service (QoS) support has become essential. This paper deals with current QoS models for MANETs. We will propose a modification of Stateless Wireless Ad hoc Networks model (SWAN) in order to improve QoS performance and will provide our simulation results..

Categories and Subject Descriptors

C.2.1 [**Computer-Comunication Networks**]: Network Architecture and Design

Keywords

MANET, QoS Model, Service differentiation

1. Introduction

One of many QoS definition is the view to QoS as the ability of the network to provide different services to various types of network traffic. It means that the goal of QoS is to achieve a more deterministic network behaviour so that data carried by the network can be better delivered and the resources can be better utilized. In wired networks, there are many approaches, techniques and protocols used to achieve this goal. Also, there exist QoS models which are complex frameworks widely used to satisfy required QoS level for chosen application. Typically, QoS is measured or represented by set of qualitative network performance metrics such as bandwidth, one-way network delay, delay variance (jitter) and packet loss. There are applications sensible to one or two metrics with requirements to minimum or maximum level of the metric. Unlike wired networks, MANETs have specific characteristics which make QoS provisioning more difficult, e.g. dynamic network topology and bandwidth constraint in wireless medium. Due to special attributes of MANET network, we can define some other QoS metrics, e.g. service coverage area or power consumption [10]. In order to satisfy QoS requirements, there is a need to have a complex framework or QoS model which can provide basic architecture of QoS provisioning. There should be the cooperation among routing, queuing, packet scheduling, admission control, signalling and traffic engineering. There has been proposed several QoS models for MANETs. Next section covers most used ones and discusses their advantages and disadvantages. Proposed extension of SWAN model is in section 3, following with our simulation results and the comparison with SWAN model in section 4. Finally, section 5 contains conclusion and description of some open issues in this area and our future work.

2. Related Work

In wired networks there are two QoS models widely used, IntServ (Integrated Services) providing hard QoS but with low scalability, and DiffServ (Differentiated Services) used in the Internet environment. Unfortunately, both are not suitable for MANETs due to their specific characteristics. When QoS model for MANETs was designed, these specific features of mobile ad hoc networks had to have been considered. Especially, features like dynamic network topology, bandwidth constraint and limited power of nodes which make MANETs really specific. And due to them, it is not possible to use conventional QoS models from wired networks. The design also needed to take under consideration the fact that a lot of MANETs are connected to the Internet. This section describes most used QoS models designed for mobile ad hoc networks.

2.1 Flexible QoS Model for MANETs

Flexible QoS Model for MANETs (FQMM) was the first QoS model designed for MANETs. It combines the advantages of IntServ and Diffserv models and provides a hybrid scheme of per-flow provisioning as in IntServ and per-class provisioning as in DiffServ [12]. FQMM operates at the IP layer with the cooperation with Medium-Access layer. It is divided into data forwarding and con-

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trol plane. The main purpose of data forwarding plane is to classify incoming packets going through traffic conditioner and packet scheduler. The control plane handles preparation for data forwarding operation with specific protocols and algorithms cooperation. This model defines three categories of nodes: ingress, interior and egress node. This nodes differentiation is borrowed from DiffServ model from wired networks. Ingress node is a source node sending data to destination. Interior nodes are nodes forwarding data to other nodes according to some routing decisions. And lastly, egress node is actually the destination node. Interior nodes forward data packets by certain PHB (Per Hop Behaviour) according to the Diffserv field in the packet header. We can look at MANET as one DiffServ domain bounded with the ingress and egress nodes [3]. It is important to note that due to the mobility of nodes in MANETs, the nodes can have different roles as they move. FQMM can provide per flow QoS provisioning for high-priority flows. The question is how many high-priority flow sessions can coexist at the same time in the network. Another open issue is the scheduling performed by intermediate nodes.

2.2 Integrated Mobile Ad hoc QoS framework

The Integrated Mobile Ad hoc QoS framework (iMAQ) is another QoS model or framework for MANETs [8]. The main idea of this model is based on a cross-layer communication approach involving network and application layer by means of so called middleware service layer. As nodes are mobile, the network can become partitioned which leads to missing data. Predictive location-based QoS routing protocol with middleware layer cooperation can predict network partitioning and provide necessary information to the application layer. Thus the main role of middleware layer is to replicate data among different network groups in order to provide better data accessibility before network partitioning occurs. The disadvantage of this QoS model is its high overhead and lack of resource reservation [7].

2.3 INSIGNIA Model

INSIGNIA model represents the first signalling framework designed for MANETs. It is based on in-band signalling approach. That means that control information is carried in data packets along the same communication path in contrast to out-of-band signalling approach where control data are carried separately in control packets sometimes even along different path than data packets. In wired networks, Resource reSerVation Protocol (RSVP) is used as a standard for resource reservation and management. RSVP is an example of out-of-band signalling. For MANETs in general, this kind of signalling is not very suitable because it consumes network bandwidth. Thus, it is a better idea to use in-band signalling which consumes less bandwidth and if control overhead is simple the information can be carried in each packet. INSIGINA signalling framework uses the options part of IP packets within all control information is carried. For each active flow in the network there is a soft state stored in all related hosts. The soft state is periodically refreshed every time when packets from the particular flow arrive at the hosts or are forwarded by the host to their destination. INSIGNIA, with admission control cooperation, reserves network resources, mainly available bandwidth, to the particular flow if the resource requirement coming from the source node can be satisfied. In order to keep INSIGNIA very simple and to not conserve much bandwidth, there are no error messages and thus no negative notification among network nodes. For example, if the resource requirement request cannot be satisfied, no error message is sent to source node. Due to the dynamic topology of MANETs, INSIGINA needs to respond fast to the topology changes. It is done by periodical informing the source node with the status of the data flow. The destination node gathers statistical information such as throughput and loss rate and sends the report to the source node. With this kind of feedback, the source node can adapt the transmission of data packet belonging to the particular flow. Due to these attributes of INSIGNIA, it can provide assured adaptive QoS provisioning to real-time flows based on the source node's requirements and resource availability in the MANETs [5]. On the other hand, the research shows that INSIGNIA has problems with scalability since state information about data flows is stored in network nodes.

2.4 Design of an Efficient QoS Architecture Model

Unlike the previous model, Design of an Efficient QoS Architecture (DEQA) model is very scalable and stabile [9]. It consists of three parts. The first one is routing protocol that search several parallel communication paths. Data packet are fragmented in source node and sent along these paths independently to the destination where they are assembled again. The goal of such a routing approach is stability increase. The next part of a model is admission control with definition of two thresholds, minimum and maximum. If the incoming QoS requirement is under the maximum limit, it is denied. On the other hand, if the requirement is below the minimum, it is allowed. But in case the QoS requirement is between minimum and maximum, the probe packet has to be sent along the communication path to the destination in order to get information about available network resources. Then, based on this information, the request is either allowed or denied. The last part of a model is congestion control which is important after admission control part allows the data flow request. After that congestion control block periodically monitors whether communication links begin to be congested. If so, Explicit Congestion Notification (ECN) technique is used with the goal to decrease transmission rate of the network traffic that do not require QoS provisioning. Some authors discuss that this behaviour is the biggest disadvantages of the model because there can be a strong unbalance between best-effort traffic and traffic requiring some level of QoS.

2.5 Cross Layer Interactions and Service Mapping QoS Model

The main idea of Cross Layer Interactions and Service Mapping (CLIASM) model is to build a shared database with data from all protocols of the network model with information about QoS [9]. Thus, it is another example of cross-layer QoS model. The goal is that each layer has the same information about the network itself, network performance parameters and available resources. There are four groups of such data corresponding to the layers of network model: application, transport, network, and link layer data. The nodes along communication path are not involved in QoS provisioning. The whole overhead is managed by source node including state information handling. This can lead sometimes to unwanted interactions and stability issues with the overall performance decrease.

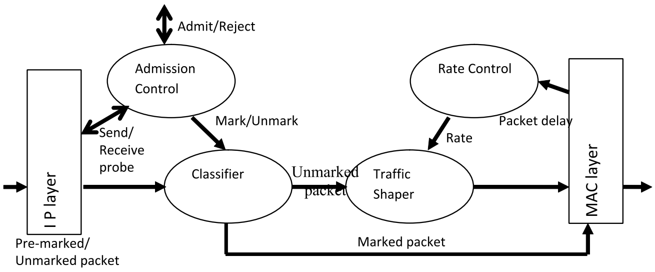

Figure 1: SWAN model [14]

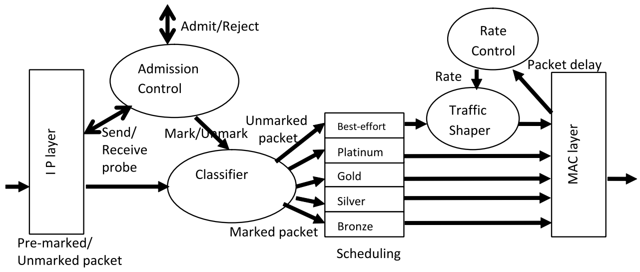

Figure 2: Proposed Extension of SWAN model.

2.6 Stateless Wireless Ad hoc Network QoS Model

The last QoS model described in this paper is called Stateless Wireless Ad hoc Network (SWAN) model. It is a distributed network QoS with stateless approach using rate control for UDP and TCP best-effort traffic based on AIMD (Additive Increase Multiplicative Decrease) [1]. Like DEQA model, it also uses ECN (Explicit Congestion Notification) to regulate real-time traffic in order to react dynamically to topology changes. Figure 1 describes the architecture of SWAN model.

The two main functional block of SWAN model are Classifier and Traffic Shaper which both operate between IP and MAC layer. The role of Classifier is to distinguish real-time traffic that should not go through Shaper. The traffic shaper in this model is represented by simple Leaky bucket shaper which is used to shape best-effort traffic based on the information from Rate Controller in order to delay best-effort packets and thus provide more bandwidth to real-time traffic. Admission Controller is a block located at source node. Its function is to send a probe request toward the destinaton node to estimate resources availability. Based on this information, Admission Control module decides whether admit or reject the request. The advantage of SWAN is that all nodes regulate best-effort traffic independently and each source node uses admission control for real-time sessions. When a new real-time flow is allowed by admission control block, all packets, belonging to the particular flow, are marked as a real-time packets. Due to this marking, classifier bypasses shaper and packets remain unregulated [6]. The fact that SWAN is a stateless model and thus it does not require maintaining information at network nodes makes it very scalable and robust QoS model solution for MANETs. The lack of reservation and signalization mechanism means that this QoS model is not suitable for hard QoS provisioning but it was not the design goal of this model.

3. An Extension of SWAN QoS Model

As stated above, SWAN model is suitable for dynamic MANET topologies. It provides soft QoS in a scalable and robust manner by means of distributed network approach with traffic rate control. We consider the ability of the model to differentiate only between two types of traffic as a drawback. Typically, there is a need to provide service differentiation in a more precise way than only real-time traffic and best-effort traffic. In many scenarios, real-time traffic needs to be differentiated according to various parameters, e.g. priority. Therefore, this paper proposes an extension to SWAN model with a scheduling module and rate control improvement. The architecture of our proposal is illustrated in the Figure 2.

The scheduling module has been added to the former SWAN model, between Classifier and MAC. Then, the functionality of SWAN model has been modified in the following manner. If Admission Controller admits the request, Classifier differentiates packets according to their marking to five classes: Platinum, Gold, Silver, Bronze, and Best-effort. Then, packets are queued in respective queues and wait for the transmission. There is a special queue for best-effort traffic which can be shaped by traffic shaper, based on the information from rate controller, in a similar way like in the former SWAN model. The scheduling algorithm is a combination of Strict Queuing, Weighted Fair Queuing and Probability called Probabilistic Priority Queuing proposed in [13]. Each queue has a parameter p which is a probability with which the particular queue is served. The basic algorithm is as follows:

1. 1. If queue i is not empty, and if all other queues with higher priority than queue i are empty, transmit one packet from queue i with probability 1.
2. 2. If at least one higher priority queue is not empty, generate a random number between 0 and 1.
3. 3. If random number from step 2 is higher or equal than p, transmit one packet from queue i, else go to step 4.
4. 4. i = the next queue and continue with step 1. Next section presents discussion and simulation results of proposed SWAN extension.

4. Simulation and Evaluation

We simulated several scenarios using network simulator ns-2 to validate our proposed solution and compare its performance with the former SWAN model. Ns-2 was chosen due to its extensive support for MANETs and SWAN model support. We used SWAN implementation for ns-2 from [11] and Probabilistic Priority Scheduling [13]. We defined following simulation parameters:

- Simulation area: 500 x 500 m
- Number of nodes: 20
- Nodes mobility: Random Waypoint Model - RWM
- Node velocity: 0 - 5 m/s
- Routing protocols: AODV, DSDV
- MAC protocol: IEEE 802.11
- Simulation time 120 s

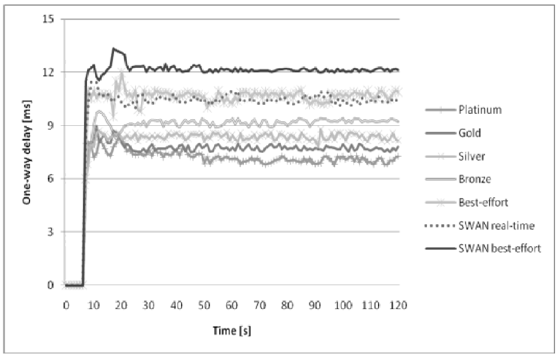

Figure 3: One-way delay comparison.

Source nodes generated five types of flows with fixed packet size. In our proposed extension model, we classified these flows from Platinum to best-effort traffic, and in SWAN model, we classified them only to two groups, real-time and best-effort. Figure 3 shows simulation results in order to compare network performance of both models.

The simulation results show that our proposal increase the ability of SWAN to provide service differentiation in a more precise way. It is capable to differentiate between five data flows and provide them different QoS level. Based on various simulation experiments with different scenarios, we argue that our SWAN modification and scheduling extension is a significant improvement of SWAN model in terms of service differentiation and end-to-end delay performance. It is important to note that we also simulated scenarios with both routing approaches, reactive and proactive. The results show no difference and independence of our proposal on routing protocols. This was expected because SWAN model itself is not dependent on any particular routing technique.

5. Conclusions

This paper deals with QoS models in MANETs. It describes most used ones and presents their advantages and disadvantages. We focus on SWAN model because due to its simplicity, robustness and scalability, it can provide soft QoS in MANET networks. We propose an extension of SWAN model in order to increase level of service differentiation and by adding probabilistic scheduling approach also end-to-end delay. Simulation experiments show that our proposal improves the performance of MANETs in terms of one-way end-to-end delay. In addition, it is compatible with different routing approaches, proactive and reactive. Our next idea for future work is to analyze the use of Random Early Detection (RED) technique in each queue to increase more network performance and to avoid congestion in the network.

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References

[1] G. Ahn et al.: Supporting Service Differentiation for RT and Best-Effort Traffic in Stateless Wireless Ad Hoc Networks (SWAN). IEEE Transaction on Mobile Computing, vol. 1, (2002), pp. 192-207.

[2] R. Hekmat: Ad-hoc Networks: Fundamental Properties and Network Topologies. Springer, (2006), ISBN 1-4020-5165-4.

[3] Y. Chen et al.: An On-Demand Link-State Multi-Path QoS Routing in a Wireless Mobile Ad-Hoc Networks. In: *European Wireless Proceedings*. 2002.

[4] P. Krishna, S. Iyengar: A cross layer based QoS model for wireless and mobile ad hoc networks. Mobile Communication. vol. 1, (2007), pp. 114-120.

[5] S.B. Lee et al.: INSIGNIA: An IP-Based Quality of Service Framework for Mobile Ad Hoc Networks. Parallel and Distrib. Comp., Special issue on Wireless and Mobile Computing and Communications, vol.60, no. 4, (2000), pp. 374-406.

[6] S. Marwaha et al.: Challenges and Recent Advances in QoS Provisioning, Signaling, Routing and MAC protocols for MANETs. In: *Proc. of Telecommunication Networks and Applications Conference*, (2008), pp. 97-102.

[7] P. Mohapatra et al.: QoS in Mobile Ad Hoc Networks IEEE Wireless Communication. (2003).

[8] K. Nahrstedt: An Integrated Mobile Ad-hoc QoS Framework [Online; accessed February 20th, 2011]. Available at: http://ftp.rta.nato.int/public//PubFull-Text/RTO/TR/RTO-TR-IST-030///TR-IST-030-W3/TR-IST-030-W3-Presentations+Discussions/TR-IST-030-W3-14.pdf

[9] M. Sulthani, D. Rao: Design of an Efficient QoS Architecture (DEQA) for Mobile Ad hoc Networks. ICGST-CNIR Journal, vol. 8, (2009).

[10] B. Tavli, W. Henzelman: Mobile ad hoc networks - energy efficient real time data communications. Springer, (2006), ISBN-10 1-4020-4632-4.

[11] The Network Simulator ns-2. [Online; accessed February 20th, 2011]. Available at: http://www.isi.edu/nsnam/ns/

[12] H. Xiao et al: A Flexible Quality of Service Model for MANET In: *Vehicular Technology Conference Proceedings*, (2000), pp. 445 - 449.

[13] J. Yuming, T. Chen-Khong, K. Chi-Chung: A Probabilistic Priority Scheduling Discipline for Multi-Service Networks. Sixth IEEE Symposium on Computers and Communications, (2001).

[14] N. Zhang, A. Anpalagan: A Comprehensive Simulation Study of SWAN QoS Model in MANETs with Proactive and Reactive Routing. In: *Proc. of Canadian Conference on Electrical and Computer Engineering*, (2009).