A CENTRALIZED RESOURCE RESERVATION FOR CELLULAR IP ACCESS NETWORKS

Rachid Zagrouba
RSM Research Team
University of Le Mans
rachid.zagrouba@univ-lemans.fr

Jean-Marie Bonnin
RSM Research Team
Telecom Bretagne
jm.bonnin@telecom-bretagne.eu

Karine Guillouard
Orange-ftgroup
karine.guillouard@orange-ftgroup.com

ABSTRACT

This paper presents a central reservation concept to enhance network performances and allow optimizing the resource utilization within the access network. The proposed approach gives an operator the capability to provide the desired QoS level with as little resources as possible, thus minimizing the operator's investment while meeting network configuration requirements. The new concept for providing IP QoS within the cellular IP network is to apply a DiffServ architecture where specific QoS classes could be adopted. Each of these classes will provide a specific QoS treatment within the access network. In the access network, the central network entity should be responsible for assigning MT (Mobile Terminating) IP traffic (addressed to the MN) to a particular class and perform a local resource reservation to this traffic. Such reservations are based on QoS profile and the network state. The central reservation for mobile node and handover management issues are analyzed in this paper.

Keywords

Wireless networks, Quality of Service, Signaling protocol, Micro mobility.

Introduction

A given mobile access network should be able to support both seamless mobility (i.e. no significant packet delays or losses during handover) and QoS guarantees for a wide variety of applications [8]. Moreover, the QoS mechanism should also be able to provide flexible priority-based services [13]. From a user perspective, the QoS provision should not be disrupted by mobility. However, the operators want to deliver higher quality (higher bandwidth or lower latency) to users that pay more and to those connected to media that is not inherently bandwidth-limited (e.g., WLAN). Because of these requirements, the new challenge for operators is to perform a set of mechanisms that provide differentiation between users and applications and to ensure that resource reserved by one user do not affect services provided to the others. The reservation mechanism requires additional functions within the intermediate router to support the interception and generation of signaling messages. Moreover, after the handover operation, the re-negotiation process generates a burst signaling messages to set up reservation and could introduce a QoS level degradation. Another disadvantage of the reservation mechanism is the request to travel to the sender's network and back before the reservation can be established and resources effectively reserved. This leads to an additional delay. In this paper, we propose the Q3M (QoS and Micro Mobility Management) protocol to provide a set of scenarios and functionalities needed for coupling QoS and mobility management. Such functionalities can help an organization to use its network resources more efficiently, increase network performance and minimize signaling traffic.

QShine 2008, July 28-31, 2008, Hong Kong, Hong Kong.

DOI 10.4108/ICST.QSHINE2008.4096

1. RELATED WORK

Within an all-IP wireless access network, the main QoS problem is when a Mobile Node (MN) using a micro mobility protocol moves from one access router to another. The path traversed by user traffic in the network may then change. Such a change may be limited to a small segment of the end-to-end path near the extremity, or it could also have an end-to-end impact. Further, the traffic related to the ongoing user's session may start using a new source address after handover. There have been a number of QoS frameworks [2, 7, 8, 9, 10, 14, 15, 16, 17] to control QoS within an all-IP wireless networks and focus on the myriad of real problems that confront mobile network operators. More than half of these QoS frameworks are based on Resource Reservation Protocol (RSVP) [3] which is designed to perform signaling and to reserve network resources. The main problem of this protocol is that the resources reserved for a MN become valid after the MN switches to a new Access Router (AR). Therefore, it may take a relatively long time before a reservation is refreshed following a handover [1]. These solutions are loosely coupled on a wired network that requires explicit signaling for the establishment of hard state QoS. In addition, hard QoS guarantees are very difficult to achieve within the wireless networks. To solve this problem, Talukdar et al. proposed MRSVP [5]. One drawback of this solution is the excessive network resource reservations since it needs a reservation at all the neighbors of the MN's current AR that called advance reservation. Recently, HMRSVP [11] and SARAH [4] have focused on minimizing the delay introduced by the resource reservation. The two proposals require considerable modifications of the existing protocols and new QoS functionalities added to the network entities in order to support the advance reservation.

2. CRR OVERVIEW

In our proposal, only two network entities will be enhanced with QoS functions. These two key entities of the Q3M architecture are QMM (QoS and Mobility Manager) and QAR (QoS Access Router) (see Figure 1). The QMM is the key entity of network resource management and it is responsible for performing resource allocation to the customer, and releasing unused resources. The QMM is also responsible for assuring that the resources will be available. This can be done by performing the dynamic configuration of the routers. The QAR entity is the first IP-based node to which a flow originated by an MN arrives (or the last IP-based node before the MN for downlink transfers). In the micro-mobility domain, the QMM should be responsible for assigning MT (Mobile Terminating) IP traffic (addressed to the MN) to a particular class. Such categorizations are based on QoS profiles. Behind this principle, the idea is to propose an IPv6 Micro-mobility protocol that can include QoS mechanisms and a rational resource management within an operator network. Indeed, if the network has got more control of the MN handover phase then it is able to better handle the traffic congestion and the load sharing.

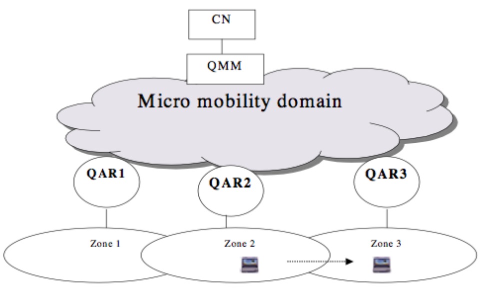

Figure 1: Network architecture

3. A CENTRALIZED RESOURCE RESERVATION

In order to enhance network performance and optimize resource utilization we propose a centralized mobility and resource management. Since the QMM has information about handover process, there is no need to wait until the soft state expires to clear the resource reservation. This enables reducing the time when the resource reservation is duplicated (i.e. at the handover procedure).

3.1 Signaling and resource reservation

The first step in establishing QoS session is, for the terminal, to exchange information on the QoS requirements. The MN initiates this procedure. The network (the QMM) may also ask the MN to initiate the QoS session establishment procedure. This may occur when a new traffic is received by QMM for MN. The different messages mixing QoS and mobility signaling are depicted in Figure 2.

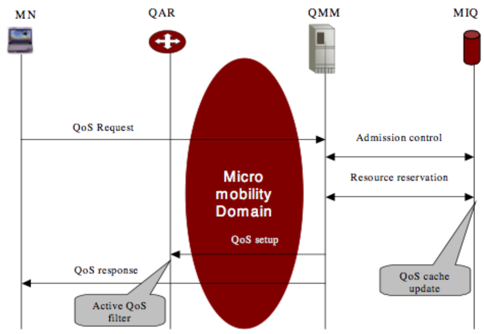

Figure 2: Central reservation concept

1. If the MN needs to initiate a QoS session, it sends a QoS request to the QMM.
2. The QMM decapsulates the QoS profile from QoS request and runs its admission control procedure.
3. If it can accept the required resource as well as the mobility registration request, it records the binding in its Binding Cache and update resource manager database.
4. In order to give the QAR the capability to control traffic, the QMM inform the QAR about the QoS class and the resource attributed to the new application.
5. In order to acknowledge both the registration and QoS requests, the QMM encapsulates the QoS class assigned to MN in a QoS response message and sends it to the MN, thus completing the resource reservation within the micro mobility domain.

3.2 Handover with resource reservation

The QMM store the resource request in a QoS cache to be able to control resource and maintain a local soft state. The QMM will always update this QoS cache based on the binding cache. This will enable to reduce signaling messages to refresh soft state. Thus, will result in more efficient usage of network resources. Figure 3 presents the flow of messages between network entities. When the mobile node deems that a handover should occur it initiates a handover procedure. After receiving the handover request, the QMM executes the admission control algorithm to choose the best target. Once the QMM has chosen the new QAR, it sends and sends backs to the MN a new Destination option called a Handover Response. After receiving a response from QMM, the MN executes a handover to the new QAR and sends acknowledgment message to the QMM. The QMM updates the QoS cache and asks the old QAR to delete any record maintained for the subscriber (see Figure 4)

3.3 MIQ database

The MIQ (Management Information of Q3M) is a part of the QMM entity. The MN sends measurement reports to the QMM. This component transfers data to the MIQ in order to be stored. Then, when the QMM receives a QoS request or handover request, a decision is made based on MIQ

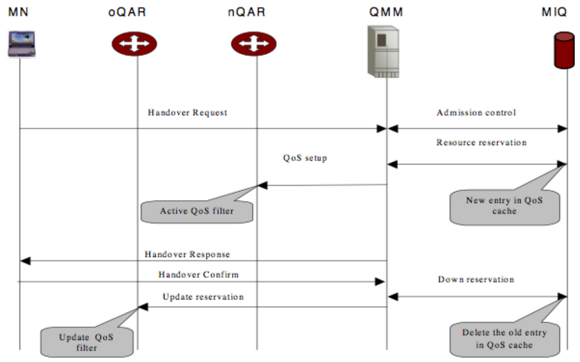

Figure 3: Handover with resource reseration

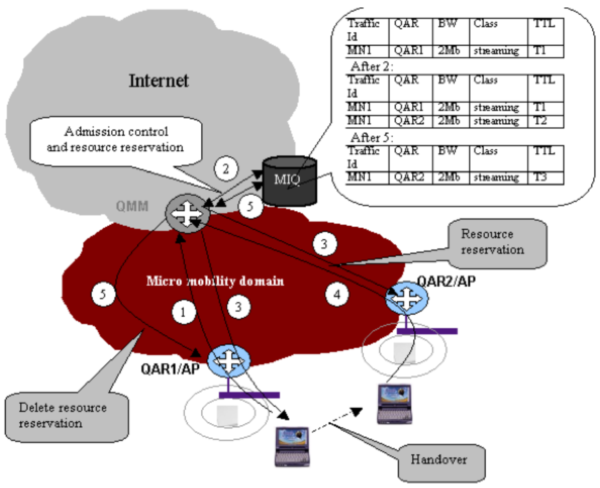

Figure 4: Resource reseration

information. The Resource Manager (RM) is responsible for updating MIQ database, so one of these main functions consists of access database. According to the database functionalities, database operations can be divided in two parts. The first part is the updating part. This component will allow inserting, updating and deleting elements while checking database integrity. The second part is a component that just selects elements into the database. Ituses the database in a reading mode.

In the QMM, the communication between different entities is shown in figure 4. The reception of a QoS request in the QMM activates a resource request to the resource manager entity. The steps involved in the resource manager entity are as follows:

3.4 QoS cache

The QoS cache aims to save the QoS session state within the micro mobility domain. In order to add robustness to our solution, the QMM periodically compare the binding cache and the QoS cache.

3.5 Local Soft Sate

Based on the QoS cache, the QMM saves the reservation state, which is controlled periodically in comparison with the binding cache (mobility state). The resource manager uses

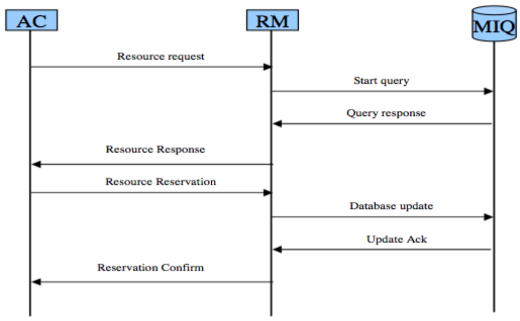

Figure 5: MIQ update

this QoS cache to update the available resources. Another important point to be noted here is that the Q3M protocol should scale well with large user number. It should also give the flexibility of update live time of an existing entry and at the same time deleting an entry before expiration time.

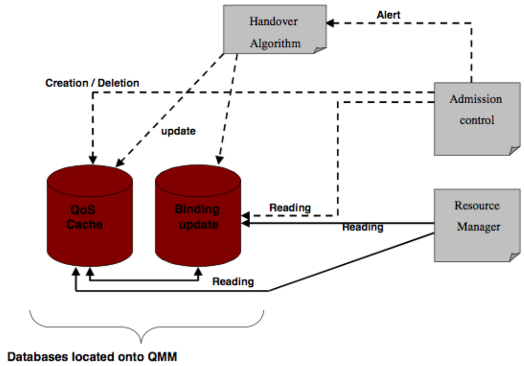

Figure 6: QoS cache

4. SIMULATION

This section presents different simulations that show the Centralized Resource Reservation (CRR) performances in a congestion state. Moreover, based on overhead traffic, we set up a comparison between our protocol and various other solutions. Simulation conducted in this study concentrated on QoS signaling problems, signaling delay and overhead. This simulation study was carried out on NS-2 (Network Simulator version-2) [12]. NS-2 is a commonly used tool among researchers for both wired and wireless network simulations. This simulator has been developed by the University of California at Berkley. In order to perform our simulations, NS-2 was extended with new C++ class definitions for the QoS signaling. The simulation scripts were written in OTcl (Object Tool command language), which is the command and configuration interface for the simulator.

The simulation network topology is shown in Figure 5. The network architecture contains a single domain and consists of a QMM, a CN (Correspondent Node), one IR (Intermediate Router) and three QAR interconnected to three access points (AP). The network is disposed in a tree structure and all internal connections are point-to-point wired links of 10 Mbits throughput and increasing delays, for each

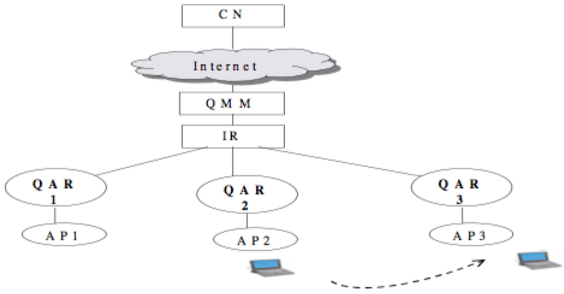

Figure 7: Simulation network

hierarchical level cluster to the QMM (respectively, 20, 10 and 20ms). Additionally, twenty MN are able to perform handover between the three QAR. In all scenarios we used a wireless link bandwidth of 10$Mbps$. Simulation is performed using CBR flows. Average packet length is 1000$bytes$.

4.1 QoS signaling scenarios

4.1.1 QoS negotiation delay

For the simulations in our study we attribute the best QoS class to the signaling traffic as a complementary solution to the coupling scheme. This technique enables the network to minimize signaling delay and minimizes loss. The first experiment evaluated QoS negotiation delay when we give priority to signaling messages. Figure 6 depicts the impact of the data traffic on signaling delay and Figure 9 depicts the impact of the congestion state on the signaling delay. Our proposal defines a new QoS class to protect the signaling traffic, Figure 7 and Figure 8 show that with this classification we can optimize signaling delay. For example, within normal network state if we assigned the best QoS class to the signaling traffic we can reduce establishment time from 850ms to 110ms (see Figure 8). Within network congestion state, we can reduce establishment time from 1s to 0.15s. Among all the QoS classes, the technical requirement of signaling traffic class is the most stringent. The stringency arises from strict upper bounds on delay and loss rate. This class is used by handover control messages and QoS negotiation messages. Thus, the goal to give the higher priority to this class is to minimize handover and QoS registration delay.

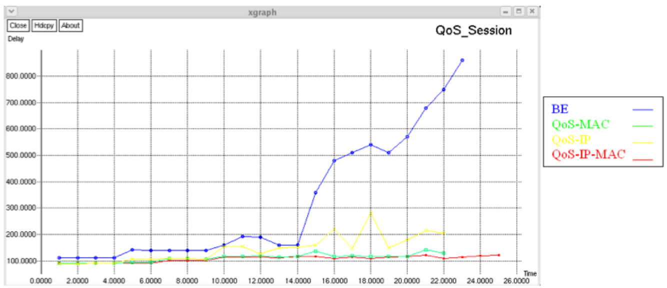

Figure 8: QoS Request without congestion

The measurement shows that the greater the amount of traffic, the poorer the signaling time; (yellow curve in Figure 8), this is around 0.55 when the 75% of network resources are used and is more then 1.3s when the 100% of network resources are used. When we assigned the best QoS class to signaling traffic, within IP and MAC layer, the QoS signaling time remained around 0.15s (see the red curve in Figure 8)

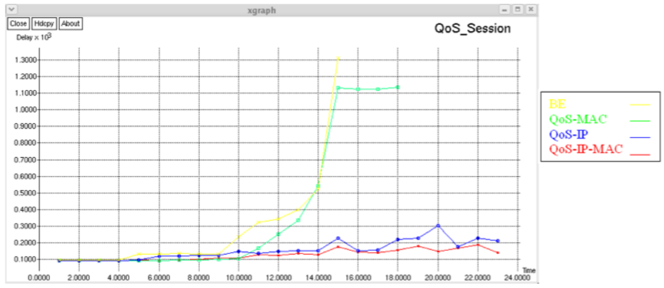

Figure 9: QoS Request with congestion state

4.1.2 QoS Transfer delay

When the network or the mobile node deems that a handover should occur, the QMM sends the QoS context to the next access routers. This QoS transfer must be lower than handover delay and could facilitate faster re-establishment of the mobile node's QoS treatment on the new QAR. Figure 10 represents the delay required to perform QoS Transfer. When the 100% of network resources are used, this delay is around 60ms (red curve in Figure 9) with Q3M and higher then 450ms without control traffic class (green curve in Figure 10). Thus, without a signaling prioritization the handover delay increases and the operator cannot guarantee seamless mobility.

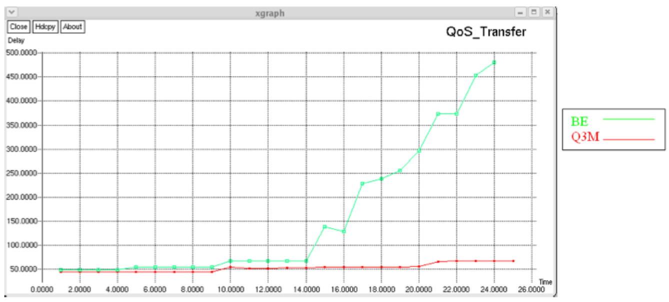

Figure 10: Transfer Delay

4.2 Traffic overhead

This scenario reveals the signaling overhead traffic of the three protocols: HMRSVP, SARAH and CRR. In the simulation settings we considered that HMRSVP and SARAH refresh their reservation soft states every 30sec, while the average time of QoS session is 5 minutes. With a higher number of QoS session in the domain, here we suppose the average number is 100 sessions, the limited bandwidth of the wireless link will be overloaded, creating serious network congestion. The CRR generates signaling traffic only when a QoS class should be negotiated between the mobile node and the CRR manager. The network continually announces the QoS classes that can be guaranteed at this moment. Receiving the QoS advertisement the mobile node decides the QoS class it wants based on the QoS advertisement and sends the request message. The CRR manager checks the request, verifies that it conforms its QoS advertisement and acknowledges it to accept the request. Otherwise, the mobile node and the CRR manager exchange only two signaling messages during QoS session. Results are shown in Figure 11. It can be shown that HMRSVP and SARAH protocols add much signaling traffic overhead. On the other hand, the CRR solution adds little or no signaling traffic overhead.

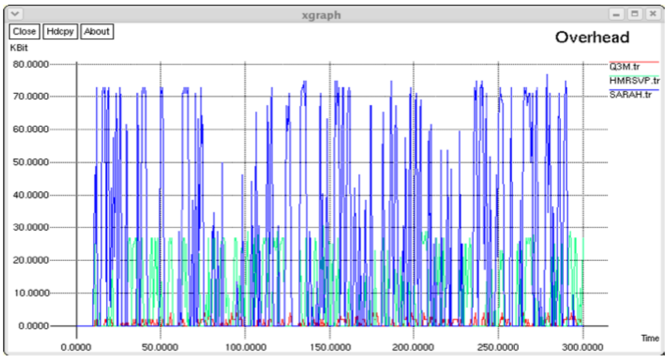

Figure 11: Signaling traffic

Conclusion

In this paper, we have studied network resources reservation in all IP cellular access networks. We have proposed a central reservation concept to enhance network performance and allow resource utilization within the access network to be optimized. We analyzed the performance of our proposal by simulation methods. The simulation results show that Q3M protocol has a good performance in terms of signaling delay and failure probability. The performances of our approach converge on very reasonable value compared to other related work such as SARAH and HMRSVP. With these proposals we duplicate resource reservation for the same session for a long period and the old access router has no information about handover process and thus must wait until the soft sate expires to teardown reservation. Within Q3M we propose to use the binding cache to refresh the reservation state in the QoS manager, thus the reservation state can be controlled without addtional signaling traffic. The state maintained by the QoS manager is dynamic; to change the set of senders or to change any QoS request, only the QoS manager refreshes reservation state. The state may be deleted at the expiration of each "refresh time out" and when the binding cache entry expires. This implies that Q3M is more efficient as a signaling protocol when the network is congested and the mobile node velocity increases. This becomes an important advantage of Q3M as well as requiring fewer changes to network operators. Moreover, the Q3M protocol enables resources utilization to be optimized. The hybrid approach of Q3M ensures that the resources reservation is not installed within each router but only in the local network manager. This entity takes a database to monitor access network load and optimize resource performance.

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