Comparative Analysis of QoMIFA and Simple QoS

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Abstract. This paper evaluates the performance of QoS-aware Mobile IP Fast Authentication Protocol (QoMIFA) compared to the well-known Simple QoS signaling protocol (Simple QoS) via simulation studies modeled in the ns2. The evaluation comprises the investigation of network load impact on both protocols with respect to the time required to reserve resources, number of dropped packets per handoff and number of packets sent as best-effort after the handoff is completed and until resources are reserved. Our simulation results show that QoMIFA is capable of achieving fast and smooth handoffs in addition to its capability of reserving resources very quickly. QoMIFA is approximately 97.75 % and 73.92 % faster than Simple QoS with respect to the average time required to reserve resources on downlink and uplink, respectively. It drops 79.63 % less on downlink and 46.6 % less on uplink and results in 98.40 % less packets sent on downlink as best-effort.

Keywords: QoS, RSVP, Mobility Management, MIFA.

1 Introduction

Ubiquitous access to information anywhere, anytime and anyhow is an important feature of future All-IP mobile communication networks, which will interconnect existing and future communication networks via a common IP core and provide higher data rates at lower costs. Achieving the goals of All-IP mobile communication networks forces network providers to overcome many challenges. A main challenge is how to guarantee suitable QoS for real-time services while moving from a point of attachment to another. In other words, how to achieve a fast re-reservation of resources during and after the handoff?.

Current IETF standard used to support mobility in IP-based networks is Mobile IP in its two versions, version 4 (MIPv4) [1] and version 6 (MIPv6) [2]. Due to the long latency resulting from MIP, it is only applicable to support global mobility, termed as macro mobility as well. To avoid the problems of MIP and to satisfy the requirements of delay-sensitive applications, various solutions for mobility management have been developed. One of the well-known solutions is Mobile IP Fast Authentication Protocol (MIFA) [3], which is capable of achieving fast and smooth handoffs. MIFA lacks, however, of supporting QoS.

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The ReSource reserVation Protocol (RSVP) is the well-known solution introduced to support QoS [4]. It enables Internet applications to obtain different QoS for their data flows by reserving resources along the path between sender and receiver. RSVP lacks, however, of mobility support.

To provide QoS and mobility management simultaneously, many proposals proposed to couple between mobility and QoS solutions, so that handoffs are executed and simultaneously resources are reserved. QoMIFA [5] is one of the best proposals achieving such coupling. This protocol integrates between MIFA as a mobility management protocol and RSVP as a solution for QoS. The idea is to introduce a new object called "Mobility object" to RSVP control messages. This object is utilized to encapsulate MIFA control messages inside, which results in supporting QoS and mobility simultaneously.

This paper aims at providing a detailed performance evaluation of QoMIFA compared to Simple QoS with respect to the time required to reserve resources on downlink as well as uplink, number of dropped packets per handoff on each direction (uplink or downlink) and number of downlink packets sent as best-effort after the handoff is completed and until resources are reserved. The performance evaluation is achieved via simulation studies modeled in network simulator 2 (ns2) [6].

The rest of this paper is organized as follows: section 2 highlights the state of the art. Section 3 presents the performance evaluation of QoMIFA compared to Simple QoS. Finally, section 4 concludes with the main obtained results and future work.

2 State of the Art

The schemes coupling between QoS and mobility solutions can be broadly classified into three categories, namely hard coupled, loose coupled and hybrid coupled solutions [7]. Hard coupled solutions attempt to extend existing mobility management or QoS protocols to simultaneously support both. Well-known example is the Wireless Lightweight Reservation Protocol (WLRP) [8]. In contrast to hard coupled approaches, loose coupled solutions separate between the protocols managing mobility and those providing QoS. However, changes occurring in one of them force performing some actions in the other. Well-known examples are Localize RSVP (LRSVP) [9], Mobile RSVP (MRSVP) [10], Hierarchical Mobile RSVP (HMRSVP) [11], Simple QoS Signaling Protocol for Mobile Hosts in the Integrated Services Internet [12], etc. Finally, hybrid coupled solutions aim at reducing the signaling burden resulting from sending mobility and QoS control messages by extending QoS control messages to include signaling for mobility or vice versa. QoMIFA is a well-known example.

WLRP utilizes RSVP to reserve resources. The Mobile Node (MN) periodically transmits reports including information about beacons received to the serving Base Station (BS), which determines based on these reports the candidate BSs the MN may move to. Following this, the serving BS requests resources for the MN to be reserved passively in each candidate BS. This ensures QoS guarantee for the MN after the handoff.

The main objective of LRSVP is to localize RSVP reservation in an access network by introducing a new proxy to split the RSVP session into two sessions. The first is between the Corresponding Node (CN) and proxy, while the second is between the proxy and MN. LRSVP introduces two new control messages to the messages known from RSVP, namely a PATH Request and PATH Request Tear message. The two messages are used to accelerate the reservation of resources on the new path and the release of resources on the old path.

MRSVP extends RSVP to understand mobility. It distinguishes between two types of resources reservation, namely active and passive reservation. The agent serving the MN is called a serving proxy, while the agents to which the MN may move from the serving agent are referred to as remote proxy agents. MRSVP functions as follows: the MN sends a Mobility SPECification message (MSPEC) to the CN. This message contains remote proxies IP addresses. The CN sends then active PATH messages to the serving as well as remote proxies. The serving proxy responds by sending an active RESV message, while each remote proxy sends a passive RESV message. Passive RESV messages result in reserving resources passively for the MN. When the MN moves to one of the remote proxies, it activates the resources reserved passively and so on.

HMRSVP integrates RSVP with MIPRR [13]. The RSVP session between the MN and CN is split in the Gateway Foreign Agent (GFA) controlling the MIPRR domain. The MN is assigned two Care of Addresses (CoAs), a Domain CoA (DCoA) and Local CoA (LCoA). The MN registers the DCoA with the Home Agent (HA). Notice that this address represents the GFA, while the LCoA represents the point of attachment and is registered with the GFA. Resources reservation outside the access network is configured for the stable DCoA. When the MN moves inside the domain, it only reestablishes the session to the GFA. To accelerate the handoff and resources reservation when movements between FAs belonging to different MIPRR domains are possible, resources are reserved passively in neighbor FAs not belonging to the current domain where the MN may move to.

Simple QoS integrates between RSVP and MIPv4. This protocol solves the problems related to packets tunneled from the HA to the MN's CoA. This is achieved by establishing an extra RSVP session between the HA and CoA to serve tunneled packets. Fig. 1 presents the handoff procedure and resources reservation on downlink. When the MN moves to a new Foreign Agent (FA), it registers the new CoA with the HA. Once the HA is notified, it establishes RSVP-tunnel between itself and the new FA. Once the CN sends a PATH message to the MN, the PATH message is intercepted by the HA and forwarded through the tunnel towards the MN. Upon receiving the encapsulated PATH message by the FA, it decapsulates and sends the message to the MN, which replies a RESV message following the same route of the PATH message. Resource reservation on uplink is totally different since the MN sends a PATH message towards the CN. The PATH message is intercepted by the first crossover router, which replied a RESV message towards the MN. Alternatively, the MN can use a reverse tunnel from the new FA to the HA.

As mentioned previously, QoMIFA integrates RSVP with MIFA. It extends RSVP through introducing a new object called "Mobility object" used to

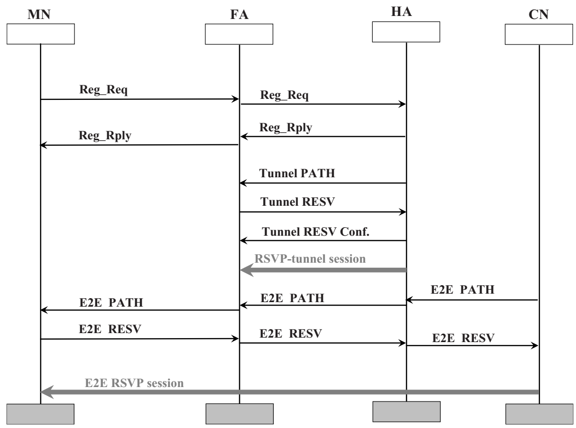

Fig. 1. Handoff procedure of Simple QoS protocol (downlink scenario)

encapsulate control messages of MIFA. The operation of QoMIFA can be briefly described as follows: the current FA serving the MN determines groups of neighbor FAs where the MN may move to from the current FA. Neighbor FAs are notified of the MN in advance of the handoff occurrence. This notification results in storing RSVP path states for the MN in each neighbor FA. Resources, however, will not be reserved passively. Once the MN moves to one of these neighbors, it sends a PATH message, containing the Registration Request(RegRqst) message encapsulated in the "Mobility object", to the new FA. The new FA in turn exchanges necessary PATH and RESV messages containing MIFA control messages with the old FA. Thereafter, the new FA sends a RESV message to the MN including the Registration Reply(RegRply) encapsulated in the "Mobility object", see Fig. 2. As a result, the uplink session between the old

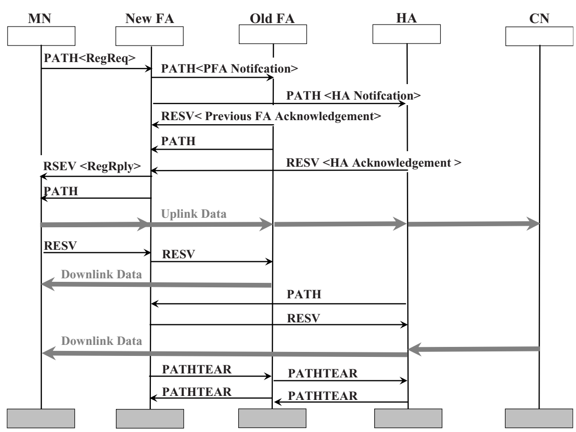

Fig. 2. Handoff procedure of QoMIFA

and new FA is established. Once the MN receives a PATH message from the old FA, it sends a RESV message to establish the downlink session. Thus, a bidirectional session is established between the old FA and MN to forward the MN's data packets until the HA is informed and a new reservation is established. After that, the old resources will be released by means of PATHTEAR message.

The main results can be summarized as follows: hard coupled solutions are more efficient. However, they are more complex and less applicable. The opposite is seen by loose coupled solutions, which are less efficient, less complex and more applicable. The best performance is achieved by hybrid solutions, which inherit the advantages of hard as well as loose coupled solutions. Table. 1 provides a detailed comparison between the approaches coupling between mobility management techniques and QoS mechanisms.

Table 1. A qualitative comparison between the approaches coupling between mobility management techniques and QoS mechanisms

RSVP problems	WLRP	HMRSVP	MRSVP	LRSVP	Simple QoS	QoMIFA
Tunneling problem	Yes	Yes	Yes	Yes	Yes	Yes
Triangular routing problem	Yes	Yes	Yes	Yes	Yes	Yes
Elements supporting QoS	MN, HA, FA, CN, all FAs	MN, HA, FA, CN, GFA	MN, HA, FA, CN, all remote Proxies	MN, AR, the proxy, cross-over node	MN, HA, FA, CN	MN, HA, FA, CN
Doubled resources during handoffs	No	No	No	No	No	No
Security	No	No	No	Yes	No	Yes
Avoiding over-reservation in all subnets	No	Yes	No	Yes	Yes	Yes
Route recovery for handoffs	Up to the old FA	Up to the GFA	Up to the anchor node	Up to a crossover-node	Up to the HA	Up to the old FA
Passive reservation	Yes	Only for inter domain handoffs	Yes	No	No	No

3 Performance Analysis

So as to evaluate QoMIFA compared to Simple QoS, both are modeled in ns2 and simulated deploying the same network topology under same assumptions. Simple QoS is selected as a candidate to compare with QoMIFA due to the fact that Simple QoS requires minimal changes to the network architecture, thus, it is simple to be employed in existing access networks. Our evaluation comprises studying the impact of network load on the time required to reserve resources, number of dropped packets per handoff and number of packets sent as best-effort until the reservation is accomplished. The following describes the applied simulation scenario and discusses the obtained results.

3.1 Simulation Scenario

The evaluation was achieved deploying a hierarchical network topology as depicted in Fig. 3.

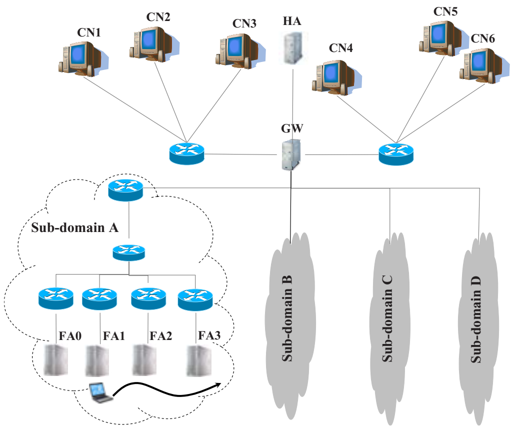

Fig. 3. Used network topology

A domain of 4 sub-domains, each has the same structure, is used. Each sub-domain includes 4 FAs. The distance between cells center of each two neighbor FAs is 198 m. A Gateway (GW) is placed on the uppermost level of the hierarchy in the domain and interconnects the domain with other nodes. The distance between the GW and each FA in the domain is 4 hops. There exist 160 MNs in the domain, 10 equally distributed MNs in the coverage area of each FA. All MNs are registered with the same HA, which is placed outside the domain. Active MNs communicate with 6 CNs placed outside the domain as well. The transmission delay on each link between each two subsequent hops inside the domain is 5 msec. The link between the HA and GW has a transmission delay of 25 msec, while the links between the GW and CN1, CN2, CN3, CN4, CN5 and CN6 have delays of 27, 23, 28, 27, 23 and 28 msec, respectively. All links have a bandwidth of 100 Mbit/s. During the simulation, an active MN is tracked. The selected MN moves from FA0 to FA15 (in sub-domain D) at a speed of 36 km/h.

As mentioned previously, we aim at a detailed analysis of the load impact. For this purpose, 80 MNs are made active, while the remaining 80 MNs stay in idle mode. Active MNs exchange constant bit rate UDP uplink and downlink streams (each has a packet arrival rate of 20 packets per second and a fixed packet size of 500 bytes) with CNs, while idle MNs only produce signaling traffic. The number of active MNs in the range of each FA is changed among 2, 3 and 4 in addition to the observed MN as depicted in Fig. 4. In order to stress the simulation results, several measurements were achieved. More concrete, each scenario was repeated 10 times, which resulted in 150 handoffs for each measurement.

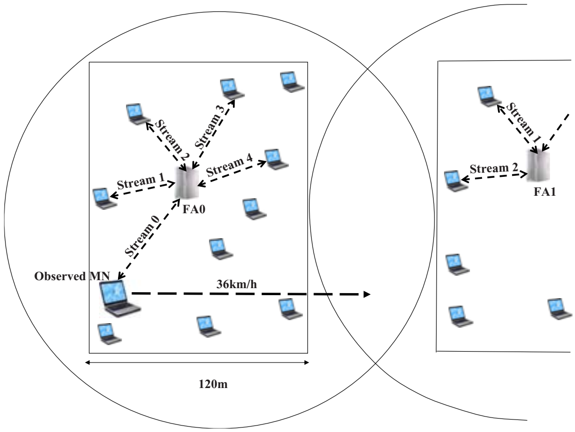

Fig. 4. Load distribution in the range of each FA

3.2 Resources Reservation Latency

Fig. 5 presents the distribution function of the time required to reserve resources on uplink when employing QoMIFA and Simple QoS. The time required to reserve resources on uplink is defined as the time duration required to achieve a handoff and reserve resources for uplink UDP streams.

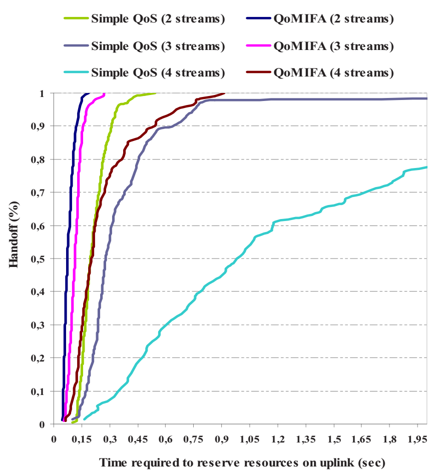

Fig. 5. Distribution function of time required to reserve resources on uplink when employing QoMIFA and Simple QoS under different network loads

This figure shows that the time required to reserve resources on uplink after the handoff employing QoMIFA is significantly reduced compared to Simple

QoS. The reason lies in the coupling between mobility and RSVP control messages in the case of QoMIFA. This coupling results in performing a handoff and simultaneously reserving resources. This is not the case for Simple QoS, which executes the handoff first and reserve resources following that. Let us consider the situation where each FA serves two active MNs, each has a bidirectional background stream on downlink as well as on uplink. While resources on uplink are reserved in less than 187 msec after all handoffs employing QoMIFA, only 43.75 % of the reservations have been accomplished in less than 187 msec employing Simple QoS. QoMIFA remains performing well when increasing the number of active MNs to be 3 in the range of each FA. Reservation of resources on uplink requires less than 187 msec in 96.22 % of the handoffs, while Simple QoS reserves resources on uplink in only 13.14 % of the handoffs in less than 187 msec. Increasing the load in the network so that 4 active MNs are located in the range of each FA, results in a deterioration of the performance of both protocols. The figure shows that QoMIFA requires no more than 187 msec to reserve resources on uplink for 44.55 % of the handoffs. In contrast, clear performance deterioration is seen by Simple QoS. According to the simulation results, the minimum latency required to reserve the required resources on uplink is 162.89 msec.

Similar results are derived from Fig. 6, which shows the minimum, average and maximum latency required to reserve resources on uplink employing the both studied protocols under the mentioned loads.

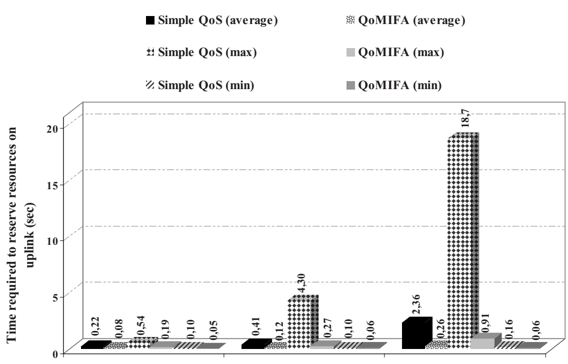

Fig. 6. Minimum, average and maximum time required to reserve resources on uplink when employing QoMIFA and Simple QoS under different network loads

Simulation results show that QoMIFA is 61.64 %, 71.2 % and 88.91 % better than Simple QoS with respect to the average time required to reserve resources on uplink after the handoff when the number of active MNs in the range of each FA varies between 2, 3 and 4, respectively. Notice that the difference between the performance of QoMIFA and Simple QoS increases as the load in the network increases, which means that Simple QoS is more load-sensitive than QoMIFA.

Let us now study the time required to reserve resources for downlink traffic, see Fig. 7, which presents the distribution function of the time required to reserve resources on downlink when employing QoMIFA and Simple QoS in the applied topology under different loads. Again, the time required to reserve resources on downlink is determined as the time duration required to complete the handoff as well as to reserve resources for the downlink UDP streams.

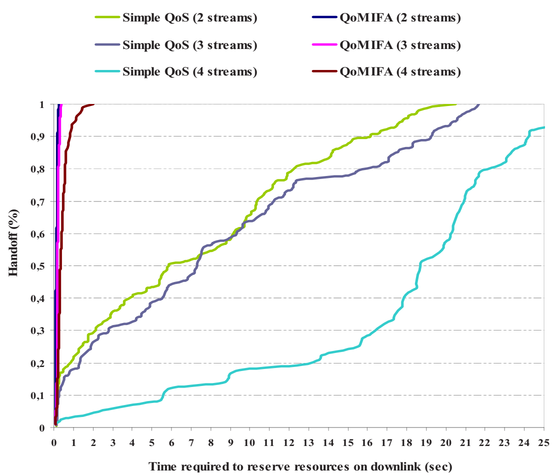

Fig. 7. Distribution function of the time required to reserve resources on downlink when employing QoMIFA and Simple QoS under different network loads

The first result that can be obtained from this figure is that QoMIFA is significantly better than Simple QoS. This is because QoMIFA requires only contacting its old FA to reserve bidirectional RSVP-tunnel between the previous and new CoA of the MN. In contrast, Simple QoS has to contact it's HA and establish RSVP-tunnel between the HA and new FA. Another result that can be observed is that the performance of QoMIFA with respect to the time required to reserve resources on downlink is comparable to its performance regarding the time required to reserve resources for the uplink traffic. More concrete, for 2 active MNs in the range of each FA, the resources on downlink are reserved in less than 247 msec after all handoffs employing QoMIFA, while only approximately 14 % of the reservations can be accomplished in less than 247 msec employing Simple QoS. QoMIFA still outperforms Simple QoS when increasing the number of active MNs to be 3 in the range of each FA. For instance, resources reservation on downlink requires less than 247 msec in 81 % of the handoffs employing QoMIFA, while Simple QoS achieves the reservation on downlink in only about 10 % of the handoffs in less than 247 msec. Increasing the load so that each FA serves 4 active MNs affects significantly the performance of Simple QoS. QoMIFA performance is affected as well, it remains, however, better than Simple

QoS. Reserving the resources on downlink requires less than 247 msec in 25 % of the handoffs when employing QoMIFA, while Simple QoS requires less than 247 msec to reserve resources on downlink in only 2 % of the handoffs.

Notice that Simple QoS performs in networks where each FA serves 2 active MNs better than when each FA serves 3 active MNs in approximately 54 % of the handoffs. For networks with 2 and 3 active MNs in the range of each FA, Simple QoS performs comparable in about 10 % of the handoffs. In the remaining handoffs, Simple QoS is better when there are only 2 active MNs in the range of each FA. This is because of the random nature of the simulation.

Simple QoS consumes significantly more time to complete the reservation for the downlink traffic than that required to reserve resources for the uplink traffic. The reason for this is that the PATH message sent towards the HA from the MN operating Simple QoS is intercepted by the crossover router existing on both the path between the HA and old FA and the path between the HA and new FA. The crossover router answers directly by a RESV message. Notice that we do not use a reverse tunnel between the new FA and HA for the uplink traffic, see [12]. On the contrary, the PATH and RESV message are exchanged between the MN and HA for the downlink traffic since the PATH message is initiated by the HA.

Similar results to those derived from Fig. 7 can be observed in from Fig. 8, which presents the minimum, average and maximum time required to reserve resources on downlink employing QoMIFA and Simple QoS under the mentioned loads.

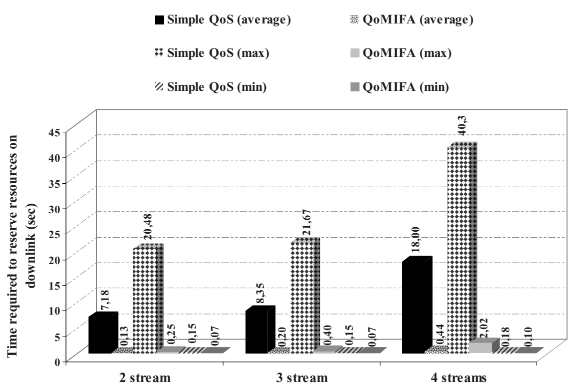

Fig. 8. Minimum, average and maximum time required to reserve resources on downlink when employing QoMIFA and Simple QoS under different network loads

The figure shows a significant performance improvement employing QoMIFA compared to Simple QoS. The reason has been discussed above while discussing Fig. 7. According to the simulation results, QoMIFA outperforms Simple QoS by 98.16 %, 97.56 % and 97.53 % with respect to the average time required to reserve resources on downlink after the handoff when the number of active MNs in the range of each FA varies between 2, 3 and 4, respectively. Again, this figure shows that QoMIFA is less load-sensitive than Simple QoS. The main reason behind this behavior is that QoMIFA requires only contacting its old FA and reserve resources between this old FA and the new one. Thus, only the load between the old FA and new one is of importance for QoMIFA. For Simple QoS, control messages should climb up to the HA. Therefore, the load in the core network affects strongly the performance of Simple QoS.

3.3 Number of Dropped Packets

Fig. 9 shows the minimum, average and maximum number of dropped packets per handoff on uplink employing QoMIFA and Simple QoS in the used topology under the mentioned loads. The results show that QoMIFA performs 51.26 %, 37.64 % and 50.91 % better than Simple QoS when the number of active MNs in the range of each FA varies between 2, 3 and 4, respectively. This is because QoMIFA performs the registration and reservation of resources simultaneously, while Simple QoS performs the handoff first and reserves resources on uplink after that.

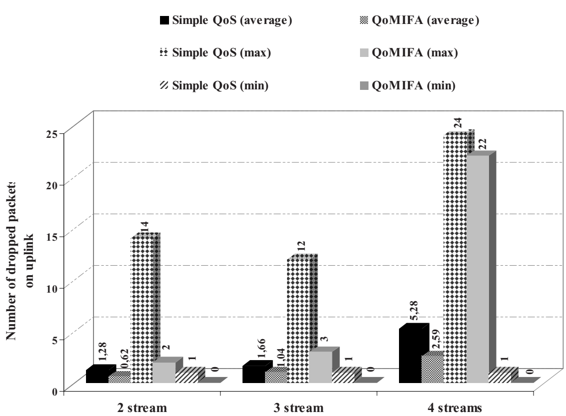

Fig. 9. Minimum, average and maximum number of dropped packets per handoff on uplink resulting from employing QoMIFA and Simple QoS under different network loads

Fig. 10 shows the minimum, average and maximum number of dropped packets per handoff on downlink employing QoMIFA and Simple QoS in the used topology under the mentioned loads. Notice that the average, minimum and maximum number of dropped packets per handoff increase while increasing the load. This is also expected since the handoff latency increases as network load increases, thus, more packets get lost during the handoff. The figure shows also that Simple QoS results in significantly more dropped packets than QoMIFA under all studied loads. The reason behind this behavior is the fast handoffs

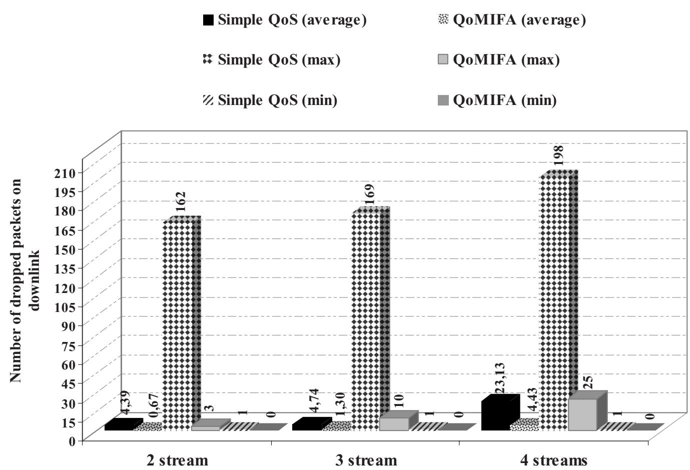

Fig. 10. Minimum, average and maximum number of dropped packets per handoff on downlink resulting from employing QoMIFA and Simple QoS under different network loads

achieved by QoMIFA that only requires, as mentioned previously, contacting its old FA. In contrast, Simple QoS registers with the HA each time the MN moves in the network. The registration with the HA consumes long time especially if the network is high loaded. According to the achieved results, QoMIFA performs 84.71 %, 72.52 % and 80.86 % better than Simple QoS when the number of active MNs in the range of each FA varies between 2, 3 and 4, respectively.

3.4 Number of Best-Effort Packets

This section analyzes the number of packets sent toward the MN as best-effort packets. As known, best-effort packets are the packets sent to the MN after the completion of the handoff and until the resources for downlink traffic are reserved. Fig. 11 shows the minimum, average and maximum number of packets sent on downlink as best-effort employing QoMIFA and Simple QoS in the applied network topology under the mentioned loads.

The figure shows that the number of packets sent as best-effort employing QoMIFA is minimized. This is because of the coupling between mobility support and resources reservation in QoMIFA. The old FA gets informed as it receives the PATH message from the MN via the new FA. It starts, therefore, at this time sending packets as best-effort and simultaneously reserves resources for the downlink traffic. Due to the fast reservation QoMIFA achieves, only few packets are sent as best-effort. In contrast, the MN operating Simple QoS registers first with the HA. After the HA gets informed, it begins forwarding data packets as best-effort to the new CoA of the MN. After the MN completes the handoff, it starts reserving resources for the downlink traffic. This consumes, of course, a considerable time, which in turn results in forwarding considerable amount

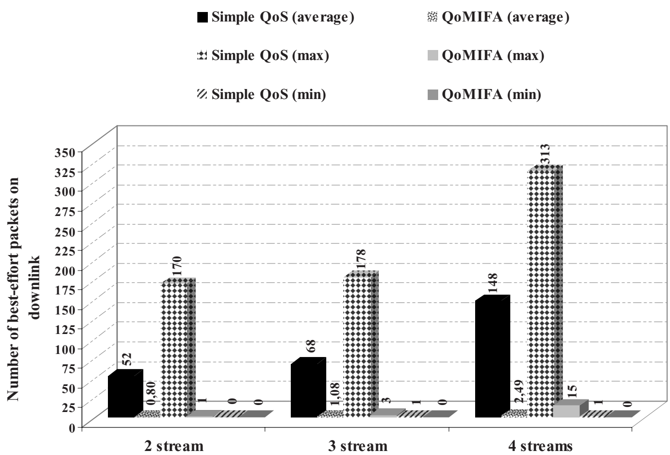

Fig. 11. Minimum, average and maximum number of best-effort packets sent on downlink when employing QoMIFA and Simple QoS under different network loads

of data packets without QoS guarantee. Clearly, this degrades the performance and is not desirable. According to our simulation results, Simple QoS forwards approximately 98.41 % more packets as best-effort than QoMIFA does.

4 Conclusion

In this paper we have evaluated the performance of QoMIFA and Simple QoS under different loads. The evaluation has been achieved by means of simulations for both protocols using ns2. The evaluation comprises the investigation of network load impact on both protocols with respect to the time required to reserve resources, number of dropped packets per handoff and number of downlink packets sent as best-effort after the handoff is completed and until the resources are reserved.

Our simulation results have shown that QoMIFA is capable of achieving fast and smooth handoffs in addition to reserving resources very quickly. This is due to the hybrid coupling between MIFA and RSVP, which enables a simultaneous support of mobility as well as QoS. QoMIFA outperforms Simple QoS under all studied loads. It reserves resources very quickly, minimizes the number of dropped packets per handoff and minimizes the number of packets sent as best-effort. Our results have shown that QoMIFA is approximately 97.75 % and 73.92 % faster than Simple QoS with respect to the average time required to reserve resources on downlink and uplink, respectively. For the average number of dropped packets per handoff on downlink and uplink, QoMIFA is 79.63 % and 46.6 % better, while regarding the number of packets sent as best-effort on downlink, QoMIFA is approximately 98.40 % better.

Currently, we are studying the impact of the network load on TCP throughput. Moreover, we are investigating the impact of MNs speed on the performance of both protocols deploying UDP as well as TCP traffic.

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