

A Dynamic QoS Provisioning Model for Network Mobility

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Abstract– This paper proposes a dynamic QoS provisioning model for network mobility. The basic idea of network mobility (NEMO) is to keep connectivity whilst the network changes its point of attachment. To achieve this, sufficient resources need to be provisioned for the entire mobile network. In our model, the packets are prioritized and classified according to the services they are subscribed to i.e. premium services or user services. Packets that are marked according to the traffic classes are then aggregated as a single request in a QoS Object in the packet header which is then sent along with the NEMO binding update message for resource reservation. QoS agents in the mobile router and access router determine whether to either send the QoS Object as a destination option or hop-by-hop option.

I. INTRODUCTION

In the next generation of network, more interactive applications are expected to be carried by mobile users such as video chatting, real time video gaming, and voice over IP, at any time and any where. In a mobile network, the frequent mobility of the users implies more difficult challenges to provide a Quality of Service (QoS) guarantee. Therefore, ideally resources should be provisioned before the handover process to eliminate the packet drops due to insufficient resources.

There are a number of studies in the area of QoS provisioning where Integrated Services (IntServ), Differentiated Services (DiffServ) and Resource Reservation Setup Protocol (RSVP) mechanisms are applied in the context of mobile networks. Reference [1] proposes a signaling protocol for mobile users for QoS negotiation per flow. A bandwidth broker is used at several domains to provide reservation for the mobile users when they roam. Reference [2] looked at the advantages of IntServ and DiffServ to support QoS in mobile IPv6.

The basic concept of network mobility is to keep connectivity whilst the network moves. Therefore, in order to provide the connectivity, the most important issue is to make sure that the visiting network is able to provide sufficient resources to the mobile network. Ideally, the reservation process should be done before the handover process. If the visiting network is unable to fulfill the requirements, the mobile network should find the nearest network to attach to which can accept the requirements.

In this paper, we proposed a set of general Quality of Service (QoS) requirements for network mobility. The idea is then applied to our proposed mechanism, i.e. a dynamic QoS provisioning model. We choose a rail network scenario to

apply the dynamic QoS provisioning mechanism to. The rail network domain is divided into a node domain and a network domain. The node domain consists of the mobile network nodes and the mobile routers whilst the network domain consists of the access router, home agent and correspondent node. The resources are provision before the handover process that is before the mobile network changes its point of attachment and after the handover where the resources are provision for the specific traffic classes. The DiffServ mechanism is modified to fit our approach. A default QoS value is allocated for new mobile routers or mobile network nodes that attach to the mobile network before identifying the services subscribed. This value is also allocated if there is any changing path at the intermediate network domain.

The QoS object is sent along with a binding update message which carries important information such as QoS requirements for the aggregated traffic classes, information of traffic volume, packet classification and packet marking for the particular mobile network nodes packets, based potentially on the types of the application used.

The rest of the paper is organized as follows. Section II discusses the basic concept of the network mobility protocol NEMO Basic Support. In section III, we discuss the related projects that have implemented the NEMO protocol in difference contexts. Section IV looks at the area of QoS. Firstly it describes two standards defined by IETF, IntServ and DiffServ. Secondly it provides a proposed set of QoS requirements for network mobility. In section V, we proposed a dynamic QoS provisioning model which is then applied to a rail network context. Finally, the paper concludes in section VI.

II. BASIC NEMO PROTOCOL

The Internet Engineering Task Force (IETF) has developed protocols to support mobility, i.e. Mobile IPv4, Mobile IPv6 and Network Mobility (NEMO). NEMO Basic Support protocol [3] is an extension of Mobile IPv6 for network mobility whilst the network moves and remains connected to the Internet. A special device called Mobile Router (MR) acts as a gateway for the mobile networks to provide a connection to the mobile nodes behind it. The mobile network nodes can be mobile or fixed. Types of mobile nodes that can be supported by the MR are local fixed nodes, local mobile nodes and visiting mobile nodes. The local fixed nodes (LFN) are the nodes that cannot be moved and are supported by the MR to achieve connectivity. These nodes have the same home agent as the MR. The nodes that can be moved and belong to the

mobile network as its home network are called local mobile nodes (LMN). The visiting mobile nodes (VMN) are the nodes that attached to the mobile network on a temporary basis and do not belong to the mobile network.

Consider figure 1 as a mobile network in a real-world situation. A public transport bus forms a mobile network (MN) which consists of multiple mobile network nodes (MNNs), where the passengers carry mobile devices and a MR as a gateway to keep the connectivity to the MNNs behind it. The MR performs a registration process when the bus at the bus station moves from its home network and attaches to a different network, i.e. a visiting link. The MR acquires a Care-of Address (CoA) from the visiting link. The CoA is a temporary address provided by the visiting link to the MR. Once the MR receives the CoA, it sends a binding update (BU) message to its home agent (HA) in the home link. The HA receives the BU message and creates a cache entry binding. The HA replies the BU message with a positive binding acknowledgement (BA). After the registration of the temporary address is complete, a bi-directional tunnel is established between the HA and MR where any packets from the correspondent node (CN) or MNNs are flows via the bi-directional tunnel. If a new passenger step into the bus bring along her PDA (i.e. a visiting mobile node) which configured with mobile IPv6, it can access the Internet through the mobile router in the bus. However, the VMN has a different home network from the mobile router therefore a bi-directional tunnel between the VMN and VMN's HA should be established. The processes involved are the same way as explained above.

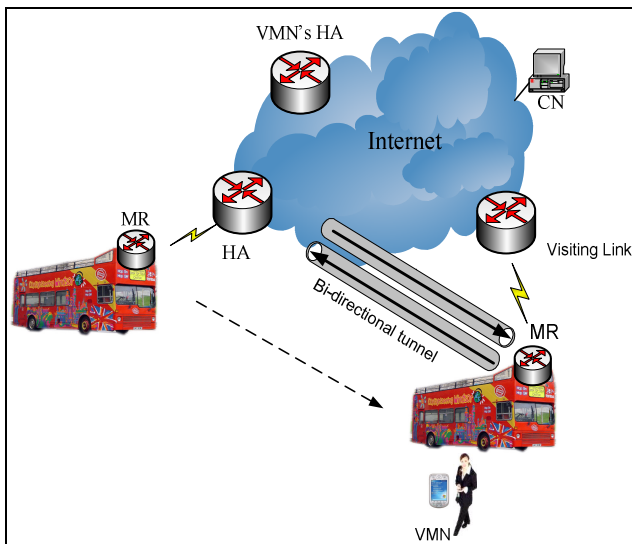


Fig.1. Establishment of bi-directional between HA and MR

III. RELATED WORK

In recent years, a number of projects have looked at the implementation and deployment of the Network Mobility (NEMO) Basic Support protocol.

The Nautilus6 group has shown its interest in the NEMO Basic Support protocol through their projects called E-Bicycle,

E-Wheelchair and E-Backpack [4]. In their recent publication on E-Bicycle [5], the group has demonstrated their project in Japan where the results were successful. The E-Bicycle project has a Personal Area Network (PAN) which consists of a Mobile Router (MR). The MR was configured using NEMO to keep connected to the Internet. The MR has multiple interfaces such as Ethernet, IEEE802.11b, 2G/3G cellular cards in order to form a multihomed mobile network. The mobile network nodes in the PAN included the PDAs and the IPv6 sensors. The sensors were used to detect the current location of the bicycle and the conditions of the surrounding areas of the cyclist; temperature, humidity and geo-location. There were also an IPv6 camera and a laptop to get the pictures of the cyclist and communicating with the cyclist using VoIP. The NEMO Basic Support protocol provided the on-going connectivity to all the mobile nodes through the MR. The demonstration showed that the NEMO Basic Support protocol worked well as the bicycle moved.

In contrast to the E-Bicycle project, the InternetCar project was initiated by a different research group at Keio University [6] to study the consistency of routing information. The InternetCar was a mobile network that consists of the computers and the sensors for the passengers. The multi-hop communication between vehicles was eliminated in this project. The utilization of Optimized Link State Routing (OLSR) in vehicle-to-vehicle and vehicle-to-road networks is used for short range communication, whilst the NEMO Basic Support protocol is used for wide-range communication. The importance of the short-range communication or vehicle-to-vehicle communication was to update the traffic information or any unpredictable events that occurred on the road. A policy routing management approach is used to avoid a conflict between the OSLR and NEMO protocols. A route management module and the policy based routing module solved the protocol conflict in the InternetCar system because it intelligently identified which protocol should be used between the OSLR and NEMO.

Another NEMO protocol implementation was from the University of Technology, Helsinki [7]. They proposed a mobile hotspot architecture which consists of a mobile router and the mobile network nodes. The mobile nodes are either local fixed nodes (LFN) or visiting mobile nodes (VMN). They implemented this prototype on a Linux platform and analysed the performance of the prototype, for example the MR handover speed, routing and protocol header overheads. The five main processes contributing to the handover latency in layer 2 and layer 3 are as follows:

- 1) Process of the MR finding the access point
- 2) Registration of the new Care-of-Address (CoA) to the HA
- 3) Performance of the Duplicate Address Detection (DAD) by the MR
- 4) Round-trip-time (RTT) and
- 5) Time set to perform the proxy DAD.

However the tests were not accurate in terms of router discovery delays because they were using Fast Router Advertisement (their proposed route optimization technique). The technique did not wait a random time to reply to the

Router Solicitation (RS) message [8]. One of the route optimization techniques was the Optimistic Duplicate Address Detection (ODAD). The ODAD alleviated the delay process in handover where the mobile node did not have to wait for a response to get a new CoA. The technique proposed achieved a greater level of performance.

IV. QUALITY OF SERVICE

The Internet Engineering Task Force (IETF) developed two Quality of Service (QoS) architectures, Integrated Services (IntServ) and Differentiated Services (DiffServ). IntServ is designed to be applied to Best-Effort traffic in Internet networks where the common theme is to reserve resources for different types of application, on a per-flow basis. In the context of IntServ, the QoS refers to the delivery of data packets which are distinguished by bandwidth, packet delay and packet loss parameters. A signaling protocol named Resource Reservation Protocol (RSVP) was designed to support the “controlled load” and “guaranteed” services and to meet the QoS requirements for a specific traffic flow. In 1997, the IETF began the development of a new QoS architecture named Differentiated Services (DiffServ), a more simple and scalable approach to QoS provisioning than IntServ [9]. The primary goal of this architecture is to offer services to aggregated service classes (rather than on a per-flow basis). Traffic is treated according to its class using parameters such as per-hop behavior, traffic limits and out-of-profile handling.

A. Integrated Services

The Integrated Services (IntServ) mechanism is defined to provide resource reservation in the Internet. The basic approach is to set up a reservation path between a sender and a receiver. The sender sends a request by characterizing the application into traffic flows and specifies the QoS requirements of the flows. The request is accepted if there are enough resources. Once the reservation set up is established the applications can send the packet along the reserved path.

The IntServ model focuses on resource reservation and admission control mechanisms. A reservation setup protocol, i.e. RSVP is used to set up the reservation along the path. Information about the traffic characterization determines whether the new reservation request can be granted or not. The admission control monitors and measures the allocation of the resources in the network. This process is performed before the reservation can be accepted.

Two service models have been standardized in IntServ, i.e. the Guaranteed service and the Controlled-Load service. A Guaranteed service (GS) provides a bandwidth guarantee and end-to-end delay bound. The service is intended for applications such as real-time video and audio streaming. This service is invoked by two specific parameters that are the traffic specification (TSpec) and reservation specification (RSpec). To determine the exact amount of bandwidth required for particular applications is difficult. However, certain applications do not need a resource guarantee where it can tolerate to lower level of resources but still provide a better

service. This is where the controlled-load service is standardized as another option.

B. Differentiated Services

Differentiated Services (DiffServ) offers a simpler solution by considering aggregates of traffic, rather than flows. In a DiffServ network there are two basic tasks that need to be accomplished, packet classification and traffic conditioning. These tasks are performed at the boundary router and internal router. The packets are marked into different classes and forwarded according to forwarding classes in the packet header. The DiffServ architecture defines forwarding treatments for each forwarding class. The forwarding classes obtain the resources through provisioning and prioritization. The customers and service provider have a privileged agreement through a Service Level Agreement (SLA). This agreement is important to determine the specific details of the services for the customers.

Per-hop behaviors (PHB) are defined for an external observable forwarding treatment at a single node. Each PHB is represented by a 6 bit Differentiated Services Code Point (DSCP). All packets with a same DSCP are treated with the same forwarding treatment. Multiple PHBs form a group of PHBs. There are two PHB groups, Expedited Forwarding (EF) [10] and Assured Forwarding (AF) [11]. EF PHB group is defined to create a low latency, low loss, and assured amount of bandwidth. Packets marked with the EF DSCP get the highest priority in the system. In AF PHB, each forwarding class is allocated a minimum bandwidth. To ensure that not all packets drop because of limited bandwidth, three drop priorities are defined. Packets with the highest drop precedence are dropped first if there is network congestion due to insufficient bandwidth. Dropping packets only occurred in the forwarding class if it exceeds its own resources.

C. Quality of Service Requirements for Network Mobility

There are many proposed ideas and frameworks for Quality of Service (QoS) in mobile or wireless communications, but not much work has been done in the area of network mobility. A handover process occurs when a mobile network moves to a new point of attachment. This may cause QoS degradation or force a service termination if there are insufficient resources in the network during the handover process.

An internet draft written by TLais [12] proposed a QoS guarantee in NEMO networks. The authors referred to IntServ and DiffServ advantages to propose a new protocol named the NEMO Reservation (NEMOR) protocol. The NEMOR that support the RSVP signalling is used to reserve resources for the aggregated flows.

The QoS models defined by the Internet Engineering Task Force (IETF) for the Internet such as Integrated Services (IntServ) and Differentiated Services (DiffServ) may or may not work in a network mobility environment. QoS requirements for the mobile IP protocol were defined in [13]. Here we extend this work to propose a set of general QoS requirements in the context of NEMO.

1) Default QoS value

A default QoS value is used to minimize interruption during a handover process at the intermediate node i.e. access router. If a packet sent by a correspondent node to a mobile network node during a handover arrived at a new access router that has no information about the QoS requirement, the packet will receive a default QoS value from the access router. If a new mobile router or mobile node attaches to another mobile network (i.e. a nesting of networks occurs), its packet will be treated as Best Effort where it gets a default value before the main router collects QoS requirements information from each node or each application.

2) QoS (re)establishment

In the network mobility context, after the handover process, the affected paths are from the mobile router to the access router and from the access router to the home agent. If QoS (re)establishment happened at these areas, the QoS provisioning should be performed at the affected paths only. However, double resource reservation should be avoided.

3) QoS release

After the handover, a QoS release of the old path should be performed. Once the access router detects that the attached mobile network has changed its points of attachment, the access router and the mobile router agree to release the reservation.

4) QoS mechanisms in heterogeneous networks

If the mobile network attached to the access router of a DiffServ network needs to handover to a new access router of an IntServ network, the QoS mechanisms can be mapped along the different packet paths. If the intermediate network domains use difference type of network protocol, i.e. MPLS, DiffServ or IntServ, mapping mechanisms are applied to ensure the QoS Object in the BU/BA message is able to accept the differences.

V. DYNAMIC QOS PROVISIONING MODEL

In this section we proposed a dynamic QoS provisioning model for network mobility. We focus on the resource reservation approach of prioritizing packets. We choose a rail network scenario showing how resources are provision for mobile network nodes on a train.

A. Assumptions in Rail Network for QoS Provisioning

In this section we introduce a number of assumptions that we have made when considering the rail network scenario. In terms of timetabling, there are two situations that may happen, services that run during peak hours and services that run during off peak hours. The peak hour trains may run on weekday mornings and evenings, whilst the off peak trains may run during the weekends, the holidays or the late evenings. Therefore, in this context, traffic patterns are almost the same for that particular time and the train moves from one station to another at a consistent rate. The resources should be reserved before the train moves to avoid packet drop.

In our model, we have divided the network into two domains, the node domain and network domain. The node domain consists of the mobile router and the mobile network nodes which then form a mobile network. The network domain consists of the access points (APs), access routers (ARs), home agent (HA) and correspondent node (CN).

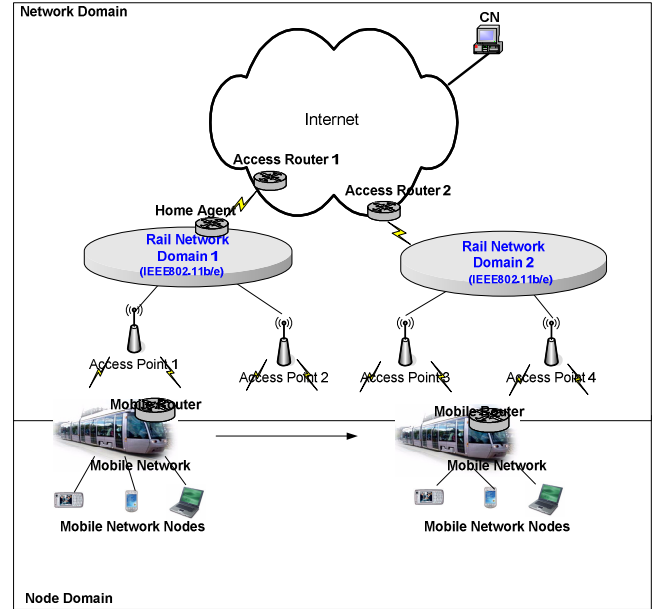


Fig. 2. Rail mobile network

The process of resource provisioning is divided into two, provisioning before a handover process and after a handover process. The resource provisioning before the handover is done at the network domain, where the mobile router changes its point of attachment from one rail network domain to another rail network domain. After the handover, the provisioning is done at the node domain where the router needs to allocate resources for each traffic class.

Regarding resource provisioning, we assume that:

- The rail network owns an Internet service where multiple access points (APs) are available along the railway which creates multiple rail network domains. The rail network provides wireless environments to the mobile train.
- A home agent is located in one of the rail network domains, e.g. rail network domain 1 as shown in figure 2.
- There might be other service providers available in between of the rail network domains. The mobile network may connect to this network when the train loses the connectivity from its AP.

With the above assumptions we now apply the QoS provisioning model to the rail network.

B. Node Domain

In the rail network, a mobile network is a train and mobile network node can be a passenger with a laptop, a personal digital assistant (PDA) or a mobile phone. A mobile router that is configured with NEMO Basic Support protocol is placed on the train to provide the connectivity to the passengers. To use the Internet services on board, the rail mobile network offered

two types of services which are a user-subscribed and a nonuser-subscribed. The subscriptions can be on a monthly or yearly basis depending on how frequently the user uses the train services. The passengers who subscribe to the service are offered a premium service at a cheaper rate. The passengers that are not subscribed to the services have to pay at a different price which is more expensive than the subscriber passengers.

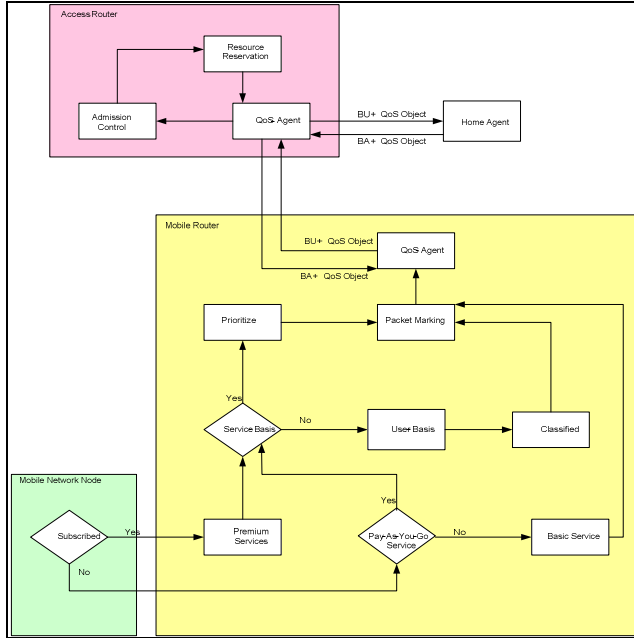


Fig. 3 Dynamic QoS-Provisioning model

As shown in a figure 3, the main entities that involved in the processes are the mobile network node, mobile router and access router. In a mobile network node, a user-subscription or nonuser-subscription process is identified in here. In the mobile router, the process of subscription or nonsubscription is done at three separate modules that are the Premium service, Pay-As-You-Go service and Basic service. From the service-basis module, the packets are prioritized in a prioritize module and marked in a packet marking module before send to the QoS agent. For the user-basis subscription, the packets are classified before the packets are marking. The three modules involved in the access router are the QoS agent, admission control and resource reservation. The admission control monitors and measures the available resources before reservation is made. The resource reservation module is used to reserve the required amount of resources for the particular traffic classes and as well as to reserve a default amount of resource for a new node.

1) Premium Service

The premium service is categorized according to a service basis and user basis. The packet which is marked on the service basis is prioritized according to DiffServ services such as Expedited Forwarding (EF), Assured Forwarding (AF) and Best Effort (BE). EF is suitable for real-time applications such as Voice over IP (VoIP) where it provides low loss, low latency and assured bandwidth. AF is suitable for one way

voice or video where it offers forwarding assurance for packets. BE is not resource guaranteed and so it depends on the available resources. If the user is subscribed to the user-basis, the packet is classified according to the user level, i.e. a higher level user, a secondary level user or a lower level user.

2) Pay-As-You-Go Service

If the passengers are a nonuser-subscriber, they are offered a Pay-As-You-Go service where it is classified as a service-basis. An extra charge is applied for this service which is higher than that for a user-subscriber. The packets are categorized and the processes performed are the same way as with the Premium Service.

3) Basic Service

If the users neither subscribed to the premium service nor the Pay-As-You-Go service, their packets are categorized as a Basic Service. In this service, the packets are treated equally and the requests are granted according to the available resources.

C. Network Domain

1) QoS Object

Chaskar and Koodli [14] proposed a QoS Object option for QoS support in Mobile IPv6. The option is used to determine whether the QoS object is treated as a destination or hop-by-hop option. There are three important fields, QoS requirement, traffic volume and packet classification. The QoS requirement is used to describe the requirement of traffic classes for mobile network nodes. The traffic volumes are to indicate the amount of traffic the packet will generate such as the average data rate, burstiness, peak data rate, minimum policed unit and maximum packet size. The packet classification consists of five parameters including TCP / UDP port numbers, source address, destination address and IPv6 flow label, where the packet classification field provides the values for these parameters in the packet headers. However, we modified the QoS object to fit in our proposed mechanism by adding another field, the packet marking field.

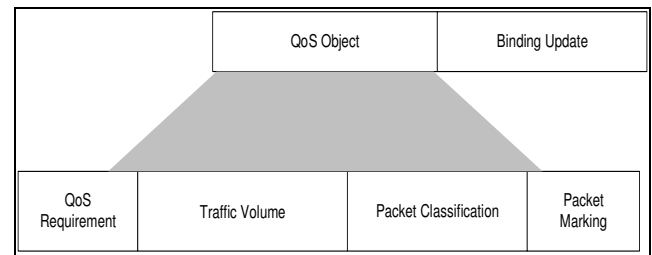


Fig. 4 QoS Object fields

The four important fields in the QoS object are shown in figure 4. These parameters are used to determine the mobile network node's packet after the classification process. The prioritized packets from the service basis are marked according to the application flow such as audio stream, video stream or non real-time applications. Whilst, the classified packets from user basis are marked according to the user level subscription,

i.e. a higher level user, a secondary level user or a lower level user.

2) QoS Agent

The packets in the same traffic classes are aggregated into one QoS Object. The QoS agent module in the mobile router sends the uplink QoS object as a destination option. The uplink streams are from the mobile network nodes to the mobile router and the mobile router to the home agent. The binding update (BU) message and QoS object are sent to the home agent at once. The home agent updates its cache entry binding with a positive acknowledgement. Once the home agent accepts the BU message, it will change the QoS object to a hop-by-hop option and send it back to the mobile router together with a Binding Acknowledgement (BA). The hop-by-hop option is used to inform the intermediate routers along the paths to make resource reservations based on the QoS requirements stated in the QoS requirements field of the QoS object. The resource reservation is only happened at the downlink path, i.e. from the home agent to the mobile router and from correspondent node to the mobile network nodes. However, if an intermediate router cannot accept the request, it will negotiate by setting a default QoS value for the particular traffic class. The QoS default value is not only used when the intermediate routers cannot accept the requirements, but it is also used if there are any changes in the path taken through the intermediate routers. The access router where the mobile network is attached uses the QoS agent module to re-establish the QoS support when the paths change.

3) Admission Control

Admission control in the access router determines whether a new reservation can be granted and measures the available resources for the particular traffic class. The QoS agent sends an aggregated packet according to its traffic class to request the resource reservation. The QoS agent functionality allows dynamic resource allocation for aggregated traffic where it can adjust the requirements based on the estimated traffic during the peak hour or off peak hour services. The QoS agent in access router negotiates with the mobile router's QoS agent to control the resources. The resource usage during the peak hour trains are higher than the off peak hour trains, therefore before the train moves or leaves the station, the QoS agent is able to estimate the amount of resources that need for the next attachment (i.e. an access point).

When the mobile network changes its point of attachment, the QoS reservation along the uplink and downlink path must be released. The QoS agent at the mobile router and access router should agree about the termination and release the reservation. The QoS release only occurs at the network domain. If the train moves from one access point (AP) to another AP that is attached to the same rail network domain, no QoS release should be performed.

VI. CONCLUSION AND FUTURE WORK

The generic QoS requirements proposed in this paper are defined to provide QoS support for network mobility. A frequent change of mobile network and its mobile network nodes implies significant difficulties in providing constant resource reservations. Therefore, the idea of providing a dynamic QoS provisioning model based on traffic patterns gives a good solution. The aggregation of QoS requirements according to the traffic classes in a QoS Object option provides scalability. The packets are marked to identify the mobile network node's packet and also types of applications that belong to the nodes. The resources are provisioned at the node domain and network domain to eliminate packet dropping during the handover. Based on the traffic pattern in the rail network, resources are reserved to guarantee uninterrupted during the handover process.

In the future, the proposed model needs to be simulated using a simulator tool such as OMNeT++ or NS-2 to show that our dynamic QoS provisioning model works well in the network mobility context. We also plan to extend the model and look at whether it fits if the mobile network gets more complex (i.e. a nested mobile network).

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