Efficient mobile multicast with QoS support using context transfer

Ilka Miloucheva[1], Olaf Menzel[2]
Fachhochschule Bonn-Rhein-Sieg[1], Fraunhofer SATCOM[2],

Abstract

There is a challenge for optimised Quality of Service (QoS) support of multicast services in mobile IPv6 infrastructures based on heterogeneous wireless networks.
Efficient technologies are required able to support:

- Seamless handover and
- "Optimal" decisions for selection of access networks for mobile services, according application and network QoS criteria.

To ensure seamless operation of multicast transport services, the Context Transfer protocol is used, which is currently a focus of standardisation in IETF [LMPK 04]. Another protocol under standardisation, i.e. the Candidate Access Router Discovery (CARD) protocol, is used to choose "optimal" access networks based on the mobile node's requirements for Candidate Access Router (CAR)'s capabilities [LSCFS 04].
This paper describes different open issues for design and development of efficient mobile multicast services with QoS support. The work is based on the mobile QoS architecture for seamless integration of heterogeneous wireless networks and broadcast media in IPv6 environment, developed in EU IST project DAIDALOS [DAIDALOS].
The main focus is the seamless handover based on efficient context transfer of mobile multicast services for source specific and any source multicast applications. The multicast context transfer depends on the kind of mobility: client (multicast receiver) and sender (multicast source) mobility, as well as on the requirements for QoS support with resource reservation of the multicast communication.
Directly interacting with the seamless handover, are the management strategies for selection of new access network with capabilities, which are optimised in respect of the preferences of the mobile node.
The paper addresses protocols and data structures, as well as QoS management issues aimed to optimise the context transfer for mobile multicast clients.
Attributes describing the capabilities of access networks used for multicast handover decisions, as well as QoS management strategies for active learning of access router performance parameters for optimised multicast client mobility are proposed.

Keywords

Seamless handover, QoS, access network, active learning, mobile multicast, context transfer, CARD

1 Introduction

Architecture for QoS support of wide range of mobile QoS based applications and services in IPv6 environment including heterogeneous wireless technologies and broadcast media is developed in the European Integrated Project DAIDALOS [DAIDALOS]. The focus of this architecture are not only point-to-point services, but also QoS based mobile mechanisms for mobile multicast applications supporting Source Specific Multicast (SSM) [RFC 3569], [D-HC 04a], [D-HC 04b] and Any Source

Multicast (ASM) [RFC 1112]. In particular, the DAIDALOS architecture is aimed to support QoS of mobile multicast communication based on:

- Management and planning of Internet resources, especially of access networks using a service provisioning platform including distributed QoS manager agents (brokers) interacting with DiffServ and IntServ/RSVP QoS provisioning technologies.
- Flexible interfaces of mobile applications for QoS parameters requests, negotiation and control.
- Mapping of transport layer QoS parameters, such as end-to-end delay and packet loss, into QoS parameters of wireless networks.
- Cross-network mapping of QoS parameters considering different wireless technologies (TD-CDMA, WLAN, WIMAX, DVB, GPRS, Bluetooth).
- Seamless handover based on Internet access networks.
- Flexible performance management for resource usage optimisation and enhanced QoS provision considering access and wireless networks included in the mobile IPv6 network infrastructure.
- Automated configuration, parameterisation and interaction of the different interfaces for QoS support.

Particular aspects of the DAIDALOS QoS architecture are described in [GIP 04], [PSGA 05], [SPSGCDF 05].

New technologies based on the context transfer, candidate access router discovery and distributed QoS management for mobile networking are integrated in the platform to support more efficiently the seamless handover, as well as QoS and resource utilisation in the IPv6 platform of heterogeneous wireless networks. The following figure gives an introduction for the DAIDALOS networking infrastructure and service provisioning for QoS based mobile multicast applications:

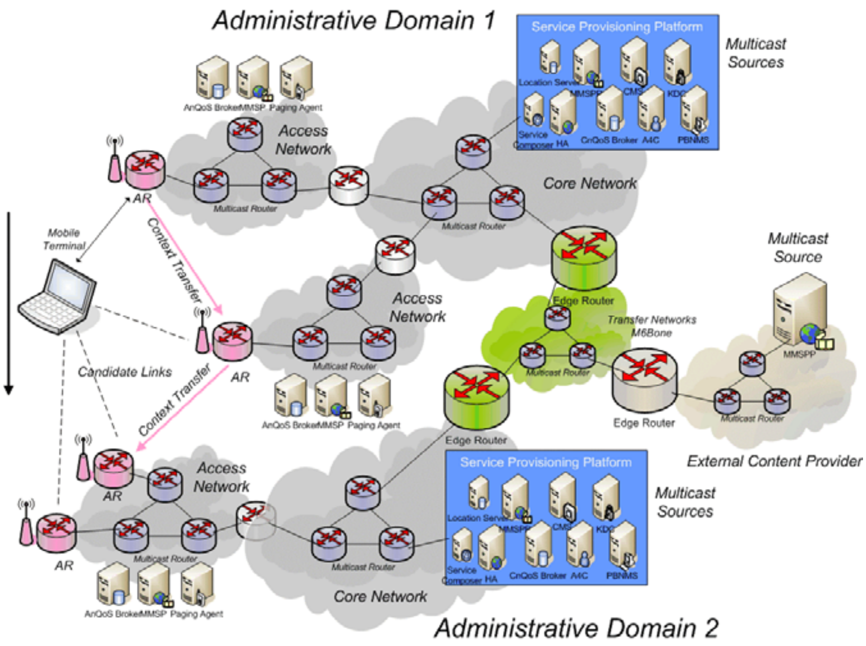

Figure 1: IPV6 mobile networking infrastructure for QoS support

The paper is aimed to describe open problems and possible solutions concerning the seamless handover of mobile multicast applications based on client mobility with QoS considerations. The efficiency of the operations of mobile multicast context transfer and the requirements for multicast Internet protocols in the different cases of the context transfer are discussed.

The focus is context transfer of access router states of following Internet protocols providing client connectivity to the multicast group:

- Group membership protocol for IPv6 multicast networking based on Multicast Listener Discovery Version 2 (MLDv2) [RFC 3810]
- Multicast routing using PIM-SM (protocol independent multicast routing – sparse mode) [D-PIM-SM]

Important requirement for context transfer in DAIDALOS is to integrate QoS support of mobile multicast services. For this purpose, interactions with distributed QoS managers, as well as QoS provisioning technologies are considered. To provide QoS of multicast applications, DiffServ for aggregate traffic [RFC3754] and IntServ/RSVP for flow based resource reservation [FKT 02], [RFC2490] were proposed in Internet documents. Different multicast client QoS models could be provided based on these technologies and included in DAIDALOS infrastructure, as for instance heterogeneous multicast client QoS model.

Access network selection for mobile nodes using the CARD technology is aimed to support optimised decisions for efficient context transfer and seamless handover.

Considering the multicast service, specific attributes could be applied, to describe capabilities of candidate access routers in order to support more efficient handover and context transfer for multicast services. Such attributes aimed to define multicast listening and routing states, as well as QoS parameters of candidate access routers are proposed in the paper.

"Active" learning strategies are required to obtain dynamic performance characteristics of access networks in order to evaluate their capabilities for efficient multicast routing. Learning mechanisms for access router capabilities based on signalling and performance databases could be integrated in QoS managers of access networks.

2 Context Transfer of multicast services

Context Transfer is a technology supporting the efficient handover and interoperable solutions for mobile services supported by Internet access networks [RFC3374]. The Context Transfer protocol is described in [LNPK 04] based on messages to initiate and authorise context transfer as well as messages transferring contexts prior to, during and after handovers.

Context transfer supports integration of different wireless networks in Internet infrastructure based on interoperable services.

The aim of context transfer is to re-establish the services in case of handovers efficiently without requiring the mobile host to explicitly perform all protocol flows for those services from scratch. In DAIDALOS, the services considered for efficient handover include multicast, QoS support, and security [Placido 04].

In case of mobile IPv6 multicast, these are services for group membership management (such as client listening) and multicast routing, which should be efficiently supported based on the context transfer. To ensure efficient transfer based on minimal communications, the transfer should be localised between the access routers of the mobile infrastructure, i.e. previous and next access router.

MLD [RFC 2710], with enhancements in Multicast Listener Discovery Version 2 (MLDv2) [RFC3810] is used by IPv6 routers to discover the presence of multicast listeners (i.e. nodes that wish to receive multicast packets) on their directly attached links, and to discover specifically which multicast addresses are of interest to those neighbouring nodes. MLDv2 supports the join or leave a

multicast group at any time and offers the SSM opportunity for receivers to filter specific multicast sources.
Multicast listener states are built at the Ipv6 access multicast routers by MLDv2 protocol. They describe the multicast groups, which have listener mobile nodes (clients) at the given access network. The problem of multicast listener context transfer for a given mobile node is to update the multicast listening states of the previous and next access router with the multicast listening context of to the node.
In MLDv2 [RFC 3810], the required parameters for service re-establishment are stored not only at the previous access router, but also at the mobile node. In this case, appropriate adaptation of the service for mobile networking is required for efficient context transfer. Currently, for each socket of a given mobile mode, with MLDv2 IPv6MulticastListen invocation, the mobile node records the required multicast listening context.
Based on the multicast listening sockets of a node, a Context Transfer Block (CTB) is built, which is used to update the state of the next access router to consider the per-socket multicast contexts per socket as available at the mobile node.

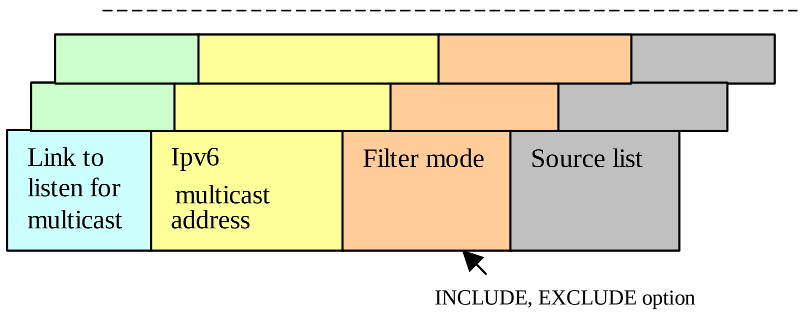

Figure 2: Multicast Context Transfer Block (CTB) for MLDv2 re-establishment

In the traditional MLDv2 implementation, the information for the multicast CTB is stored at the socket context of the node. This is leading to more complex operation due to additional communication during the handover time between the mobile node and the previous access router to get the per-socket multicast states from the mobile node.
To avoid this, the mobile multicast client context for MLDv2 re-establishment is stored at the access routers, when the IPv6MulticastListen has been invoked. It is deleted when the mobile node leaves the group. The “multicast client context per node” is an additional data structure at the previous and next access router maintained especially for efficient mobile networking. It extends the data structures as defined in the specification needed for MLDv2 context [RFC3810] for the mobile case.
According MLDv2, the aggregated context for all multicast clients stored per link at access routers is given by:

Interface à

(IPv6 multicast address, filter mode, source list)

Figure 3 shows a scenario for multicast listener context transfer of a mobile node between the previous and next access router:

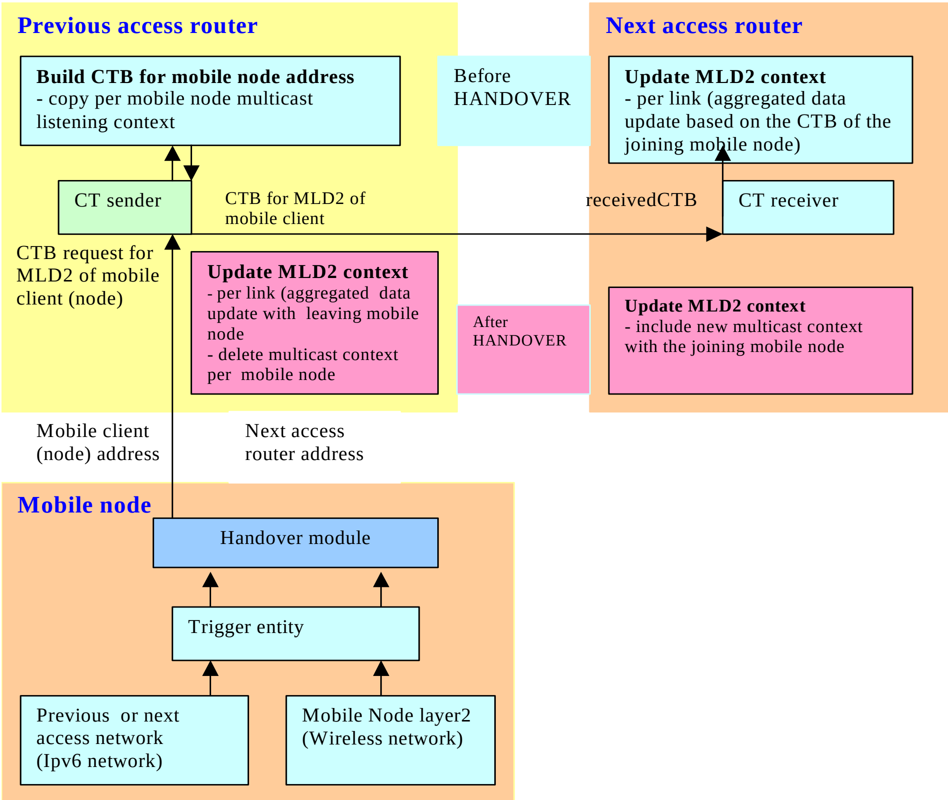

Figure 3: Scenario for multicast listening context transfer

The scenario for multicast listening context transfer shows following major steps:
Preparing the handover

1. Triggering of the handover based on
   - Wireless network of the mobile node (layer 2) or
   - IPv6 network at previous or next network based on performance management data and traffic engineering issues.
2. Decision by handover module of next access router based on the CARD protocol.
   Based on CARD response, different cases for the continuation of the handover are possible:
   - No CAR with required capabilities is found or QoS manager has rejected the resource requirement based on DiffServ or IntServ not availability. In this case, no handover is done.
   - CAR with required capabilities and established contexts. In this case, no context transfer is done. However, after the handover functions at the previous and next access router as shown in figure 3 are executed.
   - CAR with required capabilities and no established context. In this case, the context transfer and updates after the handover are fulfilled as shown in the figure 3.
3. Building of the multicast CTB for the mobile node
4. Sending the multicast CTB to the next access router
5. Updating the aggregated context per link at the next access router based on the multicast CTB.

After handover

6. At previous access router, the multicast context for the mobile node is deleted and the aggregated context per link is updated.
7. At next access router, the multicast context for the mobile node is inserted.

The efficiency of the multicast context transfer is based on

- Proactive strategy to transfer the control data reducing the overhead of communication mechanisms based on the standard MLDv2 listening mechanisms
- Localization of the communication operations between access routers.

There are other known techniques for MLDv2 mobile client transfer discussed in [RKLBB 04], such as:

- Home subscription (HS), using the home network infrastructure.
- Remote subscription (RS), based on which the mobile member joins the multicast group via the foreign network.
- Hybrid, which use both the home and the foreign network infrastructures simultaneously.
- Non-IP, i.e. multicast agent (MA) based solutions.

Some of these techniques are based on complex operations involving home and foreign networks, other are based on specific application solutions, which do not support interoperability.
The main benefit of the context transfer is to avoid additional communication mechanisms in contrast to the approaches for home, remote and hybrid subscription, and to provide IP interoperable solutions. Localising the context transfer operations between the access routers, it avoids the overhead for re-establishment based on the sending of the Multicast Listener Report (MLR) by the clients as response to Multicast Listener Report.

3 Multicast routing protocols and context transfer for IPv6

The mobile multicast node could be a client or source connected over multicast routing protocol with the multicast group.
PIM Sparse-Mode (PIM-SM) version 2 specified and enhanced in different documents [RFC2117], [RFC2362], [Pus 05] is used in DAIDALOS networking architecture to route the multicast packets from source to the receivers according the Internet multicast service model from [RFC1112].
PIM-SM is a protocol for efficiently routing multicast groups that may span wide-area (and inter-domain) Internets. PIM-SM uses the underlying unicast routing to provide reverse-path information for multicast tree building. It is not dependent on any particular unicast routing protocol.
In order to support ASM, PIM-SM takes care of source discovery by using a rendez-vous point (RP) to build the tree for multicast transfer to the group. This is a router in the PIM domain that knows which sources exist, and which groups have listeners. There can be different RP's for different groups. In a single PIM domain, all PIM routers need to be configured with the same RP-address for the same group in order to have full connectivity throughout the domain. In order to get the RP address, the IPv6 multicast access router based on PIM-SM uses the BSR specification that allows for scope [BSR] or embedded-RP [EMBRP], which specifies how the RP-address that can be encoded in the group address.
In the PIM-SM routing concept, the multicast access router, have to re-establish the trees to connect the mobile source or client to the multicast group. Tree databases are used to maintain the multicast routing state at the access router according some source or client.
As the RP points are statically configured prior to multicast tree construction, frequent handovers can lead to a situation, in which these essential multicast routers are off centre.
This can cause the non-optimality of the multicast routing paths. To overcome this problem, techniques such as RP relocation [AM 02], anycast RP routing mechanism [Ver 03], tree migration and evolution techniques for QoS multicasting [CSM 02] have been studied.

In case of PIM-SM context transfer, the trees to the multicast groups required for the mobile clients at the previous access router should be re-established at the next access router before the handover and deleted at the previous access router after the handover.
Before the mobile multicast client moves to a new access network, i.e. the handover is not completed, the multicast routing context (i.e. tree) will be established for the multicast address contained in the context transfer block and will be send from the previous to the next access router to connect the multicast receiver to the multicast group.
If the next router has not established a context to the required multicast group, it grafts a new branch to an existing multicast tree to the required group in order to connect the new receiver to the tree. As a result of tree expansion, the mobile multicast client will implicitly use the service of the same quality as the existing multicast tree to the group [RFC3754]. When an access router with connected mobile node, starts receiving packets on the RP Tree, it may as an optimization build so-called shortest-path trees (SPT's) towards the sources, instead of receiving data through the RP. It does this by sending (S, G)-joins towards the source, similar to what the RP does, and when it starts receiving on the SPT, it can prune the source from the shared tree. Some routers do this when they receive the first packet from a new source, others do it if the data rate from the source is above a certain threshold, and some never do.
If there are mobile clients joining explicit sources, the new access router can build the SPT's at once without first receiving packets from the RP.
[FKT 02] proposed to use IntServ/RSVP receiver oriented resource reservation for multicast receivers. It is used when the individual multicast receivers explicitly specifies their QoS requirements. The network delivers per user guarantee.
In DiffServ, every receiver has implicit and class based quality expectation. The network attempts to guarantee the quality to every service on aggregated base.
[RFC3745] discusses a solution for DiffServ resource reservation for the new established branch for the mobile receiver node at the next access. In particular, the solution is based on avoiding unauthorised use of resources by remarking at branching nodes all additional packets departing down the new branch [RFC3290].

4 Optimising handover decisions for multicast services

Optimal handover decisions for multicast services depends on the capabilities of access networks, to provide same services and protocols, as well as possibilities to reuse already established multicast services in another networks. Currently, they are open questions in description of capabilities of access networks and their learning.
In the case of mobile multicast services, they depend on the different kinds of client and server mobility, already established communication services for multicast group communication in neighbour access networks, as well as QoS support requirements.
To enable seamless IPv6-layer handover of a mobile node from one access router to another, the mobile node is required to discover the capabilities of CARs and to select the optimal prior to the initiation of the IP-layer handover. The discovery of CARs has the goal to:

- Identify the IPv6 addresses of the CARs
- Find the capabilities of those CARs. to provide characteristic of the service offered by the CAR that may be of interest to a mobile node for seamless handover

The candidate access router discovery (CARD) protocol was designed to support the acquisition of information about the possible access routers that are candidates for the mobile node's next handover [LSCFS 04], [TKCK 02].
During the IP-layer handover, that CAR, whose capabilities are optimal in respect to the preferences of the mobile node, is chosen as the next AR for handover. This is shown in figure 4:

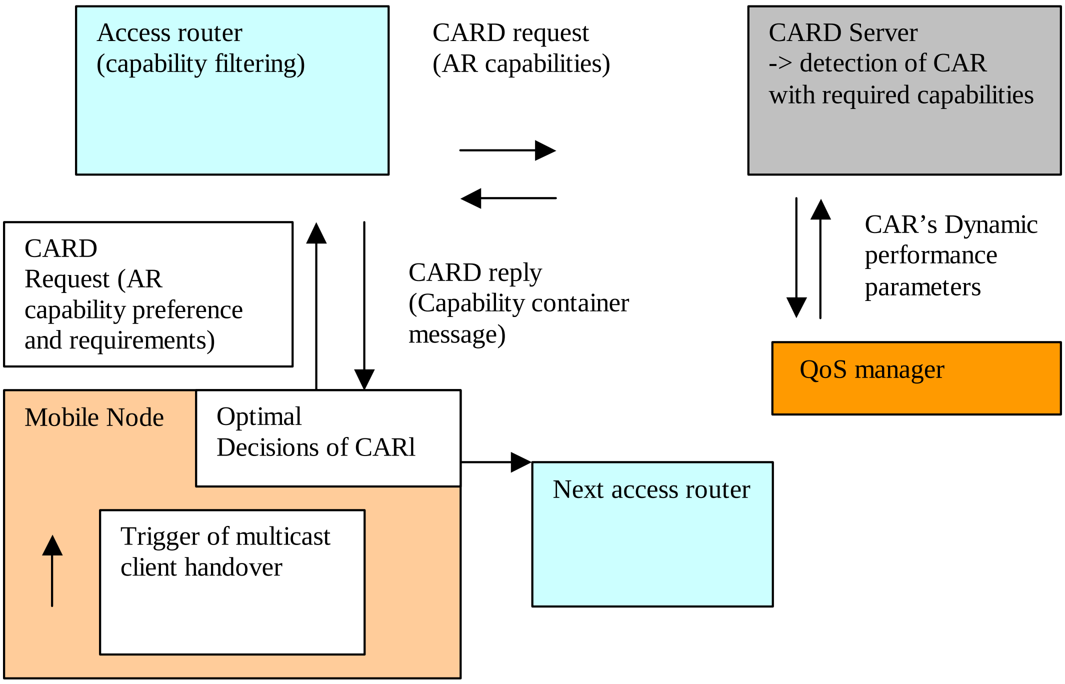

Figure 4: Decision of optimal candidate access router capabilities for mobile multicast services based on centralized CARD server

Information about capabilities of CARs can assist the mobile node in making optimal handover decisions. This capability information serves as input to the selection algorithm of the next access router. Some of the capability parameters of CARs can be static, while others can change with time.
Access router capabilities are sequences of attribute, value pairs. The content of each attribute includes values supporting selection of CAR with characteristics useful for the efficient handover and continuation of the QoS based mobile communication.
The following figure shows the different attributes selected for optimisation of mobile multicast clients during the handover

Multicast service	QoS technologies	Links	Traffic Load	Multicast sources	Multicast groups

Figure 5: CAR Attributes for optimal decisions for a seamless handover of multicast services

The paper proposes "active learning" approach based on collection of attributes of multicast access routers. Their collection and maintenance is provided by the QoS management systems.

Some attributes of multicast access routers are statically configured, such as multicast and QoS provisioning support. Other attributes are dynamically changing and should be updated periodically based on communication between access routers and QoS managers.
In order to reduce context transfer overhead, the mobile infrastructure could include further learning functions based on the performance management at the access routers, as for instance:

- Detection of a frequently used listening context to specific multicast group at the access router. It needs not to be released, because it must be again re-established for specific services.
- Learning to provide more efficient handover based on optimising the life time of context structures for multicast listening and routing at the access routers. Policies will be used to delete context structures for MLDv2 and PIM-SM at the access routers in order to support the re-use of the data structures for other mobile clients.

5 QoS management for multicast services in access networks

Capabilities of the access routers to support multicast services are managed by QoS brokers (managers) at the access network.
In the current state-of-the art of QoS brokerage architectures, there are different concepts designed and developed for specific networking architectures and services:

- Bandwidth Brokers for DiffServ networks [NJZ 99], [TWOZ 99]
- QoS managers for scalable support [ZDH 01], [ZDGH 00].
- Policy-based QoS management architecture including advance resource reservation for Grid in the framework of DataTAG project [Cap 02].

The DAIDALOS QoS management architecture includes signalling protocols and databases for QoS based mobile communication in an heterogeneous mobile IPv6 infrastructure.
Different kinds of QoS managers for inter-domain, core and access networks with specific responsibilities are interacting in this architecture. QoS managers of access networks have the responsibilities to manage the QoS of the access routers and to provide information on their capabilities.
In respect to the efficient handover and context transfer for multicast services, the following services could be included to the QoS managers at the access networks:

- Keeping knowledge of access routers with multicast services in the network, as well as multicast groups, for which MLDv2 context is established at the access routers. In the best case for efficient handover, at each time, when an interface MLDv2 context is changed at the access router based on a new mobile node entering or leaving the network, the QoS manager updates the information of the multicast groups of the access routers.
- Providing measurement or prediction information for traffic flows of multicast access routers based on the collection of traffic measurements per routers, evaluating it and predicting the trends. According this, the tasks of the QoS mangers are aimed to provide performance information to optimise decisions for CAR selection based on actual or predicted traffic load of the router.
- Advance resource reservation management for access router is promising service in the area of mobile networking [Het 05]. Especially, a service to reserve in short advance term, resources at neighbouring access routers using mobile behaviour patterns, has a future perspective for QoS based mobile networking. Other forms for advance resource reservation, used as example for adaptive bandwidth planning could also be applied for mobile networking considering predictions of mobile behaviour patterns.

6 Conclusions and further work

The paper discussed the efficient handover design based on context transfer for mobile multicast applications considering client mobility. Attributed to describe candidate access router capabilities, and QoS management strategies for learning for efficient handover were proposed to enhance DAIDALOS QoS based mobile multicast architecture.

Besides the client mobility, which is considered in the proposed mechanisms, there is also a sender mobility, which could be applied in mobile multicast scenarios in DAIDALOS.

Therefore the next topic of research is context transfer for mobile multicast applications based on sender mobility. The goal is considering efficiency issues for sender mobility and handover to complete the design of the QoS based architecture for mobile multicast services in DAIDALOS.

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