An Analysis of the DiffServ Approach in Mobile Environments

Torsten Braun, University of Berne, Switzerland. (braun@iam.unibe.ch)
Claude Castelluccia, INRIA Rhône-Alpes, France. (claude.castelluccia@inrialpes.fr)
Günther Stattenberger, University of Berne, Switzerland. (stattenb@iam.unibe.ch)

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Introduction

The main drawback of the current Internet is the lack of Quality-of-Service (QoS) support. QoS support, however, is essential for business and real-time applications such as Internet Telephony and on-line video retrieval. During the last years the Internet community spent many efforts to develop an Internet QoS architecture based on the Integrated Services (IntServ) architecture and the Resource Reservation Setup Protocol (RSVP). However, the IETF RSVP working group stated that RSVP and the IntServ approach can not be deployed in large-scale Internet backbones due to scaling and billing problems. Differentiated Services (DiffServ) [RFC2474, RFC2475] are a new approach for Quality-of-Service support in the Internet. Both DiffServ and IntServ approaches have been designed in the context of a static environments (fixed hosts and networks) and as a result, these schemes are not fully adapted to mobile environments, especially when Mobile IP is used as the mobility management protocol. The goal of this paper is to analyze the potential problems of DiffServ in mobile environments. We propose some preliminary solutions and/or future directions to study.

Integration of Mobile IP and Diffserv

Several problems occur when DiffServ is used in conjunction with Mobile IP. These problems can be classified into the following five categories :

1. *Network provisioning in mobile environments*. QoS can only be provided if the backbone networks of the Internet Service Providers (ISPs) are well designed and provisioned. However, network provisioning is a relatively complex task. Network provisioning especially becomes very difficult in highly dynamic environments, in particular in networks where the location and the QoS requirements of the end systems may change very quickly such as in mobile environments. Whereas a stationary host knows at the beginning of its communication if its bandwidth request will be fulfilled for the whole period of its communication, this is not the case with mobile users. A mobile host/user might start with enough bandwidth and then move to a network that cannot provide enough capacity to fulfil its reservation request. In this case, the service of the mobile hosts or of other users in the visited network have to be degraded. Such a service degradation might make sense in the context of adaptive applications. As a result, Premium Service might be difficult to provide in a mobile environment.

2. *Lack of dynamic configuration*. A user that wants to change his DiffServ Service Level Agreement (SLA) must notify those changes to the ISP using conventional communication mechanisms such as fax, phone or WWW forms. After the notification, network nodes within one or more ISP domains have to be reconfigured manually by network operators. This results in significant delays in the range of minutes, hours or even days. Therefore, DiffServ based on static service level agreements is not suited for dynamically changing communication requirements in the Internet. Highly dynamic environments and the static bandwidth allocation concept of DiffServ is contradictory. The goal should be to support dynamic service level renegotiations in order to allow the reaction to the dynamics of mobile users. Dynamic renegotiations can be supported by a Bandwidth Broker (BB) protocol which allows BBs to negotiate SLAs [NiJZ97, ROTZ98]. A generic service broker protocol has been defined in the context of the CATI project [CATI, SBGP99].

3. *Definition and Selection of Service Level Agreements (SLAs).* The service level that a mobile host (MH) gets at home depends on the SLAs that have been negotiated between its home network and its correspondents' networks. If a mobile host that is visiting a foreign network wants to get the same level of service that it gets at home, several other SLAs have to be negotiated. The characteristics of these SLAs depend on the mobile IP delivery mode. More specifically, the three following scenarios are possible:

   - The mobile host (MH) is using *Mobile IP in its bi-directional mode*. Packets from and to the MHs are routed through the Home Agent (HA). In this case, for all SLAs that have been established between the MH's home network and its correspondent hosts' networks similar SLAs need also to be established between the set of possible visited networks and the MH's home network. These additional SLAs are the same concerning QoS parameters such as bandwidth but differ in terms of address information. Two approaches are possible for the additional SLAs:
     (a) the home site establishes the SLAs with the set of the possible visited sites statically (e.g., every month) or
     (b) the SLAs are dynamically negotiated (e.g. using a BB protocol) when the mobile node enters the visited network.

     In the former case, the home network administrator makes sure before a mobile user is moving that there is enough bandwidth between the home network and the networks the MH is going to visit. The MH knows in advance whether it will get a DiffServ Service or not. This is especially important for the Premium Service [JaNP98]. If there are not enough resources available and the MH has a high priority, the home network administrator may then decide to downgrade the service of other mobile hosts roaming simultaneously within the visited network.

     The case of dynamic SLAs is illustrated in Figure 1. The MH at home communicates via ISPs A and B with the correspondent host (CH). When the MH moves to the foreign network, additional packets are exchanged between the MH and the HA via ISPs A and C. This requires additional SLAs between HA and CH. Those SLAs may be negotiated between the bandwidth brokers (BBs) of the different networks.

   - The mobile host is using *Mobile IP with neither route optimization nor bi-directional mode*. Packets to the mobile host are routed through the MH's Home Agent. Packets to the CH are routed along the shortest path - the route is triangular. With this scenario, for all SLAs that have been established between the CHs' networks and the MH's home network, similar SLAs have to be established between the HA's network and the set of possible visited networks (for incoming traffic) and, for all SLAs that have been established between the MH's home network and the CH's networks similar SLAs have to be established between the set of possible visited networks and the CHs' networks (for outgoing traffic).

   - The mobile host is using *Mobile IP with route optimization* (packets to and from the mobile host are routed along the shortest paths). For all SLAs that have been agreed between the MH's home network and the CHs' networks similar SLAs have to be setup between the visited networks and the CHs' networks. Pre-establishing reservations might be difficult since the visited networks and the CHs' networks have to be predicted which is generally quite challenging. The two possible alternatives are then to (1) switch to bi-directional or triangular routing, if QoS for direct communication between CH and MH can not be provided or (2) to design a dynamic SLA negotiation protocol.

     In Figure 1, the communication between the MH at the foreign network and the CH is performed via ISPs B and C but not via ISPs A and B when the MH is at home.

4. *Mobile Flow Identification.* Another problem with combining DiffServ and Mobile IP is for the first and border routers to identify micro-flows associated with mobile users. A micro-flow is generally defined as the 4-tuple (SrcIP, DestIP, SrcPort, DstPort). In the case of a mobile host, the SrcIP or DestIP fields might change. This is true for both IPv6 (the home address of the destination might be moved to the IPv6 routing header on the first part of the transmission path

and the care-of-address can be put into the source address field) and IPv4 (the original IPv4 packet is encapsulated for transmission over a Mobile IP tunnel). Flow identification based on home addresses is important for DiffServ classification procedures in first-hop routers such as multi-field (MF) classification as described in [RFC2475]. For MF classification in IPv4, the first-hop-router has to analyze the inner IPv4 header while for IPv6 the home address IPv6 destination option and the routing header need to be analyzed in order to identify the information required for MF classification. The same problem applies if MF classification is done at border routers.

The problem must be solved in particular for scenarios where the mobile node moves within the home domain, e.g. from one DiffServ first-hop router to another within the same domain. In such a scenario no additional SLAs are required or must be changed/signaled but the new DiffServ first-hop router of the MH must be able to support MF classification of Mobile IP systems. The new first-hop router shall also provide the same service to the MH as the HA. For example, in Figure 1, the MH might move from the home agent to the local foreign agent. In the case of triangular routing or route optimization, the packets from the MH do not go through the HA. However, the local foreign agent might not know the service the MH got when it has been connected to the home agent. This means that the local foreign agent has to identify the packets sent from the MH based on its home address. In addition, the local foreign agent must get information about the service the MH should get, e.g. from a central repository available in the home network.

5. *Billing.* Billing is based on SLAs which are either pre-configured or dynamically setup if a SLA negotiation protocol is used. In addition to the (usually) static SLA negotiation between home/foreign links and their ISPs, additional billing and accounting procedures must be provided for the case that a mobile node visits a foreign network and requests to use the SLAs of the foreign network. The problem is very similar to a scenario where a user demands to its ISP to setup an IP-tunnel based virtual private network (VPN) with certain QoS support. A protocol for exchanging SLAs including VPN and QoS parameters between users and ISPs as well as between ISPs is currently under development [CATI]. In general, the mobile IP node needs some mechanisms to indicate or signal to some BB in the foreign network that it desires a certain QoS. This could be supported by sophisticated protocols or signaling protocol extensions. The following alternatives could be a basis of such a solution:

   - A new special signaling protocol.

   - Special Mobile IP protocol options to be exchanged between MH and foreign agent / first-hop-router / BB.

   - Mobile nodes could request reservations via RSVP. These reservations can be accepted or rejected by some local router dependent on whether the SLA of the foreign network is sufficient or not. For this scenario, the concepts developed by the RSVP Admission and Policy work group of the IETF can be applied. A problem with RSVP might be that RSVP is able to support receiver-driven reservations only. Probably for sender-driven reservations, RSVP needs to be modified slightly.

   - Layer-4-Switching concepts or other signaling protocols: Another approach could be to avoid explicit signaling support for requesting a service and to try to identify flows which shall get a DiffServ service. Those flows could be H.323 flows, HTTP flows or any other long-lived or high-volume traffic flows. Such a flow identification functionality could be installed at a foreign agent or first-hop-router. The task of such a router is to identify flows, assign DiffServ Codepoints (DSCPs) and request the establishment / modification of a SLA at the nearest BB or directly at the ISP. This concept is similar to the MF classification concept.

   In any case, the foreign network needs some means to get the money back from the mobile node. Access and services could be pre-negotiated and paid in advance or after sending an invoice. An alternative could be that the mobile node carries some electronic cash (e-cash) and pays with this e-cash when requesting the desired service.

Conclusions

This paper identifies and analyzes several problems that occur when combining the DiffServ approach with Mobile IP. Two key components seem to be very valuable for the integration of these two protocols :

- *Adaptivity* : Adaptivity can be valuable in the following cases: An adaptive MH can use several modes dependent on the available QoS support of each mode and the security level of the communication to be supported :
  1. Bi-directional tunneling for very bandwidth sensitive data in both directions
  2. Triangular routing for very bandwidth sensitive incoming data, and
  3. Route optimization for non bandwidth sensitive data.

  An application running on a mobile node should also be adaptive in order to react intelligently on the availability of DiffServ services. This includes adapting the transmission rate (e.g., by changing the audio/video encoding), changing the DSCP (e.g., increasing or decreasing the class or the drop precedence of Assured Forwarding [HBWW99] packets) of the flow, or adding redundancy (e.g., Forward Error Correction codes) to the traffic flow. Another possibility is to use different DSCPs for different layers of a hierarchical coding scheme.

- *DiffServ Signaling Protocol* : The need for a signaling protocol is further increased by a Mobile IP environment since one can not expect that each network a mobile node visits has already established SLAs with its ISPs that are sufficient to support the Mobile IP host´s requirements. In addition, Mobile IP hosts lead to dynamically changing QoS requirements in general. Such a signaling protocol must support SLA negotiation among ISPs and among a stub network and its ISP. Usually ISPs and stub networks are represented by BBs. In addition, some kind of signaling among the Mobile IP node and a router (foreign agent, first-hop-router, BB) must be supported. This must allow a Mobile IP node to indicate the kind of desired service. Billing functions must also be supported.

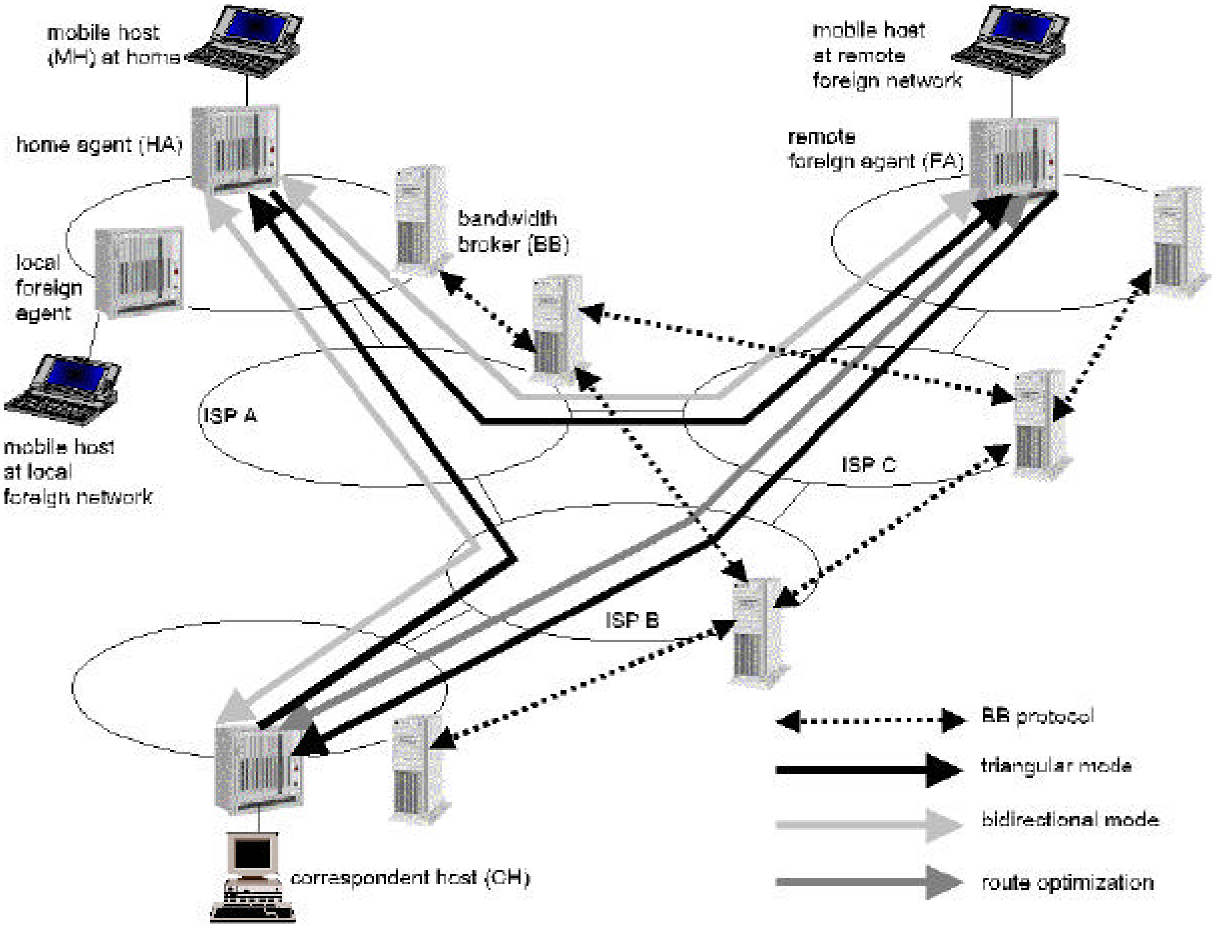

Figure 1: Mobile IP / DiffServ Scenario

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