An Analysis of the DiffServ Approach in Mobile Environments

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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) model and based on 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 mobile environments. Whereas a stationary host knows at the beginning of its communication if its request in bandwidth 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 notification, the network nodes have to be reconfigured manually by a network operator within one or more ISP domains. 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].

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 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 node delivery mode. More specifically, the four 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. 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: (1) the home site establishes the SLAs with the set of the possible visited sites statically (every month) or (2) the SLAs are dynamically negotiated 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 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.
   - 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.
   - A new scenario is introduced by the fact of integrating DS and mobility. When the MH updates the CH which starts using optimal routing, but the MH could not establish a SLA on the shortest path, MH will take advantage of the established SLA with home network and establish a new one between home network and the visited network. This is called the *inverse-triangular mode*.

4. *Mobile Flow Identification.* Another problem with combining DiffServ and Mobile IP is for the first and border routers to identify flows associated with mobile users. A 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 in the first part of the transmission path and the care-of-address is 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]. This problem must be solved for scenarios where the mobile node moves within the same domain, e.g. from one DiffServ first-hop router to another. In such a scenario no additional SLAs are required or must be changed but the new DiffServ first-hop router of the MH must be able to support MF classification of Mobile IP systems. This requires the modification of

flow classification procedures within DiffServ first-hop routers. For MF classification in IPv4, the first-hop-router has to analyze the inner IP 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, thus we call them *mobile-aware*.

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 special signaling protocol.
   - Special Mobile IP protocol options to be exchanged between MH and foreign agent / first-hop-router / BB.
   - RSVP : 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 slightly modified.
   - 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.

Routers configuration

The 3rd section, *Definition and selection of SLAs*, stated 4 scenarios for packet delivery mode: Triangular routing, bi-directional routing, Routing optimization and inverse-triangular routing. In each of these modes, the mobile host can be either sending packets and/or receiving packets (respectively, CH is receiving and/or sending packets). These 4 modes have 2 components: MH to CH delivery mode (MH-CH) and CH to MH delivery mode (CH-MH). Both can be either direct (i.e. one way Route Optimization) or indirect (i.e. via the Home Agent). Figure 1 shows this decomposition.

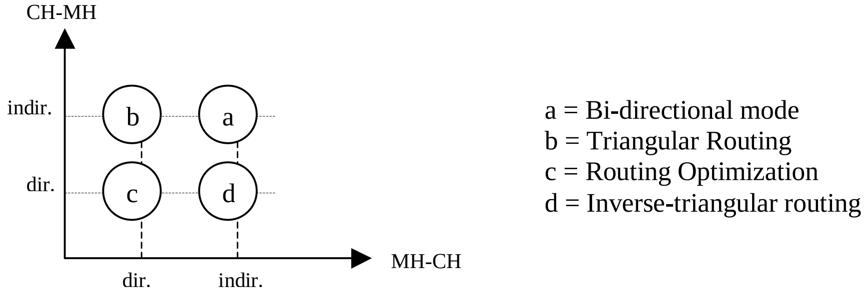

Fig. 1: Packet delivery mode combinations.

To describe mobile movement, which is independent of packet delivery mode, we add a 3rd component, "mobile movement", which can have the values:

- No movement (home)
- Within Home Domain
- Inter-domain
- Within Foreign Domain

Note: When mobile is home, not moving, packet delivery must be direct in both ways. Other modes must be avoided.

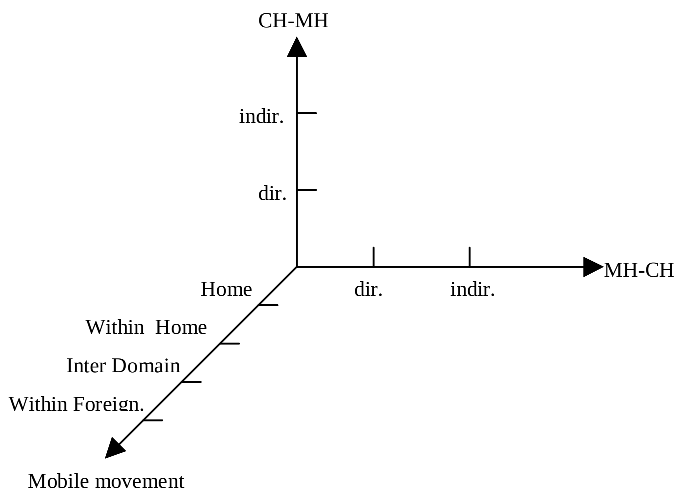

Fig. 2: Router configuration definers (?)

These 3 components will define the routers to be configured when establishing a SLA in a mobile environment. (see figure 3)

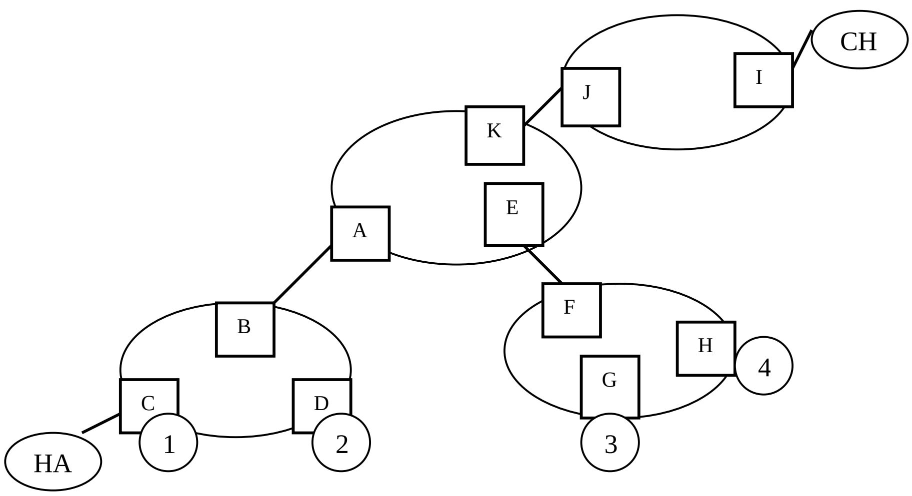

Fig. 3: Network routers involved in mobility

1. MH is the sender:

i. MH-CH = direct (i.e. either Triangular Routing or Routing Optimization)

- MH is home (position 1): A, B and C must be configured to a certain SLA from MH to CH
- MH is roaming within Home Domain (position 2): C and D should be configured for a new local bandwidth share, B being mobile-aware to look to MH's home address in the Home Address option.
- MH moves to a Foreign Domain (Foreign Domain) (position 3): E, F and G must be configured to a new SLA between MH and CH. A, B and C should be configured to release reserved resources either partly (in Triangular Routing) or totally (in case of R.O.)

- MH is roaming within Foreign Domain (position 4): G and H should be configured for a new bandwidth share, F being mobile-aware.

ii. MH-CH = indirect (i.e. either Bi-directional mode or Inverse-triangular mode)

- MH is roaming within Home Domain (pos.2): C and D should be configured for a new bandwidth share, B being mobile-aware.
- MH moves to a Foreign Domain (Foreign Domain) (pos.3): E,F and G must be configured for a new SLA. B, C and D may be configured for a new bandwidth share, depending on Home Agent location in Home Domain.
- MH is roaming within Foreign Domain (pos.4): G and H should be configured for a new bandwidth share, F being mobile-aware.

<u>2. MH is the receiver:</u>

i. CH-MH = direct (i.e. either Routing Optimization or Inverse-triangular mode)

- MH is home (pos.1): I, J and K must be configured for a new SLA.
- MH is roaming within Home Domain (pos.2): D and C should be configured for a new bandwidth share, I and J being mobile-aware (else, it would cause scalability problems).
- MH moves to a Foreign Domain (Foreign Domain) (pos.3): I, J, K (or others) must be configured which causes scalability problem for CH, proportional to the number of MHs served. E,F and G must be configured. A,B and C may be configured for resource partial release.
- MH is roaming within Foreign Domain (pos.4): H and G should be configured for a new bandwidth share, I and J being mobile aware (else, it would cause scalability problems).

ii. CH-MH = indirect (i.e. either triangular routing or bi-directional mode)

- MH is roaming within Home Domain (pos.2): C and D should be configured for a new bandwidth share.
- MH moves to a Foreign Domain (Foreign Domain) (pos.3): E, F and G must be configured, B and C may be configured depending on Home Agent location in Home Domain.
- MH is roaming within Foreign Domain (pos.4): H and G should be configured for new bandwidth share, F,B and possibly C(depends on H.A. location) being mobile-aware

Note: Routers inside the backbone/ISPs do not have to be configured at each single mobile movement/call request. They are concerned with aggregated flows, thus micro flows are statistically multiplexed. We could consider such configurations as static ones.

Analysis

The main reason to use indirect ways (1.ii and 2.ii) is to take advantage of the SLA already established between Home Domain and Correspondent Host Domain and establish a new SLA to the Current Domain only. This was proposed in [KiMu99]. This seems to be better for handoffs, when the CH cannot handle establishing new SLAs (to optimize the route) to many MHs served at a time. Thus, we can avoid the scalability problems of mode 2.i.

On the other hand, the reasons to use direct routes (1.i and 2.i) are:

- Route optimizing: thus minimizing latency, and decreasing extra load brought to the backbone.
- Possible cost optimizing: related to route optimizing.
- Robustness against Home Domain router failures: MH will not depend directly on its Home Domain

- Increase the admission set in Home Domain: The resources being released either totally or partially.

For all modes, *remote allocation* would be useful for MHs to allocate resources in advance, in case they predict their movement. This would decrease the SLA negotiation time, thus enhancing Handoffs and new connection setup.

Some of the remaining problems in DS are found to be more critical in mobile environment such as: Dynamic SLA negotiation, admission control -as detailed in the second part of this paper- and QoS routing which could enhance routing in a DS network, including QoS parameters in a path cost.

The extra load in Home Domain depends on HA location, in case of indirect routing modes. Moving it to the edge of the domain will release more resources inside this domain.

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 direction, (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 drop precedence of Assured Forwarding [HBWW99] packets), or adding redundancy (e.g., Forward Error Correction codes) to the traffic flow.
- *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.

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