Dynamic SLA Management in Cellular DiffServ Networks

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***Abstract*—Minimization of the forced termination probability of active connections during handoff is one of the most important tasks for seamless cellular network operation. Handoff delay minimization is in parallel with this task. This paper introduces a new dynamic SLA management procedure to be used in cellular DiffServ networks. With the Expected Visitor List (EVL) processor deployment at base stations in the shadow cluster and pre-messaging among them, virtual call admission control for the incoming mobile is performed in advance. No pre-reservation is performed, and the EVL processing results are stored and kept updated to achieve minimized handoff latency. Efficiency and performance the proposal have been explored via simulation experiments under different scenarios.**

***Index Terms*— Handoff, QoS provisioning, DiffServ, Expected Visitor List, Cellular Networks.**

I. Introduction

THERE exists a risk of forced termination of ongoing calls during handoff of a mobile between base stations due to two main latency sources. The first one is the handoff decision timing in accord with the signal strength measurements at any time. Late detection may result in signal level degradation that might well cause the handoff request to be blocked. On the contrary, early decision increases the unnecessary handoff probability resulting in *ping-pong effect* [1].

Other latency source, which is in the scope of this research, is the preparation time for the incoming mobile. After the handoff necessity detection, the next step to go over by the network is to make some preparations including performing a Call Admission Control(CAC) algorithm against the request.

Performing CAC involves in service level agreement (SLA) negotiation and QoS-provisioning for the mobile station in Mobile IP DiffServ networks. In this case, admission control for wireless channel is not adequate for the overall admission control of the handoff request. Even if wireless channel is allocated for the handoff request, SLA negotiation and QoS provisioning require time. This may still lead to QoS degradation and hence connection termination at worst case. On the other hand, if the new cell can not meet the QoS requirements of the prospective mobile station, the channel allocated may be wasted since it may not be utilized due to connection termination by QoS degradation. In this paper, we propose a virtual CAC method to be used to support dynamic SLA management in cellular DiffServ networks. Handoff delay minimization and efficient wireless resource utilization are the aims of the method with performing no pre-reservation. Decomposed handoff messaging reveals QoS expectations of the mobile stations and information obtained is stored as entries per mobile per neighbor cell at each EVL processor. Messaging between EVL processors makes neighbor cells aware of possible visitor mobile stations in advance. The SLA negotiation and hence QoS-provisioning results of mobiles are stored in their EVL entries. These entries are kept updated to be used at actual handoff time. If the entry of a mobile station is valid at handoff request, it can take the advantage of the method and enjoy reduced latency handoff. Otherwise, it will be served by conventional handoff techniques and SLA negotiation and QoS provisioning take place after handoff, which may result in service level degradation.

II. Cellular DiffServ with EVL Employment

A. *Cellular DiffServ Problems*

The major problem source for DiffServ implementations in Mobile IP networks is its dynamically changing nature due to mobility [3]. This invalidates the applicability of the conventional network provisioning and SLA negotiation and configuration methods for wireless networking environments. Maintenance of existing SLAs during handoff must be supported for a mobile host visiting a foreign network. Many SLAs have to be negotiated in order that the mobile host gets the same level of service that it gets at home. The service level that a mobile host experiences can be preserved by negotiating SLAs with candidate networks in advance.

This can be accomplished by implementing mechanisms like Bandwidth Broker within cellular DiffServ domain [4]. The mobile hosts announce their need or changes in their requirements to the appropriate bandwidth brokers. The bandwidth brokers control and perform the reservations of DiffServ bandwidth. This method, however, may lead to waste of resources with pre-reservation in highly dynamic mobile environments.

B. *Decomposition of Handoff Messaging*

In the proposed method, the goal is to perform admission control of the handoff request and QoS provisioning at once

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by performing overall virtual connection admission control in advance. In order to make the target cell aware of QoS expectations of the expected visitor mobiles in advance, decomposition of handoff messaging is preferable. This decomposition can be accomplished in a way that messaging at the time of handoff as in Fig. 1(a) could be so shortened that it contains only the identity information of mobile, current and target base stations excluding the pre-transferred information about the mobile demand details as shown in Fig. 1(b). Based on the information received from the decomposed handoff messaging, target base station becomes capable of initiating the virtual connection admission control for the incoming mobile in very advance. As a result, much shorter handoff latency than the conventional methods might be achieved.

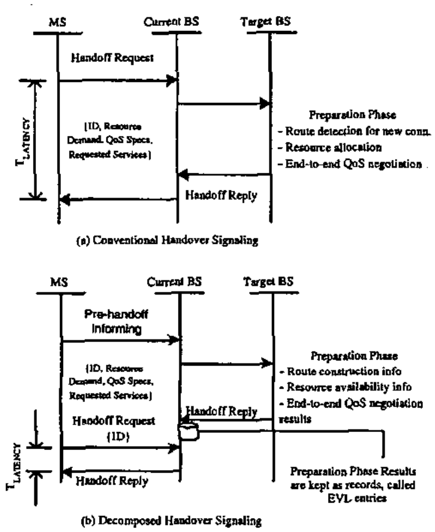

Fig. 1. Handoff messaging in existing and new scenarios.

The classical handoff messaging is decomposed into two parts, one being the non real-time component containing the information about mobile id, traffic characteristics, QoS requirements, bandwidth demands making it possible to perform preparations before a possible handoff request. The other part is the real time component and it is the message containing only the mobile id making it possible to execute the handoff based on the preparations.

C. EVL Entry Structure

In the proposed method, base stations of possible target cells keep records per neighbor, as EVL entries to store the decisions and preparations of each expected visitor . The collection of entries for a BS constitutes EVL. The practical implementation of this method can be realized by equipping base stations with EVL processors.

An EVL entry for a mobile includes the information received from the pre-messaging in shadow cluster [2], i.e. cluster of the possible target cells. According to the results of

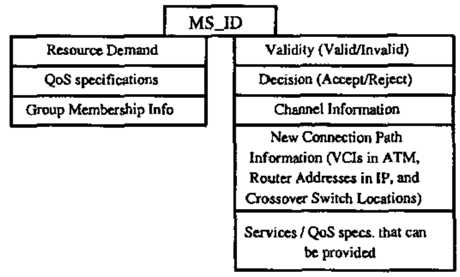

Fig. 2. A typical EVL entry structure.

connection admission control execution and some preparation algorithms such as resource allocation algorithms prior to handoff request; the fields of an EVL entry, shown in Fig. 2, are entered. Number of entries in each EVL changes as the number of mobiles in related cells change due to events such as power on/off, completion of handoff from or to these cells. An EVL entry has a field indicating its validity, and it is preset to *valid*. EVL entries with *accept* value in their decision fields are invalidated if such events occur that mobile may not be accepted in the new environmental conditions. Increase in the total resource allocation in the target cell may result in rejection of the mobile. By the same manner, decrease in the total resource allocation in the target cell may be an opportunity for EVL entries with *reject* decisions to change their admission status and that's why those entries should be revised. Therefore, any change in the QoS support that a cell is able to provide is passed to the EVL processor at the base station in order to guarantee the reflection of this change on the decision and network preparations for the mobile. These changes are called *invalidator events* which destroys the validity of an EVL entry. Invalidator events are different for entries with accept and reject decisions. Accept and Reject Invalidator events represent the decrease and increase in QoS support of the target cell, respectively. When an invalidator event occurs, corresponding valid EVL entries become obsolete and should be re-processed by EVL processors.

D. SLA Management with EVL Method

The basic cellular networking illustration with EVL deployed at base stations is seen in Fig. 3. In this example, the EVL_i has entries for all mobiles connected BS_i firstly. The resource demand, QoS expectations, traffic specifications, preemption priority and corresponding nodes data are then transferred to the other EVL processors in the shadow cluster [2], i.e. the cluster of possible target cells, of the mobile station.

As the QoS and bandwidth requirements of mobile node are introduced to its candidate subnets in advance with the help of pre-handoff messaging in shadow cluster, the SLA negotiation and network provisioning can be performed in advance. If any change occurs in QoS requirements of the mobile node, it will be propagated to the EVL processors in its shadow cluster. This change invalidates its EVL entry

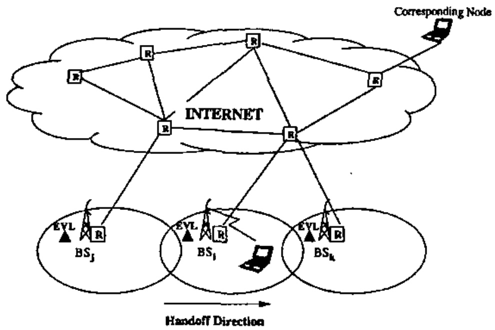

Fig. 3. An illustration of wireless environment during handoff of mobile station from BS_1 to BS_2.

and then re-processing of the entry results in the agreement on the new SLA parameters. By this way, the conventional static SLA configuration is replaced by dynamic negotiation with EVL employment. Since the candidate base station is informed about the prospective mobile in advance, the SLA configuration may be performed before the handoff. Hence, the lack of dynamic SLA negotiation in mobile environments can be compensated with EVL processor deployment in cellular DiffServ networks.

The resource pre-reservation is not a part of our method and can be implemented or not according to the different circumstances, i.e., in accord with the mobility pattern. EVL employment method provides a dynamic SLA negotiation and connection admission control method which combines CAC for wireless channel request and QoS provisioning for the mobile station. If the entry of the mobile station is valid at handoff time, it experiences low latency handoff. Otherwise, its SLA negotiation and QoS provisioning should be performed again after handoff is completed, which may result in service level degradation and even worse connection termination in worst case.

III. Performance Evaluation

The efficiency of the proposed method is directly related with the rate of entries's being valid throughout the time. A handoff requesting mobile can take the advantage of proposed method if and only if its entry has valid state at the time of handoff request.By this way, it may find its new environment according to its QoS requirements, since its SLA is already negotiated and agreed before its handoff. All events are assumed to arrive based on a Poisson traffic. The events are exponentially distributed with rates λ_{HO}, λ_{AI} and λ_{RI} for handoff request, accept invalidator and reject invalidator rate for target cell, respectively. EVL processors work to keep the EVL entries ready all the time. Performance of the methodology has been observed at various rates of λ_{AI} and λ_{RI}, EVL processing time T_{EVL}, i.e. the average time to validate an entry and EVL processor computational power c, at average number of expected visitors per cell is $N = 100$, average EVL accept decision ratio of $\rho_A = 0.9$ and handoff rate of $\lambda_{HO} = 0.1$.

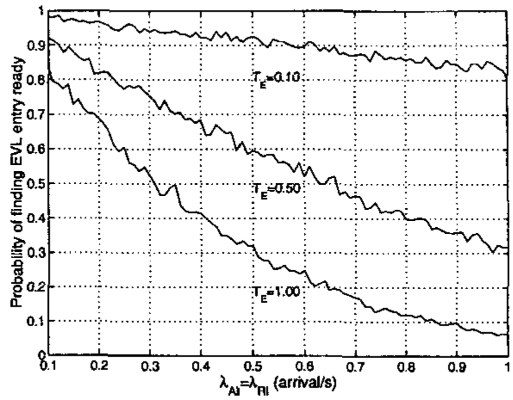

Fig. 4. Probability of finding QoS agreement of EVL entry valid vs. $\lambda_{AI} = \lambda_{RI}$, changing T_{EVL}= 0.1, 0.5, 1.0 for $\lambda_{HO} = 0.1$ arrivals/sec per cell-pair, $C = 50$, $N = 100$

An increase in invalidation rates results in decrease in mean percentage of finding valid entries at handoff request time. Fig. 3 shows that at the same value of handoff request arrival rates, as processing time T_{EVL} decreases, the probability of finding an entry valid at any time considerably increases. Hence, how fast the invalidated entries are processed, determines the efficiency of the proposed methodology.

The effect of the EVL processor computational power, c, is seen in Fig. 4. For the maximum computational power environment, entries invalidated on arrival of any invalidation event, being the bulk input for the processor, can be directly processed and validated in at most T_{EVL} seconds. However, for the limited computational power case,a queueing problem arises making invalid entries have to wait for others to be processed, giving rise to longer validation times and reduced chances of finding any entry as valid, and hence reduced chance of taking advantage of proposed method.

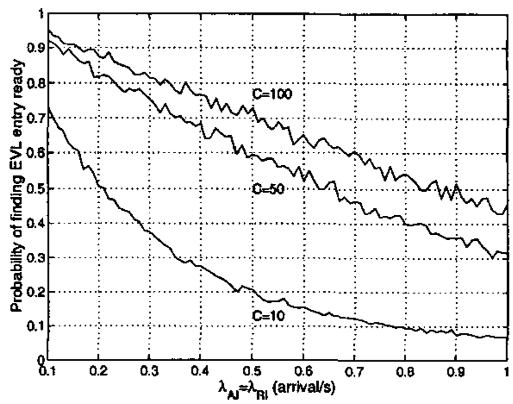

Fig. 5. Probability of finding QoS agreement of EVL entry valid vs. $\lambda_{AI} = \lambda_{RI}$, changing C= 10, 50, 100 for $\lambda_{HO} = 0.1$ arrivals/sec per cell-pair, $T_{EVL} = 0.5$, $N = 100$

Signaling overhead incurred by EVL employment for dynamic SLA management and connection admission control is shown in Fig. 6. Overhead is represented with percentage of the assumed capacity of the wired links in network. At low and moderate invalidation rates, overhead is sufficiently low being under 10%. Overhead increases with increasing invalidation rate as EVL processors are forced to perform CAC repeatedly. However, as signaling takes place on wired links instead of wireless channel, the cost of this overhead can be tolerable.

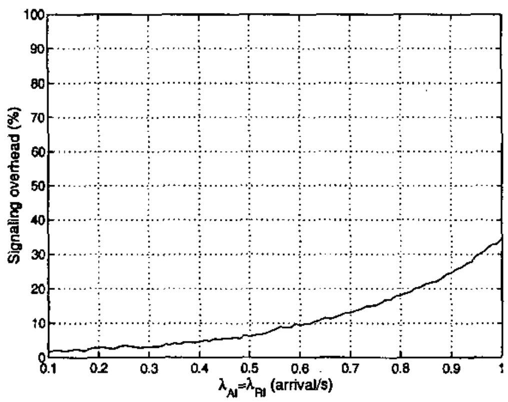

Fig. 6. Signaling overhead by EVL employment for dynamic SLA management and virtual CAC for $\lambda_{AI} = \lambda_{RI}$ for $\lambda_{HO} = 0.1$ arrivals/sec per cell-pair, $T_{EVL} = 0.5$, $C = 50$ and $N = 100$

What is common in these results is that at moderate invalidation rates, handoff latency can be reduced effectively with very low signaling overhead. For the cases explored, methodology proves to be useful over 60% in a high invalidation rates environment at low overhead %10 with moderate $T_{EVL}(0.50)$ and $c(50)$ values. If invalidation events arrival rate or T_{EVL} is not sufficiently small, performance of the methodology reduces. With today's powerful processors, even at very high invalidation rates, handoff events may take the advantage of no waiting and therefore enjoy a seamless service.

IV. Conclusions

In this research, we have proposed a new dynamic SLA management procedure to be used in cellular DiffServ networks. With the EVL processor deployment at base stations in the shadow cluster and pre-messaging among them, virtual call admission control for the incoming mobile is performed in advance. Without any pre-reservation, EVL processing results are stored and kept updated and hence minimized handoff latency is achieved. The detailed investigation of EVL processing involves in queueing theoretical analysis which is beyond the scope of this paper and left for future study.

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