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# Dynamic QoS Negotiation for Next-Generation Wireless Communications Systems

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***Abstract*— Users in next generation wireless networks are expected to be highly dynamic while maintaining connectivity through different devices with different processing and communication capabilities. In wireless environments, bandwidth is scarce and channel conditions are time-varying. To guarantee Quality of Service (QoS) to users roaming between heterogeneous wireless networks, a dynamic QoS negotiation mechanism, which allows users to dynamically negotiate their service-levels with the network, is required. Several protocols for dynamic service level negotiation have been proposed, each focusing on a particular mode. This paper presents an overview of these protocols and discusses their limitations. To alleviate these shortcomings, a dynamic QoS negotiation scheme to allow users to change their service levels in response to changes in both network conditions and their own resource requirements is proposed. In the proposed scheme, upon an intra-domain handoff of a mobile node, the visited access point consults the previously used access point to confirm the legitimacy of the service negotiation request issued by the mobile node. The performance of the proposed scheme has been investigated and compared with other dynamic negotiation approaches. It was demonstrated that the proposed scheme outperforms the state-of-the-art method, in terms of the signaling overhead and data storage, at the expense of a slight increase in the overall negotiation delay.**

## I. Introduction

With the on-going advances in mobile networks and portable devices with embedded computers, the transmission of real time multimedia services over mobile networks has become a challenging task due to resource constraints of wireless links and mobility of users. To provide Quality of Service (QoS) in such environments is also a serious challenge. In QoS aware systems [1], a user is able to choose among various service classes, each with different degrees of reliability, predictability, and efficiency. Today, service classes are selected by users via contracts with the Internet Service Provider (ISP). Thus, Service Level Agreement (SLA) remains static during the contract period [2]. If a user wants to change its service level, it needs to communicate with the ISP and negotiates for a new SLA. The change in the user's service level is manually achieved. Therefore, this kind of changes cannot be frequent. The user's service level may not be met during overloaded periods while allocated resources may be under-utilized during lightly loaded periods.

Given the mobility of users, diversity of wireless technologies and devices, QoS management should be handled in a dynamic manner. Handoff or changes in resource availability may cause degradation of QoS. Therefore, a more dynamic mechanism that allows users to negotiate their specific requirements for each application is needed. Thus, the static SLA needs to be replaced by a dynamic Service Level Specification (SLS). The objective of this work is to enable dynamic negotiation of SLS, including the initial negotiation for each session, service renegotiation, and mobility management to ensure seamless handoff.

The rest of this paper is organized as follows. Section II reviews existing works related to service level negotiation protocols. Section III describes the proposed scheme. Section IV presents the experimental setup and results. Finally, the paper is concluded in Section V.

## II. Related Work

Along with the growth in Internet multimedia applications, and the need for better QoS provisioning, the Internet Engineering Task Force (IETF) introduced two architectures for QoS support, namely Integrated Services (IntServ) [3] and Differentiated Services (DiffServ) [4]. The IntServ approach is based on per-flow service provisioning, which informs routers along an end-to-end route, about the resources required by each flow using the Resource Reservation Protocol (RSVP) [5]. On the other hand, DiffServ is based on aggregates of traffic flows. Only edge routers are informed about the resources required by each flow. Thus, DiffServ is more scalable than IntServ.

Based on these two architectures, several protocols have been implemented for ensuring service level negotiation. Common Open Policy Service for Service Level Specification (COPS-SLS) [6] is a service level negotiation protocol for IP based networks. It employs a centralized architecture and consists of two phases, namely Configuration and Negotiation. During the Configuration phase, mobile hosts are informed, via a number of messages, on how to perform the negotiation, the set of negotiation parameters, and renegotiation interval. During the negotiation phase, the mobile hosts negotiate their service levels by following the instructions received in the configuration phase. Resource Negotiation and Pricing protocol (RNAP) [7] is the framework that enables users and networks to dynamically renegotiate the contracted service level and price. The main goal of RNAP is to integrate the pricing mechanism with resources negotiation and reservation. RNAP can use both centralized and distributed architectures by means of a soft state approach. Hence, periodic signaling is required to refresh the negotiated service. Service Negotiation Protocol (SrNP) [8] is independent of any SLA format and can be applied for negotiating any document in the format of attribute-value pairs. QoS (Next Steps in Signaling) Signaling Layer Protocol (QoS NSLP) [9] is a protocol tailored for a distributed architecture. It uses the soft state approach for service negotiation and requires frequent signaling to refresh the SLS. Furthermore, two protocols have been proposed to support mobility, namely, QoS Generic Signaling Layer Protocol (QoS GSLP) [10] and Dynamic Service Negotiation Protocol (DSNP) [11]. QoS GSLP uses mobility and traffic pattern of users to predict their next access point to minimize the handoff negotiation delay. This delay reduction comes at the price of additional complexity. DSNP is a protocol tailored for centralized architectures and is exclusively developed for wireless networks. In DSNP, service negotiation managers deliver QoS profiles of users to potential access points, based on prior knowledge of the network topology. Thus, it minimizes the handoff service negotiation delay. A detailed survey on the above mentioned protocols can be found in [12].

One of the major issues in wireless networks is to track the location of a user and to inform the access points of the user's QoS profile. Some solutions to this problem increase complexity at service negotiation entities, while others incur signaling overhead or increase the service negotiation delay. Encrypted SLS [13] is a method that informs access points of users' SLSs. When a user negotiates for a service level for the first time, it receives its SLS in an encrypted form. Upon handoff, it sends its own encrypted SLS to the new access point. The access point decrypts the encrypted SLS and performs traffic conditioning. However, this method poses a security threat since malicious users can obtain the encrypted SLS from a legitimate user and steal its service level. In the following section, we propose a new scheme for dynamic QoS in wireless networks based on DiffServ.

## III. Dynamic QoS Negotiation for Next-Generation Wireless Networks

This section describes the proposed dynamic QoS negotiation mechanism for next-generation wireless networks. The proposed scheme allows users to dynamically negotiate their SLSs when a new session is initiated and also when the resource requirements change.

### A. Architecture Description

The Internet is divided into different domains administered by different ISPs. Each domain possesses a QoS Global Server (QGS), an Authentication, Authorization, and Accounting (AAA) server, several Base Stations (BSs), and subscribers, termed as Mobile Stations (MSs). The various components present in the architecture are schematically shown in Fig. 1. QGS performs service level negotiation and is responsible for maintaining global information about the available resources in the whole domain. Based on this information, QGS decides the admissibility of service requirements. QGS manages signaling traffic related to QoS negotiation only. QGS, introduced also in DSNP [11], basically functions as a policy decision point (PDP) defined in the Policy Framework presented in [14]. BSs are responsible for applying different service levels to MSs, and for controlling the traffic flow of all MSs in the subnet. BSs inform the QGS about their local resource availability and receive SLS of MSs for traffic conditioning.

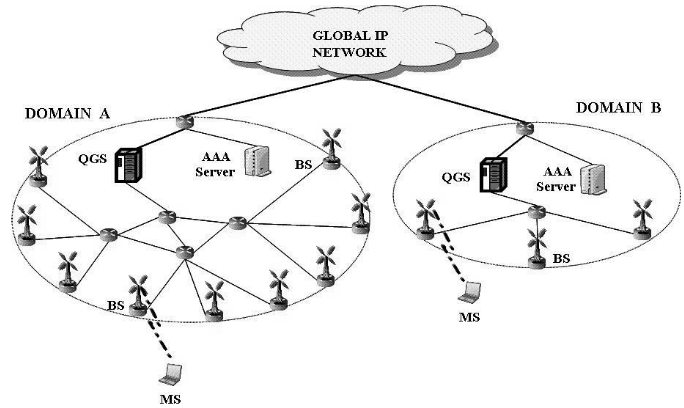


Fig. 1. Architecture envisioned for dynamic QoS negotiation in wireless networks.

### B. QoS Management

There are three main scenarios for service level negotiation. Firstly, when a MS is powered up, it needs to perform initial service level negotiation with the network. In the second scenario, when the service level requirements of the MS changes, it needs to perform service level renegotiation. Finally, when resources in the network become scarce, the QGS requires the MSs to degrade their existing SLSs to suit the current network conditions.

*1) Initial QoS Negotiation:* When a MS logs into the network for the first time, it should negotiate a service level for its traffic. This negotiation takes place with the QGS. The MS requests predefined services available in the network from the QGS. As soon as the MS obtains the information about available services, it starts the negotiation process with the QGS. Upon receiving a service request from the MS, the QGS consults its AAA server to determine if the requested service can be provided. Upon acceptance, the QGS delivers the new SLS to the appropriate BS in order to condition the traffic for this MS. It also sends a positive service negotiation response to the MS. After that, the MS starts using the service. This procedure is conceptually depicted in Fig. 2. If the MS is not authorized to acquire the requested service or there are not enough resources to satisfy the required service, a negative service negotiation response is dispatched to the MS, which includes the reasons for rejecting the request and the available resources that the MS can currently renegotiate for.

*2) QoS Renegotiation:* Once a service has been established, a MS can renegotiate a different service level at a later time. The renegotiation is similar to the initial QoS negotiation procedure apart from the fact that the MS keeps receiving service during the renegotiation period. If the QGS rejects the

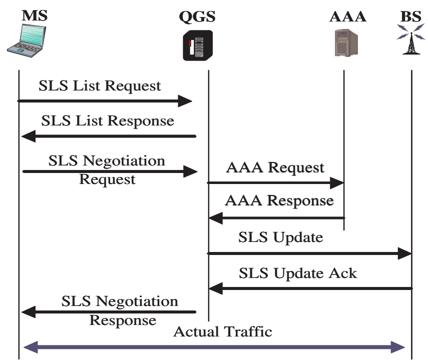


Fig. 2. Initial QoS negotiation.

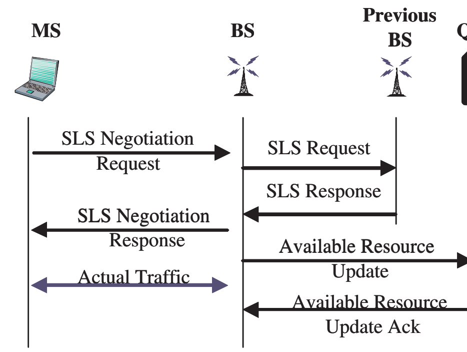


Fig. 3. Signaling for Intra-domain Handoff

new service level requested by the MS, its current service level is retained. Service renegotiation can also be initiated by the QGS if resources in the network become scarce. In this case, the QGS requires the MSs to degrade their existing SLSs.

### *C. Mobility Management*

As a MS roams over the coverage area and performs handoff to a new BS, it is necessary to appropriately condition the traffic of the MS. Therefore, the new BS has to know the SLS of this MS. For this purpose, the new BS consults the previous BS for the SLS.

*1) Intra-domain Handoff:* When a MS performs handoff to a new BS in the same domain, it sends the IP address of the previous BS to the new BS, via a service negotiation request. In response, the new BS confirms the SLS from the previous BS. If the new BS can guarantee this SLS, it sends a positive service negotiation response to the MS. The MS starts enjoying the service from the new BS immediately. Then, the new BS informs the QGS that it is currently providing service to the MS to update available resources of the new BS and the previous BS. Additionally, the previous BS erases the SLS of the MS from its database. This operation ensures that BSs store information on SLSs of only users they are currently serving. In case the new BS is unable to guarantee the SLS, it forwards the service negotiation request to the QGS. The QGS then sends a negative service negotiation response to the MS, informing the MS on available service levels that the new BS can offer. This procedure is conceptually depicted in Fig. 3.

*2) Inter-domain Handoff:* When a MS performs handoff to a new BS in a different domain, the new BS forwards the service negotiation request to the new QGS. The new QGS gets the SLS from the previous QGS via a SLS request and verifies if this SLS can be guaranteed. If accepted, the new QGS sends the SLS to the new BS and sends a positive service negotiation response to the MS. This procedure is conceptually depicted in Fig. 4.

## IV. PERFORMANCE EVALUATION

This section presents an experimental evaluation of the proposed scheme. The major issue in providing QoS in wireless networks is the users' mobility (where seamless and lossless

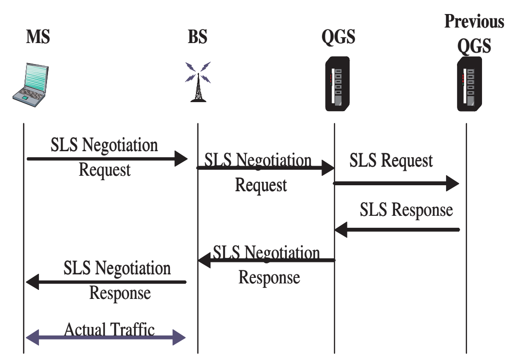


Fig. 4. Signaling for Inter-domain Handoff

handoff need to be guaranteed). Therefore, we evaluate the proposed scheme in a scenario where all MSs have already initiated their services and want to perform handoff, specially intra-domain handoff, as this is the most frequent handoff performed by MSs.

As mentioned in Section II, there are several protocols for dynamic service negotiation. The main characteristics of these protocols are summarized in Table I. There are only two protocols that support mobility management: QoS-GSLP and DSNP. QoS-GSLP is not scalable. DSNP fulfills all desirable characteristics of any service negotiation protocol. Thus, DSNP represents the state-of-the-art service negotiation protocol. Encrypted SLS [13] is scalable and robust in delivering QoS profiles to a BS. Therefore, we have compared the performance of DSNP and Encrypted SLS to that of the proposed scheme.

### *A. Simulation Description*

In order to verify the applicability of the proposed scheme, we set up a simple simulation environment using Network Simulator (ns2) [15]. The considered network topology, shown in Fig. 5, consists of one QGS, one AAA server, five BSs, and a number of MSs roaming in the domain. The number of MSs vary from 5 to 100. The simulation starts when all MSs have already initiated their services. The mobility of each MS is set randomly. The background traffic consists of Constant Bit

Table I
Comparison of service negotiation protocols

| Protocol Name | Light Weight | Reduced Signaling | Mobility Management | Scalability |
|---|---|---|---|---|
| COPS-SLS | X | √ | X | X |
| DSNP | √ | √ | √ | √ |
| RNAP | X | X | X | X |
| SrNP | X | X | X | X |
| QoS-GSLP | √ | X | √ | X |
| QoS-NSLP | X | X | X | X |

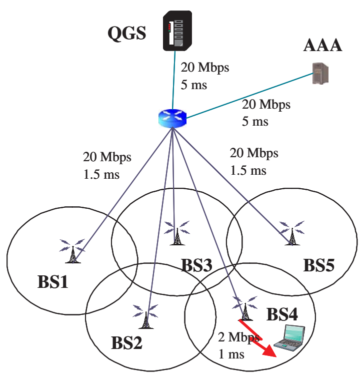


Fig. 5. Simulation topology

Rate (CBR) applications running between each pair of BSs.

### *B. Simulation results*

Fig. 6 shows that the proposed scheme exhibits higher negotiation delay than those of DSNP and Encrypted SLS. This better performance is due to the fact that the new BS gets the SLS from the previous BS in the proposed scheme, whereas the new BS already has or received the SLS from the MS in DSNP and Encrypted SLS. The difference in the delay between DSNP and Encrypted SLS is due to the SLS decryption operation. Fig. 7 shows that the proposed scheme has a reduced signaling overhead in comparison with that of DSNP and a higher one than that of Encrypted SLS. As shown in Fig. 8, the proposed scheme has the lowest number of SLSs stored in the network. This is attributable to the ability of the proposed scheme to know when to erase unnecessary SLSs.

### *C. Result Analysis*

DSNP yields the lowest service negotiation delay, as all possible new BSs have already knowledge on the SLSs. Thus, the BS can perform traffic conditioning almost immediately when the MS performs handoff. However, DSNP presents problems related to scalability in terms of the data storage and signaling overhead. When a MS performs handoff to a new BS, all neighboring BSs receive the SLS of the MS from the QGS, even if some of these BSs will never serve the MS. Thus, BSs maintain huge state tables for storing SLS of MSs that may never visit their coverage areas. Another issue of DSNP is its perpetual storages of data, as there is no mechanism to inform the BSs when to erase the SLS of MSs. In addition, the

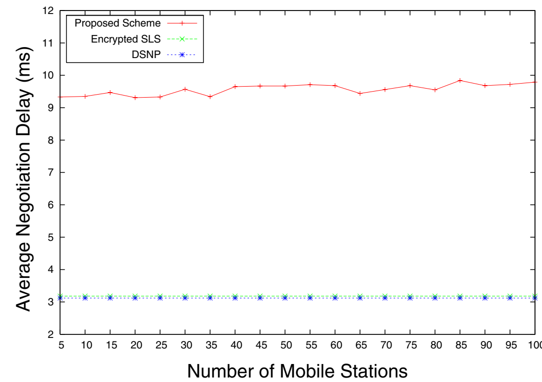


Fig. 6. Service negotiation delay

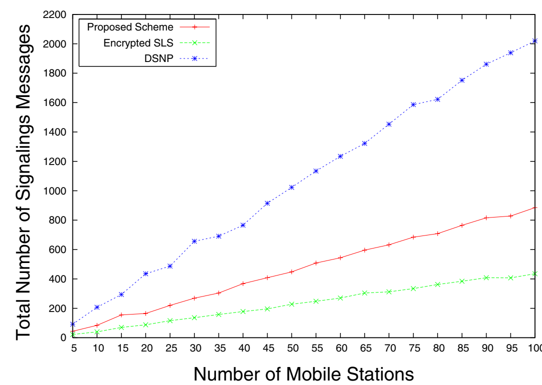


Fig. 7. Service negotiation signaling

QGS needs to know about the network topology to identify the neighbors of each BS.

Encrypted SLS presents a reasonably good service negotiation delay, similar to that of DSNP. The small difference is due to SLS decryption time. Encrypted SLS has the lowest signaling overhead, but it also involves perpetual storage of data. Moreover, QGS has no information about local resources of each BS. Thus, each service negotiation or renegotiation requires to consult its related BS about the local resources. The major drawback of this method is lack of security. Although delivering encrypted SLSs to MSs seems to be secure because users cannot modify them, these encrypted SLSs can be captured by malicious users (man-in-the-middle), who can then use these encrypted SLSs to steal the service levels belonging to other users. This fact dampens the applicability of the Encrypted SLS method.

In contrast, our proposed scheme solves the security problem of Encrypted SLS, as SLS is manipulated by BSs and QGS alone. It also addresses the scalability problem of DSNP, as it introduces a mechanism to erase the SLSs of departing MSs. In this way, each BS maintains the SLS of only MSs that currently exist in its coverage area. This reduces the size of the tables of BSs and also the time required to search into these tables. The signaling overhead is much smaller than that of DSNP as SLSs are delivered to only the required BS. The trade-off of the improved performance of the proposed

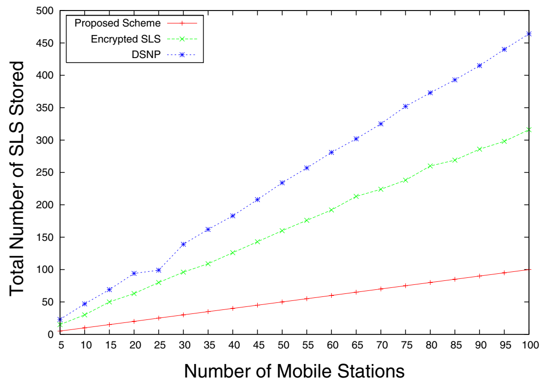


Fig. 8. Data stored along the network

scheme is its relatively long negotiation delay. On average,with respect to DSNP, our proposed scheme incurred an additional negotiation delay of 6 ms for 5 MSs and 6.6 ms for 100 MSs, respectively, in our simulations.

## V. Conclusion

In this paper, we have proposed a new scheme to dynamically negotiate QoS profiles between users and networks. The scheme allows users to renegotiate their service levels in a small time scale. It can also mitigate network congestion by requiring, through negotiation, users to degrade their service levels. The results have demonstrated the applicability of our proposed scheme. Indeed, although the proposed scheme incurs a little higher negotiation delay, it is more scalable than DSNP in terms of both reduced signaling overhead and state information storage. To cope with the additional negotiation delay, mainly in wireless environments where the coverage areas of access points partially overlap, a possible solution is to refer to the mobility patterns of users to predict the next access point to which users will likely attach after handoff. Users then anticipate their service negotiation with the next point of attachment while they are still connected to the old access point. By this operation, the negotiation procedure can be terminated before the actual handoff to the new access point and users can immediately start enjoying their service right after the handoff. This will intuitively reduce the effect of the slight increase in the negotiation delay incurred by the proposed scheme. Incorporation of mobility pattern prediction schemes with the proposed scheme forms the focus of the authors' future research work.

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