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A Study on Handoff Techniques to Communicate in Cellular Networks

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***Abstract**— The continuation of an active call is one of the most important quality measurements in cellular systems. Handoff process enables a cellular system to provide such a facility by transferring an active call from one cell to another. Different approaches are proposed and applied in order to achieve better handoff service. The principal parameters used to evaluate handoff techniques are: Forced termination probability and call blocking probability. Mechanisms such as guard channels and queuing handoff calls decrease the forced termination probability while increasing the call blocking probability. In this paper we present an overview about the issues related to handoff initiation and decision and discuss about different types of handoff techniques available in the literature.*

***Keywords**— Handoff, QoS provisioning, Expected Visitor List, Decomposition of Handoff Messaging, Base Station, Handoff Initiation, Handoff Decision.*

I. INTRODUCTION

Next Generation (NG) wireless networks should be able to provide users with reliable QoS levels. Handoffs between coverage areas of the same architecture as well as different architectures will require intelligent handoff management to preserve the service level of the mobile stations. The QoS requirements cannot be satisfied or guaranteed only by local resource availability information in the wireless domain, i.e., base stations, or switching centres. Application specific service requirements should be satisfied in an end-to-end fashion. This necessitates the integration of QoS provisioning and/or resource reservation in wireless and wired parts of the end-to-end traffic flow during handoff.

The preparation latency of the QoS requirements along the new path, however, brings the forced termination riskof active connections during handoff. After the detection of the handoff necessity, next step to go over by the network is to make some preparations. These include performing an admission control algorithm against the owner of the incoming handoff request, and hence (in case of acceptance) performing network preparations for the handoff including route reconstruction for transferred connections, determination of crossover switches and applying a channel assignment strategy for the mobile in its new cell. With the NG wireless networks, additional preparation phase task is to make end-to-end QoS provisioning and resource reservation (if possible) for the incoming mobile. In current literature, there are studies proposed to provide seamless QoS levels during handoff in wireless networks [1], [2], [3], [4], [5]. All these proposals either requires mobility pattern information, which may not be accurate in heterogeneous next generation wireless networks, or makes some actual reservations in advance, which may result in waste of resources. Resource ReSerVation Protocol [6], is a powerful protocol for setting up reservations for certain QoS specifications along a path. Hence, it can be easily adopted by wireless networks to provide end-to-end QoS guarantees. However,plain implementation of RSVP in wireless networks will bring high overhead in wireless resources during handoff. With the help of an agent deployment at access points of wireless networks, the overhead can be reduced and the strength of RSVP can be benefited.

In this research, a new handoff method is proposed to provide QoS continuity during handoffs in next generation wireless networks. This is tried to be achieved by informing candidate base stations about the QoS requirements of the prospective mobile stations well before the handoff time. Expected Visitor List (EVL) processors at candidate BSs, which are aware of the mobile's QoS expectations, can then execute RSVP-based virtual QoS provisioning procedure to capture the end-to-end resource availability status. The result of the provision query will be stored in a record called EVL entry at the EVL processor. Any change in the resource availability will be reflected to the provision result and the entry will be kept updated to be ready in case of actual handoff. Hence, the incoming mobile will take the advantage of the method if its entry contains up-to-date information. The performance simulations shows that the proposed method is a promising methodology for QoS maintenance in next generation wireless networks.

II. Handoff Initiation

Handoff initiation is the process of deciding when to request a handoff. Handoff decision is based on the received signal strengths (RSS) from the current BS and neighboring BSs. In Fig. 1, we examine the RSSs of the current BS (BS1) and one neighboring BS (BS2). The RSS gets weaker as the MS moves away from BS1 and gets stronger as it gets closer to BS2 as a result of signal propagation characteristics. The received signal is averaged over time using an

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averaging window to remove momentary fading's due to geographical and environmental factors [1-2]. Below, we will examine the four main handoff initiation techniques mentioned in [2-3]: Relative signal strength, relative signal strength with threshold, relative signal strength with hysteresis, and relative signal strength with hysteresis and threshold.

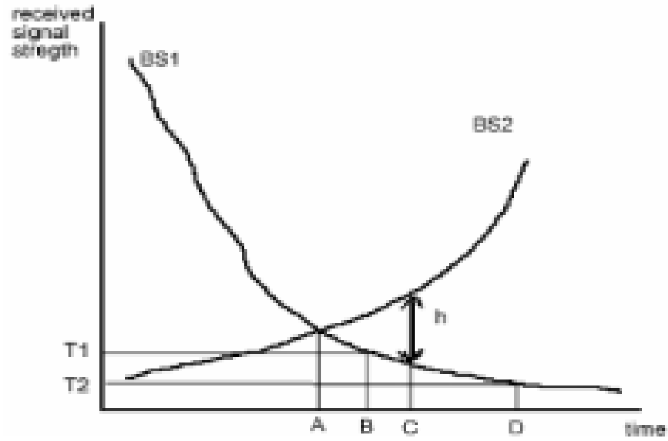

Fig.1 Movement of an MS in the handoff zone

A. Relative Signal Strength

In relative signal strength, the RSSs are measured over time and the BS with strongest signal is chosen to handoff. In Fig. 1, BS2's RSS exceeds RSS of BS1 at point A and handoff is requested. Due to signal fluctuations, several handoffs may be requested while BS1's RSS is still sufficient to serve the MS. These unnecessary handoffs are known as the ping-pong effect. As the number of handoffs increase, forced termination probability and network load also increases. Therefore, handoff techniques should avoid unnecessary handoffs.

B. Relative Signal Strength with Threshold

Relative signal strength with threshold introduces a threshold value (T1 in Fig. 1) to overcome the ping-pong effect. The handoff is initiated if BS1's RSS is lower than the threshold value and BS2's RSS is stronger than BS1's. The handoff request is issued at point B in Fig. 1.

C. Relative Signal Strength with Hysteresis

This technique uses a hysteresis value (h in Fig. 1) to initiate handoff. Handoff is requested when the BS2's RSS exceeds the BS1's RSS by the hysteresis value h (point C in Fig. 1).

D. Relative Signal Strength with Hysteresis and Threshold

The last technique combines both the threshold and hysteresis value concepts to come up with a technique with minimum number of handoffs. The handoff is requested when the BS1's RSS is below the threshold (T1 in Fig. 1) and BS2's RSS is stronger than BS1's by the hysteresis value h (point C in Fig. 1). If we would choose a lower threshold than T1 (but higher than T2) than the handoff initiation would be somewhere at the right of point

C. All the techniques discussed above initiate handoff before point D, which is the "receiver threshold". The receiver threshold is the minimum acceptable RSS for call continuation (T2 in Fig. 1) [1, 5]. If the RSS drops below the receiver threshold, the ongoing call is than dropped. The time interval between the handoff request and receiver threshold enable cellular systems to delay the handoff request until the receiver threshold time is reached when the neighboring cell does not have any empty channels. This technique is known as queuing handoff calls and will be discussed in Section V. In [8], a handoff algorithm using multi-level thresholds is proposed which assigns different threshold values to the users according to their speed. Since low speed users spend more time in handoff zone they are assigned a higher threshold to distribute high and low speed users evenly. High speed users are assigned lower thresholds. The performance results obtained by [8] shows that an 8-level threshold algorithm operates better than a single threshold algorithm in terms of forced termination and call blocking probabilities. In [9] and [10], an improved threshold-based method is introduced and compared with the basic initiation techniques such as maximum power handoff (MPH or RSS), RSS with hysteresis, RSS with threshold, and combinations of hysteresis and threshold based methods in a ten-cell structure.

III. Handoff Decision

In the previous section, we discussed the time in which a handoff is requested. In this section, we will examine the handoff decision protocols used in various cellular systems.

A. Network Controlled Handoff (NCHO)

NCHO is used in first generation cellular systems such as Advanced Mobile Phone System (AMPS) where the mobile telephone switching office (MTSO) is responsible for theoverall handoff decision [11]. In NCHO, the network handles the necessary RSS measurements and handoff decision. The handoff execution time is on the order of many seconds because of the high network load [12].

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B. Mobile Assisted Handoff (MAHO)

In NCHO, the load of the network is high since the network handles all of the processes itself. In order to reduce the load of the network, the MS is responsible for making RSS measurements and sending them periodically to BS in MAHO.Based on the received measurements, the BS or the mobile switching center (MSC) decides when to handoff [3-4]. MAHO is used in the Global System for Mobile Communications (GSM). The handoff execution time is about 1 sec [4, 12].

C. Mobile Controlled Handoff (MCHO)

MCHO extends the role of the MS by giving overall control to it. Both, MS and BS, make the necessary measurements, and the BS sends them to the MS [3].

Then, the MS decides when to handoff based on the information gained from the BS and itself. Digital European Cordless Telephone (DECT) is a sample cellular system using MCHO with 100-500 ms handoff execution time [4, 12].

IV. Expected Visitor List (EVL)

A. Decomposition of Handoff Messaging

The target cell accepts a handoff request if its resources can support the resource demands of the mobile with certain characteristics at the time of handoff. Otherwise handoff request is simply rejected and the ongoing call is forced terminated. This approach brings about considerable latency since decision making process about the admission of the mobile requires some messaging between the mobile, current base station and the target base station.

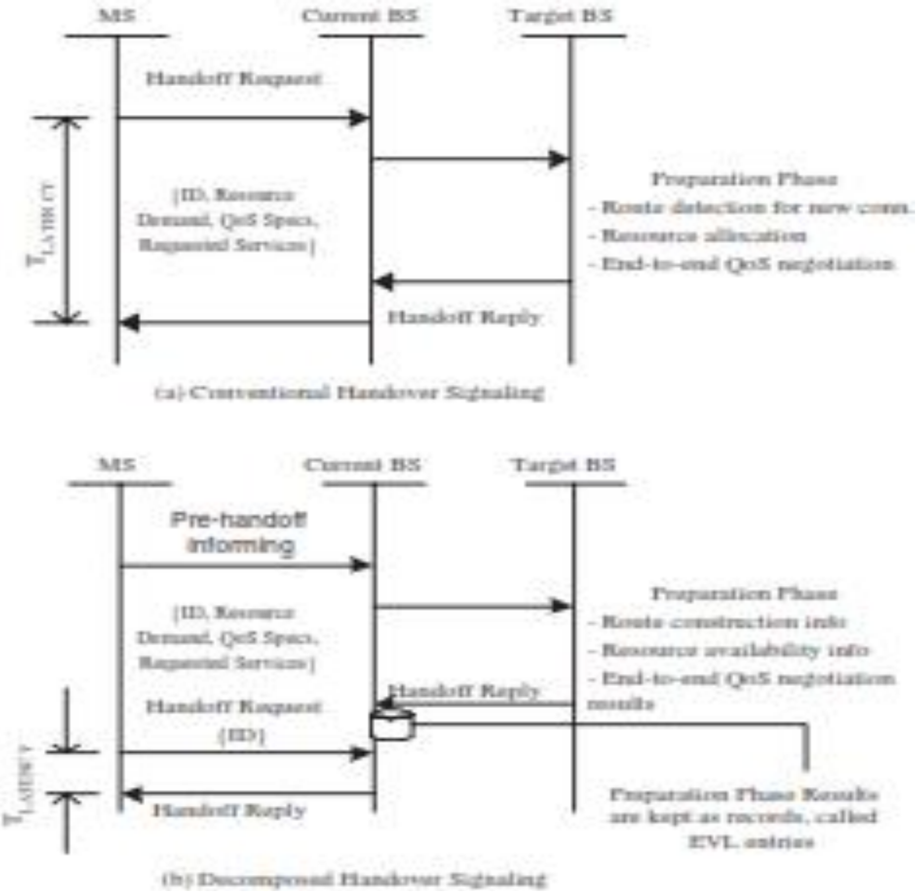

Fig.1 Handoff messaging in existing and new scenarios.

On the other hand, to make some QoS provisioning in advance, QoS expectations of the mobile station must be learned a priori. In order to make the candidate cells aware of expected visitor mobiles in advance, decomposition of handoff messaging is preferable in a way that messaging at the time of handoff as in Fig. 1(a) could be so shortened that it could contain 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, candidate base stations become capable of initiating the preparations for the incoming mobile in very advance. As a result, much shorter handoff latency than the conventional methods might be achieved. The classical handoff messaging is decomposed into two parts, one being the non real-time component containing the information about mobile id, traffic specifications, QoS expectations, resource 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.

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B. EVL Entry Structure

In the proposed method, EVL processors at base stations keep records per neighbor,i.e., EVL entries, to store the decisions and preparations of each expected mobile station. The EVL entries are created first at the EVL processors deployed at the current cell of the mobile. This is because the QoS expectations are captured by the EVL processor at the current base station. A sample EVL entry, as shown in Fig. 2, will include fields for Resource Demand, QoS Expectations, Traffic Specifications, Pre-emption Priority, and Corresponding Nodes of the mobile station, and the results of the QoS provisioning and connection admission control tasks.

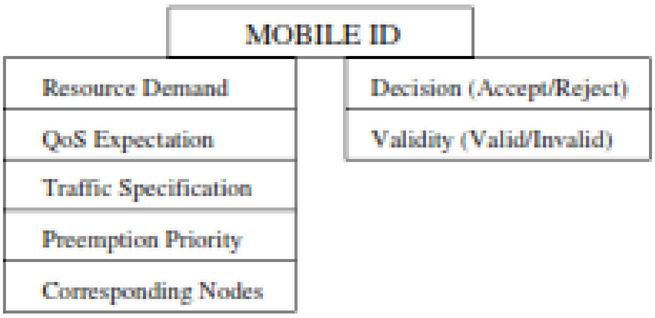

Fig.2 A typical EVL entry structure.

The basic wireless networking illustration with EVL deployed at base stations is seen in Fig. 3. In this example, the has entries for all mobiles connected firstly. The resource demand, QoS expectations, traffic specifications, preemption priority and corresponding nodes data are entered in the appropriate fields of the EVL entry. Since the EVL processor does not process the entries which are current residents of the same cell with itself, the result fields are not entered. Upon the creation of the entries at the original EVL, they are copied to the other EVL processors in the shadow cluster [7], i.e. the cluster of possible target cells, of the mobile station.

The cloning of the EVL entries in the neighbor EVL processors requires signaling between the original EVL processor and the ones in shadow cluster. First, the synchronization of the EVL databases between is performed. All entries are set valid upon their creation, and their validity is preserved until the EVL processors receives any signal indicating the change in network conditions which might invalidate the current acceptance status of the entry. If any resource status change event occurs in any of router resource capacity for either increase or decrease cases, i.e., invalidator event, the valid EVL entries will be invalidated to reflect the changed environment conditions to their admission control decisions. If an event is a capacity decrease of a path or a router along the path, then EVL entries, whose connection pass over that path, with accept decisions will be invalidated. In the same manner, if an event represents a capacity increase, then valid EVL entries with reject decisions will be invalidated.

The invalidated EVL entries will be reprocessed and their preparation results and call admission control decision will be re-evaluated and stored again in the proper fields to be used for handoff requests.

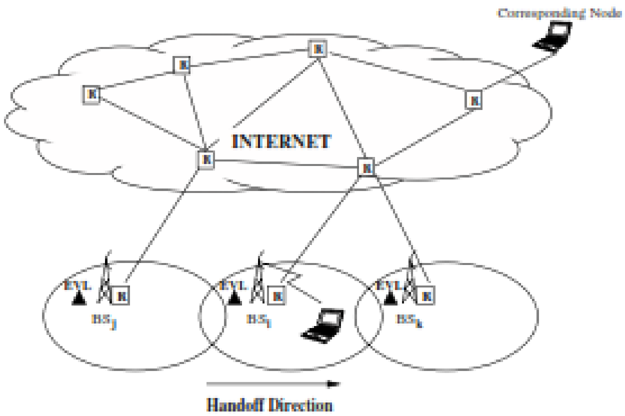

Fig..3 An illustration of wireless environment during handoff of mobile station from BS_1 to BS_2.

C. Virtual QoS Provisioning

Decision (Accept/Reject) field evaluation of an EVL entry is a more involved task than the call admission control process of handoff requesting mobile station. Although the consideration for scarce wireless resources is still important, QoS provisioning, i.e., accept/reject state of an EVL entry, must be performed in an end-to-end fashion. Since resource requirements and expected constraints are to be provided throughout the path, the accept/reject evaluation of the EVL entries should be performed by considering the resource availability states of the routers which are on the path for connections of the incoming mobile. This will be performed as if new RSVP reservation setup is being performed by the mobile station as it is described in [6]. Although RSVP has its diagnostic messaging functionality, [8] specifically identifies checking the resource availability along the path as useful but non-goal for the diagnostic messages. However this function can be easily adopted by an extension to RSVP for resource availability query. The 8-bit *Msg Type* field in

RSVP message is used for distinguishing seven different RSVP message types. This means that we can further identify two additional message types with the unused bits in that field. These two new messages are *PathQuery* and *ResvQuery* which will be used for virtual QoS provisioning. Having a functionality to obtain resource availability status without actual reservation is indeed very useful in highly dynamic environments like wireless networks. Resource reservation for mobile stations before handoff occurs may lead to underutilization of network resources. Keeping EVL entries with the QoS provisioning results will help to reduce handoff latency without reserving network resources in advance. In order to perform this provisioning, EVL processor sends PathQuery message along the path to the corresponding node. This continues down to receiver and it sends back ResvQuery message. Here, unlike the actual RSVP setup process no resource reservation takes place. If any router cannot provide the expected requirements of the request, then it will return a notification of failure. Then the decision field for this EVL entry will be set as reject. If no error is received and the ResvQuery message is received, then the decision can be set accept. This method also reduces overhead due to RSVP signalling between two nodes. EVL processor at the base stations will do the signaling on behalf of the mobile station. By this way, signaling is performed only in wired portion of the end-to-end connection path, and the scarce wireless resources are saved.

The method also checks for resource availability of the cell in terms of wireless channels. In case of excessive bandwidth requirements, if no adequate wireless resource exists then handoff request for the incoming mobile station will be inevitably denied. This QoS provisioning result is merged by the EVL processor with the wireless channel availability status, then the final decision is made.If the entry of a mobile contains Accept in its decision field, it will enjoy seamless service. Otherwise, its handoff request will not be approved. By this way, handoff call admission control is integrated with the QoS provisioning of the mobile. This method provides virtual QoS provisioning procedure with exact resource availability information. Any resource availability change on the way to corresponding node, will be reflected to the current acceptance status of the entries. The preemption priority may also be taken into account during this virtual resource reservation and provisioning process.

V. CONCLUSIONS

In this paper, we introduced an overview on the concept of handoff and its evaluation parameters. We discussed the handoff initiation techniques based on the received signal strength and also the handoff decision protocols that are used. In addition, the handoff types based on channel usage, microcellular and multilayered systems and network characteristics are explained. Finally, we presented the handoff prioritization schemes to reduce the handoff call blocking probability, such as guard channels and queuing handoff calls.

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