Forced Low latency Handoff in Mobile Cellular Data Networks

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Abstract: In this paper, a hand off procedure is proposed which in addition to eliminate the packet loss and reduce the packet delay, it reduces the network overhead. In this method, the future cell is predicted and packets are transmitted to this cell during hand off time. Then mobile host is allowed to handoff to this cell only. We call this procedure, forced handoff. In addition, we propose a simple topology to localize handoffs. Simulation results will evaluate our protocol compare to the previous protocols.

I. Introduction

In recent years, the number of wireless communication services increased significantly and it is expected in few years that the number of wireless internet terminal exceeds the number of wire internet terminal. Consequently, to delivery whole services in wireless network, it is necessary to use IP data services [1-5]. For channel reusing and decrease consuming power, micro cell and pico cell structures appear more and more in the next generation of communication systems. The increase of number of handoff is result of high speed in small cells. That clears the importance of handoff discussion. One difficulty of holding internet connection when the Mobile Host (MH) is out of Host Agent (HA) is real time servicing with high QoS. Some protocols are proposed to handle of QoS in handoff time. Among these protocols, Seshan protocol [6] is close to our proposed protocol. However, our protocol has more advantages to Seshan protocol. In the rest of the paper we describe our proposed protocol and discuss the simulation results.

II. Novel Hand off Protocol

The main purpose of the proposed handoff protocol is reducing network overhead during handoff process. In this protocol, the direction of MH is estimated and due to this estimation the packets are routed to the cell which is estimated to be MH future cell. The packets is only routed to one cell most of the time and during the hand off they are routed to two cells, MH correspond cell and estimated future cell. This protocol, similar to other protocols with multicasting and packet buffering, prevents delay and loss of data packets. In addition, it minimizes buffering time and number of cells which packets have to be routed to them. The proposed protocol will be done in 3 following steps:

1- A good Mobility tracking algorithm estimates next cell with high accuracy.

2- In addition to route packets into corresponding cell, data packets are transmitted to this estimated cell when MH is near boundary and wants to hand off. This will take only a short time.

3- The network permits MH to hand off to only this cell. We call this hand off, forced hand off.

At the rest of the paper we describe these steps with more details.

III. Mobility Tracking Algorithm

To estimate the MH path dynamically with three RSS (received signal strength) measurement, as it explained in [5], an extended Kalman filter is needed. For this reason, first semi-Markovian states are estimated. Then they are used in Kalman filter equations. The detail of mobility tracking is out of scope of this paper and can be found in [7].

IV. Routing Rule Algorithm

In our structure, each Foreign Agent (FA) is responsible for a group of BSs. It receives data packets from their sources and decapsulates them and delivers to MH through BS that is responsible for this MH. Each FA separately connects to network and it needs independent routing for receiving its data packets. Data packet routing for BSs that are in one FA group is similar. Thus, multicast protocol for two BSs in one group is equal to unicast protocol for their common FA. Handoff between two BSs in one group is named 'local handoff' and between two different groups is named 'global handoff' (Fig. I).

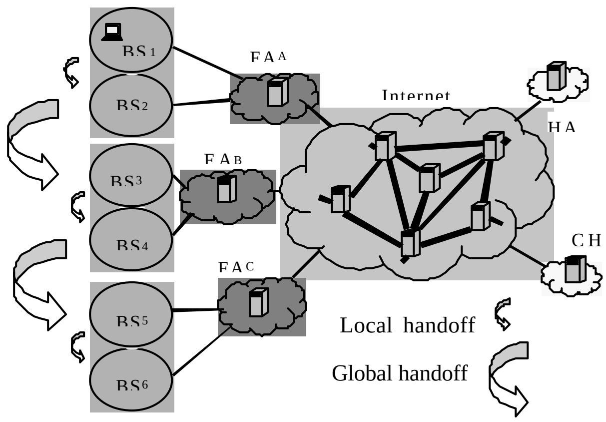

Fig I: Local and Global hand off

It is assumed that one MSC exist beside each FA. In each MSC, MSS part keeps some information about positions of MHs in its region, corresponding BSs and their neighbors and power of beacon in each BS. Assume, at the first, the MH communicates with BS1, which its FA is A. After MH arrives at the vicinity of boundary cell and passes the distance threshold, according to the three greater measured powers that the MH sent to the MSC, next cell is estimated by MSS. Afterwards, if new FA related to the new BS (BS2) is as same as old FA (A), 'local handoff', data packets through common FA are sent to BS2 and asked to be buffered there. Then, BS2 put this MH in the list of users that it buffers their packets. Buffer length is limited and if the size of received packet exceeds the buffer size, packets are discarded with the rule of FIFO. The other case is when new FA (B) related to the new BS is not as same as old FA (A), 'global handoff'. In this case, data packets are transmitted to the new BS2. Therefore, the old FA (A) sends a message to the source and asks it to unicast simultaneously packets to both FA (A) and FA (B). Then, FA (B) sends these packets to new BS and asks it to buffer them and to put this MH in the list of users which their packets are buffered.

As it is seen, in local handoff that one FA sends packets to two BSs, there is no difference between unicast protocol and multicast protocol. The advantage of this method is escape from complexity of multicast protocol. In addition, in global handoff there is no difference in complexity between unicast and multicast protocol. In multicast protocol there are packet managing problem and finding cross over point which are not exist in our method. In addition, multicast protocol is not economical for two destinations.

V. Forced Hand off Algorithm

Simultaneous with transmitting of data packet to BS2, the network permits the new BS to accept handoff request of the MH whose packets are buffered. Other BSs, which do not have this MH in their buffer list, decline handoff request of this MH. Therefore, the MH can just handoff to the new estimated BS. Handoff occurs when the MH finds another BS with stronger beacon and this BS is allowed to handoff by network. Handoff process in both local handoff and global handoff is depicted in Fig. 2. According to Fig. 2, the MH travels from BS1 to BS2. When the MH received greater beacon signal power, based on some hysteresis, it decides to handoff to new BS. Then, the MH sends a greeting message to this new BS (BS2). Hystersis prevents unnecessary handoff requests. Afterwards, if the name of this MH exists in the buffer list of BS2, BS2 sends an acknowledgment message to the MH that it accepts the handoff request. Then, BS2 begin retransmitting the buffered packets of this MH to it. In this time, old BS transmits packets to the MH too and the MH receives them (soft handoff). If there is not the name of the MH in the buffer list of BS2, BS2 discards the handoff request and dose not response to the MH.

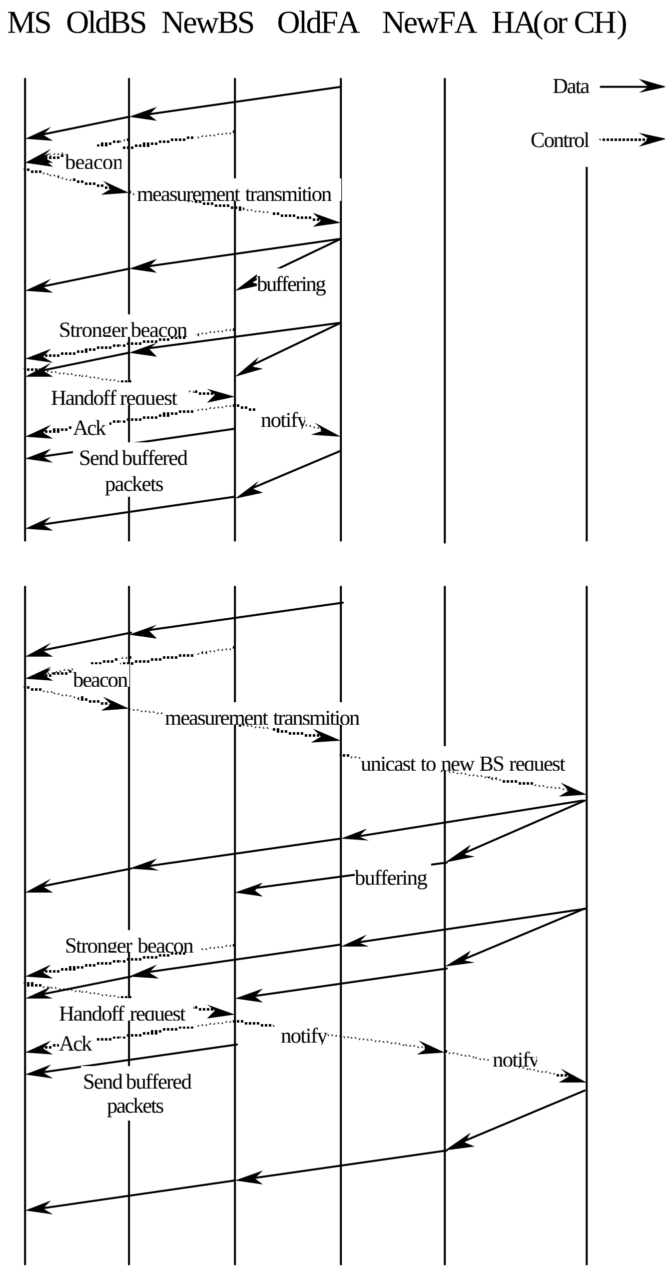

Fig. 2: Forced Hand off Algorithm

In this case, after expiring of the time response, the MH tries to find another BS to handoff. If no BS has handoff conditions, the MH continues its communication with BS1. This function is done per each power measurement. Finally, the MH is forced to handoff to predicted cell. We call this kind of handoff "forced handoff". Next, BS2 sends a control message to BS1 through its FA that old BS stops forwarding data packets to the MH and handoff process is completed. This message is sent to common FA in local handoff and it is asked to end the MH data packet transmission to BS1. In global handoff, this message is sent through new FA (B) to HA and then HA stops transmission of the MH data packets to old FA (A) and as a result to BS1. In this case, this message carries new address of the MH. After ending data packets transmission

into BS1, it only forwards data packets that received before. Therefore, there is probability of duplication packets in the MH. Another possibility of creating duplicate packets is due to data packet buffering in new BS, especially in long buffer length, when handoff process is done fast. Although duplication packets are allowed in internet, in fixed wire network is very rare. To prevent this, beside handoff request message we can send ID and source address of the last received packet that the MH has received [5, 6]. Consequently, after handoff, BS2 just sends data packets with ID greater than the last sent packet. In this way, the number of duplication packets is reduced. Size of this additional information is only six bytes that dose not have so much effect in load of network. To diminish error rate in sending the last ID, it had better to use proper error correcting code.
Sometimes after sending data packets to BS2, the MH changes its way suddenly and it dose not go towards predicted cell and no handoff occurs. In this case, to prevent to waste network resource in BS2, if handoff process dose not happen for a specific time, data packet transmission to BS2 is stopped.

VI. Network and Simulation Model

For simulation of the proposed handoff protocol, we consider 61 cells with 1000m in diameter that user can move freely everywhere with arbitrary velocity. Simulation parameters are according to Table I.

Table I: Simulation Parameters

LAN bandwidth	10Mbps
WLAN bandwidth	2Mbps
Size of data packet	1KB
Delay of internet network transmission	30ms
Delay between FA and BS	0.78ms
Delay between BS and MH	3.9ms
FACCH control channel capacity	1Mbps
SACCH control channel capacity	500Kbps
Buffer length	1~5 packets
Mean of geometric distribution to generate data packet	1.95 time unit
Delay between data packets transmission in buffer	1 time unit
Time unit	5ms
Period of beacon signal	T=0.48s
Deviation of random acceleration in random movement model	$0.2m/s^2$
Deviation of random part of absolute velocity in real movement model	1m/s
Deviation of phase variation of velocity n real movement model	0.1^o
Max. acceleration	$\lvert A_{max}\rvert=10m/s^2$
Velocity limitation	$\lvert V\rvert<100Km/h$
Power of beacon transmission	20W
Cell radius	1000m
Reuse factor	7

VII. Simulation Results

Fig. 3 shows three MH sample paths and their estimations for shadow deviation of 4. The dark lines are the original MH paths that simulated by real movement model and the light lines are estimated paths by Kalman filter. Starting point of all movements is center of cell 1. Then MH can move freely. MSS estimates the MH path by using power information sent by the MH. As seen in the figure, error of estimation that is rather high at the beginning of path after the Kalman filter becomes stable reduces and estimated path vibrates about real path. Average error of estimation is about 10% with deviation of 8% that are proper for our goal. Accuracy of next cell prediction in all shadow deviation is close to 100%.

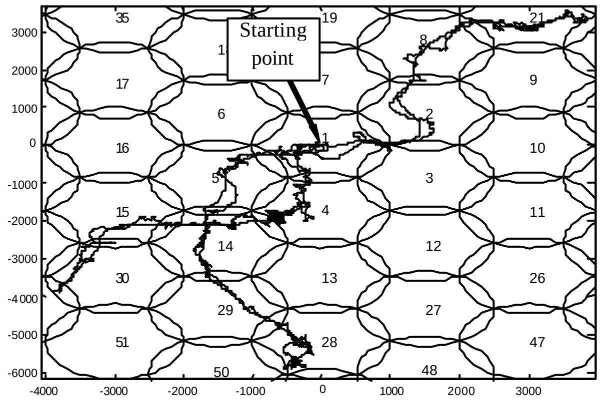

Fig. 3: Three MH sample paths and their estimations

The only place error can exist is near boundary of three cells and when Mobile suddenly changes its direction. In this case, according to Fig.4, our system can adjust itself. In Fig.4, cell 3 is considered as next cell, but the MH changes its way to cell 2.

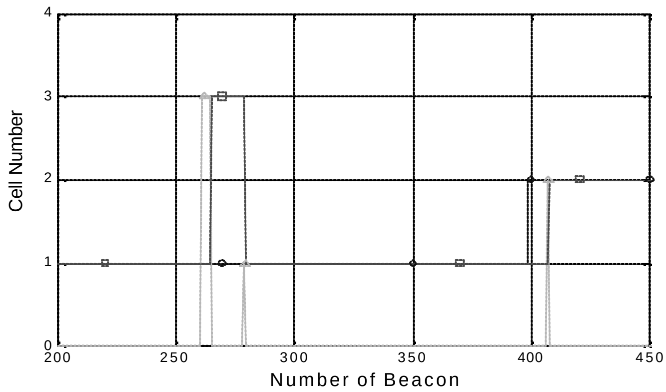

Fig.4: Adjustment in fault handoff

At first data packets of this MH are sent to cell 3 then the MH hands-off to cell 3. After that, our system understands its fault and figures out the correct cell is cell 2. It sends data packets to cell 2 and allows the MH to handoff to this cell. Since the powers of three cells in the boundaries are the same, there is no problem in the MH communication.

Fig.5 and Fig.6 depict delivery of data packets sequence in two assumed handoff protocols for both local and global handoff. In case one, after handoff, BS2 sends all buffered data packets to the MH. As a result, depend on buffer size the MH receives many duplicated packets. Whereas in case two, the ID of the last received packet by the MH is sent with handoff request message. Therefore, the number of duplicated packets is very low. In both cases, it is seen that the number of duplicated packets in global handoff is more than those in local handoff. In the second case and in local handoff, not only there is no packet loss but also there is no duplicated packet that is ideal for the MH.

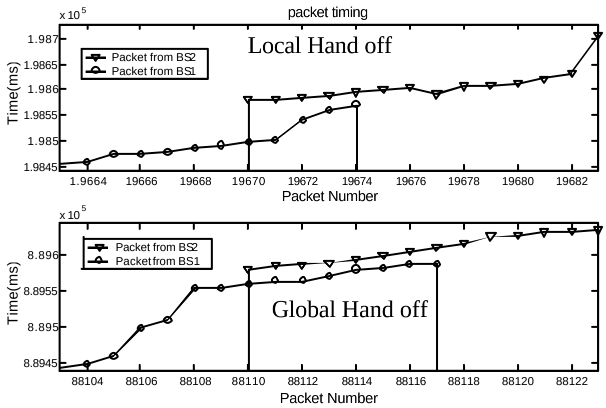

Fig.5: Case I hand off (a) Local (b) Global

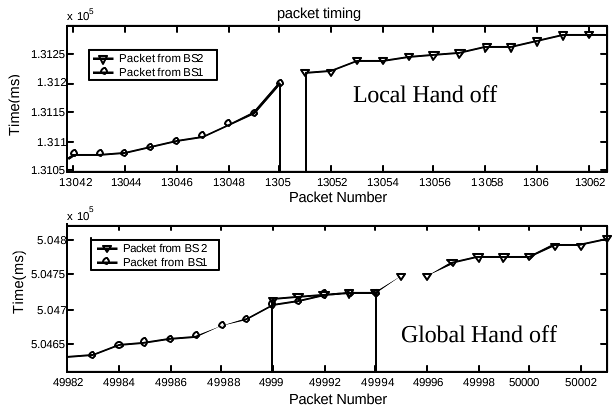

Fig.6: Case II hand off (a) Local (b) Global

Number of duplicated packets versus buffer length is shown in Fig.7 in both cases. Long buffer length causes more duplicated packets when BS2 sends all buffer contents to the MH. However, in the second case, the number of duplicated packets is negligible in the local handoff and it is constant in the global handoff independent to buffer length. In general, duplicated packets are more in the global handoff than local handoff. That is due to delay of delivering stop control message to HA to stop data packet transmission to the old BS. Simulations illustrate, there is no packet bss when data packets are sent to predicted cell and buffered there before the MH is allowed to handoff to this cell. Necessary buffer length to prevent packet loss depends on the packet size.

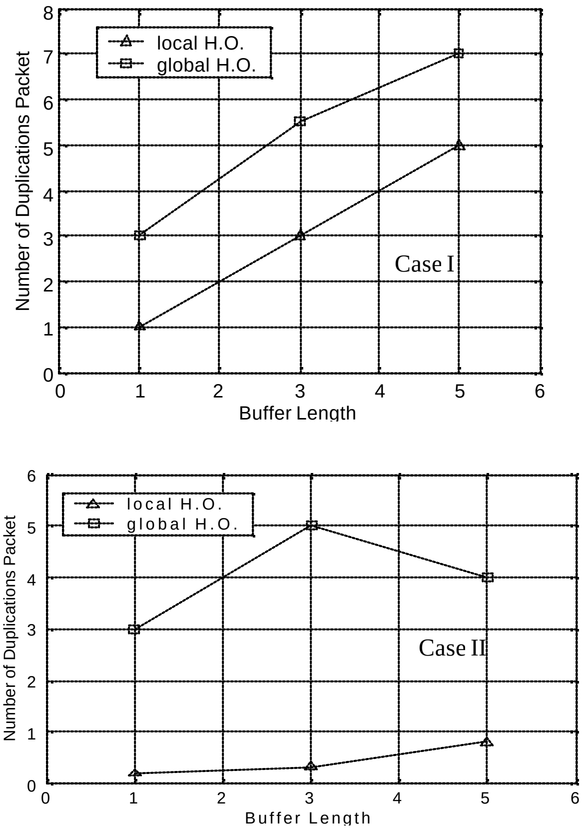

Fig.7: Duplicated packets versus buffer length (a) Case I (b) case II

VIII. Compare the proposed protocol with the Previous Protocols

Network resources overhead depends on four items: reserved bandwidth, time of resources reservation, the number of cells to be reserved and the number of hopes in reserved mode. In proposed protocol, there is no change in bandwidth. The number of reserved cells has reduced to only one cell. The number of reserved hopes in the local handoff is only one hope and in the global handoff is depend on the distance between source and predicted BS. Furthermore, this forehand data packet transmission is in less than one second per handoff. Therefore, network overhead in our algorithm diminish rather than previous algorithm. For example, the number of reserved cell reduced from six cells in [6, 8] or three cells in [9] to only one cell in proposed protocol. Time of reservation also decreased from permanent data packet transmission in [6] to less than one second in this protocol. Moreover, we avoid complexity of management in multicast method and use unicast transmission.

Fig.8 shows network overhead based on the number of transmitted packets to be buffered in next cells. Horizontal axis is cross over point in multicast. There are seven hopes between server BS and HA. One hope in our protocol

Top

means local handoff. Other numbers of hope are the same and equal to global handoff. These results are averaged in fifteen handoffs. As it is seen, for cross over point of one, in Seshan algorithm [6] there are 35 thousand transmitted packets to be buffered while they decrease in Baaktieshal [8] and Bea [9] algorithms to 10 thousand packets. Nevertheless, simulation results show unestimated handoffs, delay and packet loss in all previous algorithms. Instead, the overhead packets in our protocol are only 50 packets without packet loss or delay. That is considerable decrease in network overhead. On the other hand, increase in distance of cross over point causes a linear increase in network overhead in previous algorithms but it is constant in our protocol. That is due to unicast transmission from HA.

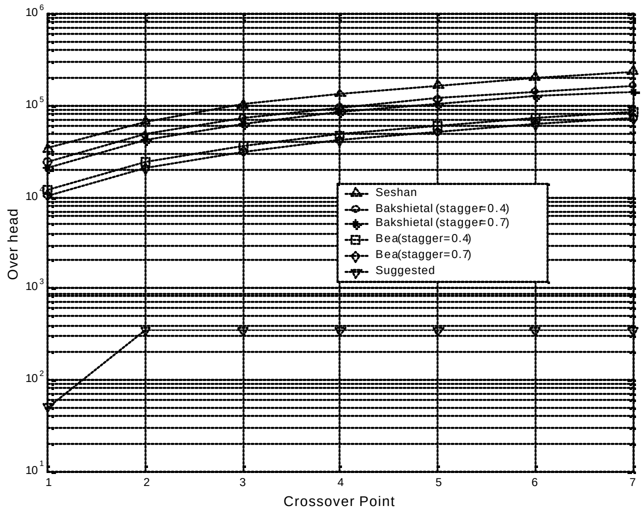

Fig.8: Network overhead

Table 2 compares numbers of control messages in each handoff process in different algorithm. In this comparison, control messages between HA and multicast group are neglected. Number of Control messages in proposed protocol is high. This is because power measurements are sent periodically to MSC. However, these control messages are used in many ways, such as estimation of mobile position in GPS. In other words, mobile station locating is part of GSM standard and we use it in our protocol.

TABLE II: Number of Control messages

Algorithm	Number of control messages
Seshan	8
Bakshietal	14
Bea	8
Proposed (local handoff)	405
Proposed (global handoff)	423

IX. Conclusion

In this paper, a hand off procedure has been proposed which in addition to eliminate packet loss and reduce packet delay, network overhead is reduced. In proposed protocol, the future cell is predicted and packets are transmitted to this cell during hand off time. Then mobile host is allowed to handoff to this cell only, forced handoff. In addition, a simple topology to localize handoffs is proposed. This method not only prevents packet loss and reduces latency, but also reduces network overhead. The simulation results have been shown that the performance of proposed method is superior to former methods.

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Top