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Adaptive Handoff Algorithm in Next-generation Cellular Networks

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Abstract: The objective of this research is to propose an adaptive handoff algorithm which can effectively deal with hotspot cells in next-generation cellular networks. Under the proposed algorithm, the signaling burden is evenly distributed and the regional network boundary is dynamically adjusted according to the traffic load, handoff type and speed of mobiles in advance, before handoff execution. A simulation model is developed to investigate the handoff performance. The simulation results find that the proposed algorithm is better than traditional handoff algorithm. Therefore, this algorithm enhances the service quality of users by flexibly manage the overloaded cells.

Key words: Mobility, seamlessly, handoff, capacity, load

INTRODUCTION

Next-generation wireless networks will integrate services of different access technologies such as cellular networks, WLAN and satellite networks. For this reason next-generation wireless systems will require the integration and interoperation of distributed architecture and these access systems will be connected via., a common Internet Protocol (IP) based core network that will also handle interworking between different systems. Regardless of the network, one of the most important and challenging problems for next-generation all-IP based wireless systems is to design mobility management techniques that take advantage of IP-based technologies to achieve global roaming between various access networks. A users, with a large range of mobility, will access the network and will be able to seamlessly reconnect to different networks, even within the same session. The core network will enable inter- and intra-access handoff. In the next-generation wireless systems coverage/capacity will change dynamically to accommodate changing user patterns. Users will automatically move from congested cell to allow the network to dynamically self-balance. Therefore, there is a critical need for radio resource management in order to effectively control resources and maintain the acceptable service quality.

There has been many proposals to solve radio resource problems. In the research area of the radio allocation scheme, major studies investigate a number of network sharing concepts and alternatives have been proposed by Bartlet and Jackson (2002), Hultell *et al*. (2004), Johansson *et al*. (2004) and Al-Qahtani and Baroudi (2006a, b). This solution offers cost savings in site acquisition, civil works, transmission, RAN equipment costs operation expanses. Two methods for resource controlling and allocating in a roaming-based scenario were proposed by Johansson *et al*. (2004) and Al-Qahtani and Baroudi (2006a, b). A number of channel-borrowing algorithms which utilize available resources of lightly loaded cells and alternatives have been proposed by Das *et al*. (1996, 1997). In the research area of the load distribution scheme, power control and handover-based algorithms have been investigated by Chen (1995) and Verdone and Zanella (2002). In ACS (Adaptive Cell Sizing) scheme (Chen, 1995), this algorithm controls the transmitting power of the base station based on CDMA (Code Division Multiple Access) cellular system. Similarly, in soft handover resizing algorithm (Verdone and Zanella, 2002), it reduces the size of soft handover area in the hotspot cell by increasing the value of the threshold value but these algorithms can be only used in the particular system and it requires the negotiation between cells in order to support seamless services for mobiles. A cell which has heavier traffic load than adjacent cells is referred to as hotspot cell which can be determined by resource affordability, the ratio between the amount of available resources and the total amount of resources in a cell. Hotspot cell can be generated by sudden concentration of traffic load and this hotspot cell problem can cause poor service quality (Kim *et al*., 2005). Kim *et al*. (2007) proposed an effective traffic management

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scheme using adaptive handover time. Handover time is adaptively controlled according to the amount of traffic load of cells.

In this study, we proposed an adaptive handoff algorithm in order to adaptively controls the handoff initiation time according to the load status of cells. Under the proposed algorithm, the regional network boundary is dynamically adjusted based on the speed of the user and handoff type.

ADAPTIVE HANDOFF ALGORITHM

Several factors influence the design of policies on the best network selection for handoff process. This algorithm proposed an adaptive handoff algorithm for dynamic traffic load distribution in the hotspot cell. It is essential to distribute traffic load of the hotspot cell in order to effectively use remained resources and maintain the acceptable service quality. The traffic load can be estimated by measuring the number of users in the states, ON and HANDOFF.

$$\text{Traffic} = \frac{\text{ONcurrent} + \text{alpha}\times\text{HANDOFFcurrent}}{\text{ONcurrent} + \text{alpha}\times\text{HANDOFFtotal}} \quad (1)$$

where, alpha is adaptive factor between 0 to 1 and the amount of traffic load varies from 0 to 1. The value of traffic is approximated to 1 when the current cell becomes to be the status of hotspot. And as the number of mobile nodes is fewer, traffic is approximated to 0 and the current cell is regarded as the lightly loaded cell.

The next step is to determine the right time to start handoff procedures. Mohanty *et al*. (2006) proposed an analytical framework to study the effect of layer 2 and 3 parameters on the performance of handoff management protocols. The researcher proposed the use of adaptive S_{th} for handoff initiation to limit handoff failure probability and at the same time, to reduce unnecessary load on the system that arises because of false handoff initiation. However, the handoff performance in the case of cell overlap is not analyzed. In this study, we had modified the framework and did an analytical model and formulation based on the overlapping cells. We predict the handoff type in advance. Moreover, we estimate the speed of mobiles. Then the required value of d for a desired value of the probability of handoff failure, pf is determined.

$$p_f = \left(\frac{1}{\theta}\right)\cos^{-1}\left(\frac{n}{2d}\right)\left(\frac{d}{vt}\right);\quad \frac{d}{v} < \tau < \frac{\sqrt{\frac{2h^2}{4} + d^2}}{v} \quad (2)$$

where, d is the distance of mobile from the boundary, ν is the speed of mobile and t is the handoff type. Once d is calculated, the RSS at the entrance of the boundary area, i.e., the RSS at a distance from the boundary of the cellular coverage is determined using the path loss model given by:

$$\text{RSS} = (d)[\text{dB}] = \text{RSS}_{\min[\text{dB}]} - 10\beta\log_{10}(s) + \in[\text{dB}] \quad (3)$$

where, β is the path loss co-efficient, $RSS_{min[dB]}$ is the minimum RSS required for the mobile to communicate with base station and s is the distance between mobile and base station. e[dB] is a zero-mean Gaussian random variable with standard deviation σ (typical value of σ is 6 to 8 dB) that represents the statistical variation in e[dB] caused by shadowing. Using Eq. 3 the RSS at the entrance of boundary area that we refer as dynamic RSS threshold (S_{dth}) is given by:

$$S_{dth}[\text{dB}] = \text{RSS}_{\min[\text{dB}]} - 10\beta\log_{10}(R-d) + \in[\text{dB}] \quad (4)$$

The S_{dth} value should be carefully selected in order not to degrade the service quality of other users. Adaptive threshold value avoids too early or too late initiation of the handoff process (registration). They are completed before the user moves out of the coverage area of the serving network.

SIMULATION RESULTS

For simulation the following scenarios and parameters are considered: a macro cellular system with cell size of d = 0.5 km, a micro cellular system with cell size of d = 0.5 macro km, deviation of shadow fading parameter, e = 8 dB and path-loss co-efficient, β = 4 for macro and micro-cells. We assume that the target handoff failure probability is pf = 0.02. We consider that the maximum value of users' speed in micro and macro-cellular system are 14 and 100 km h^{-1}. Moreover, we assume that the value of S_{min} is -64 dBm in cellular network.

Effects of handoff time control of traffic load: Here, we analyzes the effects of handoff time control of traffic load. Figure 1 and 2 show the effects of adaptive handoff time control of traffic load based on mobile's speed and handoff type. Present algorithm shows a lower drop rate than fixed algorithm. The reason the fixed algorithm has a high handoff call drop rate is that it just tries to reduce traffic load of the hotspot cell even though the neighboring cells are in the hotspot status and these handoffs may be dropped in the cells. In addition, the algorithm forcibly executes handoffs without considering the speed and handoff type status of mobiles. On the other hand, this algorithm shows lower drop

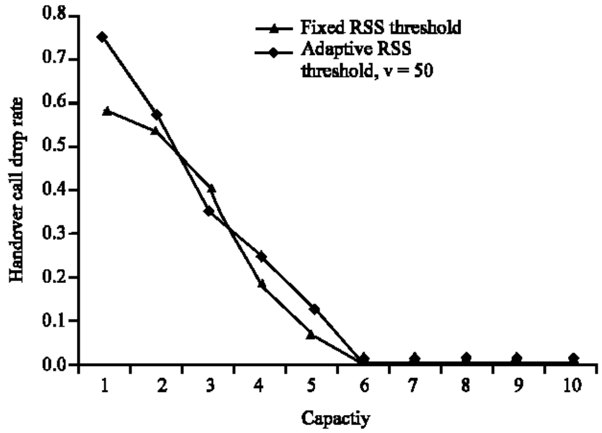

Fig. 1: Effects of adaptive handoff time control of traffic load based on mobile's speed

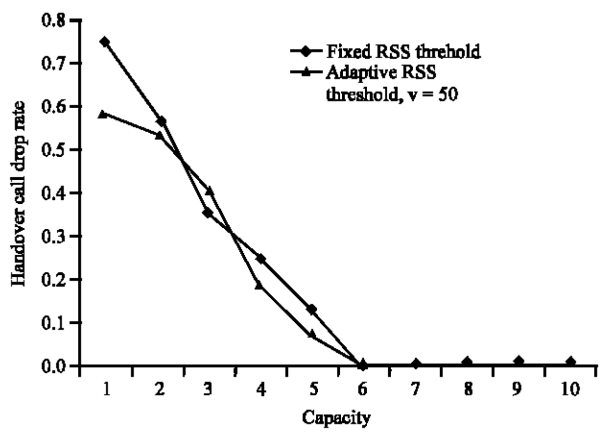

Fig. 2: Effects of adaptive handoff time control of traffic load based on handoff type

rate compared to fixed algorithm. The current serving cell delays all handoff executions if neighboring cells are in hotspot status, which can lead to a small dropping of handoff calls. Present algorithm also adaptively controls the handoff time based on the mobile's speed and handoff type.

False handoff initiation probability: The probability of false handoff initiation is calculated as follow:

$$p_a = 1 - \frac{1}{\pi} x \arctan\left(\frac{h}{2d}\right) \qquad (5)$$

where, h is half of the length of each side of hexagonal cells and d is the distance of mobile from the boundary. Equation 5 shows that the probability of false handoff initiation increases if an unnecessarily large value for d is used for handoff initiation. This increases the load on the network that arises because of the handoff initiation. Moreover, this leads to the wastage of limited wireless system resources.

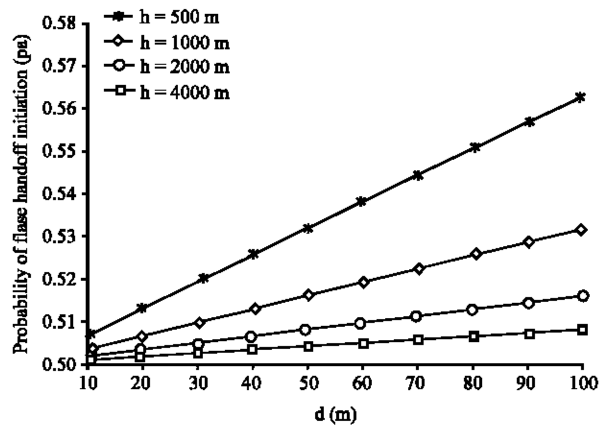

Fig. 3: Relationship between false handoff initiation probability and d for a different value of h

Figure 3 shows the relationship between the probability of false handoff initiation and d for different cell size, h. The probability of false handoff initiation increases as d increases as shown in Fig. 3 for a particular value of h. It also shows that the problem of false handoff initiation becomes more and more severe when the cell size decreases. The cell size of wireless systems is decreasing so that the capacity and data rate may increase. Therefore, in NGMS it is essential to select the proper value of d so that the false handoff initiation probability can be reduced.

$$h = \mathrm{Req} \sin \varnothing \qquad (6)$$

Therefore, Eq. 6 becomes:

$$p_a = 1 - 1/?\ x \arctan\ (\mathrm{Req} \sin \varnothing / d) \qquad (7)$$

where, Req is the radius of the approximating circle. A handoff percentage, ∅ is used to consider the viability of inter-cell overlap when commissioning a new cell. It is also clear from Eq. 7 that if an unnecessarily large value for d is used for handoff initiation, the probability of false handoff initiation increases. Increasing ∅ will potentially increase the potential for coverage and also increase total cost of the network (because more base stations can occur).

The relationship between probability of false handoff initiation and d is shown in Fig. 4 for different ∅. Figure 4 shows that for a particular value of ∅, the probability of false handoff initiation increases as d increases. It also shows that the problem of false handoff initiation becomes more and more severe when the handoff percentage decreases. The parameter ∅ is central to controlling infrastructure efficiency, because it dictates

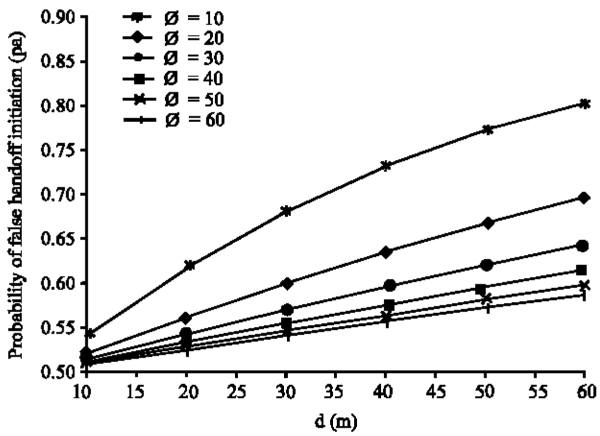

Fig. 4: Relationship between false handoff initiation probability and d for a different value of Ø

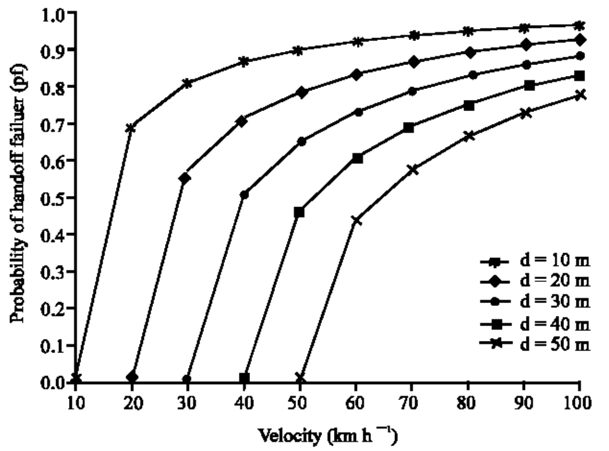

Fig. 5: Relationship between handoff failure probability and v for intra-system handoff with t = 1 sec

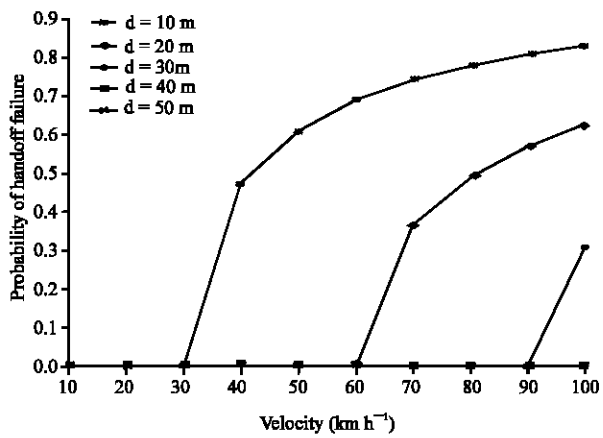

Fig. 6: Relationship between handoff failure probability and v for intra-system handoff with t = 3 sec

how closely packed cells (and therefore base stations) are. Hence, the optimal setting for Ø with a view to maximizing infrastructure efficiency, represents a useful best possible guide for network planners.

Relationship between handoff failure probability and speed: From Eq. 2 it shows that the handoff failure probability depends on the speed of the mobile. The probability of handoff failure increases as the speed increases. Figure 5 and 6 show the relationship between the handoff failure probability and mobile's speed for intra and inter system handoff, respectively. Figure 5 and 6 show the numerical value of p_f for different values of d. Mobile with high speed, will travel more distance compared to a slow moving mobile. Hence, the handoff process must start from a farther distance from the boundary of cellular for a fast moving mobile compared to a slow moving one. Therefore, when the speed of the mobile is higher the size of boundary area is larger compared to a lower speed case.

Handoff latency of 1 and 3 sec are considered for intra and inter system handoff procedures, respectively. The handoff failure probability increases as speed increases for a particular value of d, for both intra and inter system handoff as shown in Fig. 5. The mobile with high speed requires less time to cross the coverage region of old base station. Hence, it is important not to use the same value of Receive Signal Strength (RSS) for intra and inter system handoff.

From the analysis, it can be concluded that to guarantee a desired handoff failure probability, the value of d and therefore, the value of receive signal strength should be adaptive to the speed of the mobile and to the type of handoff.

Relationship between handoff failure probability and handoff type: The higher and the lower value of handoff types correspond to intra and inter system handoff, respectively. Figure 7 shows the handoff failure probability increases as the handoff type increases. Therefore, it is essential to predict the handoff type in advance and then use an adaptive value for receive signal strength to limit the handoff failure probability for a certain value.

Relationship between S_{dth} and speed: To determine the relationship between S_{dth} and mobile's speed (ν), different values of handoff types (τ) for micro and macro cellular system is analyzed. Firstly, the required value of d is determined for different values of *v*. Then, the required value of S_{dth} is calculated. Figure 8 and 9 show that the value of S_{dth} increases as mobile's speed increases

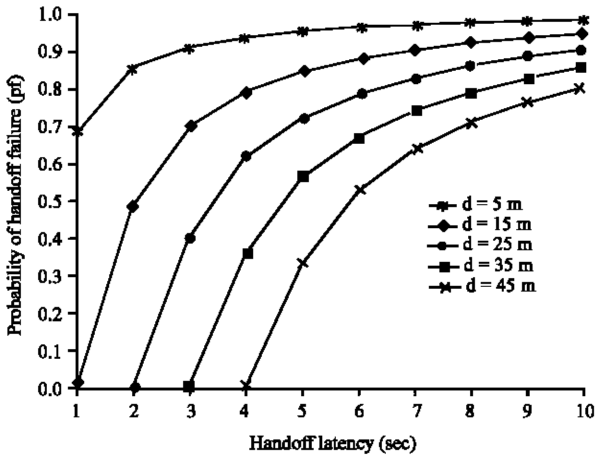

Fig. 7: Relationship between handoff failure probability and t

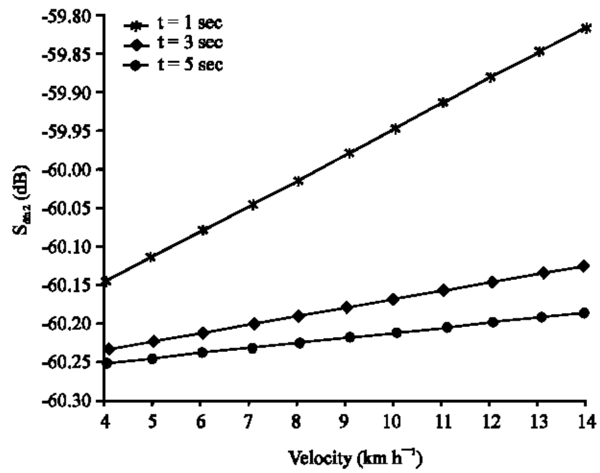

Fig. 8: RSS threshold (S_{dth}) for different values when the serving BS (OBS) belong to a macro-cellular system

for particular value of τ. This is because for a mobile with slow speed, the handoff initiation should start later compared to a high moving mobile to guarantee the desired handoff failure probability.

The results also show that S_{dth} increases as τ decreases. This implies that for a mobile with high τ, the handoff initiation must start later compared to when τ is low. The higher and lower values of τ correspond to inter and intra system handoff, respectively.

CONCLUSIONS

In this study, we proposed an adaptive handoff algorithm in order to adaptively controls the handoff initiation time according to the load status of cells.

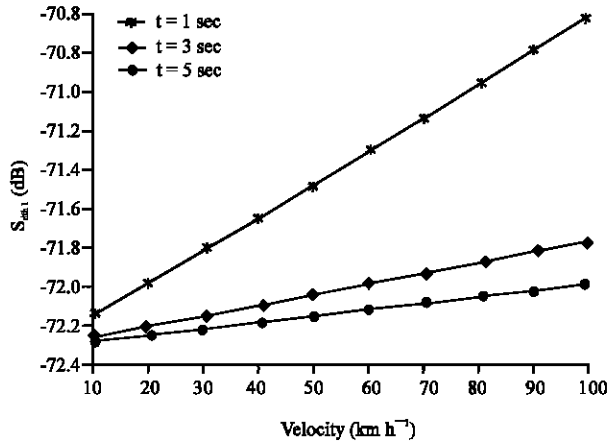

Fig. 9: RSS threshold (S_{dth}) for different speed values when the serving BS (OBS) belong to a micro-cellular system

Present proposed algorithm considers traffic load as an important factor for initiating handoff since heavy traffic load causes significant degradation of network performance. We use the concept of dynamic boundary area to initiate handoff process. This boundary area selects a dynamic RSS threshold to initiate the handoff in such a way that the handoff procedures are completed before the mobile moves out of the coverage area. The simulation results show that the proposed algorithm supports higher service quality. As a future scope, simulation study for detailed performance analysis with respect to handoff latency and packet loss is under processing.

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