A SMART HANDOFF PROCEDURE IN 4G NETWORKS

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Abstract: For the next generation mobile communication systems, all IP packet networks instead of the legacy networks that are mixture of circuit and packet switching services have been studied to guarantee the high-speed data transfer rate even in the high-speed mobile environments. In the packet networks, the rate that mobile users are serviced varies according to the number of users in a single cell. Moreover, as the adaptive modulation and coding adjusts the data rate in terms of channel conditions, the service quality are dominated by two components; service rate by cell load and data rate by channel conditions. Therefore, we propose the smart handoff procedure considering both the service rate and the data rate for the service quality in the next generation communication systems.

1 INTRODUCTION

The upcoming next generation mobile communication networks such as 4G will be all IP packet networks (J. Manner, 2002). The packet switching networks have the advantage in terms of the highly efficient utilization on the limited resources by using shared resources rather than dedicated resources. In the other words, available resources are not determined in advance. Instead, resources are scheduled by packet scheduler, and new resources are allocated temporarily whenever users transfer packets providing better quality of services to more users with higher probability. However, the opportunity for each mobile terminal to get services varies with the number of users in a cell in case of the wireless packet networks (Y. Gwon, 2002). Namely, the less loads with less users in a cell, the more services each terminal can get, and vice versa.

It is essential to improve the entire system throughput as well as the instantaneous throughput in the wireless systems. The application of adaptive modulation and coding (AMC) is introduced to enhance the entire system performance. The AMC scheme selects the appropriate modulation and coding scheme (MCS) in accordance with the estimated channel condition (J. Yang, 2002; E. Armanious, 2003). For the fourth generation wireless systems, the AMC can be applied, because it is suitable to OFDM systems. That is, the AMC can be applied on each subcarrier to optimally assign subchannels, because OFDM systems assign different subcarriers to each user and the orthogonal subchannel assignment reduces interference among users. However, channel condition varies continuously and it is difficult to send channel information in the wireless systems. In case of systems exploiting the adaptive modulation and coding, the channel condition would be better as the data rate becomes higher, and vice versa.

Therefore, the service quality varies with the cell load as well as the channel signal condition in base stations in the beyond 3G (B3G) systems. In this paper, we propose the handoff algorithm based on the two related factors to enhance the service quality; the service rate and the data rate.

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2 RELATED WORKS

The service quality is not easy to measure instantaneously due to the packet burstiness, self-similar traffic pattern, or high-speed packet processing in the

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wired packet networks. To make things worse, routers have no information about the current number of users or cell loads exactly. The L4 router could make it possible, but it is not widely deployed yet. The IP QoS is the other approach to measure the service quality. It is classified into integrated and differentiated services (Y. Tang, 2001). However, the IP QoS cannot be easily guaranteed in wireless systems because wireless resources are much lesser than wired ones (S. Sen, 1999; M. Ricardo, 2002). The IP QoS cannot maintain service qualities of all calls. This scheme simply rejects calls to obtain the QoS of other calls and it cannot resolve traffic congestion problems. Moreover, QoS is not yet widely available even on the fixed networks.

The use of AMC is one of the state-of-the-art techniques in the standards for third and fourth generation wireless systems that have been developed to achieve high spectral efficiency on fading channels (A.J. Goldsmith, 1998). The principle of AMC is to change the modulation and coding format adaptively depending on instantaneous variations of the channel conditions. These conditions are subject to the system restrictions. The AMC extends the system capability to adapt to good channel conditions. Channel conditions should be estimated based on the feedback from the receiver. For the AMC-OFDMA systems, higher order modulation with higher code rates (*i.e.*, 16 QAM with R=5/6 Turbo Codes) are typically assigned to users near the cell site. On the other hand, lower order modulation with lower code rates (*i.e.*, QPSK with R=1/3 Turbo Codes) are assigned to users at the cell boundary. The AMC allows various data rates to be assigned to different users depending on their channel conditions. Since the channel conditions change over time, receivers collect a set of channel statistics which are used by both the senders and the receiver to optimize system parameters such as modulation and coding, signal bandwidth, signal power, training period, channel estimation filters, automatic gain control, etc (Lu, 2004).

Most of the handoff algorithms are designed to perform handoff based on the link gain or the received signal strength (RSS). These algorithms can find target base stations in terms of the link gain or the signal strength before the current signal power is too weak to sustain communications (M. McGuire, 1997). Thus, the conventional handoff algorithms can help to get services from a base station which has the better signal strength, but they cannot optimize the service quality in the packet networks. In the circuit switching networks, the received signal strength can be a metric to measure the service quality for the allocated resources, because resources are dedicated. However, new factors besides the link gain or the received signal strength have to be considered in case of packet networks (N.D. Tripathi, 1999; Cao, 2003). Therefore, we need new handoff methodology in terms of the service quality each terminal gets instead of the legacy handoff algorithms which only considers the link gain or the received signal strength.

3 HANDOFF PROCEDURE

In this chapter, we propose new handoff algorithm based on the service quality which is related with two components; the service rate and the data rate.

3.1 System Environments

Our handoff algorithm operates on the shared channel with a lot of users in the packet-based networks. How many users exist in the same cell determines how often each user can be served because the channel is allocated by the segment, the fundamental transfer unit scheduled by there exist data to send. If the number of users is small, then users can be served frequently. On the other hand, intervals each user is served become longer as the number of users increases.

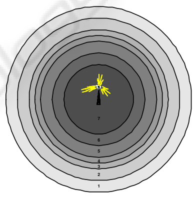

Figure 1: Example of the cell layout with AMC

We consider the cell layout with the adaptive modulation and coding to enlarge the system capacity as Figure 1 and Table 1.

Table 1: Example of adaptive modulation and coding

Fraction	Code Rate	Modulation
1	1/3	QPSK
2	1/2	QPSK
3	2/3	QPSK
4	5/12	16QAM
5	1/2	16QAM
6	2/3	16QAM
7	5/6	16QAM

The AMC helps more users can be served with the higher data rate in a permissible range of the bit error rate (BER) by applying the appropriate modulation and coding method depending on the signal to interference plus noise ratio (SINR). Hence the actual data rate each terminal gets differs with the received signal strength and the amount of noise which varies with the traffic condition. Generally, mobile terminals near the base station can be served with the higher data rate while the terminal far from the base station are served with the low data date by applying AMC.

3.2 Smart Handoff Algorithm

To optimize the service quality, we make a smart handoff algorithm which performs handoffs considering both the received signal strength and service quality simultaneously. We discuss how to measure the service quality in the following sections. The smart handoff algorithm follows:

```
Smart-Handoff-Algorithm
If (RSSCUR > threshold)
    Begin}
    For (each neighbor)
        Begin
        Measure the RSS;
        If (RSSNEIGHBOR > threshold) Then
            Begin
            Measure Service Quality (SQ);
            If (SQNEIGHBOR > SQCUR) Then
                Handoff to new cell;
            End
        End
    End
Else
Begin
    For (each neighbor)
        Begin
        Measure the RSS;
        If (RSSNEIGHBOR > threshold) Then
            Handoff to new cell;
        End
    If (No neighbor cell to handoff) Then
        Handoff to highest RSS cell;
    End
```

Figure 2: Smart handoff algorithm

The smart handoff is mobile-controlled. It tries to perform handoffs when the RSS from any base station of the neighbor cells is stronger than the specific threshold and the target base station of selected cell is expected to provide better service quality than the serving base station. Therefore, mobile terminals perform handoffs to the cell which is estimated to offer the highest service quality among the adjacent cells as long as its RSS is above the threshold. If the RSS from all neighbor base stations including the serving base station, then mobile terminals will try to handoff to a cell which has the highest RSS between its base station and the mobile station.

3.3 Estimation of Traffic Amount

The subchannels assigned to a specific user can be hardly detected and the amount of channel utilization often changes sharply due to the packet burstiness in the packet-based channel sharing systems. It is not appropriate to determine the traffic amount by measuring the static channel occupancies in packet networks as cellular networks being currently used (Cao, 2003).

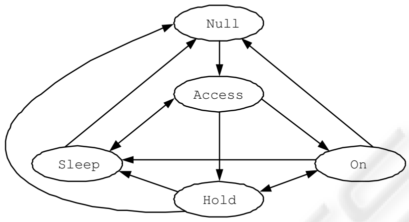

Figure 3: MAC state diagram

We determine the amount of traffic by the number of users in the specific MAC state in our algorithm. Figure 3 illustrates the MAC state diagram which indicates the traffic amount (A. ONeill, 2000; A. ONeill, 2001). The *ON* state means that data is being transferred while the *HOLD* state indicates that data is not currently exchanged but the station is waiting for the traffic. Therefore, the station has the downlink and the uplink traffic channels in the *ON* state, while it has the downlink and the thin uplink channels in the *HOLD* state. It has no traffic channel in the other states. In other words, the service quality is the product of the data rate and the service rate. The service rate is inverse proportion to the cell load, and the data rate is related with the channel condition. Consequently, we determine the amount of traffic by measuring the amount of terminals in *ON* and *HOLD* states.

$$ON_{CURRENT} + \alpha \times HOLD_{CURRENT}, \quad 0 \le \alpha \le 1 \quad (1)$$

In (1), the value of α decides the amount channels potentially assigned to users. Therefore it has influence on the traffic amount calculation. We can make a handoff function depending on the service quality by this equation. The complete handoff function will be discussed in the following sections.

3.4 Estimation of Data Rate

By the adaptive modulation and coding, we are able to estimate the coding rate and modulation scheme for the current subchannels being used when the channel condition is known by the value of the pilot signal's SINR. After the coding rate and modulation is determined, then we can decide the data rate that means how many bytes can be loaded to the unit segment. For instance, the amount of data per segment can be determined in accordance with the coding rate and modulation as Table 2 in the Flarion's FLASH-OFDM technology (Flarion, 2004).

Table 2: Data size per traffic segment (Case of Flarion's FLASH-OFDM)

Coding Rate	Modulation	Data per Traffic Segment
1/3	QPSK	420 bits (2 frames)
1/2	QPSK	630 bits (3 frames)
2/3	QPSK	840 bits (4 frames)
5/12	16QAM	1050 bits (5 frames)
1/2	16QAM	1260 bits (6 frames)
2/3	16QAM	1680 bits (8 frames)
5/6	16QAM	2100 bits (10 frames)

3.5 Estimation of Service Quality

The service quality is up to how often services are provided and how many data can be sent or received. The problem of how often each user can be served is in inverse proportion to the amount of traffic on a serving base station (load), and how many data can be transferred each time is in proportion to the data rate in case of the multicarrier communication systems which share subchannels. Therefore, the equation to calculate the service quality is as below:

$$ServiceQuality = DataRate \times \frac{1}{Load}$$

$$= \frac{N_{TS} \times DATA_{TS\_CH}}{TIME_{sslot}} \times \frac{1}{ON_{cur} + \alpha \times HOLD_{cur}}$$

$$, \quad 0 \leq \alpha \leq 1 \qquad (2)$$

In (2), the N_{TS} is the number of traffic segment available for each cell and it varies with the load of the neighbor base stations. The $DATA_{TS\_CH}$ means the amount of data per traffic segment according to the channel condition, and $TIME_{sslot}$ is the frame duration of the superslot. The ON_{cur} and $HOLD_{cur}$ is the number of users in the state of *ON* and *HOLD* respectively. We assume that there exists at least one user.

3.6 Smart Handoff Procedure

The smart handoff procedure applying the algorithm suggested in the previous section is as Figure 4. Each mobile subscriber station (MSS) perceives the time to perform the handoff by measuring the received signal strength through the pilot signals from the serving and neighbor base stations. The information about the traffic load and the modulation and coding to be applied is broadcasted to the MSSs periodically. The MSSs determine the adaptive modulation and coding by measuring the pilot signal's SINR. Finally, each MSS calculates the service quality from the information measured which is described earlier. If there is any base station providing better services, then MSS initiates the handoff by sending handoff request message to the target base station.

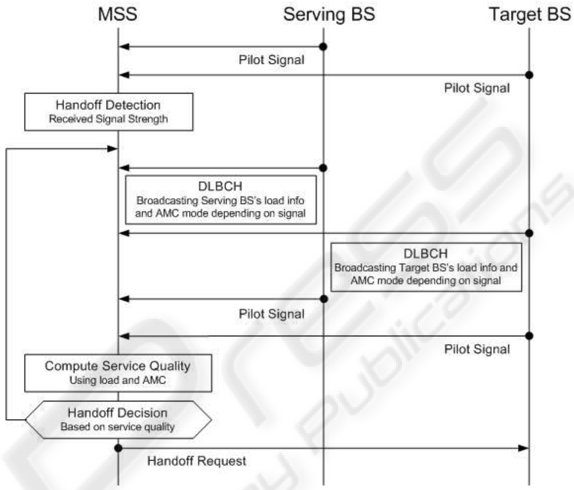

Figure 4: Smart handoff procedure

4 SIMULATION RESULTS

We compared the smart handoff with the conventional handoff measuring handoff performance on simulation results with the OPNET simulator (Opnet, 2004). The simulation models and parameters used in this simulation are shown in Table 3.

Table 3: Simulation environments

Radio model	One level modulation and coding
	Pilot and frame duration: 20ms
Traffic model	ON users
Mobility model	Random way-point
	10 moving nodes
	0-10 stationary nodes
Simulation time	1 hour

For simplicity, single-level modulation and coding scheme has been applied for the radio model. Only users in the *ON* state are considered for traffic for one-hour simulation. The pilot signal and frame duration is 20ms and this simulation is performed on the single-tier seven-cell environment. By reducing the capacity of the center cell gradually, it can be considered that the center cell has more users (see Figure 5). The random way-point movement model is used for the mobility. There are twenty MSSs in this simulation. We changed the number of stationary nodes from zero to ten meanwhile we fixed the number of mobile nodes to ten.

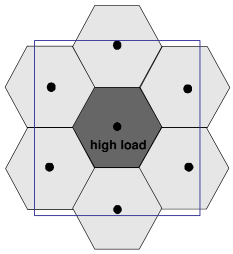

Figure 5: Cell layout for simulation

We define the node throughput as the number of frames received from a base station per second for handoff. The performance of the mobile and stationary nodes is measured by this metric according to the number of stationary terminals as Figure 6. The experimental results verify that the smart handoff is better than the conventional handoff in terms of performance, because the number of frames processed for the smart handoff is more than the one for the conventional handoff.

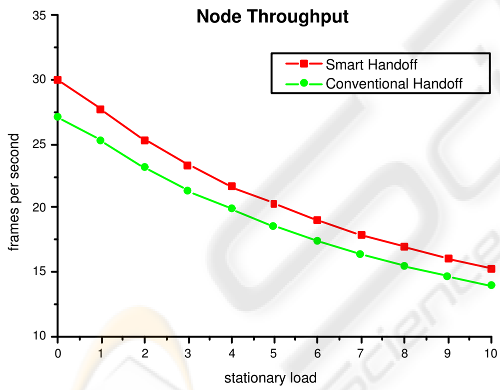

Figure 6: Handoff performance for the mobile and the stationary nodes

The handoff performances of the mobile and fixed terminals are shown in Figure 7 and Figure 8 respectively. For the mobile nodes, the handoff performance is more remarkable than the one in the stationary nodes. This is because the number of stationary nodes increases while the amount of data which MSSs can receive is limited on the serving base stations. From these simulation results, the smart handoff performance is better in terms of both the mobile and stationary users.

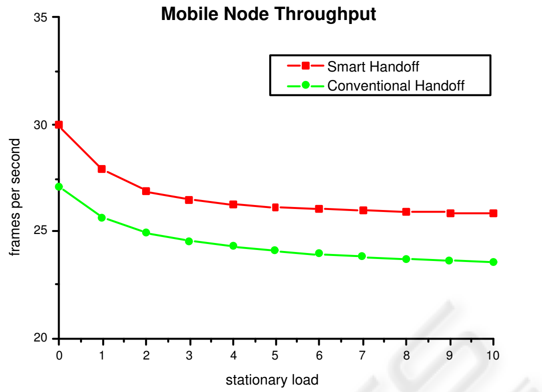

Figure 7: Handoff performance for the mobile nodes

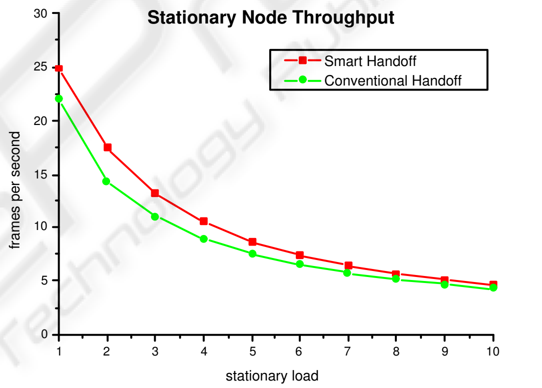

Figure 8: Handoff performance for the stationary nodes

5 CONCLUSION

In the next generation "all-IP" packet switching systems, the network or radio resources are shared by users. The resource allocation is temporarily scheduled by the packet scheduler whenever packet communications occur rather than that allocation is determined earlier. Therefore, the opportunity that each user can use the shared resources decreases as the number of users in a cell increases. Moreover, the adaptive modulation and coding will be applied for the next generation mobile communication networks. It helps communications applying various data rate in accordance with the current channel condition. Hence the service quality each mobile station can get changes with the current load condition in the serving base station as well as the link gain.

The smart handoff algorithm we proposed in this paper simultaneously considers the service rate determined by the number of users belong to the serving base station and the data rate varied with the adaptive modulation and coding by the instantaneous channel condition besides the received signal strength or the link gain. We demonstrated that the smart handoff enhances the service quality for each user and it is optimal for the all IP packet networks, particularly in 4G wireless systems.

The smart handoff is the mobile-controlled handoff as mentioned above. Therefore, it can be applied as the vertical handoff (Q. Zhang, 2003; A. Misra, 2002; J. McNair, 2000) among the heterogeneous networks which are expected to be common in the B3G systems.

We are currently working on the problem of how to measure the cell load more precisely. We also have plan to verify the smart handoff performance by simulation in the multi-tier nineteen cell environments that the adaptive modulation and coding is applied elavorately.

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