Handoff Performance of Delay-Insensitive Data Services in DS-CDMA Systems

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Abstract

We investigate the performance of handoff policies for data services and voice services in a DS-CDMA system with respect to delay sensitivity. A slotted ALOHA random access scheme on the reverse link is employed to support data services. A soft handoff policy, hard handoff policy and restricted-transmission policy for data packets in a soft handoff region are compared in terms of throughput, system delay, and system capacity. The soft handoff policy and the restricted-transmission policy yield better performance than the hard handoff policy. The restricted-transmission policy yields the highest maximum throughput, but the longest delay among the three handoff policies. Thus, it is useful to restrict packet transmission for delay-insensitive data services in the soft handoff region when the traffic load in a cell is high.

I. Introduction

Third generation wireless systems are aimed to support a wide range of multimedia services. DS-CDMA systems can be a strong candidate for these future systems because of such advantages as large system capacity, soft capacity, soft handoff, and inherent robustness to fading phenomena[1], [2].

Data services have been extensively studied in DS-CDMA systems because they are quite different from voice services accommodated in conventional wireless systems[3]-[9]. However, there are still few discussions on system performance of the data handoff process. Chang and Wang [6] proposed an admission control scheme in circuit-based CDMA networks and the scheme gives a higher priority to data handoff calls. And I and Nanda [9] suggested that users in a soft handoff region transmit data packets with a minimum rate. But the characteristics of data services are not fully taken into account.

Data services usually require a wide range of specifications for delay, data rate, and bit error rate. Delay sensitivity is one important feature in the admission control of new calls and data handoff calls. Delay-sensitive data services require to hold channels continuously like conventional voice services and to perform fast handoff. For delay-insensitive data services, on the other hand, a technique to efficiently share channels can be used with a less strict specification for delay, and the processing time for handoff is not so critical as for delay-sensitive calls.

In this paper, we focus on handoff policies for delay-insensitive data services. We adopt a slotted ALOHA protocol for data calls and compare the performance of a soft handoff policy, a hard handoff policy, and a restricted-transmission policy for data calls, on the reverse link, in terms of throughput, system delay, and system capacity. In the restricted-transmission policy, some interference margin is expected at the cost of increased delay, compared with the soft handoff policy because high transmission power near the cell boundary is restricted for delay-insensitive data calls. The restricted-transmission policy is expected to be very useful when offered load is high.

The remaining part of this paper is as follows: In section 2, we describe three handoff polices and the related multiple access protocol in a DS-CDMA system. The performance of the three handoff policies are compared by simulation in section 3. Finally, concluding remarks are drawn and further study is given in section IV.

II. Handoff Policies for Data Services in DS-CDMA Systems

Cell capacity in DS-CDMA systems is limited by interference from inner and outer cells. Not only for voice services but also for data services in wireless cellular DS-CDMA systems, it is a crucial problem to assign channels adaptively to the interference. For call adimission, the features of data services should be considered. Delay sensitivity of data services is one of important characteristics. If a data service is delay-sensitive like conventional voice services, it requires to hold a channel continuously until the end of the service. For delay-insensitive data services, the specification for delay is less strict. Thus, there is no need to hold channels continuously, instead channels can be dynamically assigned. Another important feature of data services is whether they are stream-based or packet-based [3]. Packet-based data services with short burst time increase the efficiency of link, but frequent channel assignments may increase the overhead of link setup and release.

Considering these characteristics of data services, it is reasonable that different protocols are applied to different types of data services. We assume that the stream-based, delay-sensitive data services, hereinafter called *real-time* data services, are supported in circuit mode, even though they may require different bit rates and different transmission power. The other types of data services are stream-based delay-insensitive and packet-based. These services, hereinafter called *non-realtime* data services, are supported by a slotted ALOHA protocol. Basically we adopt a DS-CDMA slotted ALOHA scheme to support the non-realtime data services [10]. We also assume that the number of spreading codes is large enough to assign all the users in a cell. Cell capacity in DS-CDMA systems is limited by other-user interference not by the number of spreading codes.

Based on the protocol described above, we consider three handoff polices for data services. A soft handoff policy, which is a typical scheme in DS-CDMA systems, is assumed as in the IS-95 specification [11] and a hard handoff policy is assumed with a hysteresis parameter T_{HARD} which prevents so-called the `ping-pong effect'. Figure 1 shows the thresholds for soft and hard handoff policies. In addition to the two typical policies, we propose a restricted-transmission handoff policy for delay-insensitive data services. Signals from mobiles near the cell boundary cause more interference than those in the inner region of a neighbor cell even if the soft handoff technique mitigates the difference. Besides, most of data services require higher transmission power than voice services because of low bit error rates and high bit rates. Thus, the restricted transmission of delay-insensitive data signals in the soft handoff region is expected to increase system capacity.

Figure 2 shows a block diagram of the slotted ALOHA protocol with the restricted-transmission policy. When a delay-insensitive data call is found to be in the handoff region, it holds its transmission of each packet for a time period t_{RES} before it is out of the handoff region. After waiting for t_{RES}, a packet is transmitted according to a retransmission process. At the beginning of a packet transmission, a preamble is used for acquisition. It is assumed that the data rate in a preamble can be chosen much lower than the data rate in the packet such that the preamble can be correctly received with a proper error correction scheme as long as total user interference does not exceed the system capacity. If an acknowledgement for the transmitted packet is negatively received, the packet is retransmitted after an exponentially distributed backoff time. The proposed handoff policy can accommodate more offered load than the typical soft handoff policies satisfying the specifications of various types of data services by restricting the high power transmission of user packets in the soft handoff region with a less strict delay specification.

III. Performance Evaluation of Handoff Polices for Delay Insensitive Data Services

The three handoff policies are compared in terms of throughput, system delay time and cell capacity by simultion in a mobile environment which supports voice and delay-insensitive data services. The mobile environment is considered to have a hexagonal cell structure of 19 cells as shown in Figure 3. To investigate the effects of restricted transmission in a soft handoff region on performance, we assume a relatively simple situation. With a number of active voice calls we focus on the performance of delay-insensitive data calls. The required bit error rate for data calls is set at 10^{-5} which is 10^{-2} times lower than for voice calls at the same bit rates of 16 kbps. The power difference in decibels bitween voice and data calls is set at 2.6 dB. A data burst which transmits a certain number of data packets is generated according to Poisson distribution with an arrival rate of λ_d. Each data packet is assumed to be successfully transmitted if the total received power in the base station is less than the total interference margin. A call admission scheme which is adaptive to varying other-cell interference is better than the schemes of a fixed margin [12]. Assumptions associated with the slotted ALOHA adopted are as follows:

- Acknowledgement messages are error-free.
- The round-trip propagation delay between a mobile and its home base station is negligible.

- Retransmission delay is exponentially distributed with a mean of 10 packet time.

Users who are uniformly distributed in a hexagonal cell coverage of 19 cells move around with a velocity that is uniformly distributed in $(0,\ V_{max})$ and with a direction that is set uniformly among all the directions. Users getting out of the cell coverage are assumed to reenter the cell coverage immediately at the opposite position of the departing position. The parameters used in the simulation are given in Table 1.

Figure 4 shows the average throughput in the number of successful packets per slot versus the offered load in the number of packets per slot when 5 active voice users and 100 delay-insensitive data users share the resources allocated in each cell. The soft handoff policy and the restricted-transmission policy yield obviously higher throughput than the hard handoff policy. The maximum throughput of the hard handoff policy increases inversely proportional to T_{HARD} but for small value of T_{HARD} the probability of the ping-pong effects increases. The restricted-transmission policy yields the highest maximun throughput among the three handoff polices and the enhancement is even larger as the timer t_{RES} increases. Throughput gain in the restricted-transmission policy is obtained by restricting the high power transmission of mobiles near the cell border.

Figure 5 shows the average delay in the number of slots versus the average throughput for accommodating the same numbers of voice and data users as in Figure 4. It can also be observed that the restricted-transmission policy yields the highest maximun throughput. However, the delay of the restricted-transmission policy is longer than for the soft handoff policy. For a larger value of t_{RES}, more packets of users in the soft handoff region are held and the interference to other cells is less. Thus, the maximum throughput of the restricted-transmission policy increases but the delay also increases as t_{RES} increases.

From the performance of the handoff policies, it is observed that the restricted-transmission policy is very useful at an overload condition because it can increase the maximum throughput at the expense of the increased system delay. For delay-insensitive data calls, packet tranmission can be restricted within the given delay specifications if the timer t_{RES} of each packet transmission is properly set. Even if the delay specification of delay-insensitive data services can not be conformed due to heavy traffic load, it is better than not keeping the delay specification of delay-sensitive data services which means the immediate losses of transmitting data. Figure 6 shows the cell capacity in the interference margin which is normalized to the interference of one voice channel for a data arrival rate of 0.5 as the number of data users increases. It is noted that the restricted-transmission policy yields the largest cell capacity.

Table 1: Parameters used in the simulation

Parameters	Symbol, unit	Value
Cell radius	R, km	4
Processing Gain	PG	128
Total number of cells	N	19
Propagation path loss coefficient	n	4
Bit rate of a voice call	R_v, kbps	16
Bit rate of a data call	R_d, kbps	16
Required BER for voice calls	BER_v	10^{-3}
Required BER for data calls	BER_d	10^{-5}
Average length of a delay insensitive data burst	T_{din}, ms	62.5
Length of a packet	L_{pkt}, ms	20
Add threshold for soft handoff	T_{ADD}, dB	-145.07
Dropping threshold for soft handoff	T_{DROP}, dB	-145.07
Dropping time for soft handoff	T_{TDROP}, s	2

IV. Concluding Remarks and Further Study

In this paper, we investigated the performance of the three handoff policies for delay-insensitive data services in a DS-CDMA system. The soft handoff policy and the restricted-transmission policy in a soft handoff region yield obvioulsy better throughput-delay performance than the hard handoff policy. The restricted-transmission policy has the highest maximum throughput among the three handoff policies, but yields longer delay. This policy is very useful in DS-CDMA systems when the traffic load in a cell is high. It is necessary, as a further study, to analyze the performance for the restriction of packet transmission of delay-insensitive data services in the soft handoff region when delay-sensitive data services as well as conventional voice service are accommodated. Especially, more detailed study on the performance of the restricted-transmission policy in an overloaded situation is required.

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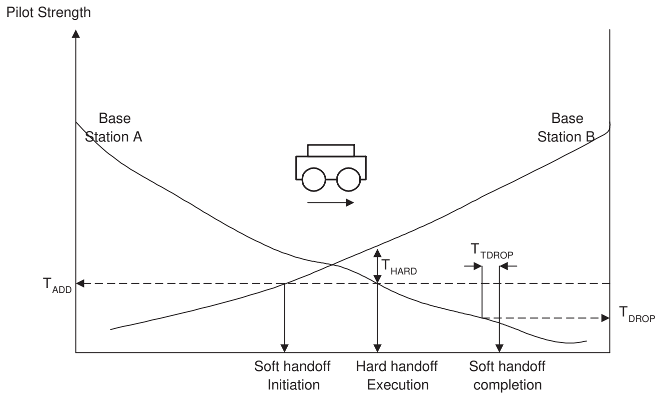

Figure 1: The thresholds for soft and hard handoff policies.

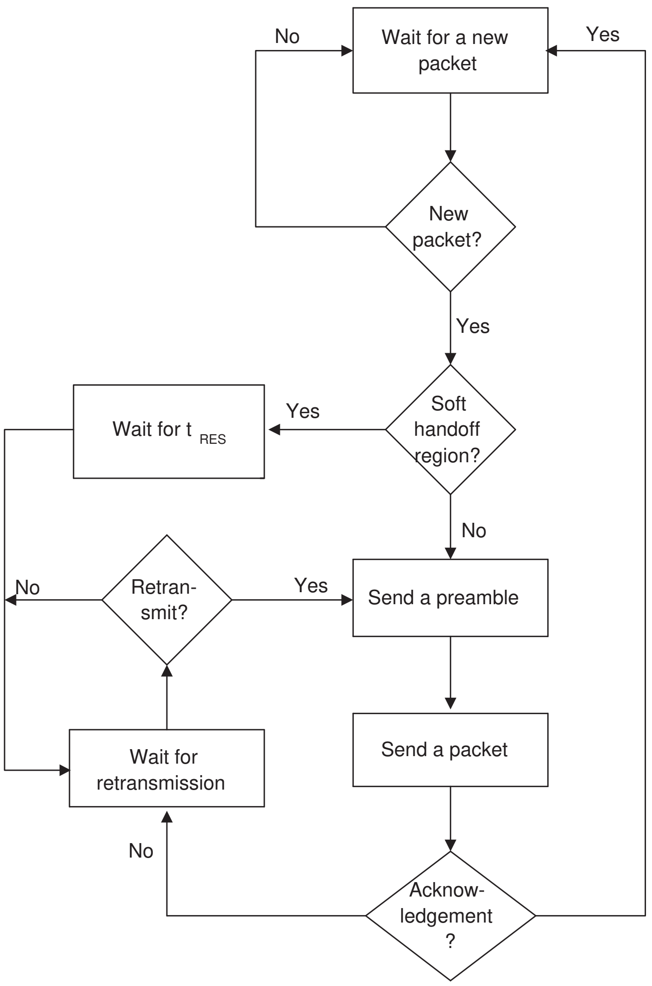

Figure 2: Block diagram of slotted ALOHA protocol with the restricted-transmission policy.

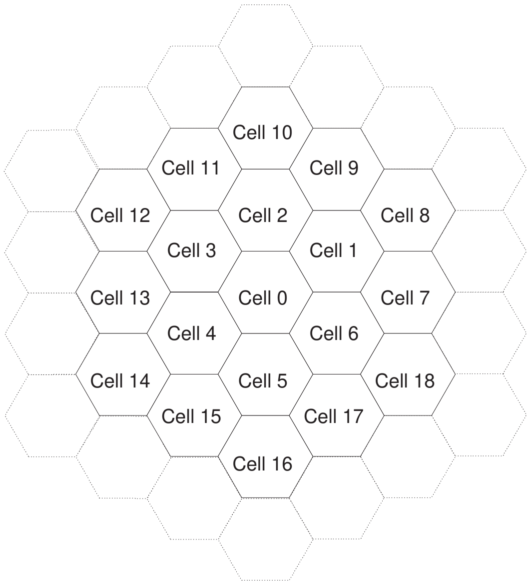

Figure 3: Hexagonal cell coverage.

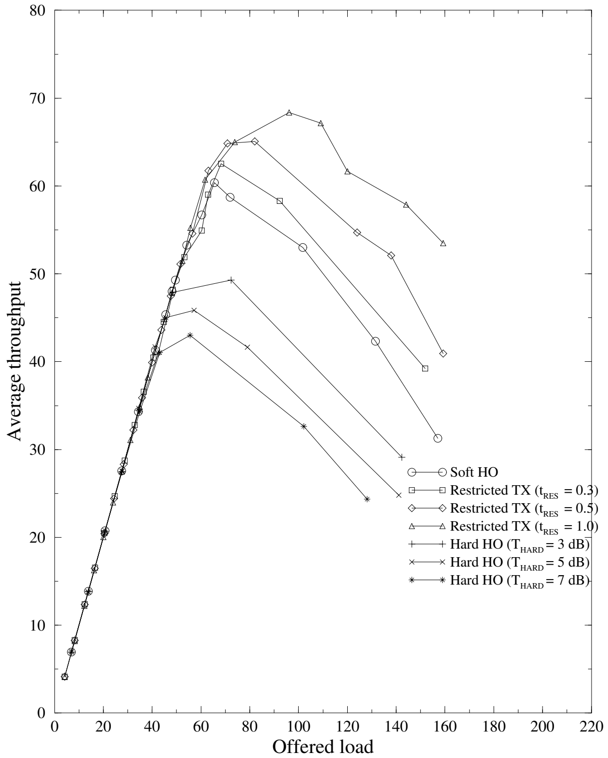

Figure 4: Average throughput versus the offered load for three different handoff policies (5 active voice users and 100 data users).

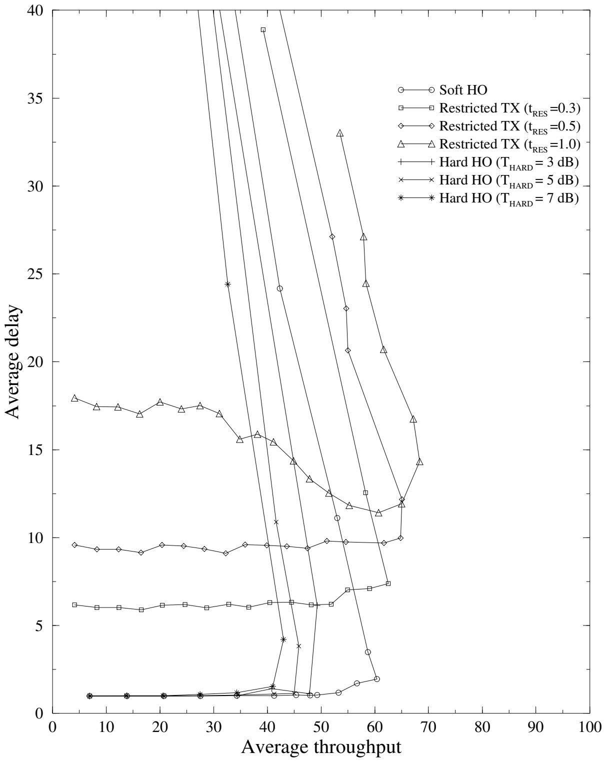

Figure 5: Average delay versus average throughput for three different handoff policies (5 active voice users and 100 data users).

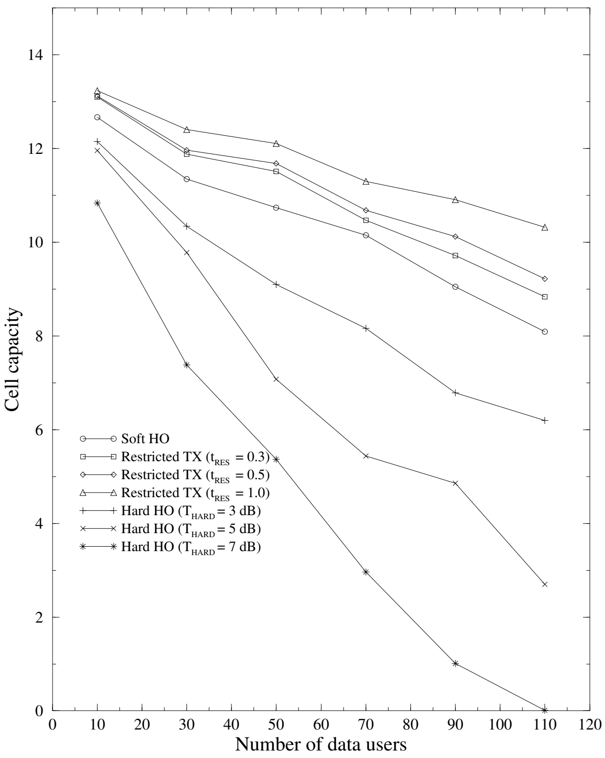

Figure 6: Cell capacity for three different handoff policies.