Fast Cell Selection procedure considering network constraints in HSDPA

André R. Braga , Leonardo S. Cardoso & Francisco R. P. Cavalcanti

***Abstract*— In this paper, the mobility management function for the High Speed Downlink Packet Access (HSDPA) system is investigated. This procedure is also known as the Fast Cell Selection (FCS), in that the cell change procedure is performed in a short amount of time trying to track the best cell instantaneously. We consider the User Equipment (UE) controlled cell selection, where the mobile user selects its serving cell based on channel measurements by sending uplink signaling. There are some limitations to this procedure regarding signaling overhead and that is the point discussed in this work. Some procedures are evaluated with the aim to minimize the signaling through the radio access network with little impact on the system performance.**

***Keywords*— UTRAN , HSDPA , Fast Cell Selection , Mobility.**

I. INTRODUCTION

The HSDPA is a concept that has emerged as a cost-effective enhancement step of the Universal Mobile Telecommunications System (UMTS) for the provision of high speed data transfer on wireless networks, predicted for the $3th$ generation of mobile telecommunications (3G). The main planned improvement capability is the peak data rates increase, leading to better quality of service (QoS) and spectral efficiency for asymmetrical data services.

To achieve its improved performance, the HSDPA uses some features such as higher order modulation and variable rate channel encoding, which is accomplished by the Adaptive Modulation and Coding (AMC) scheme; Hybrid ARQ, using either chase combining or incremental redundancy; shared channel transmissions in a short Transmission Time Interval (TTI) using fast scheduling; and Fast Cell Selection (FCS) procedures. All of this enable a higher capability of coping with higher multimedia traffic demands, maximizing throughput and minimizing delays under loaded conditions.

This work investigates the FCS operation regarding possible network constraints such as delays in the cell selection procedure and different measurement window lengths for the algorithm decision. Our main purpose is to reach an optimal operational configuration in order to extract the maximal improvement of the FCS and respecting the possible network limitations.

The remainder of this paper is organized as follows. Section II describes all the modeling used to perform the investigations concerning the FCS. Section III details the FCS functionality and issues concerning advantages and complexity, and also describes the main focus of this work. All of the purposes are evaluated and discussed in Section IV. Finally, in Section V some conclusions are drawn.

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TABLE I
MAIN SIMULATION PARAMETERS.

Property	Value
Timestep	1 Slot (0.667ms)
TTI	3 Slots (2ms)
Number of NodeBs (base stations)	16
Number of Cells/Sectors	48
Interference tiers	1
Shadow standard deviation	8dB
Inter NodeB correlation	0.5
User arrival rate	0.05, 0.1, 0.14, 0.2, 0.3 users/s
WWW offered load	32kbps
Reading time	12.5s
Mobility model	Pedestrian (3 km/h) , Vehicular (120 km/h)
RLC polling interval	300ms
RLC payload size	320bits
HARQ scheme	Chase combining
Scheduling Algorithm	Round Robin
SHO Time to Trigger	3s
SHO Threshold	2.0dB
SHO Threshold Hysteresis	1.0dB
SHO Replacement Hysteresis	2.0dB

II. SYSTEM MODEL

Aiming to perform a complete evaluation of the HSDPA technology using a system level approach, a dynamic simulator has been developed using an Object Oriented approach in C++. Its capabilities focuses on handling the traffic generated by each user and delivered to the Radio Link Control (RLC) / Medium Access Control (MAC) protocol stack in a standalone HSDPA network, representing a scenario in which the high speed packet switched services are offered using a different carrier than the one used in which the Release'99 WCDMA services are mapped.

The HSDPA simulator models a tri-sectored macrocell system in a wrap around grid [1]. To faithfully recreate the link conditions, its modeling includes the pathloss as in [2], the log-normal shadowing [3], and the rayleigh fast fading model is based on the Jakes Model [4]. Both WWW traffic and mobility modeling follow [5].

The RLC modeling was carried out as in [6]. The MAC-hs portion of the MAC layer was modeled following the recommendations in [7].

In Table I the main simulation assumptions used are shown.

The physical layer mainly models the link-to-system interface, Transport Format and Resource Combination (TFRC) selection, transmission and reception. The link-to-system interface used is based on [8]. The 5 Modulation and Coding

TABLE II
MCS TO CQI MAPPING.

	MCS1	MCS2	MCS3	MCS4	MCS5
CQI values	3	10	16	18	27
MAC-hs PDU Size	233	1262	3565	4664	21754

Schemes (MCS) defined in that work were mapped into Channel Quality Indicator (CQI) values, for UE category 10 [9], in order to aproximate the coding rates assumed in [8] and standardized in [9]. This mapping can be seen in Table II as the payload size of the MAC-hs PDU in each TFRC. It was based on the Average Value Interface (AVI) in which the scheduled user performs measurements of the inner- to outer-cell interference ratio (I_{or}/I_{oc}) in each slot during the current TTI period and, in the end, calculates the average value to be used in a look-up table using the link-level results. The value returned defines the probability of erroneous reception of the MAC-hs PDU that is currently being transmitted.

The Soft Handover (SHO) procedure is also modelled aiming to compose the Active Set (AS) of the UE, which is the set of cells directly connected through dedicated channels (control signaling), used by the FCS algorithm to perform the serving cell selection among the cells within the AS, since only one cell is allowed to transmit in each TTI. The SHO is accomplished following [10].

III. Fast Cell Selection

The main idea of the FCS comprises allowing the UE to control the cell change procedure, enabling it to be faster in tracking the best connection and taking advantages of the cell diversity provided by the channel variations of the radio links between the UE and the cells within the AS, as long as the macro-diversity gain provided by the SHO to the Dedicated Channels (DCHs) is not applied to the High Speed Downlink Shared Channel (HS-DSCH) used in the HSDPA. Figure 1 illustrates a situation where the FCS may provide remarkable gains. The UE is on the cell edge and experiences fast channel variations between both cells. As shown in Figure 2, the FCS algorithm may select as the serving cell the one with the best instantaneous channel condition. While the SHO algorithm is making measurements for the next time to trigger, the FCS can act providing the instantaneous best connection.

The drawback of this approach is a higher amount of uplink signaling and user context transfer between old and new serving cells, if they do not belong to the same NodeB. This network overhead and the limitations in the signaling between cells may not allow the UE to change the serving cell in an optimal manner.

This problem becomes more critical when the FCS is accomplished between cells not belonging to the same NodeB. The MAC-hs sub-layer of the new serving NodeB must have the information of the acknowledged PDUs, that were previously delivered by the RLC to the cells within the UE AS (context synchronization). This information can be exchanged by using uplink signaling or through the RNC [11], leading to a huge increase in the amount of network signaling. One possibility is the MAC-hs status to be cleared, demanding

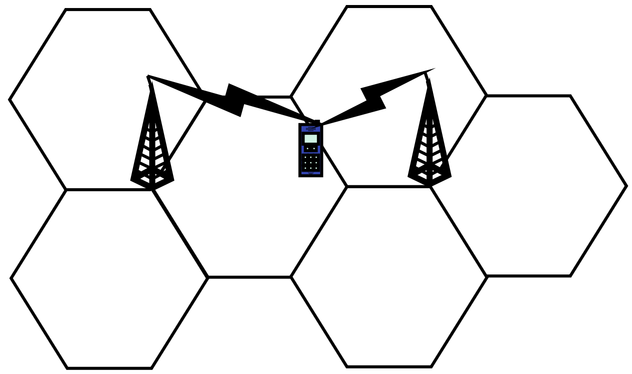

Fig. 1. Illustration of a scenario with the UE in the cell edge, where the FCS algorithm can provide a better performance.

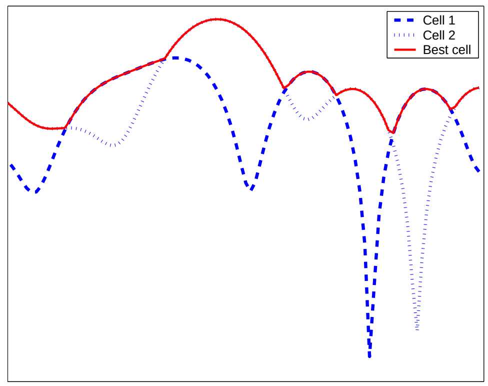

Fig. 2. Illustration of the signal fluctuation between the UE and two nearby cells, and the possibility to achieve macro-diversity gains by implementing the FCS.

the RLC packets to be retransmitted. This approach incurs in possible packet losses if the RLC operates in Unacknowledge or Transparent Modes, UM and TM respectively [12].

A practical limitation may arise when taking into consideration that the choice for the best radio link may not be assumed by the network instantaneously after the decision, resulting in a decision delay. This happens because of the context synchronization time or the requirement of the uplink signaling for multiple requests, since it is less reliable [13].

Another issue consists on the FCS measurement window length during which the UE performs channel quality measurements and, in the end, decides which to be its serving cell. Short lengths means higher capacity to track the channel variations but imposes higher signaling to the network.

Performance improvements may be reached if the UE performs the cell change only when the new cell has really higher possibility to provide a better throughput. It must also be considered that, when the channel quality between the old and the new cell has little difference, it is not worth to perform the cell change, with all the signaling overhead, to provide minimal or no improvement. Cell loading information would also be interesting to be used.

In this work, two possible limiting factors of the FCS were evaluated in order to obtain their impact over the system performance. The first is the delay between the decision of the serving cell and the effective change. Two delay values

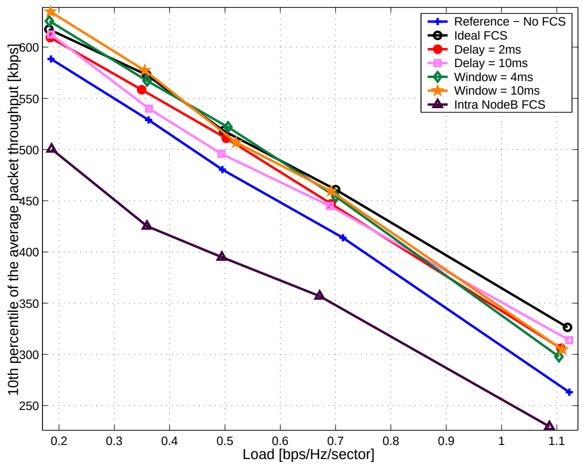

Fig. 3. Load effect on the average packet throughput per session considering a pedestrian mobility profile.

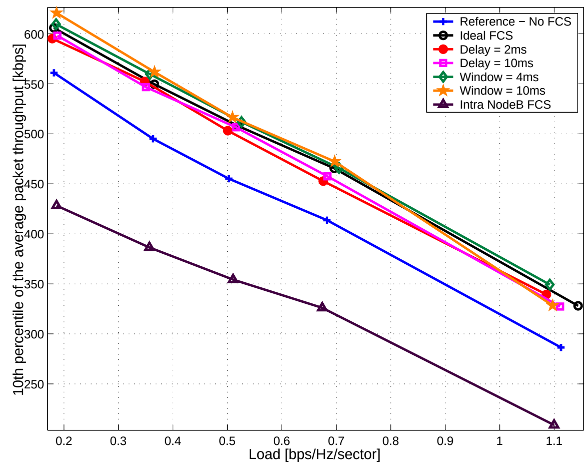

Fig. 4. Load effect on the average packet throughput per session considering a vehicular mobility profile.

were evaluated: 2 ms (a TTI period), and 10 ms. Another parameter that was investigated was the measurement window size. Lengths of 4 ms and 10 ms were evaluated considering no delay after the decision. The results were compared to an ideal operation with no delay and using a window length of 2 ms, meaning that in each TTI period the user is able to change its serving cell, based on the average Common Pilot Channel (CPICH) perceived power measured on the previous TTI. Another result used for comparison is the case where no FCS is used. This was obtained by setting the maximal active set size to 1. This means that, the cell change procedure will take place only when the event 1C (cell replacement in the AS) is performed during the event triggering of the SHO. In addition, the intra-NodeB FCS, which comprises the FCS among sectors/cells within the same NodeB, meaning no inter-NodeB signaling demand for cell change purposes. No MAC-hs clearance was considered.

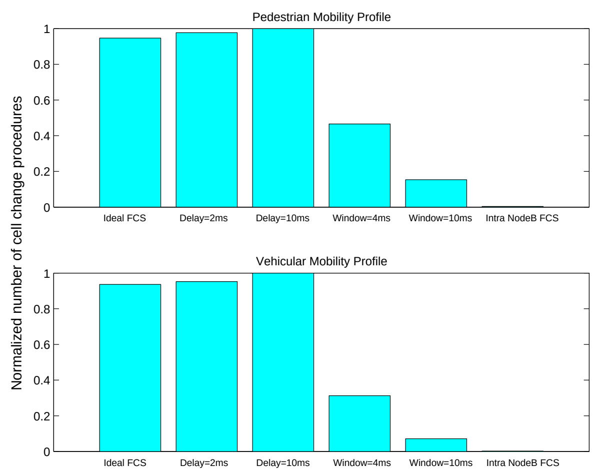

Fig. 5. Signaling amount in each FCS configuration, showing that larger window sizes results in less network overhead.

IV. PERFORMANCE RESULTS

In Figure 3, the system performance for the pedestrian mobility profile is assessed through the $10th$ percentile of the average packet throughput in each session. When the FCS is used and some delay is considered in the algorithm, the performance suffers some minimal degradation. When the measurement window size is modified, the behavior is a little bit different. Even with the largest considered window length, which is five times the ideal size (10 ms), the performance is quite similar to the ideal operation. The most important conclusion is that all the inter-NodeB FCS operation modes have better performance than the reference scenario.

When the vehicular mobility profile is applied on Figure 4, the FCS gain is more evident over the reference scenario, since much more handover procedures are necessary. This is due to the high variation of the radio channel. Even the ideal operation of the FCS, works in a time step that is larger than the channel correlation time.

An interesting result noticed is that, when the window length is larger than the ideal, the performance is something better. This is due to the smaller influence of the fast fading variations on the decision for the cell change procedure. It can also be concluded that all the limiting variations of the FCS have more similar behavior than in the pedestrian scenario.

Another evaluation that was made concerned the amount of signaling. To give an idea of the signaling load in each of the configurations, the number of cell change procedures was counted and, in Figure 5, the results normalized by the higher value are presented for a simulation with user arrival rate of 0.1 users/s in both mobility profiles considered. It can be noted that, for pedestrian users, when a window length of 4 ms is considered, the amount of signaling reduces about 50%. This reduction reaches more than 80% when the window length value is 10 ms. For vehicular users, the results are quite similar, but the cell change procedures for larger window sizes suffer an even larger reduction, 60% and 90% for 4 and 10 ms respectively.

One interesting result concerns about the intra-NodeB FCS. Figure 5 shows that almost no cell change procedure is performed by this FCS mode. This explains its poor performance

TABLE III
PERCENTUAL USE OF EACH MCS.

	MCS1	MCS2	MCS3	MCS4	MCS5
Ideal FCS	35.88	8.57	6.14	16.1	33.4
Delay=2ms	39.34	8.66	6.12	15.61	30.3
Delay=10ms	38.7	8.8	6.3	16.0	30.2
Window=4ms	31.9	9.03	6.54	17.1	35.42
Window=10ms	28.0	9.39	6.77	17.7	38.1
Reference	38.0	10.0	6.54	15.7	29.8
Intra NodeB FCS	58.7	8.88	5.18	11.1	16.2

in Figures 3 and 4, because there is no macro-diversity gain. This happens because the UEs in softer handover are very uncommon and do not provide any good channel diversity due to the tri-sectored antenna pattern.

The intra-NodeB is also worse than the reference scenario, although both perform the serving cell change procedure during the event triggering of the SHO. This is due to the fact that the intra-NodeB chooses the new serving sector only by reordering the cells in the AS based on the more recent measurement window, while, in the reference scenario, the serving cell change is accomplished by triggering the 1C event, considering the required thresholds and hysteresis. Therefore, the intra-NodeB is more likely to suffer influence from fast channel variations occurred during the last measuremet window. Being not able to provide the best connection, since the FCS range is limited to cells within the NodeB of the selected initial serving cell.

In Table III the MCS usage is represented for pedestrian scenario. It can be noticed that with the FCS operation the system concentrates more its transmissions using higher MCS, leading to the higher spectral efficiency as seen on the throughput results. It is also clear that with the intra-NodeB, almost 60% of the transmissions uses the lower MCS, meaning that the UE is experiencing worse quality channel conditions.

V. FINAL REMARKS

In this work, the FCS technique, foreseen for the deployment of the HSDPA in the evolution of the UMTS standard, was assessed in order to find a trade-off between performance and complexity, in the form of network signaling load.

Through the results obtained, it can be concluded that the FCS algorithm is flexible in order to reduce its control signaling without degradation on its expected gains in providing the best instantaneous connection.

There are some other issues that are also interesting to be explored. For example, a threshold, in order to restrict the cell change procedure to cells really able to provide a better radio link, avoiding excessive and useless signaling overhead. Another approach would be to use information regarding the cell loading signaled periodically to the UE, in order to provide higher throughputs, but still considering a user controlled cell selection.

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