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Title: Criteria for Cell Selection/Re-selection Algorithm

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1. Cell selection

1.1 Cells to be monitored when the UE is switched on

When a UE is just switched on, it has to get information regarding its covering cells. For this purpose, the UE can:

- *either* search the whole set of UTRA assigned carrier frequencies and cell codes,
- *or* recall the last used set of carrier frequencies and codes.

The latter possibility would improve the cell selection delay in the vast majority of accesses to the network. In order to reduce the cell selection delay also when an exhaustive search would be required (e.g., when the UE is switched on for the first time in an area never visited before), it would be useful to assign codes to cell according to a known pattern: this would allow the mobile to identify the codes of neighboring cells; in this case, as soon as the mobile measures a cell signal sufficiently strong, it would be also capable of measuring immediately all the neighboring cells, thus ending the process without the need of completing the exhaustive search.

In both cases, the UE measures the corresponding signal strengths and compiles a list of them.

1.2 Cell selection criteria

The cell to camp on can be chosen based on path loss consideration or, in addition, considering other criteria such as, for example:

- available services;
- cell load;
- operator only cell;
- UE speed.

It has to be noted that due to the peculiarities of CDMA, the path loss criterion must always be considered when comparing co-frequency cells (i.e., cells belonging to the

same layer).Other criteria such as available services can be taken into account for the choice of the cell to camp on, only if the path loss criterion is considered.
Therefore, in order to ensure a reliable cell selection process, it is suggested to stick to the path loss criterion within the appropriate cell layer; other criteria can be considered during the cell re-selection process (see next section).

1.3 Example of possible algorithm

A possible algorithm could be the following:
1] Recall the last used set of carrier frequencies and codes (if feasible)
2] Per each cell (i.e., per each couple frequency/code), assess whether the maximum allowed UE speed is greater than the actual UE speed; in this case remove from the list of candidate cells all cells with maximum allowed UE speed higher than the one of the cell currently assessed (i.e., only cells with the lowest maximum UE speed are considered)
3] Per each cell, the path loss is evaluated:

Path_Loss_BS = (BS_tx_p - UE_rx_p)

where:

Path_Loss_BS	path loss to the cell currently considered
BS_tx_p	BS transmitted power (on the broadcast channel)
UE_rx_p	UE received power (on the broadcast channel)

4] If Path_Loss_BS < Path_Loss_TH (where Path_Loss_TH is an appropriate threshold) the current cell is discarded
5] The UE compiles the list of available cells, sorted according to the path loss.
6] When all cells identified by the last used set of carrier frequencies and codes have been considered, if the cardinality of the list of available cells is smaller than its maximum dimension, other cells have to be measured (possibly avoiding the exhaustive search).
7] When the list of avaialble cells is full, the cell at the top of the list and all cells characterised by a path loss within a RE_TH interval (RE_TH being a parameter set by the operator) are considered as candidate cells. Per each of them, a UE transmission power factor (UE_TX_factor_BS) is evaluated according to the following equation:

UE_TX_factor_BS = I_rx_p + Path_Loss_BS

where:

I_rx_p	total power currently received by the considered cell

8] The UE creates the list of candidate cells, sorted according to the transmission power factor.

9] The UE tries to camp on the cell with the lowest transmission power factor.

10] If the cell selection attempt fails, the UE tries to camp on the subsequent cell in the list of candidate cells.

2. Cell Re-selection

2.2 Cell Re-selection criteria

The UE monitors adjacent cells and updates the relevant list. The monitoring can be performed either continuously or periodically; in the latter case the measurement period can be set based on the UE speed.

When the mobile is in idle state, it selects a new cell if e.g. one of the following has occurred:

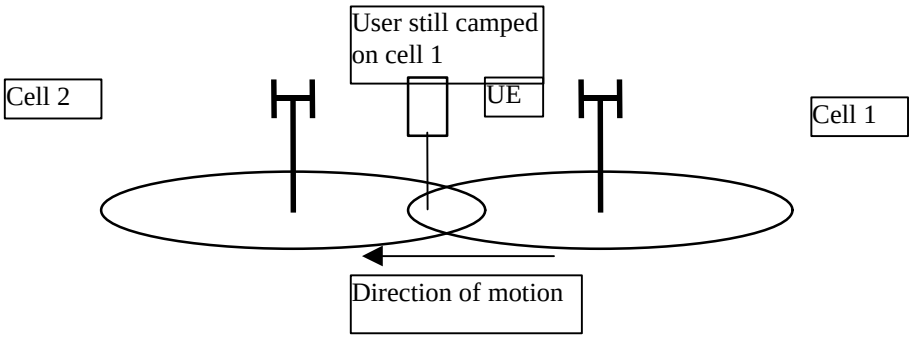
- Surrounding cells provide a better link
- The UE Speed has changed.
- The current serving cell is out of action
- The current serving cell is barred from access
- The UE can no longer decode the cell information in the BCCH
- The UE can no longer decode the paging channel

The UE can also select a new cell immediately before the call set up; this in order to access the most suitable cell based on services required by the mobile as well as on the status of the network at call set up.

- Failure of random access process
- Service dependent cell re-selection
- The current serving cell is overloaded.

Cell re-selection may exploit a number of different processes each of which corresponds to a particular criterion listed above. These processes can be configured by the UE manufacturers and network operators.
In any case, the crucial point in a CDMA network is that each access is considered as a source of noise and it is necessary that UE have comprehensive cell information in order to be capable of selecting a suitable cell. A fast and intelligent cell selection technique is required to operate correctly a CDMA network (see [1] and [2]).

As an example, the case in which the current serving cell is overload can be considered. This is a typical situation in which the operator may desire to try to move part of the UEs camped on the overloaded cell to an adjacent cell. This has to be done very carefully in a CDMA network in order to avoid major problems. In fact if a UE is forced to camp on a second choice cell (i.e. not the best server), this will result in high transmitted power at call set up, therefore causing major interference to the best choice cell, thus effectively reducing its capacity (see figure 1). This implies that the choice of the new cell to camp on shall be performed by the UE based on comprehensive information on the current serving cells as well as on adjacent cells; therefore, it is necessary to ensure that each cell broadcasts information on its current traffic load. The UE, based on the signal strength of



the serving and adjacent cells, on the information on their current load, as well as on other criteria such as traffic management or required services, will be capable of correctly selecting the new cell to camp on, if necessary. This implies that it could be possible for the UE to realise that it neither the best serving cell, nor any of the adjacent ones are available for the provision of the required service. In this case the mobile will not make any attempt to establish the call, but will inform the best serving BS of the situation, so that the best serving BS can take some actions, if appropriate (e.g., trying to free some resources if the new UE requesting service is a VIP). With respect to this possibility, it has to be noted that in a CDMA system it is not possible to the BS to simply move some UEs to an adjacent BS in order to reduce its own carried traffic. However, the BS can re-negotiate services to the UEs currently in communication (i.e., reduce the bit rate provided to them): this would lead to lower interference and therefore lower carried traffic.

2.2 Example of possible algorithm

A possible algorithm for cell re-selection based on path loss and UE speed criteria could be the following:

1] Per each cell to be monitored, assess whether the maximum allowed UE speed is greater then the actual UE speed; in this case remove from the list of candidate cells all cells with maximum allowed UE speed higher than the one of the cell currently assessed (i.e., only cells with the lowest maximum UE speed are considered)

2] Per each cell, the path loss is evaluated:

Path_Loss_SEL = (BS_SEL_tx_p - UE_rx_p_SEL)

Path_Loss_ADJ = (BS_ADJ_tx_p - UE_rx_p_ADJ) + cell_reselect_PL_hysteresis

where:

Path_Loss_SEL	path loss to the cell the UE is currently camped on
Path_Loss_ADJ	path loss to adjacent cell

BS_SEL_tx_p	transmitted power of the BS the UE is currently camped on (on the broadcast channel)
BS_ADJ_tx_p	transmitted power of neighboring BS (on the broadcast channel)
UE_rx_p_SEL	UE received power on the broadcast channel of the cell the UE is currently camped on
UE_rx_p_ADJ	UE received power on the broadcast channel of adjacent cell

3] The UE updates the list of available cells, sorted according to the path loss; this implies that some cells previously belonging to the list of available cells can be replaced by better adjacent cells.
4] When all cells to be monitored have being considered, the cell at the top of the list and all cells characterised by a path loss within a RE_TH interval (RE_TH being a parameter set by the operator) are considered as candidate cells. Per each of them, a UE transmission power factor (UE_TX_factor_SEL/ADJ) is evaluated according to the following equation:

UE_TX_factor_SEL = I_rx_SEL_p + Path_Loss_SEL
UE_TX_factor_ADJ = I_rx_ADJ_p + Path_Loss_ADJ + cell_reselect_TXF_hysteresis

where:

I_rx_SEL_p	total power currently received by the cell the UE is currently camped on
I_rx_ADJ_p	total power currently received by adjacent cell

5] The UE updates the list of candidate cells, sorted according to the power margin.
6] If a better cell (i.e., with a lower UE transmission power factor) replaces the cell the UE is currently camped on, the UE tries to camp on the newly identified best cell.

The above algorithm has to be further elaborated in order to consider the cell overload and required service criteria immediately before the call set up. This would ensure that the UE tries to establish the call on the most suitable cell, avoiding excessive interference to other users. This would also imply that the UE can realise that there is no cell available for the provision of the required service; in this case the UE can inform the best serving BS of the situation and a re-negotiation of resources can be initiated.A possible example of such an algorithm is reported in the Appendix.
Other algorithms can be considered, in particular addressing specific cases such as cell re-selection in case of emergency calls.

APPENDIX

Example of possible algorithm (service & cell load based)

In the DL:
1DL] When the UE has to require a given service to the network it evaluates whether:

(MAX_T_BS_SEL_tx_p – T_BS_SEL_tx_p) > UE_SER_rx_p + (BS_SEL_tx_p - UE_rx_p) + Acc_marg_SER

where:

MAX_T_BS_SEL_tx_p	maximum total transmitted power of the BS the UE is currently camped on (to be transmitted on the broadcast channel)
T_BS_SEL_tx_p	total transmitted power of the BS the UE is currently camped on
(BS_SEL_tx_p - UE_rx_p)	Path loss
Acc_marg_SER	suitable margin chosen by the operator which can vary depending on the service (default value: 0) (to be transmitted on the broadcast channel)
UE_SER_rx_p	target power which has to be received by the UE; it can be evaluated on the basis of the known target C/I (Carrier to Interference ratio) required by the relevant service, cansidering I = UE_rx_p*Ort_fact where Ort_fact is the ortogonality factor which depends on the scenario.

In the UL:
1UL] When the UE has to require a given service to the network it evaluates whether:

MAX_I_rx_BS - I_rx_BS > UE_SER_tx_p - (BS_SEL_tx_p - UE_rx_p)

where:

MAX_I_rx_BS	maximum total interference power accepted by the BS the UE is currently camped on (to be set by the operator and to be transmitted on the broadcast channel)
I_rx_BS	total interference power currently received by the BS (to be transmitted on the broadcast channel)
UE_SER_tx_p	power which has to be transmitted by the UE; it can be approx evaluated on the basis of the known target C/I (Carrier to Interference ratio) at the base station which is required by the relevant service, considering I = I_rx_BS

2] If the above conditions are true, the UE can attempt a call set up in the cell it is currently camped on.
3] If at least one of the above conditions is false, the UE can not attempt a call set up in the cell it is currently camped on. Each of the remaining cells belonging to the candidate list is checked.
If none of them is compliant with both above conditions, the UE will not try any call set up; and it will inform the best serving BS accordingly.

References

[1] TSGR2#3(99)240, “Idle and dedicated mode performance requirements and Vodafone
[2] TSGR4#4(99)182,”Cell Selection/Re-selection & Handover Requirements”, Source:CSELT, TIM, Vodafone