
Agenda item: **AdHoc #**

Source: **ETRI**

Title: **Seamless Interfrequency Hard Handover**

Document for: **Discussion**

Summary:

In this contribution, we propose an efficient method for seamless interfrequency hard handover for 3GPP's release'5 specifications. With this proposal, before the handover execution, the UE transmits preamble (unmodulated DPCCH) using uplink compressed mode (or similar mode for GSM and TDD) on the new uplink frequency and the target BS responds on the new downlink frequency with an acquisition indicator (AI) spreaded by $OVSF_{target}$ which is to be used in the downlink for DPCH channelization. This proposal has following advantages.

- The UTRAN(SRNC) can calculate the frame offset between the SFN_{target} and the CFN_{UE} before the handover execution so that there is no loss of frame (TTI disconnection) in the downlink as well as uplink even though the UTRAN does not know the frame offset.

- Even though the UTRAN knows the frame offset before the handover execution, there is an inefficiency in the uplink with current 3GPP's specification, since at least one TTI block will be lost and in the worst case several blocks may be lost due to the following reasons.

  - The target base station should find the uplink signal after frequency change of UE and it takes at least a few msec.
  - If the cell coverage of target BS is large, then the uplink handover search window size increases (for example, 1024 chip for 40 Km cell coverage). In this situation, the search time may be several ten's of msec or above and it depends on the capability of uplink searcher of target BS
  - Initial transmit power of UE after the frequency change should only rely on the open loop power estimate so that the received power at the target BS may be large in some cases but may be small in other cases. This can cause additional synchronisation delay in the target BS.

  However, with this proposal the target BS can acquire the uplink synchronization using the preamble before the handover execution so that there is no loss of frame in the uplink.

- By using the power ramping strategy for transmitting the preamble, the initial DPCH transmit power from the UE can be adjusted.

This proposal can be used in the following inter-frequency handover situations [9].

Case 1) Hot-spot scenarios, where a cell uses more carriers than the surrounding cells
Case 2) Hierarchical cell structures, where macro, micro, and pico layers are on different frequencies.
Case 3) Handovers between different operators
Case 4) Handover between different systems, that is, TDD -> FDD, GSM -> FDD
(Our proposal does not relate to FDD -> TDD, FDD-> GSM handover)

I. Intra-cell hard and inter-cell soft handover method (existing method)

Figure 1 illustrates a handover situation which may frequently take place in a CDMA network in which adjacent base stations use different number of carrier frequencies. Generally there is a common frequency allocation (so called "primary FA") in a CDMA network of an operator. Using this primary FA, UE acquires initial network synchronization as well as basic system information. After acquiring the initial network synchronization and basic system information using primary FA, the UE may change the frequency for paging or random access and so on.

In figure 1, f_1 is the primary FA and the UE is communicating with home BS with non-primary FA (that is, with f_2). In the situation of figure 1, when the UE moves to the handover region, inter frequency hard handover should be executed because target BS does not support f_2. If the inter-frequency hard handover is directly performed from f_2 of home cell to f_1 of target cell, there will be loss of frames in the uplink even though the UTRAN knows the frame offset between UE's CFN and target BS's SFN. The reason is that the target BS finds the uplink signal after frequency change of UE and it takes at least a few msec and may be several ten's of msec or above in worst case situation (it depends on the cell coverage and searcher capability of target BS and capability of round trip delay estimation between UE and target BS before handover execution).
In addition, as stated previously, when the UTRAN does not knows the frame offset, the problem is more severe because TTI disconnection must take place in downlink as well as in uplink [3,4,5,6,7].

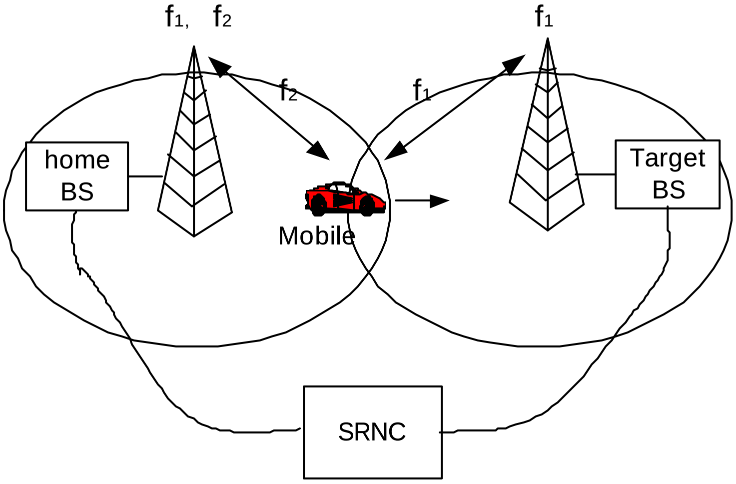


Figure 1. inter frequency hard handover situation with common primary FA

The basic concept of intra-cell hard and inter-cell soft handover method is to use the common frequency between adjacent BSs. That is, from f_2 to f_1 interfrequency hard handover is excuted within home cell and then with common frequency, f_1 , ordinary soft handover between home and target cells is executed. This approach is based on the fact that the path delays for the different frequencies are the same within home cell. Similar technology is currently being used for IS-95 based CDMA cellular and PCS system in Korea.

Figure 2 is the basic procedure and figure 3 is an example of required signaling procedure of intra-cell hard and inter-cell soft handover method. When the UTRAN does not know the frame offset, the single receiver UE can measure the SFN_{target} and calculate the frame offset after intra-cell hard handover execution and before soft handover execution.

This method is simple, but there should be a common frequency between the neighbor cells. So it is only suitable for case 1 scenario and can not be used in case 2, 3, 4 inter frequency hard handover scenarios. In the next section, a new method, which satisfies all the situations, will be proposed.

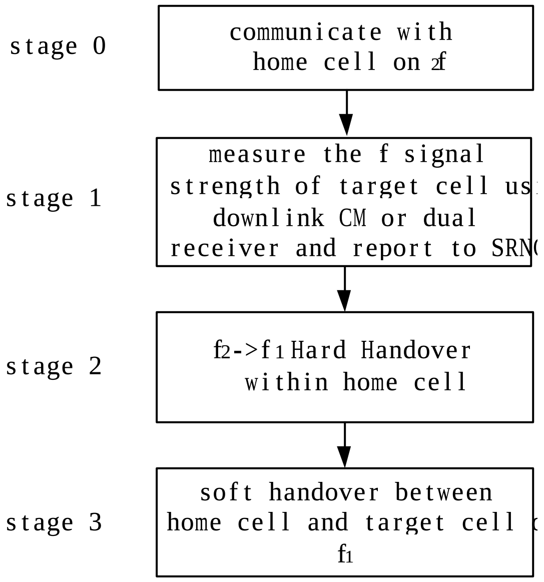


Figure 2. handover procedure of intra-cell hard and inter-cell soft handover method

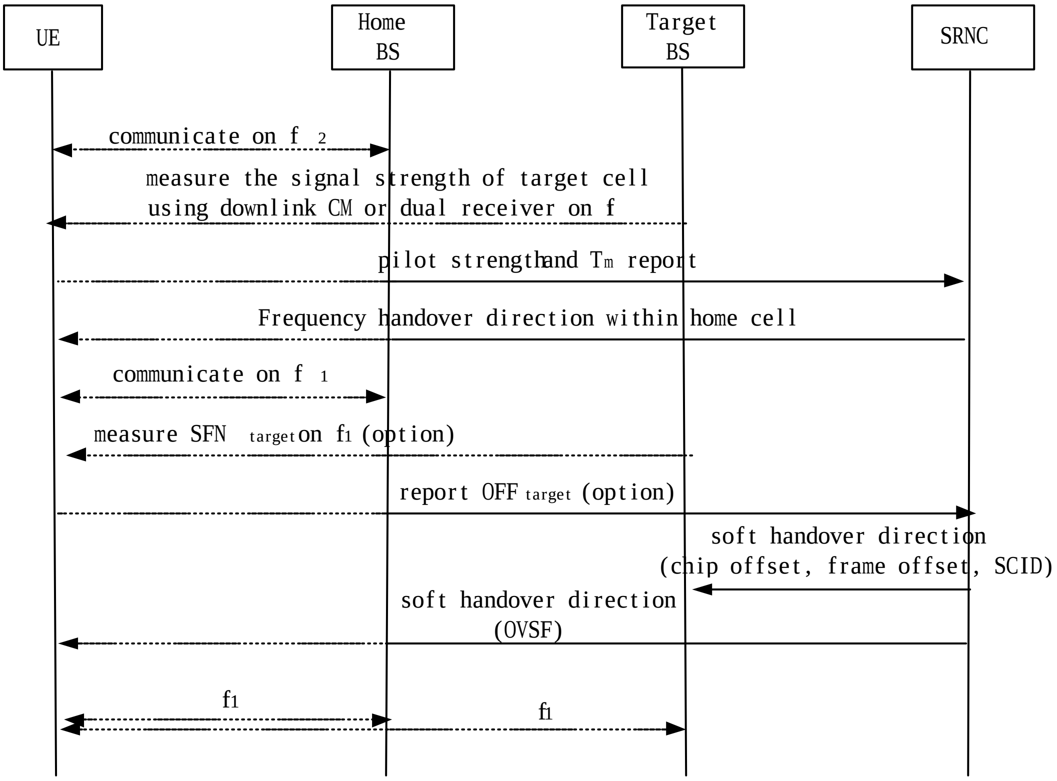


Figure 3. simple example of signaling procedure of intra-cell hard and inter-cell soft handover method

II. Proposed method (preamble transmission method using uplink compressed mode)

Figure 4 is general inter frequency hard handover situation. There may be common frequency between neighbor cells or may not. And the home BS and target BS may belong to different operators. The method presented in the previous section is not suitable for this general situation when there is no common frequency.

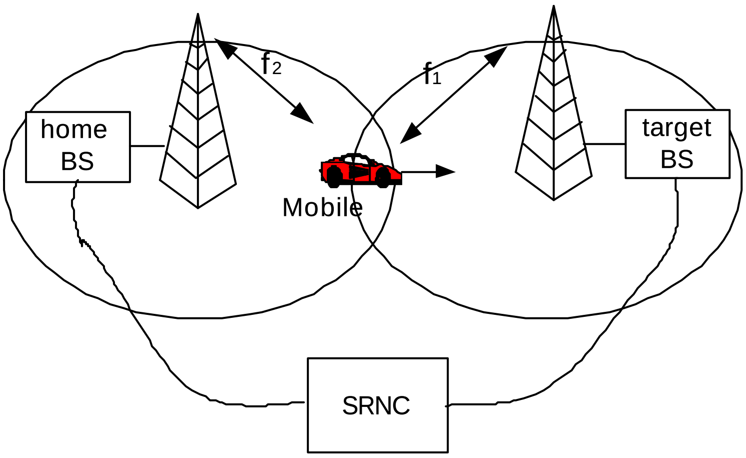


Figure 4. general inter frequency hard handover situation

The basic concept of the proposed method is that the UE transmits preambles with new frequency before the handover execution and the target BS acquires the uplink synchronization using the preambles before handover execution. The proposed method can be used not only for inter-frequency hard handover within WCDMA FDD network but also for WCDMA TDD to WCDMA FDD case or for GSM to WCDMA FDD case. In this contribution, however, we focus only on the inter-frequency hard handover within the WCDMA FDD system.

To transmit the preamble, the UE utilizes the uplink compressed mode as shown in figure 5. The preamble is an unmodulated DPCCH signal and the scrambling code is the same as in the normal transmission. That is, during the TG (transmission gap), by only changing the frequency and transmitted power, the UE can transmit the preamble. But the guard time (T_{grd}) and preamble duration should be defined in 3GPP's physical layer specifications.

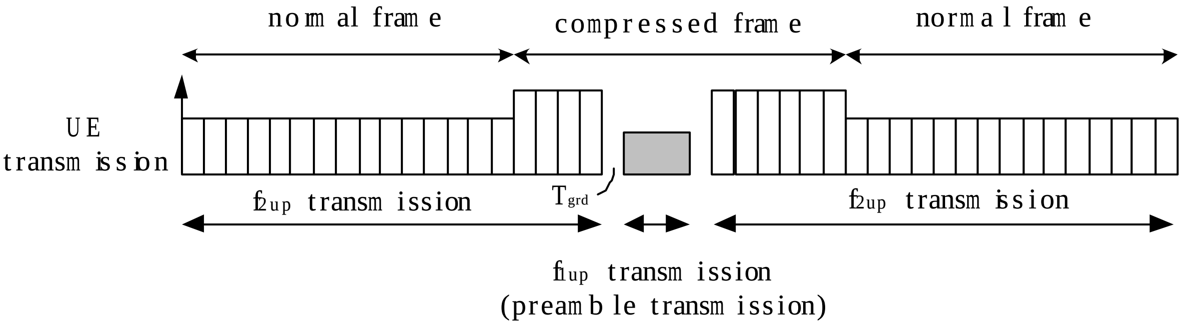


Figure 5. uplink preamble(DPCCH) transmission example of proposed method

When the UTRAN knows the frame offset before the handover execution, the AI (acquisition indicator) may or may not be transmitted at the new frequency. But when the UTRAN does not know the frame offset, the AI should be transmitted. With this structure, the UTRAN can acquire the frame offset. We will explain in detail how the UTRAN can acquire the frame offset before the handover execution in subsection 2.2.

Dual receiver UE can acquire the downlink P-CCPCH frame boundary and measure the SFN_{target} at anytime when it wants so that there is no problem in the downlink. But in the uplink, the problem is the same with that for the single receiver UE since the target BS should find the uplink signal after the UE changes the uplink frequency. Even though it does, in this paper we only focus on the single receiver UE.

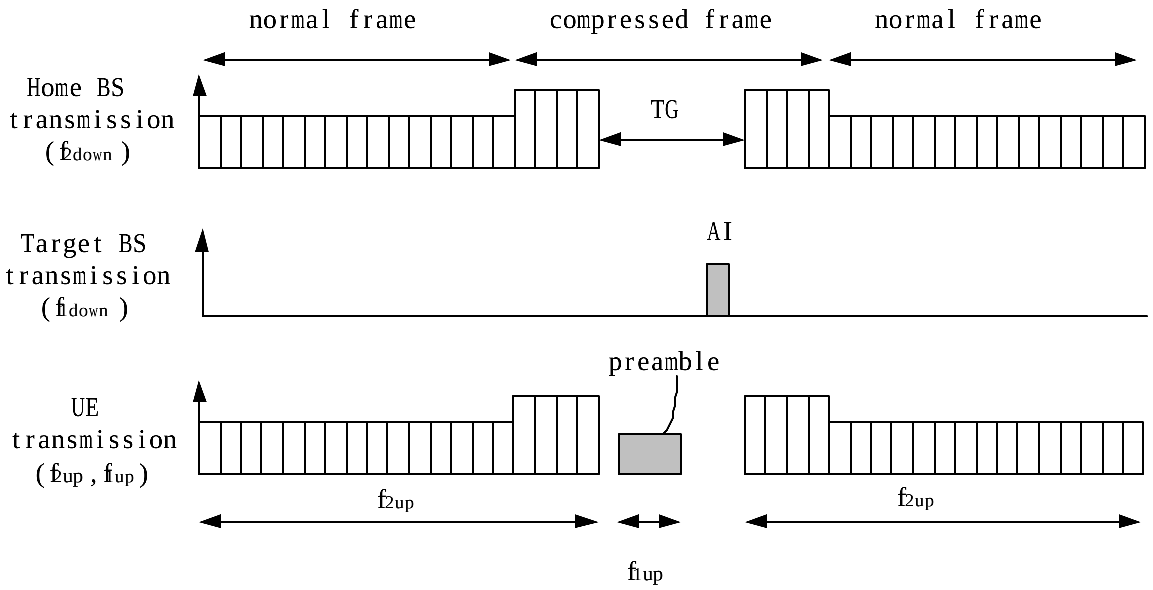


Figure 6. up and downlink transmission example for the single receiver UE

The channelization code for AI is the $OVSF_{target}$ which is to be used for channelization code for DPCH in the new down link. And the demodulation of AI can be performed coherently (by using CPICH of target BS). The length of AI should be defined in 3GPP's physical layer specification

The signaling procedures and behaviors of UE, BS and SRNC when the UTRAN does not know the frame offset may be somewhat different with those when the UTRAN knows the frame offset. In the following two subsections, we explain this point in detail.

2.1 When UTRAN knows the frame offset

Figure 7 shows one example of signaling procedure when UTRAN knows the frame offset between UE's CFN and target BS's SFN. Time0 is the situation when all the required downlink measurement of UE and all the required signaling related to the target BS's resources has been completed. That is, at time0

- UE and home BS are communicating using old frequency f_2.
- UE has acquired the frame boundary of P-CCPCH of new downlink from the target BS [8].
- Target BS has the resource to support the UE at new f_1 link.
- SRNC knows the frame offset as well as chip offset and had been reported $OVSF_{target}$ from target BS which is to be used in new radio link
- **Target BS does not get the uplink synchronization from the UE**.

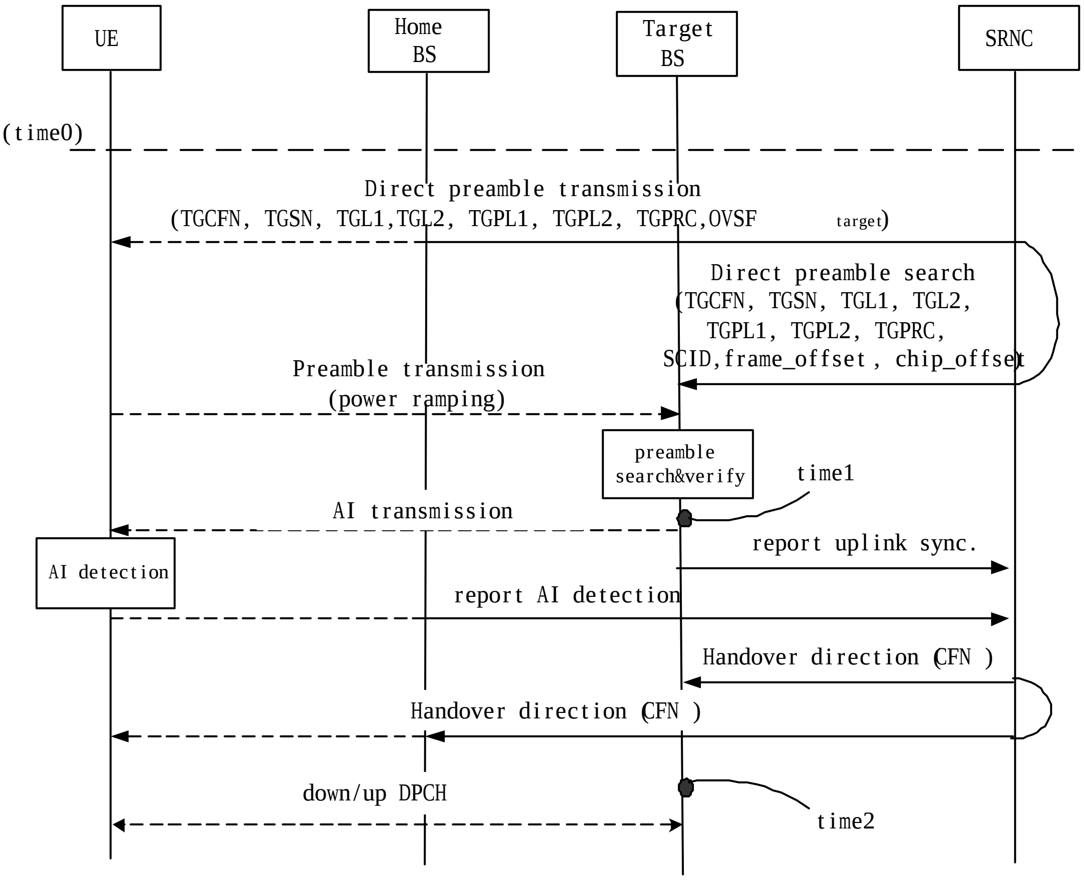


Figure 7. example of singling procedure of proposed method (frame offset is known in UTRAN)

After time0, the SRNC sends compressed mode parameters to the UE and direct to transmit the preamble at the every corresponding TGs. The SRNC also sends $OVSF_{target}$ to the UE which is to be used for channelization of AI and the new downlink DPCH.

At the same time, the SRNC sends the same compressed mode parameters to the target BS and direct to search the preamble at the every corresponding TGs. Of course, the SRNC sends frame offset and chip offset to the target BS. This information is used for target BS to determine the search window starting point. We will explain the timing relationship between UE and target BS in the later part of this section in detail. After preamble search and verification the target BS transmits the AI to the UE and reports uplink synchronization to the SRNC.

The UE checks the AI at every TGs at which it transmits uplink preamble and if AI is detected, it reports AI detection success to SRNC. After AI detection the UE may transmit the link maintenance preamble using remaining TGs with equal power and it depends on maximum signaling time requirement between time2 and time1 as in figure 7. If the maximum signaling time requirement between time2 and time1 is less than 200 msec, then link maintenance preamble might not be transmitted (when the vehicle speed is 300 km/hr, 1/4 chip deviation time of a path is about 235 msec and when 150 km/hr, 470 msec).

By receiving the uplink synchronization success report from the target BS and the AI detection success report from the UE, the SRNC directs inter frequency hard handover to the UE and the target BS with CFN at which the handover should take place. The initial uplink DPCH power from UE is based on the last transmitted preamble power similar to that of initial random access procedure.

The overall false handover direction of SRNC depends heavily on the false alarm probability of preamble search strategy of target BS. We will further discuss this point in the later part of this section and section III.

Figure 8 is one example of timing relationship of UE and target BS when the UTRAN knows the frame offset. The target BS can determine the preamble search window using the compressed mode pattern related information received by SRNC. First, the target BS calculates the SFN corresponding to the TGCFN received by SRNC using the following equation [1],

$$SFN_{\mathrm{mod}}256 \ ? \ (frame\_offset \ ? \ TGCFN)_{\mathrm{mod}}256 \qquad (1)$$

Because the range of SFN is 4096 and that of TGCFN is 256, the possible number of SFN, which satisfies equation (1) is 16. In the example of figure 8, it may be one of 123, 239, 635 … . By choosing the nearest one from the SFN time at which the target BS received the preamble search direction message from SRNC, this ambiguity can be removed. In the example of figure 8, if we assume that the target BS received that message from SRNC at the SFN=120, then the SFN, corresponding to the TGCFN=56, is 123.

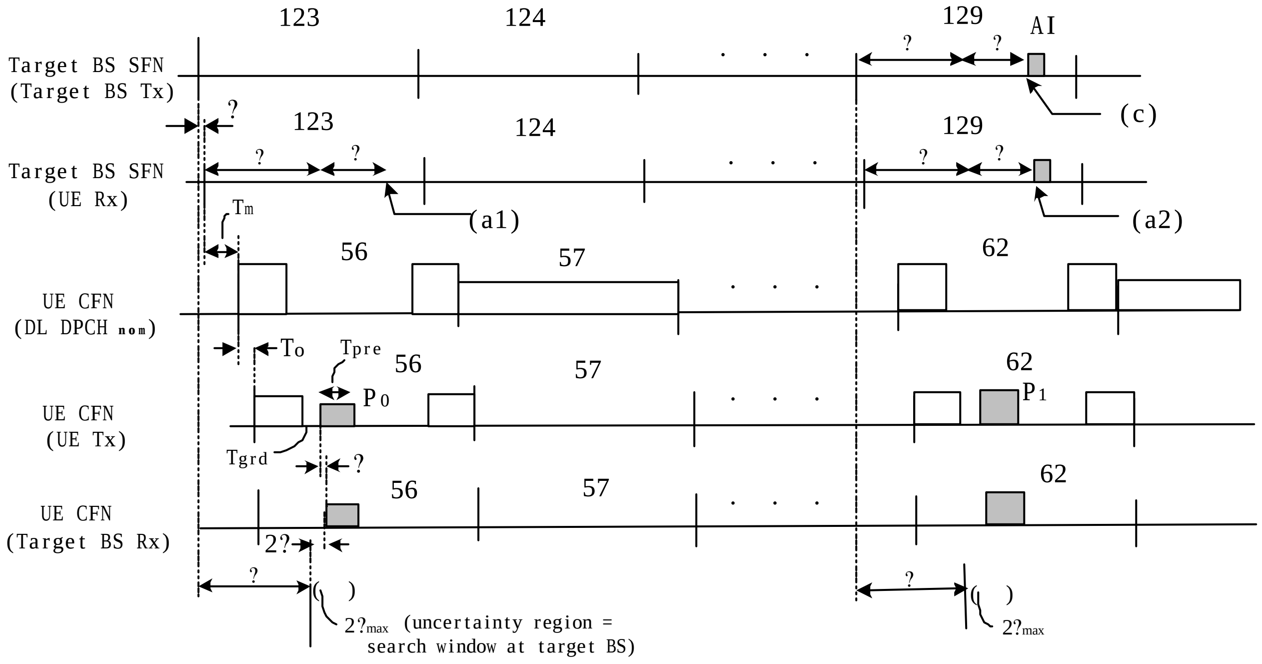
The target BS defines an interval from the point which is "?"chips apart from the frame (SFN=123) boundary and searches the uplink preamble using the received signal during that interval. The length of the interval is $T_{pre}+2?_{max}$. Where $2?_{max}$ is maximum round trip delay between UE and target BS and it becomes the preamble search window size of target BS since there is no way to estimate round trip delay (2???between UE and target BS before handover execution in 3GPP's WCDMA. It is directly determined by the cell coverage of target BS. So if the cell coverage of target cell is 40 Km, the search window size becomes almost 1024 chips. This may be the same with that of initial random access preamble searcher of the target BS.

? may be larger than 38400 chips or less and defined as following

$$? \ ? \ T_m \ ? \ TGSN \ ? \ 2560 \ ? \ T_0 \ ? \ T_{grd} \qquad (2)$$

T_m is $(T_{UETx}-T_0) - T_{RxSFN}$ and defined in [1]. T_0 is 1024 chips and also defined in [1].

The target BS searches the preamble at the every TG until the search procedure is completed. In the example of figure 8, the target BS acquires the uplink synchronization in the second TG so that it transmits the AI in that TG duration. The AI transmission starting point at the target BS is "?+? " chips apart from the boundary of the PCCPCH frame which specified by the compressed mode pattern. Where?? should be larger than $T_{pre}+2?_{max}$ and should be defined in 3GPP's physical layer specifications. The UE transmits preambles at the every TG which is specified by the compressed mode pattern parameters until it detects the corresponding AI from the new downlink. As in the initial random access attempt, power ramping is used for the preamble transmission. The UE attempts AI detection at every TG. The exact AI detection point is "?+? " chips apart from the boundary of the received PCCPCH frame which is specified by the compressed mode pattern. In figure 8, (a1) and (a2) is the AI detection points of the UE.



frame_offset=67, TGCFN=56,TGPL1=TGPL2 = 6, TGL2 = 0

?? = Tm +TGSNx2560+To+T grd

? > 2?max +Tpre

P0 : first preamble Tx power
P1 : second preamble Tx power (=Po+?)

Figure 8. example of preamble and AI transmission timing of proposed method for the single receiver UE (frame offset is known in UTRAN)

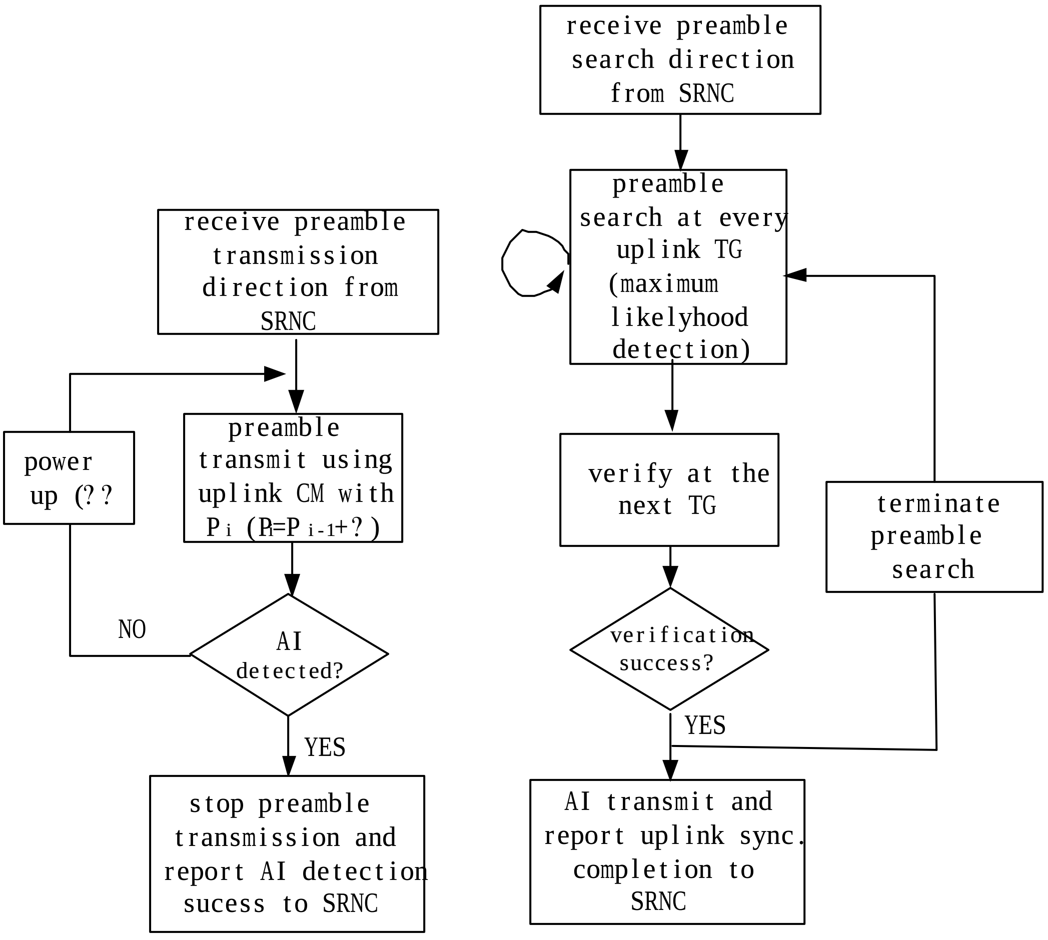
Figure 9 shows one example of UE's behavior and target BS's one when the UTRAN knows frame offset. As shown in the figure, UE's operation is very simple

In the example of figure 9, target BS's search procedure is composed of search mode and verification mode. This may be somewhat different from preamble search algorithm of initial random access procedure. In the search mode, maximum likely hood detection scheme can be applied since post processing is possible in the target BS using the memory element which is idle before handover execution. As stated earlier, the target BS searches the preamble every TG and verifies that at the next TG. Since overall false handover direction probability of SRNC depends heavily on the false alarm probability in the verification mode, it is important to determine the threshold in the verification mode. As an extreme example, if we assume that the error probability of AI detection is 0 and the detection probability of preamble search mode for an attempt is also 0, then the false handover direction probability for that attempt is the same as the false alarm probability of preamble verification mode.

With verification success, the target BS should select multipaths which are to be used for finger assignment of new uplink DPCH after handover execution using the last transmitted preamble.

SRNC starts a timer as soon as it receives synchronization success report from the target BS or AI detection success report from the UE. If there is no report from the other side until the timer has expired then the SRNC should direct the target BS and the UE to stop all the procedure. And if necessary, it may redirect new procedure.

The handover miss probability highly depends on the AI miss probability of UE when we set the false alarm probability of preamble verification very small. The target BS may retransmit the AI if there exist a preamble even though it transmitted the AI in the previous TG. The retransmission of AI can significantly reduce the handover miss probability.



(a) UE’s operation (b) Target BS’s operation

Figure 9. one example of the operations of UE and target BS when frame offset is known at the UTRAN

2.2 When UTRAN does not know the frame offset

Many contribution papers has dealt with the inter frequency hard handover related problem of current 3GPP's rel'99 specifications [3,4,5,6,7]. The problem is that there should be TTI disconnection in the downlink as well as uplink when the UTRAN does not know the frame offset between the UE's CFN and target BS's SFN. But no obvious solution has been proposed yet.
In this contribution, we propose a solution to overcome this problem.

Figure 10 shows one example of signaling procedure of proposed method when UTRAN does not know the frame offset between UE's CFN and target BS's SFN. At time0,

- UE and home BS are communicating using old frequency f_2.
- UE has acquired the frame boundary of P-CCPCH of the new downlink from the target BS [8].
- Target BS has the resource to support the UE at new f_1 link.
- SRNC knows chip offset but **does not know the frame offset**
- SRNC had been reported $OVSF_{target}$ from target BS which to be used in new radio link
- **Target BS does not get the uplink synchronization from the UE**.

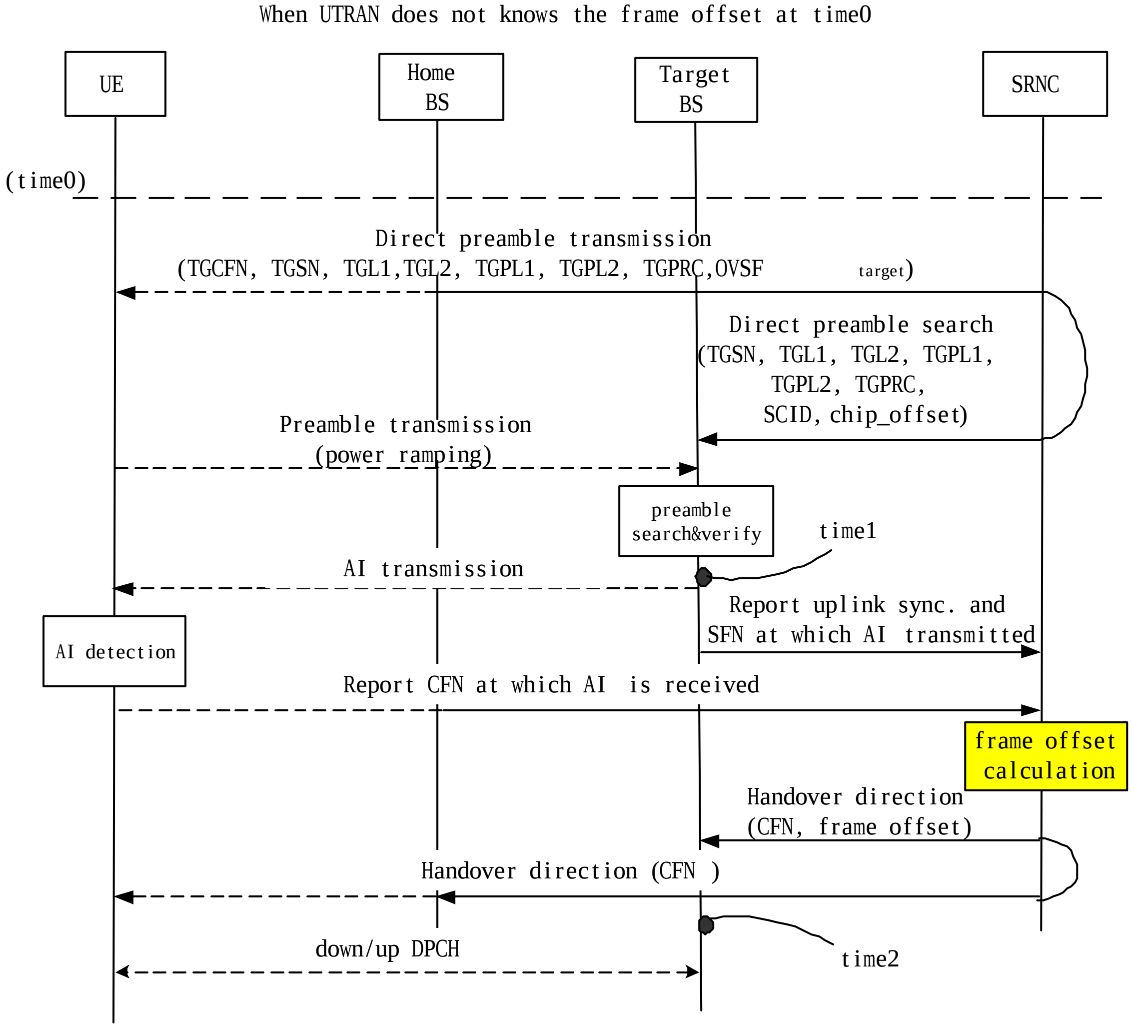


Figure 10. example of signaling procedure of proposed method (frame offset is unknown)

After time0, the SRNC directs the UE to transmit the preamble at every corresponding TGs. All the information, which SRNC sends to the UE, is the same as that when UTRAN knows the frame offset (see figure 7). But the information, which SRNC sends to the target BS, is somewhat different from that when UTRAN knows the frame offset. That is, the information does not contain the frame offset and TGCFN. The reason is that the SRNC does not know the frame offset. Even if it does, with this proposal, UTRAN(SRNC) can calculate the frame offset between UE's CFN and target BS's SFN before the handover execution. This is based on target BS's SFN and UE's CFN information which are sent to SRNC, by the target BS and the UE after uplink synchronization and AI detection , respectably. That is, after uplink synchronization and AI transmission, the target BS sends the SFN at which it transmits the AI to the UE to SRNC. And the mobile also sends the CFN at which it receives the AI to the SRNC. Using this information, the SRNC can calculate the frame offset.

We explain how the SRNC can know the frame offset with figure 11, 12
The target BS does not know SFN where the preamble is to be received because there is no TGCFN and frame offset information. But it can calculate ? using equation (2) based on chip offset(T_m) which received by SRNC.

The target BS starts searching the uplink preamble as soon as it has received the preamble search direction message from SRNC. Preamble search is done during the specified interval of every frame. The starting point of the interval is specified by $?_{mod}38400$. The reason in using $?_{mod}38400$ instead of ? is that ? may be larger than 38400 chips. As stated in the previous subsection, the duration of the interval is $T_{pre}+2?_{max}$. But there are *T*-1 incorrect hypothesis search windows (Ho windows) and one correct search window (H_1) between adjacent transmission gaps. Where *T* is the number of frames between adjacent transmission gaps. When the UTRAN does not knows the frame offset, distance between any adjacent TGs should be uniform as *T*.

The reason why the target BS should search the preamble at every frame is that the UTRAN does not know the frame offset. After uplink synchronization, the target BS transmits AI to the mobile and report uplink synchronization completion to SRNC with SFN information at which it sends the AI.

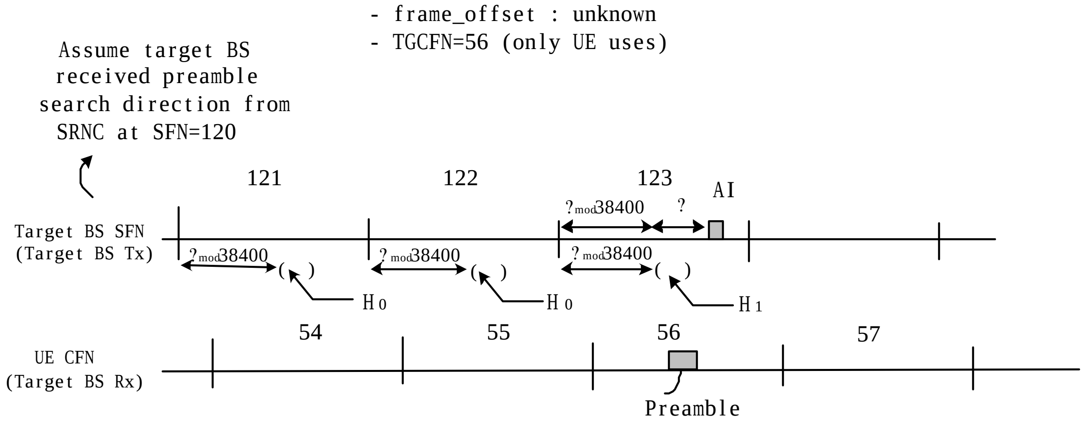


Figure 11. timing diagram to explain target BS's search window (when frame offset is unknown)

The UE transmits the preamble at every TGs specified in the compressed mode parameters received from SRNC and detect the AI. The channelization code for AI is $OVSF_{target}$ which to be used for DPCH in the new link. If AI is detected, the UE report the CFN at which the AI is received.

Using target BS's SFN and UE's CFN information which are sent to SRNC, the SRNC can calculate the frame offset by following equation

$$\begin{aligned} &frame\ offset ? (\mathrm{SFN} - \mathrm{CFN} - 1)_{\mathrm{mod}} 256, &&\text{when } (? \ ? \ ?)_{\mathrm{mod}} 256 \ ? \ chip\ offset \\ &frame\ offset ? (\mathrm{SFN} - \mathrm{CFN})_{\mathrm{mod}} 256, &&\text{when } (? \ ? \ ?)_{\mathrm{mod}} 256 \ ? \ chip\ offset \end{aligned} \qquad (3)$$

Figure 12 is the timing diagram explaining how SRNC can calculate the frame offset.

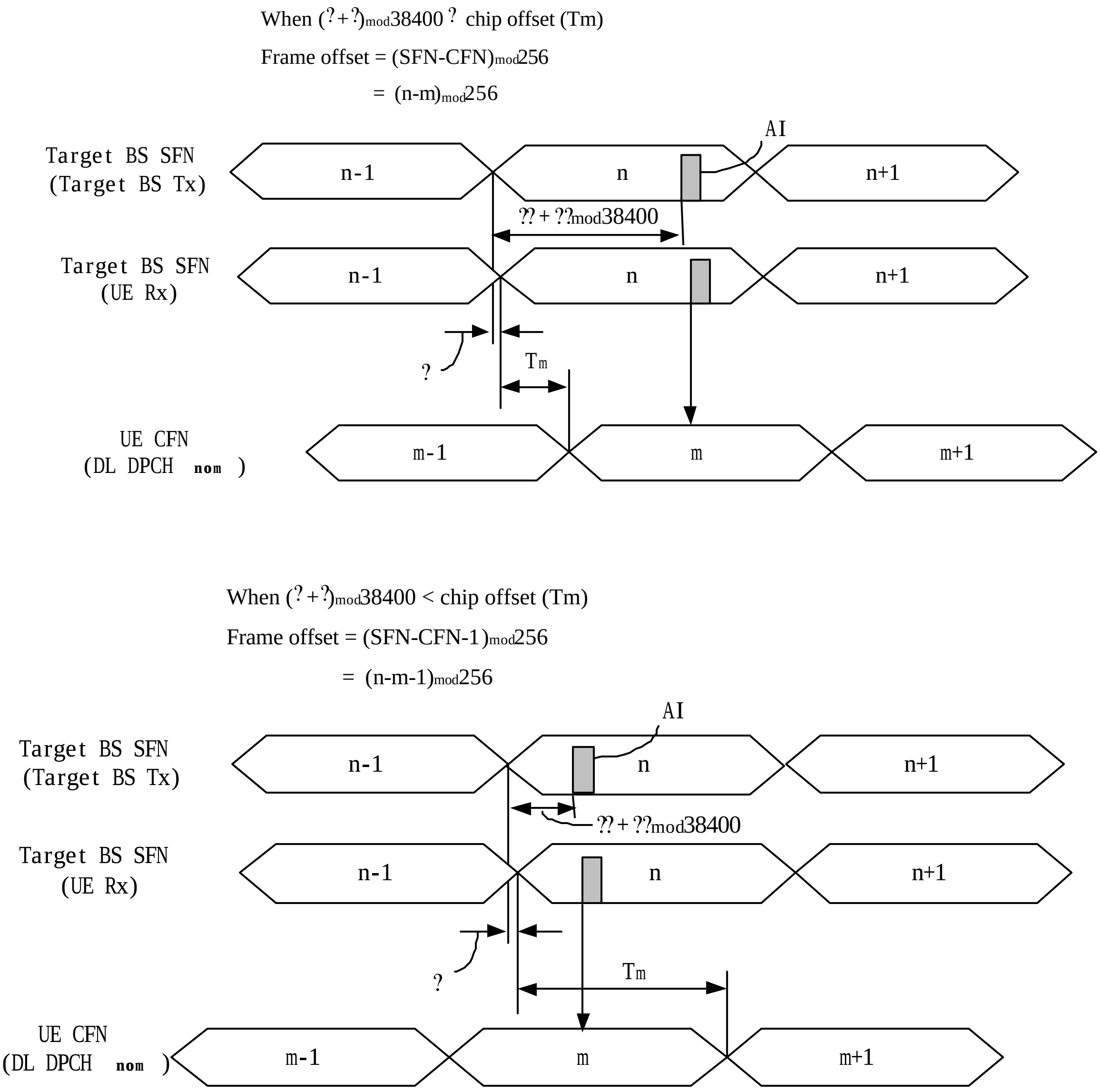


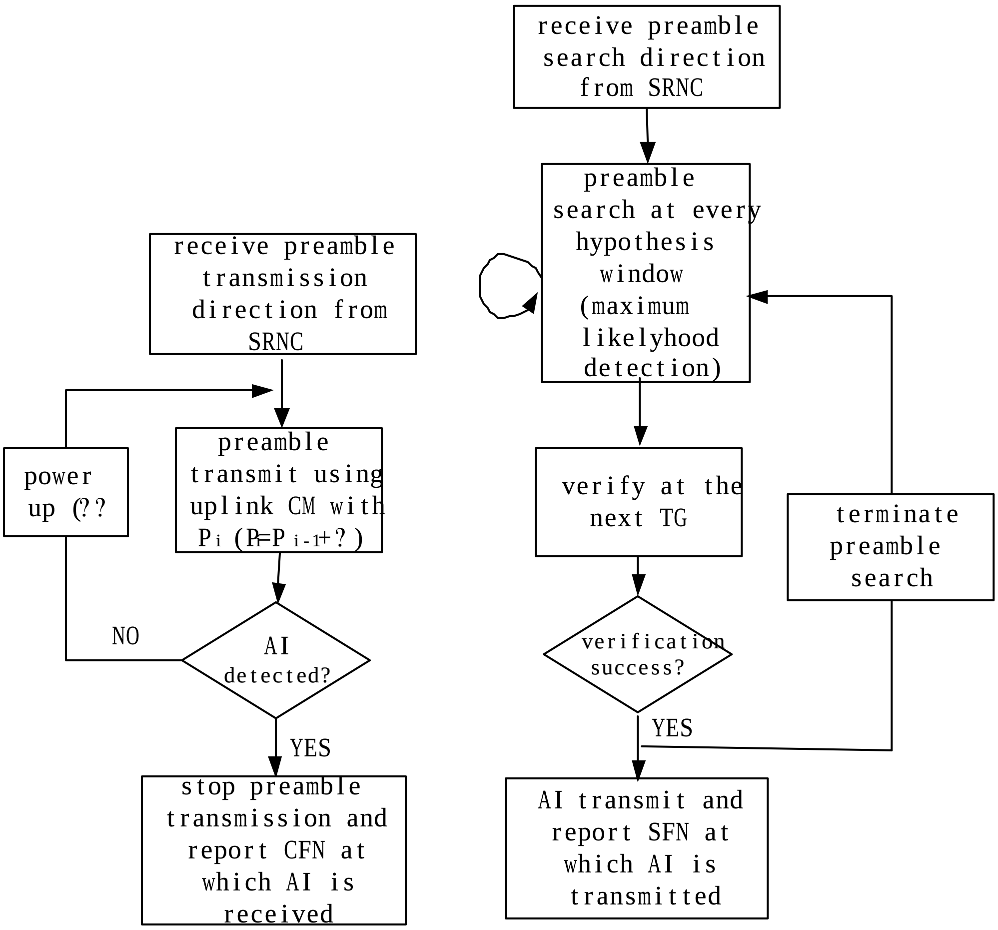
Figure 12. frame offset calculation at the SRNC

Figure 13 shows one example of UE's behavior and target BS's behavior when the UTRAN does not know the frame offset. As shown in the figure, UE's operation is almost the same as that when the UTRAN knows the frame offset except reporting CFN. After AI detection, the UE may transmit maintenance preamble with equal power in the remaining TGs.

Target BS's search procedure is similar with that when the UTRAN knows the frame offset. That is, it is also composed with search mode and verification mode. But unlike when the UTRAN knows the frame offset, the search procedure starts as soon as the target BS has received the preamble search direction message from the SRNC. In the search mode, maximal likelihood detection also can be applied. And all the hypothesis windows (H_1 and H_0s) are searched and verified because the target BS does not knows what is the correct hypothesis window.

SRNC starts a timer as soon as it receives synchronization success report from the target BS or AI detection success report from the UE. If there is no report from the other side until the timer is expired then SRNC should direct SRNC and UE to stop all the procedure and if necessary, it may redirect new procedure.

With verification success, the target BS should select multipaths which are to be used for finger assignment of new uplink DPCH after handover execution using the last transmitted preamble.



(a) UE's operation (b) Target BS's operation

Figure 13. one example of the operations of UE and target BS when the UTRAN does knot knows the frame offset.

III. Detection and false alarm probability performance analysis

The performance measures to estimate the overall handover procedure are false handover direction probability and handover miss probability. If we define those as the followings,

P_F(HO) : False handover direction probability
P_M(HO) : Handover miss probability

then the handover success probability is 1- P_F(HO)- P_M(HO).

There are many parameters which may influence P_F(HO) and P_M(HO). For example, T, TGPRC, N_{re}, ? . where

T : distance between adjacent TG
TGPRC : one period of compressed mode pattern
? ?? ?: Power ramping step size of preamble
N_{re} : The number of repetition of the overall procedure when handover miss event occurs.

Besides above parameters, P_F(HO) and P_M(HO) may heavily depend on detection probability of preamble search mode, false alarm and detection probability of preamble verification mode and those of AI detection mode.

Target BS side :
P_D(PS) : Detection probability of preamble search mode
P_F(PV) : False alarm probability of preamble verification mode
P_D(PV) : Detection probability of preamble verification mode
UE side :
P_F(AI) : False alarm probability of AI detection mode in UE
P_M(AI) : Miss probability of AI detection mode in UE

It is very time consuming job to analyze all the effects of above parameters to P_F(HO) and P_M(HO).

In this contribution, we analyze P_D(PS), P_F(PV), P_D(PV) and P_F(AI), P_M(AI) firstly.
Even though those performance measures do not show all the effect of proposed method, we can still foresee the feasibility of proposed method from these values.

3.1 Detection/false alarm probability in the uplink (in target BS's searcher)

3.1.1 Simulation condition

- Preamble length : 4096 chips
- Search window size at the preamble search mode: 1024 chips
- coherent integration length : 1024 chips
- noncoheretly accumulated segment : 4 segments
- Period of TG (T) : 5 msec
- Single path fading channel (Jake's model) and other user interference is modeled as additive Gaussian
- Optimal sampling (that is, one sample per chip and no pulse shaping)
- Frequency offset is 0 Hz

3.1.2 Detection probability in preamble search mode

As stated in section II, we assumed maximum likelihood selection rule for preamble search mode.

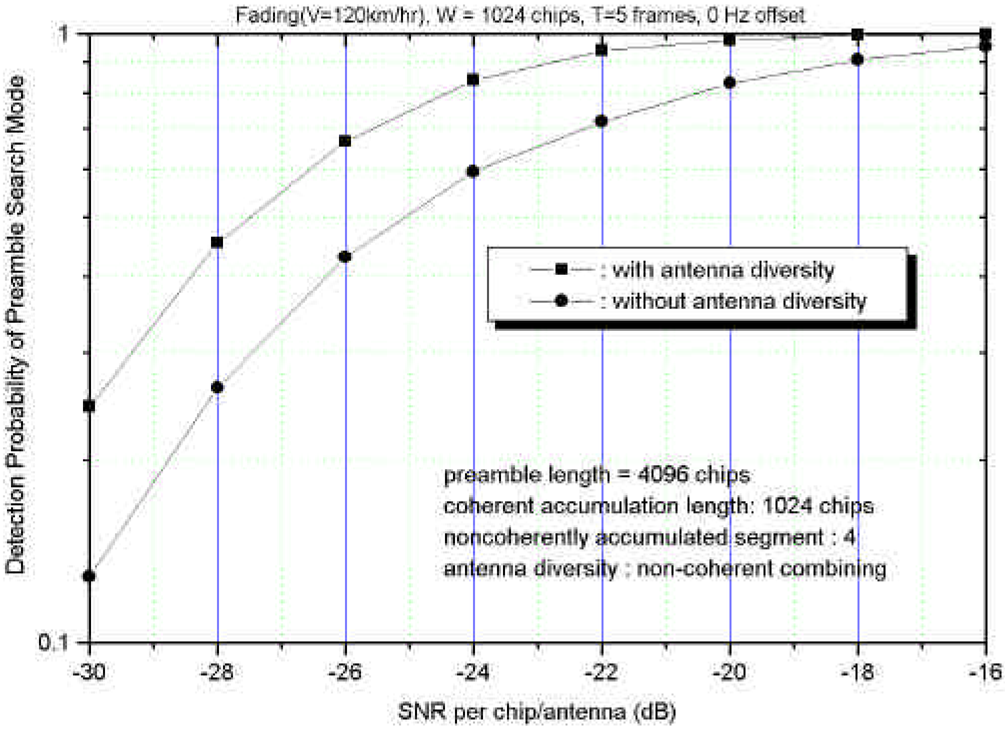


Figure 14. Detection probability of preamble search mode (V=120 Km/hr)

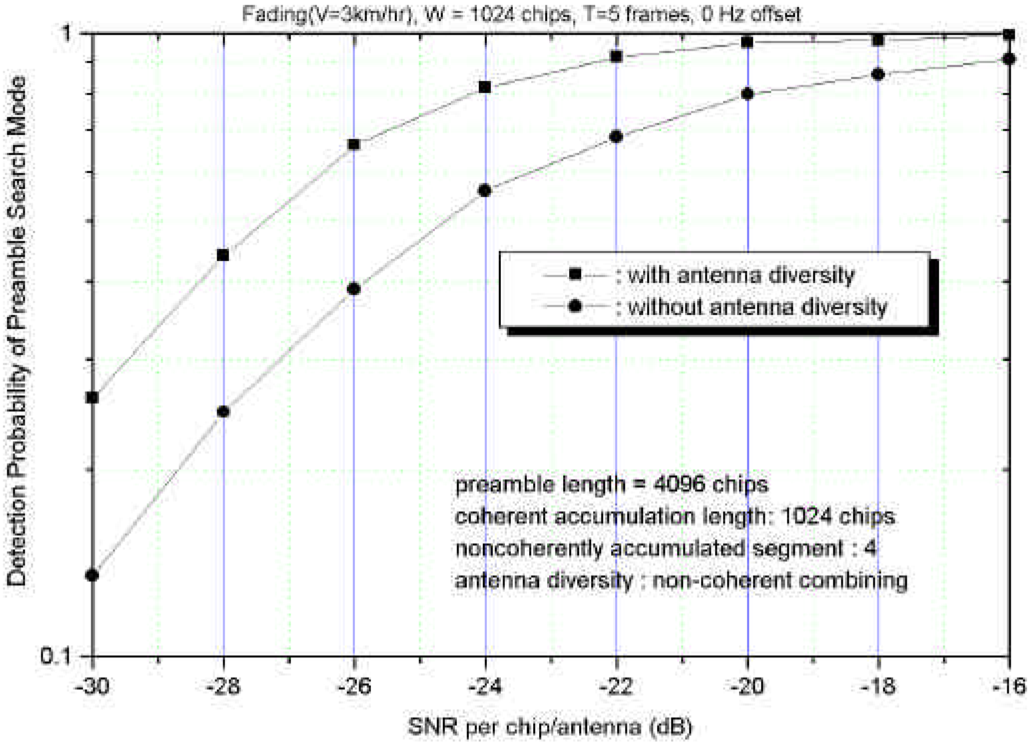


Figure 15. Detection probability of preamble search mode (V=3 Km/hr)

3.1.3 False alarm/detection probability in preamble verification mode

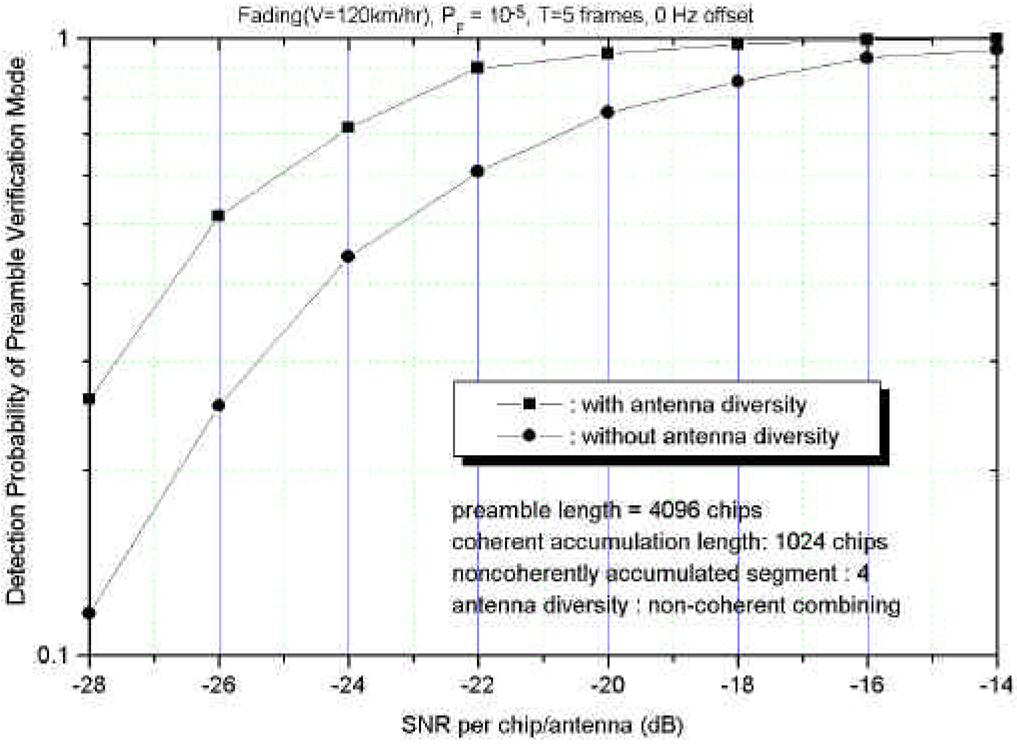


Figure 16. Detection probability of preamble verification mode (V=120 Km/hr)

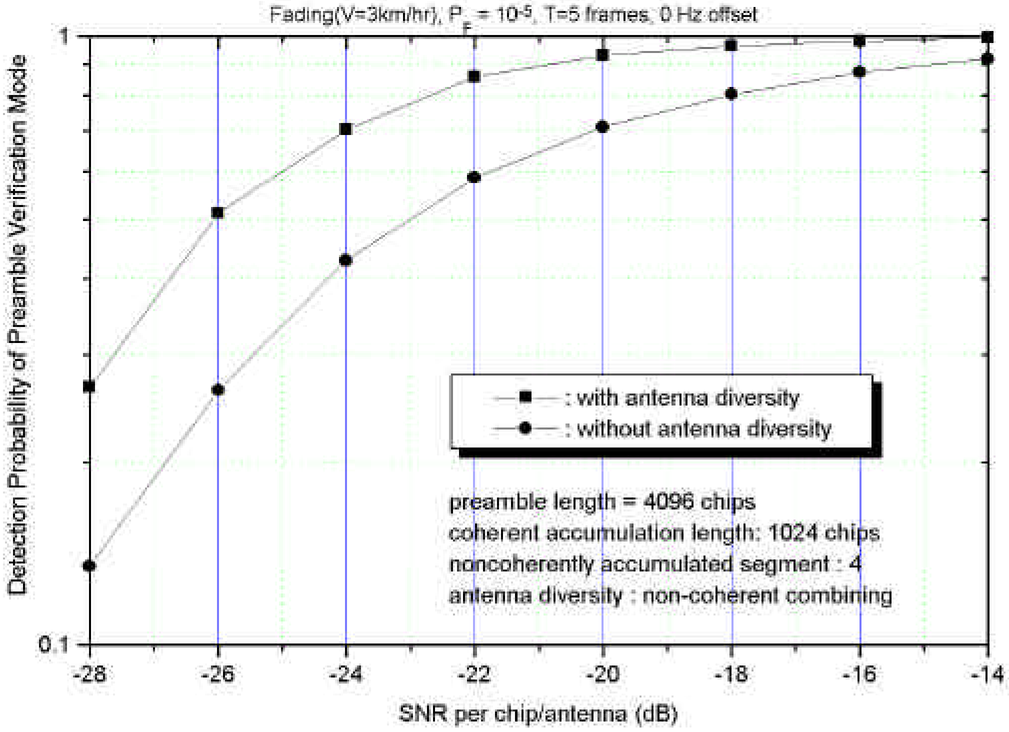


Figure 17. Detection probability of preamble verification mode (V=3 Km/hr)

Figure 14 and 15 show the detection probability of preamble search mode for given SNR when vehicle speeds are 120 km/hr and 3 km/hr, respectively. As stated in section II, we assume maximum likely hood selection rule in preamble search mode. As a worst case we assume search window size as 1024 chips and this corresponds 40 Km cell coverage.

In the figures, the detection probability is depicted only for a given SIR. If we consider the power ramping procedure, the aggregated detection probability becomes greater. For example, in figure 14, with antenna diversity the detection probabilities are 0.24 for –30 dB, 0.45 for –28 dB, 0.67 for –26 dB, 0.84 for –24 dB, 0.94 for –22 dB and so on. But if we assume the power ramping starting point is –30 dB and the false alarm probability of preamble verification mode is "0". And if we also assume independent events between adjacent TGs, then the aggregated detection probability of preamble search mode becomes 0.24 for –30 dB, 0.582 until –28 dB, 0.862 until –26 dB, 0.977 until –24 dB, 0.99955 until –22 dB and so on.

The –20 dB of SNR per chip means 1% of uplink capacity. And if we consider that the duty cycle of preamble transmission is 0.0213(= 4096/(38400x5) in this example), the capacity loss of uplink is negligible.

Figure 16 and 17 show the detection probability of preamble verification mode for given SNR when vehicle speeds are 120 km/hr and 3km/hr, respectively. In the preamble verification mode, the decision variable is compared with a threshold to give a detection probability. The signal was set so that when no signal was presented, the probability of the statistic being greater than the threshold was equal to a false alarm probability of 10^{-5}. As stated in the section III, because the overall false handover direction probability P_F(HO) mainly depends on the false alarm probability of preamble verification mode of target BS it is very important to select the threshold so that the false alarm probability of preamble verification mode has appropriate value. The value 10^{-5} is only one example.

Unlike when UTRAN knows the frame offset, all the hypothesis windows (H_1 and H_0s) are searched and verified when UTRAN does not knows the frame offset. If the threshold for preamble verification mode is the same for both case, the false alarm probability of overall preamble search procedure of target BS when the UTRAN does not know the frame offset may be T times than that when the UTRAN knows the frame offset. Even though it does, the overall false handover direction probability P_F(HO) may almost the same for the both cases because the UE detects AI only at the specified position, that is, only H_1 position for both cases. But the handover miss probability P_M(HO) when UTRAN does not know the frame offset may somewhat larger than that when UTRAN knows the frame offset.

3.2 False alarm/detection probability in the downlink (in UE's AI detection)

3.2.1 Simulation condition

Figure 18 is the simplified downlink simulation model for AI detection in UE. In the model $\hat{I}_{or}$ is total received power from the target cell and I_{oc} stands for power density of other cell interference.

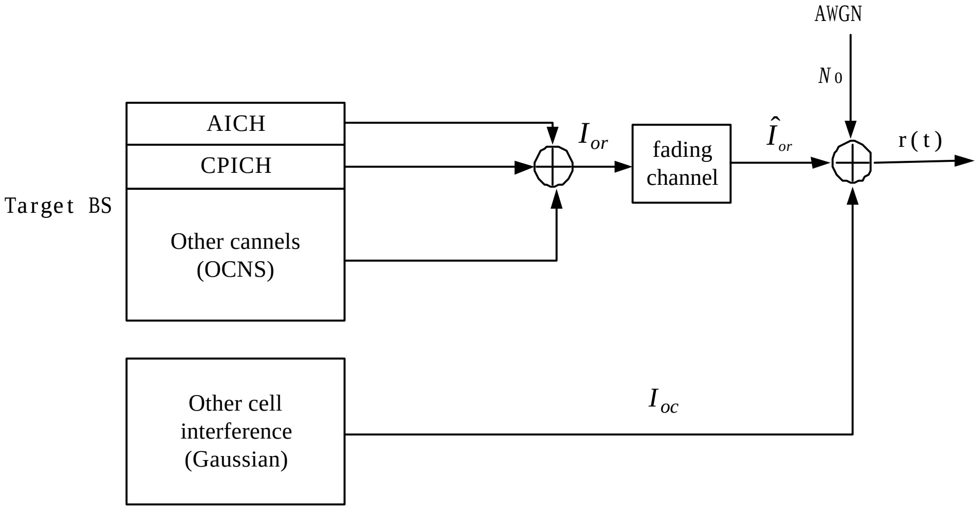


Figure 18. simple downlink simulation model

- AI length : 4096 chips
- AICH_Ec/Ior : test dependent
- CPICH_Ec/Ior : -10 dB (fixed)
- Detection method : coherent detection based on channel estimates using CPICH
- Channel estimation : 512 chips coherent integration of CPICH channel
- $\hat{I}_{or}/(I_{oc}+N_0)$: test dependent
- Single path fading channel (Jake's model)
- Optimal sampling
- Frequency offset is "0" Hz
- When the Tx diversity is employed, the power is evenly distributed.

The decision variable is compared with a threshold to give a detection (or miss) probability. First, we chose a threshold so that, when there is no AICH signal, the probability of the decision variable being greater than the threshold was equal to false alarm probability of 10^{-3}. The threshold varies according to $\hat{I}_{or}/(I_{oc}+N_0)$ values.

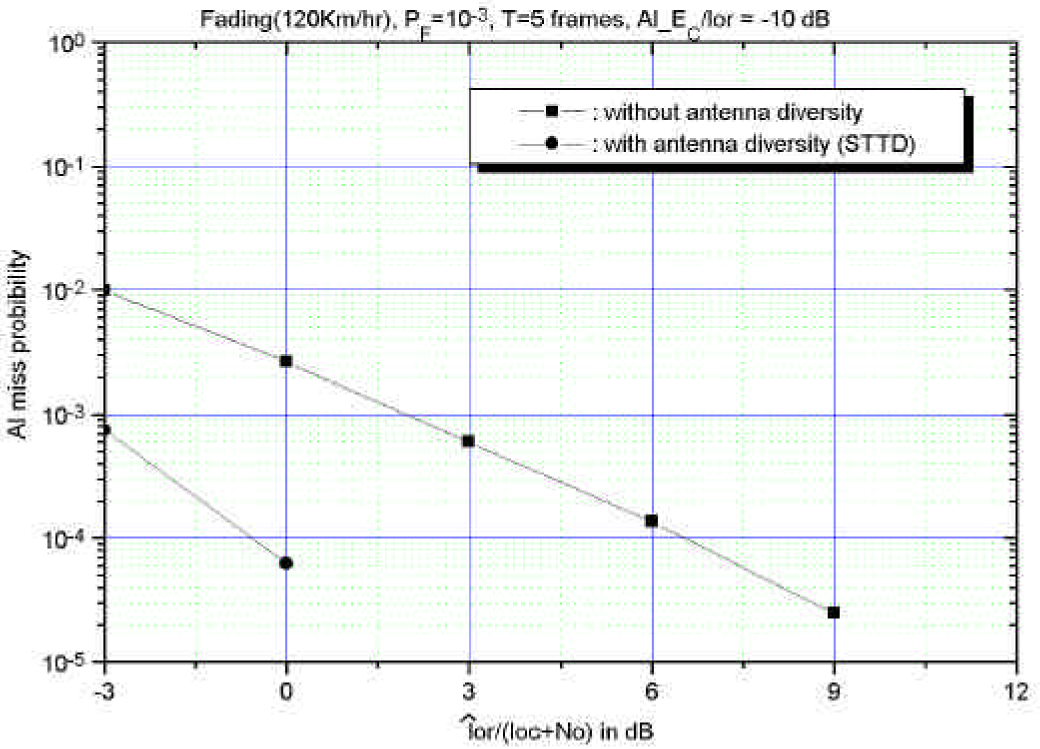


Figure 19. AI miss probability of the UE (V=120 Km/hr, single path)

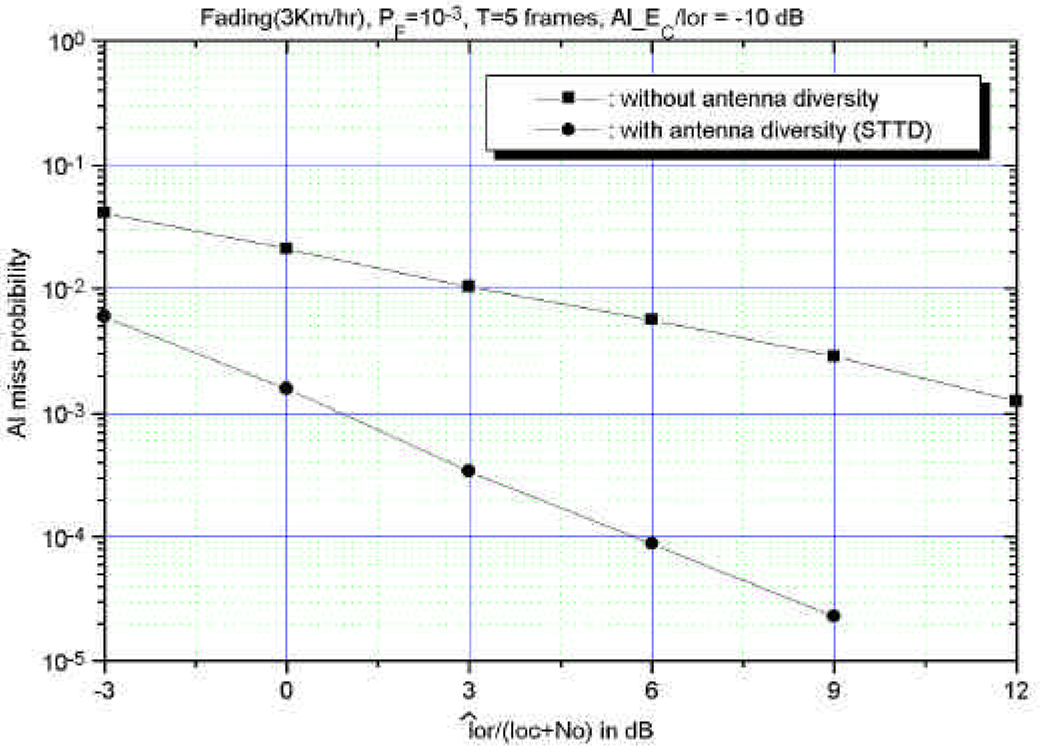


Figure 20. AI miss probability of the UE (V=3 Km/hr, single path)

From figure 19 and 20, we can notice that the AI miss probability with Tx diversity is much smaller than the one without Tx diversity. This is predictable results. We can also notice that the AI miss probability for high vehicle speed is smaller than the one for low vehicle speed. This means that there is time diversity effect during AI length (4096 chips) when vehicle speed is high. In this simulation we only consider single path model but this is the worst case model for the single Tx antenna case, if we assume multipath model, the AI detection performance may be better especially for the single Tx antenna case.

As stated in section III, the handover miss probability P_M(HO) may heavily depend on the AI miss probability of UE. So it is important to minimize the miss probability of AI. We can see that the AI detection performance with Tx antenna diversity is very good. But when the vehicle speed is low and Tx diversity is not applied, the AI detection performance is poor.

One approach to reduce the AI miss probability is retransmission of AI. As stated in subsection 2.1, the target BS may retransmit the AI if there exists a preamble even though it transmitted the AI in the previous TG. But this approach may have a problem when the UTRAN does not know the frame offset since there may ambiguity between the SFN and the CFN which sent to SRNC from the target BS and from the UE, respectively. So that when the UTRAN does not know the frame offset, in order to retransmit the AI, it should be separable in the UE. For example, if we assume that the only one retransmission is allowed, then we may define two kind of AI, that is, AI_1 and AI_2. (The AI_1 and AI_2 can be discriminated simply by binary orthogonal modulation, that is, $b_0=b_1=1+j$ for AI_1 and $b_0=1+j$, $b_1=-1-j$ for AI_2). The target BS transmits AI_1 when it first detects a preamble and reports the SFN(at which the AI_1 was transmitted) to SRNC and if it detects a preamble again in successive TG, it transmits AI_2 (but target BS may or may not report the SFN at which AI_2 was transmitted to SRNC).
The UE checks AI_1 and AI_2 simultaneously in every AI position and if any one between AI_1 and AI_2 is detected then report the SRNC the number of AI as well as the CFN at which it received the AI.
By using the CFN, SFN and AI number reported by target BS and the UE, the SRNC can calculate the frame offset without ambiguity.
The retransmission of AI can reduce the AI miss probability significantly.

Another approach is to repeat all the attempt when handover miss event occurs. This approach may be suitable when the vehicle speed is low, since when the vehicle speed is low, the long term propagation condition does not change so fast that the handover delay time requirement is not urgent.

Those two approaches can be combined to improve the AI detection performance in the all the channel situation. But as we can see from the simulation results, when the AI power is 10% of total power, the AI detection performance is good especially for the STTD encoding in spite of no retransmission of AI.

We guess that the influence of AI transmission to downlink capacity is negligible because the AI is transmitted only one for an UE which is preparing the interfrequency hard handover.

IV. Impacts on physical layer specification

* TS25.211

- Some parameters should be defined but does not require any modification of existing parameters
  T_{pre} : handover preamble length (ex, 4096 chips)
  T_{AI} : handover AI length (ex, 4096 chips)
  T_{grd} : guard time between last transmitted DPCH and handover preamble(ex, 1024 chips)
  ? : a parameter larger than $2?_{max}+T_{pre}$ (ex, 1024+4096+some processing time in chips)
  ? ?: power ramping step size for handover preamble

* TS25.214

- Some functional description should be added but does not require any modification of existing functions

* 25.212, 25.213, 25.215

- Modification and addition are not required

V. Conclusions

In this contribution, we proposed a method for seamless interfrequency hard handover for 3GPP's WCDMA. With this proposal, the UE transmit preamble with new uplink frequency using the uplink compressed mode and the target BS responds to it with an acquisition indicator (AI).
This proposal guarantees the seamless inter frequency handover in uplink as well as in downlink regardless of knowing the frame offset before the handover execution.
So we propose to adopt this method as a work item for 3GPP's release'5 specification.

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