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1 Introduction

Out-of-sync is an essential UE internal procedure that is initiated when the UE detects loss of the downlink, i.e. the mobile does not receive any information on the downlink. The procedure exists for idle mode, connected mode on common channel and connected mode on dedicated channels. The goal with this contribution is to discuss the need for UE layer 1 out-of-sync indication, and how such indication can be provided in the different modes of operation.

2 General

There must be a UE initiated start of a recovery action when the downlink physical channel quality is considered to be so bad that the probability for the system to reach and control the UE is in practice non-existing. The specified triggers of the recovery actions and the recovery actions themselves serve several purposes:

- Minimise the impact on the radio network from UE's that have lost the downlink connection and is out of control from the network.
- Allow the network to initiate release of the network resources that is probably not used by a specific UE anymore.
- Allow the UE to scan and find service if possible from current or other PLMN or RAT covering the area.
- Trigger the UE to perform RRC Connection re-establishment attempts.

Typical recovery actions for UE’s are to turn off the output power and go to idle mode and start a general search for cells that may cover the area. When using a dedicated channel the UE may first initiate the RRC connection re-establishment procedure and if the RRC connection re-establishment attempts fail then the UE should go to idle mode.

The basis to trigger the recovery actions is the out-of-sync indication. TS 25.302 v3.0.0 describes the status primitives CPHY-Sync-IND and CPHY-Out-of-Sync-IND between L1 and RRC, which indicate in-sync and out-of-sync. The primitives need to be sent periodically to match was is stated in 25.331 with regards to triggering conditions, e.g. triggering by “N312 successive in sync indications” need periodic reporting from layer 1.

The UE detection out-of-sync on layer 1 can be a trigger for events both on layer 1 and as an input for triggers on higher layers, where counters and timers are used to determine when appropriate action shall be taken. For example, in idle mode multiple out-of-sync indications may trigger a new cell search, in dedicated mode it may trigger RRC connection re-establishment. The higher layer definitions of the triggers and recovery actions are described in TS

25.331 v3.1.0 in the sections 8.5.4 - Physical channel establishment criteria, 8.5.5 - Detection of out of service area, and 8.5.6 - Radio link failure criteria.

3 Required triggers and recovery actions

An essential procedure on the physical layer is that the UE shuts it transmitter off if it detects downlink out-of-sync in connected mode. This is essential since a mobile that does not receive any downlink information is most likely not power controlled in a proper way. It may therefore be a “rogue” mobile, possibly creating uncontrolled interference to cells within its own network. The UE may also have lost its downlink due to close proximity to a base station using an adjacent frequency, in most cases not in its own network. Also here it is essential to shut the transmitter off not to create excessive interference on the adjacent frequency.

It is further important that the layer 1 activity needed for the out-of-sync detection must not cause the UE battery consumption to increase. This is especially important when the UE is using DRX in Idle, Cell_PCH or URA_PCH states. This can be achieved by limiting the required update rate of the UE layer 1 synchronisation status to be performed only at the paging occasions when using DRX. This means that the time it takes for an individual UE to decide to start recovery actions is dependent on the DRX cycle length used.

The trigger criteria used by the UE are RRC state dependent and should be possible to adjust from the network. The network may use this option to fine-tune the actual UE behaviour when using different RB and services. Further, it is assumed that change of L1 synchronisation status is retrieved from the physical channel the UE needs to receive with good enough quality in order to be reachable from the network. Hence, the physical channel monitored will hence be dependent on the UE RRC state.

Finally, an important aspect is that the criteria should be testable to ensure correct UE operation. Hence, the criteria will be specified at least in the WG4 specification TS 25.133.

The proposed criteria to use in different modes are outline in the following sections. It should be noted that the parameter values used are preliminary guesses that may require further consideration.

2.1 Idle mode

In idle mode, the UE monitors the PICH and PCH to detect pages. When these channels can not be detected reliably anymore, the UE shall be considered to be out-of-sync. Higher layers will then initiate timers, that when they expire forces the UE to take appropriate action.

Direct detection of the quality of the PCH and PICH channels is difficult, since the PCH is only read very seldom and the UE function that reads the PICH may be rather specialised. However, since there is a known power difference between the PICH and Primary CPICH, the PICH quality can be determined from the Primary CPICH quality. Moreover, since there already is functionality in the UE to measure the Primary CPICH Ec/No, this criteria is proposed to be used in idle mode. Periodical reporting from L1 to higher layers is needed.

Hence, when detecting the PICH during the PICH frames belonging to the UE's DRX cycle, the UE should simultaneously measure the Primary CPICH Ec/No and compare it to a configurable threshold Q_{idle}:

- if Primary CPICH Ec/No $\leq Q_{idle}$, L1 shall report out-of-sync using the CPHY-Out-of-Sync-IND status primitive;
- if Primary CPICH Ec/No $> Q_{idle}$, L1 shall report in-sync using the CPHY-Sync-IND status primitive.

Testing this function of the UE can be done by verifying that when the out-of-sync threshold is reached, the UE does a cell selection and is capable of selecting a cell that is not included in the neighbouring cell list broadcast. The cell the UE selects should belong to another Location Area so the UE should be forced to make a random access and a RRC connection request to be able to register within X seconds. These X seconds are probably a rather long time.

2.2 Connected mode on common channel

In connected mode on a common channel, DRX may or may not be employed.

If DRX is used (Cell_PCH and URA_PCH states) the UE monitors the PICH and PCH to detect pages. When these channels can not be detected reliably anymore, the UE is out-of-sync. Hence, the same criteria as for idle mode can be used to detect out-of-sync.

Hence, when detecting the PICH during the PICH frames belonging to the UE's DRX cycle, the UE should simultaneously measure the Primary CPICH Ec/No and compare it to a configurable threshold $Q_{conn,PCH}$:

- if Primary CPICH Ec/No ≤ $Q_{conn,PCH}$, L1 shall report out-of-sync using the CPHY-Out-of-Sync-IND status primitive;
- if Primary CPICH Ec/No > $Q_{conn.PCH}$, L1 shall report in-sync using the CPHY-Sync-IND status primitive.

In Cell_PCH state, the recovery action upon too many out-of-sync indications is to detect out of service, which will lead to a search for a cell to camp on within the neighbouring cells, which in turn leads to the transmission of a cell update if a cell is found and in service area is detected. Hence, this out-of-sync criteria can be tested by generating an out-of-sync downlink and see that the RACH with the cell update message is received in the new cell within X seconds. In URA_PCH state cell update shall also be the recovery action, but then the new cell that shall receive the RACH is in another location area.

If DRX is not used (Cell_FACH state) the continuously monitors the FACH. When the FACH can not be detected reliably anymore, the UE shall be considered to be out-of-sync. Higher layers will then initiate timers, that when they expire forces the UE to take appropriate action.

Direct detection of the quality of the FACH is difficult, since the network may use different power in different FACH frames. For example, it is possible that the network sends rather low power frames containing FACH messages to UEs close to the base station. Those messages cannot and need not be detected by all other UEs. Hence, the UE cannot determine the FACH to be out of sync just because it cannot detect messages on the FACH that are not addressed to the UE in question. Instead, the Primary CPICH quality can be used to limit the cell size.

Hence, the UE should continuously measure the Primary CPICH Ec/No and every frame compare it to a configurable threshold $Q_{conn,FACH}$:

- if Primary CPICH Ec/No ≤ $Q_{conn,FACH}$, L1 shall report out-of-sync using the CPHY-Out-of-Sync-IND status primitive;
- if Primary CPICH Ec/No > $Q_{conn,FACH}$, L1 shall report in-sync using the CPHY-Sync-IND status primitive.

Testing of this criteria can be made similar to above, since the action upon too many out-of-sync indications shall be an cell update.

Periodical reporting from L1 to higher layers is needed in all cases.

2.3 Connected mode on dedicated channel

On a dedicated channel, the UE receives at least the DPCCH in the downlink. The most essential part for correct physical layer operation are the TPC bits for uplink power control, which should be ensured to be of adequate quality.

In the IS-95 CDMA system, the UE monitors the CRC of each frame received in the downlink. If a certain number of frames in a row are detected as incorrect, it shuts of the uplink transmitter. This ensures that uplink is not transmitting when the downlink is lost. A similar mechanism is useful, but not sufficient for UTRA. Since the downlink channels are power controlled and the power level of different parts of a downlink channel can be individually set, direct monitoring of TPC quality will always be necessary. The quality of other parts of the downlink signal will not be directly related to the quality of the TPC bits. In addition, there may not be CRC available if no downlink DPDCH data is transmitted (due to DTX) or if the transport channels are configured to not use any CRC.

Another difference to IS-95 is the downlink power control. In a power-controlled system, temporary (very short term) loss of downlink information may be compensated momentarily by the downlink power control loop. Triggering of out-of-sync based on lost information only should therefore not be too rapid. It is proposed that out-of-sync cannot be triggered before the UE outer loop SIR target has reached its maximum value. When this maximum value has been reached, the UE cannot request any more power from the network, and hence cannot make the out-of-sync radio link to become in-sync.

Based on the above discussion, it is clear that multiple criteria to detect out-of-sync on the dedicated channel are needed. It is proposed that layer 1 shall report sync status in every radio frame using the status primitives, based on the following criteria:

L1 shall report out-of-sync using the CPHY-Out-of-Sync-IND status primitive if:

- The downlink SIR target is at its maximum allowed value,
- and any one of the following is fulfilled:
  - The UE estimates the TPC commands over the last [200 ms] period to be received with an error rate exceeding [20%] on all radio links. This may correspond to another criteria that the UE actually measures, but the test is for an TPC command error rate of [20%].
  - Successive CRC failure, detected when the following conditions occur simultaneously:
    - No CRC are received correct on any TrCH within a [200 ms] period,
    - and [20] consecutive CRCs as observed on all TrCH are received incorrectly.

L1 shall report in-sync using the CPHY-Sync-IND status:

- If the UE estimates the TPC commands on at least one radio link in the last frame to be received with an error rate not exceeding [10%];
- or, if CRC is used on the TrCH, at least one CRC is received correct.

When L1 reports out-of sync it shall shut its transmitter off, and when L1 has reported in-sync in two consecutive frames, the UE transmitter may again be turned on. The two frames criteria to start the transmitter is seen as a reasonable trade-off between starting the transmitter prematurely and being too slow starting it. Moreover, the "false-alarm" probability of detecting a valid CRC despite incorrect decoding is kept low.

The CRC failure criteria for indicating out-of-sync is defined in such a way that the downlink has to fail at least [200 ms] to be considered lost, in order not to have fading dips or short bursts of interference trigger out-of-sync. Also, at least [20] consecutive lost frames are needed to ensure that the decision is based on sufficient statistics.

The CRC criteria will need quite many CRC errors to fulfil out-of-sync, but as soon as the links get better and one CRC is received correctly the links are considered to be in-sync again. We want to have a similar behaviour for the TPC criteria, since the higher layers do not know what was the cause of the sync-indication, and hence treats the criteria equally. To achieve similar effect for the TPC command error rate, some hysteresis is needed. If the criteria was 20% error rate both for moving out-of-sync and in-sync, links with an error rate of 21% on the average would move in and out of sync all the time, instead of staying out-of-sync which is what is wanted. To overcome this problem, different TPC command error rate thresholds are proposed for out-of-sync and in-sync reports.

3 Split of description over the specifications and WGs

It is proposed that WG1 describes:

- how the status primitives are set,
- that the UE shall switch off its output power when entering out-of-sync in connected mode on dedicated channel.

It is proposed that WG2 describes:

- how the indications from L1 are used to trigger recovery actions (includes setting end expiring timers).

It is proposed that WG4 describes:

- the tests required to make sure that the UE triggers the correct recovery actions when needed.