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Agenda item: **17**
Source: **Golden Bridge Technology**
Title: **CPCH Access Procedures**
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Abstract: This contribution provides the system-wide view of CPCH access procedures

This update to this document contains new information including:

- IDLE-AICH feature in which the Node B broadcasts the availability of a CPCH channel at the end of a packet transmission
- Deletion of redundant data rate from CPCH parameter list (data rate is implicit in UL channelisation code)
- Detailed definition of use of codes, signatures, and phases for CPCH preambles and AICHs.
- Updated delay measurement concepts and nomenclature.

CPCH Access Procedure

1.1 Overview of PHY and MAC

- The Random Access procedure is based on a DSMA-CD multiple Access method.
- Access Preamble (AP) signatures are used to identify the particular CPCH resource which the UE is attempting to access.
- The access preamble ramp-up is similar to the RACH mechanism. However, there is a collision detection/resolution mechanism that follows the access preamble ramp-up. The UEs receive AP-AICH indicating their success in ramp-up and granting access to the CPCH. The UEs will refrain requesting a busy CPCH channel. UEs may log and timestamp all received AP-AICHs in a recency table. This table allows the UE to estimate the probability that a given CPCH is unused at any particular time. This models the DSMA-CD protocol.
- Layer 1 in Node B is responsible for Call Admission Control and resource management for the CPCH set assigned by the RNC to Node B. This permits Node B to respond immediately to CPCH channel access requests without the need for communication with higher layers.

1.2 Overview of RRC

- UTRAN assigns CPCH capacity to the base node based on the traffic volume measurement reports. It generates persistency parameters for each CPCH allocated to the Base Node. PV_{CPCH} persistency parameters for each CPCH channel are recalculated periodically to permit UTRAN (RNC) a quick means of controlling congestion and access to CPCH.
- UTRAN broadcasts the CPCH related parameters, including backoff control parameters, to the UEs in the cell.
- The UEs and the Base Nodes transmit the measurement reports (throughput reported by SRNC MAC-d, radio access delay and RLC buffer delay reported by UE) so that UTRAN can decide on the capacity allocation and persistency parameters.
- UTRAN transitions the UEs from RACH/FACH state to RACH+CPCH/FACH or DCH/DCH states based on UE traffic demand which is estimated from the measurement reports.

1.3 CPCH Parameters

For each CPCH physical channel allocated to a cell the following parameters are included in the System Information message:

- CPCH Set ID to which this CPCH belongs.
- UL Access Preamble (AP) code (256 chip)
- DL AP-AICH channelisation code (256 chip)
- UL CD preamble code (256 chip)
- DL CD-AICH channelisation code (256 chip)
- Signature set: set of n preamble signatures (up to 16) for AP to access the CPCH channels.
- Priority values used to select initial access delay
- Backoff control parameters
- CPCH timing value

NOTE: All the above parameters are unique to this CPCH set, but are common to all the CPCH channels in the CPCH set

- CPCH UL scrambling code (40,960 chip)
- CPCH UL channelisation code (variable, data rate dependant, data rate is implicit in this code)
- DPCCH DL channelisation code (512 chip) [FFS]
- N_frames_max: Maximum packet length in frames [2-TBD] [FFS]

- Persistency value (PV_{cpch}): assigned by RNC to control congestion and for load balancing

NOTE: The above list of parameters specifies a single CPCH channel in this CPCH set. A CPCH set contains N (up to 16) CPCH channels

The following parameters are set by RNC and control CPCH access, collision detection/resolution, backoff, priority, and timing:

$\mathbf{N_{I\ P}}$ = Max number of slots for the initial priority delay for priority level I. The UE randomly selects a delay before beginning the preamble ramp-up.

$\mathbf{N_{AP\_retrans\_max}}$ = Maximum Number of allowed consecutive access attempts (retransmitted AP preambles) if there is no AP-AICH response. This is a CPCH parameter and is equivalent to Preamble_Retrans_Max in RACH.

$\mathbf{N_{access\_fails}}$ = Number of successive AP access ramp cycles without AICH before failure report.

$\mathbf{NF\_{}_{bo\text{-}collision}}$ = Maximum number of frames that UE will back off in case of a collision.. This parameter is a congestion control measure and relates to Bandwidth management

$\mathbf{NF\_{}_{bo\_no\_aich}}$ = Maximum number of frames that UE will back off after sending $N_{AP\_retrans\_max}$ preambles without an AICH response. . This parameter is a congestion control measure and relates to Bandwidth management

$\mathbf{NS\_{}_{bo\text{-}busy}}$ = Maximum number of slots that UE will back off in case of an access attempt to CPCH which is currently busy. This parameter is a congestion control measure and relates to Bandwidth management

$\mathbf{NF\_{}_{bo\text{-}all\_busy}}$ = Maximum number of frames that UE will back off in case of an access attempt to the last available CPCH when all CPCHs are busy. This parameter is a congestion control measure and relates to Bandwidth management

$\mathbf{T_{cpch}}$ = CPCH transmission timing parameter, an integer ranging from 0 to TBD. This parameter is similar to PRACH/AICH transmission timing parameter.

NOTE: The random functions to be used for delay and back off are TBD, pending WG1 decisions.

The following are power control and CPCH timing parameters set by RNC and used by PHY for CPCH and RACH transmission:

$\mathbf{P_{RACH} = P_{CPCH}}$ = Initial open loop power level for the first CPCH access preamble sent by the UE. [RACH/CPCH parameter]

$\mathbf{\Delta P_0}$ = Power step size for each successive CPCH access preamble.
[RACH/CPCH parameter]

$\mathbf{\Delta P_1}$ = Power step size for each successive RACH/CPCH access preamble in case of negative AICH
[RACH/CPCH parameter]

1.4 CPCH Timing

Figure 1 shows the timing of the CPCH uplink transmission with the associated DPCCH control channel in the downlink.

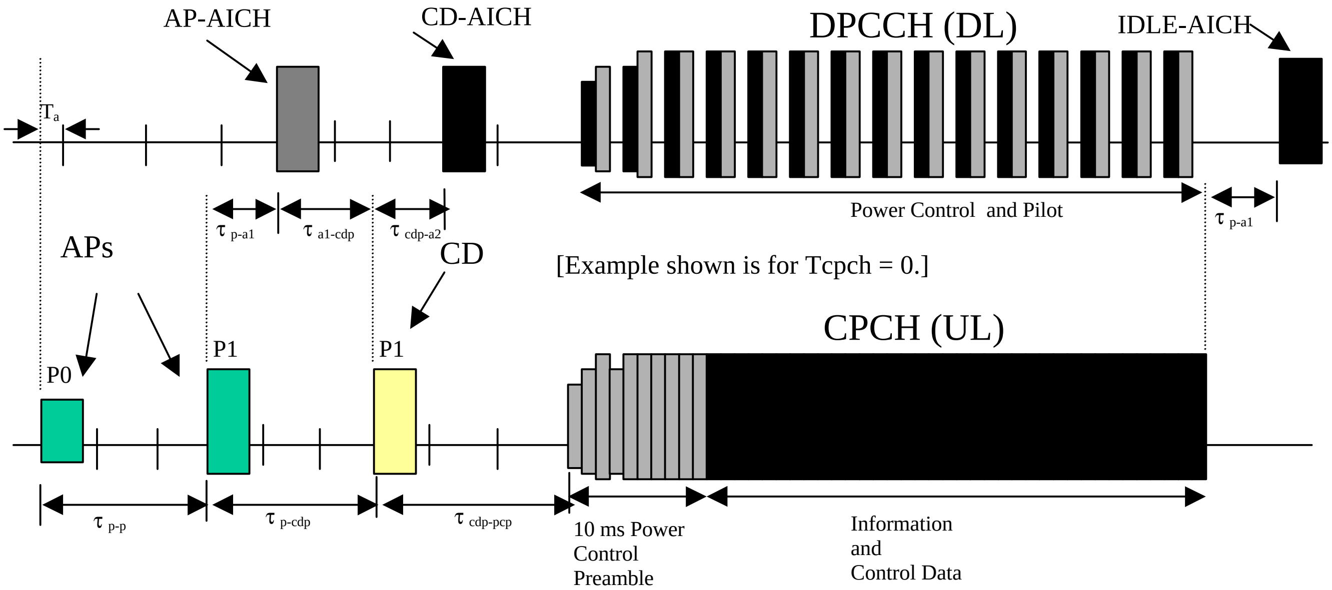


Figure 1. Common Packet Channel (CPCH) Timing Diagram

$\tau_{p\text{-}p}$ = Time between Access Preamble (AP) to the next AP.
= 3.75ms + 1.25ms X Tcpch (CPCH timing parameter)

$\tau_{p\text{-}a1}$ = Time between Access Preamble and AP-AICH or end of packet to IDLE-AICH
= 1.75 ms + 1.25ms X Tcpch

$\tau_{a1\text{-}cdp}$ = Time between receipt of AP-AICH and transmission of the CD Preamble.
= $\tau_{a2\text{-}pcp}$
= 2.0 ms

$\tau_{p\text{-}cdp}$ = Time between the last AP and CD Preamble.
= $\tau_{p\text{-}p}$
= 3.75ms + 1.25ms X Tcpch

$\tau_{cdp\text{-}a2}$ = Time between the CD Preamble and the CD-AICH
= $\tau_{p\text{-}a1}$
= 1.75 ms + 1.25ms X Tcpch

$\tau_{cdp\text{-}pcp}$ = Time between CD Preamble and the start of the Power Control Preamble

$= \tau_{p-p}$
$= 3.75ms + 1.25ms \times Tcpch$

T_a = fixed offset value between uplink and downlink access slots.
= 0.5 ms

1.5 Preamble and AICH Definitions

The following descriptions define the codes, signatures and phase of the preambles and AICH bursts used for access to CPCH channels

AP (access preamble):
Code: the UL Access Preamble (AP) code specified for this CPCH set.
Signature: selected by UE MAC to indicate request for specific CPCH channel number.
Each signature specified for this CPCH set maps to one of the N (1 to 16max) CPCH channels specified in this CPCH set. There are n signatures (1 to 16) specified in a CPCH set. Number of signatures must be equal to or greater than number of CPCH channels specified, i.e. $N \leq n$.

AP-AICH:
Code: the DL AP-AICH channelisation code specified for this CPCH set.
Signature: selected by PHY in Node B to match the signature of the requesting AP, maps to the requested CPCH channel in this CPCH set.
PHASE: ACK indicates requested CPCH channel is available and will be assigned to one of the requesting UEs.
NAK indicates requested CPCH channel is not available for access.
NOTE: PHY Node B may transmit multiple AP-AICH_naks (with different signatures) in the same slot with ONLY ONE AP-AICH_ack.
This allows Node B to quickly inform UEs when the requested CPCH channels are busy.

CD (collision detection preamble):
Code: the UL CD preamble code specified for this CPCH set.
Signature: randomly selected by the UE from among the n signatures specified for this CPCH set.

CD-AICH:
Code: the DL CD-AICH channelisation code specified for this CPCH set.
Signature: selected by PHY in Node B to match the signature of the requesting CD.
If there are several UEs (multiple CDs) requesting the same CPCH channel in this slot, PHY in Node B selects one signature from among those received in the CDs to resolve the contention for the CPCH channel.
PHASE: CD-AICHs always use the ACK phase.

IDLE-AICH:
Code: the DL CD-AICH channelisation code specified for this CPCH set.
Signature: selected by PHY in Node B to match the signature of the requesting AP, maps to the requested CPCH channel in this CPCH set. This is the CPCH channel which has just finished the packet transmission and is now idle.
PHASE: IDLE-AICHs always use the NAK phase.

UEs which are not accessing CPCH resources (but are assigned to use the CPCH set) may monitor the AICH broadcasts from Node B to assess the availability of the CPCH channels in the CPCH set. Node B broadcasts an AP-AICH_ack when a CPCH channel becomes busy. Node B may broadcast AP-

AICH_naks while a channel is being used. Node B broadcasts an IDLE-AICH when a CPCH channel becomes idle. These broadcasts allow all UEs to have busy/idle status indicators on the CPCH channels in the CPCH set.

Broadcast CPCH channel BUSY/IDLE indicators:
BUSY: any AP-AICH with a signature that maps to a CPCH channel in the CPCH set indicates that the CPCH channel is busy. The AP-AICH may be an ack or a nak phase.
IDLE: any IDLE-AICH with a signature that maps to a CPCH channel in the CPCH set indicates that the CPCH channel is idle. The IDLE-AICH always uses nak phase.

1.6 CPCH Delay Measurements

In addition to the normal traffic volume measurements that UTRAN may implement, there are four new CPCH measurements proposed to quantify the delay performance of CPCH services:

1. Buffer delay average: average delay since last report.
2. Buffer delay max: maximum delay since last report.
3. Radio access delay average: average delay per access since last report.
4. Radio access delay max: maximum delay per access since last report.

Buffer delay is operationally defined to be the time between the arrival of a block of data in the RLC data buffer and the first output of that transport block to PHY for uplink transmission. The time is rounded up to the next frame and quantified in number of frames. Buffer delay is equivalent to the time the data spends in Layer 2.

Radio access delay is operationally defined to be the time between the first output of that transport block to PHY for uplink transmission until the transport block is transmitted on the CPCH channel air interface. This period may include multiple unsuccessful access attempts to busy CPCH channels, collision backoff s, etc. The time is rounded up to the next frame and quantified in number of frames. Each CPCH access is measured. Radio access delay is equivalent to the time the data spends in Layer 1.

Figure 2 shows the use of timestamps to permit the measurement of the traffic delays for CPCH. In this concept the MAC layer implements the uplink traffic delay measurements. When traffic delay measurements are requested by RNC, RLC timestamps (TSA, in the figure) the arrival of upper layer data blocks into the specified RLC buffer. MAC receives this timestamp with each uplink transport block from RLC. MAC then timestamps (TSC1) the first transmission of the transport block to PHY for uplink transmission.   If the access to the uplink is granted, PHY transmits the transport block and returns a status indicator signifying that the data has been successfully transmitted. MAC then timestamps (TSC2) the arrival of the data sent status indicator. If PHY is unable to transmit the transport block, it returns a status indicator with an event code explaining the cause. MAC would then take an appropriate response, e.g. retransmit the transport block later, or retransmit the transport block on a different CPCH channel. Assuming the timestamp values are integers equivalent to current frame number, the required traffic delay measures are simply the difference between the timestamps.

Buffer delay = TSC1 – TSA

Radio access delay = TSC2 - TSC1

Note that total UL CPCH packet delay is the sum of Buffer delay plus Radio access delay for any given measurement period.

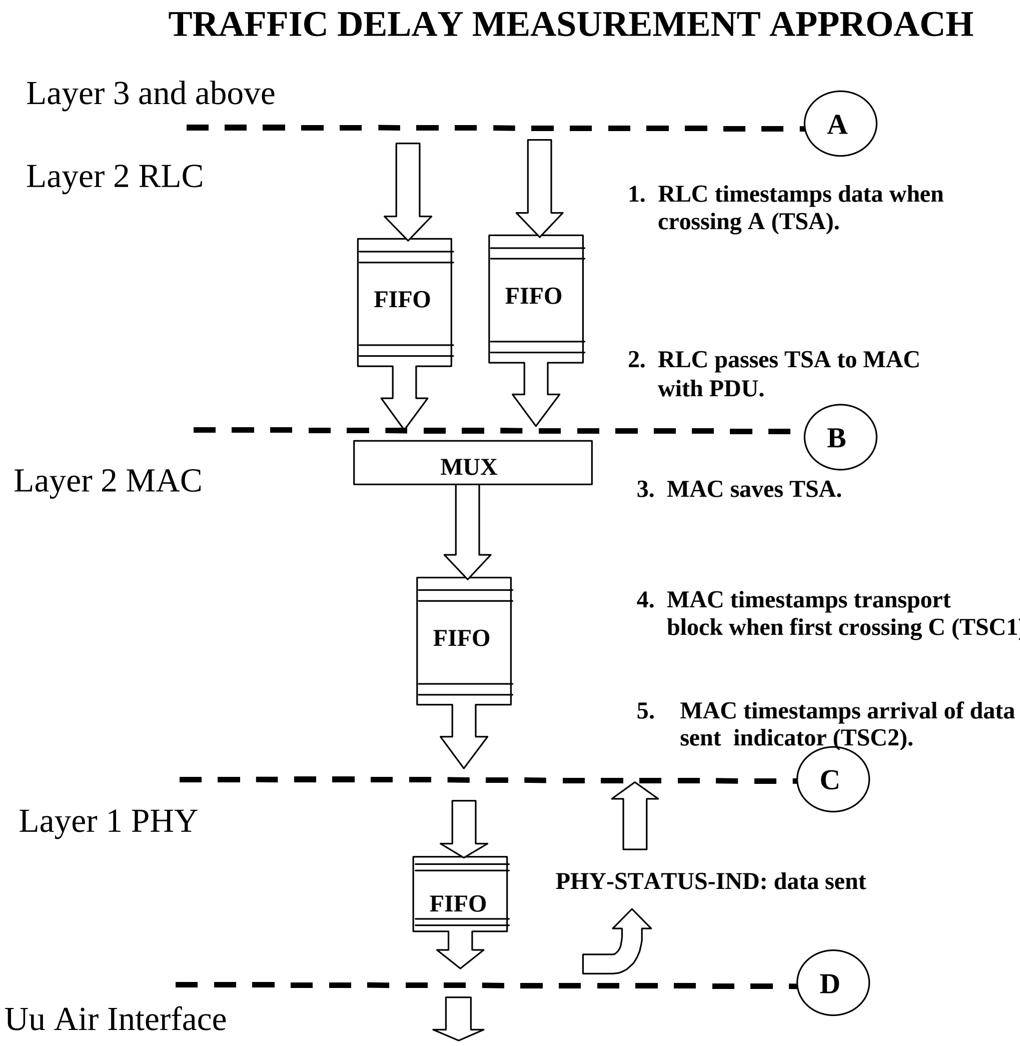


Figure 2. Concept for CPCH Delay Measurements

1.7 Temporal Sequence of CPCH Events for Normal Access

This section describes the sequence of events for the operation of CPCH-UL/DPCCH-DL. Refer to the Flowcharts 1-2 for the CPCH Access Procedures in the UE and UTRAN. The following temporal description is normal access procedure and entails both the UE and UTRAN side.

1. UTRAN performs the following tasks periodically:

- Collect traffic and CPCH measurements from the UEs and the cells
- Reassign priorities to all UE CPCH transport channels to maintain QoS
- Allocates CPCHs to Cells based on traffic measurements (cell demand)
- The UTRAN calculates the Persistency values for all CPCHs to balance loads and relieve congestion.
- UTRAN broadcasts all the CPCH parameters on BCCH.

2. The UE or UTRAN may initiate RRC connection request and transition the UE to the RRC connected state. When UE traffic demand increases, UTRAN will assign a CPCH set to UE. This then places the UE into the RACH+CPCH/FACH substate and permits the UE to access CPCH resources.

3. In the RACH+CPCH/FACH substate the UE performs the following background tasks:

- The UE monitors the CPCH set resources, persistency values, and other parameters in BCCH
- It executes the RLC ARQ procedure
- The UE reports traffic measurements as directed by UTRAN.

4. UE may monitor the transmission of AICHs to construct an Availability Table (recency) which stores the last time (timestamp) that each CPCH was assigned by the cell to any UE. The receipt of an AP-AICH_ack indicates that an idle CPCH channel is now becoming busy. The receipt of an AP-AICH_nak indicates that the CPCH channel is still busy. The receipt of an IDLE-AICH indicates that the CPCH channel is now idle. This table is used to estimate the probability that a particular CPCH is available at given time. Selecting CPCH channels which are likely to be available decreases the radio access delays experienced by the UE.

5. Once the MAC receives an indication that one of the RLC logical channels has a transport block to transmit, it will collect UL data from all of the RLC buffers. MAC multiplexes transport blocks from multiple logical channels to build a packet for CPCH transmission.

6. The UE selects a CPCH from the assigned set of CPCHs. CPCH selection is based on the persistency parameters, the status of the CPCH in the Availability Table, the status of the CPCH Busy Table (records which CPCH channels have already been requested and denied during this access cycle), and the capacity of the CPCH vs. the size of the packet to schedule. If several CPCHs are available with the same desired capacity, then the UE selects one of these CPCHs randomly. If there are several AP signatures assigned to the selected CPCH, the UE selects one of these signatures randomly

7. The UE executes a persistency test using the PV_{cphc} for the selected CPCH. If the UE fails the persistency test, the CPCH is marked busy in the Busy Table, the UE backs off a random number of slots and continues from step 6, above.

8. If the UE passes the persistency test, the UE executes an initial priority delay. In selecting the transmission time, the UE picks a random initial delay number from the [1, N_{IP}] range where N_{IP} is a number assigned by RNC for the Ith priority level of the highest priority transport block in the packet.

9. UE MAC then schedules the CPCH packet transmission with PHY. MAC passes to PHY the packet transport blocks along with the selected CPCH channel codes, initial access slot number, and Pcpch (initial open loop power level). The UE Physical layer then transmits successive APs while waiting for an AP-AICH response from UTRAN.

10. UTRAN constantly monitors the access slots to detect AP preamble requests for CPCH access. The preamble signature used in the AP maps to a particular CPCH channel controlled by the Physical layer in Node B. Node B can detect multiple APs in each slot, similar to RACH detection. However, unlike RACH, Node B may only reply with a single AP-AICH_ack per access slot. This restriction is necessary to permit the collision detection/resolution segment of CPCH access control to work properly. Node B may respond with multiple AP-AICH_naks in each slot to indicate that the requested CPCH channel is currently busy. If the Node B receives several APs requesting different CPCH channels which are available, Node B selects one of the CPCH channels and send an AP-AICH_ack with a signature which matches the received AP preamble. This AP-AICH_ack also serves as a broadcast indication from UTRAN to all UEs that this CPCH channel is now busy.

11. Upon reception of the AP-AICH_ack with a signature which matches the AP, the UE randomly selects one of 16 signatures and transmits a CD preamble, then waits for a CD_AICH response with a matching signature from Node B.

12. After sending an AP-AICH_ack, Node B monitors the next CD access slot to detect a CD preamble from all of the UEs which had sent an AP requesting the same CPCH channel in the previous access slot. Node B receives and decodes all CDs in the appropriate slot. If multiple CDs are received with different signatures, Node B selects one signature and uses it to reply by sending a CD-AICH_ack with a matching signature. This selection resolves the contention access.

13. Upon receipt of a CD-AICH_ack with matching signature, the Physical layer of UE begins packet transmission. The UE transmits 10 ms of power control preamble $\tau_{cdp\text{-}pcp}$ ms after the start of the CD preamble. At the same time Node B begins sending DPCCH in the DL and receives the CPCH power control preamble in the UL. The UE and Node B use close loop power control for the duration of the CPCH packet transmission.

14. At the end of the 10 ms power control preamble period, the UE begins transmitting the CPCH packet data.

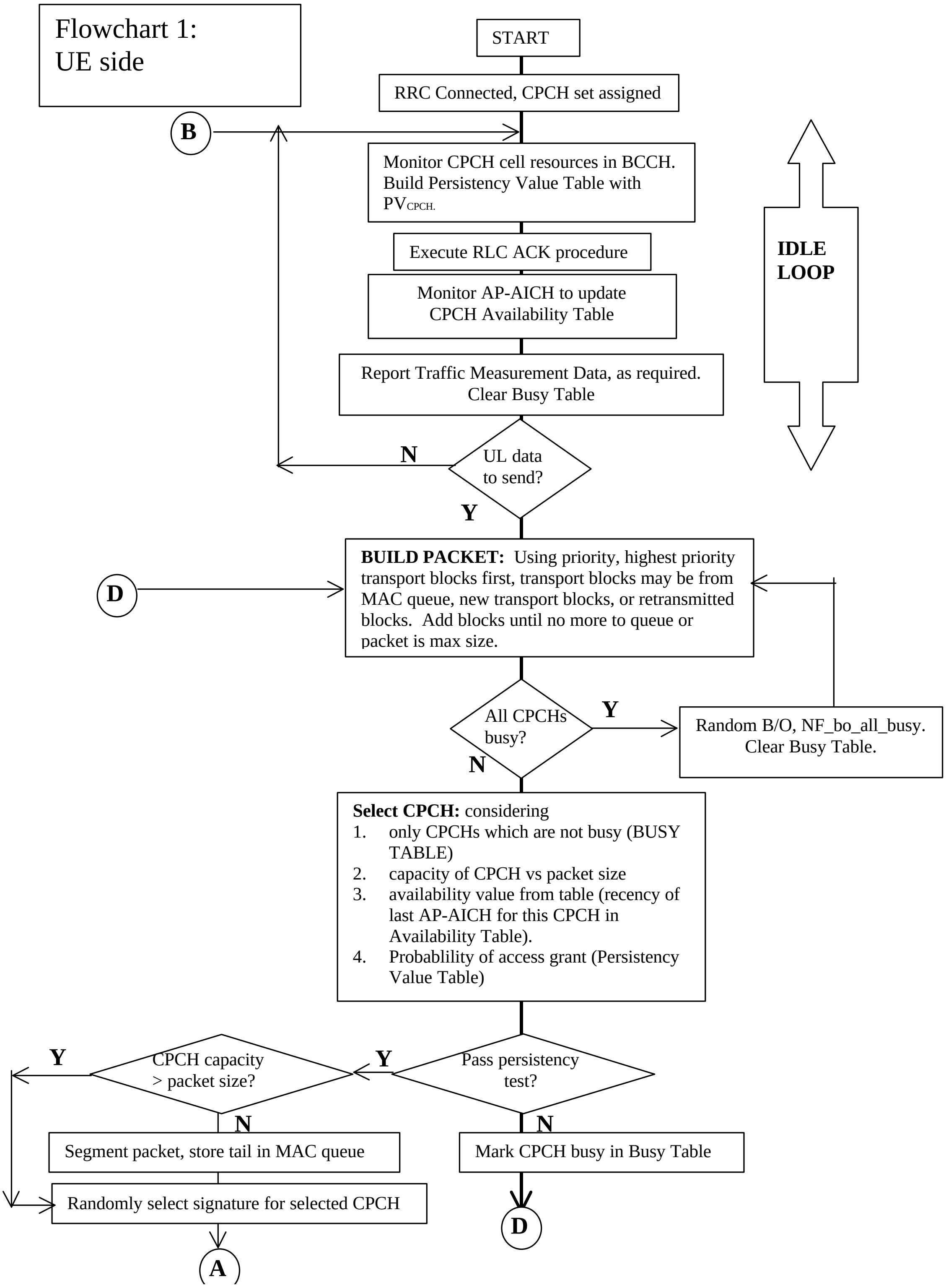
15. If during CPCH data transmission the UE detects loss of the DPCCH on the DL, it aborts CPCH transmission on the UL. This feature may be used by Node B as a mechanism to implement an emergency "stop" to handle temporary capacity overloads at the cell.

16. When the UTRAN Node B detects the end of the UL packet transmission, it sends an IDLE-AICH using a signature which maps to the CPCH channel in use. This serves as a broadcast indication to all UEs that this CPCH channel is now idle and available for access.

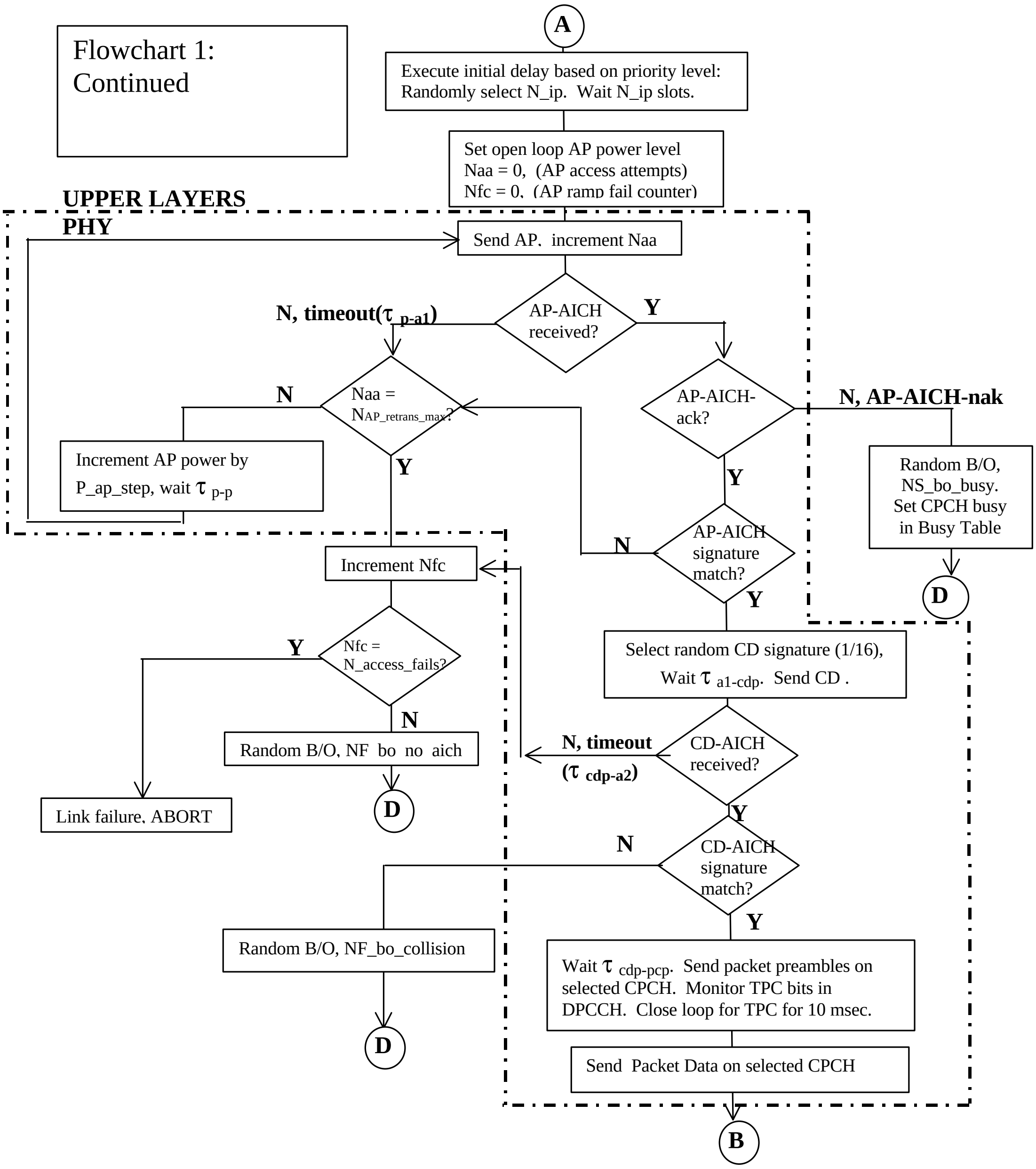
17. After CPCH packet data reception, the UTRAN provides ACK/NAK responses to the transmitting UE using the RLC algorithm appropriate for each transport block. The ACK/NAKs are sent using the FACH.

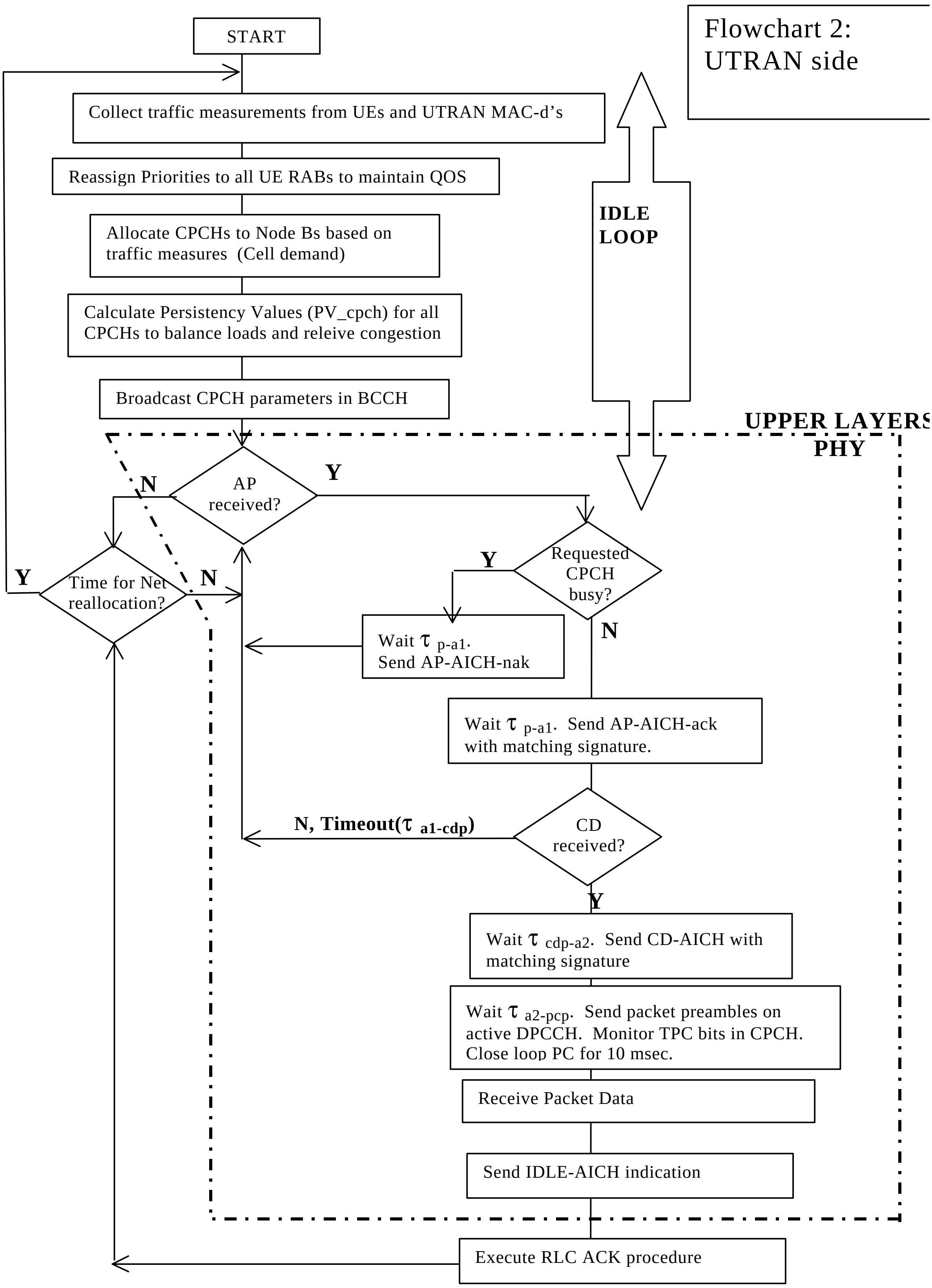
OTHER NOTES:

A. The UE backs off in cases of no AICH response after $N\_{AP\_retrans\_max}$ preamble transmissions, called an unsuccessful preamble ramp. If there is no success after N_access_fails preamble ramps, the UE executes a link failure procedure.
B. There are many CPCH access failure modes which are not discussed here. For each failure mode there is a separate backoff parameter proposed to quantify the maximum backoff period for that failure mode. The UE would randomly select a backoff period which is less than the maximum specified in the parameter. Random functions to select backoff and backoff algorithms are FFS.


Flowchart 1:
UE side
START
RRC Connected, CPCH set assigned
B
Monitor CPCH cell resources in BCCH. Build Persistency Value Table with PVCPCH.
Execute RLC ACK procedure
Monitor AP-AICH to update CPCH Availability Table
Report Traffic Measurement Data, as required. Clear Busy Table
IDLE LOOP
N
UL data to send?
Y
D
BUILD PACKET: Using priority, highest priority transport blocks first, transport blocks may be from MAC queue, new transport blocks, or retransmitted blocks. Add blocks until no more to queue or packet is max size.
All CPCHs busy?
Y
Random B/O, NF_bo_all_busy. Clear Busy Table.
N
Select CPCH: considering
1. only CPCHs which are not busy (BUSY TABLE)
2. capacity of CPCH vs packet size
3. availability value from table (recency of last AP-AICH for this CPCH in Availability Table).
4. Probablility of access grant (Persistency Value Table)
Y
CPCH capacity > packet size?
Y
Pass persistency test?
N
N
Segment packet, store tail in MAC queue
Mark CPCH busy in Busy Table
Randomly select signature for selected CPCH
D
A

Flowchart 1: Continued





Flowchart 2:
UTRAN side
START
Collect traffic measurements from UEs and UTRAN MAC-d's
Reassign Priorities to all UE RABs to maintain QOS
Allocate CPCHs to Node Bs based on traffic measures (Cell demand)
Calculate Persistency Values (PV_cpch) for all CPCHs to balance loads and releive congestion
Broadcast CPCH parameters in BCCH
IDLE LOOP
UPPER LAYERS
PHY
AP received?
Y
N
Requested CPCH busy?
Y
N
Time for Net reallocation?
Y
N
Wait τ p-a1. Send AP-AICH-nak
Wait τ p-a1. Send AP-AICH-ack with matching signature.
CD received?
N, Timeout(τ a1-cdp)
Y
Wait τ cdp-a2. Send CD-AICH with matching signature
Wait τ a2-pcp. Send packet preambles on active DPCCH. Monitor TPC bits in CPCH. Close loop PC for 10 msec.
Receive Packet Data
Send IDLE-AICH indication
Execute RLC ACK procedure