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Agenda item: **13**
Source: **Golden Bridge Technology**
Title: **Optimization of the Cell-FACH state by providing closed loop power control over FACH**

Document for: **Discussion and approval**

INTRODUCTION

At RAN#7 a new R2000 feasibility study work item titled "Feasibility Study for Improved Common DL Channel for Cell-FACH State" was approved. This contribution discusses the feasibility of and proposes for development a closed-loop power controlled FACH as an improved Common DL channel for Cell-FACH state. Other proposals are possible and are invited for discussion.

DISCUSSION

The attached paper describes the benefits and feasibility of using a closed-loop power controlled (CLPC) FACH as an improved common DL channel in Cell-FACH state. This is accomplished by scheduling reserved PCPCH channels to be used for CLPC during certain segments of the common DL FACH channel which are addressed to individual UEs.

PROPOSAL

RAN1 should discuss this proposal to confirm the feasibility and benefits of the CLPC FACH approach. It is proposed that RAN1 recommend this proposal for development as a new R2000 work item at RAN#8.

Optimization of the Cell-FACH state by providing closed loop power control over FACH

This paper describes the benefits of using a CLPC FACH in the Cell-FACH state and further describes the feasibility and complexity required to schedule use of PCPCH channels using UL and DL power control preambles to establish CLPC to be used for segments of the DL FACH.

1.0 Motivation for CLPC on FACH in the downlink direction and problem statement

Let's assuming a case where 100% of cell is dedicated to non-real time multi-media services. Furthermore, CPCH/FACH sub-state is used to transfer the data. In this case, in absence of closed loop power control on FACH the downlink, capacity will be degraded by a significant factor (factor of 3 reduction for the FACH portion of the downlink capacity and for the worst case indoor scenario). If the service mixture in the cell is changed, the overall capacity impact reduces, however, the degradation persists.

2.0 Required changes by introduction of CLPC on FACH

a. No need to introduce a new physical channel. TPC bits to be used for power control of the Downlink FACH are provided by the UL power control preamble in an associated uplink PCPCH.
b. There is a requirement for scheduling the FACH transmission to coordinate use of the associated PCPCH.

3.0 What is the Gain associated with introduction of Closed loop Power Control on FACH?

3.1 Downlink Capacity formulation

A. Direct dependency on the required SNR and Downlink versus Uplink capacity

$N_{dl} = PG/ \{ (f_{spill} + r_{orth}) x\ SNR_{req-DL} \}$
$N_{ul} = PG/ \{ (f_{spill} + 1) x\ SNR_{req-UL} \}$

Let's assume the following:

r_{orth}= .1/.9 (indoor) = other paths/ Main path =.11
r_{orth}= .4/.6 Vehicular = .67
r_{orth}= .06/.94 Pedestrian = .067
f_{spill}= .5 for both uplink and downlink cases

$\alpha 1 = N_{dl} / N_{ul} = (1.5\ SNR_{req-UL}) / (.61\ SNR_{req-DL}) = 2.46\ SNR_{req-UL} / SNR_{req-DL}$
$\alpha 2 = N_{dl} / N_{ul} = (1.5\ SNR_{req-UL}) / (1.17\ SNR_{req-DL}) = 1.28\ SNR_{req-UL} / SNR_{req-DL}$
$\alpha 3 = N_{dl} / N_{ul} = (1.5\ SNR_{req-UL}) / (.567\ SNR_{req-DL}) = 2.65\ SNR_{req-UL} / SNR_{req-DL}$

SNR imbalance depends on the performance of macro and micro diversity gains in uplink and downlink directions. Macro diversity is the soft handover gain and micro diversity is the antenna diversity gain (transmit diversity versus receive diversity). STTD transmit diversity functions identical to the receiver diversity. The overall implementation loss in the UE can be assumed to be worse by a small margin. The RAKE in the UE could be less complex as well. Although, the cost of having similar number of RAKE receivers in the UE and Base Node is minimal. The latter two could lead to a 1-2 dB imbalance between the uplink and downlink in the SNR sense.

Let's assume that the SNR required in the uplink and downlink are imbalanced by 1-2 dB in favor of the uplink direction. In that case we will have the following tabulated results:

Environment/ SNR imbalance	1 dB	2 dB
Indoor	1.95	1.56
Pedestrian	2.1	1.68
Vehicular	1.01	.80

The table entries are the capacity ratio of downlink over uplink. As can be seen in most cases there is a significant imbalance in favor of the downlink direction. The exact figure depends on the SNR imbalance and the operating environment.

Two conclusions can be drawn from the above formulation: 1) There is a direct dependency on SNR_{req} for both uplink and downlink capacity.2) The orthogonality in the downlink leads to significantly more capacity in the downlink.

B. Impact of power control on Downlink Capacity

The figures in the next two pages capture the essence of the case and comparison of performance in the cases of deployment of open loop power control and closed loop power control on FACH. Here are the assumptions in these simulations:

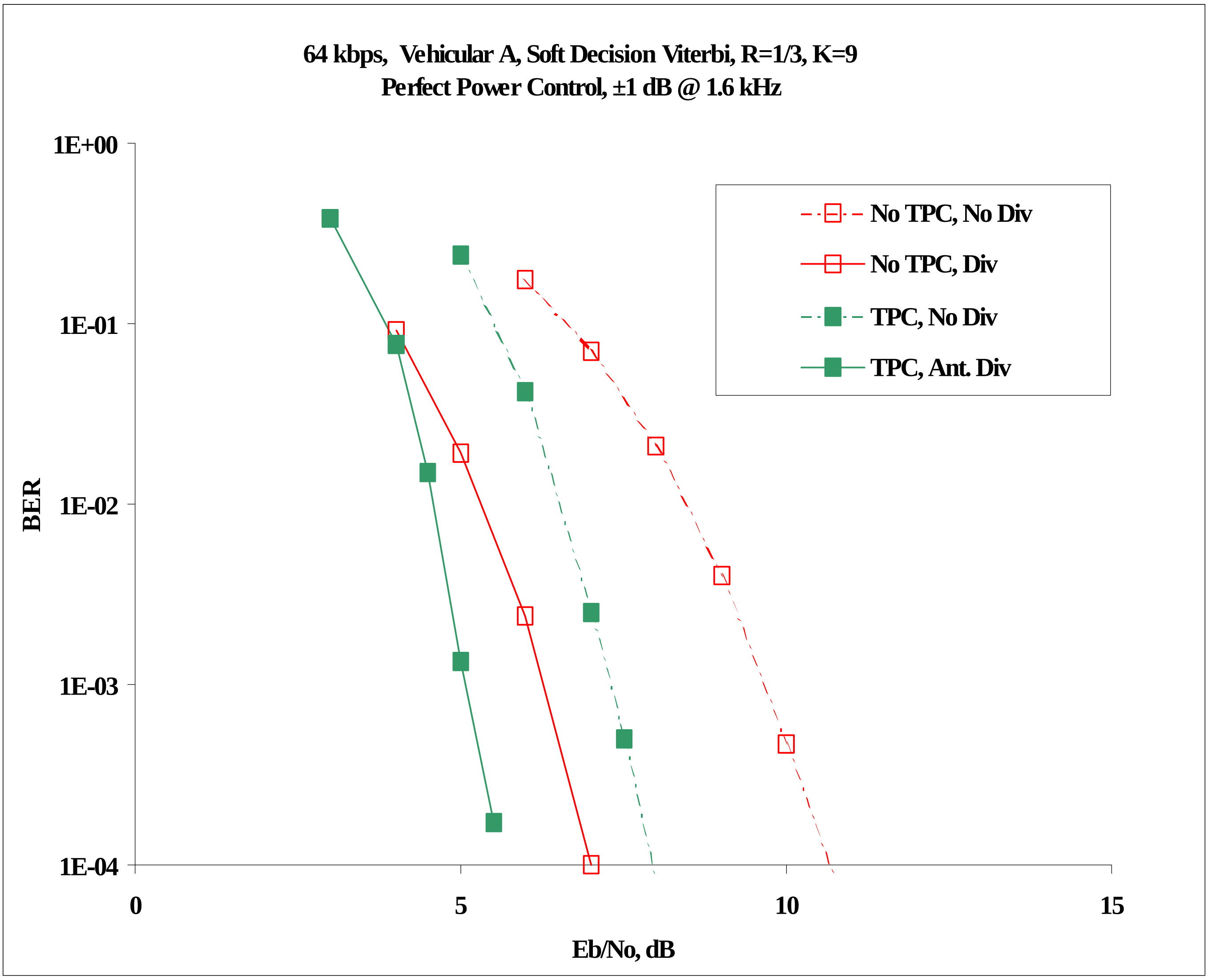
- STTD Diversity Technique is used
- Results are based on link level simulations
- No errors on the power control channel
- ITU Channel model A is used in the simulations
- Maximal ratio combining RAKE is used
- Step size of 1 dB
- 10 ms interleaving, Convolutional rate 1/3, K=9
- The source of the simulations is a joint paper presented at IEEE Sarnoff Symposium on Advanced Wired and Wireless Communications, March 17, 1999Further work will be done in the following areas:

- 20 ms, 40 ms and 80 ms interleaving cases
- Use of Turbo Code and 80 ms interleaving

However, there is conclusive evidence on significant gain by introduction of some form of CLPC specially in slow fading environments which require the higher bit rates.

Source: **On the Performance of the Multi-code CDMA Systems: A Simulation**

By: AT&T Labs. - Research
Saeed Ghassemzadeh, Matthew Sherman, Donald Bowen


64 kbps, Vehicular A, Soft Decision Viterbi, R=1/3, K=9
Perfect Power Control, ±1 dB @ 1.6 kHz
1E+00
1E-01
1E-02
1E-03
1E-04
BER
0
5
10
15
Eb/No, dB
No TPC, No Div
No TPC, Div
TPC, No Div
TPC, Ant. Div

3.2 Conclusions on impact of Closed Loop Power Control

As can be seen from the above simulation results, the worst case scenario (indoor) yields a 5 dB gain when Closed Loop Power Control is deployed (@ BER = 10^{-3}). 5 dB translates into a factor of 3.16 in capacity. This constitutes a strong case for considering the closed loop power control on FACH especially for facilitation of high bit rates.

4. Scheduling and Timing for CLPC for FACH

This section describes the scheduling method and timing for the CLPC FACH.

4.1 Overview of CLPC for FACH

Closed loop power control for the FACH is achieved by scheduling use of a CPCH channel to establish DL power control, using the TPC bits in the UL PCPCH power control preamble. This is achieved by using the existing PCPCH access protocol which also provides TPC bits in the DL-DPCCH associated with PCPCH. CLPC FACH is addressed to an individual UE which must establish closed loop power control using an associated PCPCH channel prior to the beginning of the FACH transmission (FACH segment) intended for that UE. The PCPCH channels associated with the CLPC FACH are PCPCH channels specifically reserved for this purpose and which are broadcast in the System Information with other PCPCH parameters.

UTRAN using CLPC FACH must broadcast the schedule for the CLPC segments of the FACH transmissions. The CLPC FACH schedule is broadcast as part of the FACH to all UEs. The information contained in the CLPC FACH schedule includes:

1) the UE ID (e.g. CRNTI) addressed in this segment of the CLPC FACH,
2) the SFN# for the beginning of the CLPC FACH segment,
3) the duration of the CPCH FACH segment in frames.
4) Identification of the PCPCH to be used for this segment

The UEs receive the CLPC FACH schedule and determine if any of the CLPC FACH segments are intended for them. If a CLPC FACH segment is to be received by any UE, the UE calculates the beginning of the CPCH Power Control Preamble (τ_{CLPC}) period. The τ_{CLPC} period length is calculated using broadcast system parameters per the equation:

$\tau_{CLPC} = (N_{ap\_retrans\_max} + 1)\tau_{next\_slot} + 5.28msec$,

where τ_{next_slot} = Time to next available access slot, between Access Preambles.
= 3.75ms + 1.25ms X Tcpch (CPCH timing parameter)

Note that this is equivalent to:

τ_{CLPC} = [max period from first AP to start of PCP] + [8 slot length PCP]

The UE schedules access to the CPCH channel associated with the CLPC FACH segment to begin τ_{CLPC} slots before the scheduled CLPC FACH segment. At the scheduled time, the UE accesses the associated CPCH channel, closes the power control loop using the CPCH power control preamble (PCP), and maintains the power control preamble until the end of the CLPC FACH segment addressed to that UE. This UL-PCP transmission includes power control and pilot, without TFCI and without message part, and shall operate at the lowest possible data rate [SF=512].

UTRAN schedules the CLPC portions of the FACH with the constraint that each CLPC FACH segment must be separated by a minimum period equal to τ_{CLPC} if there is only one associated PCPCH. This period permits the UE which is to receive the following segment to access the associated CPCH channel in order to establish closed loop power control with the Node B. If there are more than one associated PCPCH, then UTRAN alternates use of these PCPCHs so that CLPC FACH segments may be transmitted contiguously.

At the beginning of the CLPC FACH segment, the Node B transmits the CLPC FACH segment using a power level which is offset by a fixed value from the CLPC power level used by the DL DPCCH on the associated CPCH channel. Figure 1 below shows an overview of the CLPC FACH timing between the Node B and the UEs.

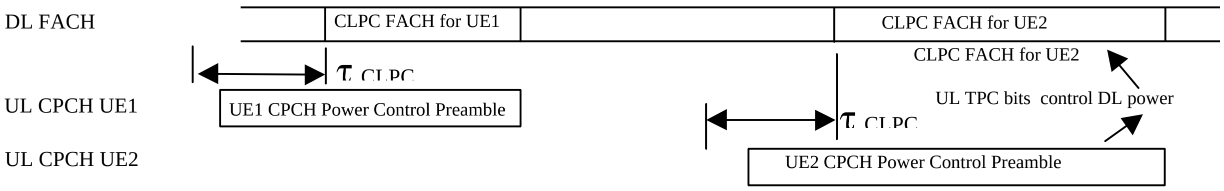
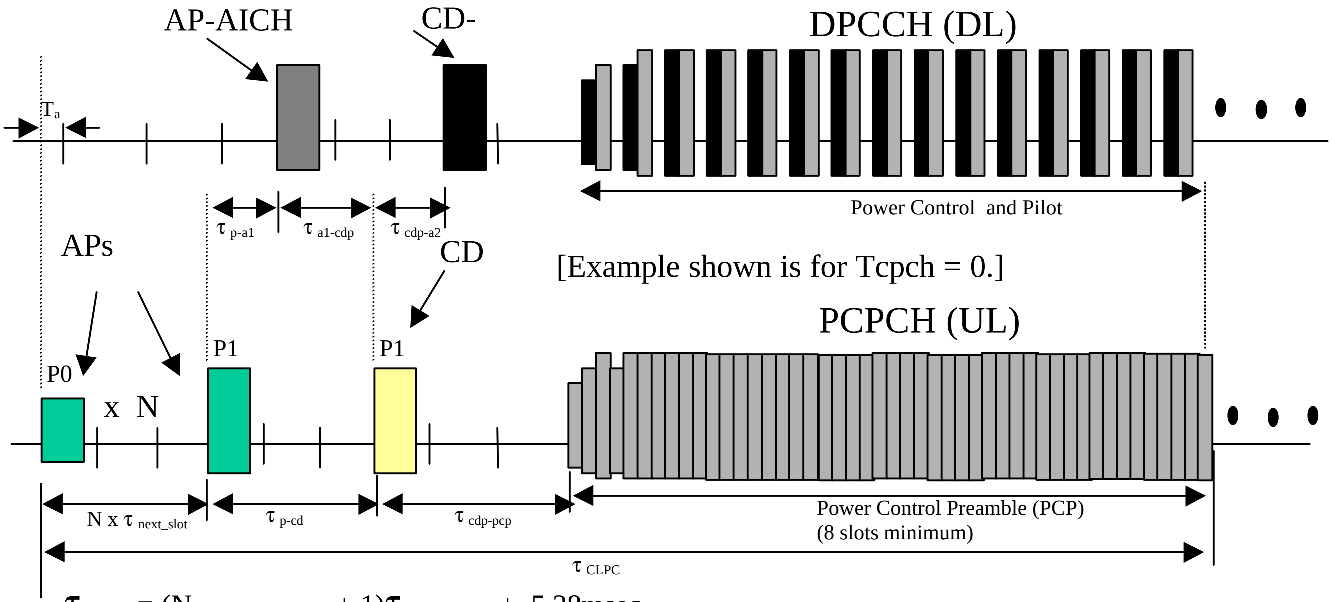


FIGURE 1. CLPC FACH Timing.

For UEs in the PCH state, UTRAN shall transmit paging messages to alert UEs of forthcoming DL FACH messages which may use CLPC FACH. Upon receipt of an alert for a forthcoming DL FACH message, the UE shall transition to Cell-FACH state and use the procedure described here for receipt of CLPC FACH. The UTRAN must schedule the paging alert for CLPC FACH sufficiently early to permit the UE time to transition to Cell-FACH state, receive the CLPC FACH schedule, and access the associated PCPCH channel before the beginning of the scheduled CLPC FACH segment.

4.2CPCH Power Control Timing for CLPC FACH

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



$\tau_{CLPC} = (N_{ap\_retrans\_max} + 1)\tau_{next\_slot}$ + 5.28msec

= [max period from first AP to start of PCP] + [8 slot length PCP]

Figure 1. CPCH Power Control Timing Diagram for CLPC FACH

τ_{next_slot} = Time to next available access slot, between Access Preambles.
Minimum time = 3.75ms + 1.25ms X Tcpch (CPCH timing parameter)
Maximum time = 1.25msec X 12 = 15 msec
Actual time is time to next slot in allocated access slot subchannel set.

$\tau_{p\text{-}a1}$ = 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.
= minumum time is 3.75ms + 1.25ms X Tcpch
= Actual time to next randomly selected slot from CD access slot subchannel group

$\tau_{cdp\text{-}a2}$ = 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
= $\tau_{p\text{-}p}$
= 3.75ms + 1.25ms X Tcpch

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

5. Temporal Sequence of Events for CLPC FACH

This section describes the sequence of events for the operation of CLPC FACH using an associated PCPCH channel. Other events related to normal CPCH operation are not repeated here.

1. UTRAN performs the following tasks periodically:
   - UTRAN defines the CPCH Parameter list to include PCPCH definition for closed loop power control of FACH. This parameter list is broadcast as part of System Information and does not dynamically change.
   - UTRAN defines a FACH schedule for the CLPC segments of the FACH for the next scheduling period. The information contained in the CLPC FACH schedule includes:
     a) the UE ID (e.g. CRNTI) addressed in this segment of the CLPC FACH,
     b) the SFN# for the beginning of the CLPC FACH segment,
     c) the duration of the CPCH FACH segment in frames,
     d) Identification of the PCPCH to be used for this segment.

   - UTRAN broadcasts the CLPC FACH schedule on the FACH before the first CLPC FACH segment in that schedule
2. The UE shall receive the CLPC FACH schedule which is broadcast on the FACH.
3. The UE shall parse the CLPC FACH schedule to locate any CLPC FACH segments addressed to that UE. For each CLPC FACH segment addressed to this UE, the UE shall create a schedule for access to the associated PCPCH channel associated with the CLPC FACH. The PCPCH schedule is created by subtracting a τ_{CLPC} period from the scheduled start of frame time for the CLPC FACH segment to be received. This time is the scheduled PCPCH access time for the CLPC FACH segment to be received.
4. At the scheduled PCPCH access time, the UE shall attempt access to the PCPCH associated with the CLPC FACH. Since this is a scheduled resource, there will be no contention for this PCPCH.
5. The Node B shall respond to an AP on the associated PCPCH from the UE and shall complete the PCPCH access procedure. This PCPCH access is used to establishi the intial DL power level for the addressed UE.
6. The UE shall complete PCPCH access protocol and shall send/receive Power Control Preamble for a minimum period of 8 slots before the start of the CLPC FACH segment. The UE and Node B shall maintain the closed loop power control using the PCP until the end of the CLPC FACH segment to be received.
7. At the beginning of the CLPC FACH segment for this UE, the Node B shall modify the FACH power level for that segment to be fixed power offset level above the closed loop power level for the DL DPCCH on the associated PCPCH. During transmission of this CLPC FACH segment, the Node B shall adjust the CLPC FACH power to track power changes on the DL DPCCH on the associated PCPCH. If Node B does not establish CLPC with the addressed UE on the associated PCPCH before the beginning of the CLPC FACH segment, the Node B shall transmit the FACH segment with open loop power control
8. At the end of the CLPC FACH segment for this UE, both the UE and the Node B shall stop transmission of the PCP on the associated PCPCH.