TSG-RAN Working Group1 meeting #5
Cheju, KOREA, 1-4, June 1999

TSGR1#5(99)669(rev)

Agenda Item:

Source: **SAMSUNG Electronics Co.**

Title: **Performance evaluation of uplink/downlink DPCCH gating(rev) (Rev. of TSGR1#5(99)606(rev))**

Document for: **Discussion**

---

1. Introduction

We have proposed the gated transmission of DPCCH during DCH/DCH in Control Only Substates(COS)[1]. However, there was no chance to present it due to lack of time during 3GPP RAN WG1#4 meeting. The gated transmission of DPCCH means reduced transmission rate of L1 control information during COS. Therefore, this gated transmission reduces UE's power consumption and air interference level while maintaining the dedicated channel between UE and UTRAN. It is asked to clarify the performance benefits from E-mail discussions after the 3GPP RAN WG1#4 meeting. In this document, we show the performance evaluation results of the gated transmission during DCH/DCH in COS.

2. Gated transmission of uplink/downlink DPCCH in COS

The DPDCH is used for transmission of both user and signalling traffic in user data active substate, whereas it is used for transmission only of signalling traffic in COS. The bi-directional dedicated channel is maintained in COS in order to achieve fast transition to user data active substate. This maintains synchronisation, power control loop between UE and UTRAN, and it is performed by transmitting of TPC, TFCI and pilot every 0.625ms. The normal transmission rate (i.e. once every 0.625 ms) of TPC, TFCI and pilot to maintain reasonable FER(Frame Error Rate) in COS seems to be superfluous because no traffic is transmitted on DPDCH in most frames.

If gated transmission scheme is applied on DPCCH in COS, then the transmission rate of TPC, TFCI and pilot is decreased with predefined or specified value following state transition to COS from user data active substate. When transmitting signalling message on DPDCH, UE or UTRAN increases its transmission power to compensate the effect of reduced power control rate.By this operation, in most case, we can save UE's battery power and reduce interference level because of the reduced frequency of transmission of the L1 control information. However, the reduced L1 control information does not lead to the degradation of DPDCH FER, because the power is increased during the actual transmission of signalling via the DPDCH.

2.1 Detailed operation

The gated transmission of uplink/downlink DPCCH is initiated by the state transition from user data active substate to COS. Since RRC(Radio Resource Control) procedure will provide stable state transition mechanism ensuring RRC state consistency between UE and UTRAN, there is no need to design initiation procedure only for gated transmission. Therefore, we can initiate gated transmission of uplink/downlink DPCCH by defining gated transmission related parameters as a part of physical channel parameters of RRC procedure. A sending of link level acknowledgement message as a response to state transition order message is recommended for gated transmission confirmation. However, there is no need to define additional response message only for gated transition. Even the case that no signalling messages are used for state transition between user traffic active substate and control only substate, for example just using timer, it is possible to initiate gated transmission if the gated transmission related parameters had been negotiated between UE and UTRAN during RAB(Radio Access Bearer) control procedure. It is also possible to terminate gated transmission without any additional signalling message.

If gated transmission is initiated, then the transmission of both uplink and downlink DPCCH are gated simultaneously. For example, the unit period of the gated transmission is 0.625ms(1 slot), with gating rate option of 1(no gating), 1/2, 1/4 and 1/8 gating. The 1/2 gating means transmitting DPCCH by 2 unit periods(1.25ms), the 1/4 gating means transmitting DPCCH by 4 unit periods(2.5ms), etc. The actual gating rate can be decided by UTRAN according to air-link status. While transmitting signalling message on DPDCH in gated transmission applied COS, the UE and UTRAN increases transmission power of DPDCH in order to compensate the effect of reduced power control rate. While transmitting signalling message on DPDCH even at gated transmission in COS, the transmitter fully transmits pilot signals without gating to assist demodulation process of DPDCH being performed at the receiver side. Figure 1 shows the structure of uplink/downlink DPCCH gatings.

♦ Key features of gated transmission of DPCCH
- Maintain closed loop power controlled air-link
- Reduction of uplink interference level and UE power consumption
- Reduction of downlink interference level
- Unit period of uplink/downlink DPCCH gating : 0.625ms
- Multiple options for the gating rate : 1/1, 1/2, 1/4, 1/8
- Gating rate, action time : negotiation by higher layer signalling

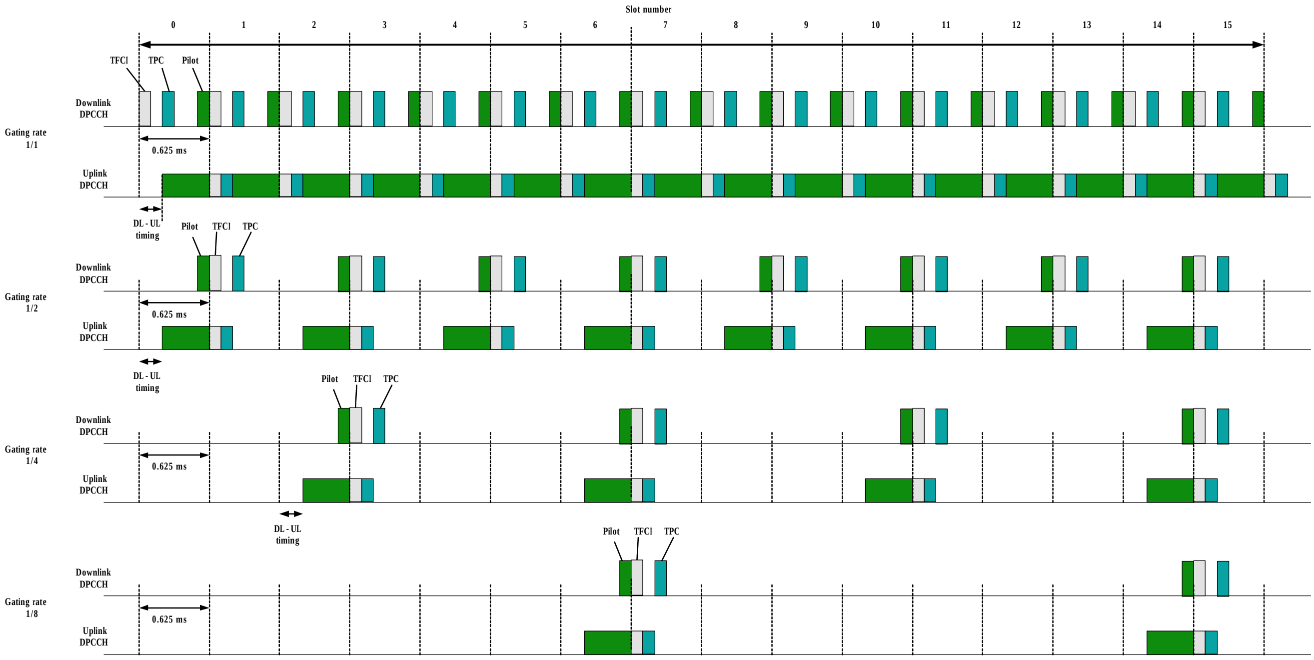


Figure 1. Examples of uplink/downlink DPCCH gating

3. Link level simulation
3.1 Simulation parameters

The link-level simulation was used to evaluate the performance of gated transmission of uplink/downlink DPCCH. The detailed simulation parameters are as shwon in table 1.

Table 1. Simulation parameters (uplink)

Carrier frequency		2 GHz
Chip rate		4.096 Mcps
Channel Symbol rate	DPDCH	32 ksps
	DPCCH	16 ksps
Modulation	Data	BPSK
	Spreading	QPSK
Frame format(DPDCH)		Random data, 320symbols / 10ms
Slot structure	DPCCH	Pilot: 8, TPC: 2
	DPDCH	Data: 20
Channel model	Multi-path fading	1 path Rayleigh
	Doppler frequency [Hz]	5.6 , 56, 222
Power ratio of DPDCH/DPCCH		3dB
Power control	Dynamic range	unlimited (assume ideal power amplifier)
	Step size	1.0 dB
	Rate	1600Hz(1/1 gating = no gating), 800Hz(1/2 gating), 400Hz(1/4 gating), 200Hz(1/8 gating)

	TPC error	4%
	Outer loop target FER	1%
Channel estimation		WMSA

3.2 Simulation results

Table 2. Uplink DPDCH Performance (required Rx. E_b/N_0[dB], FER=1%)

Doppler frequency [Hz]	Gating Rate			
	1/1	1/2	1/4	1/8
5.6 (3km/h)	**2.44**	3.15 (**+0.71**)	4.28 (**+1.84**)	6.20 (**+3.76**)
56 (30km/h)	**3.62**	4.69 (**+1.07**)	5.58 (**+1.96**)	6.27 (**+2.65**)
222 (120km/h)	**4.08**	4.64 (**+0.56**)	5.51 (**+1.43**)	5.86 (**+1.78**)

* ( ) indicates Eb/No difference compared with 1/1(no gating)
Rx. $E_b = E_{DPDCH} + E_{DPCCH}$ per one antenna

The simulation results of uplink DPDCH performance are shown in table 2. It is noted that the DPDCH performance degradation on 1/2 gating at 3km/h is about 0.71dB, however the reduced uplink interference is about 3.0dB due to 1/2 duty cycle, therefore we still have about 2.29dB gain as the uplink interference reduction. Table 3 summarises the net gain in terms of uplink interference reduction compared with 1/1 gating(no gating). Figure 2, 3, and 4 show the TPC performance as a measure of uplink DPCCH.

Table 3. Uplink interference reduction [dB]

f_d [Hz]	Gating rate								
	1/2			1/4			1/8		
	perf. loss	inter. reduction	inter. reduction gain	perf. loss	inter. reduction	inter. reduction gain	perf. Loss	inter. reduction	inter. reduction gain
5.6	0.71	3	**2.29**	1.84	6	**4.16**	3.76	9	**5.24**
56	1.07	3	**1.93**	1.96	6	**4.04**	2.65	9	**6.35**
222	0.56	3	**2.44**	1.43	6	**4.57**	1.78	9	**7.22**

- perf. loss : performance loss
- inter. reduction : interference reduction due to gating
- inter. reduction gain : overall interference reduction gain (= inter. reduction – perf. loss)

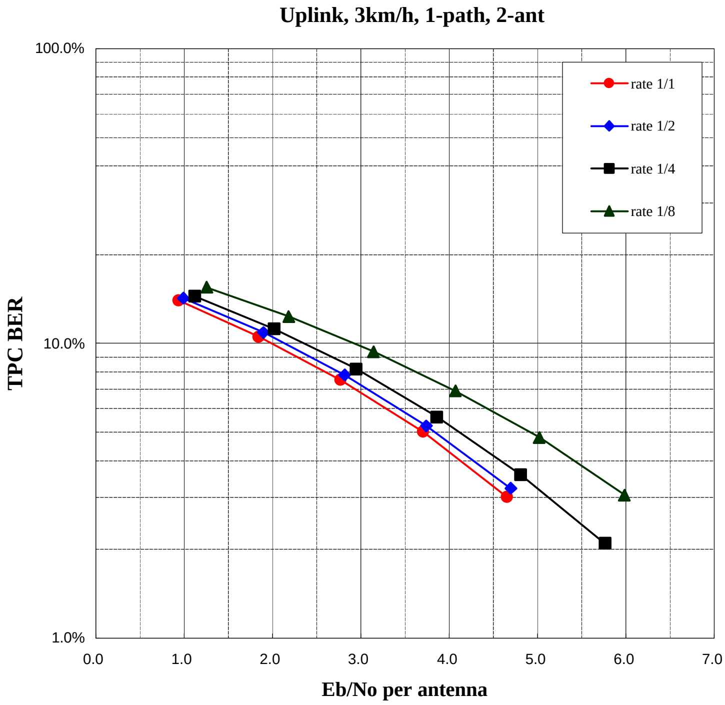


Figure 2. Uplink TPC Performance (3km/h)

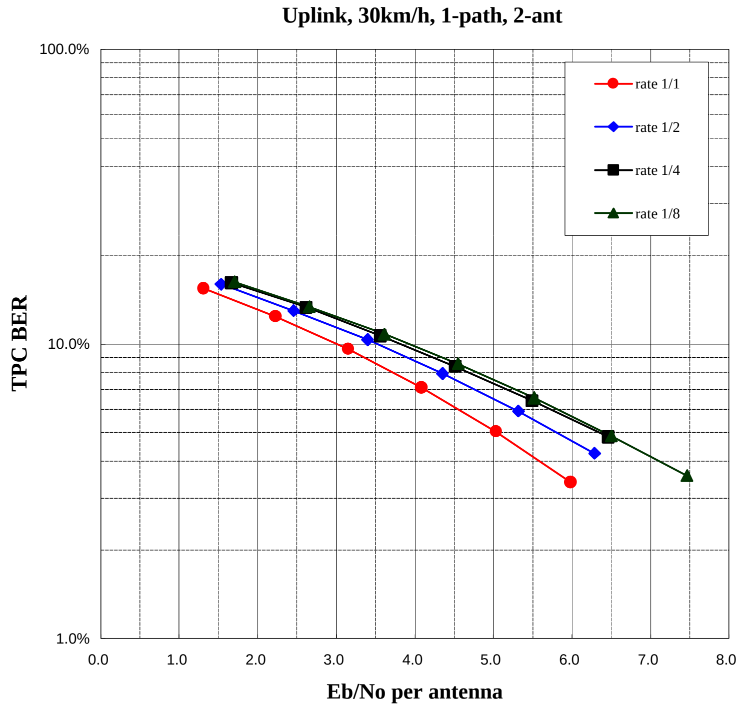


Figure 3. Uplink TPC Performance (30km/h)

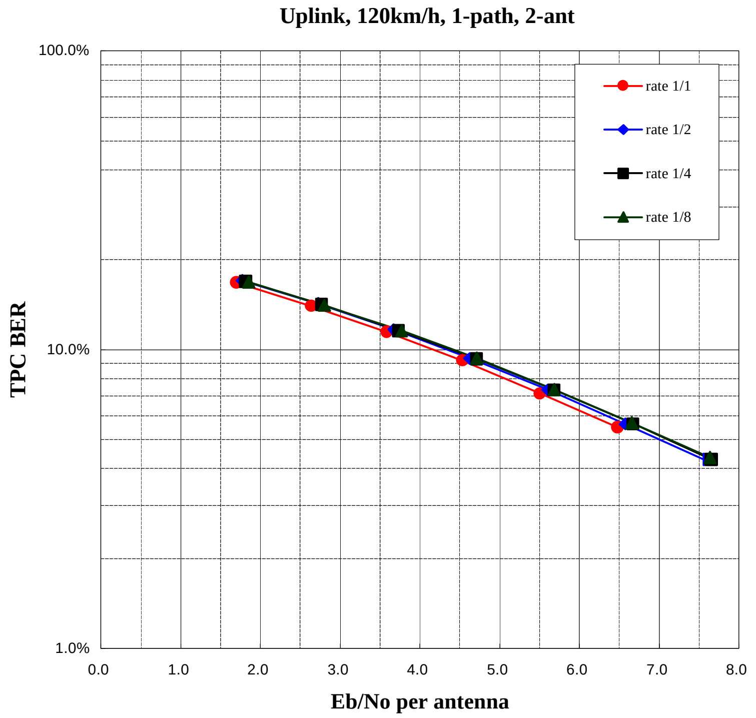


Figure 4. Uplink TPC Performance (120km/h)

4. Performance for Web browsing type applications

The performance is considered in terms of the battery life of the phone during a packet session and uplink capacity for the Web browsing type applications. It is assumed that the Web traffic is transported only on the downlink and the uplink is used for link maintenance and control purpose only. We assume a simple packet call model and energy estimation is based on the measured current of the IS-95 terminal employing MSM3000. We only considers mobile speed 3km/h.

4.1 Uplink packet call model

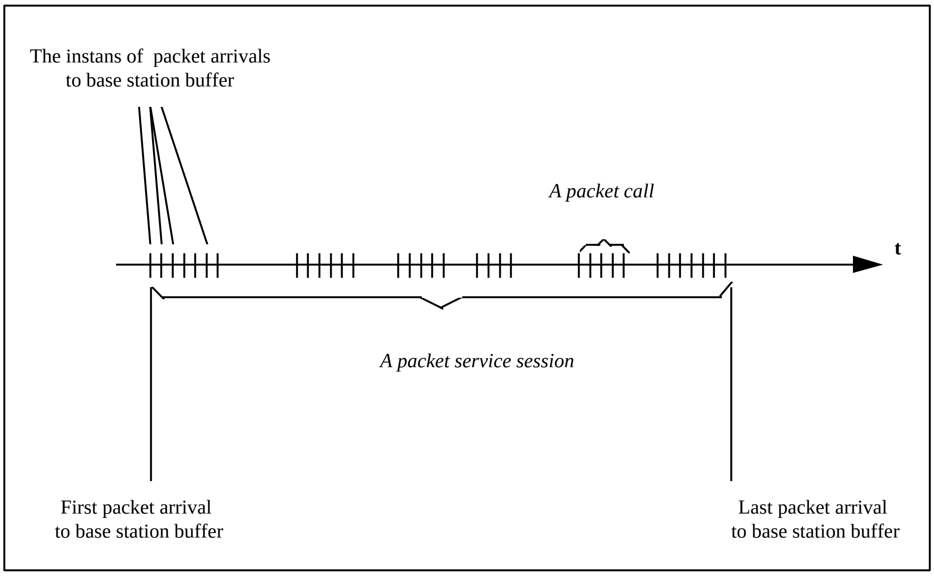


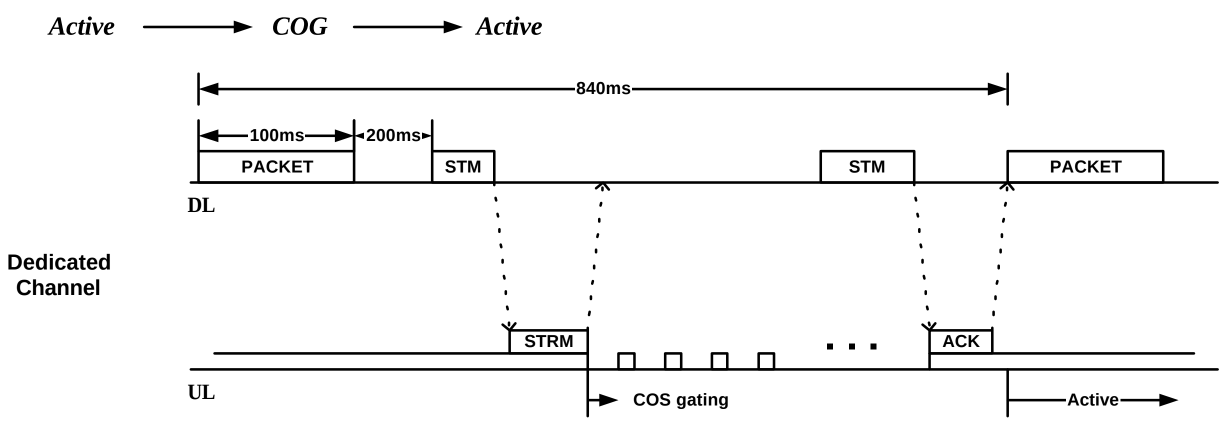
Figure 5. Typical characteristic of a packet service session

Figure 5 depicts a typical WWW browsing session which consists of a sequence of packet calls [10]. The Web traffic parameters and the values of timer used in this model is based on[7][8]. Only mean values for these parameters are used throughout this analysis to get initial estimates of the energy consumption and the uplink capacity without regards to higher order statistical variations.

In this model, the following Web session parameters are assumed.

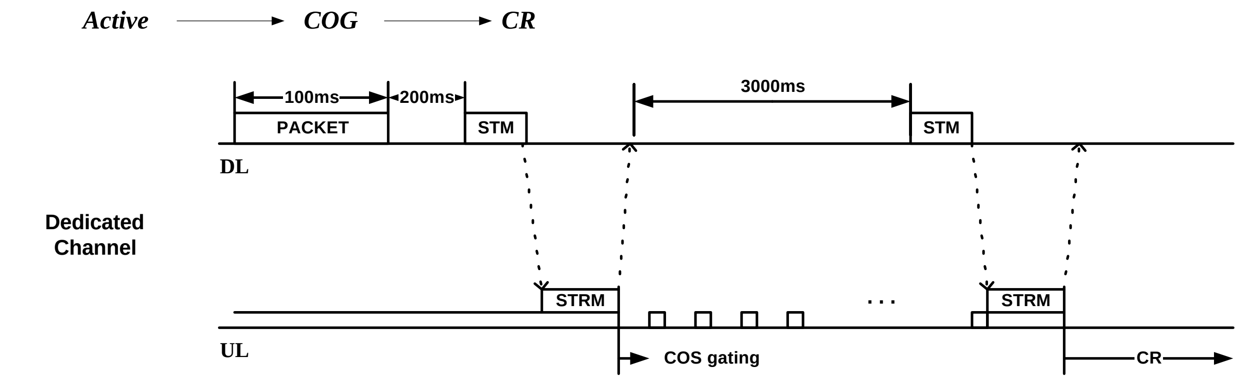
- One session consists of 18 packet calls
- Inter session interval is 30 seconds
- A packet call consists of 1 packet.
- Inter-packet interval is 840 ms
- One packet transports 670 bytes

Air transportation time for a packet is assumed to be 100ms considering 64 kbps frames are used with one frame margin, since 670 bytes are transportable by nine 64 kbps frames.



* COG : Control Only Gated
* STM : State Transition Message
* STRM : State Transition Response Message

Figure 6. Simple model for intra-session call flow



* CR : Connection Released

Figure 7. Simple model for inter-session call flow

Figure 6 and 7 show simple models for intra and inter-session call flow. Depending on the timer values, the following is considered.

The timers for COS is ;

- *T_active_to_cog* = 200 ms, which is the timer from Active to Control Only Gated(COG). This represents the maximum staying time in DPCCH non-gating mode after completion of a packet transmission.
- *T_cog_to_cr* = 3000 ms, which is the timer from COG to Connection Released(CR). This represents the maximum staying time in DPCCH gating mode after T_active_to_cog expires.
- *T_active_to_cr* = 3200 ms, which is the timer from active to Connection Released(CR). This represents the maximum staying time in DPCCH non-gating after completion of a packet transmission

4.2 UE energy consumption

The following parameters for a UE energy consumption are assumed :

1. UE switchable transmit current = 60 + Tx current (mA),
2. UE current when transmit off = 156 mA.
3. UE total current at 100% duty = switchable current + txoff current (mA).

As is assumed in the previous section, only mean values for the time parameters are used throughout our analysis to get initial estimates of the energy consumption without regards to higher order statistical variations. We performed the simulation for the case where the power ratio of the DPDCH/DPCCH is 2(3dB).

- Total energy (Intra-session plus inter-session energy) estimation

We consider the following three different UE positions in the cell.

Position A:
When the UE is near the cell site, its power amplifier energy consumption is nearly constant as the UE transmit power varies, In this case we assume that the power amplifier current is 106mA.

Position B:
We consider the medium range case where the range of Tx. current is 110~130mA.

Position C:
When the path loss is large, the power amplifier energy consumption significantly depends on the UE transmit power. In this case, typical range of Tx. power is 160~260mA.

Relative battery life for DPCCH gating compared with DPCCH non-gating in linear scale for these three cases is shown table 4.

Table 4. Relative battery life(total energy consumption)

UE position	No gating (gating rate=1/1)	gating rate = 1/2	gating rate = 1/4	gating rate = 1/8

A	100° (100)	110° (119)	117° (132)	120° (139)
B	100° (100)	111° (119)	117° (132)	121° (140)
C	100° (100)	113° (122)	121° (137)	125° (145)

- ° indicates the case when continuous energy consumption is assumed during connection released state for demodulating signals from network.
- () indicates the case when enery consumption is intermittently off during connection released state

We can conclude that battery life during a packet session can be increased by about 32% when using DPCCH gating rate 1/4.
The intra-session and inter-session current is evaluated as follows:

- Intra-session enery estimation

Each session consists of 18 packets transported and 17 inter packet intervals of 840ms. Each packet takes 100ms. During a session, signaling to assign and de-assign DPDCH takes up 10ms*17, and signaling to start gating takes up 10ms*17. The simple model for intra-session call flow is shown in figure 6. In this figure, length of each signaling frame is 10ms.
The energy consumption is represented as follows:

E_nogating = Tpkt*18*Curr + (730*Curr + 10*Curr_Tr)*17
E_gating = Tpkt*18*Curr + (210*Curr_1 + 510*(g*Curr_g + (1-g)*CurrTxOff) + 20*Curr_Tr)*17

where Tpkt is packet length(100ms). Curr is current consumption when there is no data to transmit. Curr_Tr is current consumption when signaling frame is transmitted, and CurrTxOff is current consumption during gated off. Also, g is gating rate and Curr_g is current consumption during gated on. When the UE is near the cell site, its power amplifier energy consumption is nearly constant as the UE transmit power varies. Relatvie battery life of DPCCH gating compared with DPCCH non-gating in linear scale is shown table 5.

Table 5. Relative battery life(intra-session energy consumption)

UE position	No gating (gating rate=1/1)	gating rate = 1/2	gating rate = 1/4	gating rate = 1/8
A	100° (100)	118° (118)	130° (130)	137° (137)
B	100° (100)	119° (119)	131° (131)	138° (138)
C	100° (100)	121° (121)	135° (135)	142° (142)

- ° indicates the case when continuous energy consumption is assumed during connection released state for demodulating signals from network.
- () indicates the case when energy consumption is intermittently off during connection released state

- Inter-session energy estimation

Inter-session duration is 30s. 30s is decomposed into T_active_to_cog of 200ms and T_cog_to_cr of 3000ms and the rest for the gating. 30s is decomposed into T_active_to_cr of 3200ms and the rest for the non-gating. The simple models for inter-session call flow and initial access call flow are shown in figure 7. In this figure, length of each signaling frame is 10ms. The energy consumption is represented as follows.

E_nogating = 3210*Curr + 10*Curr_Tr + Tpch*Cpch + Einit,
E_gating = 210*Curr + 3010*(g*Curr_g + (1-g)*CurrTxOff) + 20*Curr_Tr + Tpch*Cpch + Einit,

where Tpch and Cpch are total time and current consumption required for such as paging channel reception. Einit is energy consumption during initial access.

Relative battery life of DPCCH gating compared with DPCCH non-gating in linear scale is shown table 6.

Table 6. Relative battery life(inter-session energy consumption)

UE position	No gating (gating rate=1/1)	Gating rate = 1/2	gating rate = 1/4	gating rate = 1/8
A	100° (100)	105° (121)	107° (136)	108° (145)
B	100° (100)	105° (122)	107° (137)	109° (146)
C	100° (100)	106° (126)	110° (145)	111° (156)

- ° indicates the case when continuous energy consumption is assumed during connection released state for demodulating signals from network.
- () indicates the case when energy consumption is intermittently off during connection released state

4.2 Uplink capacity comparison

With required Ec/Io obtained via uplink simulations, average load is calculated and pole capacity, i.e, the upper bound on the number of calls in a cell/sector for a given Eb/Nt [9], is compared.
Single-cell uplink pole capacity for voice service is expressed, in a first order approximation,

$$\frac{PG}{\nu \cdot \frac{E_b}{N_t}}$$

where ν is voice activity and PG is the processing gain of 128 in voice. This can be expressed equivalently and more generally as

$$\frac{1}{\text{per-user load}} = \frac{1}{E[\frac{E_c}{N_t}]}$$

The pole capacity is estimated approximately in the sense that only mean interference level is used. This approximation is justified when there is a sufficiently large number of data users.

Under the following uplink simulation conditions:

- 1-path Rayleigh
- 1/3 convolutional code
- 2-antenna receive antenna diversity
- Outerloop power control
- DPDCH/DPCCH power = 2 (3dB)
- Mobile speed = 3km/h

The following results are obtained.

Table 7. Uplink simulation results summary

	COS gating rate=1/1	COS gating rate=1/2	COS gating rate=1/4	COS gating rate=1/8
Required rx Eb/Nt per ant. [dB]	2.44	3.15	4.28	6.20
Required rx Ec/Nt per ant. [dB] when tx on	-23.4	-22.69	-21.56	-19.64
Relative Interference	1.0 (0dB)	0.85(-0.71dB)	0.65(-1.84dB)	0.42(-3.76dB)

The ratio of the pole capacity of DPCCH gating is evaluated.

Table 8. Pole capacity of DPCCH gating

	No gating (gating rate=1/1)	gating rate = 1/2	gating rate = 1/4	gating rate = 1/8
Relative capacity	100	130	155	162

We can conclude that the pole capacity during a packet session can be increased by 55% when using DPCCH gating rate 1/4.

3. Conclusion

It has been shown that the proposed gated transmission of uplink/downlink DPCCH in control only substate will lead to the following advantages.

♦ Uplink/downlink interference can be reduced
- Send DPCCH signal only fraction time duration
- Put more users in control only substates which provides fast response time to user data active substate

♦ UE power consumption can be saved
- Battery life increased :

Gating rate 1/2 : 19%, garing rate 1/4 : 32%, gating rate 1/8 : 39%
- Can increase the talk time/stand by time of UE
- Can increase the staying duration in the control only substate
- Can reduce the mean response time of transition to the user data active substate

♦ Uplink pole capacity increased
- Gate rate 1/2 : 30%, gating rate 1/4 : 55%, gating rate 1/8 : 62%

4. Reference

[1] TSGR1#4(99)478, "Gated transmission of DPCCH in DCH/DCH control only substates", SAMSUNG.
[2] TSGR2#4(99)439, "RRC procedures and parameters for gated transmission of uplink/downlink DPCCH in control only substate", SAMSUNG.
[3] 3GPP RAN S1.14 V2.0.0(1999-04) "FDD Physical layer procedures".
[4] TSGR1#3(99)191 "Detail description of transmission stop and resumption control"
[5] 3GPP RAN S1.11 V2.0.0(1999-04) "FDD physical channels and mapping of transport channels onto physical channels"
[6] 3GPP RAN S2.03 V0.1.0(1999-04) "UE Functions and Interlayer Procedures in Connected Mode"
[7] Kevin Thompson, Gregory J Miller, and Rick Wilder in MCI Telecommunications Corporation, "Wide-Area Internet Traffic Patterns and Characteristics", IEEE Network Magazine, pp.10~23, November/December 1997.
[8] D.N.Knisely, "Performance Analysis of Control Hold, Suspended, and Dormant State for Packet Data Services", Lucent Technologies,TR45.5.1.5/98.12.
[9] Joseph Shapira, "Microcell Engineering in CDMA Cellular Networks", IEEE Transactions on Vehicular technology, Vol. 43, No.4, November, 1994.
[10] UMTS 30.03 v3.2.0, "Selection procedure for the choice of radio transmission technologies of the UMTS.

[Contact]
Changsoo PARK : chang@telecom.samsung.co.kr, soo2min@unitel.co.kr
Hyeonwoo LEE : woojaa@samsung.co.kr

TSG-RAN Working Group1 meeting #5
Cheju, KOREA, 1-4, June 1999

Addendum to R1(99)669(rev)

Agenda Item:

Source: **SAMSUNG Electronics Co.**

Title: **Power control threshold update for DPCCH gating**

Document for: **Information**

---

5. Introduction

We have proposed the gated transmission of DPCCH during DCH/DCH in Control Only Substates(COS)[1][2]. As shonw in [2], more transmit power is required to maintain the same link quality since the power control rate is reduced during gated transmission. (However, total interference can be reduced since data is transmitted during small portion of time.) This means that different power control threshold value is required for gating mode and non-gating mode. If the same threshold value is used for power control when the Network or UE transits from user data active substate to control only gating state, more frame errors will occur until the threshold level becomes converged to higher level by outer-loop power control. In opposite case, excessive transmit power will be consumed until the threshold level is converged to lower level by outer loop power control.

6. Proposed scheme

As we pointed out in previous section, it is inefficient way to use the same threshold value between non-gated and gated mode. To reduce the convergence time and to avoid unnecessary frame error occurrence or excessive transmit power consumption, we propose that the Network and UE change power control threshold value when they enter the gating mode. The amount of the change can be transmitted to UE by several different ways: This information can be transmitted through the broadcast message, or a form of power control parameter message, or signaling message which indicates state transition. The offset value from the current threshold may be different for each gating rate and for each different state transition. This value can be determined through link level simulation.

7. Reference

[11] TSGR1#4(99)478, “Gated transmission of DPCCH in DCH/DCH control only substates”, SAMSUNG.
[12] TSGR1#4(99)669, “Performance evaluation of uplink/downlink DPCCH gating”, SAMSUNG.