TSG RAN WG1#4 **TSGR1#4(99)395**
Yokohama Japan
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Agenda item: Ad-hoc 14: Packet Mode Operation
Source: Golden Bridge Technology
Title: Methods of operation of CPCH
Document for: discussion

Abstract: In this contribution, we discuss the concerns and issues surrounding the CPCH scheme. The following issues are addressed in this contribution:

1. **More details on the CD field (bits , coding rate)**
2. **The operation of power control when two mobiles collide in the uplink.**
3. **The timing issues related to Closed Loop Power Control**
4. **The number of power control commands per slot was of concern.**
5. **The possibility of sending the L1 ACK immediately after the reception of preamble at the base station.**
6. **Optimization parameters**

These issues have been raised in the first ad-hoc meeting and the discussions on the reflector. While there are some optimization and refinement issues surrounding the CPCH scheme, this scheme is feasible.

Issue 1: More details on the CD field (bits, coding rate)

What is the collision probability?

Assumptions:

- Poisson Arrival

$P(m, T) = e^{-\lambda T} (\lambda T)m / m!$
$\lambda = K / N T_p$
K = number of users which transmit a packet of mean value T_p every NT_p seconds

- Exponential service distribution/ Exponentially distributed Packet length

$f(x)= \lambda e^{-\lambda x} = (1/L) e^{-(x/L)}$
Mean length = L

Collision Probability

The collision probability can be described as follows for any ρ:

$P_c= P_{c|2} P(2,T) + P_{c|3} P(3,T)+ P_{c|4} P(4,T) + P_{c|5}P(5,T)+ \ldots$

Where:
$T = T_p+T_{cc}$
T_{cc} = contention cycle
T_p = Packet length

The collision probability can be approximated as follows:

$M_s = N_s \times N_c$
N_s = number of access slots
N_c = Number of available signature codes
$N_m = m! / \{2x(m-2)!)\}$

$P_{c|m} \cong N_m / M_s$

Sample calculations:

ρ= 1,
T_{cc} = 5 ms
T_p = Packet length = 40 ms
T = 45 ms

$P_{c|2} = 1/16$, $P_{c|3} = 3/16$
$P_{c|4} = 6/16$, $P_{c|5} = 10/16$

	ρ= 1	ρ= 2	ρ= 3	ρ= 4	ρ= 5
P(0,T)	.32	.1	.034	.011	.004
P(1,T)	.37	.27	.12	.05	.02
P(2,T)	.2	.24	.195	.113	.06
P(3,T)	.07	.2	.22	.169	.11
P(4,T)	.02	.11	.185	.19	.15
P(5,T)	.01	.05	.13	.17	.17

	ρ= 1	ρ= 2
Pc M_s = 8	8%	25%
Pc M_s = 16	4%	12.5%

Collision Detection Field specification issues

The CD field length and its coding are optimization issues. The length of the field impacts the probability of collision detection. For example, when the field length is 6 bits, the probability of undetected collision is 1/64 given that two UEs arrived at the Node B at the same power level. In other words, the two UEs pick the same access slot, signature code and the same Random number.

Example: What is the probability of two mobiles arriving in 40 ms time interval, and picking the same mini-slot and the same signature code (2 available)?

P(undetected collision) = .125 (ρ = 2) x 1/(16) x 1/64 = $10^{(-4)}$

If the CD field transmission is repeated twice, the probability of undetected collision reduces to 10^{-6} . Transmission of 12 bits via in-band signaling at 4 kbps, takes 6 ms. Assuming that the packet length is 50 ms, the collision feedback delay cycle will be 6 ms which is 12% of the transmission time. The fast collision feedback delay cycle requires that the signaling information be not interleaved.

ρ	2	2	2	2
CD bits	4	5	6	7
Code rate	1/2	1/2	1/2	½
Signaling rate	4 kbps	4 kbps	4 kbps	4 kbps
Pc	.125	.125	.125	.125
Collision feedback cycle	4 ms 8%	5 ms 10%	6 ms 12%	7 ms 14%
P(undetected collsion)	4 x $10^{(-4)}$	2x $10^{(-4)}$	$10^{(-4)}$	.5x$10^{(-4)}$
Delta in dB as compared with R=1/3, interleaver	R=1/2 requires .5 dB more as compared to R=1/3	R=1/2 requires .5 dB more as compared to R=1/3	R=1/2 requires .5 dB more as compared to R=1/3	R=1/2 requires .5 dB more as compared to R=1/3

	Interleaver gain= 1-3 dB *	Interleaver gain=1-3 dB*	Interleaver gain=1-3 dB*	Interleaver gain=1-3 dB*

* These results are for indoor (1 dB) and outdoor (3 dB) at BER of 10 $^{(-3)}$. This is also done for R=1/3, when the coding rate is changed to R=1/2, there is a loss of .5-1 dB in coding gain.

Link level Simulation Results:

No interleaver, PC with 4%error

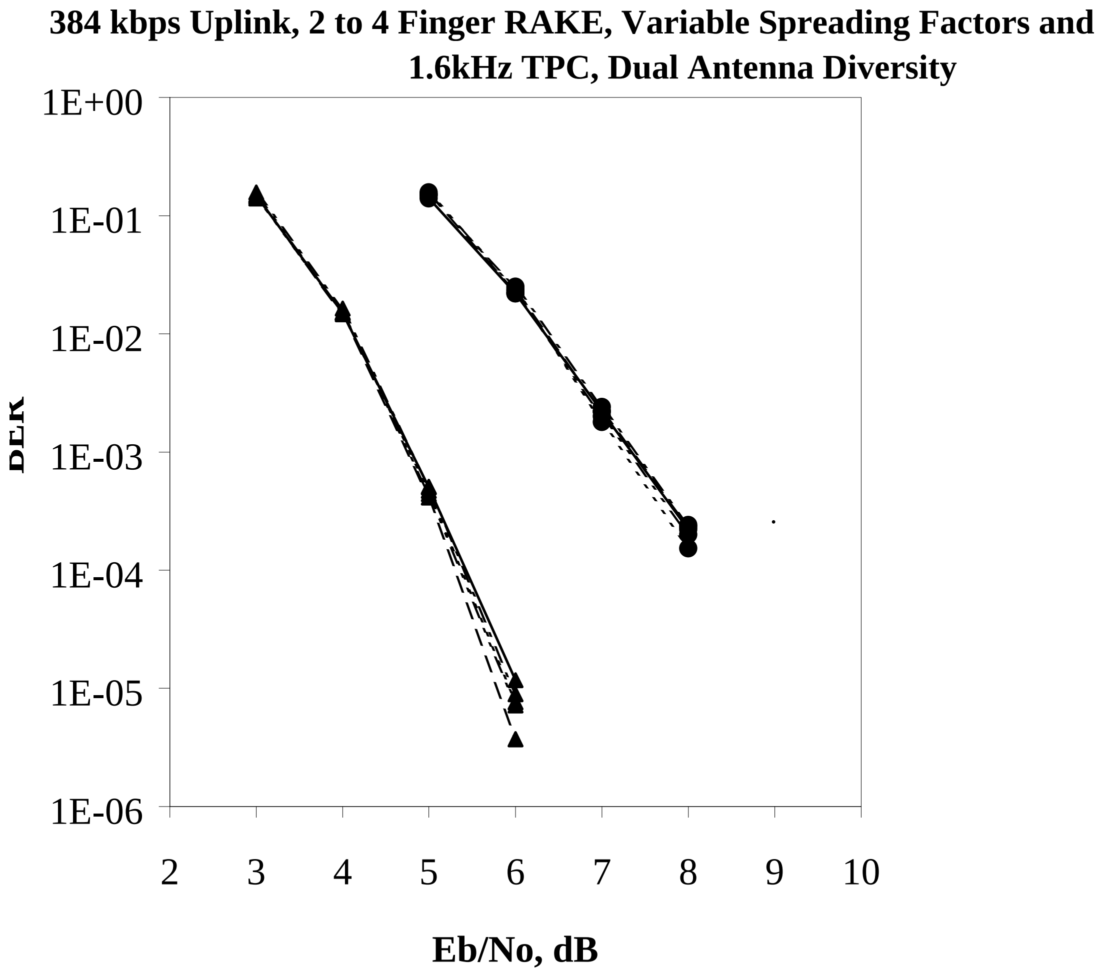
	Indoor	
Eb/No	PG=4	PG=64
4	0.048	0.0475
5	0.0078	0.0078
6	0.0007	0.00078

	Vehicular	
Eb/No	PG=4	PG=64
8	0.023	0.0192
9	0.011	0.0084
10	0.0058	0.0041

The figure in the next page [1] illustrates the performance of the 384 kbps link in indoor and vehicular environments. These results could be used as a baseline for comparing the case of FEC/interleaver and FEC/no interleaver.

Conclusion: The CD field is transmitted at 3-4 dB higher power level as compared to the interleaved data transmission.

[1]: Saeed Ghassemzadeh, Mathew Sherman, Don Bowen (AT&T labs), Joe Baccouzi, George George Efthymoglou (Cadence Design Systems), Kourosh Parsa, Emmanuel Kanterakis (GBT) "On the Performance of the Multi-code CDMA Systems: A Simulation", Presented at: IEEE Sarnoff Symposium Advanced Digital Cellular Communications, March 1999.



384 kbps Uplink, 2 to 4 Finger RAKE, Variable Spreading Factors and 1.6kHz TPC, Dual Antenna Diversity
1E+00
1E-01
1E-02
1E-03
1E-04
1E-05
1E-06
BER
2
3
4
5
6
7
8
9
10
Eb/No, dB

Issue 2: The operation of power control when two mobiles collide in the uplink.

Collision condition and Node B power control issues

In the previous section, we showed that the probability of undetected collision is 10^{-4}. This means that any 2 mobiles will actually collide once in 10,000 cases. Since the mobile is power controlled, a concern has been raised regarding the operation of the two UEs in the collision state and if there are any scenarios that might lead to hostile condition. In this section, we show that as long as the Base Node transmits its L1 ACK at the right level, the chances of having a hay-wired UE is practically zero.

Scenario A: The received power level of the collided mobiles is comparable

Note that the Node B power controls any of the two collided UEs that is received at higher SNR level. Under collision condition where two UEs arrive at close power levels, then the total energy (SNR) detected in the Node B will always exceed the individual received SNRs and the Node B will ask for 'reduction' since it detects higher SNR levels. So, there is no chance that of the two contending UEs will transmit at higher level than Base-SNR-level. This undetected collision condition (one in 10,000 case) only reduces the throughput negligibly.

Scenario B: L1 ACK is transmitted at Downlink Common Control Channel power level

Let's take a case of when two UEs, which are located at R1 (near Base Node), and R2 (near cell edge) receive L1 ACK indicating that they have control of the channel. Let's further assume that the collision is undetected. In this case one UE (R1) initially dominates. However, the interfering UE (R2) is receiving erroneous TPC commands and might become a power threat to the dominating UE. At one point, the Base Node begins responding to the interfering UE. From that instant to the instant that the UE begins receiving correct TPC commands from the Base Node, there is a potentially-threatening-transient condition [1-2 frames] that the newly dominating UE might exceed the Base-SNR level delta dB reducing the cell capacity. This transient condition persists only until the cell-edge-located UE begins receiving the Base Node TPC commands correctly. This only happens after a transient period [1-2 frames] in which the Base Node adjusts its DPDCH power control level for the cell-edge-located UE.

The UE would be limited in terms of transmitted power level beyond one specified by the process. The justification for his is that the UE is already at the proper power level. Keeping the change in power over a number of frames to within ΔP from the starting power level should allow for most of the gain to be harnessed.

Scenario C: L1 ACK is transmitted at a tailor-made power level

If the UE power control the Base Node prior to L1 ACK transmission, then the chances that the interfering/ colliding UE becomes a threat is practically zero. The undetected collision probability in this case is as follows:

P{undetected collision) = P(two colliding UEs are within 3 dB distance from each other and their respective received SNR (L1 ACK) is less than 3 dB) x $10^{(-4)}$. The above probability is highest at the cell edge and is calculated as follows:

1. What is the probability that any two UE are located within a 3-dB ring?

3 dB corresponds to a factor of 1.2 when the propagation path loss is 40 dB per decade. When P_{R1}-P_{R2} = 3 dB, then the following relationship is true between R1 and R2:

R1 = α x R2
3 dB = $P_{R1}-P_{R2} = 10 \log (1/R^4) - 10\log (1/(\alpha R)^4)$
3 dB = $10 \log (\alpha^4)$
$\alpha = 1.2$
If R2 =1/2, then the probability of the two UEs being in that ring is .11.

2. Given that two UEs are within the 3 dB ring, what is the probability that the difference of the average received SNRs is less than 3 dB?

Let's assume that X and Y are Gaussian RVs with mean of m_x , m_y and standard deviations of σ_x , σ_y. Then Z=X-Y is also a gaussian RV with the following statistics:

$m_z=m_x-m_y$ and
$\sigma_z = (\sigma_x^2 + \sigma_y^2)^{½}$ = 11.3 dB

P{X-Y < 3dB} = .25

3. Given that two UEs are in the 3 dB ring, what is the probability that Z=X-Y is less than 3 dB?

P{ X-Y < 3 dB | X,Y $\in$ 3 dB ring } = .24 x .11 = .026

P{undetected collision) = .026 x $10^{(-4)}$ = 2.6 x $10^{(-6)}$

When such a condition occurs, there is no near-far problem as described in the previous scenario.

Issue 3: **The timing issues related to Closed Loop Power Control Optimization issue:**

The two way propagation delay as a function of the cell radius:

GBT has done some simulations which were presented as part of the TR46.1 package to ETSI in March 1998 (Sophia Antipolis) and we showed the feasibility of 4 kbps APC rate and the advantages associated with that as far as reducing the required Eb/N0 is concerned. In T1P1/TR46.1, other companies have presented higher TPC rates (low power 64 kbps with higher error rate). The TPC rate is limited by the two-way propagation delay. For example, for a 20 mile radius (200,000 feet = 40 miles = 200 micro-seconds), the maximum TPC rate should be less than 5 kbps (1/(two way delay) to avoid overshoot. The 8 kbps TPC rate applies to the case of 125-microsecond (two-way) delay, which corresponds, to 12.5 mile cell radius. The two-way delay varies from environment to environment. For a maximum cell radius of 12.5 miles, the maximum feasible TPC rate is 8 kbps. For shorter cell radii, higher TPC rates are possible. The following table entails some examples.

Cell Radius	Two way propagation delay
10 km	33x2 = 66 μsec
20 km	66x2 = 132 μsec
25 km	83 x 2 = 167 μsec

So, the relationship between the loop delay and the TPC rate is as follows:

$F_{tpc} < 1/(\tau_{two\text{-}way\text{-}delay})$

Issue 4: The number of power control commands per slot was of concern.
Optimization/refinement issue

The two way propagation delay as a function of the cell radius:

Cell Radius	Two way propagation delay
10 km	33x2 = 66 μsec
20 km	66x2 = 132 μsec
25 km	83 x 2 = 167 μsec

Power control issues (Number of updates per slot):

What is the maximum possible TPC rate?

Assuming that the round trip delay is 125 microsecond, then the maximum achievable TPC rate will be 8 kbps. When the rate is 16 kbps, 2 symbols are allocated to each TPC information bit. Let's assume that the TPC rate is 8 kbps for N access slots prior to data transmission. This means that 5 x N TPC bits are sent to the UE prior to the data transmission.

Dynamics of Fade Rate, Packet Duration (n x 10 ms) and Convergence

1. CLPC is required at low fading rates, since the negative impact on capacity is significant when the frame arrives at higher Eb/N0 values.
2. Convergence of closed loop power control at high fading rates within a frame
3. This table shows why fast convergence is critical at high fade rates
4. It also clearly demonstrates why we should have closed loop power control on packets longer than a frame especially at higher rates.

	Fade Rate in Hz	Average Fade Arrival time in ms	Max. offset in dB in 2.5 ms
Delta1 = 30 dB Delta2=10 dB	10	100 ms 1 fade per 100 ms 1 valley/peak in 50 ms	Offset1= 2.5 x 30 / 50 Offset1 = 1.5 dB Offset 2 = .5 dB
Delta1 = 30 dB Delta2 =10 dB	20	50 ms 1 Fade in 50 ms 1 valley/peak in 25 ms	Offset1 = 3 dB Offset2 = 1 dB
Delta1 = 30 dB Delta2 = 10 dB	50	25 ms 1 valley/peak every 12.5 ms	Offset1 = 6 dB Offset 2 = 2 dB
Delta1 = 30 dB Delta2 = 10 dB	100	12.5 ms 1 valley/peak every 6.25	Offset1 = 12 dB Offset2 = 4 dB

		ms	

Fast Convergence

- After the L1 ACK slot, the TPC slot is transmitted in the DL direction to force convergence prior to data transmission.

- At SF of 512, the rate is 8 kbps, which means that we have 80 bits per 10 ms or 5 symbols per slot. Perhaps the first frame can operate in that rate if necessary.

The following table shows how fast the power control converges at the proposed high TPC rates.

Number of Slots @ 8kbps	Number of TPC steps
1	5 dB correction
2	10 dB correction
3	15 dB correction

Issue 5. The possibility of sending the L1 ACK immediately after the reception of preamble at the base station.

Optimization/refinement issue

The processing delay in the mobile and base is that it is negligible as compared to the propagation delay. For a 10-mile radius, the propagation delay is 50 microseconds. We think the preamble detection in the base can be done almost instantaneously. So, the total delay to L1 ACK transmission is in the order of 50 microseconds (10-mile radius). However, the current RACH scheme is calling for 2 slots (settable parameter) before the Transmission of L1 ACK. This time-gap can be used for power controlling the base station.

The combination of propagation delay and processing in the base for a 10-mile radius base is around 50 microsecond. We are proposing to allocate total of two (default) access slots (2.5 ms) for the mobile to power control the base (at 8 kbps, this means 10 TPC updates). The real value in this will be the transmission of the L1 ACK at the right level from the base station. As it stands now, the L1 ACK is sent (current RACH scheme) such that it serves the worst case scenario (mobile at the cell fringe). So, we think it is beneficial to have the base power controlled before it sends its L1 ACK. In terms of timing, we think this can be done within 2-3 access slots (this parameter should be subject for optimization).

Base Station Power Control by the UE after preamble detection

- If the base station is power-controlled prior to L1 ACK transmission, then transmission of several simultaneous L1 ACKs will not consume the Base Node power (capacity) as much. If the L1 ACKs are not sent without any open loop power control, they will have to reach the cell edge (power requirement is similar to DL Common Control Channels).

- If the L1 ACK is sent to the entire cell, the probability of collision increases significantly. This is due to the fact that any mobile in the entire cell, which has picked the same sequence, will assume that it has the control of the channel.

- Power control of the base node prior to L1 ACK transmission is beneficial in both not wasting the capacity as well as reducing the collision probability.

Issue 6: Optimization Parameters

Here is a list of parameters, which might have to be specified and optimized.

1. Number of access slots between successive preambles: M1
2. Number of access slots for power controlling the Node B: S1
3. The time of the L1 ACK transmission from Node B: T1
4. The number of access slots for power controlling the UE: S2
5. The rate of TPC bits for power controlling the Node B: R1
6. The rate of TPC bits for power controlling the UE: R2
7. Initial power level of TPC from UE: P_TPC UE
8. Initial power level of pilot from Node B: P_pilot B
9. Initial power level of TPC from B: P_TPC B
10. Initial power level of pilot from UE: P_pilot UE
11. Step size of the power control UE: Step_UE
12. Step size of the power control B : Step_B
13. Base_SNR_th
14. UE_SNR_th