Performance of Data Services in cellular CDMA in Presence of Soft Handoff, Beam -forming and Packet Combining

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ABSTRACT:

Performance analysis of data services is studied in CDMA network in presence of packet combining, beam forming and soft handoff (HO). Beam forming in conjunction with soft handoff and packet combining is found to enhance throughput and reduce delay and BER significantly. It also reduces packet delay variation (PDV) significantly. Both the cases of perfect and imperfect Beam forming are investigated.

Two different packet combining schemes for packet data service, one based on log likelihood ratio (LLR) and another based on equal gain combining (EGC) have been studied. A cross layer interactions between ARQ and packet combining at link layer and soft HO and beam forming in physical layer has been shown. Truncated automatic repeat request (T-ARQ) is used at link layer to satisfy a prescribed delay constraint. The impact of processing gain, number of retransmissions, throughput, delay and packet loss on system performance is studied.

Keywords: CDMA**,** *soft handoff, Beam forming, Packet Combining, BER, LIR, EGC, SNR*

1. Introduction:

High rate packet data transmission is becoming important in wireless networks supporting multimedia services. There is increasing demand for downlink traffic such as High Speed Downlink Packet Access (HSDPA) and asymmetric network requirements. Downlink capacity should be higher than reverse link capacity. CDMA uses soft handoff (HO) where the handoff mobile near a cell boundary transmits to and receives from two or more BS-s simultaneously. Soft HO provides a seamless connectivity in contrast to hard handoff by allowing a “make before break approach” connection. It reduces “ping-pong” effect as present in hard HO, probability of lost calls and eases power control. Soft handoff affects both uplink and downlink.

We have investigated performance analysis for the forward link of cellular CDMA. Performance in terms of outage simulation only is carried out in presence of soft handoff in Cellular CDMA for forward link mainly for voice users However, for data services throughput and delay need to be analyzed. A new packet is generated as soon as the preceding packet is delivered successfully.

2. Evolution of wireless networks:

The ability to communicate with people on the move has evolved remarkably since Guglielmo Marconi first demonstrated radio’s ability to provide continuous contact with ships sailing the English Channel. That

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was in 1987, and since then new wireless communications methods and services have been enthusiastically adopted by people throughout the world

A brief history of the evolution of mobile communication throughout the world is useful in order to appreciate the enormous impact that cellular radio and personal services (PCS) will have on all of us over the next several decades.

3. System Model:

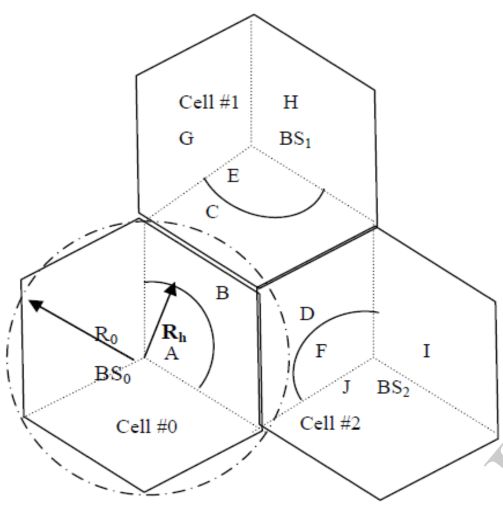

Fig 1: cellular layout for soft handoff.

- The processing gain(pg) =W/ R_b
- Poisson distributed with mean arrival rate λ as: $P_m(\iota) = (\exp(-\lambda)\lambda^{\iota}) / \iota!$
- Link gain for a location (r,θ) is given as:
  - $G_i(r,\theta) = d_i(r,\theta)^{-\alpha}{}_p\, 10^{\xi s/10}$
- Total in-cell interference in cell # 0 is $I_{in} = I_1 + I_2$
- Out-cell interference is
- $I_{out} = 2\,(I_E + I_{C1} + I_{C2} + I_{C0} + I_G + I_H)$
- The time required for transmitting a packet of length L_p by a data user transmitting at a fixed rate of R_b is:

$$T_p = \frac{L_p}{R_b} = \frac{L_p \quad pg}{R_c} \qquad (1)$$

- The average delay:

$$D = \frac{T_i}{(1-P_r)} = \frac{L_p\ pg}{R_c(1-P_r)} \qquad (2)$$

- The average throughput:

$$G = \frac{L_p r_c}{D} = \frac{r_c R_c(1-P_r)}{pg} \qquad (3)$$

4. Simulation Model:

A. Generation of user's location and interference:

1. The number of users (N_d) is generated by generating a Poisson distributed random variable with mean λ.
2. Locations (r,θ) of all (N) users are generated and users are divided into non-HO (N_h) and soft HO (N_s) region based on their location. Assuming the desired user in non-HO region, let the remaining users in non-HO are (N_h -1). Number of users in soft HO region: $N_s = N - N_h$.
3. For each of those in soft HO region (N_s), the forward transmitted power has been generated as per equations

$$P_{T\_R} = \sum_{i=1}^{N_{nh}} P_R(i) + \left(N_{s,B} + N_{s,C} + N_{s,D}\right) \times P_C \qquad (4)$$

4. Next forward transmit power of BS_0 for (N_h -1) MS-s in non-HO region (A) of reference cell is obtained as per equations

$$P(r,\theta) = \frac{\left(G_R(r,\theta) + G_1(r,\theta) + G_2(r,\theta)\right)}{G_i(r,\theta)} \times P_C \qquad (5)$$

$$P_R(r,\theta) = \frac{\left(G_R(r,\theta) + G_1(r,\theta) + G_2(r,\theta)\right)}{G_R(r,\theta)} \times P_C \qquad (6)$$

$$P_R^{\varepsilon}(r,\theta) = \frac{\left(G_R(r,\theta) + G_1(r,\theta) + G_2(r,\theta)\right)}{G_R(r,\theta)} \times P_C^{\varepsilon} \qquad (7)$$

5. Signal from desired BS is, P_C or P_C^{ε} depending on situations either perfect or imperfect and SIR is as in equations

$$SIR_{forward} = \frac{P_C}{\sum_{i=1}^{N_{nh}} P_R(i) + (N_{s,B} + N_{s,C} + N_{s,D}) \times P_C} \quad (8)$$

$$P_R^{\varepsilon}(r,\theta) = \frac{(G_R(r,\theta) + G_1(r,\theta) + G_2(r,\theta))}{G_R(r,\theta)} \times P_C^{\varepsilon} \quad (9)$$

B. BER simulation of data

1. A sequence of random data bits +1 or -1 is generated which indicates the transmitted bits.
2. A Gaussian noise sample is and added to each transmitted bit, where SIR_d is found following steps A(1) to A(5).
3. The received bit is first detected as +1 or -1 after comparing with threshold 0.then each received bit is compared with corresponding transmitted bit.
4. Steps B(1) to B(3) are repeated for large N_{total} number of times to yield estimate of BER as $P_e = erroe\_count \,/\, N_{total}$

C. Delay, throughput simulation:

1. A packet consisting of L information bits are generated.
2. If received packet is incorrect, the same packet is retransmitted until the packet is received correctly finally.
3. Total no. of erroneous packet is counted out of a large no. of transmitted packets to PER.
4. Average delay (D) is estimated as $((N_P + retx\_count)./N_P)\,T_i$
5. The throughput is: $G = L_P\, r_c / D$

5. Packet Combining:

- Packet combing in conjunction with soft HO is found to enhance throughput ,reduce delay and packet delay variation (PDV) significantly.
- Two different packet combining schemes are Log likelihood ratio (LLR) and Equal gain combining (EGC)
- Average LLR based packet combining :
- LLR values are computed for all bit positions of the packet $LLR=2x_k/\sigma^2$
- EGC Based packet combining : After the ι-th ARQ transmission, the SIR is ι times that without ARQ SIR= ι x SIR_{noARQ}
- retransmission is continued till packet is received correctly.

❖ Throughput:

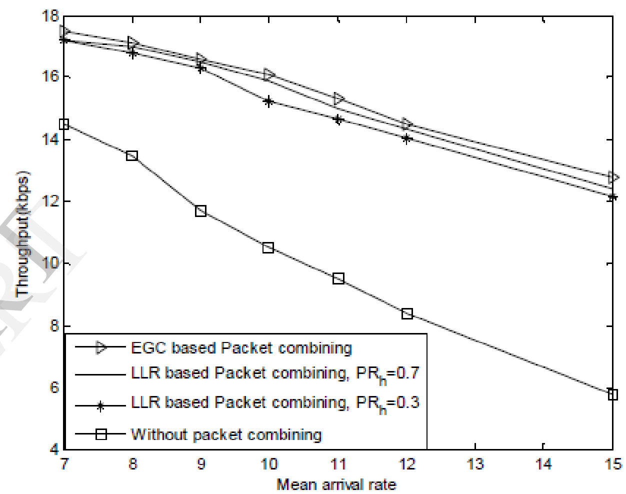

Fig 2: Throughput vs. mean arrival rate (λ) for different cases of packet combining.

❖ Delay:

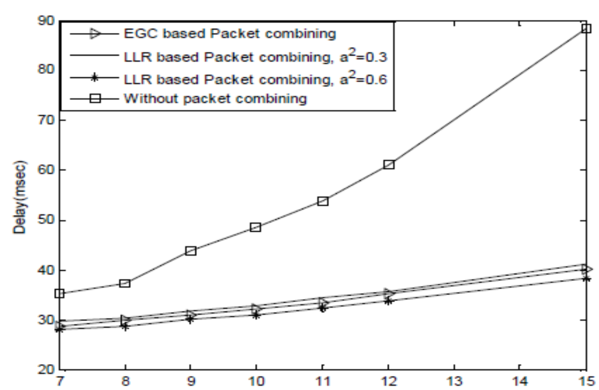

Fig 3: Throughput vs. mean arrival rate (λ) for different cases of packet combining.

❖ Packet delay variation:

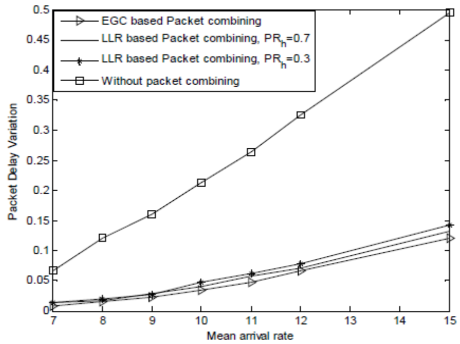

Fig.4: Packet delay variation vs. mean arrival rate (λ) for Different cases of packet combining.

❖ No. of retransmissions:

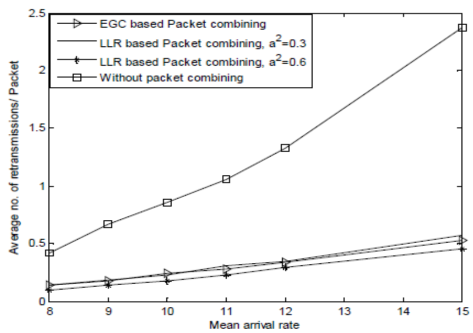

Fig.5: Average number of retransmissions /packet vs. mean arrival rate (λ) for different cases of packet combining.

❖ Packet error rate:

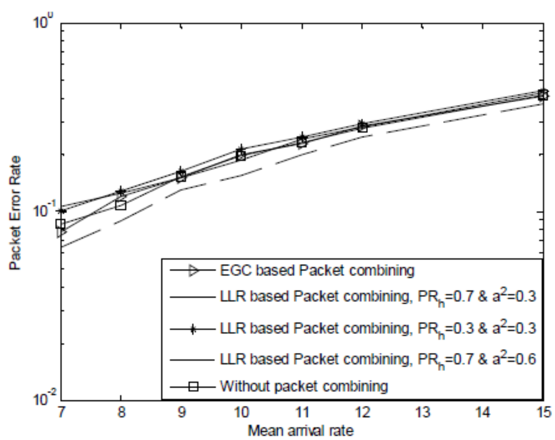

Fig 6: Packet error rate vs. mean arrival rate (λ) for different Cases of packet combining.

6. Results & Discussions:

Spread bandwidth, W	5 MHz
Chip rate R_{ch}	5 Mcps
R_b = W/pg; processing	128, 256
Packet length, L_p	1024
Power control error, σ	1 and 2 dB
Path loss exponent ,α_p	4
Standard deviation of	6 dB
FEC code rate, r_c	0.5.
Shadowing correlation, a^2	0, 0.3 and 0.6
Degree of soft HO, PR_h	0.3, 0.7

Table 1: simulation parameters

❖ BER:

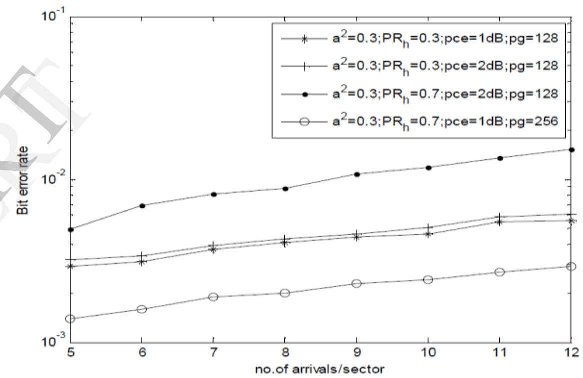

Fig 7: BER vs. mean arrival rate for different soft handoff conditions and shadowing

❖ Throughput:

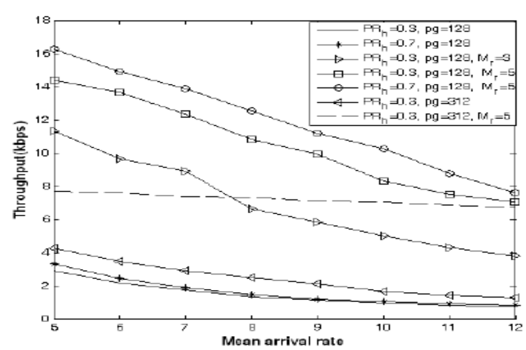

Fig.8: Throughput vs. mean arrival rate for different Soft handoff conditions and shadowing

❖ Delay:

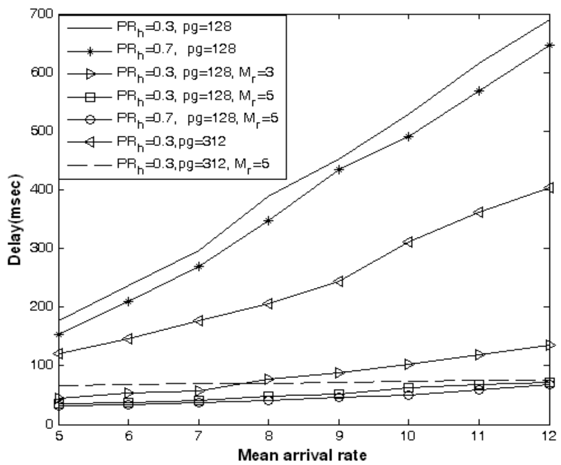

Fig.9: Delay vs. mean arrival rate for different soft handoff conditions and shadowing

7. Conclusion:

A scheme of combining beam forming, packet combining and soft HO in forward link data service is proposed and evaluated. The joint effects of beam forming, packet combining and soft handoff on data services in the forward link are investigated. Soft handoff parameters, shadowing correlation and *PRh* are found to have significant impact on data service..

Throughput is increased whereas delay, packet delay variation are decreased by utilizing packet combining schemes such as LLR, EGC etc. Average number of retransmission is decreased for packet combining schemes. Packet combining technique reduces number of retransmissions because old copies of the packet are not neglected. Rather, they are taken into consideration for reducing packet error probability.

Increase in shadowing correlation improves throughput and delay performance. Increase in *PRh* reduces interference and thus improves performance of the network.

8. Future work:

The results of this paper can serve as the basis for the following further research:

1. Beam forming may be incorporated in our forward link data service model to improve the overall performance.
2. We are planning to study joint rate allocation for future generation wireless net works like UMTS, cognitive radio networks WiMAX etc.
3. Power allocation techniques (SSDT, LPPA, EPA) in the down link can be incorporated for the CDMA system.

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