Packet Data with Truncated Power Control and Truncated ARQ in Presence of Soft Handoff

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Abstract

In this paper, performance of data services in presence of truncated power control and truncated ARQ in cellular CDMA network has been investigated. The combined effects of soft handoff parameters, truncated power control at physical layer and truncated ARQ (TARQ) at data link layer on throughput and delay performance of packet data is studied. Truncated ARQ has been considered to keep delay within tolerable limit. Truncated power control improves performance by suspending transmission of mobile stations (MSs) under deep fade along with soft handoff (HO). A variable packet length scheme has been investigated where packet size is adjusted under different traffic and soft handoff conditions so as to maintain a prescribed level of packet loss associated with TARQ. We carry out investigations on interactions between power truncation parameter and soft handoff parameters.

Keywords: *TARQ, Truncated power control, Variable packet length, Throughput, Packet loss*

1. Introduction

Emerging wireless communication networks need high rate packet data services. Code Division Multiple Access (CDMA) is very promising to meet the demand for high data rate and quality of service (QoS) in wireless networks. Variable processing gain (VSG) and multi-code are two interesting approaches for controlling data rate in CDMA [1]. In VSG scheme, the spreading ratio is reduced as the data rate is increased whereas multi-code CDMA (MC-CDMA) uses additional parallel codes for higher data rate. Performance of wireless link and cellular capacity is severely limited by multi-user interference and channel fading. CDMA uses soft handoff (HO) where the handoff mobiles near cell boundary transmit to and receive from two or more BS-s simultaneously [2]. Since an MS is power controlled by the BS requiring the least power, soft HO extends the coverage, reduces overall interference, and increases the reverse link capacity [3,4]. To enhance the throughput performance of future packet data oriented systems adaptive modulation and coding (AMC), adaptive antenna array providing space diversity and several receiver algorithms have been advocated at physical layer [5,6]. An alternative way to mitigate channel fading is to rely on automatic repeat request (ARQ) protocol at the data link layer, which ensures persistent retransmission of packets associated with a particular message until it is received correctly. Since retransmission is activated only when necessary, ARQ is effective in improving system throughput relative to only forward error correction (FEC) [6]. Further ARQ can be combined with FEC in a hybrid ARQ scheme. To minimize delay and buffer sizes, truncated ARQ has been adapted to limit the number of retransmissions in practice. Transmission of video or image requires that the delay be restricted to a certain limit. Hence packet loss may take place after the allowed number of retransmissions [5]. Several studies have been conducted on the combined effects of physical layer issues and the link layer issues [5, 6, and 7]. Impact of various linear multi-user detector algorithms at physical layer, ARQ and packet combining at MAC layer have been studied [6]. A cross layer design approach which combines adaptive modulation and coding (AMC) at physical layer with truncated ARQ at data link layer is shown to improve spectral efficiency and throughput under prescribed delay and error constraint in [5]. Power control on the other hand is one effective way of combating near-far problem and improving the cellular capacity [8, 9]. Power control ensures that the received signal strengths from all users at BS are almost equal. A number of power control algorithms, such as signal strength based, SIR based have been suggested in the literature [8]. An interesting power control scheme called *truncated power control scheme* has been analyzed [9]. In this scheme the power transmission from an MS is suspended when it goes into deep fading thereby reducing the interference caused by mobiles near cell boundaries. The outage performance with truncated power control has been analyzed [9]. However, soft handoff has not been considered in the earlier mentioned studies [5, 6, 7, 8 and 9]. Space diversity in presence of soft handoff is analyzed for fixed data rate services only employing multi-code CDMA (MC-CDMA) with conventional power control [10]. Tele traffic behavior of CDMA cellular networks has been considered in presence of soft HO [12]. However, performance of data services has not been considered in [12]. In [13], forward link performance has been analyzed considering soft handoff and SIR based power control.

In the present paper, we have assessed the performance of data services with truncated power control in presence of soft handoff. Performance of CDMA network has been analyzed in presence of soft HO and conventional strength based power control in [4]. However, our scheme considers cross layer interaction between truncated ARQ in link layer and truncated power control in presence of soft HO in physical layer. The combined interactions of truncated power control, soft HO at physical layer and TARQ in link layer have been investigated on overall data performance. A simulation study has been carried out to evaluate the joint effects of soft handoff, truncated power control, and truncated ARQ on throughput and delay performance of packetized data in a CDMA network with imperfect power control. The performance is compared with that of the conventional power control scheme. A scheme based on variable packet size transmission satisfying a constraint on packet loss associated with truncation has been evaluated. Section 2 and 3 describe the cellular scenario and our simulation model, respectively. Results and discussions are presented in Section 4. Finally, conclusions are reported in Section 5.

2. System model

In Figure 1, the three-cell network model of interest in this work is shown. The network has a cluster of three sectored cells (as in [4]) with uniformly distributed mobile users (MS) and equal number of MS-s (N_d) per sector. We assume that a data user can transmit at a rate R_b. Each sector of a cell is divided into two regions, viz., soft handoff and non handoff region. The soft HO region is defined based on the distance from the base station (BS) as in Figure1. An MS located outside the handoff boundary R_h is considered to be under soft HO with three neighboring BS-s. Each sector is divided into two regions, soft HO regions (B, C, D) and non-HO regions (A, E, F) of cell # 0, 1and 2, respectively. BS_0, BS_1 and BS_2 are the BS-s of cell # 0, 1 and 2, respectively. The propagation radio channel is modeled as in [4]. The link gain for an MS at location (r,θ) is:

$$G_i(r,\theta) = d_i(r,\theta)^{-\alpha_p} 10^{\xi_S/10} \tag{1}$$

where $d_i(r,\theta)$ is the distance between the MS and BS_i, α_p is the path loss exponent and $10^{\xi_s/10}$ is the log-normal component with ξ_S normally distributed with zero mean and variance σ_s^2. The shadow fading at i-th BS is:

$$\xi_{s-i} = a\zeta + b\zeta_i \text{ with } a^2 + b^2 = 1 \tag{2}$$

where ζ and ζ_i are independent Gaussian random variables (r.v-s) with zero mean and variance σ_s^2 [4]. Out-cell interference consists of interference due to MS-s from region (E, C, G, H) of cell #1 and (D, F, I, J) of cell #2. MS-s in furthest sectors (G, H, I, J) are assumed to be power controlled by respective BS-s. The reference user is located in non-HO region of the reference sector i.e., in region 'A'. Total in-cell interference in cell # 0 is:

$$I_{in} = I_1 + I_2 \tag{3}$$

where I_1 is due to all MS-s in A and those in B connected to BS_0, I_2 is due to MS-s in B but connected to BS_1 and BS_2. The out-cell interference is:

$$I_{out} = 2(I_E + I_{c1} + I_{c2} + I_{co} + I_G + I_H) \tag{4}$$

I_E is the interference due to MS-s in E and connected to BS_1. Similarly I_{c1} and I_{c2} are due to MS-s in region C and power controlled by BS_1 and BS_2 respectively. I_{co} is due to MS-s in C and controlled by BS_0. I_G and I_H are the interference due to MS-s in G and H. MS-s in these farthest sectors are assumed to be power controlled by respective BS i.e. BS_1. A multiplication factor of two is used in (4) to include contribution of cell #2. The actual received power from the desired user is $U = S_R e^S$; where S is a Gaussian random variable with zero mean and variance σ_e^2. Thus σ_e represents the standard deviation of power control error (pce). The desired user is assumed to be in non-handoff region and not under power truncation. With truncated power control the 'k'th mobile estimates the propagation gain G_k and adjusts its transmission power as [9]:

$$S(G_i) = \left(S_R / G_k \right) e^{r_n} \text{ for } G_k \geq \gamma_0$$

$$= 0 \text{ otherwise} \tag{5}$$

where γ_0 is the cutoff fade depth. Here r_n is a Gaussian random variable with zero mean and variance σ_e^2. The truncation probability is given by $(1 - p(\gamma_0))$ where $p(\gamma_0) = \Pr ob(G \geq \gamma_0)$. A "continuously active" data traffic model as in [11] is considered where each user generates a sequence of fixed length packets. A new packet is generated as soon as the preceding packet is delivered successfully. The BER (P_e) for data user is simulated as described in later section in the above soft HO and truncated power control environment considering direct sequence spreading and BPSK data modulation having spread bandwidth of W. The retransmission probability P_r is given by [7, 10].

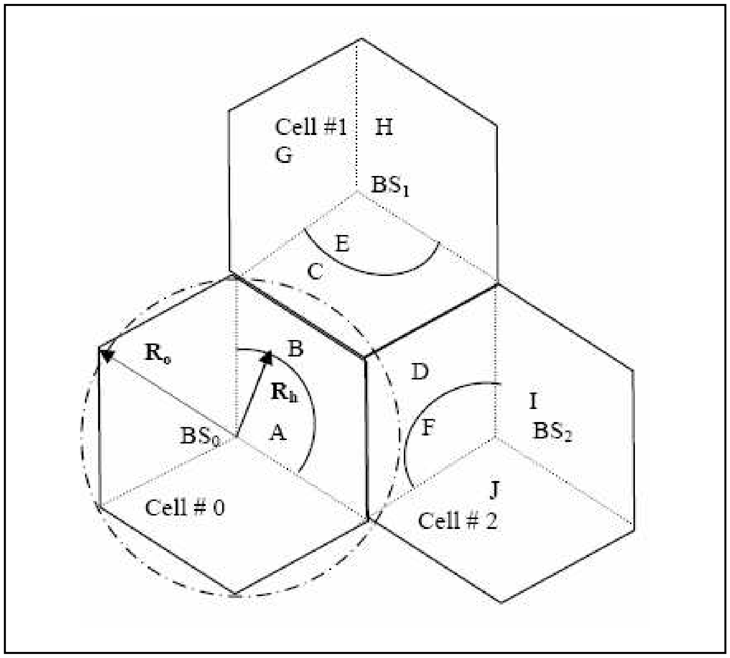


Figure1. Cellular layout for soft HO. A, E, F are non HO region. B, C, D are soft HO region. Cell # 0 is the reference cell.

$$P_r = 1 - (1 - P_e)^{L_p r_c} \tag{6}$$

where L_p is the length of the coded packet in bits and r_c is the FEC code rate. There is no waiting delay in the queue for continuously active data users. So the average packet delay is the same as the packet transfer time T_i. The time required for transmitting a packet of length L_p by a data user transmitting at a rate of R_b is given as:

$$T_i = \frac{L_p}{R_b} = \frac{L_p\, pg}{R_c} \tag{7}$$

where R_c is the chip rate and pg is the processing gain. We assume that acknowledgement from the receiver is instantaneous and perfectly reliable. If T_{max} is the maximum allowed packet delay, the maximum number of retransmissions is given as $N_{max} = \lfloor T_{max} / T_i \rfloor$. Thus with truncated ARQ if a packet is not received correctly after N_{max} retransmissions, it is dropped and declared as a packet loss. The average delay with truncation:

$$D = \frac{L_p . pg}{R_c} \left\{ \frac{1 - P_r^{(N_t+1)}}{1 - P_r} \right\} \tag{8}$$

where $N_t = 1, 2, ..., N_{max}$

The average throughput is defined as the average number of information bits successfully transferred per sec and is given by:

$$G = \frac{L_p r_c}{D} = \frac{r_c R_c (1 - P_r)}{pg(1 - P_r^{(N_t+1)})} \tag{9}$$

The packet loss probability after N_t retransmissions:

$$P_{loss} = (P_r)^{(N_t+1)} \tag{10}$$

Some services may require maintaining packet loss (packet QoS) up to a prescribed limit (δ). A variable packet length scheme is used where the packet size is adjusted under different traffic and soft HO conditions so as to maintain packet loss up to the desired limit (δ). The length of the packet (L_p^*) is selected satisfying $P_{loss} \leq \delta$, i.e.,

$$\{1-(1-P_e)^{L_p^* r_c}\}^{N_t^*+1} \leq \delta, N_t^* = \lfloor T_{\max} / T_p^* \rfloor \tag{11}$$

$$\text{where} \quad T_p^* = L_p^* / R_b \tag{12}$$

The packet size L_p^* is found by simultaneously satisfying (11) and (12).

3. Simulation model

The simulation is done using MATLAB with the following parameters: PR_h indicating the degree of soft HO, shadowing correlation is denoted as a^2 and the standard deviation of power control error is σ_e. The soft HO region boundary R_h given as $R_h = R_o\sqrt{1 - PR_h}$ where R_o is the radius of the cell which is normalized to unity and hexagonal cell is approximated by a circular one with radius R_o. Traffic intensity is assumed to be uniform in each cell. Locations (r,θ) of all (N_d) users are generated and users are divided into non-HO (N_h) and soft HO (N_s) regions based on their locations. Assuming the desired user in non-HO region, let the remaining interfering users in non HO region are $(N_h - 1)$. The number of users in soft HO region is $N_s = N_d - N_h$. The link gains corresponding to three BS-s involved in soft HO for each of those in soft HO region is generated as in equation (1). The user is power controlled by BS_i when G_i is maximum; $i = 0, 1, 2$. The interference received at the reference BS is:
(i) For conventional power control, the interference due to 'k'th MS:

$$I_k = S_R \exp(r_n)\left(\frac{G_0}{G_i}\right) \tag{13}$$

if connected to BS_i; where $i = 0,1,2.$

(ii) For truncated power control, the interference is given as:

$I_k = S_R \exp(r_n)\left(\frac{G_0}{G_i}\right)$ when power controlled by BS_i and $G_i \geq \gamma_0$, $i = 0,1,2.$

$$\text{else} \quad I_k = 0 \tag{14}$$

Here r_n is a normal random variable with zero mean and standard deviation σ_e. S_R is the required received power at the respective BS which is normalized to is normalized to unity in the simulation since SIR is unaffected by assigning S_R=1. We have total interference due to all mobiles in region 'B' (following 14) as

$$I_B = \sum_{k=1}^{N_S} I_k \tag{15}$$

Similarly, interference powers from users at regions, 'C', 'D', 'E', 'F', 'G', 'H', 'I', 'J', are also evaluated. However, interference due to ($N_{nh} - 1$) MS-s in non-HO region (A) of the reference cell each power controlled by BS_0 is considered as:

$$I_A = S_R \sum_{i=1}^{N_{nh}-1} e^{r_{n,i}} \phi(i) \tag{16}$$

where $\phi(i) = 1$ for conventional power control. However, in case of truncated power control:

$$\phi(i) = 1 \quad if\ G_0 \geq \gamma_0 \text{ else } \phi(i) = 0\text{; for } i \text{ th user, } i = 1, 2, \ldots (N_{nh}\text{-}1) \tag{17}$$

Total interference,

$$I = I_A + I_B + I_C + I_D + I_E + I_F + I_G + I_H + I_I + I_J \tag{18}$$

Here I_l indicates the interference from MSs in region 'l', where l = A, B, C,……. J

The received signal from the desired user is:

$$U = S_R e^x \text{ and } SIR = U / I \tag{19}$$

where x is Gaussian with zero mean and variance σ_e^2.

3.1. BER Simulation

Direct sequence spreading and BPSK modulation is assumed. A Gaussian noise sample n_g with zero mean and variance $\sigma_g^2 = 1./(2 \times pg \times \gamma)$, (where γ = SIR) is added to each bit of a transmitted sequence and received bits are compared with the transmitted bits to estimate BER.

3.2. Packet loss and variable packet length

A sample of Gaussian noise, as found in Subsection 3.1, is added to each transmitted bits of a packet of $L(= L_p r_c)$ information bits. The received L bits of a packet are checked with their corresponding transmitted bits to estimate packet error. If the received packet is incorrect, the same packet (i.e., the same bit pattern) is retransmitted N_t times; where N_t = 1, 2,… $N_{\max}$. A packet loss occurs if it is not received correctly after N_t retransmissions. The average delay (D) is estimated as:

$$D = ((N_p + retx\_count)./N_p)T_i \quad (20)$$

where T_i is as shown in equation (7), N_p denotes the number of transmitted packets, $retx\_count$ denotes the total retransmissions of N_p packets. The throughput is:

$$G = L_p r_c / D \quad (21)$$

An initial small packet size is chosen and it is incremented in steps (Δ=2) till packet loss just exceeds δ. The highest packet length for which $P_{loss} < \delta$ is L_p^*. Now throughput, delay and packet loss are estimated by simulation following the steps as mentioned above where L_p is chosen as L_p^*.

3.3. Packet delay variation (PDV)

All packets will not have same delays. Delay of an individual packet (e.g. i th packet), $D(i)$, is recorded. Thus, variations in packet delay with respect to an average delay (D) have been observed for large number of packets. PDV is evaluated as:

$$PDV = E[\{D(i) - D\}^2]/D^2 \quad (22)$$

In the next section we provide some important results obtained based on our simulation.

4. Results and discussions

The following parameters are used for simulation: the spread BW is W = 5.0 MHz, the chip rate is $R_c = 5.0$ Mcps, the processing gain is pg = 312, fixed packet length is L_p = 1024. It is assumed that the standard deviation of power control error (pce) is σ_e = 2 dB, the path loss exponent is α_p = 4, the standard deviation of shadow fading is σ_s = 6 dB and the FEC code rate is r_c =0.5. The shadowing correlation is $a^2 = 0.3$. Two values of PR_h = 0.3 and 0.7 are assumed. The maximum allowed packet delay is T_{max} = 350 msec and the number of allowed retransmissions is N_t = 0.5 N_{max}. Several values of truncation probabilities $(1 - p(\gamma_0))$, for example, 0.01, 0.1 and 0.3 are considered. We assume $\sigma_s = 6dB$, $\sigma_e = 2dB$, $a^2 = 0.3$, $pg = 312$ for all results unless mentioned explicitly.

Figure 2 shows the effects of truncation and soft handoff on packet error rate. The truncation probabilities are given as $(1 - p(\gamma_o))$. It has been possible to reduce the packet error rate (PER) using truncation in comparison to conventional power control due to reduction in the interference as seen in curves (i,ii,iii,iv). PER reduces with increase in truncation probability as higher truncation reduces interference further as seen in curves (ii, iii, iv). Under same conditions of soft handoff, higher truncation improves the PER. PER can be reduced with higher degree of soft handoff as in curves (iii, v).

Throughput vs. mean arrival rate of users under different conditions of truncation and soft handoff is shown in Figure 3. Significant improvement in throughput is observed with truncated power control as compared to conventional power control (curves (i, ii, iii and iv)). A higher truncation probability of 0.3 yields a higher throughput as compared to a truncation probability of 0.1 (curves (ii, iii)). This is achieved by suspending the power transmission of some mobiles whose required transmission power crosses a threshold. For λ = 7; throughput increases by 7.21% when truncation probability (1-$p(\gamma_0)$) is increased from 0.1 to 0.3 for P_{Rh} = 0.3. Under same condition of truncation throughput is improved by using a higher degree of soft handoff (curves (i, iii)). For λ =7; throughput increases by 28.5 % as P_{Rh} increases from 0.3 to 0.7 while $p(\gamma_0)$ is = 0.9.

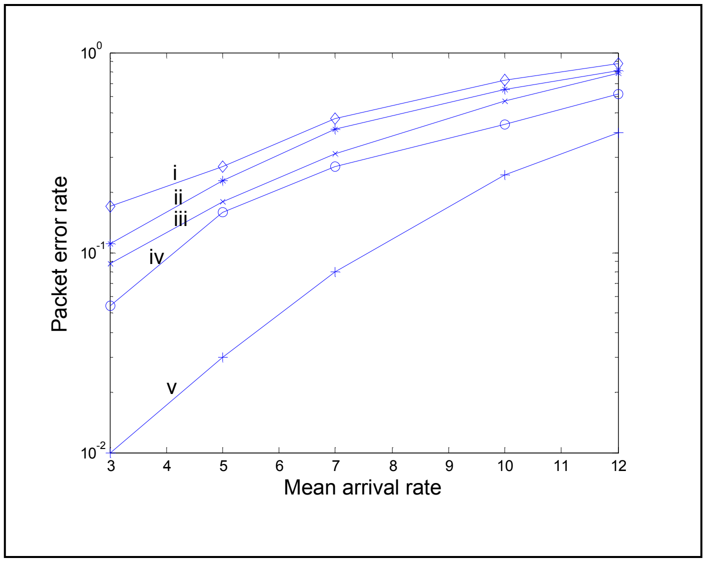


Figure2. Packet error rate vs. mean arrival rate under different truncation probability and soft handoff conditions. (i) $PR_h = 0.3$**, conventional power control; (ii)** $p(\gamma_o) = 0.99$**,** $PR_h = 0.3$**; (iii)** $p(\gamma_o) = 0.9$**,** $PR_h = 0.3$**; (iv)** $p(\gamma_o) = 0.7$**,** $PR_h = 0.3$**; (v)** $p(\gamma_o) = 0.9$**,** $PR_h = 0.7$

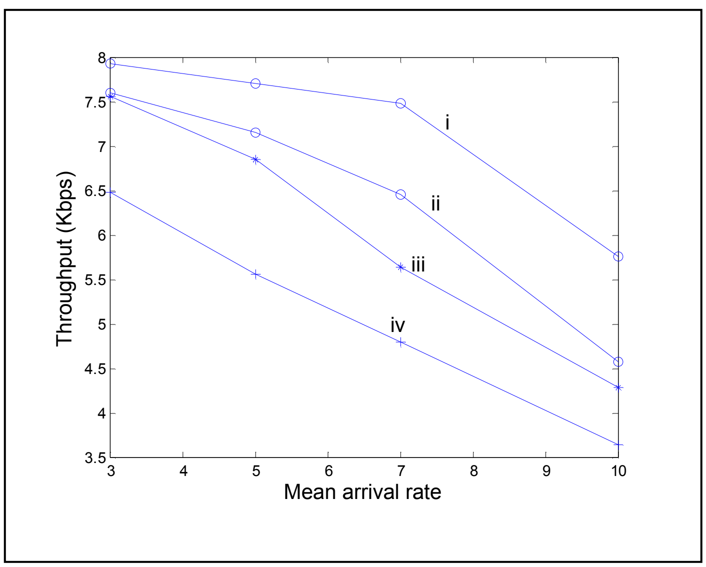


Figure3. Throughput (Kbps) vs. mean arrival rate under different truncation probabilities and soft handoff. (i) $p(\gamma_o) = 0.9$**,** $PR_h = 0.7$**; (ii)** $p(\gamma_o) = 0.7$**,** $PR_h = 0.3$**; (iii)** $p(\gamma_o) = 0.9$**,** $PR_h = 0.3$**; (iv)Conventional power control,** $PR_h = 0.3$**,** $a^2 = 0.3$**.**

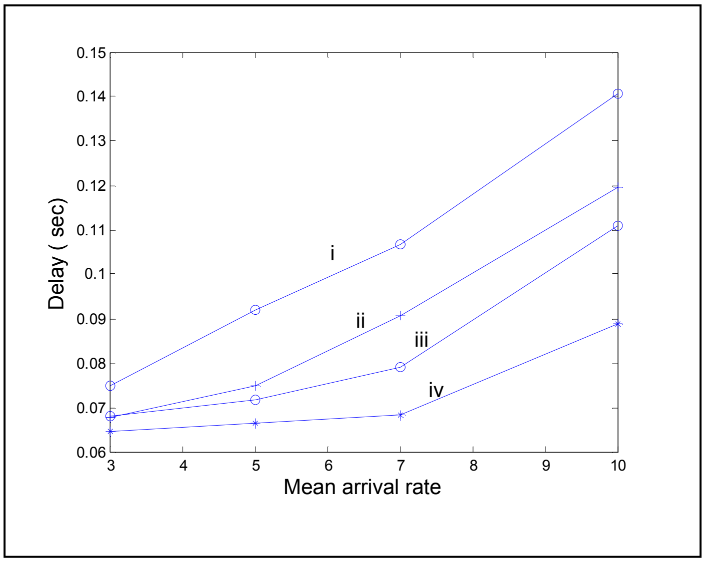


Figure4. Delay (sec) vs. mean arrival rate under different truncation probabilities and soft handoff. (i) Conventional power control, $PR_h = 0.3$**; (ii)** $p(\gamma_o) = 0.9$**,** $PR_h = 0.3$**; (iii)** $p(\gamma_o) = 0.7$**,** $PR_h = 0.3$**; (iv)** $p(\gamma_o) = 0.9$**,** $PR_h = 0.7$**.**

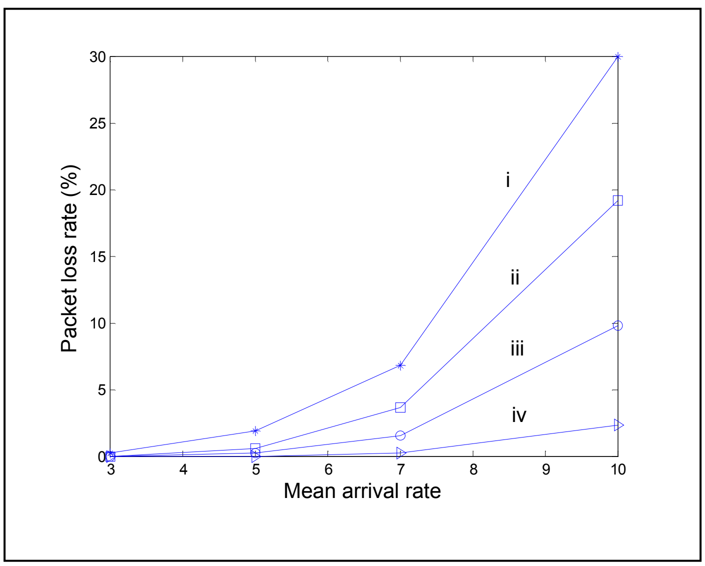


Figure5. Packet loss rate vs. mean arrival rate under different truncation probabilities and soft handoff. (i) $p(\gamma_o) = 0.99$**,** $PR_h = 0.3$ $a^2 = 0.3$**; (ii)** $p(\gamma_o) = 0.9$**,** $PR_h = 0.3$ $a^2 = 0.3$**; (iii)** $p(\gamma_o) = 0.7$**,** $PR_h = 0.3$ $a^2 = 0.3$**; (iv)** $p(\gamma_o) = 0.9$**,** $PR_h = 0.7$**,** $a^2 = 0.3$

Similar effects of truncation and soft handoff on delay (sec) are depicted in Figure 4. Using truncated ARQ, average delay is always maintained below the desired limit. Truncated power control yields significantly lower delay as compared with conventional power control (curves (i, ii, iii, iv)). A higher truncation probability reduces delay due to reduction in overall interference (curves (ii, iii)). Further, reduction in delay is possible with increasing degree of soft handoff (curves (ii, iv)).

Figure 5 shows the packet loss associated with truncated ARQ under different power truncation and soft handoff conditions. It is seen that higher truncation probability reduces packet loss due to decrease in interference level. Packet loss is obtained by increasing the degree of soft handoff from $PR_h = 0.3$ to $PR_h = 0.7$ as seen in curves (ii, iv). For λ = 7; packet loss rate reduces by 52% when truncation probability (1-$p(\gamma_0)$) is increased from 0.1 to 0.3 for P_{Rh} = 0.3. Packet loss rate reduces by 97% as P_{Rh} increases from 0.3 to 0.7 while $p(\gamma_0)$ is fixed at 0.9.

Figure 6 shows the variation of packet length (in bits) with traffic. The packet size is varied in order to ensure a packet loss $<= 5\%$. Higher traffic requires smaller packet size. Higher degree of truncation allows larger packet size (curves (ii, iii, iv)). Higher degree of soft handoff allows larger packet size (curves (i , iii)).

Figure 7 shows the plots of PDV vs. mean arrival rate. Higher truncation probability reduces packet delay variation. For example, PDV reduces by 10.5% when $p(\gamma_0)$ is reduced from 0.9 to 0.7 while P_{Rh} is fixed at 0.3 for λ = 5. However, PDV reduces by 80.3% as P_{Rh} increases from 0.3 to 0.7 when $P(\gamma_0)$ is fixed at 0.9.

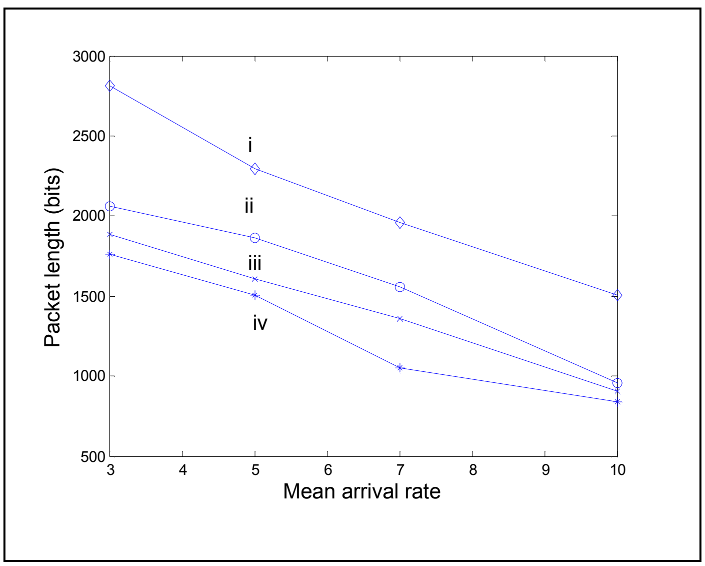
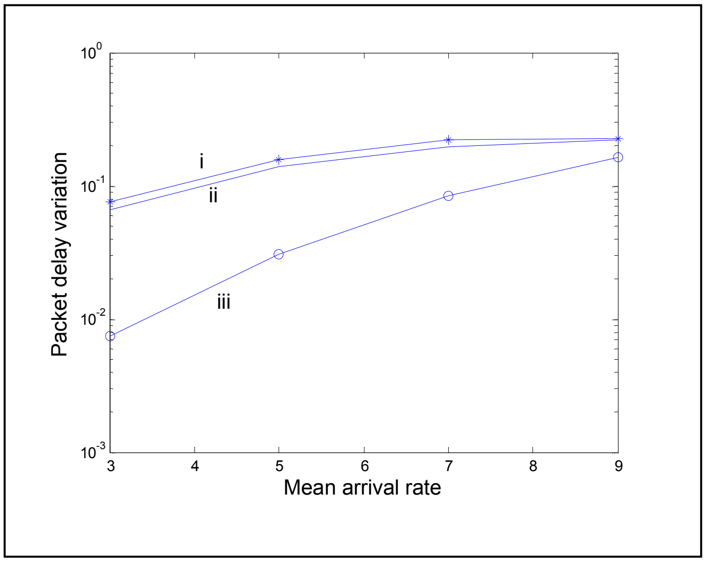


Figure6. Packet length (bits) vs. mean arrival rate under different truncation probabilities and soft handoff. (i) $p(\gamma_o) = 0.9$, $PR_h = 0.7$**; (ii)** $p(\gamma_o) = 0.7$, $PR_h = 0.3$**; (iii)** $p(\gamma_o) = 0.9$, $PR_h = 0.3$**; (iv)** $p(\gamma_o) = 0.99$, $PR_h = 0.3$, $a^2 = 0.3$ **in all cases.**



Fugure7. Packet delay variation (PDV) vs. mean arrival rate under different truncation probabilities and soft handoff. (i) $p(\gamma_o) = 0.9$, $PR_h = 0.3$; **(ii)** $p(\gamma_o) = 0.7$, $PR_h = 0.3$; **(iii)** $p(\gamma_o) = 0.9$, $PR_h = 0.7$.

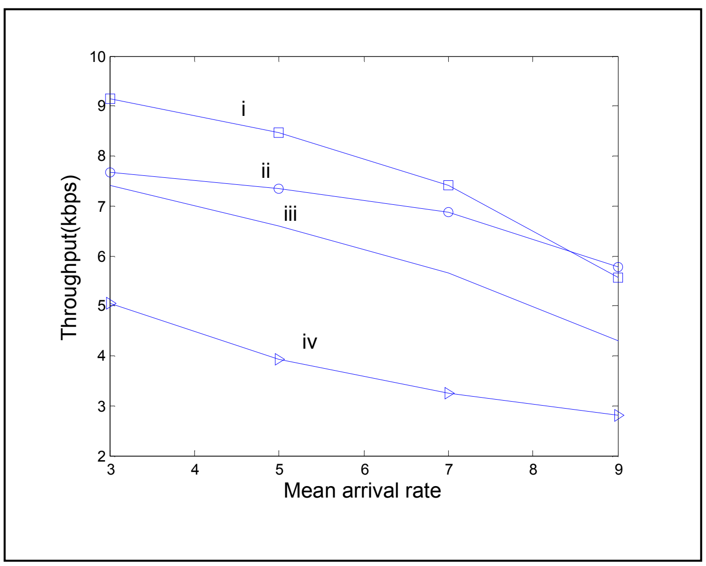


Figure8. Effects of power control error, shadowing, PRh on throughput. (i) $\sigma_s = 6dB$, $\sigma_e = 2dB$, $pg = 256$, $PR_h = 0.3$; **(ii)** $\sigma_s = 6dB$, $\sigma_e = 1dB$, $pg = 312$, $PR_h = 0.3$; **(iii)** $\sigma_s = 6dB$, $\sigma_e = 2dB$, $pg = 312$, $PR_h = 0.3$; **(iv)** $\sigma_s = 8dB$, $\sigma_e = 2dB$, $pg = 312$, $PR_h = 0.3$, $p(\gamma_o) = 0.9$ **for all cases.**

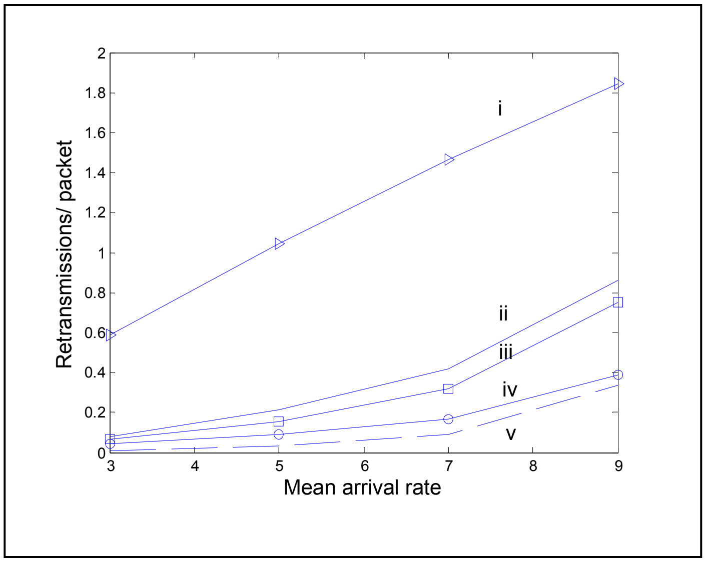


Figure9. Packet Retransmission rate vs. mean arrival rate. (i) $\sigma_s = 8dB$, $\sigma_e = 2dB$, $pg = 312$, $PR_h = 0.3$; **(ii)** $\sigma_s = 6dB$, $\sigma_e = 2dB$, $pg = 312$, $PR_h = 0.3$; **(iii)** $\sigma_s = 6dB$, $\sigma_e = 2dB$, $pg = 256$, $PR_h = 0.3$; **(iv)** $\sigma_s = 6dB$, $\sigma_e = 1dB$, $pg = 312$, $PR_h = 0.3$; **(v)** $\sigma_s = 6dB$, $\sigma_e = 1dB$, $pg = 312$, $PR_h = 0.7$; $p(\gamma_o) = 0.9$ **for all cases.**

The effects of power control error, shadowing and processing gain on throughput are shown in Figure 8. We have assumed $p(\gamma_o) = 0.9$ for all the curves in Figure 8. Throughput decreases as power control error increases (curves (ii) and (iii)). Change in the value of processing gain affects interference and data rate. Data rate decreases with increase in processing gain (curves (i) and (iii)). It is observed that throughput is higher for $pg = 256$ at lower range of mean arrival rate. But interference also increases with decrease in processing gain. This causes throughput to become nearly same for two different processing gains at higher traffic i.e., $\lambda = 9$ (curves (i) and (iii)). Throughput would be more at $pg = 312$ as compared to the case with $pg = 256$ when mean arrival rate increases beyond 9. This is expected as interference also increases due to increase in traffic (higher mean arrival rate).

Retransmission rate vs. mean arrival rate under various conditions is plotted in Figure 9. The effects of power control error, shadowing and processing gain on the average number of retransmission per packet are shown. Higher power control error requires more number of retransmission per packet (curves (ii) and (iv)). Similarly, retransmission rate is reduced as processing gain or degree of soft HO is increased. This is due to improvement of signal to interference ratio under such conditions (curves (ii), (iii), (iv) and (v)).

Table1. Truncation probabilities (1-p(γ0)) under various propagation conditions

No	γ_0	$(1-p(\gamma_0))$ $\sigma_s = 6$; $a^2 = 0$	$(1-p(\gamma_0))$ $\sigma_s = 6$; $a^2 = 0.3$	$(1-p(\gamma_0))$ $\sigma_s = 8$; $a^2 = 0$	$(1-p(\gamma_0))$ $\sigma_s = 8$; $a^2 = 0.3$
1	0.05	0.0030	0.0007	0.0148	0.0060
2	0.1	0.0108	0.0042	0.0334	0.0174
3	0.15	0.0209	0.0100	0.0507	0.0304
4	0.2	0.0320	0.0175	0.0669	0.0436
5	0.5	0.0988	0.0747	0.1430	0.1147
6	1	0.1893	0.1672	0.2274	0.2035
7	1.5	0.2573	0.2415	0.2855	0.2677

Table 1 presents the variations of truncation probability $(1-p(\gamma_o))$ with respect to cutoff fade depth (γ_0) for different values of shadowing correlation (a^2), and the standard deviation of shadow fading (σ_s). If shadowing correlation is increased from 0 to 0.3, truncation probability reduces. The truncation probability increases, if cut off fade depth is considered to be high, or if we consider higher shadowed environment. An MS requires increasing its power when shadow fading is high. In such case, BS truncates that mobile. Hence the truncation probability is increased in case of higher shadowing. An MS receives better signal, when shadowing is correlated, so truncation probability is reduced.

Table2. Number of retransmissions under various situations ($\sigma_s = 6dB$, $\sigma_e = 2dB$, $a^2 = 0.3$, $pg = 312$ for 5000 packets in each case.

No	λ	PR_h=0.3; $p(\gamma_0)$=0.9	PR_h=0.7; $p(\gamma_0)$=0.9	PR_h=0.3; $p(\gamma_0)$=0.7
1	3	409	38	377
2	5	1065	156	903
3	7	2088	467	1570
4	9	3655	1172	2679
5	10	4319	1684	3290

When truncation probability is high, the interference is reduced as more number of MSs are truncated. This improves signal to interference ratio (SIR) or packet error rate (PER) and hence reduces number of retransmissions (shown in Table 2). The number of retransmissions reduces by 26.7% when $p(\gamma_0)$ is reduced from 0.9 to 0.7 for P_{Rh} = 0.3 & λ = 9. Increase in the truncation probability $(1-p(\gamma_0))$ leads to better power management for other users maintaining overall lower interference at the BS. The number of retransmissions reduces by 68 % if P_{Rh} is increased from 0.3 to 0.7 and $p(\gamma_0)$ is fixed at 0.9. Higher degree of soft HO reduces interference in the reverse link, and improves overall performance by reducing number of retransmissions.

5. Conclusions

Performance of packet data service is evaluated in presence of soft handoff and truncated power control algorithm. Truncated ARQ is used in link layer to maintain the average delay below the desired limit. A significant improvement in performance of data services is achieved under combined influence of truncated power control and soft handoff. Higher level of power truncation, as well as, higher degree of soft handoff, reduces packet error, thereby improves delay and throughput performance. Variation in packet delay could be minimized with probabilistic increase in truncation. The number of required retransmission could be made low with higher degree of soft handoff. Truncated ARQ at link layer improves the situation by maintaining a constraint on packet delay. Packet loss associated with truncation on ARQ could be compensated using higher level of truncation on power or higher degree of soft handoff. A variable packet length transmission scheme is adopted to maintain packet loss below the desired limit. Both packet loss and delay constrained QoS are simultaneously satisfied using variable packet length and TARQ. Higher degree of soft handoff, as well as, higher level of power truncation allows higher packet length under a given loss constraint. Thus higher level of power truncation improves performance of data services in terms of delay, throughput and packet error. However, with increase in truncation probability, more number of interfering users is suspended from transmitting and they need to contend for network access when they come out of deep fading situation. This work can further be extended incorporating mobility of users.

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