Comparing the Performance of Inter-Sector/Intra-Sector Scheduling and ARQ for Multimedia Traffic in Wireless Access Networks

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***Abstract*-Multimedia transmission in wireless networks requires high quality of service in terms of packet error rate (PER), throughput and packet delay. Inter-Sector/Intra-Sector Scheduling (ISISS) has been proposed [1] to use basestations coordination in packet scheduling to reduce PER by avoiding (minimizing) concurrent transmission of potential cochannel interferers. Since ARQ schemes can also be used for PER reduction, it is imperative to compare the performance of ISISS with that of ARQ. Results show that ARQ is more effective in reducing PER at the expense of the incurred packet delay due to packet retransmission particularly at medium to high loading.**

***Keywords*-ARQ, packet scheduling, multimedia wireless communications.**

I. INTRODUCTION

Inter-Sector/Intra-Sector Scheduling (ISISS) concept has been introduced in [1] as a dynamic time slot allocation that enhances the packet-level system performance by minimizing the cochannel interference. In ISISS, basestations (BSs) exchange information of the available traffic. Then, each BS schedules its local traffic based on this information to avoid concurrent transmission by potential dominant interferers. Therefore, ISISS schedules the packet transmission in each sector taking into account the traffic information in the sectors of potential dominant interferers. For instance, as shown in Fig. 1, the potential dominant interferers for users in sector 1(shaded sector)/cell 4, are the signals transmitted for users in sector 1/cell 1 and sector 1/cell 7. It is noteworthy that users in sector 1/cell 7 cause this interference in the downlink because of the assumed wraparound grid. Therefore, BS 4 sends the traffic information of users in sector 1/cell 4 to BSs 1 and 7. Meanwhile, BS 4 receives the traffic information of users in sector 1/cells 1 and 7. This information includes the arrival time and service type of each packet waiting in the transmission queue. BSs 1, 4, and 7 use this information to avoid (or minimize) concurrent transmission of any users in these three sectors (sector 1/cells 4, 1, and 7). We call these sectors that have potential dominant interferers "interference group". By eliminating the concurrent transmission within each interference group, the interference level can be drastically reduced. Obviously, there are other users that still can cause interference to users in sector 1/cell 4 including users in sector 1/cells 2, 3, 5, 6, and 9. However, their interference level is much less than that of sector 1/cell1 1 and 7 because of the large path loss and the antenna directivity at both BSs and SSs. The number of occupied slots in each sector as well as the decision of which time slots are allocated to which users in each sector depend on the employed intra-sector and inter-sector scheduling schemes.

The intra-sector scheduling scheme schedules the packet transmission of all users inside a sector while the inter-sector scheme schedules the traffic transmission of different sectors within the interference group as shown in Fig. 2. First Come First Serve (FCFS), Weighted Round-Robin (WRR), Weighted Fair Queuing (WFQ), or any other schemes can be used at any of the two levels.

It has been shown in [1] that ISISS can reduce the packet error rate (PER) by one order of magnitude but at the expense of the packet delay. Automatic Repeat Request (ARQ) schemes can also be used to decrease PER. However, ARQ is expected to cause significant packet delay and throughput degradation. Hence, it is essential to compare the performance of both schemes

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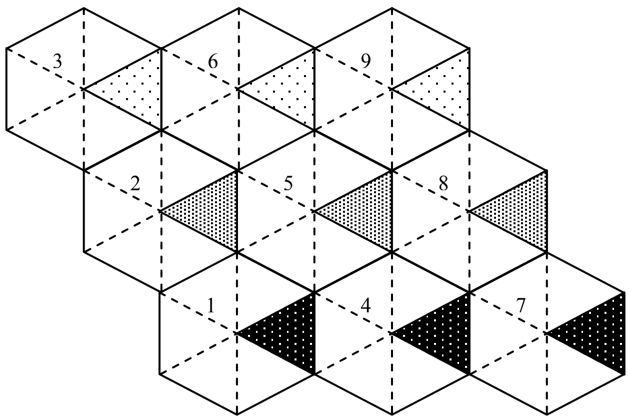

Fig. 1. Interference groups of sector 1.

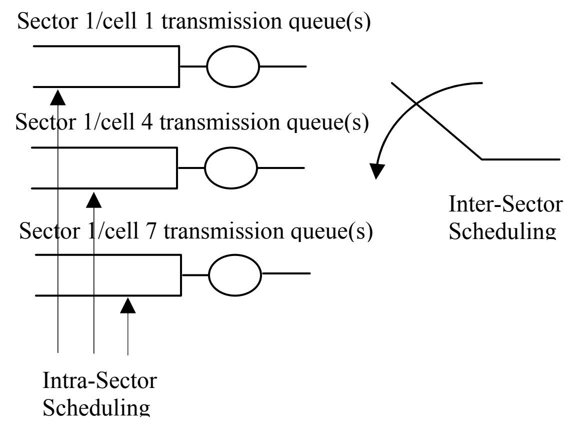

Fig. 2. Intra-sector and inter-sector scheduling.

(ISISS and ARQ) for multimedia transmission. In this paper, we compare the packet-level performance of ISISS and ARQ in terms of PER, packet delay, and throughput.

II. SYSTEM MODEL

A hexagonal cellular structure with a wraparound structure is used. Each cell is divided into 6 sectors. Sinc-shaped beam pattern with 60^o beamwidth is used at both BSs and subscriber stations (SSs). While the antenna beams at the BSs are fixed, it is assumed that the antenna beams at the SSs are electronically steered to point at the direction of the serving BSs. The channel model consists of an exponential path loss model with an exponent (n) of 3, lognormal shadowing with a standard deviation (σ) of 8, and flat Rayleigh fading.

A frequency reuse plan of 1/6 is employed such that the total spectrum is divided into 6 equal sub-bands allocated to the 6 sectors and reused in each cell as shown in Fig. 1. The employment of directional antennas at both BSs and SSs enables such a tight frequency reuse plan. Time is divided into frames with a frame-duration of 5 ms consisting of 9 slots in a TDMA fashion.

This work focuses on the downlink performance since it is the limiting factor in many multimedia applications. However, the proposed algorithm can be implemented in the uplink as well. Real-time video service is assumed here. Packets are generated using two superimposed Interrupted Poisson Processes (IPP). The traffic model used in this work is proposed for broadband wireless access networks in [2]. 16-QAM with bit-interleaved coded modulation (BICM) [3] is used in this work. The required SIR value corresponding to BER of 10^{-4} is equal to 9.25 dB.

Fixed users assumed in this work. However, the proposed algorithm can be utilized by mobile users. It is assumed that users are uniformly distributed and are assigned to the best serving BS (not necessarily the nearest one). It is assumed that the ARQ scheme uses Go-Back-N policy since the selective repeat policy is rarely used because of its complexity [4]

III. PERFORMANCE ANALYSIS

The performance of ISISS has been analyzed using computer simulation [1]. In order to analyze the performance of ARQ, the system is modeled as M/G/1 system as shown in Fig. 3. Assuming that all errors are detectable, PER of ARQ scheme (PER_{ARQ}) can be given by

$$PER_{ARQ} = PER_o^{n+1} \tag{1}$$

where PER_o is the PER without ARQ and n is the maximum number of retransmission. The assumption of having all errors detectable is reasonable taking into account that in wireless access networks, CRC-32 is employed for error detection [5]. Limiting the number of retransmission is necessary since for real-time applications it is more efficient to drop the delayed packet rather than trying to retransmit it after exceeding a certain delay threshold value. The packet delay (D_p) is given by

$$D_p = 0.5T_f + \frac{\lambda E[\tau^2]}{2(1-\rho)} \tag{2}$$

where T_f is the frame duration, λ is the packet arrival rate, ρ is the utilization factor which is equal to λ/μ,

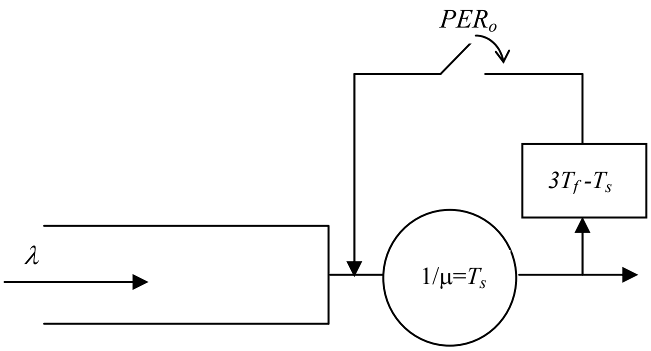

Fig. 3. ARQ M/G/1 Model.

where $1/\mu$ is the packet transmission time without any retransmission (i.e. without ARQ) which is equal to T_s, and $E[\tau^2]$ is the second moment of the packet transmission time with ARQ (τ). The first term of D_p ($0.5T_f$) is the framing delay, while the second term is the queuing delay of M/G/1 systems [6].

In order to calculate $E[\tau^2]$, the probability mass function (pmf) of τ has to be determined. As shown in Fig. 4, if a packet in frame1 in DL is erroneously detected, then a negative acknowledgement (NACK) will be sent in frame 2 in UL. As a result, the same packet will be scheduled for transmission in frame 4 in DL since packets to be transmitted in frame 3 had to arrive before the frame starting point. Hence, each retransmission incurs an additional delay of $3T_f$. Then, the pdf of τ can be expressed as

$$Pr(\tau = T_s + 3iT_f) = (1 - PER_o)\, PER_o^{\,i} \qquad (3)$$

where T_s is the slot duration, and i is the number of retransmission (i=0, 1,…, n).

IV. Results

Fig. 5 shows PER of ISISS and ARQ (with n=1 & 2). It is apparent that ARQ is more effective in reducing PER particularly at low to medium loading and with higher maximum number of retransmission (n). For instance, at 100 user/cell, PER is reduced from $1.49\text{x}10^{-2}$ with ISISS to $2.1\text{x}10^{-4}$ with ARQ (n=1) and to $3.3\text{x}10^{-5}$ with ARQ (n=2), while at 400 user/cell, ARQ reduces *PER* from $1\text{x}10^{-2}$ to $9\text{x}10^{-3}$ (n=1) and to $8.7\text{x}10^{-4}$ (n=2). This enhancement in PER comes at the expense of higher packet delay (D_p) as depicted in Fig. 6. At low loading values ISISS and ARQ have the same value of D_p, which is equal to the framing delay. At medium loading values, ARQ has a higher D_p but still tolerable. For instance, at loading values of 300 user/cell, D_p is

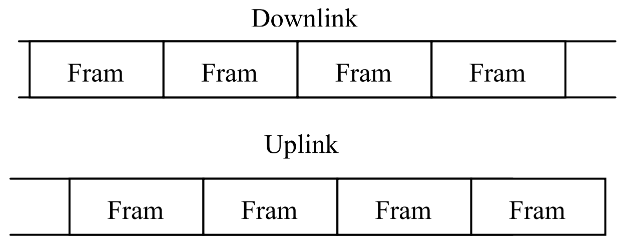

Fig. 4. Downlink/Uplink Frames.

increased from 7.7 msec with ISISS to 42.3 msec with ARQ (n=1) and to 88.6 msec with ARQ (n=2). At high loading values, D_p of ARQ is much higher than that of ISISS. For example, At 350 user/cell, D_p is jumped from 110 msec with ISISS to 400 msec with ARQ (n=1) and to more than 600 msec with ARQ (n=2). Throughput is not affected by ISISS as shown in [1]. However, the throughput reduction due to ARQ is shown to be increasing with loading and can be up to 15% especially at high loading values

V. Conclusions

A comparison of the packet-level performance of ISISS and ARQ is presented in this paper. It is shown that PER reduction due to ARQ is higher than that of ISISS. However, ARQ causes higher packet delay especially at medium to high loading values. Hence, at low loading values ARQ has a better performance in terms of PER, D_p and throughput, while at medium to high loading values it is shown that ISISS outperforms ARQ. Developing a joint ARQ & ISISS scheme is a topic for future research.

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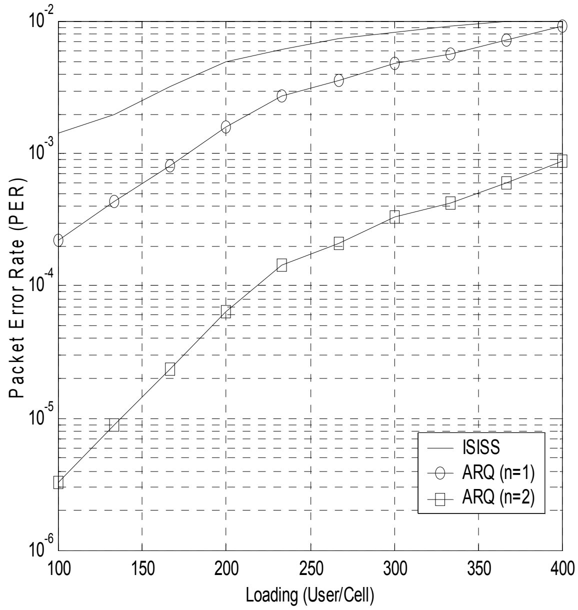

Fig. 5. Packer Error Rate (PER) of ISISS and ARQ.

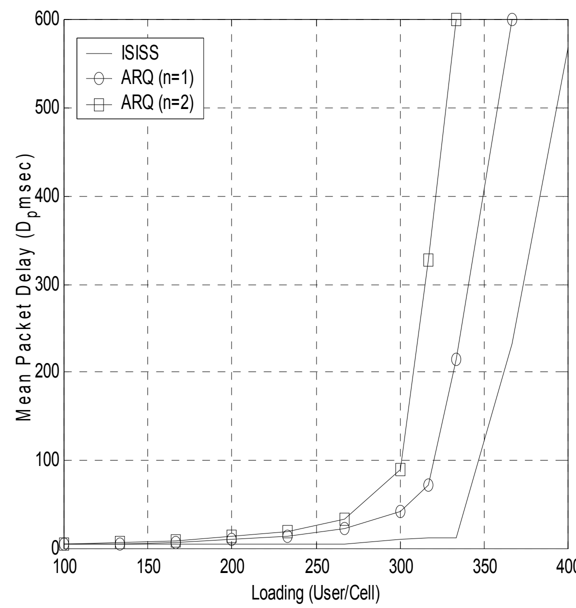

Fig. 6. Mean packet Delay (D_p) of ISISS and ARQ.