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Title: System Performance Comparison of Chase Combining and Adaptive IR for HSDPA

Document for: Discussion and Decision

1 Introduction

System simulation results comparing the performance of Chase combining with the asynchronous, adaptive incremental redundancy (A^2IR), originally proposed in [4], are presented.

2 Simulation Results

Results for both Chase combining and A^2IR were obtained using the data rates table shown in Table 1. Both schemes use variable TTI for transmission as shown in the table.

Table 1. Data rates

TTI [slots]	Data rate [Kb/s] (Modulation, Coding Rate)				
	7680 bits code block	5120 bits code block	3840 bits code block	2560 bits code block	1280 bits code block
15	768 (QPSK, 0.16)	512 (QPSK, 0.106)	384 (QPSK, 0.08)	256 (QPSK, 0.053)	128 (QPSK, 0.027)
5	2304 (QPSK, 0.48)	1536 (QPSK, 0.32)	1152 (QPSK, 0.24)	768 (QPSK, 0.16)	384 (QPSK, 0.08)
3	3840 (QPSK, 0.8)	2560 (QPSK, 0.53)	1920 (QPSK, 0.4)	1280 (QPSK, 0.27)	640 (QPSK, 0.13)
2	5760 (8PSK, 0.8)	3840 (QPSK, 0.8)	2880 (8PSK, 0.4)	1920 (QPSK, 0.4)	960 (QPSK, 0.2)
1	11520 (64QAM, 0.8)	7680 (16QAM, 0.8)	5760 (8PSK, 0.8)	3840 (QPSK, 0.8)	1920 (QPSK, 0.4)

The throughput metrics used viz. Over-The-Air (OTA) Throughput, Service Throughput and Packet Call Throughput are as defined in the TR (see [1]). In addition, the cumulative distribution function (cdf) of the UE packet call throughput is also provided as a measure of quality of service.

As used in [1], the following assumptions are made (other assumptions from TR are listed in the Appendix of this document).

– 30% power used by overhead channels

– Single path Rayleigh fading with 3km/hr and 30 km/hr speeds.

– Fractional Recovered Power (FRP) is 0.98

The following additional assumptions are made in obtaining the simulation results:

- No limit on maximum number of retries.
- Fast cell selection is not considered.
- Results do not count padding into the throughput (i.e. only information bits count towards throughput).
- Channel quality measurement and ACK/NACK feedback are error-free.
- The channel quality feedback delay is assumed to be 6 slots and the ACK/NACK delay is assumed to be 3 slots.
- Maximum C/I scheduler is used for both schemes.

The Chase combining scheme has flexibility in selecting the MCS and TTI only for the first transmission of a frame. The selection is done using Table 1. The A^2IR scheme can select MCS and TTI both on the first transmission as well as on retransmissions of a frame, again using Table 1. The adaptive scheme uses link quality feedback valid during previous transmissions of a frame to obtain an estimate of the aggregated energy for that frame at the receiver. That information is used in conjunction with the most recent link quality feedback to determine the MCS and TTI for retransmission. This adaptive scheme attempts to pick the MCS and TTI to fulfil the residual energy required for the frame to be successful with high probability. For example, for a given MCS, suppose we need E_b/N_o of 1 (= 0 dB) for successful decoding. If E_b/N_o from earlier transmissions is 9/10, then we need only 1/10 (= -10 dB) more. The MCS for retransmission can be selected to provide just the required energy (= -10 dB) under the current channel conditions.

2.1 System performance at 3.0 Km/h

The average throughput metrics are shown for A^2IR and Chase combining in Table 2 and Table 3 respectively for the case of 3 km/hr. In addition to the gains seen in service throughput and average packet call throughput, it is important to consider the cdf of the packet call throughput seen by UEs. This is a measure of the Quality of Service provided to UEs by the system.

Table 2. Throughput performance of A^2IR

Number of UEs	OTA [Kb/s]	Service [Kb/s]	Packet [Kb/s]	Utilization
12	1522.0	433.8	1081.8	0.288
37	1764.5	1321.9	938.1	0.735
46	1831.1	1556.2	871.8	0.851
50	1927.4	1765.5	831.9	0.917
56	2018.2	1908.8	813.4	0.947
65	2198.7	2145.9	799.4	0.976
75	2368.3	2356.5	756.0	0.995
80	2424.7	2420.0	731.4	0.998

87	2526.5	2525.3	736.0	1.000
100	2653.0	2653.0	723.9	1.000
110	2776.7	2776.7	716.5	1.000
120	2879.4	2879.4	708.5	1.000
130	2957.5	2957.5	702.9	1.000

Table 3. Throughput performance of Chase combining

Number of UEs	OTA [Kb/s]	Service [Kb/s]	Packet [Kb/s]	Utilization
12	1303.0	440.9	977.9	0.346
37	1520.3	1288.3	786.2	0.850
56	1780.9	1756.4	693.4	0.987
75	2037.8	2036.9	669.2	1.000
100	2351.7	2351.7	660.4	1.000

In Figure 1-Figure 4 we try to match the user packet call throughput CDFs obtained from Chase combining and A^2IR as a measure of increased capacity from A^2IR for the same quality of service. In general, it can be observed that gains in number of UEs supported with A^2IR as compared to Chase combining (for roughly the same QoS) can range from 30-40%.

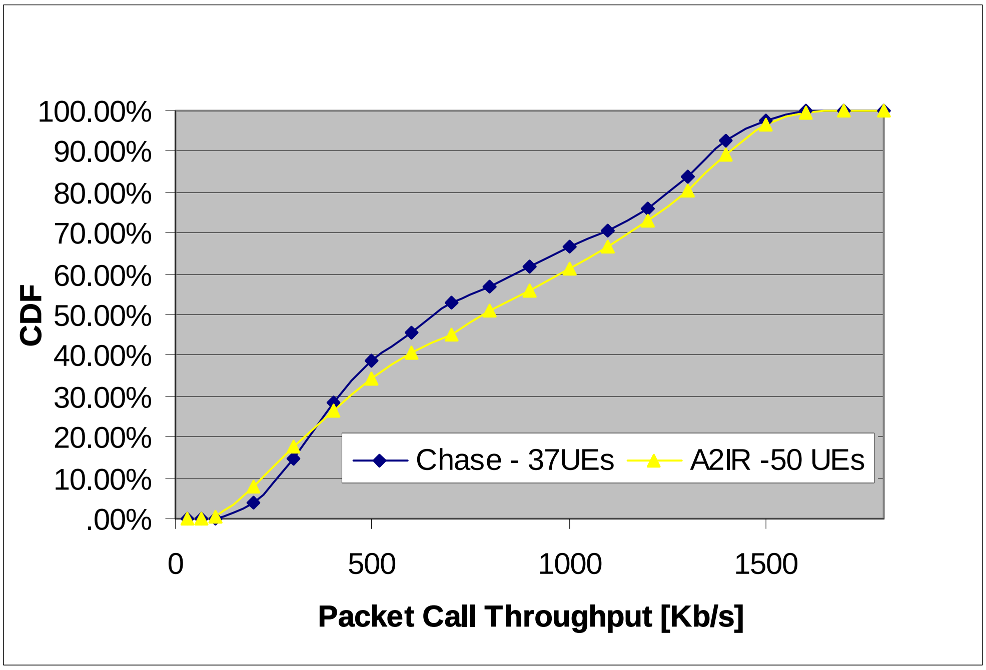

Figure 1. CDF of Packet Call Throughput at 3.0 Km/h

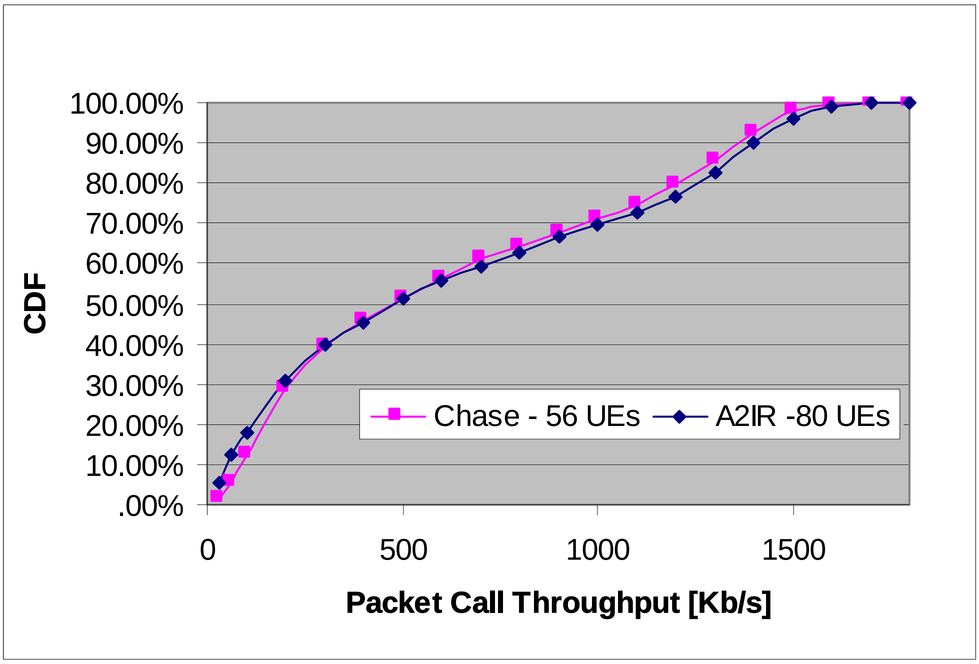

Figure 2. CDF of Packet Call Throughput at 3.0 Km/h

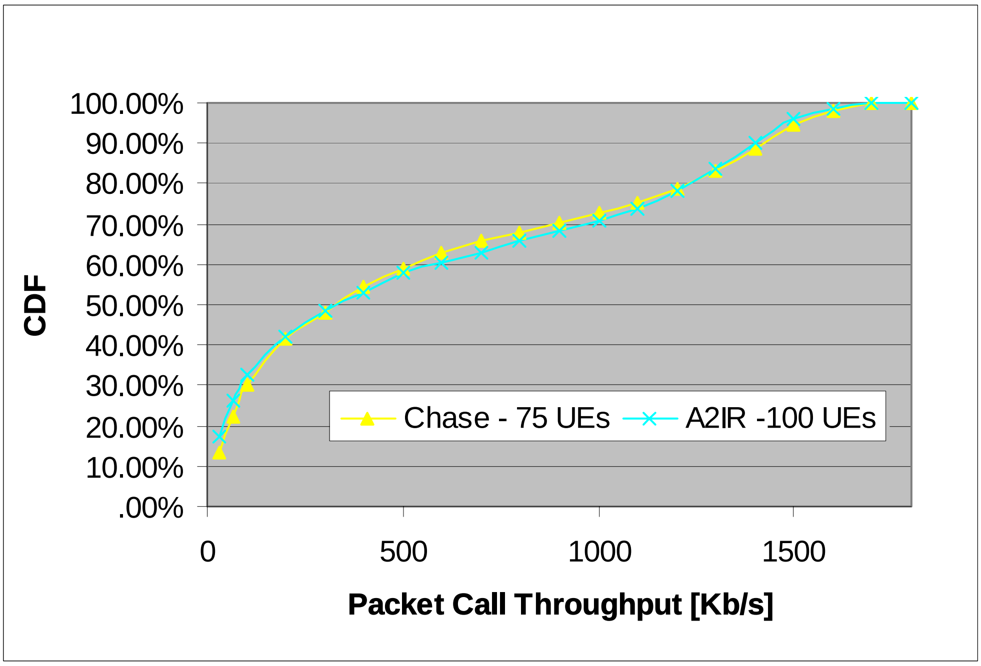

Figure 3. CDF of Packet Call Throughput at 3.0 Km/h

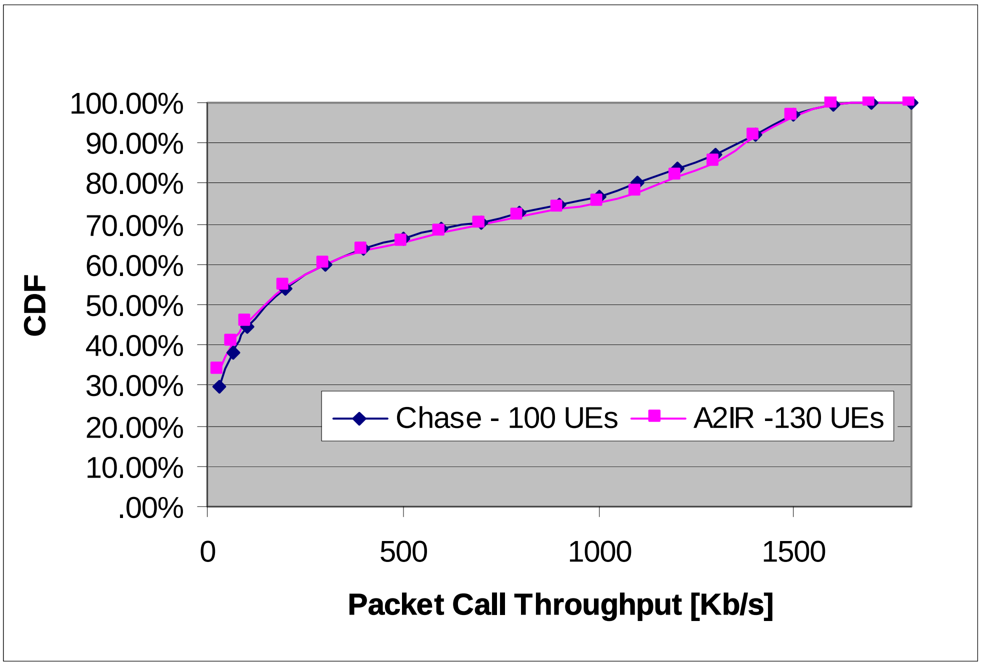

Figure 4. CDF of Packet Call Throughput at 3.0 Km/h

2.2 System performance at 30.0 Km/h

The average throughput metrics are shown for A^2IR and Chase combining in Table 4 and Table 5 respectively for the case of 30 km/hr.

Table 4. Throughput performance of A^2IR

Number of UEs	OTA [Kb/s]	Service [Kb/s]	Packet [Kb/s]	Util
12	1490.7	428.5	1078.3	0.291
37	1766.4	1311.2	935.7	0.737
46	1833.1	1574.6	862.5	0.860
56	2012.6	1893.5	833.0	0.941
65	2156.2	2109.9	785.3	0.979
75	2291.5	2283.9	752.2	0.997
87	2485.4	2483.1	740.6	0.999
100	2629.8	2629.8	714.0	1.000
110	2711.3	2711.3	707.7	1
120	2853.9	2853.9	730.9	1

Table 5. Throughput performance of Chase combining

Number of UEs	OTA [Kb/s]	Service [Kb/s]	Packet [Kb/s]	Util
12	1302.971	440.9024	977.889	0.345525
37	1520.297	1288.273	786.218	0.849984
56	1780.909	1756.409	693.3747	0.986756
75	2037.769	2036.939	669.1564	0.999599
100	2351.71	2351.71	660.407	1

Similar conclusions can be drawn for the case of 30km/hr speed as shown in Figure 5-Figure 8

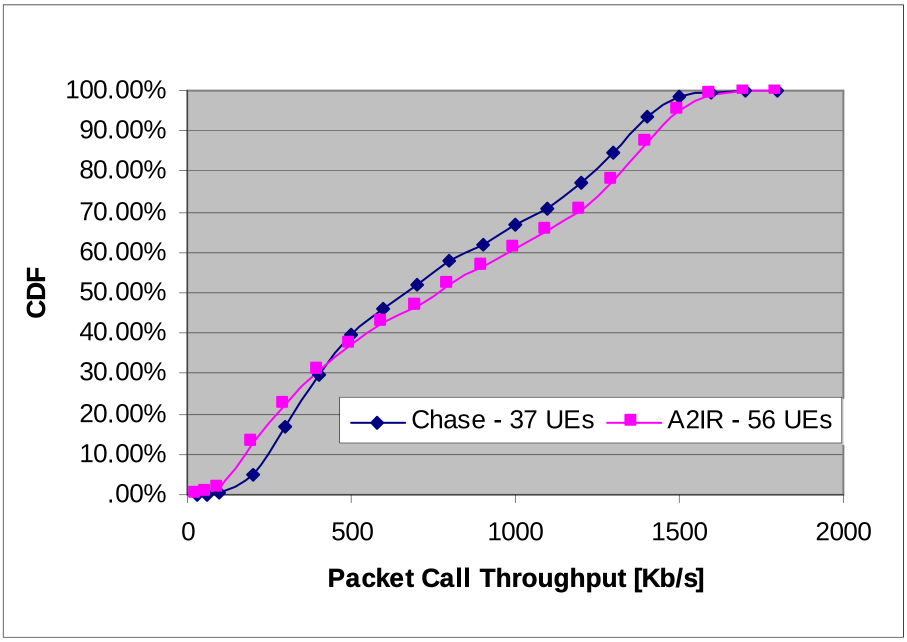

Figure 5. CDF of Packet Call Throughput at 30.0 Km/h

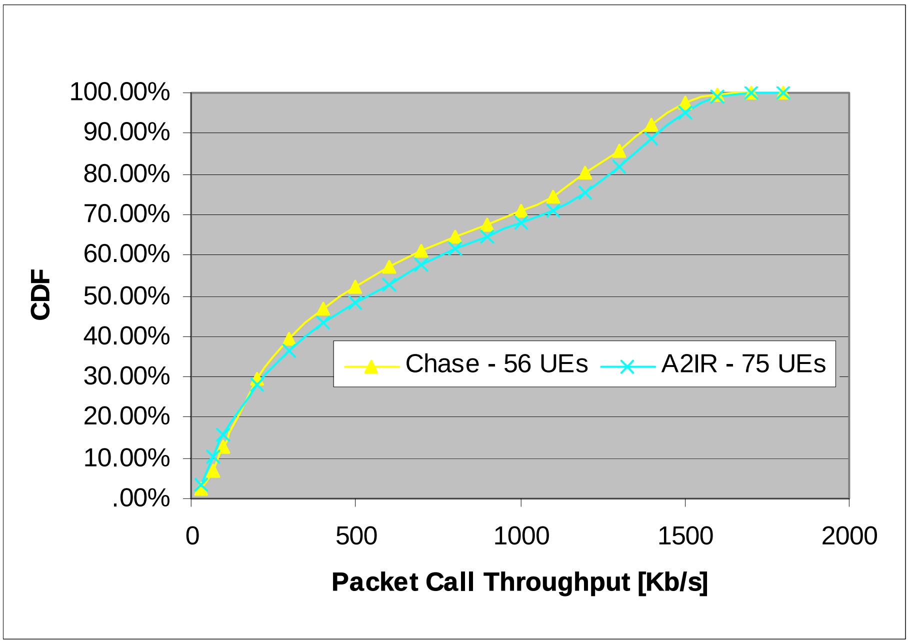

Figure 6. CDF of Packet Call Throughput at 30.0 Km/h

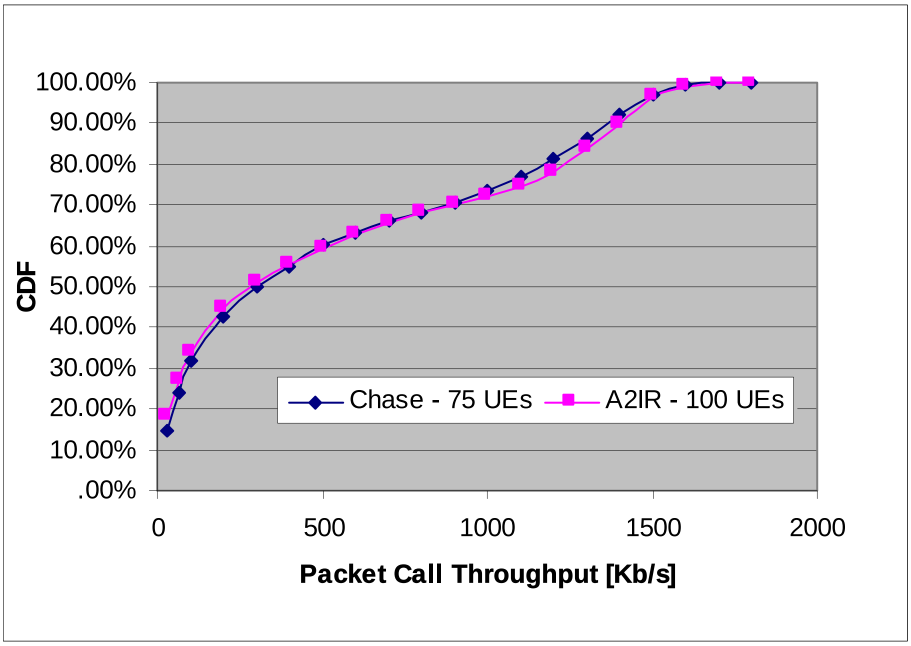

Figure 7. CDF of Packet Call Throughput at 30.0 Km/h

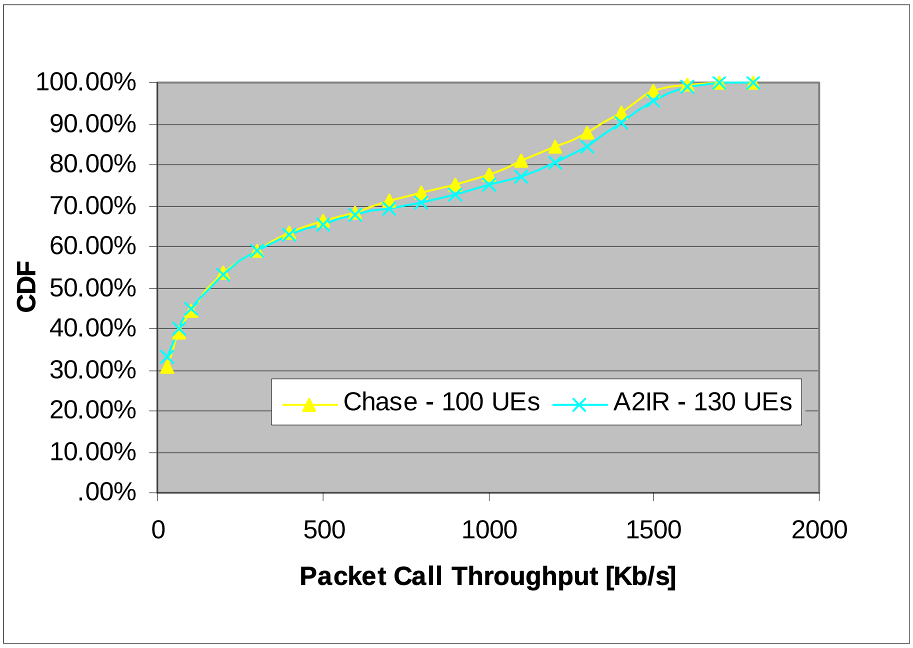

Figure 8. CDF of Packet Call Throughput at 30.0 Km/h

3 Signalling and Buffer Requirements

A total of 2 bits will be needed for New/Continue and redundancy version indication for adaptive IR as shown in Table 6. With the highest coding rate of 0.8 and mother code rate of 0.2 a maximum of 4 different versions of IR transmissions are possible. Note that the at least 1-bit New/Continue indication will even be needed for Chase combining in order to recover from ACK/NACK errors [5]. Therefore, IR needs only 1 bit of additional signalling compared to Chase combining.

'00'	First Transmission and New Indication
'01'	First Redundancy version and Continue Indication
'10'	Second Redundancy version and Continue Indication
'11'	Third Redundancy version and Continue Indication

Table 6. Signalling for adaptive IR

An estimate of the buffering needed at the receiver (input of the Turbo decoder) for IR is given in Table 7. In general, the buffer sizes needed for IR are 2-3 times more compared to Chase combining as is also pointed out in [5].

Code block size [bits]	Number of coded symbols (R_c=1/5)	Maximum buffer size for N-channel SAW [Kbytes] (N=1)		Maximum buffer size for N-channel SAW [Kbytes] (N=4)	
		8-bits to indicate a soft value	4-bits to indicate a soft value	8-bits to indicate a soft value	4-bits to indicate a soft value
7680	38400	38.4	19.2	153.6	76.8
5120	25600	25.6	12.8	102.4	51.2
3840	19200	19.2	9.6	76.8	38.4
2560	12800	12.8	6.4	51.2	25.6
1280	6400	6.4	3.2	25.6	12.8

Table 7. Estimates of buffer requirements for adaptive IR

4 Summary of Performance Results

Number of UEs supported for the same quality of service (packet call throughput CDF)		Service Throughput [Kb/s]		A^2IR Gain (Number of UEs, Service Throughput) [%]
Chase Combining	A^2IR	Chase Combining	A^2IR	
37	50	1288.3	1765.5	(35, 37)
56	80	1756.4	2420.0	(43, 38)
75	100	2036.9	2653.0	(33, 30)
100	130	2351.7	2957.5	(30, 26)

Table 8. Performance Comparison of Chase Combining and A^2IR at 3.0Km/h.

5 Conclusion and Recommendation

A system performance comparison is given for Chase combining and Asynchronous Adaptive Incremental Redundancy (A^2IR). Both schemes use variable TTI. The A^2IR can support 30-43% more UEs compared to Chase combining and provide 26-37% improvement in system throughput. The adaptive IR scheme needs larger buffer sizes at the receiver compared to Chase combining and one additional bit of signaling on the downlink. This increase in cost is marginal compared to the gains achieved. It is therefore recommended to allow Adaptive Incremental Redundancy operation for HSDPA and provide the necessary signalling support.

6 References

[1] "Physical Layer Aspects of UTRA High Speed Downlink Packet Access" TR25.848.

[2] "Performance Comparison of Hybrid-ARQ Schemes", TSG-RAN #17(00) 1396, Motorola.

[3] "Performance Comparison of Chase Combining and Incremental Redundancy", TSG-RAN #17(00) 1428, Ericsson.

[4] "Asynchronous, Adaptive Incremental Redundancy (A^2IR) for HSDPA", TSG-RAN #17(00) 1382, Lucent.

[5] "HSDPA related signaling parameters in downlink, version 2", R2-011177, Nokia.

7 Annex: Simulation parameters

The system level simulation parameters are listed in Table 9 below.

Table 9. Basic system level simulation assumptions.

Parameter	Explanation/Assumption	Comments
Cellular layout	Hexagonal grid, 3-sector sites	Provide your cell layout picture
Site to Site distance	2800 m	
Antenna pattern	As proposed in [2]	Only horizontal pattern specified
Propagation model	$L = 128.1 + 37.6\ Log_{10}(R)$	R in kilometers
CPICH power	-10 dB	
Other common channels	- 10 dB	
Power allocated to HSDPA transmission, including associated signaling	Max. 70 % of total cell power	
Slow fading	As modeled in UMTS 30.03, B 1.4.1.4	
Std. deviation of slow fading	8 dB	
Correlation between sectors	1.0	
Correlation between sites	0.5	
Correlation distance of slow fading	50 m	
Carrier frequency	2000 MHz	
BS antenna gain	14 dB	
UE antenna gain	0 dBi	
UE noise figure	9 dB	
Max. # of retransmissions	Specify the value used	Retransmissions by fast HARQ
Fast HARQ scheme	Chase combining or adaptive IR	
BS total Tx power	Up to 44 dBm	
Active set size	3	Maximum size
Frame duration	3.33 ms	
Scheduling	Max C/I	
Specify Fast Fading model	Jakes spectrum	Generated e.g. by Jakes or Filter approach

The fundamentals of the data-traffic model are captured in Table 10 below.

Table 10. Data-traffic model parameters

Process	Random Variable	Parameters
Packet Calls Size	Pareto with cutoff	A=1.1, k=4.5 Kbytes, m=2 Mbytes, μ = 25 Kbytes
Time Between Packet Calls	Geometric	μ = 5 seconds
Packet Size	Segmented based on MTU size	(e.g. 1500 octets)
Packets per Packet Call	Deterministic	Based on Packet Call Size and Packet MTU
Packet Inter-arrival Time (open- loop)	Geometric	μ = MTU size /peak link speed (e.g. [1500 octets * 8] /2 Mb/s = 6 ms)

Packet Inter-arrival Time (closed-loop)	Deterministic	TCP/IP Slow Start (Fixed Network Delay of 100 ms)