TSG-RAN WG1#17 TSGR1#17(00)1395

Stockholm, Sweden, 20th-24th Oct 2000

Agenda Item: Adhoc#24, HSDPA

Source: Motorola

Adaptive Modulation and Coding (AMC)

1.0 Introduction

This contribution provides the text for Section 6.2 titled "Adaptive Modulation and Coding" of the technical report (TR#25.848) for HSDPA[1].

2.0 Adaptive Modulation and Coding (AMC)

In cellular communication systems, the quality of a signal received by a UE depends on number of factors—the distance between the desired and interfering base stations, path loss exponent, log-normal shadowing, short term Rayleigh fading and noise. In order to improve system capacity, peak data rate and coverage reliability, the signal transmitted to and by a particular user is modified to account for the signal quality variation through a process commonly referred to as link adaptation. Traditionally, CDMA systems have used fast power control as the preferred method for link adaptation. Recently, Adaptation Modulation and Coding (AMC) have offered an alternative link adaptation method that promises to raise the overall system capacity [1]. AMC provides the flexibility to match the modulation-coding scheme to the average channel conditions for each user. With AMC, the power of the transmitted signal is held constant over a frame interval, and the modulation and coding format is changed to match the current received signal quality or channel conditions. In a system with AMC, users close to the Node B are typically assigned higher order modulation with higher code rates (e.g. 64 QAM with R=3/4 turbo codes), but the modulation-order and/or code rate will decrease as the distance from Node B increases.

AMC is most effective when combined with fat-pipe scheduling techniques such as those enabled by the Downlink Shared Channel. On top of the benefits attributed to fat-pipe multiplexing [2], AMC combined with time domain scheduling offers the opportunity to take advantage of short term variations in a UE's fading envelope so that a UE is always being served on a constructive fade. Figure 1 shows the Rayleigh fading envelope correlation vs. time delay for different values of Doppler frequency. The figure suggests that for lower Doppler frequencies it is possible to schedule a user on a constructive fade provided that the scheduling interval (i.e. frame size) is small and the measurement reports are timely (i.e. distributed scheduling). To take advantage of this technique, both a smaller frame size and distributed scheduling have been proposed as part of the High Speed Downlink Packet Access (HSDPA) study item.

The implementation of AMC offers several challenges. First, AMC is sensitive to measurement error and delay. In order to select the appropriate modulation, the scheduler must be aware of the channel quality. Errors in the channel estimate will cause the scheduler to select the wrong data rate and either transmit at too high a power, wasting system capacity, or too low a power, raising the block error rate. Delay in reporting channel measurements also reduces the reliability of the channel quality estimate due to the constantly varying mobile channel. Furthermore changes in the interference add to the measurement errors. Hybrid ARQ (HARQ) enables the implementation of AMC by reducing the number of required MCS levels and the sensitivity to measurement error and traffic fluctuations.

For the HSDPA study item, an AMC scheme using 7 MCS levels as outlined in Table-4 of the Appendix were simulated using a symbol level link simulator. The AMC scheme uses QPSK, 8-PSK and 16 and 64 QAM modulation using R=1/2 and R=3/4 Turbo code and can support a maximum peak data rate of 10.8 Mbps. Figure 2 to Figure 4 shows the performance of the AMC at 3 kmph and with Hybrid ARQ (Chase combining) enabled/disabled. Figure 6 to Figure 8 shows the performance of the AMC at 120 kmph and with Hybrid ARQ (Chase combining) enabled/disabled. Figure 5 and Figure 9 show the area probability for both 3 kmph and 120 kmph, respectively. Figure 10 shows the probability of choosing different MCS levels with 100 UEs per sector and using 20% overhead based on system simulation with parameters as per the Appendix. Table 1 shows the average sector throughput of the various scenarios for an equal average power scheduler. The following observations are made from the figures:

a. MCS level 1 (R=1/4 using QPSK) and MCS level 3 (R=3/4 using 8 PSK) does not have any throughput advantages for geometries (Ior/Ioc) ranging from 0 dB to 20dB. In view of the above, the number of MCS levels can easily be reduced from 7 to 5. Table 1 shows that the average throughput is not affected if the number of MCS levels is reduced from 7 to 5. The throughput changes by only 0.1 Mbps if the number of levels is reduced to 3 i.e. use QPSK with R=1/2 turbo code and 16 QAM with R=1/2 and R=3/4 turbo code.

b. AMC with HARQ provides higher throughput than AMC without Hybrid ARQ especially at slow speeds. A HARQ system with fast feedback, can ensure that extra redundancy is sent only when needed while still meeting delay constraints.

c. Although, the probability of choosing 64 QAM modulation is pretty low with the present scheme, it may be used widely in the future with the use of adaptive antenna solutions.

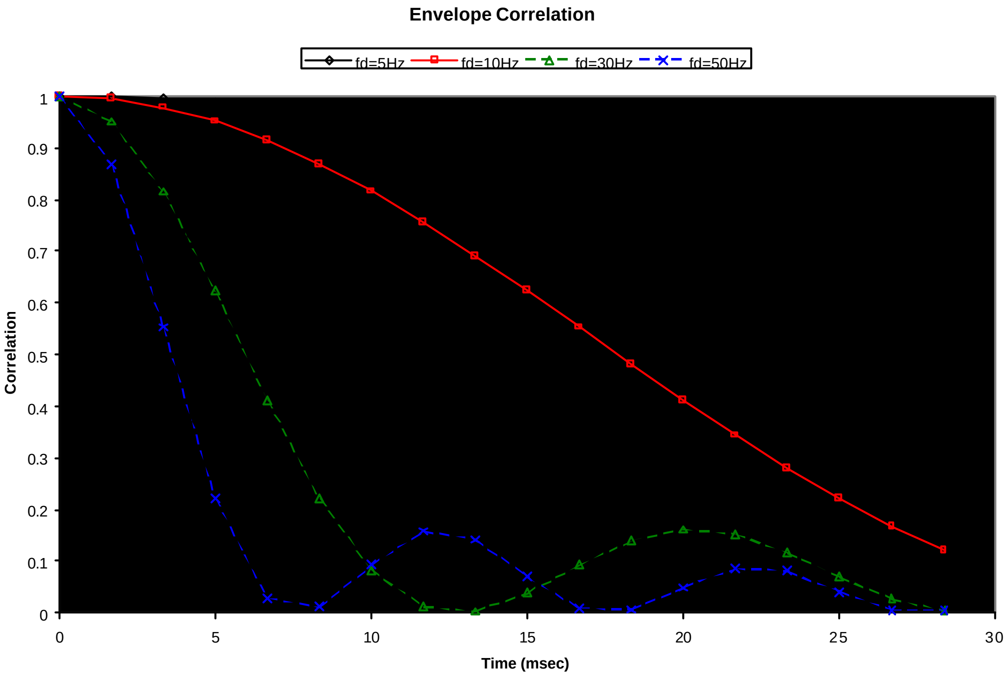

Figure 1. Envelope Correlation as a function of different doppler

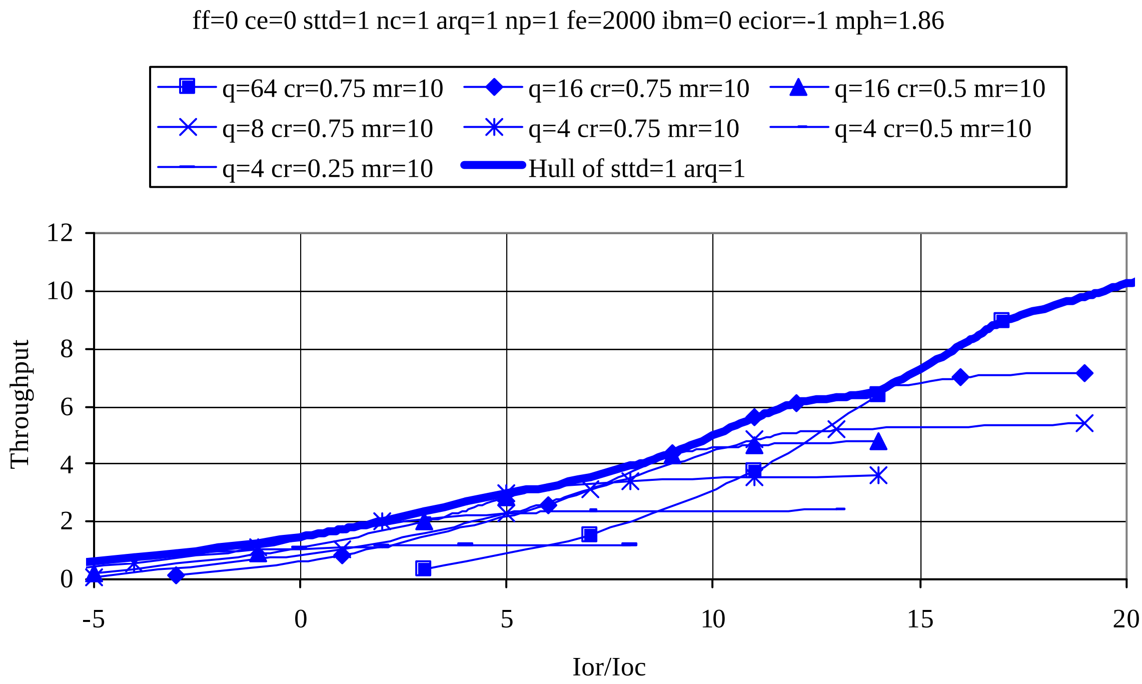

Figure 2.

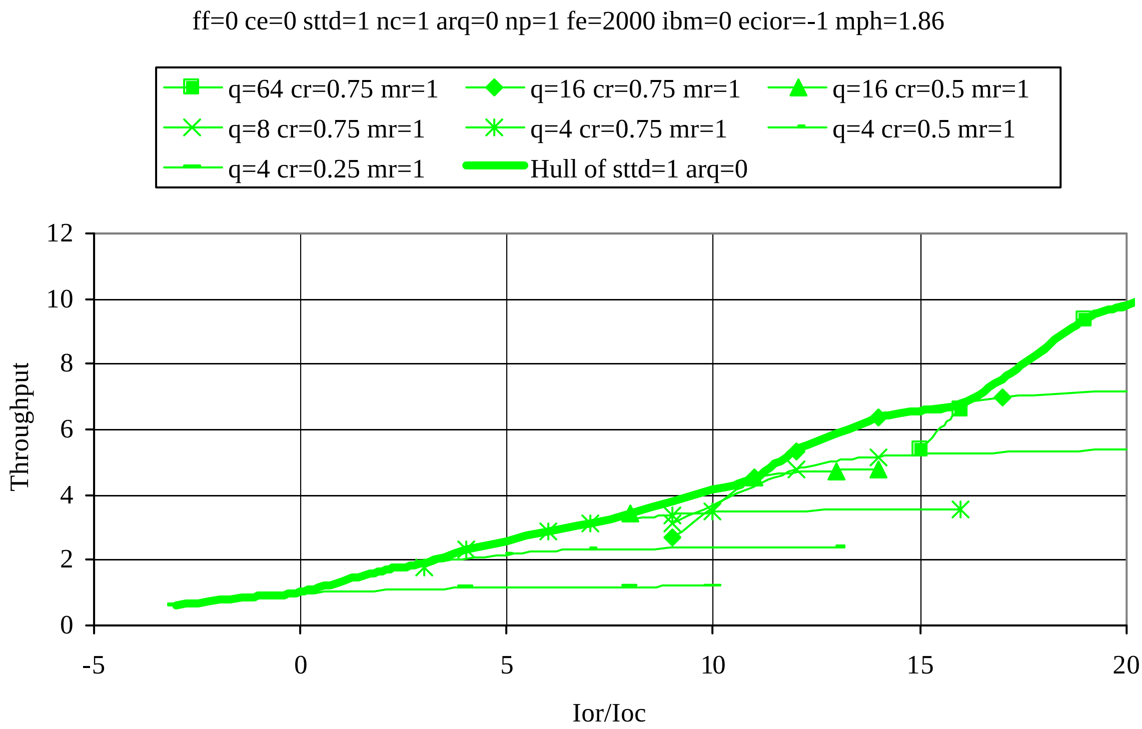

Figure 3

Figure 4

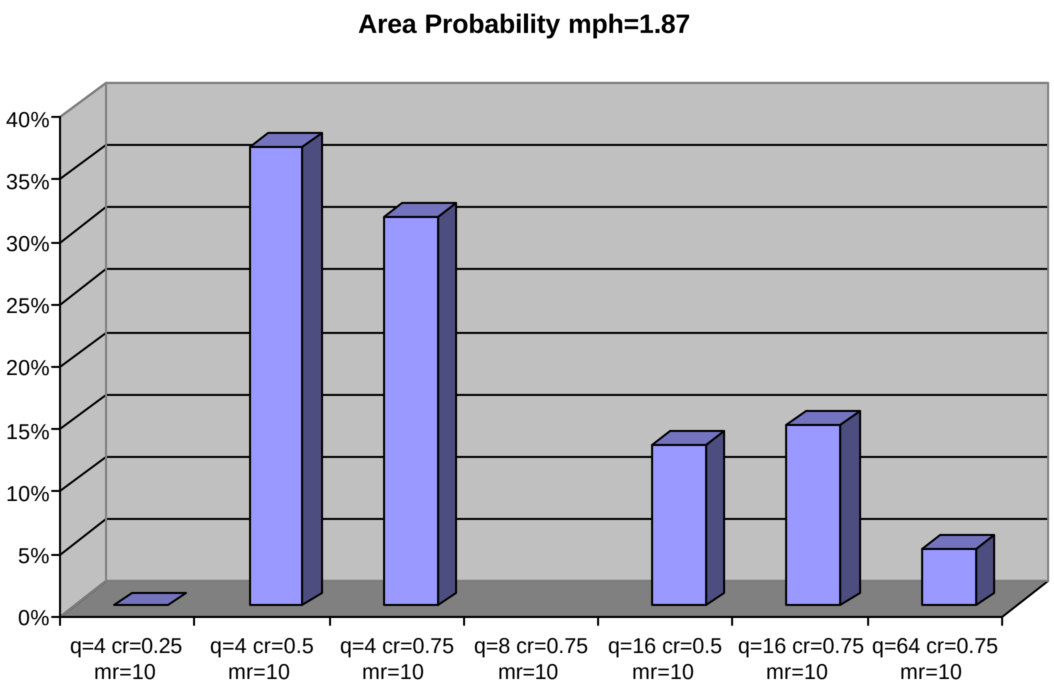

Figure 5

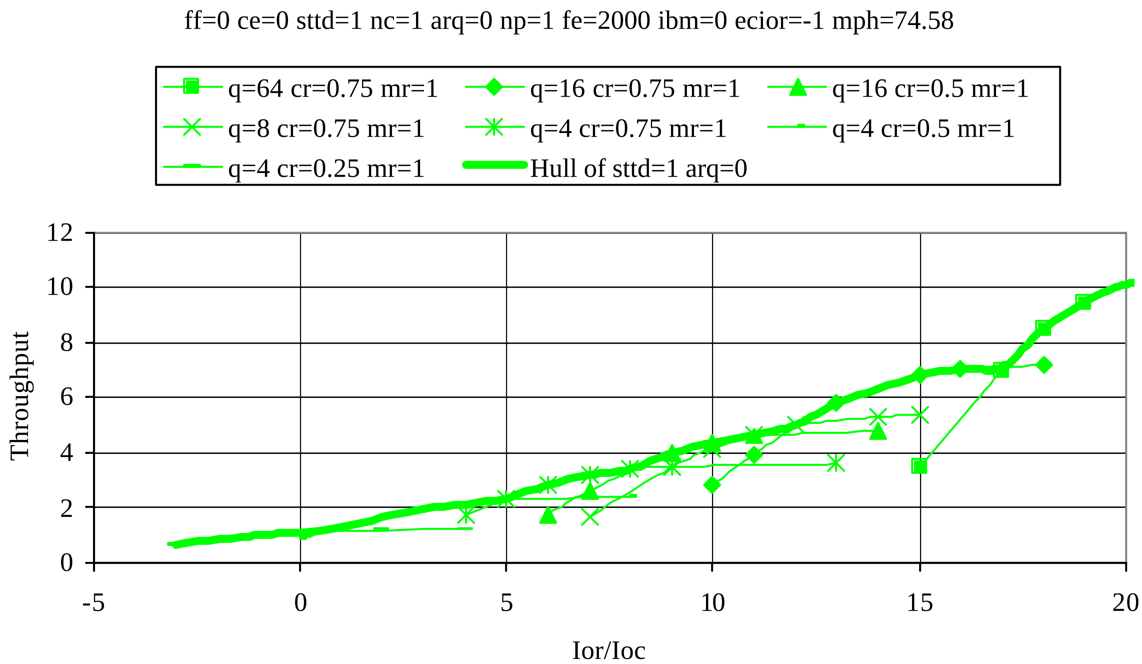

Figure 6

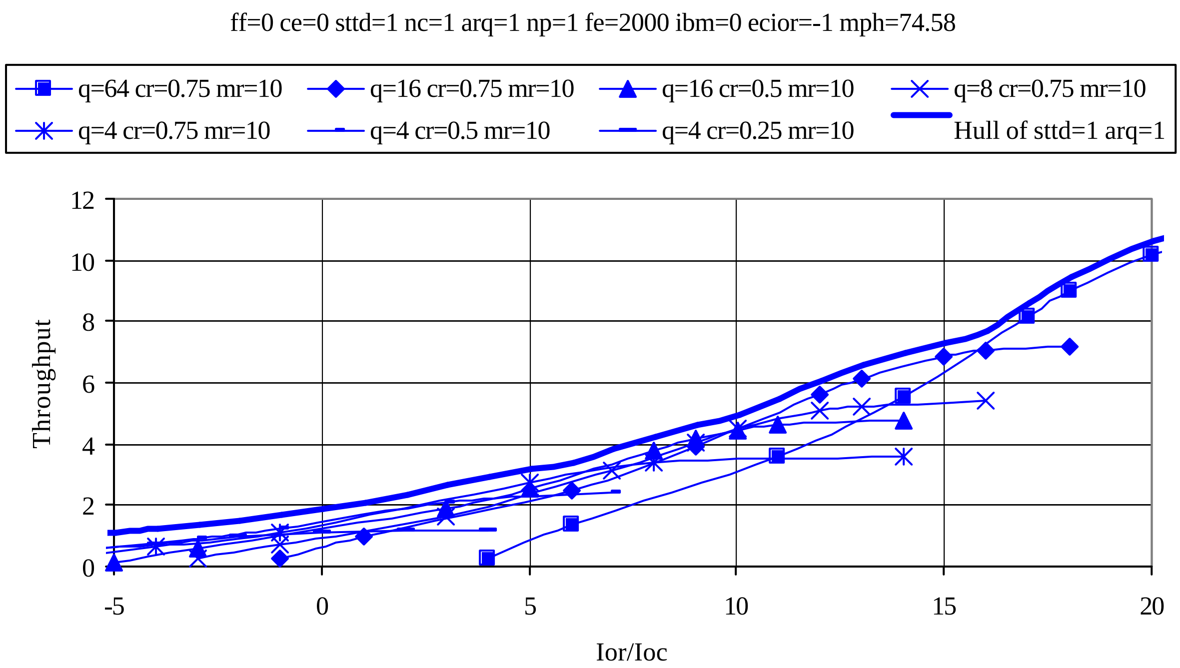

Figure 7

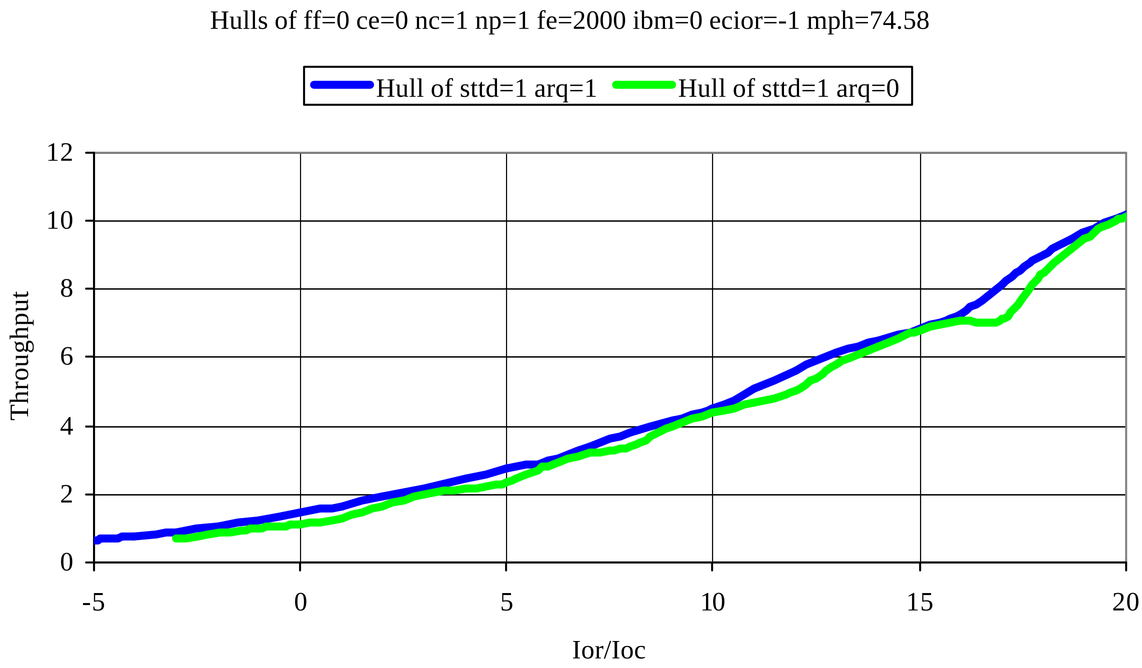

Figure 8

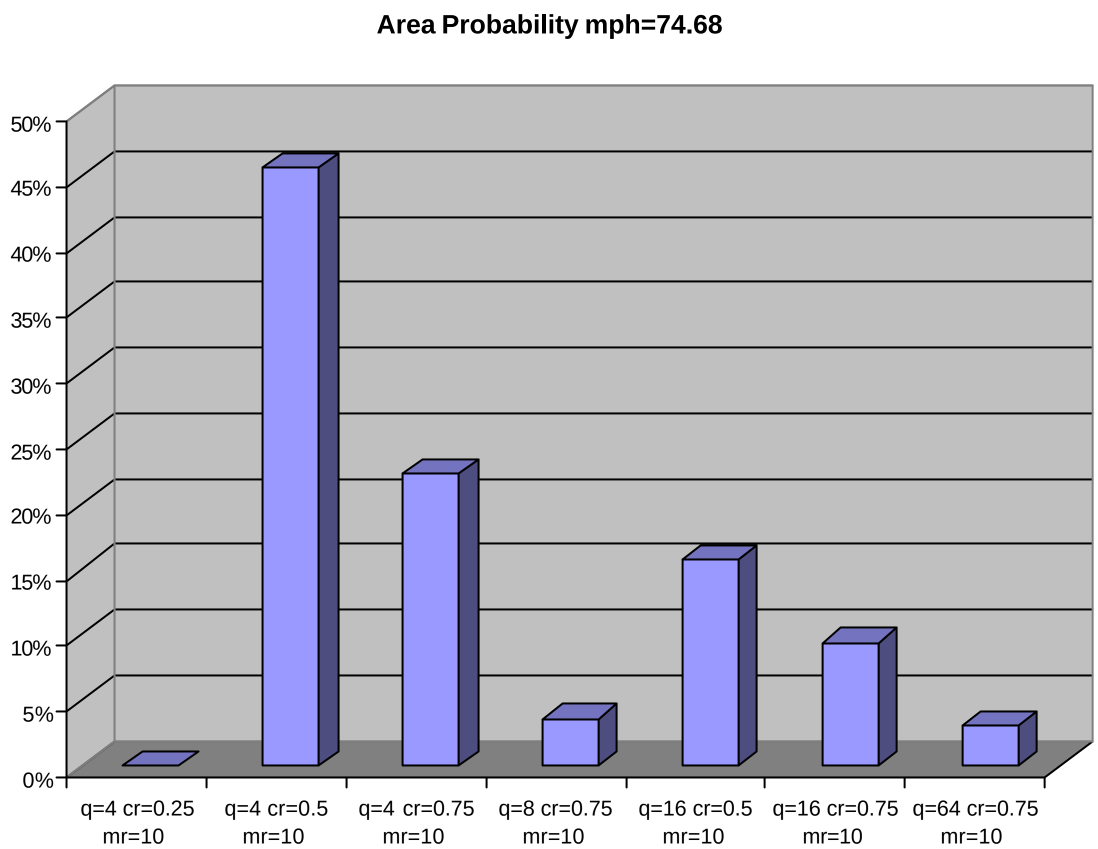

Figure 9

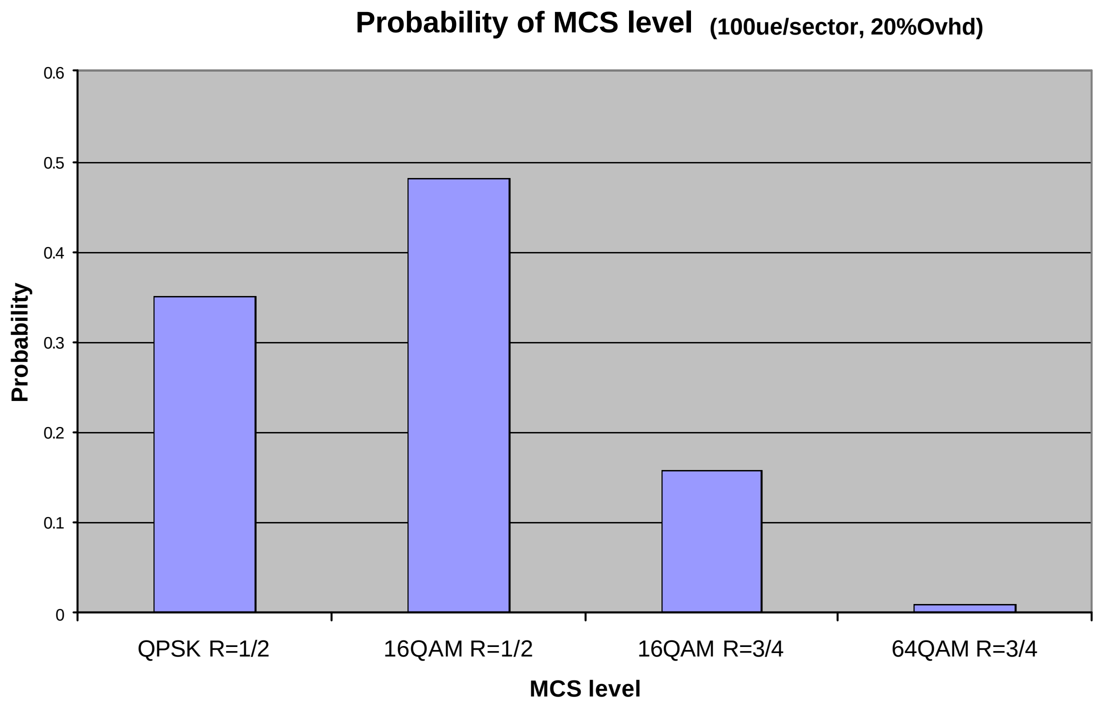

Figure 10

Table 1 Delivered Sector Throughput for Various Link Adaptation Schemes

Link Adaptation Scheme	Sector Throughput (Mbps)	
	(kmph=3)	(kmph=120)
AMC with HARQ, 7 Levels	2.6	2.4
AMC with HARQ, 5 Levels	2.6	
AMC with HARQ, 3 Levels	2.5	
AMC without HARQ, 7 Levels	2.2	2.2

3.0 Conclusion

It is recommended to use a fewer MCS level for the AMC. Table 2 gives one of the possibilities for the range of MCS levels.

Table 2

MCS	Modulation	Turbo Code Rate
4	64 QAM	3/4
3	16 QAM	3/4
2	16 QAM	1/2
1	QPSK	1/2

4.0 References

[1] TSGR1#16(00)1316, "TR on HSDPA"

[2] TSGR1#12(00) 0556, "Feasibility study of Advanced techniques for High Speed Downlink Packet Access", Motorola.

[3] SMG2 UMTS L1 682/98, "Channel Bandwidth Allocation Strategy", Motorola.