Home

Dynamic Link Mode Selection in High Data Rate Wireless Access Systems

Bassam Hashem and Riyadh Alruwais
Saudi Telecom Company
Riyadh, Saudi Arabia
bahashem@stc.com.sa

Abstract – Modern radio communication systems make use of adaptive modulation to improve their capacity (and efficiency). These systems dynamically change the modulation and coding (link mode) being used for each transmission in order to achieve the best throughput for the current channel conditions. The receiver estimates the channel quality and reports it back to the transmitter. The transmitter then maps the reported quality into a link mode. This mapping however, isn't a one-to-one mapping. In this paper we propose an adaptive scheme to map the link quality into a link mode and investigate the gain from the proposed scheme. We show that the proposed scheme can result in more than 35% gain in the system data throughput.

I Introduction

The rate of data transmission through a radio channel depends on the characteristics of the channel and these characteristics vary with time. Modern radio communication systems make use of adaptive modulation to improve their capacity (and efficiency). These systems dynamically change the modulation and coding (link mode) being used for each transmission in order to achieve the best throughput for the current channel conditions. Link Mode adaptation is offered as a means to match the carrier to interference ratio (C/I) observed by the link to the best data rate that can be delivered. When the C/I observed is high, a higher link mode is employed allowing a higher data rate for a given expected performance (like a block error rate BLER). When the observed C/I is low, a lower link mode is employed to achieve the same performance target.

To achieve this, however, requires that the terminal send the information to determine the desired link mode to the transmitter. This is done by the transmitter measuring the carrier to interference ratio (C/I) and mapping it into a desired link mode. After receiving the desired link mode, the transmitter uses that mode for the data transmissions. The success of the adaptive modulation process thus depends critically on the accuracy of mapping the C/I into a link mode. Unfortunately, there is not a one-to-one mapping between the measured C/I and the link modes to achieve a desired Block Error Rate (BLER). This is because the achieved BLER will also depend on the propagation conditions (channel type). The propagation conditions are variable with time making it inefficient to have a static C/I to Link mode mapping. This paper proposes a scheme that dynamically adapts the mapping of the C/I into link modes. This enables the use of the right link mode irrespective of changes in the channel conditions.

Table 1: C/I mapping into link modes in the DVB standard

		Required C/I to achieve a BER of 2×10^{-4}		
Modulation	**Coding**	**Gaussian Channel**	**Ricean Channel**	**Rayleigh Channel**
QPSK	1/2	3.1	3.6	5.4
QPSK	3/4	5.9	6.6	10.7
16 QAM	1/2	8.8	9.6	11.2
16 QAM	2/3	11.1	11.6	14.2
64 QAM	2/3	16.5	17.1	19.3

II. Mapping to Link Modes

Adaptive modulation coding (AMC) has been used in digital broadcasting systems. Table 1 is taking from the DVB standard where it shows the required C/I to achieve a specific bit error rate for different channel types. This is shown here is an example of how it is impossible to have a direct mapping between the measured C/I and the link mode. A measured C/I of 9 dB, for example, might support the link mode of 16 QAM with coding rate ½. However, to do such a mapping we need to know the channel type. To be in the safe side, we need to map the measured C/I of 9 dB into the link mode of QPSK and coding rate ¾. This is designing with a margin which is similar to the old concept of designing with a fading margin. This of course results in lowering the system throughput.

Another issue in adaptive modulation systems is the accuracy of the used channel quality report (C/I). The receiver will have some measurements error when measuring the C/I. Also, reporting the C/I back to the receiver can't happen instantaneously but will happen after some delay. Also, there will be some delay at the transmitter before the reported C/I is applied. In a mobile environment, these delays means that there will be a difference between the reported C/I and the actual C/I at the time of the transmission. This also nictitate the need for an adaptive mapping scheme.

III. Adaptive link modes mapping

This paper proposes a scheme to dynamically adapt the mapping of the C/I into link modes that does not require knowing the type of channel or the propagation conditions. The initial mapping can be based on a static scenario and allowing the proposed scheme to change it dynamically or by having an initialization stage (before sending actual data) to allow proper C/I to link mode mapping.

Table 2:Initial C/I to link mode mapping

C/I	Link Mode
$C/I \le X_1$	0
$X_1 < C/I \le X_2$	1
$X_2 < C/I \le X_3$	2
$X_3 < C/I \le X_4$	3
$X_4 < C/I \le X_5$	4
$X_5 < C/I \le X_6$	5
$X_6 < C/I \le X_7$	6
$X_7 < C/I \le X_8$	7

Assume that for the initial data transmission the mapping to be given by Table 2. Then, the receiver will check if the received data is in error or not. This can be done every block of data or every *n* blocks. By checking the CRC bits, the receiver can determine whether the received data is in error or not. If the received data is consistently error free, this indicates that the same C/I can support a better link mode. As an example, suppose that the measured C/I was 0 dB and it was mapped to link mode 4, receiving an error free transmission indicates that a C/I of –0.2 dB might be able to support the same link mode (4). The error free reception is an indication of an improvement in the channel type/ propagation conditions and hence the C/I values for supporting the same link modes should be decreased by Δ as shown in Table 3. The value of Δ should be small to make sure that the following transmissions will use a link mode that can be supported. The C/I can be iteratively decreased to a level where the BLER threshold is matched. In the case of repeatedly having errors in the received data, this indicates that the same C/I should support a lower rate link mode. In such a case, the C/I values for supporting the same link modes should be increased by δ as shown in Table 4. The value of δ should be large enough to prevent a series of errors in the received data. In the above example a 0.5 will be used to map to link mode 4 instead of 0 dB. Simulations show that the following relation achieves the desired Block Error Rate (BLER):

$$\delta = \Delta / (1/BLER - 1)$$

Hence if the desired BLER is 1% and Δ is 0.5 dB, then δ should be 0.005 dB. This guarantees that at equilibrium, the desired mapping will be achieved (1- BLER) of the times and hence the error rate will be BLER. This formula is the same formula that is used in the outer loop power control algorithm [1].

This process ensures that the adaptation is better matched to the channel conditions, whatever they may be. Rather than increase the number of retransmissions on a poor channel due to inaccurate C/I mapping, it increments the C/I to reflect a better association of C/I to data rate as the transmissions progress. The method also improves the allowable data rates when the C/I conditions seem more favorable than expected.

Table 3: C/I to link mode mapping in case of error

C/I	Link Mode
$C/I \le X_1 - \Delta$	0
$X_1 - \Delta < C/I \le X_2 - \Delta$	1
$X_2 - \Delta < C/I \le X_3 - \Delta$	2
$X_3 - \Delta < C/I \le X_4 - \Delta$	3
$X_4 - \Delta < C/I \le X_5 - \Delta$	4
$X_5 - \Delta < C/I \le X_6 - \Delta$	5
$X_6 - \Delta < C/I \le X_7 - \Delta$	6
$X_7 - \Delta < C/I \le X_8 - \Delta$	7

Table4: C/I to link mode mapping in case of no error

C/I	Link Mode
$C/I \le X_1 + \delta$	0
$X_1 + \delta < C/I \le X_2 + \delta$	1
$X_2 + \delta < C/I \le X_3 + \delta$	2
$X_3 + \delta < C/I \le X_4 + \delta$	3
$X_4 + \delta < C/I \le X_5 + \delta$	4
$X_5 + \delta < C/I \le X_6 + \delta$	5
$X_6 + \delta < C/I \le X_7 + \delta$	6
$X_7 + \delta < C/I \le X_8 + \delta$	7

IV. Performance of the proposed scheme

In simulations performed for algorithm evaluation purposes, 18 adjacent link modes with a link mode spacing of 0.5 dB were considered. A total of 100000 blocks (or time slots) were used for each simulation run. If the observed C/I value was too low for any of the link modes to be used, then no data was transmitted during that particular time slot. Correlated Rayleigh fading with a Doppler frequency of 2 Hz was used to emulate a fixed wireless environment. Desired BLER (Block Error Rates) of 1%, 5%, and 10% were considered. Throughput was estimated as the total number of correct data bits transmitted as compared to the total number of blocks transmitted (this latter value was the sum of the numbers of both the correctly and incorrectly transmitted blocks).

The proposed algorithm is evaluated as a function of the offset between the required C/I to achieve a given BLER and the used C/I. A negative offset means that the a conservative C/I value is being used and hence the BELR will be lower than what is required. This of course reduces the system throughput were a higher link mode could have been used. A positive C/I offset means that an aggressive C/I to link mode mapping is being used. This of course results in increasing the BLER which results in more errors (lower throughput). Thus, we see that the proposed scheme increases the system throughput in both cases. The proposed scheme also results in achieving the target BLER.

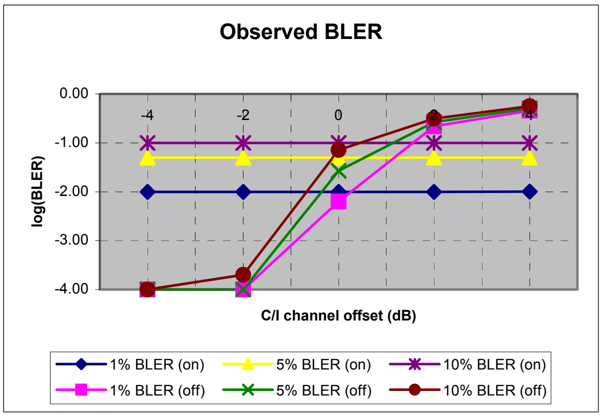

Figure 1: Achieved BLER as a function of C/I offset

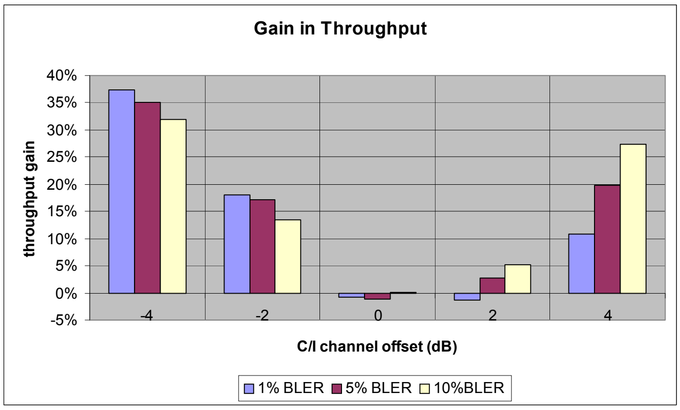

Figure 2: Gain from the proposed scheme as a function of C/I offset

V. Conclusion

In this paper, we proposed an adaptive scheme to map the link quality into a modulation/coding level. We show that a static mapping has to be designed with a margin resulting in lowering the system data throughput. An aggressive mapping also results in more errors which eventually reduces the system throughput. The proposed scheme keeps the BLER at the desired level which results in increasing the system throughput. Simulations show that the throughput gain from the proposed scheme can be as high as 35%.

References

[1] Sampath, A.; Sarath Kumar, P.; Holtzman, "On setting reverse link target SIR in a CDMA system," *IEEE Vehicular Technology Conference, Vancouver-Canada 20021. 1997, IEEE 47th , Volume: 2 , 1997 Page(s): 929 -933 vol.2*

[2] Bender, P.; Black, P.; Grob, M.; Padovani, R.; Sindhushyana, N.; Viterbi, S., "CDMA/HDR: a bandwidth efficient high speed wireless data service for nomadic users," *IEEE Communications Magazine , Volume: 38 Issue: 7 , July 2000, Page(s): 70 -77*