Rate-Compatible Product-Code Scheme for Wireless Channel

Sibonginkosi Ntuli, Ling Cheng, and Jaco Versfeld
School of Electrical and Information Engineering
University of the Witwatersrand, 1 Jan Smuts Avenue, Braamfontien 2000 Johannesburg
Tel: +27 11 717 7244, Fax: +27 11 717 7237
email: sibonginkosi.ntuli@student.wits.ac.za, {ling.cheng, jaco.versfeld}@wits.ac.za

Abstract- The wireless channel has become one of the leading communication channels in today's world. Its tether-less connectivity is very attractive to users. This can be noted in how it has been well adopted in both the developing and developed nations.

As mobile devices move from devices that are used for voice and simple text communication, to devices that are more multimedia oriented, the need to make communication on the relatively noisy communication channel more reliable becomes more imperative. FEC has been used to mitigate the impact of noise on the wireless channel. When developing a FEC scheme one needs to take into account the compromise between the error-correcting capability of the FEC technique, the code rate and the delay introduced by the decoding complexity. In this study we propose to address these three considerations by the use of rate adaptable product codes to mitigate the impact of noise on wireless channel.

Index – FEC, product codes, rate-compatible,

I. INTRODUCTION

In [1], Shannon introduced a method to calculate the maximum rate at which data could be transmitted over a channel without error, given the channel's signal to noise ratio and bandwidth. As a consequence, by using a sufficiently long error correcting code, it is possible to transmit data error free as long as the coded bits are transmitted at a rate less than the channel capacity. Shannon did not provide the codes. A lot of research has been done to find codes that can achieve Shannon's limit.

The wireless medium is one of the harshest of communication channels, where little or no control can be exercised over the external noise sources and interfering signals interacting with the communication signal. Wireless channels suffer from noise and fading due to multipath propagation of the signal, co-channel interference, inter-channel interference and physical obstructions [2][3]. Forward error correction (FEC), has been used to mitigate the impact of noise on the wireless channel.

With FEC redundant information is added to the actual information being transmitted in a process known as encoding. The redundant information is used to recover the original information at the receiving end in a process known as decoding. The code rate is a measure of the amount of redundancy a code has. It is defined as the ratio of the message length to the codeword length. The maximum value of the code rate is 1. Redundancy adds overhead to communication and thereby costing resources, it is ideal to keep the code rate as close to 1 as possible [4].

II. PRODUCT CODES

In 1954 Elias introduced product codes [5]. The concept of product codes is a way to obtain long and powerful codes by using simple constituent codes.

A two dimensional product code can be represented by a rectangular array in which each row is a codeword in one code, and each column is a codeword in another code [6]. The figure below shows a two dimensional product code.

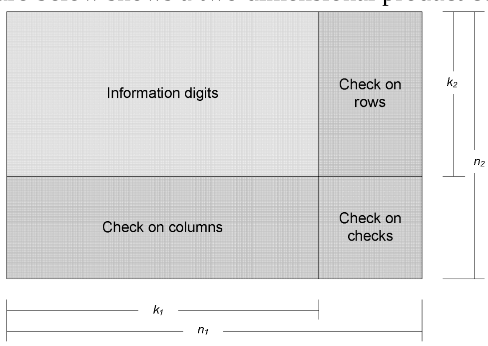

Figure 1: Structure of a systematic product code

Various studies have shown that a simple way of decoding the product codes would be to use iterative decoding. The simplest though not the most optimal would be to decode first the rows then the columns and iterate until the codeword is decoded [4]. Because the component codes of the product code are simple to decode, product codes provide a good compromise between powerful codes and decoding complexity. These make them attractive to use in wireless communication. Multidimensional product codes have been shown to be efficient for wireless communication channels.

The major drawback of product codes is their poor code rate. Elias showed that the code rate of a two dimensional code *C*, composed from the component codes C_1 and C_2 is the product of their respective code rates . To improve the code rate of product codes, Battail introduced single parity check product codes (SPCPCs) [8]. SPCPCs have a parity bit appended at the end of each row and each column. In an even parity binary product code, the summation of the bits in each row or columns is zero [9].

III. RATE ADAPTIVE CODES

In a study by Wu et al [10], using finite states to vary the code rate, it was shown that the throughput of coding scheme can be improved by dynamically adapting the code length of a codeword to respond to the channel conditions.

In the wireless channel, the conditions are ever varying.

This makes the design of coding schemes for wireless channels challenging. In earlier coding schemes, the coding schemes usually selected a fixed rate and correction capability, either for the average or the worst case channel conditions [10]. In the wireless channel there is a need to be more flexible. Using a variable code rate allows the managing of the error correcting capability of the code, thereby keeping the code rate optimal while keeping the throughput high.

A number of studies have been done on how the code rate of product codes can be varied. In [12], Stark and Ji propose varying the code rate by using multiple product codes. A multiple product code is a product code with more than 2 dimensions. Varying the code rate of a product code can be done by increasing the number of dimensions. As the dimensions increase the code rate is lowered [12]. Multiple product codes provide better error correcting capability while the decoding complexity increases linearly with the dimensions.

In [13], a method of shortening product codes is proposed. This method was proposed for systematic product codes. Firstly the columns of the parity bits with the most number of ones are deleted. Then a parity check matrix of shortened code with every row having the same number of ones is generated. Other methods used for changing the code rate are proposed in [14][15].

The rate of product codes can also be varied by changing the rates of the component codes [16]. The component code is chosen according to the channel BER. When the channel signal to noise ratio is high, the component codes used have a high code rate. As the signal to noise ratio decreases, lower code rate component codes are used. It is worth noting though that for product codes with Hamming codes as component codes, changing the block code length does not change their minimum distance. Making the block code length smaller, lowers the code rate, but at the same time decreases the number of bits that maybe received erroneously.

IV. Our Study

In our study we intend to study product codes, by adapting their rate to the varying conditions of a wireless channel. We will simulate the study and carry out a comparison of the methods that have been proposed in the preceding section. We intend to do a comparison of the decoding complexities of the various methods and the throughputs each of the methods at different signal to noise ratios. The result will be used to simulate a product code system for a wireless channel.

V. Conclusion

This paper is a survey of product codes and the methods that have been used to vary the code rate, to ensure their throughput is kept optimal in wireless networks.

VI. References

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Sibonginkosi Ntuli is currently studying for his Masters of Science degree at the University of the Witwatersrand. His research interests include product codes and rate compatibility in codes.