COMPARISON OF DIFFERENT SCENARIOS FOR PATH DIVERSITY PACKET WIRELESS NETWORKS

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Abstract. *This article discusses the use of the principles of network coding in wireless networks to increase the overall robustness of the transmission. Path diversity on the packet level is investigated as a software alternative to classical diversity techniques commonly used to improve wireless devices communication. The article describes the initial stage of the research of network coding in elementary form with network traffic duplication. Objects of investigation are two different types of transmission in two scenarios, where the resulting transmission loss is evaluated with dependency on the packet length.*

Keywords

Optimization, path diversity, wireless transmission.

1. Introduction

Optimization of wireless networks is a very broad field; our work is focused on the optimization within the meaning of ensuring the desired balance between the network throughput, delay and packet loss size. There are situations when maximal throughput and minimal delay are required (e.g. voice services), however, there are situations when every single packet is important and must be delivered to its destination (e.g. file transfer). Our approach is to find the appropriate connection scheme for unicast network using the path diversity. Furthermore, various packet loss probabilities in separate channels, resulting from the usage of more or less robust modulation techniques, are an integral part of the design of two individual schemes. This article compares these two different transmission schemes with respect to probability of packet loss.

2. Optimization Design

The first part of this chapter consists of different ways to optimize the data transmission, and then focuses on the description of our transmission schemes.

2.1. Related Work

A common way to improve the transmission characteristics in the physical layer is the MIMO technology (Multiple-Input Multiple-Output), i.e. the use of multiple antennas at the receiver and transmitter. MIMO has two variants; the first one is based on the spatial diversity which means transmitting the same data through several antennas. Spatial multiplexing is the second one and its core function is based on the sending different data through the each of antennas [1]. Other optimization techniques in the physical layer area for wireless networks are, for example, dynamic subcarrier assignment, adaptive power allocation 0, or interference cancelation [3]. Optimization in the link layer is typically based on some kind of adaptability in order to adjust the protocol parameters to the actual network conditions [4], scheduling [5], or different back off mechanisms [6]. Different type of articles focused on the network optimization covers new routing methods, such as dispersity routing. Unlike conventional directory routing procedures, which route a message along a particular path between the source and destination, this routing mechanism sub-divides the message and disperses it through the maze of paths comprising the network [7].

2.2. Transmission Schemes

In the following section is discussed two separate wireless channels system optimizing data transmission. Optimization of throughput or resilience, in systems with path diversity in use, has its reflection in MIMO methods of spatial diversity and multiplexing. Proposed techniques of our work, on the contrary, are intended to be universal and independent on the physical layer.

1) Load Balance System Model

Consider a transmission system with two separate channels as depicted in Fig. 1. System with uniformly distributed load relies on the assumption that if there are two parallel data streams and each will transmits the half of input data, then, thanks to a lower bitrate for a single data channel will be achieved higher resistance using more robust modulation. Overall throughput will be the same as in the basic system with a single channel.

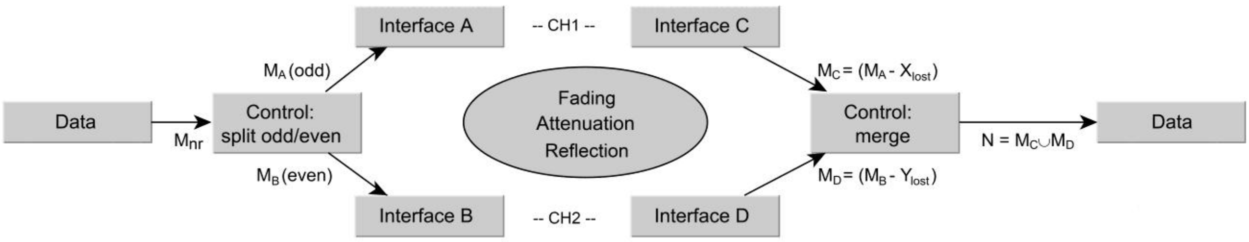

Fig. 1: Load balance transmission system.

2) Backup System Model

System with data mirroring (see Fig. 2) takes advantage of the situation that two parallel channels transmits the completely same data. There is necessary to have a less robust modulation, compared to the previous method, which is capable to transmit data with the same overall throughput. For example, if there is a network with two channels based on the standard IEEE 802.11g and request for a 24 Mbps throughput, then with the first system is necessary to have a two QPSK (Quadrature Phase Shift Keying) channels (standard defines bit rate of 12 Mbps). With the second system, one can use a less robust 16-QAM (Quadrature Amplitude Modulation) modulation which is defined for the bit rate of 24 Mbps in the mentioned standard (see Tab. 1). The total bitrate will not increase, because of the selection just of the original data at the destination, but due to parallel transmission of data will be preserved high durability and very low error rate despite higher error rate per channel caused by less resilient modulation technique.

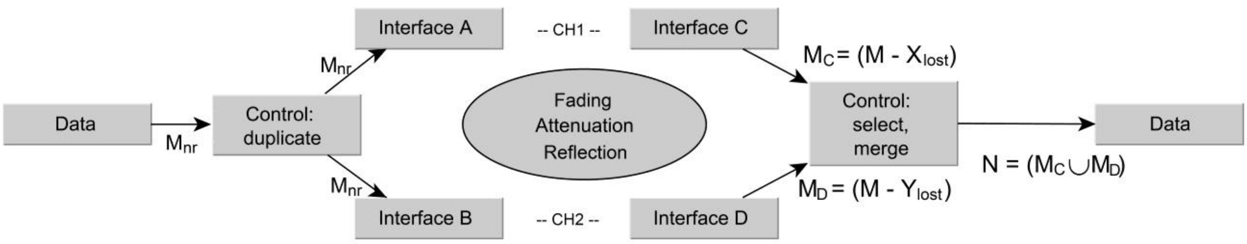

Fig. 2: Backup transmission system.

2.3. Packet Error and Throughput

The background of this comes from the fact that robustness is decreased with the greater number of symbols in modulation constellation. Equation 1 shows the impact of type of modulation on the packet error rate (PER). The bit error rate depends on the bit to symbol mapping, for SNR >> 1 (Signal-to-noise ratio) and Gray-coded assignment is possible to assume that each symbol error causes only one bit error; then the probability of bit-error per carrier is [8]:

$$PER = 1 - \left[1 - \frac{2}{b}\left(1 - \frac{1}{2^{b/2}}\right) \cdot erfc\sqrt{\frac{3b}{2^{b+1}-2} SNR}\right]^n, \qquad (1)$$

where b is number of bits per symbol; number of symbols in modulation constellation $M = 2^b$, n is packet length in bits and $erfc(x)$ is Gaussian complementary error function.

Modulation techniques and coding rates, which indicates the ratio of the number of bits of useful information to the total number of bits (including the added redundancy), for each type of modulation is defined by IEEE standard 802.11g [9] and presented in Tab. 1.

3. Comparison of Schemes for Different Scenarios

Our comparison of presented schemes in terms of packet loss with respect to packet length is divided into two scenarios. The first one deals with additive white Gauss. noise and with different modulations in use for backup and load balance system. The second one is based on the same probabilities of interrupt for both systems and shows how these systems are capable to deal with them.

3.1. Packet Loss for Gaussian Noise

Only additive white Gaussian noise is considered in the first scenario. The diference between load balance and backup system is approximately four orders of magnitude greater in favor of the load balance system. This is so because systems are designed to operate with different modulations and, therefore, is important to work with appropriate probabilities of bit error. These are possible to get from well-known equations for a particular type of modulation (more in [8]).

For this comparison, we have chosen 16-QAM modulation for the backup system channels and the QPSK modulation for the load balance system. Appropriate bit error probabilities for 15 dB SNR are shown in Fig. 3.

Tab.1: Throughput for modulation techniques and coding rates defined in IEEE standard 802.11g.

Modulation	Coding rate	Bit rate
BPSK	1/2	6 Mbps
BPSK	3/4	9 Mbps
QPSK	1/2	12 Mbps
QPSK	3/4	18 Mbps
16-QAM	1/2	24 Mbps
16-QAM	3/4	36 Mbps
64-QAM	2/3	48 Mbps
64-QAM	3/4	54 Mbps

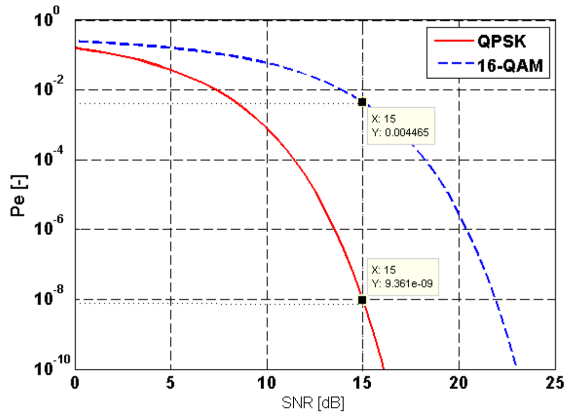

Fig. 3: Bit error probabilities for QPSK and 16-QAM modulation.

Figure 4 shows how looks the situation with different modulations in use. The load balance system is significantly more resilient against bit errors. This is caused by great difference of probabilities of error for QPSK and 16-QAM modulation.

3.2. Packet Loss for Interrupt and Interference in Wireless Channel

For comparison which of schemes is more robust and less error-prone is good to know how is probable that an error will happen. The packet error should be more probable in the load balance system because it is sufficient that error occurred only at one of channels and the packet is lost. On the contrary, when the packet is lost in one channel of the backup system, is still delivered to its destination by the second channel. These two different behaviours are described in following equations.

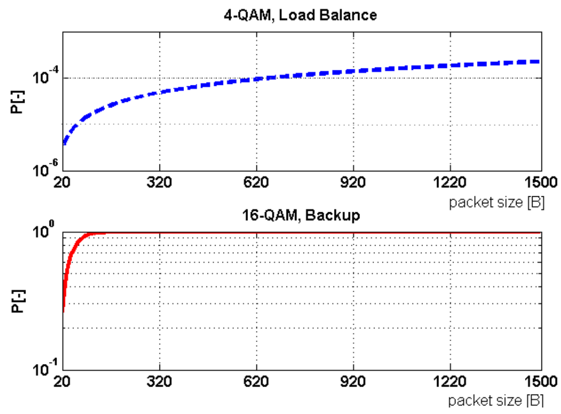

Fig. 4: Comparison of systems with different modulations in use.

The probability that an error occurs in the interval of the packet length n in the load balance system is:

$$P_L = \left[1-(1-p_1)^n\right] + \left[1-(1-p_2)^n\right] - \left[1-(1-p_1)^n\right] \cdot \left[1-(1-p_2)^n\right]. \quad (2)$$

The probability that an error occurs in the interval of the packet length n in the backup system is:

$$P_B = \left[1-(1-p_1)^n\right] \cdot \left[1-(1-p_2)^n\right]. \quad (3)$$

where p_1 and p_2 are probabilities of error in one bit.

Comparison of these equations for various packet lengths and for the same interrupt error rate 10^{-5} for both systems is depicted in Fig. 5. The difference between load balance and backup system is approximately three orders of magnitude greater in favor of the backup system. Therefore, for a wireless transmission affected by fading or antenna shading [10] is a backup system more appropriate.

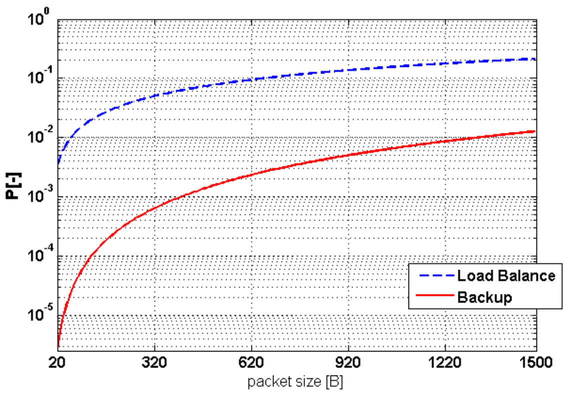

Fig. 5: Comparison of systems for interrupt in channel.

4. Conclusion

This article presents two different path diversity wireless transmission schemes and their comparison of packet loss for various packet lengths. The first scheme is based on load balancing of sent data into two separate channels. Thanks to lower bitrate for a single data channel is achieved higher resistance using more robust modulation. The second scheme uses both transmission channels for parallel sending of the same data. Therefore, high resistance against error is achieved by data backup. Comparison of these schemes is done from two points of view. Firstly, for the additive white Gaussian noise channel model it is shown that load balance system is far more resilient for all tested packet lengths. Subsequently, for the situations with signal interrupt (e.g. shaded antenna) the backup system proved to be more suitable. These results will be used for further work on these schemes and its usage for specific purposes.

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