MODELLING OF WIRELESS NETWORK CODING

Petr Svobodník
Bachelor Degree Programme (third year), FEEC BUT
E-mail: xsvobo98@stud.feec.vutbr.cz

Supervised by: Zenon Kuder
E-mail: xkuder00@stud.feec.vutbr.cz

Abstract: During data exchange in the Point-to-Point wireless topology, in case where end nodes aren't accessible directly, a relay is deployed. However, the basic approach to relays – Store-and-Forward – isn't the way to reach the maximum throughput. Network Coding operation is performed by combining data words (packets) travelling through the network in opposite directions into one packet. End nodes, with knowledge of the data sent, can decode received packet. Packet exchange is then finished in shorter time which results in an increase of network throughput. There are more methods of Network Coding which differ from each other in the time requirements or the ability to work in a noisy channel. In this paper they will be described and compared.

Keywords: Data Flow, Wireless channel, Wireless Network Coding, Decode-and-Forward, Amplify-and-Forward, Denoise-and-Forward

1 INTRODUCTION

Fast communication is crucial in the computer era and many connections are wireless. Unfortunately, capacity of a wireless channel is limited by several factors. Mathematician Shannon in his theory of information [1] defined well-known formula $C = B \cdot \log_2(1+\gamma)$ (C stands for bitrate[1], B for frequency bandwidth and γ for Signal-to-Noise Ratio). Normalised channel capacity $\frac{C}{B_0}$ is converging to value of 1,443 (bit/s)/Hz, where $B_0 = \gamma B$, and it can be reached only theoretically.

Nowadays during data exchange (not regarding transport media) classical routing principles are used for its simplicity and satisfactory results. In topologies with multiple hops this technique doesn't bring the best results. In 2000, R. Ahlswede with his team came in [2] with theory, that by mixing of content of sent packets a network performance may be increased. The receivers are, on the base of knowing transmitted packet, able to decode data dedicated for it. There are several ways of proceeding this step, but all of them are based on reversible bitwise eXclusive OR logical operation.

Let's consider half-duplex topology Two Way Relay Channel (2WRC) shown in fig. 1 where A and B are end users and R is relay. Now we can define reference channel capacity for further comparison:

$$R_R = \frac{2N}{4T_S} = \frac{N}{2T_S} = \frac{R_S}{2} \tag{1}$$

where R_R stands for channel capacity using routing, N for size of packet in bits, T_S is length of timeslot and R_S capacity of single channel. Using routing algorithm we need 4 timeslots to exchange 2 packets of information.

2 WIRELESS NETWORK CODING

During time, three main approaches were figured out. All of them work on the physical layer of ISO/OSI model, which allows to take advantage of interference. On the other hand wireless channel

[1] In this paper, R will be used to denote channel capacity

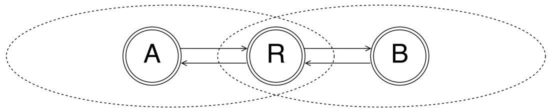

Figure 1: Scheme of 2WRC topology (dotted lines show range of transmitters)

is an unreliable medium and has lower total performance when SNR is low.

2.1 Decode-and-Forward (DF)

This method is in principle the same as Network Coding mentioned before in [2] and was introduced in [3]. Time needed for data exchange is shortened to 3 timeslots. Relay receives data from A and B in two slots and subsequently performs XOR operation. This new packet (of the same length) is sent via broadcast wireless channel to both receivers at the same time. After XOR operation of received data with transmitted, end station gets data meant for itself. Advantage of DF is good performance when interference is present, because the data packets are received, fully decoded and then sent again. According to [3], gain of this method in comparison with routing is:

$$G_{DF} = \frac{\frac{2N}{3T_S} - \frac{2N}{4T_S}}{\frac{2N}{4T_S}} = \frac{\frac{2R_S}{3} - \frac{R_S}{2}}{\frac{R_S}{2}} = \frac{1}{3} = 33\% \tag{2}$$

2.2 Amplify-and-Forward (AF)

Another two methods have in common that they need only 2 timeslots for exchange of two packets. In the first slot both stations A and B are transmitting and relay is receiving mixture of signals. Then the gain is:

$$G_{2T_S} = \frac{\frac{N}{T_S} - \frac{2N}{4T_S}}{\frac{2N}{4T_S}} = \frac{R_S - \frac{R_S}{2}}{\frac{R_S}{2}} = 1 = 100\% \tag{3}$$

The AF method introduced in [4] is based on listening to the mixture of signals (which is nothing else than their linear combination), amplification and sending packet back to end stations. Then the receivers subtract transmitted signal from the received (in analogue way) and try to decode remaining signal degraded by noise. Here is shown the weak spot of this method. The error rate in channel with low SNR will be just higher. On the other side, advantage is in minimal computing performance of the relay, because signal is only amplified. That's why AF is also called Analogue Network Coding.

2.3 Denoise-and-Forward (DNF)

An improvement of AF was presented in [5]. The difference is that the relay tries to match the received analogue data to symbols used in modulation alphabet in a certain way, but in comparison with the DF data aren't decoded, only denoised. The effect is pretty similar. This method can be used in channels with lower SNR than AF. When this parameter is higher, the performance of both methods is equal. Main disadvantage is high required computing performance of the stations.

3 REASONS (NOT) TO USE WNC

No matter the level of noise in wireless channel it's always beneficial to use Network Coding. Even by using Decode-and-Forward method the gain is 33% and can theoretically increase to up to 100% by using two-steps methods, which are on the other hand more susceptible to noise. The disadvantage is that WNC has to be customized for every usage (considering channel delays). Also, especially DNF requires higher computing power at all the stations than usual.

4 MODELLING

Now, my task is to create a simulation of WNC methods in AWGN and Rayleigh fading channel using BPSK or QPSK digital modulation with tunable noise level. The result will be bit error rate (BER), a measurable parameter for comparison at given conditions. In Fig. 2 is shown basic scheme of the program. Input parameters are number of bits, type, SNR and attenuation of channels, modulation and method. The WNC technique block then chooses one of set of functions depicted in Fig. 3. The

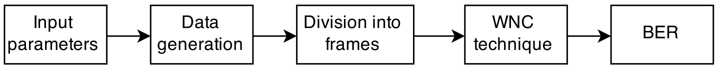

Figure 2: Block scheme of the program

channel models are simulated with Matlab integrated functions from Communications Toolbox.

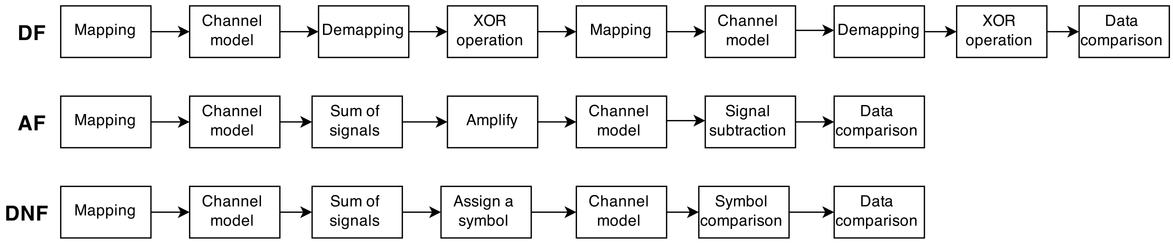

Figure 3: Possible WNC technique blocks

5 CONCLUSION

Wireless Network Coding is way to increase network performance. It can also be used in topologies with more than two hops. In the first testbed the results were even better than expected (less packets were dropped in queues) [6]. Another possible use is in mobile devices to save the battery by shortening time of transmission

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