

Analysis of the new modulation and coding techniques for xDSL

Ing. Tomáš Pajda, doc. Ing. Rastislav Roka, PhD.

Abstract— Nowadays, the demand on higher transmission speed increased, because of more users using the Internet and the applications are demanding the higher transmission speed, too. In this article, I would like to give you my point of view on increasing the transmission speed in xDSL technology, because the DSL is most popular technology used in WAN. I tried to use Reed-Solomon codes to correct errors in case when the channel capacity was overloaded. Below I will provide you the recepie and results.

Index Terms— Reed-Solomon, Forward Error Correction, DMT modulation, Transmission Speed.

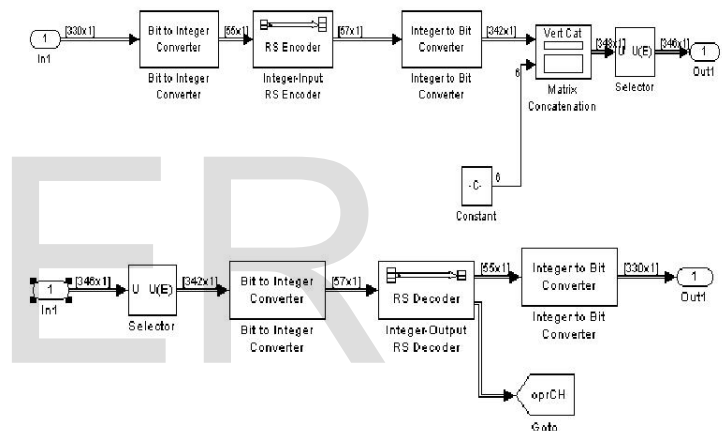
1 INTRODUCTION

The motivation to write this article is based on positive results from testing in Matlab. I tried to overload the measured channel capacity. The overloading was made in terms of sending more modulation symbols than the SNR provided for certain distance. I used two model situations. Let's assume, that we have two results for distance 400 m. One result is with modulator settings for 300 m, where we can put more modulation symbols, because the signal to noise ratio is higher and we can get into distance 400m by using the Reed-Solomon codes and correct errors, that happened because of lower signal to noise ratio in 400m than in 300m. In this case I used virtually higher channel capacity for 400 m (capacity was from the distance 300m). The result was that more transmission errors occurred. I was thinking, how to correct it and the ReedSolomon codes were the solution. Below is the description of thinking during the analysis.

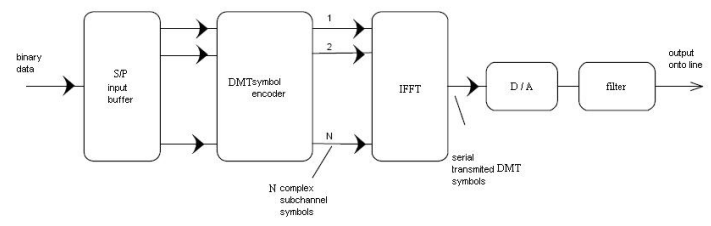
2 ANALYSIS

For the purpose of analysis I used communication model created in matlab [2].

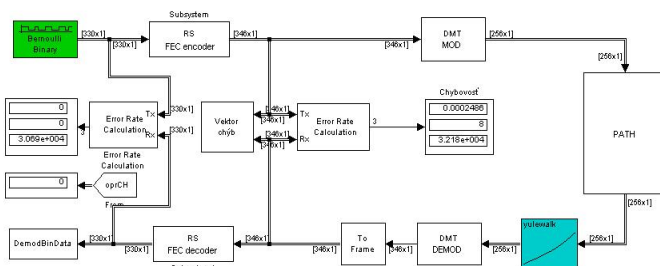
600m. If some error occurred for certain distance, I made another measurement to accommodate the modulator to get errorless capacity and so transmission speed in each measured distance.



Picture 2. : Reed-Solomon encoder, decoder



Picture 3. : DMT modulator



Picture 1. Simulation model.

The simulation model is composed of Bernoulli binary generator as a source of data, Reed-Solomon encoder, DMT modulator, transmission path with error simulation, DMT demodulator, Reed-Solomon decoder and receiver of the transmitted information. There are two errors calculators, first one is for modulation errors and the second one is for errors after application of Reed-Solomon codes.

First of all, I measured the channel capacity without ReedSolomon codes for the distances 300m, 400m, 500m,

After this measurement, I had the number of modulation symbols N , that could be transmitted for each distance for which the measurement was made. The N parameter was then used as a length of codeword for Reed-Solomon codes. Assuming the equation for FEC and channel capacity, that is:

$$K/N < C \quad (1),$$

where N is the number od modulation symbols (and length of the codeword), K is the amount of usefull information and C is the channel capacity.

Because

$$N = K + 2^*T \quad (1.1),$$

and the N parameter is set by measurement, we have two parameters to vary with (K and T). The equation (1) can be also written in this way:

$$K / (K + 2 \cdot T) < C \quad (2),$$

From this equation (2), we can say, that if we want to transmit more data that parameter K represents, we must increase the T parameter, that represents the number of errors, that ReedSolomon codes have to be able to repair. This equation (2) can be also written in a way:

$$1 + (K / 2 \cdot T) < C \quad (3),$$

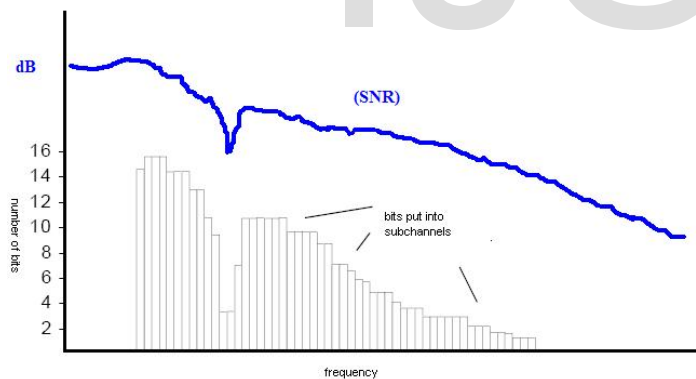
so if we want to increase the amount of data (K) to be transmitted through the channel with capacity C, we should increase the T parameters value. If we set the C value for 300m and the real distance is 400m, we have to be able to correct more errors, but the result is higher transmission speed, even if more errors occur during the transmission, because we can correct those errors using Reed-Solomon codes and the amount of data used for parity of FEC is less than the gain of data in bits that we obtained by application of more modulation symbols and Reed-Solomon codes. If we use higher channel capacity than real, let's say in 400m if we use capacity for 300m, the N parameter will be higher, what means that

$$K / (K + 2 \cdot T) \quad (4),$$

where

$$K + 2 \cdot T = N \quad (5),$$

the K parameter can be higher, so the amount of the useful data can increase, so the transmission speed can be higher. If we now keep the settings (N, K) for the channel capacity in 400m for the distance in 300m, we will have to accommodate the T parameter for the equation number (2) to be valid.

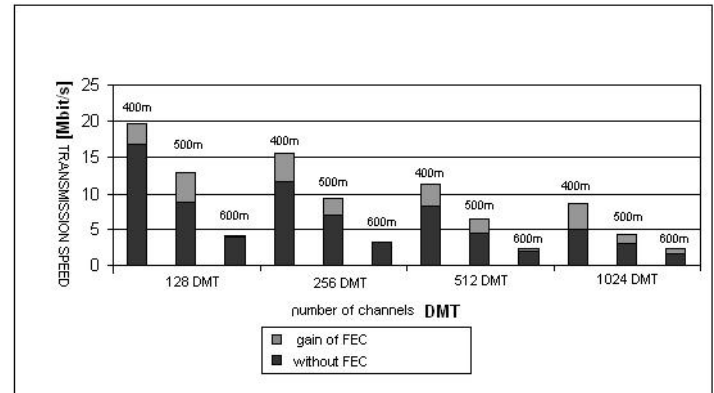


Picture 4.: Signal-To-Noise Ratio

From the signal-to-noise ratio and measurement of the channel capacity in bits/s, we can find out the number of transmittable symbols, what is the codeword length as a

parameter for Reed-Solomon codes. Because of characteristics of metallic lines used in DSL, the signal-to-noise ratio with increasing distance decreases because of the influence of the metallic lines characteristics. So if we want to increase the transmission speed in longer distance, we should use Reed-Solomon codes and so we can afford to use higher channel capacity than the metallic lines in required distance can provide us. Reed-Solomon codes are good solution, because they

can locate and correct the errors that occur during the transmission. Below I will show, that even if more parity bits are necessary to correct more errors when the channel capacity is overloaded (for the distance of 400 m we used settings of modulation for 300m), we will still get gain in terms of transmission speed.



Picture 5.: Results of testing

The picture 5 is showing us the results from testing previous assumptions. Because of positive results I wanted to define, what was happening and wanted to understand, why we can get this gain in transmission speed. From the results we can say that there is some gain visible. Next question is, whether the gain versus parity length is still providing gain in terms of more data to transmit. I made an analysis from the table below (obtained from the measurement in matlab made in [3]),

I [m]	N	K	bit/symbol	RSOPCH [symbol]	frvST [bit]	frM [bit]	RpM [Mbit/s]	RpC [Mbit/s]	errM [bit]	errC [bit]	sum(snr) [10*logdB]	max(snr) [dB]	mean(snr) [dB]
300	51	49	6	1	294	311	24.88	23.52	12	0	21.55	51.13	16.83
325	51	49	6	1	294	311	24.88	23.52	15	0	20.36	49.55	15.91
350	51	49	6	1	294	311	24.88	23.52	47	11	18.76	47.99	14.65
350	51	43	6	4	258	311	24.48	20.64	51	0	18.16	47.47	14.19
350	46	44	6	1	264	278	22.24	21.12	27	3	17.55	47.14	13.71
350	46	40	6	3	240	278	22.24	19.2	18	0	18.36	47.28	14.34
375	46	40	6	3	240	278	22.24	19.2	61	0	16.44	45.99	12.64
400	46	40	6	3	240	278	22.24	19.2	142	0	14.25	44.71	11.14
425	46	40	6	3	240	278	22.24	19.2	332	13	11.79	43.43	9.21
425	46	36	6	5	216	278	22.24	17.28	521	0	10.11	41.96	7.9
425	36	30	6	3	180	217	17.36	14.4	90	0	10.01	43.7	7.82
450	36	26	6	4	168	217	17.36	13.44	245	0	8.34	41.85	6.51
450	32	26	6	3	156	197	15.76	12.48	150	0	6.29	42.16	4.91
475	32	24	6	4	144	197	15.76	11.52	317	0	9.11	40.96	2.82
475	30	26	5	2	130	151	12.08	10.4	24	0	1.42	40.72	1.11
500	30	26	5	2	130	151	12.08	10.4	95	0	-0.82	39.46	0.64
500	27	23	5	2	115	136	10.88	9.2	45	0	-1.29	35.41	-1.01

Tab: 1. Results of testing,

where I put the gain is transmission speed in bits on one side and the amount of data used for parity of FEC on the other side. Let's say that the gain for 350m was 20,64 Mbits/s - 19,2 Mbits/s, what equals to 1,44 Mbits/s. One more parity symbol was used, and if each parity symbol in this case means 6 bits, 1*6 is 6 more bits to transmit. If we subtract 1,44 Mbits/s - 6 bits/s, the result is 1,444 Mbits/s. This means, that even if more parity symbols were used to get into longer distance errorless, we still will get the gain in terms of percentage, here 1,444 / 19,2, what equals to cca 7,52 % of gain. From the results we can say that even if more errors occurred when the channel was overloaded in terms of more symbols transmitted in a unit of time, if we correctly set the ReedSolomon codes, we will be able to repair the errors that occur during the

transmission and because the errors count is not increasing faster than the reed-solomon possibility to correct it, these codes are good for increasing the transmission speed in xDSL. My another idea is also to try to define the maximum of the channel overloading to define the maximum speed that using of these codes can provide. Let's assume the limmity:

$$\lim_{T \rightarrow \infty} (1 + K / 2^*T) < C \quad (6),$$

how K depends on increasing the T parameter? We can write the equation $K / 2^*T$ also in a form $\frac{1}{2} * K/T$, so we can say, that if T increases by 1, the K, which represents the amount of data must increase 2 times, what is in terms of transmission speed positive. But we must keep in mind also the equation mentioned above $N = K + 2^*T$. So the upper limmity of increasing the the parameters K and T is defined by this equation. Another fact that follows these assumptions is that if we want to increase the transmission speed in longer distance, we must use the number of modulation symbols from previous measured distance, or just use higher number of modulation symbols than measured by modulator.

4 ADVANTAGES OF FEC

Reed-Solomon codes and the RM OSI model

From the RM OSI model perspective, the modem is working on the physical layer. There are two possibilities of implementing the Reed-Solomon codes. The first one is the implementation into the modem, where we can have modulation and FEC in one device. The second one is, that we can make a device called Reed-Solomon codec and use it on the customers premisses. The problem is, that the definition of Reed-Solomon codes should be same on each side of the transmission, what means that the generating polynome must be the same, to be able to encode and DECODE the information transmitted through the channel.

Reed-Solomon codes and synchronisation

The one problem, that is not solved, yet, is the synchronisation of the FEC. Let's say, that two clients want to communicate and both are using the modem with Reed-Solomon codes. First of all, there must be the same generating polynome for the codes on both sides. Second condition that must be accomplished is, that during the settings of the connection on both sides, all parameters must be set properly (parameter N, K, T) and the same on both sides. This can be done by setting some exchange of parameters for beginning the transmission protocol. This will be time consuming at the

beginning, but can be usefull in terms of higher transmission speed.

Reed-Solomon codes versus agregation

Another benefit is, that using Reed- Solomon codes we can get higher transmission speed without the agregation of lines with lower speed together. And so if we do agregate these lines with Reed-Solomon codes, we can get much more higher capacity and so transmission speed than with aggregation and without Reed-Solomon codes. We can play with these settings to obtain as much high speed as possible.

Reed-Solomon impleamentation

The possible implementation could be based on defining the Galois field from the channel capacity measurement. After the mesurement we have defined the number of modulation symbols that can be transmitted in a period of time, so called modulation transmission speed. Each combination of symbols is a codeword of FEC. The number of symbols possible to transmitt in a period of time is a codeword length. So if we use higher codeword length, let's say in the distance 350m if we use the codeword length appropriate for 300m, which is higher, we can get higher modulation speed, but with more errors. But if we use some portion of the codeword for correction of the transmission errors, so called parity of the FEC, we will get higher transmission speed in 350m, than if we use the modulation settings for 350m. So there is a benefit of using the FEC, here the Reed-Solomon codes, in possibility to increase the transmission speed and get better results than before.

5 CONCLUSION

From the text above, we can consciently say, that it is possible to increase the transmission speed by appropriately using the FEC, in this article Reed-Solomon codes, to get into longer distance with higher transmission speed. This also means, that we can keep the existing infrastructure od metallic lines and using the mathematical methods we can get into longer distance with higher transmission speed as well as increasing the amount of data, that we are willing to transmitt by increasing the N parameter over the measured value. One thing that is not defined yet is the maximum of increase of the N parameter in each distance compared to measured value in this distance. This idea can be a topic for further research in this topic. I just wanted to show, that there is a way of increasing the transmission speed using mathematical methods and if the idea is clear and the goal is to help in developing a new technology for the benefit of humanity, it is very probable, that the idea will be successful.

I think, that this idea can be used also in different conditions than metallic lines, because every medium used for the transmission of data is producing errors on the transmitted data. The only thing that will change is the medium. I suggest testing in different types of medium than metallic DSL lines.

REFERENCES

- [1] S. Dlháň, Analysis of coding and precoding techniques for VDSL technology in access network, May 2003,
- [2] M. Halás, Analysis of new modulation techniques for VDSL technology in access network, May 2003.,
- [3] T. Pajda, R. Róka, Analysis of the new modulation and coding techniques for technology VDSL, May 2009.

IJSER