Reduction of Packet Loss by Optimizing the Antenna System and Layer 3 Coding

Petr CHLUMSKY[1], *Zbynek KOCUR*[1], *Jiri VODRAZKA*[1], *Tomas KORINEK*[2]

[1]Department of Telecommunication Engineering, Faculty of Electrical Engineering, Czech Technical University in Prague, Technicka 2, 166 27 Prague, Czech Republic
[2]Department of Electromagnetic Field, Faculty of Electrical Engineering, Czech Technical University in Prague, Technicka 2, 166 27 Prague, Czech Republic

petr.chlumsky@fel.cvut.cz, zbynek.kocur@fel.cvut.cz, vodrazka@fel.cvut.cz, korinet@fel.cvut.cz

Abstract. *The article describes the verification of the application of methods of network coding in the mobile wireless network environment with specific antenna system in use. Network coding principles are used for increase the reliability of data transmission. The proposed principles are demonstrated by modelling of the transmission system using data from real mobile networks. The effectiveness of network coding for deployment in wireless mobile networks is demonstrated on the basis of simulation in the simulation environment Omnet++. The input data of the simulation model are obtained by measuring in real mobile network of 2nd generation.*

Keywords

Data transmission, measurement, mobile network, simulation.

1. Introduction

We developed the innovative data transmission scheme used in this article during work on a project that addressed the problem of data transmission over multiple transmission channels with an emphasis on the wireless environment [1]. We optimized common backup path diversity transmission scheme [2] in order to reach a better resiliency of transmission. Results from the performance analysis of the proposed scheme were beneficial; improved resiliency of the transmission was confirmed [3]. In this mentioned work, transmission channels error rate was modeled as a theoretical packet error rate steady on a certain value. In this article, the channels packet error rate is modeled based on data from a real measurement.

This measurement, during which values of packet error rate (PER), round trip time (RTT) and data throughput were obtained, was performed as a result of parallel data communication over data networks of Czech mobile operators Telefonica O2 CZ and T-Mobile CZ on a route by car. Antennas system for the measurement was designed as a multiple band and multi-polarization. We want to use these data for more accurate results how will operate the proposed scheme under realistic conditions with focus on the data resiliency.

2. System Design

Innovative data transmission scheme, which analysis on real data is presented, is intended for use in systems with two separate data channels. It is developed as a part of the system under project "Development of adaptable and data processing systems for high-speed, secure and reliable communication in extreme conditions". It is designed to be more robust compared to the common backup data transmission scheme. Therefore, the overall transmission packet loss is the most important value. This scheme has its basis in the network coding theory which was firstly introduced in [4]. The key feature is in the idea of not only moving packets to different paths but also modifying packet content. We realized this modification using bitwise exclusive disjunction (XOR) for manipulation with the content of packets. The benefit of this data operation is in the possibility of decoding missing data from correctly received packets without any retransmissions. The scheme is designed as end-to-end rather than point-to-point correction system, therefore, it brings the possibility to overcome network nodes in the transmission path.

2.1. Transmission System Design

Principle of the scheme is shown in Fig. 1. Packet from the data source on the left side is sent directly to channel 0, whereas its copy is combined with the previous packet which is saved in the queue. This combination is done by exclusive-or (XOR) operation. After the operation is executed, the resulting packet is sent through channel 1. The packet that was previously saved in the queue is replaced by the current one (the copied packet used for a combination). Therefore, the size of the queue in the coding part of the scheme is just the length of two consecutive packets.

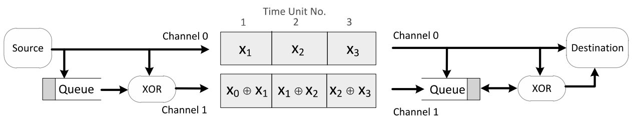

Fig. 1: Transmission scheme principle.

When a packet from channel 0 is lost, or corrupted, there is still possibility of its recovery. Moreover, the recovery of the original packet from channel 0 is still feasible even in a situation where the corresponding packet from the redundant channel is also lost. This is possible because of the characteristics of the XOR operation and the decoder function. This recovery is an advantage compare to the common backup scheme where both channels transmit the same data, so it is impossible to recover the missing packet. Proposed scheme is able to reconstruct up to three consecutively missing packets. For this reason, the decoder part (on the right side of Fig. 1) requires a queue for saving previously, correctly received or reconstructed packets. Example of this situation is shown in Eq. (1). The packet from channel 0 (x_1) and its correspondent packet from channel 1 ($x_0 \oplus x_1$) are lost and, moreover, the following packet from channel 0 is also lost (x_2). The proposed transmission scheme is capable of reconstructing both of the lost packets from channel 0 without any retransmissions. Packets from channel 1 are no need to recover because this channel is intended as a redundant one. For a reconstruction of the original data it is necessary to receive the redundant packet for the second lost packet from channel 0 ($x_1 \oplus x_2$) and also receive the following pair of original (x_3) and its corresponding redundant packet ($x_2 \oplus x_3$).

$$\begin{aligned} x_1, (x_0 \oplus x_1), x_2 \ldots lost \\ x_3 \oplus (x_2 \oplus x_3) \Rightarrow x_2 \\ x_2 \oplus (x_1 \oplus x_2) \Rightarrow x_1 \end{aligned} \quad (1)$$

Process of reconstruction in the decoder relies on the number of consecutively missing packets. The example in Eq. (1) describes situations when two original packets in a row and a single redundant packet are lost. When the number of consecutively missing packets is lower, then the process of decoding is less complicated and it has lower demands on the length of the decoding queue. Complete description of the scheme and its performance analysis is in [3].

2.2. Antenna System Design

Instead of previous configuration of measurement system described in [5], the current version used traffic generator powered by FlowPing application [6]. This application is highly configurable UDP measurement tool with possibility of round trip time measurement. The other difference besides previous is in use of the antenna system. The previous system used simple dipole antennas. Now, we used multiple band and multi-polarization antennas which are more suitable for the mobile environment in urban and suburban areas. The designed antenna stabilizes received signal level during the movement and significantly reduces packet losses. Comparison of this antenna with different types is shown in Fig. 2. The detail description of used antennas is in the Tab. 2 and in Fig. 3. Reflection coefficient (S11 parameter) for both frequency bands shows the graph in the Fig. 4.

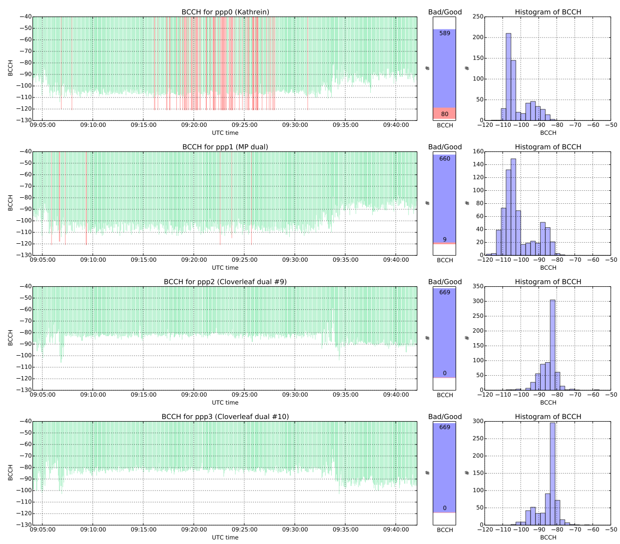

Fig. 2: Comparison of antennas signal level.

Tab. 1: Selected antenna parameters.

Type	Cloverleaf omnidirectional
Polarization	Circular
Frequency Band	900, 1800 MHz
Gain	3 dBi (900 MHz) 5 dBi (1800 MHz)

Fig. 3: Antenna testbed at the roof of the car.

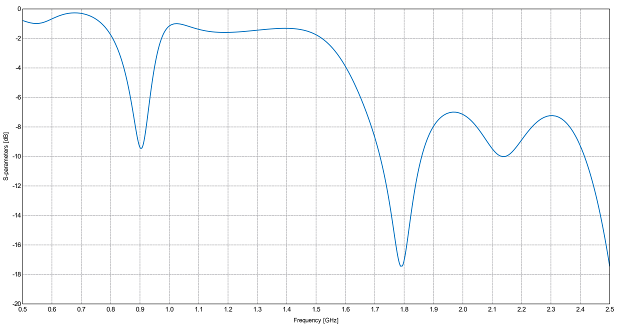

Fig. 4: S11 parameter of the dual band cloverleaf antenna.

Tab. 2: Setting of the measurement equipment.

Parameter	T-Mobile	Telefonica O2
Channel number	0	1
Technology	EDGE	EDGE
Traffic generator	Flowping	
Traffic type	UDP	
Traffic throughput	45 kb·s^{-1}	
Packet size	1000 Bytes	
Measured parameters	PER, RTT, Throughput	
Measurement time	140 s	
Velocity of car	$\sim$ 20 km·h^{-1}	
Measurement date	27.5.2014	
Measurement location	Dejvice, Prague, Czech Republic	

3. Data Transmission Modeling with Layer 3 Coding

The proposed scheme was completely implemented in C++ programming language in the simulation framework OMNeT++. OMNeT++ is an object oriented modular system which is based on the processing of discrete events; more information about this framework are in [7]. It was necessary to simulate packet losses for the testing of the transmission scheme recovery capabilities. We decided to model the channel packet error rate from the data from real measurement. Obtained data allowed us to model the behavior of the transmission scheme more accurately under realistic conditions of mobile networks. For this purpose, it was necessary to implement a new channel for the simulation; this channel is able to read parameters obtained during the measurement and adjust the simulation based on them. Implementation is based on the reading of the input file and matching actual channel parameters based on the simulation time.

3.1. Input Data from Real Measurement

Real measurement was done by a special testbed based on system which was presented in [5]. The measurement system is able to measure the actual delay and throughput of passing packets in each of the communication interfaces. System is able, on the interface of mobile networks, to determine the current physical layer parameters, such as the type of the mobile network (2G/3G), level of the received signal (RSSI), or cell ID (Cell ID) to which is a data terminal connected. A key part of that system is a unit of time synchronization that allows to perform the correlation of measured quantities.

The purpose of the measurement was to obtain data about transmission channels behavior under real conditions. The measurement was based on the packet error rate on separate communication interfaces during movement of the testbed. A constant data flow was generated between the mobile testbed and the Internet server part in the uplink direction from the testbed. Data were received and analyzed on the server part. Among the measured parameters were also throughput and round trip time. Subsequently, these values were adapted for use in the simulation environment Omnet++.

3.2. Simulation Results

The obtained parameters of packet round trip time were used as delay values for the transmission channels, the throughput parameters were set as a maximum throughput for the channels. The most important parameter for our purpose, the packet error rate, was also set, as previous parameters, specifically for every specific time based on the measured values. Table 3 shows average values of mentioned parameters. The simulation was performed with the same settings also for the common backup scheme. Table 4 shows the channel error rates from the measurement and, in the *Resulting PER column*, there is an overall packet error rate for the data transmission in simulation. The advantage of using two channels, in terms of communication robustness, is obvious. The common backup scheme was able to reduce the loss ratio almost by an order of magnitude. Nevertheless, the impact of the recovery abilities of the proposed scheme is clear. The possibility of the recovery of two packets in a row from one of the channels results in the packet error rate of 0.003.

Tab. 3: Measurement results.

Parameter	T-Mobile	Telefonica O2
RTT	4904 ms	3946 ms
Throughput	6.2 kb·s^{-1}	7.9 kb·s^{-1}
PER	13.5 %	11.9 %

Tab. 4: Simulation results.

	Channels PER		Resulting PER
Proposed scheme	13.5 %	11.9 %	0.3 %
Backup scheme	13.5 %	11.9 %	2.6 %

It is important to mention that the character of measured data has inevitable impact on the resulting packet error rate. This impact is based on the spread of the lost packets and based on the number of these lost packets in a row. Long bursts of errors that occur only at one of the channels favors the common backup system where the second channel continuously transmits the same original data as on the erring channel. Short transmission interrupts that occur while roaming between mobile operators cells or when the antenna is shaded has similar impact on both schemes in case that the second channel continues in transmission without error. The backup scheme has full redundancy for these cases, the proposed scheme is able of packet reconstruction. Nevertheless, in case that both channels are influenced with this short packets outage, then the proposed scheme gains considerable advantage in the possibility of recovery of missing packets.

4. Conclusion

This article presents verification of innovative data transmission scheme in simulation where transmission channel parameters were modeled by data from measurement. The proposed transmission scheme operates with two separate transmission channels. The first channel is used for original data and the second channel is designed as a redundant one. An important part of this scheme is in the packets combinations that are transmitted through the second channel. These combinations are realized by the exclusive-or operation. Because of the possibilities given by the combined packets from the second channel is the decoding part of the scheme capable of reconstruction of missing packets without any retransmissions.

Advantage of this scheme in transmission resiliency was already confirmed [3] with channel packet error rate modeled as a theoretical value, now, we wanted to verify this scheme with transmission channel modeled based on the data from measurement. Measurement was performed by a special testbed with specific multiple band and multi-polarization antennas. The parameters of packet error rate, round trip time and throughput were obtained and used for modeling the channel parameters in dependency on the time. Simulation was also performed for the common backup scheme for the possibility of comparison. Results proved that the proposed scheme is able to be more robust compared to the backup scheme that uses both channels for transmission of the same data. The difference between these schemes depends on the actual transmission channels conditions, whether packet losses occurs in long bursts or as an individual interrupts.

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About Authors

Petr CHLUMSKY was born in 1985. He received his M.Sc. from the Czech Technical University in Prague in 2010. Since 2010 he has been studying Ph.D. degree. His research interests include wireless transmission, network coding and network simulation.

Zbynek KOCUR was born in 1982. He received his M.Sc. degree in electrical engineering from the Czech Technical University in Prague in 2008 and Ph.D. degree in electrical engineering in 2014. He is teaching communication in data networks and networking technologies. His research is focused on wireless transmission and data flow analysis, simulation and optimization. He is currently actively involved in projects focused on high speed data transmission from fast moving objects and data optimization via satellite network.

Jiri VODRAZKA was born in Prague, Czech Republic in 1966. He joined the Department of Telecommunication Engineering, Faculty of Electrical Engineering, Czech Technical University in Prague in 1996 as a research assistant and received his Ph.D. degree in electrical engineering in 2001. He has been the head of the Transmission Media and Systems scientific group since 2005 and became Associate Professor in 2008. He participates in numerous projects in cooperation with external bodies. Currently he acts also as vice-head of the Department.

Tomas KORINEK was born in Jicin, the Czech Republic, in 1979. He received the M.Sc. degree and the Ph.D. degree in radio electronics from the Czech Technical University in Prague, the Czech Republic, in 2005 and 2012 respectively. From 2007 to 2008, he was a research and designer engineer at RFspin s.r.o., where he was engaged in antennas and microwave circuits. He is currently an Assistant Professor and the head of laboratories at the Department of Electromagnetic Field at the Czech Technical University in Prague. His research interests include the area of measurements in EMC and antennas.