FEC Data Communication with Reed-Solomon Codes in HIPERLAN/2 Networks

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Abstract - **The abilities of data communications in HIPERLAN/2 Networks are considered. An algorithm for FEC data communication with Reed-Solomon codes is presented. It is made an analysis of potential noise retainability for quality and reliability of data information, according to the ETSI and MIL-STD standards. We analyze a possibility for use of this data coding in these networks and the quality of its services (QoS). Comparative analysis is made of presented algorithm for data communication with convolution coding of data.**

I. INTRODUCTION

HIPERLAN/2 is a technology, which is created by European Telecommunications Standard Institute (ETSI) as a project for Broadband Access Networks (ETSI BRAN). They will provide data communication with data rate of up to 54 Mbitps for connections into open and covered areas at short distances (at least 150 m). At present time of the development stage unification between ETSI and Japanese ARIB is realized about specifications of the basic system parts. This standard is developed as a distension of IEEE 802.11 Standard for High-Speed Applications [1].

The basic motives, which necessitate Broadband Radio Access Networks applications, are:

- Huge growth of wireless and mobile communications;
- A rise of multimedia applications in radio communications;
- Providing of high-speed INTERNET Access;
- Telecommunication Market and Industry Change.

Current wireless telecommunication networks, which are usually narrowband, are use prevalently for voice connections. Cellular mobile systems of 3G (3-th Generation) try to provide high-speed client access up to 2 Mbitps for each channel. This improves data transfer by burst commutation for mobile multimedia applications. It is possible to achieve even higher data rates into LAN's by the use of new traffic management for wireless communication at short distances.

Radio access networks of type BRAN (Broadband Radio Access Networks) are developed, which standardize in different wireless broadband networks HIPERLAN/2 (High Performance Radio Local Area Network) with high quality of services.

These radio communication systems will provide high-speed access to different types of fixed and mobile broadband gates. In comparison with other cellular systems its mobility is limited.

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The more typical applications can be LAN at skyscrapers, offices, homes, blocks of flats, airports, railway stations and others.

II. SYSTEM'S DESCRIPTION

HIPERLAN/2 standard specifies a network for radio access, which can connect to transport networks with different communication technologies. This is possible due to [3]:

- Flexible architecture, which defines independent of transport environment PL (Physical Layer) and DLC (Data Link Control);
- Multitude of sub-layers, which allow connection to different transmission systems (fig.1). They define some sub-layers, some of which are in standardization process. These are layers for interaction with:
  - INTERNET Protocols (IP) to transport networks (LAN/Ethernet) and Data Channel Point-to-Point Protocol (PPP);
  - Asynchronous mode for data communication and transport networks as ATM;
  - 3G (3-th Generation) transport networks;
  - Networks, which use Protocols IEEE-1394 (Fire-wire) and applications.

Data packages, which are transmitted via these transport

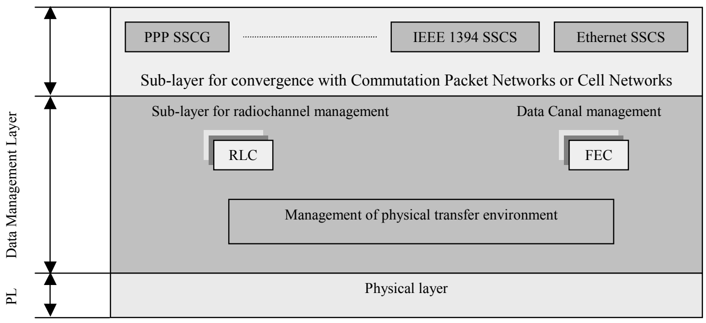

Figure 1

networks, can have various lengths, types and contents. A Special layer for concordance in HIPERLAN/2 packages the data in segments with fixed length, i.e. client data unit for U-SDU (Service Data Unit) services, and it transmits them to final recipient by transfer services of DCL data channel and PL.

HIPERLAN/2 standard supports maximal data terminal equipment speed up of to 10 mps. Also it presents an environment for elimination of various noise and jamming factors of radio wave pervasion with aim [3]:

- Communication link support in hard noise conditions;
- Support of exact quality of services;
- Finding optimal effective ratio between communication distance and data rate.

HIPERLAN/2 air interface is based of TDMA (Time Division Multiplex Access), which helps create flexible platform for business and home multimedia applications with data rates up to 54 Mbitps. HIPERLAN/2 is based of cellular mobile network technologies by mixed connections area-to-area (ad-hoc). The basic work modes are two [3]:

- CM-Central Mode – It is for cellular network technology, where each radio cell is managed by AP (Access Point), which covers a definite geographical area;
- DM-Direct Mode – It concerns topology, by which some communication link consists of a couple of areas, usually private networks, and the whole service area is cell area.

CL (Convergence Layer, which is presented on figure 1) has two basic functions:

- It adapts service announces from higher layers to services, presented by DLC;
- Coverts the packages with fixed and variable lengths in fixed unit lengths SDU, used in DLC.

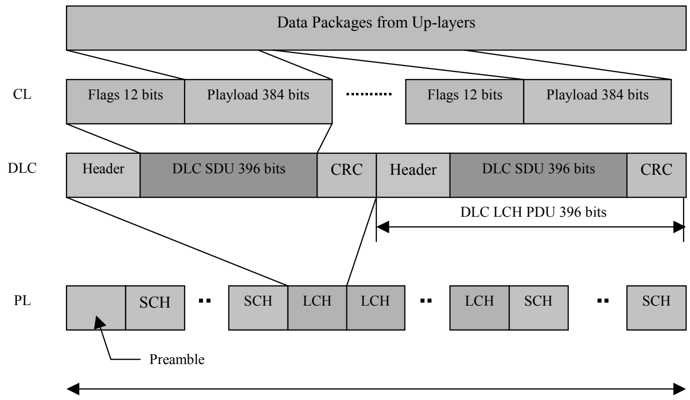

Figure 2

The segmentation, adding and assembly of the data with fixed length DLC SDU (Data Link Control Service Data Unit) is the basic function, which allows the standardization and realization of DLC and PL layers, independently of transport environment. On figure 2 is presented the way of physical layer formation by higher layer data. For numerical data moving DLC SDU are package data PDU (Protocol Data Unit), transmitted by the channels for traffic type of the LCH (Long Transport Channel). Data packages with control messages move by the channel type SCH (Short Transport Channel) [1].

III. DATA COMMUNICATION

The basic function, which makes each contemporary digital communication network, performs data communication, regardless of its application. Therefore for present services quality it is very important to know the structure of DLC layer. It has the following sub-layers:

- RLC (Radio Link Control);
- EC (Error Control);
- MAC (Medium Access Control).

RLC sub-layer manages access, radio resources and establishing and breaking up of client data channel.

Basic organization of physical digital radio interface frame has a continuance of 2 ms and it holds information for management of the broadcasting, of the frame, of the access feedback, of the data moving to terminal and back and a management of random access mechanism. This makes MAC sub-layer.

The EC sub-layer defines in significant extent the quality of the presented services QoS (Quality of Services). Depending on type of services methods with repeats and confirmations are used. They require comparatively huge radio resource and they constrict the time, when it makes different communication type. This type of data communication is possible to realize in low-speed information transmissions, where the demands on transmitting information reliability are very hard.

The largest application in practice is of the methods for data communication without confirmation. It is possible to realize a communication with short time delay and BER (Bit Error Rate) within the limits of 10^{-5} using FEC (Forward Error Control). HIPERLAN/2 standard documentation recommends convolution-coding use [3]. Because data communication is realized in ISM Band (Industrial Scientific Medical), where the basic frequency is about 2.4 GHz, in received information there are burst errors. For communication BPSK (Binary Phase-Shift Keying), QPSK (Quaternary Phase-Shift Keying) and M-QAM (M-ary Quadrature Amplitude Modulation) signals are used, depending on desired data rate and error control symbol numbers, which is presented by modulation code index in Table 1 [1].

Table 1

Mode	**Modulation**	**Modulation Code Index**	**Data Rate**
1	BPSK	1/2	6 Mbitps
2	BPSK	3/4	6 Mbitps
3	QPSK	1/2	12 Mbitps
4	QPSK	3/4	18 Mbitps
5	15-QAM	9/16	27 Mbitps
6	16-QAM	3/4	36 Mbitps
7	64-QAM	3/4	54 Mbitps

HIPERLAN/2 standard defines measurements and signalizations, which support a great number of radio network functions as:

- Automatic Frequency Selection;
- Radio Link Adaptation;
- Connection transference between network cells;
- Multi-ray antennas and equipment manufacturing.

These functions and their algorithms are determined by equipment manufacturing companies. This allows FEC with Reed-Solomon using for data communication codes, as it takes into consideration modulation code index according to the data rate and radio signal types, which are presented in Table 1. Reed-Solomon Codes are non-binary cyclic codes, which have very good correcting abilities into channels with package errors as in ISM Band. Bit Error Rate P_e and symbol probability P_s determine after receiver decoder QoS. P_s can be used in the determination of the length of one code element of the Reed-Solomon code. The probability for error after the decoder can be calculated with the equation [4]:

$$P_{eRS} = \sum_{i=n-k-1}^{n} \binom{n}{i} P_e^i \left(1 - P_e^i\right), \quad (1)$$

where n is the whole code word length and k is the number of code word information elements.

If we don't use noise retainability coding of the information BER for the presented on table 1 modulation signals can determine with the following analytical expressions [4]:

- For M-QAM signals Bit Error Rate P_e is:

$$P_e = \frac{1}{2M} erfc\left(\frac{1}{2}\sqrt{SNR}\right), \quad (2)$$

where conversely error function can be presented with [2]:

$$erfc(x) = \frac{2}{\sqrt{\pi}} \int_x^{\infty} e^{-t^2} dt, \quad (3)$$

and SNR is Signal-to Noise-Ratio of the receiver input.

- For M-PSK signals as in BPSK signals phase index M=2 and for QPSK signals M=4, BER is calculated with [4]:

$$P_e \approx erfc\left[\left(\sqrt{2SNR}\right)\sin\left(\frac{\pi}{M}\right)\right]. \quad (4)$$

The relationship between BER and Ps for non-binary modulation systems can be show by the equation [4]:

$$P_e = \frac{2^{k-1}}{2^{k-1} - 1} P_s, \quad (5)$$

where $k = log_2 M$.

IV. NUMERICAL RESULTS, SIMULATION, CONCLUSSIONS AND DISCUSSIONS

On figure 3 is presented a research by PC simulation of BER for BPSK and QPSK signals after Reed-Solomon receiver decoder from input SNR on the presented in Table 1 data rate with 8 bits code element length. On figure 4 is shown a research by PC simulation of BER for M-QAM signals after Reed-Solomon receiver decoder from input SNR with 8 bits code element length. The chosen code element length of 8 bits is optimal for standardization data communication frame (figure 2). The researched Reed-Solomon codes are with non-maximal length, as (48,24) corresponds to modulation code index 1/2, (48,36) corresponds to modulation code index 3/4 and (48,28) corresponds to modulation code index 9/16. Produced polynomials for these codes can be found in [6].

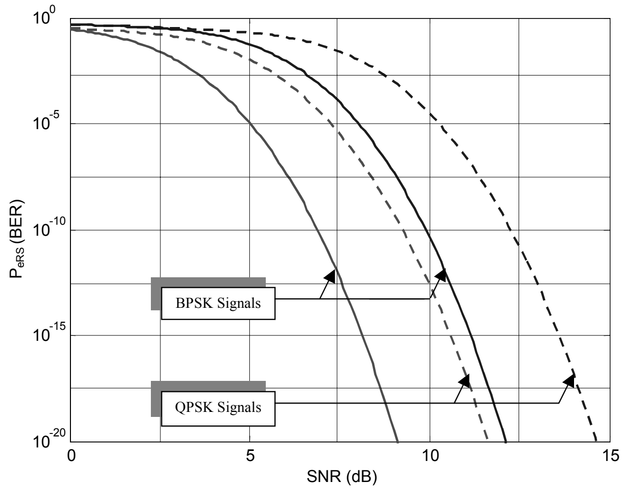

Figure 3

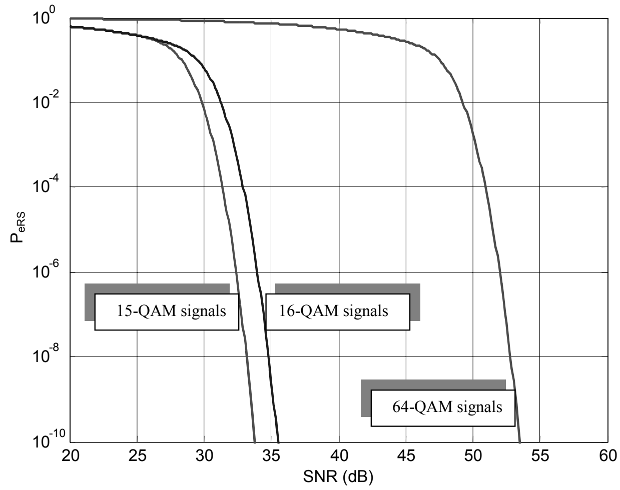

Figure 4

From the researches we can draw the following conclusions:

1. It is possible to realize quality connection down to 5 dB depending on used modulation signals and modulation code indexes;
2. Presented data communication approach is easy to realize and at the same time it is flexible too. This allows its use in building of HIPERLAN/ networks;
3. According to MIL-STD standards for data communication establishing we can use BPSK signals with modulation code index 1/2 and data rate up to 6 Mbitsps;
4. In high-speed connections it is possible to realize communication by shorter code element, corresponding to one or two symbols of the modulation signals;
5. It is possible use Reed-Solomon codes with minimum 6 bits code element length, as we make precursory estimation of the syndrome decoding profit in the receiver;
6. The presented algorithm improves on noise retainability of data communication, compared to the researches of convolution codes in [3]. The profit is about 5 dB. This

allows its use for military and civil wireless LAN's building for Air Traffic Management on the Airports;

It is necessary to research the maximum distance for the realization of radio communication of this type of wireless LAN. This would help for the building, design and support of these networks. This can help the interaction between the clients of the networks and it is very important for management of the transport and other economy sectors.

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