The Algorithm of Mathematical Modeling of Digital Stream of Television Broadcasting Taking into Account Systemic Relationships

Aleksei V. Voronin[1]

[1] Institute of Informatics Problems, Federal Research Center 'Computer Science and Control' of the Russian Academy of Sciences, Moscow, Russia, aleksey.v.v@mail.ru

Abstract

Data analysis in digital streams of television broadcasting at the modern stage of metadata development does not meet the requirements for their structuring in modern information systems (television, geoinformation and telecommunications). One of the main requirements is the relevance of meta and geodata to be analyzed. Keeping data up to date is a non-trivial task. Currently, to keep meta and geodata up to date, they are regularly and periodically updated using statistical methods for processing and analyzing data. The statistical models of bit sequences used in this case do not allow to take into account the qualitative change that occurred at the present stage of development of information and communication systems, namely the presence and increase in the volume of transmission of control information in digital streams transmitted by information systems. The article is devoted to the modeling of data transmitted in digital streams of television broadcasting.

1 Introduction

The global market of information and communication equipment requires substantial upgrading. This is due to advances in scientific and technological progress. A variety of systems, topologies for building networks that form the diversity of the information communication world. The resistance of various devices (networks) is provided through standardized interface converters of various levels of the reference model of open systems interaction.

Analysis of data circulating in digital streams (DS) at the current stage of metadata development allows us to draw the following conclusion. The requirements imposed by the standards for their structuring in television, geo-information, telecommunications, do not correspond to relevance. Currently, to keep meta and geodata up to date, they are regularly and periodically updated using statistical processing and analysis methods [1–5]. The statistical models of bit sequences used in this case do not allow to take into account the qualitative change that occurred at the present stage of development of information and communication systems [6–10]. These include the presence and increase in the volume of transmission of control information in the digital streams of information systems.

Purpose of the study. Development of an algorithm for mathematical modeling of a digital stream on the example of television broadcasting. The system relationships of the composition of control and data planes are taken into account.

Solved problems.

1. Analysis of digital streams generated in accordance with ISO/IEC 13818 and ETSI 300468 standards.
2. Development (synthesis) of an algorithm for mathematical modeling of a digital stream of television broadcasting, taking into account the systemic links of the composition of control and data.

2 Analysis of Digital Streams (ISO/IEC 13818, ETSI 300468)

The main standard governing the formation of a digital stream of broadcast media broadcast television, is ISO / IEC 13818 [8]. At the core of the digital television broadcasting project is the MPEG-2 container concept. The standard regulates three methods for introducing data into MPEG-2 packets during the formation of elementary, program, and transport streams of broadcasting.

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1. Data piping. The essence consists in placing the data directly in the load area of the MPEG-2 packet. There is no time information in the packet header. The transfer takes place only in asynchronous mode.

2. Data streaming. The data is placed directly in the useful part of the program stream. Transfer is carried out in an asynchronous, synchronous or synchronized modes. In the header of a packet, the corresponding mode of operation information is transmitted (reference to the system clock).

3. Multiprotocol encapsulation. Data generated by other protocols (for example, IP) are placed in sections of MPEG-2 packets. This process is managed by a special DSM-CC transport protocol.

Consider streaming based on MPEG-2 packets. Compressed using audio or video codec data is placed in a container. Packages containing data of the same type (for example, audio) form a elementary stream (ES) of data (for example, an elementary stream of audio data). Elementary streams that have a common clock synchronization (for example, one program), form a program stream (PS) data.

MPEG-2 packets of the elementary stream have a fixed length of 188 bytes. Four bytes are allocated to the header and 184 bytes to the data. This can be video or audio data, user data. The packet size is chosen for compatibility with the widely used asynchronous ATM data transfer standard used in communication networks.

The MPEG-2 packet header structure is presented in Table 1.

Table 1: The MPEG-2 packet header structure.

Field	Bit
Sync byte	8
Ttransport error indicator	1
Payload unit start indicator	1
Transport priority	1
Program identifier – PID	13
Transport scrambling control	2
Adaptation field control	2
Continuity counter	4

The analysis of the fields is considered on the example of a fragment of the MPEG-2 packet (Table 2). The byte values are given in hex and binary systems, the numbering of bytes begins with the sync byte of the MPEG-2 packet.

Table 2: The fragment of the MPEG-2 packet (header).

№	0	1	2	3
Hex	47	40	6A	1D
Bin	01000111	0 1 0 00000	01101010	00 01 1101

The MPEG-2 transport packet header contains:

– sync byte – a field with a length of 8 bits (zero byte in Table 2), the value of which is 0x47;

– transport error indicator – a field with a length of 1 bit (the first bit of the first byte in Table 2), “1” is an error in the packet;

– payload unit start indicator (PLUSI) – a field with a length of 1 bit (the second bit of the first byte in Table 2) for the implementation of the data fragmentation mechanism ("1" – in the package, the beginning of the section);

– transport priority – a field with a length of 1 bit (the third bit of the first byte in Table 2), “1” – packet priority;

– packet identifier – PID – a 13-bit field (five bits of the first byte and the second byte in Table 2) for identifying data of the same type;

– transport scrambling control – a field with a length of 2 bits (the first debit of the third byte in Table 2) to indicate the scrambling of the load;

– adaptation field control – a field with a length of 2 bits (the second flow rate of the third byte in Table 2) to indicate the presence of an adaptation field;

– continuity counter – a field of 4 bits in length, the value of which is increased by one in packets with the same program identifier.

If an adaptation field identifier in the MPEG-2 packet header indicates that it is in the data field, then the adaptation field itself occupies a part or area of useful data. It also serves to input control and auxiliary signals transmitted in a packet (for example, synchronization signals).

A program flow is formed by multiplexing one or several elementary streams with a common time base and individual identifiers (PID). A television program forms a program stream consisting of elementary video, audio, and synchrotact streams.

At the stage of formation of a transport stream (TS), program streams are combined by the method of asynchronous batch multiplexing into a single transport stream. The TS can be built directly from elementary streams or other TSs while maintaining the general syntax rules of the MPEG-2 transport packets. Such a hierarchical structure provides greater flexibility in the construction of broadcasting systems. For example, you can declare one elementary stream belonging to more than one program and organize several virtual streams.

In addition to video, audio, user data and synchrotacts, PSI (Program Specific Information) tables are entered into the stream (ISO/IEC 13818).

Each thematic table forms the elementary stream of the corresponding control data. For their unambiguous identification, the standard regulates the system of identifiers: PID, Table id.

In addition, the transport stream of digital broadcasting in relation to the program stream represents a higher level of data organization [9, 10]. One transport stream carries several programs that are not connected by a single time base, implementing an asynchronous data transfer method. The ETSI 300468 standard regulates the structure of the DVB transport stream, which is formed as a multiplex of program streams (audio, video, sync data, PSI) and Service Information (SI).

Service information [9] is intended to automate the process of managing user terminals and informing consumers about services. SI describes the composition and parameters of the network (a set of TSs transmitted in a single delivery system), services (a set of ESs belonging to one program and having a common time base), bouquets of programs (a set of services offered to the subscriber as a single product) and events (group of ESs belonging to the same service and having a certain start and end time).

The service information is broadcast in the form of thematic tables consisting of sections, is transmitted to the load field of MPEG packets. The size of the sections does not exceed 1024 bytes. Table sections consist of a header, the actual data (control information) and the CRC.

The analysis of digital streams (ISO/IEC 13818, ETSI 300468) allows us to conclude about the current trend of structuring DS. At the same time, along with data, control information is entered into the stream at all levels of the reference model of open systems interaction (for example, MPEG-2 packet headers, program specific and service information). We use these results to develop an algorithm for mathematical modeling of a digital stream of television broadcasting.

3 The Algorithm of Mathematical Modeling of a Digital Stream of Television Broadcasting Taking into Account the System Links of the Composition of Control and Data

The current trend in the development of the telecommunications world is an increase in the volume of transmitted data (control, payload) and the standardization of services offered to consumers [6]. The stream formed according to the standard of digital television broadcasting contains information and control data [8–10].

The telegeoinformatics [7] deals with the control data, which gives answers to the questions of building and maintaining information and communication systems in space. Networks at the same time have a developed topology. Circulating data streams have a multiplex structure reflecting the system communications and patterns of composition of control and data at all levels of the reference model of open systems interaction (Fig. 1) [2–4, 12].

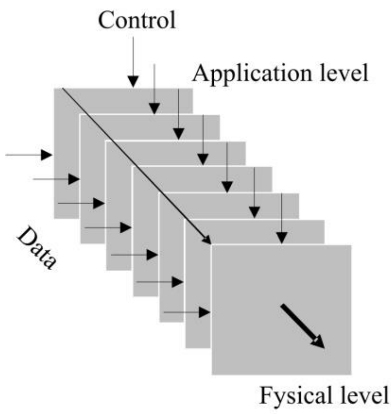

Figure 1: The composition of control and data

Control information - data containing characteristics parameters, commands and control tables at all levels of the reference model of open systems interaction, ensuring the transfer of user data and the functioning of the system as a whole.

Currently, the following traffic patterns are known that are used in advanced planning, performance forecasting, regulation and organization of traffic management of information and communication systems.

1. Model elastic traffic. Able to take into account changes in the flow rate in accordance with changes in network bandwidth (e-mail, file transfer, network news, interactive applications).

2. Model of inelastic traffic. Not able to take into account changes in the flow rate (multimedia applications, audio, and video).

3. The first group of statistical models of traffic. Traffic is defined as a probabilistic discrete-time process with the missing autocorrelation function (Poisson and Bernoulli processes).

4. The second group of statistical models of traffic. The traffic is defined as a probabilistic process of discrete time by introducing a dependence into a random sequence – the presence of an autocorrelation function (Markov model).

5. Model traffic in the form of fluid flow. Characterized by flow rate and traffic capacity. Requires significant computational resources when modeling.

6. Autoregressive traffic model. Describes traffic by a linear autoregressive function.

7. Model of video traffic. Represents a data stream as a result of a combination of actions of heterogeneous processes, which are described by various functions and expressions.

None of these models take into account the current trend in the development of the telecommunications world, which consists in increasing the share of control information in digital streams.

Based on the foregoing, the digital streams of television broadcasting are described by the expression (1)

$$DS = \sum_{n=1}^{N} ES_n + \sum_{k=1}^{K} ES_k, \tag{1}$$

where DS – digital stream of broadcasting;

ES – elementary streams;

N – the number of elementary traffic data streams in the DS;

K – the number of elementary control information streams in the DS.

The expression allows to take into account the proportion of traffic data and control data transmitted at all levels of the reference model of interaction between open systems. Describes a digital stream of television broadcasting as the sum of elementary streams, which contain both traffic data and control information.

Each ES contains data and control information of the appropriate level of the reference model of open systems interaction

$$ES_{n_j} = \sum_{l=1}^{L} D_l + \sum_{h=1}^{H} D_h, \tag{2}$$

where data (D) is analyzed at the j-level of the reference model of interaction of open systems;

L – the number of control information protocols at the j-level reference model of the interaction of open systems;

H – the number of protocols with data at the j-level of the reference model of interaction of open systems.

Using expressions (2) and (1), we obtain an expression describing the digital stream of television broadcasting:

$$DS = \sum_{j=1}^{J} \left(\sum_{n=1}^{N} \left(\sum_{l=1}^{L} D_l + \sum_{h=1}^{H} D_h \right)_n + \sum_{k=1}^{K} ES_k \right)_j, \tag{3}$$

where J – the number of levels of the reference model of interaction of open systems.

Model concretization taking into account the intensity of following byte-multiples of user and control data:

$$\upsilon t = \sum_{j=1}^{J} \left(\sum_{n=1}^{N} \left(\sum_{l=1}^{L} \lambda_l d_l 8t + \sum_{h=1}^{H} V_h \right)_n + \sum_{k=1}^{K} \lambda_k d_k 8t \right)_j, \tag{4}$$

where λ – the intensity of data following;

d – data size in bytes;

υ – information speed of data broadcasting;

V – the volume of data;

t – time.

The developed model allows you to systematize and update knowledge about the data transmitted to the DS for information and communication systems. Based on the obtained (synthesized) expressions, the adequacy of the developed mathematical model of the digital stream of television broadcasting was tested. The check was carried out taking into account the system relationships of the composition of the control and data according to the completeness criterion (volume correspondence) of the transmitted control information and user data in the simulated DSs and real ones.

The following data was used as the initial data in the modeling of traffic flows:

– the intensity of the following and the size of the control data (ISO/IEC 13818 and ETSI EN 300486) [8, 9];

– information speed of broadcasting data of real digital streams of television broadcasting up to υ = 40 Mbit/s with a volume of samples of realizations up to V = 300 Mbyte and observation time t = 1 min.

The calculations can be used by Hybrid high-performance computing cluster of Federal Research Center ‘Computer Science and Control’ of the Russian Academy of Sciences [13].

The results of checking the adequacy of the developed model are presented in Table 3.

Table 3: The results of checking the adequacy of the developed model.

Standard	ISO/IEC 13818	ETSI EN 300486
Results	0,98	0,95

Adequacy indicators are determined by the observation time and the presence of jitter following actual control data in real digital streams. Jitter is due to batch transmission of data to the DS.

The value of the adequacy indicators indicates the correctness of the synthesis of mathematical expressions of the model of the digital stream of television broadcasting.

Expressions (1)-(4) are the basis of the algorithm for mathematical modeling of the digital stream of television broadcasting, taking into account systemic relationships of the composition of control and data. The algorithm is intended for the study of digital streams by the definition of control information, the calculation of the efficiency of the use of container capacity for the transfer of payload [14].

Thus, the accounting control data entered into the digital stream at the present stage of development of information and communication systems, has allowed to develop an algorithm for mathematical modeling of the digital stream of television broadcasting. The algorithm not only takes into account the composition of the control and data, but also provides adequate reflection (simulation) of real DSs. The results are based on the analysis of digital television broadcast streams and the synthesis of mathematical expressions (1)-(4). The expressions form an algorithm for mathematical modeling of the digital stream of television broadcasting, taking into account the systemic links between the composition of control and data.

4 Conclusion

The global market of information and communication equipment is undergoing significant modernization. Infocommunication networks are diverse in topology, content, implemented functions. The interfacing of devices and networks is provided through standardized interface converters with circulating data. The analysis of data in digital streams allows us to conclude that statistical models of bit sequences do not allow to take into account the qualitative change that occurred at the present stage of development of information and communication systems. The trend is to increase the amount of transmission of control information in the digital streams of information systems. The digital stream is formed from elementary traffic and control data streams transmitted at all levels of the reference model of interaction of open systems.

Accounting control data entered into the digital stream at the present stage of development, allows you to synthesize the DS model of television broadcasting. Mathematically, the model is defined by expressions (1)-(4) and takes into account the systemic relationships of the composition of control and data. The adequacy of the proposed model is confirmed by a full-scale experiment of matching the volumes of transmitted control information and user data in simulated and real digital streams. Adequacy was 0.98 (ISO/IEC 13818) and 0.95 (ETSI EN 300486).

Expressions (1)-(4) are the basis of the algorithm for mathematical modeling of the digital stream of television broadcasting, which is designed to study digital streams by definition control information, calculate the efficiency of using the capacity of the container for the transfer of payload.

The results indicate the solution of the tasks of analyzing digital streams (ISO/IEC 13818, ETSI EN 300486) and synthesizing the algorithm of mathematical modeling of the DS. Purpose – the development of an algorithm for mathematical modeling of a digital stream on the example of television broadcasting – has been achieved.

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