A New Reliable Scheme for IP Service Transmission in T-DMB Systems

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***Abstract*—In this paper, based on the analysis of the existing encapsulation schemes, Generic Stream Encapsulation (GSE) is chosen to transmit IP-based services in the Terrestrial – Digital Multimedia Broadcasting (T-DMB) system. As a new emerging technology, no corresponding Forward Error Correction (FEC) function is considered for GSE. This motivates us to propose a GSE-FEC method for obtaining additional error protection, in the form of Reed Solomon (RS) outer error protection and virtual interleaving. To further improve the error correction capability of the proposed GSE-FEC, an Improved GSE Erasure (IGE) decoding scheme is presented. This IGE scheme allows us to obtain the erasure information and GSE-FEC frame reconstruction information by an Improved GSE (IGSE) encapsulation scheme. Simulation results demonstrate that the IGE scheme shows better characteristics than the Non-Erasure (NE) decoding scheme and the GSE Erasure (GE) decoding scheme which is based on the original GSE encapsulation. Moreover, compared with the GE scheme, the proposed scheme can reserve the correct bytes to the best of its ability for avoiding information wasting.**

I. INTRODUCTION

Following the great technical advances in IT, nearly every aspect of our lives has been changed. Especially, in the fields of communication and broadcasting, widespread broadband networking and digitalization are the technologies at the forefront to enrich the quality of life.

There are several broadcasting systems that can provide multimedia services in a mobile environment. These broadcasting systems include the T-DMB [1], Digital Video Broadcasting-Handheld (DVB-H) [2], Mobile Broadcast Services (BCAST) [3], etc. Although each system has its strong and weak points, T-DMB has distinguishable characteristics compared with the others. It emerged on the basis of the Eureka-147 Digital Audio Broadcasting (DAB) system to meet the demand for all services in one for a mobile environment such as telephone, TV broadcast, audio and data services. Based on the DAB system, the T-DMB system includes extra functional blocks such as the T-DMB processor which is composed of the Moving Picture Expert Group-4 (MPEG-4) format to MPEG-2 format converter and the FEC block to adapt the stream mode of the DAB system and achieve better bit error rate performance. However, there is no IP layer in the T-DMB system. In order to adapt the T-DMB system to other systems based on IP and consequently provide richer services to customers, it is an important issue to enable IP-based service transmissions in the T-DMB system.

The existing technology for IP importing includes the IP tunneling, Multiple Protocol Encapsulation (MPE) and recently proposed GSE. In this paper, we will compare the GSE scheme with IP tunneling and MPE. Results show that GSE is the preferable choice for IP importing in the T-DMB system, since it represents higher encapsulation efficiency and less overhead. However, as a new emerging technology, there is no corresponding FEC function in GSE. In order to improve the reliability, we propose the GSE-FEC scheme, where the IGE decoding scheme and IGSE encapsulation scheme are developed for further improving its performance, to provide additional error protection ability. Experiments show that the proposed scheme represents good performance. By this way, IP-based services can be transmitted reliably in the T-DMB system.

II. IP IMPORTING FOR THE T-DMB SYSTEM

A. Existing Technologies

The IP tunneling scheme is defined in [4] to provide DAB with a mechanism for the adaptation of Internet services to DAB and is also a key component for DAB services using two-way interaction with personal DAB. It means encapsulating the IP datagrams into the Main Service Channel (MSC) data groups.

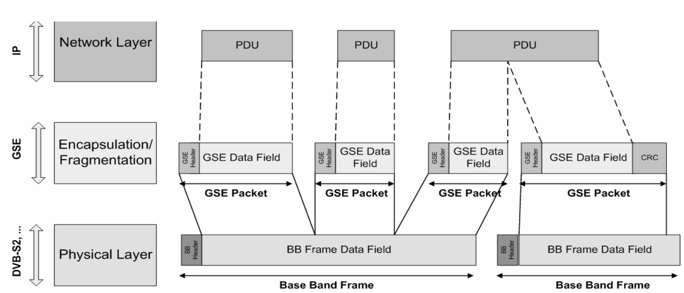

Fig.1. GSE within the DVB protocol stack.

The MPE method provides a mechanism for transporting data network protocols on top of the MPEG-2 Transport Streams in DVB networks [5]. It covers unicast, multicast and broadcast. The 48-bit Media Access Control (MAC) addresses are used for addressing receivers. Using MPE, each IP packet arriving at MPEG Encapsulator Gateway has a MPE header attached to form a Protocol Data Unit (PDU). The entire PDU is then fragmented to form a series of MPEG-2 Transport Streams packets.

GSE is a new strategy emerging recently [6], which allows efficient encapsulation of IP and other network layer packets over a "generic" physical layer. Such a "generic" physical layer is intended as a transport mode that carries a sequence of data bits or data packets, possibly organized in frames, but with no specific timing constraints. The GSE protocol has been devised as an adaptation layer to provide network layer packet encapsulation and fragmentation functions over the generic stream format of the DVB-S2 standard. GSE provides efficient encapsulation of IP datagrams over variable length Layer 2 packets, which are then directly scheduled on the physical layer into baseband frames. Fig. 1 illustrates the GSE operation.

It is believed that, although devised for the generic stream profile of DVB-S2, GSE flexibility grants the protocol a wider applicability. According to the characteristics of the GSE protocol, we can use GSE to import the IP layer in the T-DMB system. The protocol stack is shown in Fig. 2. It is known that the T-DMB transmission system combines three channels, which are MSC, Fast Information Channel (FIC) and synchronization channel [7]. The GSE packets are carried in the T-DMB stream sub-channel as the sub-channel payload, and finally make up of MSC, after synchronization channel and FIC field.

B. Analysis and comparison

In this paper, we focus on the overhead analysis to compare GSE with IP tunneling and MPE. Taking the 1500-byte PDU for example, we compare the overheads of these three schemes in Table I. The overhead is defined as

$$overhead = \frac{\sum_{all\ packets} Overhead\ bits}{\sum_{all\ packets} Overhead\ bits + PDUbits} \times 100\% \quad \text{with}$$
$$overheadbits = enc\_header + padding + CRC\ . \quad (1)$$

Table I shows that the GSE scheme presents the highest encapsulation efficiency and the least encapsulation overhead. For PDU ranging from 100 bytes to 5000 bytes, the overheads of three schemes are illustrated in Fig. 3. It can be seen that GSE represents better characteristics than IP tunneling and MPE. The fluctuations of overhead values of MPE and IP tunneling are caused by the more padding when the length of PDU just exceeds the critical length. While for GSE, there is no padding thanks to the variable length of GSE packets. However, when the length of the PDU exceeds 1500 bytes, it will be fragmented. So, there is a fluctuation existing near the multiple of 1500 bytes in Fig. 3, although the fluctuation is very small.

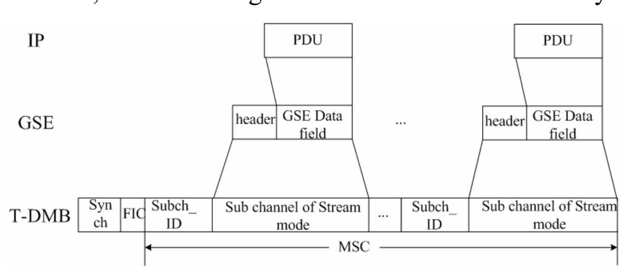

Fig. 2. GSE within the T-DMB protocol stack.

TABLE I
COMPARISON OF THREE SCHEMES

Scheme	Analyse	Overhead
DAB IP tunneling	1500-byte IP packet	9.4%
	2-byte Data Group Header	
	2-byte Data Group CRC	
	3-byte Packet Header	
	2-byte Packet CRC	
	Four different packet data field lengths are allowed in T-DMB, that is 24，48，72 and 96 bytes.	
	If choose 72 bytes, we will need 23 packets to transport, and the last packet will need 37 bytes padding.	
MPE+TS	1500-byte IP packet	11.3%
	12-byte MPE header	
	4-byte MPE CRC	
	4-byte TS packet header	
	Need 9 TS packets to transport, and the last packet will need 140 bytes padding (The MPEG-2 TS packet length is 188 bytes).	
GSE	1500 byte IP packet	0.7%
	10-byte GSE header (6-byte label used for addressing).	

Based on the comparison above, we can see that the GSE scheme is a preferable choice for IP-based service transmission in the T-DMB system. Moreover, GSE can outperform IP tunneling and MPE in many other aspects. Some key GSE characteristics can be found in [8]. However, as a new emerging technology, there is no corresponding FEC function for GSE. We will propose a GSE-FEC method to provide additional error protection at the link layer.

III. THE GSE-FEC SCHEME

This paper proposes a GSE-FEC method to provide additional error protection, in the form of RS outer error protection and virtual interleaving. It is illumined by the "DVB-H implementation guidelines" [9], which defines the RS code used in the MPE-FEC. GSE-FEC frame is used to implement FEC function, while virtual interleaving means that data is written column-wise and encoded row-wise in a GSE-FEC frame. Fig. 4 shows the structure of a GSE-FEC frame.

A GSE-FEC frame consists of application data table and RS data table as shown in Fig. 4. The leftmost 191 columns of the GSE-FEC frame are called Application Data Table (ADT) and filled with IP datagrams and padded symbols. The rightmost 64 columns of the GSE-FEC frame are called RS data table and filled with the parity symbols of RS (255,191) code. Different GSE-FEC code rates are achieved with code

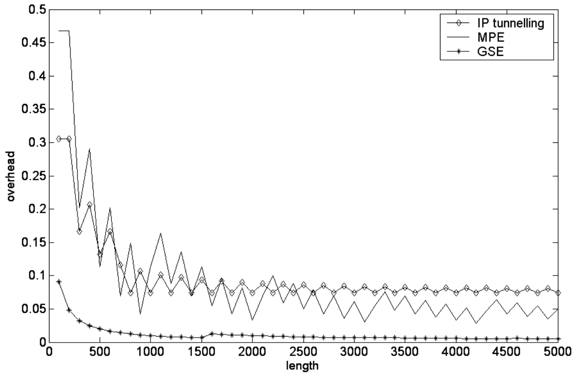

Fig. 3. The overheads of IP tunneling, MPE and GSE.

shortening and puncturing. The code rate is 3/4 if all 191 data columns and 64 redundancy columns are used. Other options for the code rate are 1/2, 2/3, 5/6, 7/8 and 1.

The IP datagrams are encapsulated column-wise into the GSE-FEC frame, whose size is service independent. The number of rows of the GSE-FEC frame can be 64, 128, or 256.

In this section three different decoding methods are presented. It is known [10, 11] that any code of distance d corrects for sure t_e erasures and t_u errors whenever

$$t_e + 2t_u < d \,. \tag{2}$$

For an RS codes the distance d equals to the number of redundancy bytes plus one. If pure erasure decoding is used, the amount of corrected erasures equals the amount of redundancy bytes available. For pure error decoding the error correction capability is half of the amount of redundancy bytes. Thus, using the code rate 3/4, the decoding is successful if a row of the GSE-FEC frame contains no more than 64 erasures or 32 errors.

A. Non-erasure (NE) decoding

Non-erasure decoding is Reed-Solomon error decoding, where no erasure information is utilized but all bytes are considered as possible errors. Theoretically, the error correction capability is half of the erasure detection capability.

B. GSE Erasure (GE) decoding

In erasure decoding, an erasure info table (EIT), which is a matrix of the same size as the GSE-FEC frame, is used to keep track of the reliability of each byte in the frame. In the following description it is assumed that 1 in the EIT denotes an

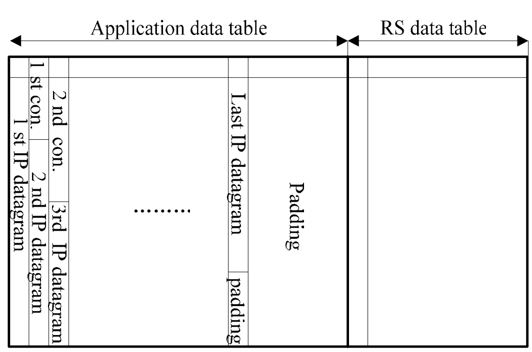

Fig. 4. The structure of a GSE-FEC frame.

Original GSE header	GSE-FEC frame address	GSE Data Field	CRC

Fig. 5. The IGSE scheme for a single IGSE packet.

erased, or unreliable byte in the GSE-FEC frame. A reliable byte is denoted with 0.

GSE erasure decoding is the combination of Reed-Solomon coding with Cyclic Redundancy Check (CRC-32). In GE, the bytes of a GSE packet are marked as ‘reliable’ or ‘unreliable’ depending on the CRC-32 decoding. If the CRC detects errors, the bytes are marked with 1 in the EIT. Otherwise they are marked with 0.

However, GSE does not include a mechanism for integrity check of single GSE Packets. A CRC-32 is only appended to the last PDU fragment of a fragmented PDU to verify the correctness of the reassembly operation [8]. It is far from optimal, since fragment usually is operated to large PDU, in such situation, all the bytes in GSE fragments in which CRC detects errors are marked as unreliable even though many of them are correct.

C. Improved GSE Erasure (IGE) decoding

Based on the discussion above, we propose an IGE decoding method, in which IGSE is presented to provide the erasure information and GSE-FEC frame reconstruction information. The IGSE is defined as follows:

For single GSE Packets, the format is shown in Fig. 5. Compared with the original GSE, the improvements include:

1) The 2-Byte GSE-FEC frame address field is designed after the original GSE header to indicate the position of the encapsulated data in the GSE-FEC frame. The value is the offset relative to the top left corner of the frame. This field will be used in the frame reconstruction of the receiver. For IP data, it is less than 0xBF00（256×191）, while for RS data, it is less than 0xFF00（256×255）.
2) The CRC is added at the end of the packet.

For fragmented PDU, the improved scheme is shown in Fig. 6. An example study case is shown, where a PDU is divided in three fragments that are transmitted in three IGSE Packets. Address field is also represented in this scheme. The CRC of these three packets are calculated based on CRC_1, CRC_2, and CRC_3 respectively. The CRC_ALL of the last packet is calculated based on CRC_1+CRC_2+CRC_3, that is, starting from the Total Length field, omitting all subsequent GSE Packet Headers of the same Frag ID up to, but not including the CRC field. Based on the IGSE scheme, our IGE method can be summarized as follows:

For single IGSE Packets: If the CRC detects errors, the bytes of the IGSE packet are marked with 1 in the EIT. Otherwise they are marked with 0. The position of the bytes in the IGSE packet in GSE-FEC frame can be found through the value of frame address field.

For fragmented PDU: The receiver determine whether the whole PDU is received based on the Frag ID field and indicators in the IGSE packets. Then the receiver first check the CRC_ALL, if the value is valid, the bytes of the whole PDU will be marked with 0 in EIT. Otherwise, the CRC of

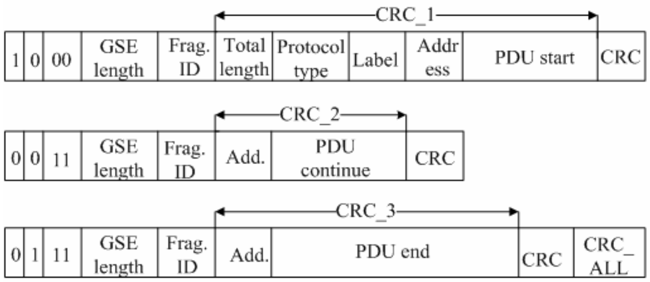

Fig. 6. The CRC scheme for a fragmented PDU.

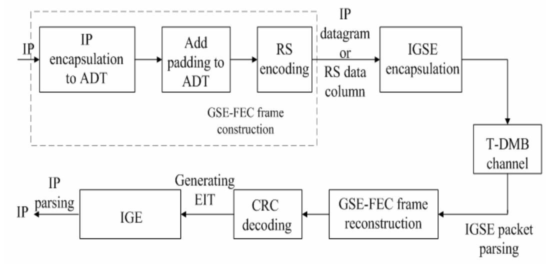

Fig. 8. Overview of the simulation system blocks.

every GSE packet will be detected subsequently to find out which part of the PDU is polluted by noise, and the corresponding bytes in the IGSE packets will be marked in EIT based on their CRC results. By this means, the correct part of the PDU can be reserved to avoid information wasting.

As we can see, the IGSE scheme can provide Erasure information to IGE, further improving the reliability of the transport. Although the IGSE scheme will bring more overhead comparing with the original GSE scheme, the influence is limited. The overhead comparison of GSE and IGSE is illustrated in Fig. 7. Therefore, it is a feasible method to obtain the trade-off between the overhead and the reliability.

IV. Simulation Results

Our GSE-FEC algorithm for IP-based service transmission in the T-DMB system consists of the steps illustrated in Fig. 8. In Fig. 9 some simulation results are presented. The physical channel is Rayleigh fading channel and the modulation is QPSK, with the convolutional code rate 1/2 and the Doppler frequency 20Hz. The payload, consisting of 200-byte IP packets, is transmitted in GSE-FEC frames with 64 or 128 rows with GSE-FEC code rates 1/2, 2/3 or 3/4. It can be seen that performance is better with the code rate lower, because lower code rate means less data are transmitted through channel. It also means that there will be less errors in a row in GSE-FEC frame, so the correction capacity will be overtopped seldom. Moreover, as can be seen from Fig.9, two kinds of frame size get the similar results with the same code rate, which means the impact of frame size is small for 200-byte IP packets. There are slightly larger differences for code rate 1/2, because the columns of RS data are equal to that of application data here, consequently the transmission of RS data will have larger influence to the performance comparing with other code rates. With the worse SNR, 128 rows will have worse results because of the more errors in RS data. While with the better SNR, 128 rows will outperform 64 rows due to the higher interleaving depth of 128 rows.

Fig.10 illustrates the performance comparison of IGE and NE decoding schemes. The results are compared in terms of Bit Error Rate (BER) and Frame Error Rate (FER). FER is the rate of uncorrected GSE-FEC frames. Even if only one-byte is in error in the reconstruction of a GSE-FEC frame after decoding, the frame will be regarded as an uncorrected frame. According to the analysis above, in the experiment, the payload we simulated, consisting of 200 bytes IP packets, is transmitted in GSE-FEC frames with 64 rows with FEC code rate 3/4. This means that 60 IP packets are filled in a GSE-FEC frame. These IP packets and 64 columns RS data are encapsulated in GSE packets and transmitted through T-DMB channel. When the receiver reconstructs the GSE-FEC frame, error bytes per row usually overtop the correction capacity of NE scheme, i.e., 32 bytes. Therefore, the BER and FER of NE scheme are dissatisfying. While using the IGE scheme for RS decoder, the correcting ability is double compared with NE, so the receiver can obtain the improved performance of $BER \approx 10^{-8}$ and $FER \approx 10^{-5}$ at 15 dB respectively.

The comparison of GE and IGE schemes is shown in Fig.11. In the simulation, there is a large IP packet consisting of 5000 bytes. As mentioned above, in GSE encapsulation, when the length of PDU exceeds the 1500 bytes, it will be fragmented, so there will be three GSE packets including 1500-byte payload and one GSE packet including the last 500 bytes. Through T-DMB channel, 1000 bytes in the packet are polluted by the noise, as shown in Fig. 11(a). If using the GE

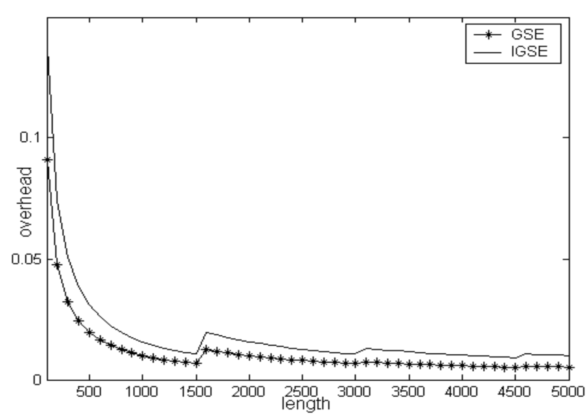

Fig. 7. The overhead comparison of GSE and IGSE.

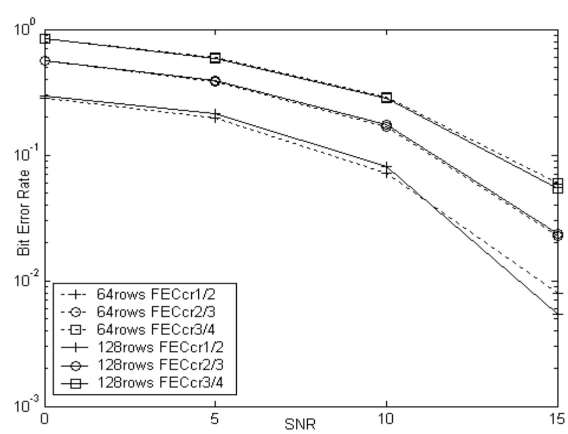

Fig. 9. Bit Error Rates after GSE-FEC with NE decoding.

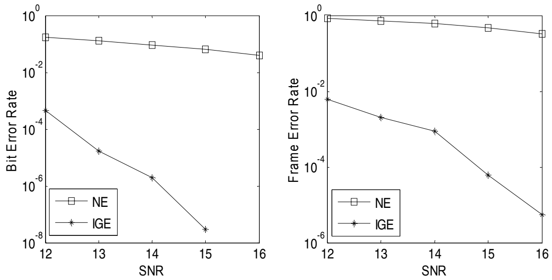

Fig. 10. NE versus IGE decoding.

decoding, the only field which can provide erasure information is the CRC appended to the last PDU fragment. The invalid CRC can tell us there is an error in the whole four GSE packets, but the positions of the errors are unknown. The only thing we can do is to mark all the 5000 bytes with 1 in the EIT, which will waste a lot of information. Moreover, too many identifiers '1' in EIT might lead to the RS decoding failure. While for the IGE decoding, we find that there are some errors existing in the IGSE packets through CRC_ALL check, and then each CRC field will be checked. The results indicate that there are errors in the second IGSE packets, so the corresponding positions in the EIT are marked with 1. It can save 3500 bytes correct information compared with the GE decoding.

Fig.12 illustrates the performance comparison of IGE and GE decoding schemes. The payload we simulated, consisting of 5000 bytes IP packets, is transmitted in GSE-FEC frames with 128 rows with FEC code rate 3/4. It can be seen that IGE scheme represents better performance. The reason for this is that too many identifiers '1' in EIT in GE scheme leads to the RS decoding failure for some GSE-FEC frames. The IGE scheme can not only improve the performance of BER and FER but also avoid the information wasting. It is an effective decoding scheme.

V. CONCLUSIONS

IP-based service transmission is an important issue for the T-DMB system. It will push the integration of T-DMB and other IP-based broadcast systems. The analysis of the existing technologies has shown that GSE is the preferable choice for transmitting IP-based data in the T-DMB system. However, as a new emerging technology, there is no corresponding FEC

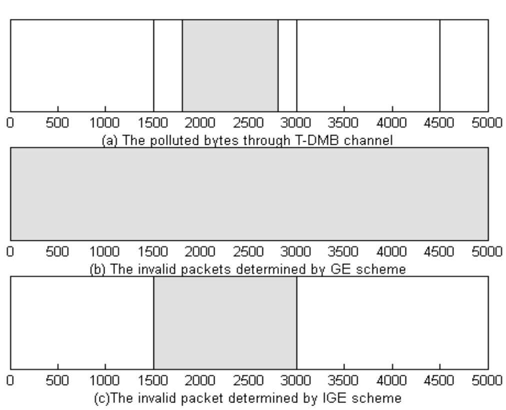

Fig. 11. Comparison of GE and IGE schemes.

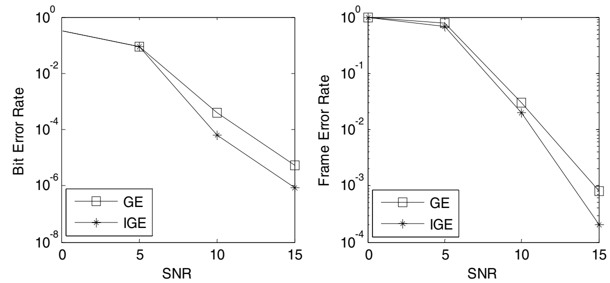

Fig. 12 GE versus IGE decoding.

function for GSE. This paper has proposed a GSE-FEC scheme to provide additional error protection for GSE packet transmissions. In order to improve the error correction performance of GSE-FEC, a new decoding method IGE has been proposed. Moreover, IGSE formation has been designed to provide erasure information and GSE-FEC frame reconstruction information for the IGE decoding.

The IGE decoding method has been compared with NE and GE methods. Experiments show that the proposed method represents better capacity of error correction. Moreover, compared with GE, our method can protect the correct bytes more effectively.

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