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Analysis of CAN bus encryption and decryption performance of different chips

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Abstract. In the rapid development of intelligent network connected vehicle, many information security risks have been exposed. The application of CAN bus encryption and decryption technology can solve the problem of safety communication in vehicle intranet. The sender and the receiver use the same set of key. The sender encrypts the data before sending it, and the receiver decrypts the data before applying it. In order to study the influence of CAN bus encryption and decryption on transmission efficiency, taking tc299, s32k144, mpc5606b and spc560b54 chips as examples, different encryption and decryption algorithms are used to encrypt and decrypt data of different lengths. The research shows that the time of symmetric encryption is much less than that of asymmetric encryption; With the increase of the length of the data to be encrypted and decrypted, the time required for encryption and decryption also increases; There is no significant difference in encryption and decryption efficiency between different chips. The time consumed by encryption and decryption is us level, which will not affect the real-time performance of the bus.

1. Introduction

1.1. Intelligent networked car development status

With the diversification of automotive networking technology and the continuous improvement of networking rate, the market potential of automotive networking services will be gradually released[1]. Intelligent Connected Vehicle (ICV) is equipped with advanced on-board sensors, controllers, actuators and other devices, and integrates modern communication and network technologies to realize intelligent information exchange and sharing between vehicles and X (vehicles, roads, people, clouds, etc.).

Automobile intelligent network connection technology has triggered a new round of international scientific and technological competition. Mercedes-Benz, Ford, Toyota, Volvo and other top automobile manufacturers in the world have carried out research and development on the technology of autonomous vehicles of different grades. At the same time, in recent years, IT giants represented by Google, Apple, Intel and other companies in the United States have spared no effort to invest in the field of auto-driving technology. The acquisition of Mobileye Company by Intel for US\$ 15.3 billion is the embodiment of this fierce competition and an important part of its overall strategy of establishing auto-driving.

As the "five senses" of the automobile, the Internet of vehicles can more effectively understand the external environment and internal operation status of the car. As the "brain" of the automobile, artificial intelligence can make decisions according to the comprehensive judgment of information [2].



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1.2. information security threats faced by intelligent connected vehicles

1.2.1. background server threat

Server is a kind of computer. It runs faster, has higher load and is more expensive than ordinary computer. The server provides computing or application services for mobile app and vehicle terminal in the network. Servers are usually faced with threats such as data vulnerability, account hijacking, apt virus, permanent data loss, potential crisis caused by sharing [3].

1.2.2. mobile app security threats

Mobile app security threat refers to that hackers use these remote control apps to obtain personal information and vehicle control rights through root user's mobile terminal or luring users to download and install malicious programs [4].

1.2.3. can bus security threats

Automotive electronic components are connected through can network, and the communication between electronic components is through can package. The CAN bus security threat obtains its communication matrix through reverse engineering, fuzzy test and other methods, and breaks the application layer bus protocol of the automobile, so as to realize the automatic control function of the automobile without adding the automobile actuator. In other words, as long as the CAN bus is grasped, We can control the car by grasping the nerve of the car.

1.3. The necessity of communication encryption in vehicle Intranet

In the current vehicle network, most of the data transmission is carried out without any security measures, even if there are security measures, most of them are very simple. Therefore, in most cases, the controller interacts with data in the form of original data. Even if the receiving node can check the rationality of the data, the improvement of data reliability is limited. The receiving node cannot verify whether the data comes from the expected sending node or other nodes, that is, it cannot verify whether the data is true. At the same time, the data transmitted on the bus can also be freely accessed, so the content of the data can be deduced by analyzing the original data transmitted on the bus. Such data transmission is neither confidential nor authenticated. For example, the most widely used can communication design did not consider the problem of information security at the beginning. Its plaintext transmission, message broadcast transmission, few network segmentation and other characteristics make hackers who enter the vehicle network as if they enter the playground. They can easily forge messages to control the vehicle

2. Common attack methods in the car network

Please follow these instructions as carefully as possible so all articles within a conference have the same style to the title page. This paragraph follows a section title so it should not be indented[2-3].

2.1. Formatting the title

The title is set 17 point Times Bold, flush left, unjustified. The first letter of the title should be capitalized with the rest in lower case. It should not be indented. Leave 28 mm of space above the title and 10 mm after the title.

2.2. CAN bus attack

2.2.1. CAN data frame flooding attack

The CAN bus network communication protocol stipulates that the priority of data frames transmitted between ECU is determined by the ID of CAN data frames, and the smaller the ID, the higher the priority of data frames [6]. Therefore, if an intruder sends a high priority CAN data frame on a CAN

bus at a high frequency, it will probably block the sending of other data frames, thus realizing DoS attack.

2.2.2. CAN ID forgery

Because the CAN bus network communication is broadcast communication, intruders CAN easily obtain all the data frames sent on one CAN bus. Generally, CAN data frames are transmitted in plaintext. intruders can analyze the format and content of data frames by guessing, traversing or other means, and reverse crack the key control signals of vehicles. Further, illegal data frames are sent on the CAN bus in the name of these IDs, thus interfering with or blocking the normal communication between ECU's, and even actually controlling one or more ECU's of key systems (such as power system).

2.2.3. CAN data frame replay attack

Because the CAN bus network communication is broadcast communication, intruders CAN easily capture all the data frames of a specific CAN ID in time sequence, and then re-inject these data frames into the CAN bus network, so as to interfere with and illegally control one or more ECU.

2.3. in-car Ethernet attack

2.3.1. ICMP flooding attack

A simple denial of service attack, also known as ping flooding attack, in which the attacker floods the victim with ICMP "ping" packets [9].

2.3.2. UDP flooding attack

A denial of service attack using UDP, a session-free, connectionless transport layer protocol.

2.3.3. Teardrop attack

In the header of IP packet, there is a field called fragment offset, which indicates the starting position or offset of the fragmented packet in the original unfragmented packet.

Teardrop attack refers to using IP packets which maliciously modify the IP fragment offset value to attack, which makes the attacked person unable to reassemble the IP packets normally, and even leads to system crash.

2.3.4. IP spoofing attack

IP address spoofing refers to the attacker sending packets by impersonating the IP address of a legitimate host, so as to gain the trust of the attacker or hide the attacker's real IP address.

2.3.5. ICMP Smurf attack

This attack method combines IP spoofing attack and ICMP flooding attack. The attacker forged the source address of internet control message protocol and set the destination address of the packet as the broadcast address of the network [11]. If the network device does not filter this traffic, the internet control message protocol will be broadcast to all computers in the network.

3. Introduction of common encryption algorithms

3.1. AES algorithm

Advanced Encryption Standard(AES) in cryptography, also known as Rijndael encryption method, is a block encryption standard adopted by American federal government.

This standard is used to replace the original DES(Data Encryption Standard), which has been analyzed by many parties and widely used all over the world. After a five-year selection process, the Advanced Encryption Standard was published in FIPS PUB 197 by NIST on November 26, 2001, and

became an effective standard on May 26, 2002. In 2006, Advanced encryption standard has become one of the most popular algorithms in symmetric key encryption [12].

In cryptography, block cipher operation mode is an algorithm that uses block cipher to provide information services such as confidentiality or authenticity. Block-based symmetric cryptographic algorithms such as DES/AES only describe how to encrypt a fixed length (block) of data according to the secret key. For longer data, The working mode of block cipher describes how to repeatedly apply an algorithm to encrypt packets to safely convert data larger than blocks.

To put it simply, AES algorithm describes how to encrypt a data block, and the working mode of block cipher determines that multiple data blocks are long if repeated encryption is performed.

There are five working systems of block cipher: 1. Electronic Codebook (ECB); 2. Cipher Block Chaining (CBC); 3. Cipher feedback mode (CFB); Output feedback mode (OFB).

3.1.1. ECB

ECB mode is the simplest encryption mode, in which plaintext messages are divided into fixed-size blocks (packets), and each block is encrypted separately.

Encryption and decryption of each block are independent, and the same method is used for encryption, so parallel calculation can be performed. However, once a block is cracked, all plaintext data can be decrypted by using the same method, and the security is relatively poor.

It is suitable for the case of less data, and it is necessary to fill the plaintext data to an integral multiple of the block size before encryption.

3.1.2. CBC

In CBC mode, each packet should be XOR-XOR with the encrypted data of the previous packet, and then encrypted.

In this way, each ciphertext block depends on all plaintext blocks before the block. In order to keep each message unique, the first data block needs exclusive OR operation with initialization vector IV before encryption.

CBC mode is one of the most commonly used encryption modes. Its main disadvantage is that encryption is continuous and cannot be processed in parallel. Like ECB, message blocks must be filled to whole multiples of block size.

3.1.3. CFB

CFB mode is similar to CBC mode. The ciphertext of the previous packet is encrypted and XOR with the plaintext of the current packet to generate the ciphertext of the current packet. Decryption of CFB mode and encryption of CBC mode are very similar in flow.

3.1.4. OFB

OFB mode converts block cipher into synchronous stream cipher, which means that stream cipher with corresponding length can be generated independently according to plaintext length. It can be seen from the flow chart that OFB is very similar to CFB. CFB is the encrypted ciphertext of the previous packet and XOR the plaintext of the current packet. OFB is the stream cipher XOR the plaintext of the current packet before the previous packet and the previous plaintext block. Because of the symmetry of XOR operation, the decryption and encryption of OFB mode are exactly the same.

Based on the above four block encryption modes, it is considered that OFB mode is safer and more reliable, and it is a safer measure in the future. This paper chooses OFB mode.

3.2. Sha256

An N-bit hash function is a mapping from an arbitrarily long message to an N-bit hash value, and an N-bit encrypted hash function is a one-way and collision-free N-bit hash function. Such a function is an extremely important means in digital signature and password protection at present.

At present, the popular hash functions mainly include 128-bit MD4 and MD5 and 160-bit SHA-1. The SHA-2 family introduced today has more output hash values, which is more difficult to crack and can improve higher security.

SHA-2, whose name comes from the abbreviation of Secure Hash Algorithm 2 (English), is a cryptographic hash function algorithm standard developed by the National Security Agency of the United States and released by the National Institute of Standards and Technology (NIST) in 2001. It belongs to one of SHA algorithms and is the successor of SHA-1. It can be further divided into six different algorithm standards, including SHA-224, SHA-256, SHA-384, SHA-512, SHA-512/224 and SHA-512/256. The HASH value calculation process is shown in Figure 1 below.

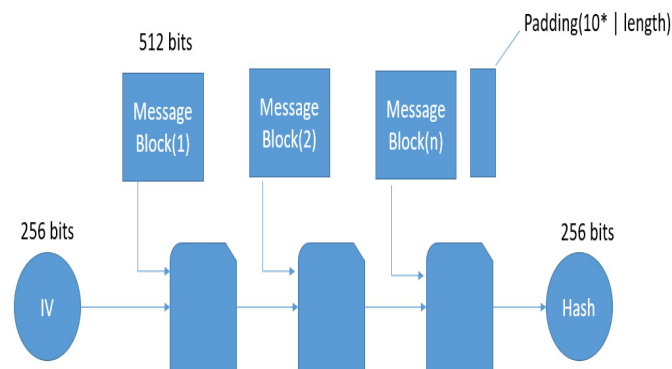


Figure 1. Hash value calculation process

3.3. Hmac_sha256

Hmac is a method to construct message authentication code by using one-way Hash function, in which H in Hmac means hash.

The one-way hash function used in Hmac is not limited to one type. Any high-strength one-way hash function can be used in Hmac, and if a new one-way hash function is designed in the future, it can also be used.

Hmac constructed using Sha-256 is called Hmac_sha256, and its calculation process is shown in Figure 2 below.

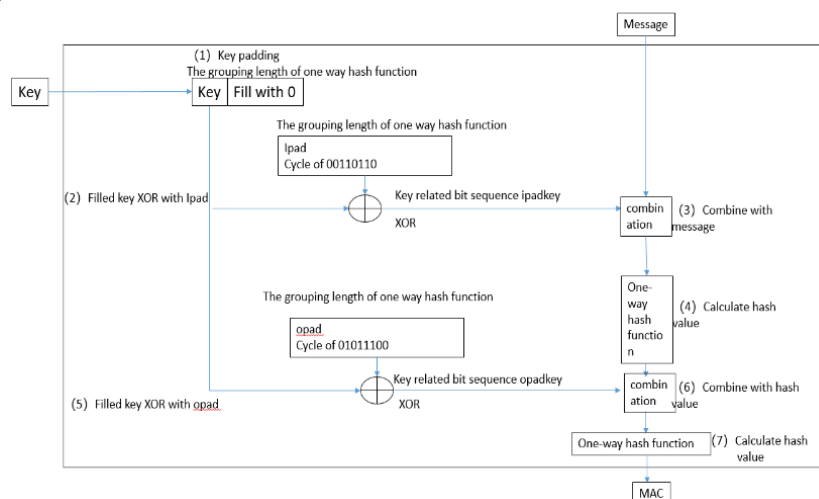


Figure 2. Calculation steps of Hmac_sha256

4. Analysis of the influence of encryption and decryption on the real-time performance of CAN messages

4.1. Space occupancy rate of different algorithms

For a vehicle-mounted microcontroller, its memory size (RAM and FLASH) is an important index to measure its performance. Insufficient or overflowing memory will cause the vehicle controller to crash. Therefore, it is necessary to know the memory space occupied by various algorithms before applying encryption and decryption algorithms on CAN bus [13].

The ROM space changes before and after calling the algorithm are calculated respectively, so as to determine the space occupied by each algorithm.

4.1.1. Space occupied by AES algorithm

The memory changes before and after calling OFB mode of AES algorithm are as follows:

(1) before calling OFB mode of AES algorithm

Before calling OFB mode of AES algorithm, the occupied ROM space is 0x4d1c (sixteen mechanisms).

(2) after calling AES algorithm

After calling OFB mode of AES algorithm, it shows that the occupied ROM space is 0x88c2 (sixteen mechanisms).

It is calculated that after calling AES algorithm, 14.9K ROM memory space is used more.

4.1.2. Space occupied by Sha256 algorithm

The memory changes before and after calling Sha256 algorithm are as follows:

(1) before calling Sha256 algorithm

Before calling Sha256 algorithm, it shows that the occupied ROM space is 0x4d1c (sixteen mechanisms).

(2) after calling Sha256 algorithm

After calling Sha256 algorithm, it shows that the occupied ROM space is 0x5308 (sixteen mechanisms).

According to the calculation, after calling Sha256 algorithm, 1.48K ROM memory space is used more.

4.1.3. Space occupied by Hmac_sha256 algorithm

The memory changes before and after calling Hmac_sha256 algorithm are as follows:

(1) before calling Hmac_sha256 algorithm

Before calling Hmac_sha256 algorithm, it shows that the occupied ROM space is 0x4d1c (sixteen mechanisms).

(2) after calling Hmac_sha256 algorithm

After calling Hmac_sha256 algorithm, the occupied ROM space is 0x558c (sixteen mechanisms).

According to the calculation, after calling Hmac_sha256 algorithm, 2.11K ROM memory space is used more.

It can be seen from the above that different encryption algorithms occupy space ranging from 2K to 15K, and most microcontrollers will spare this memory at present.

4.2. Encryption and decryption efficiency of different algorithms

4.2.1. calculation steps and principles of encryption and decryption time

1. Test environment

The efficiency of encryption and decryption algorithm is related to chip processing and other hardware environments. this paper calculates the encryption and decryption time of AES algorithm (OFB mode), Sha256 and Hmac_Sha256 for four chips. Chip information is shown in Table 1.

Table 1. Performance parameters of chips.

brand name	model	Basic frequency
Infineon	TC299	200MHz
NXP	S32K144EVB	80MHz
NXP	MPC5606B	64MHz
RENESAS	SPC560B54	48MHz

2. Calculation steps

The steps of calculating encryption and decryption time are as follows:

- (1) before calling the encryption function, pull up the output voltage; After calling the encryption function, pull down the output voltage;
- (2) Check the external logic analyzer and check the encryption time;
- (3) before calling the decryption function, pull up the output voltage; After calling the decryption function, pull down the output voltage;
- (4) Check the external logic analyzer and check the decryption time;

3. View the results

In the picture below they represent encryption start time, encryption end time, decryption start time and decryption end time respectively. The logic analyzer can directly calculate the encryption and decryption time.



Figure 3. Schematic diagram of encryption and decryption time

4.2.2. Encryption and decryption time analysis

Compare and analyze the efficiency of four kinds of chips to deal with different encryption and decryption algorithms.

1. OFB mode of AES algorithm

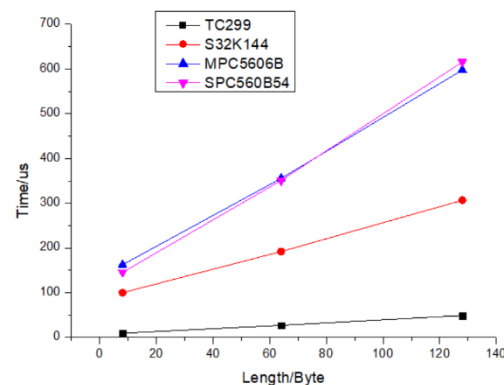


Figure 4. Encryption performance of OFB mode of AES algorithm in different chips

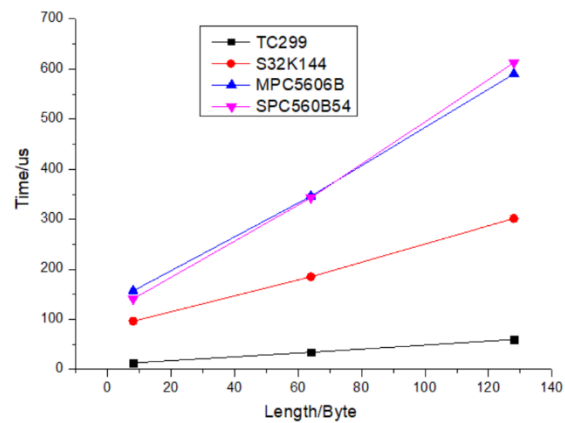


Figure 5. Decryption performance of OFB mode of AES algorithm in different chips
2.Sha256

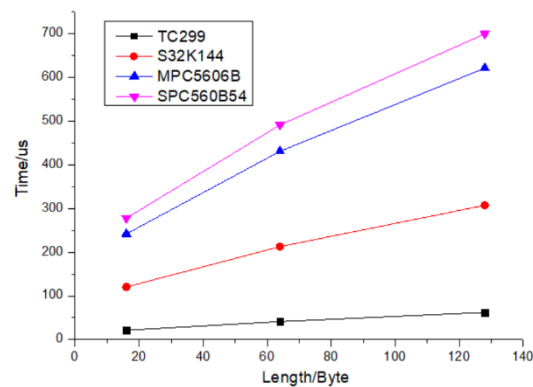


Figure 6. Encryption performance of Sha256 algorithm in different chips

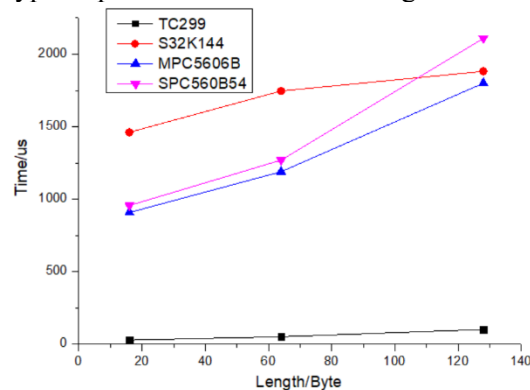


Figure 7. Decryption performance of OFB mode of AES algorithm in different chips
3.Hmac_sha256

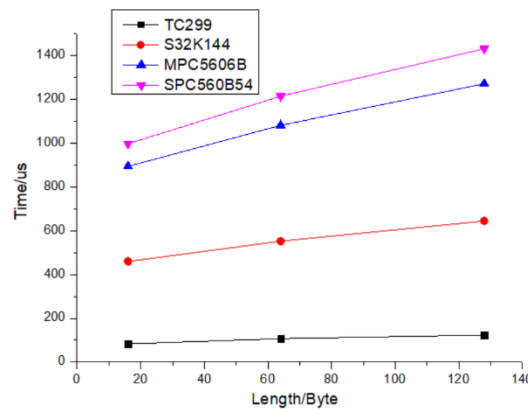


Figure 8. Encryption performance of Hmac_sha256 algorithm in different chips

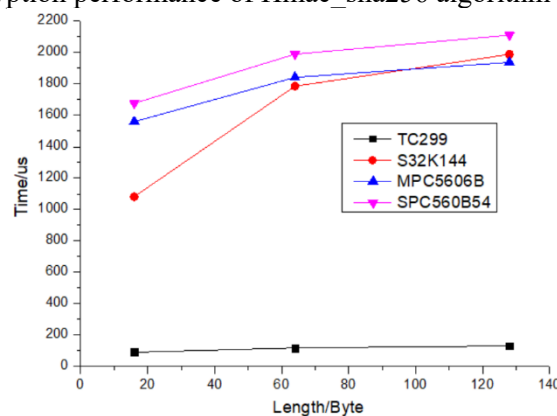


Figure 9. Decryption performance of Hmac_sha256 algorithm in different chips

5. Conclusion

In the early stage, due to the limited resources of ECU design and the less consideration of information security, the protection ability of ECU is very weak, which is easy to lead to hacker attacks. Through the bus encryption and decryption of vehicle intranet, the security risk can be well avoided. Through the above research, we can draw the following conclusions:

1. symmetric encryption takes far less time than asymmetric encryption;
2. As the length of data to be encrypted and decrypted increases, the required encryption and decryption time also increases;
3. The efficiency of different encryption and decryption algorithms is obviously different, and AES algorithm takes the least time;
4. For the common 8-byte message in the market at present, the set CAN reading period is about 5 ms. The time consumed to encrypt and decrypt it is us level, which will not cause obvious influence on the real-time performance of the bus.
5. In different chips, the efficiency of different algorithms has little difference.

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