Review: Plaintext Recovery Attacks against SSH

Introduction to Cryptographic Algorithms '12/'13

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Outline

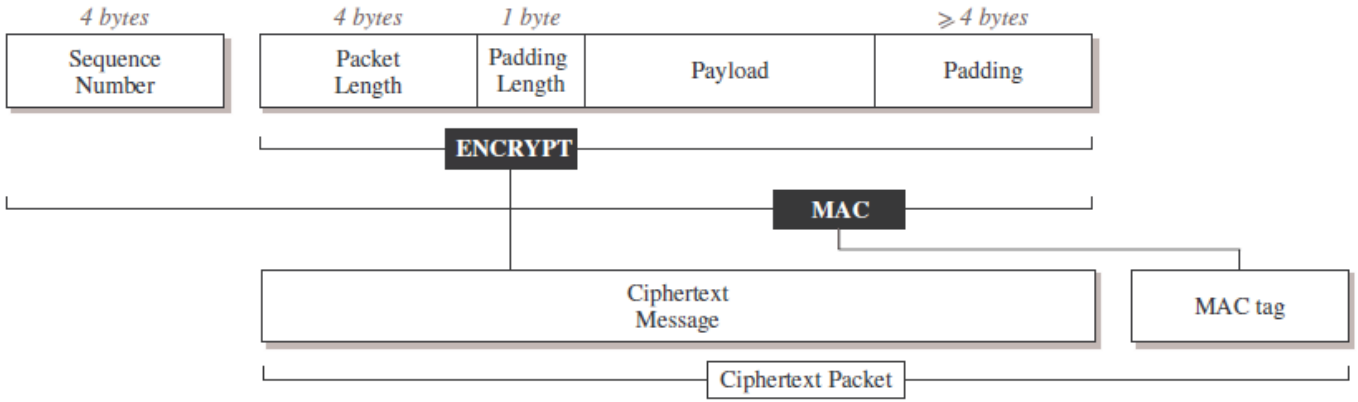
What is SSH?

- Secure Shell (SSH) connects computers securely over insecure network connections.
- It was released in 1995 and was designed to replace rlogin, rsh, Telnet and similar insecure protocols.
- The SSH protocol covers authentication, confidentiality and integrity.
- Our review article "Plaintext Recovery Attacks against SSH" paper focuses on the OpenSSH implementation.

What is the SSH-BPP protocol?

- The Binary Packet Protocol (BPP) of SSH encrypts a plaintext and then protects it's integrity by appending a MAC value.
- Prefixed with 4 byte packet-length, 1 byte padding-length
- Suffixed with 4 to 255 bytes of padding
- The message is then encrypted with a cypher of choice, for example aes128-cbc.
- MAC is calculated over this message and a 32-bit packet sequence number
- MAC is appended to the message

Schematic of a BPP block



What is the SSH-BPP protocol? cont.

- The packets then form a data stream since the encryption is in CBC mode.
- Every packet $i-1$ on a connection will be the initialization vector (IV) for packet i on the same connection.
- For decryption it is essential that the receiver decrypts the first ciphertext block to be able to read the length field.
- The SSH protocol also specifies error handling for the BPP protocol.
- Terminate whenever a transmission error occurs or MAC verification fails.
- Implementations are free to send error messages to their peer when an error occurs.

Open SSH implementation of SSH BPP

- Open SSH first performs a length check. If the length given in the length field is not between 5 and 2^{18} it sends a *SSH2 MSG DISCONNECTED* error back to the sender.
- Next OpenSSH checks that the total number of bytes expected is indeed a multiple of the block size. When this check fails, the TCP connection will terminate without an error message.
- When all data for the package has arrived, OpenSSH performs a MAC check. If this check fails, a *Corrupted MAC on input.* error message is returned to the sender.
- Note that an attacker can differentiate those failure modes.

Some notations

Key

K is the key of our block cipher

Encrypt/Decrypt

F_k and F_k^{-1} are the encryption and decryption operations of the block cipher

CBC Mode

Given a sequence $p_1, p_2, ..., p_n$ of plaintext blocks making up a packet, we have: $c_i = F_k(c_{i-1} \oplus p_i), i = 1, 2, ..., n$ where c_0, the Initializing Vector (IV), is the last block of the previous ciphertext. Decryption works as follows: $p_i = c_{i-1} \oplus F_k^{-1}(c_i), i = 1, 2, ..., n$

Recovering first 14 bits of plaintext

- OpenSSH implementation of BPP only supports lengths up to 2^{18} bits.
- Length field is 4 bytes long.
- A packet will only pass the length check if the first $32 - 18 = 14$ bits are all 0
- So when no *SSH2 MSG DISCONNECTED* error occurs, we recovered first 14 bits of plaintext.

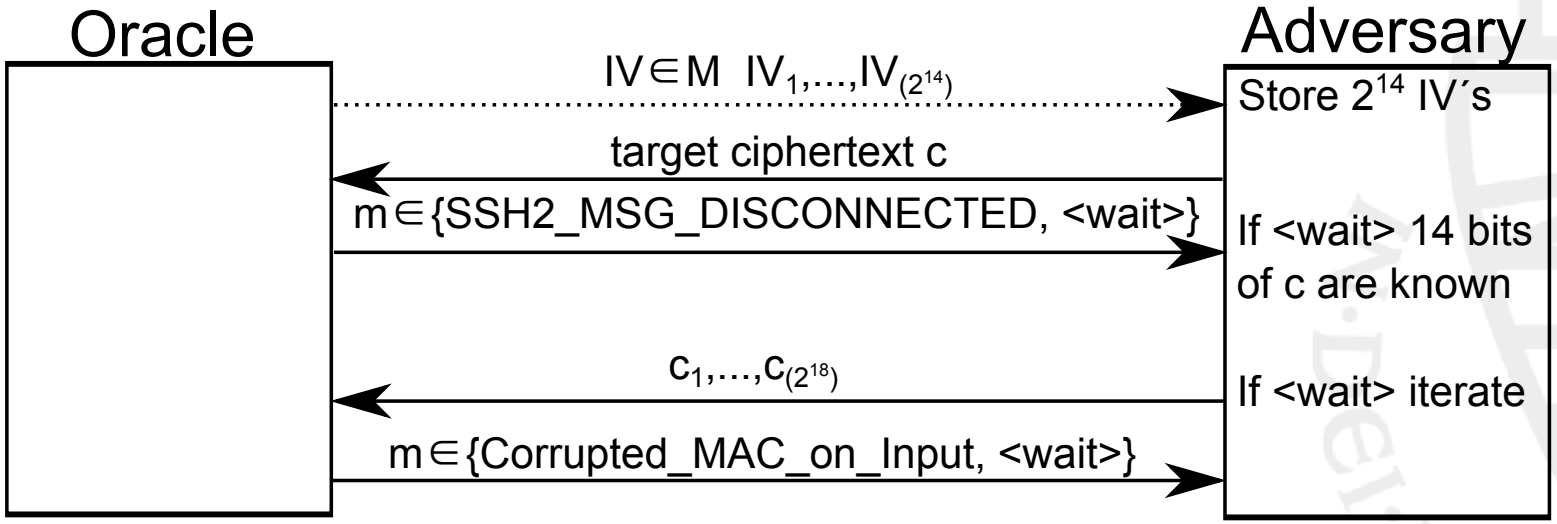
Recovering some more bits

- When the ciphertext block passes the block length check we get to know more bits
- In case of $L = 16$ (as with AES) the we know the last 4 bits for a total of 18 bits.
- In case of $L = 8$ (as with 3des) the we know the last 3 bits for a total of 17 bits.

Recovering 32 bits of plaintext

- When the first 2 check succeed, the SSH connection enters wait state.
- Feed random cyphertext blocks into this connection and wait after each block.
- When the target returns a *Corrupted MAC on input.* error we know that it received enough blocks to trigger a MAC check.
- At this point we know exactly how long the packet length is, and therefore all 32 bits of the length-field.
- Because of the chaining property of the CBC mode these 32-bits leak information about the rest of the ciphertext.

Security game



Countermeasures

- Return the same error message when either the length check or the block-length check failed.
- Randomize the length field if the length check fails.

Conclusion

It is possible to recover plaintext bits from a proven secure SSH implementation. Therefore it is also hard to know whether improvements to resolve this issue won't lead to new attacks on these SSH implementations.

Questions

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