Introduction to Cryptology

5.2 - A Padding Oracle Attack

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- Examples: if $b = 1$, 00000001 is appended to the end of the message; if $b = 2$, 00000010||00000010 is appended.
- The padded message is called encoded data.

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When decrypting, the correctness of the padding of the decrypted message is verified:

- the value b of the last byte is read, and it is checked if it is the value of the last b bytes;
- if the padding is correct, the last b bytes are dropped to get the original plaintext.
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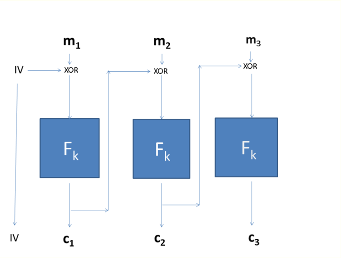
Some deployed protocols return a notification when a ciphertext does not decrypt correctly.

It can be seen as a limited decryption oracle for adversaries, and exploited to recover the entire plaintext from a ciphertext.

A Padding Oracle Attack - Example

Consider a 3-block ciphertext (IV, c_1, c_2) which corresponds to the message (m_1, m_2) (unknown to the attacker).



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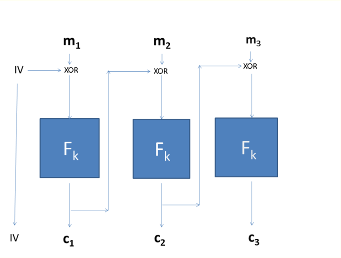

- $m_2 = F_k^{-1}(c_2) \oplus c_1$ and it should end with $\underbrace{0\mathrm{x}b \cdots 0\mathrm{x}b}_{b \text{ times}}$.
- Key idea: given $c_1' = c_1 \oplus \Delta$, the decryption of (IV, c_1', c_2) returns (m_1', m_2') where $m_2' = m_2 \oplus \Delta$.

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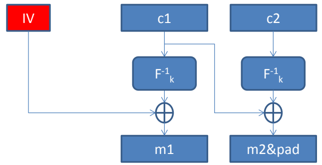
Step 1: learn b (number of padded bytes).



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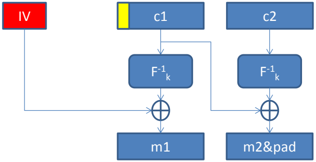

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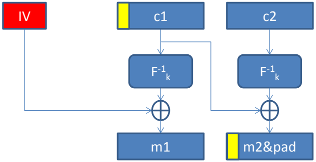

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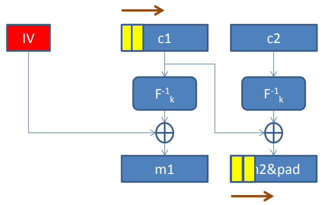

A Padding Oracle Attack

Step 2: recover the plaintext byte by byte.

The adversary modifies c_1 with the perturbation

$$\Delta_n = 0x0 \cdots 0x0{\color{red}0xn}\underbrace{0\mathrm{x}b+1+b \cdots 0\mathrm{x}b+1+b}_{b \text{ times}}.$$

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Let B be the value of the last byte of the unpadded message:

- if a decryption failure is notified, then $0xn \oplus B \neq b+1$;
- when the decryption is valid, it can be deduced that

$$0xn \oplus B = b+1 \Leftrightarrow B = 0xn \oplus b+1.$$

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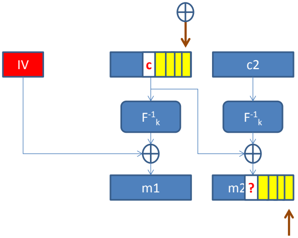

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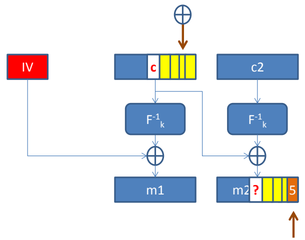

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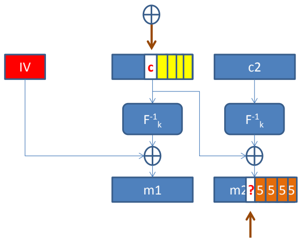

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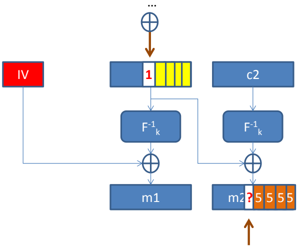

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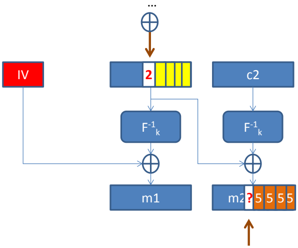

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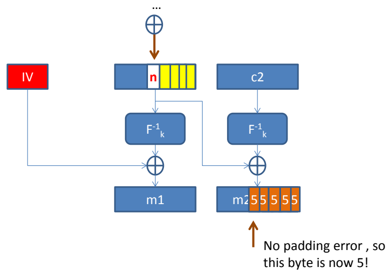

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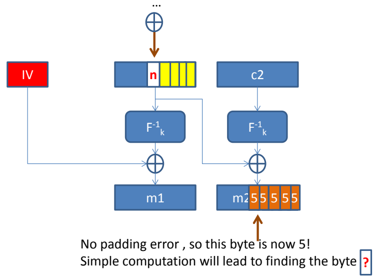

Further Reading I

Don Coppersmith.
The data encryption standard (DES) and its strength against attacks.
IBM journal of research and development, 38(3):243–250, 1994.

Itai Dinur, Orr Dunkelman, Masha Gutman, and Adi Shamir.
Improved top-down techniques in differential cryptanalysis.
Cryptology ePrint Archive, Report 2015/268, 2015.
http://eprint.iacr.org/.

Further Reading II

Itai Dinur, Orr Dunkelman, Nathan Keller, and Adi Shamir.
Efficient dissection of composite problems, with applications to cryptanalysis, knapsacks, and combinatorial search problems.
Cryptology ePrint Archive, Report 2012/217, 2012. http://eprint.iacr.org/.

Itai Dinur, Orr Dunkelman, Nathan Keller, and Adi Shamir.
New attacks on feistel structures with improved memory complexities.
In Rosario Gennaro and Matthew Robshaw, editors, Advances in Cryptology – CRYPTO 2015, volume 9215 of Lecture Notes in Computer Science, pages 433–454. Springer Berlin Heidelberg, 2015.

Further Reading III

Lov K Grover.
A fast quantum mechanical algorithm for database search.
In Proceedings of the twenty-eighth annual ACM symposium on Theory of computing, pages 212–219. ACM, 1996.

Howard M Heys.
A tutorial on linear and differential cryptanalysis.
Cryptologia, 26(3):189–221, 2002.