

Block Cipher Operation

CSS441: Security and Cryptography

Sirindhorn International Institute of Technology
Thammasat University

Prepared by Steven Gordon on 20 December 2015
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Modes of Operation

Electronic Code Book

Cipher Block Chaining Mode

Cipher Feedback Mode

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Feedback Characteristics of Modes

XTS-AES

Modes of Operation

- ▶ Block cipher: operates on fixed length b -bit input to produce b -bit ciphertext
- ▶ What about encrypting plaintext longer than b bits?
- ▶ Break plaintext into b -bit blocks (padding if necessary) and apply cipher on each block
- ▶ Security issues arise: different **modes of operation** have been developed

Modes

ECB

CBC

CFB

OFB

CTR

Feedback

XTS-AES

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Cipher Feedback Mode

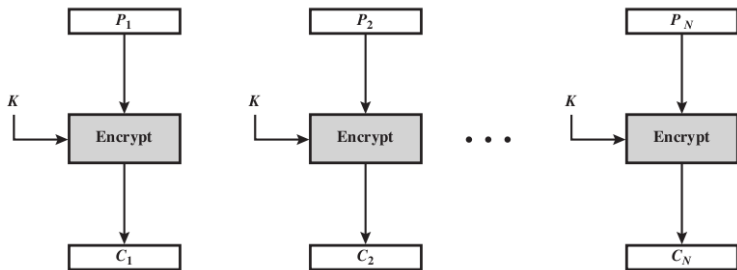
Output Feedback Mode

Counter Mode

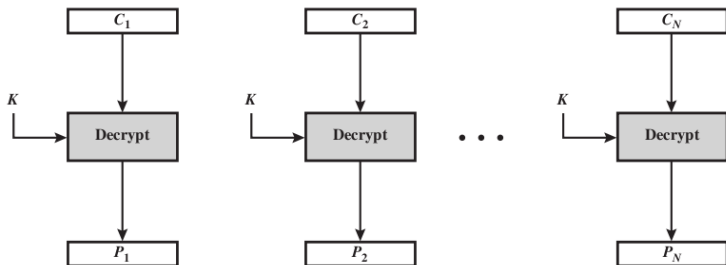
Feedback Characteristics of Modes

XTS-AES

ECB Encryption



ECB Decryption



Summary

- ▶ Each block of 64 plaintext bits is encoded independently using same key
- ▶ Typical applications: secure transmission of single values (e.g. encryption key)
- ▶ Problem: with long message, repetition in plaintext may cause repetition in ciphertext

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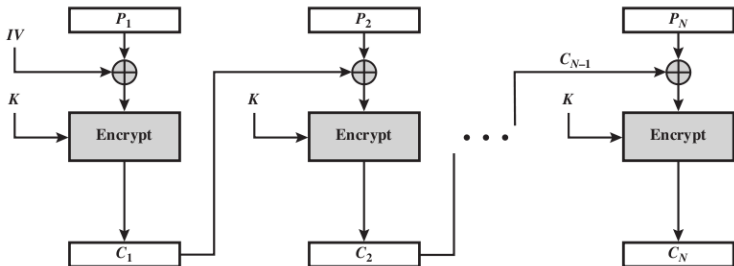
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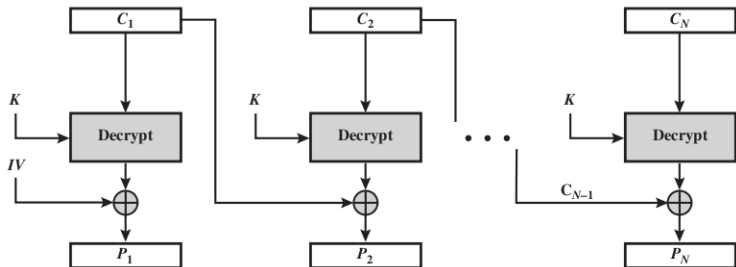
Feedback Characteristics of Modes

XTS-AES

CBC Encryption



CBC Decryption



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CBC Summary

- ▶ Input to encryption algorithm is XOR of next 64-bits plaintext and preceding 64-bits ciphertext
- ▶ Typical applications: General-purpose block-oriented transmission; authentication
- ▶ Initialisation Vector (IV) must be known by sender/receiver, but secret from attacker

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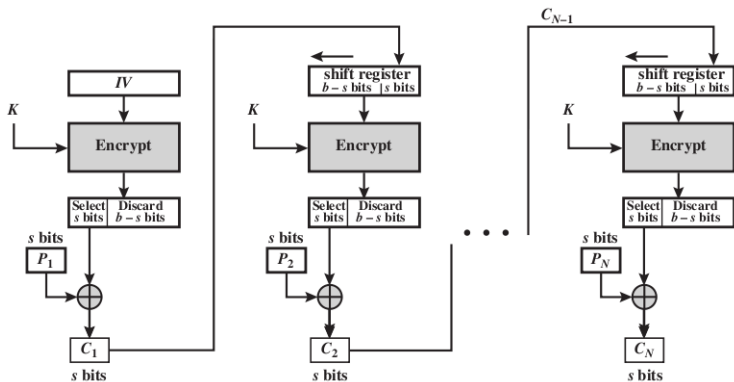
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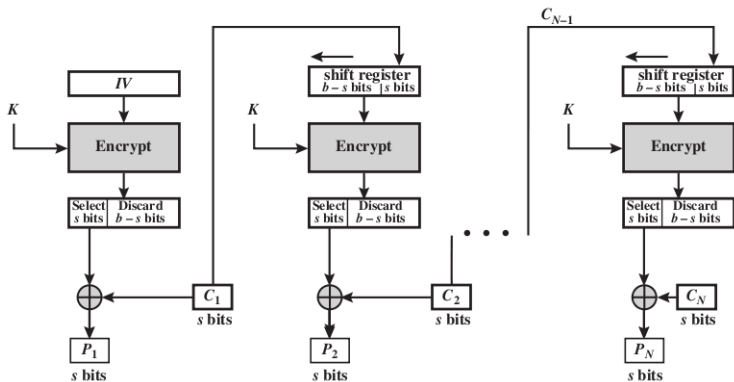
Feedback Characteristics of Modes

XTS-AES

CFB Encryption



CFB Decryption



CFB Summary

- ▶ Converts block cipher into stream cipher
 - ▶ No need to pad message to integral number of blocks
 - ▶ Operate in real-time: each character encrypted and transmitted immediately
- ▶ Input processed s bits at a time
- ▶ Preceding ciphertext used as input to cipher to produce pseudo-random output
- ▶ XOR output with plaintext to produce ciphertext
- ▶ Typical applications: General-purpose stream-oriented transmission; authentication

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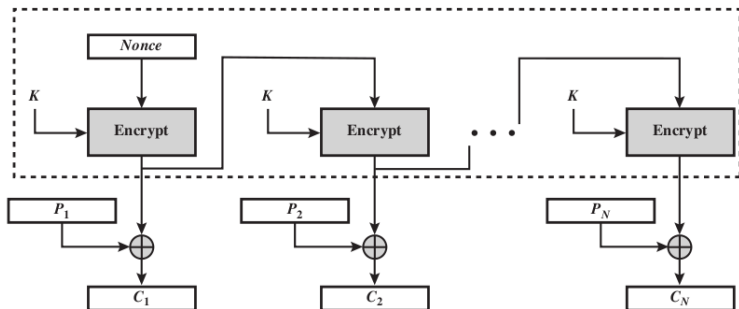
Output Feedback Mode

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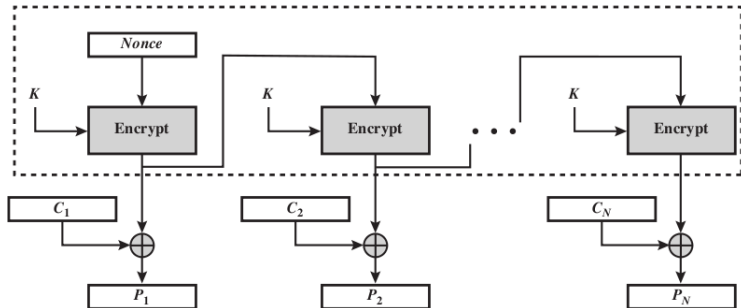
Feedback Characteristics of Modes

XTS-AES

OFB Encryption



OFB Decryption



OFB Summary

- ▶ Converts block cipher into stream cipher
- ▶ Similar to CFB, except input to encryption algorithm is preceding encryption output
- ▶ Typical applications: stream-oriented transmission over noisy channels (e.g. satellite communications)
- ▶ Advantage compared to CFB: bit errors do not propagate
- ▶ Disadvantage: more vulnerable to message stream modification attack

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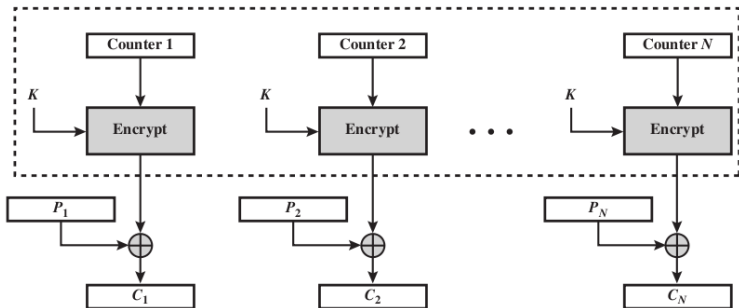
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Feedback Characteristics of Modes

XTS-AES

CTR Encryption



Modes

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CBC

CFB

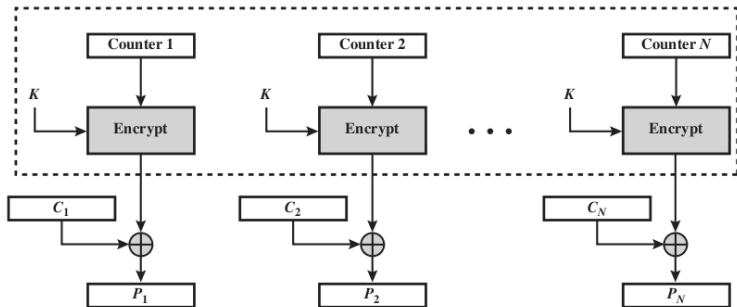
OFB

CTR

Feedback

XTS-AES

CTR Decryption



Modes

ECB

CBC

CFB

OFB

CTR

Feedback

XTS-AES

CTR Summary

- ▶ Converts block cipher into stream cipher
- ▶ Each block of plaintext XORed with encrypted counter
- ▶ Typical applications: General-purpose block-oriented transmission; useful for high speed requirements
- ▶ Efficient hardware and software implementations
- ▶ Simple and secure

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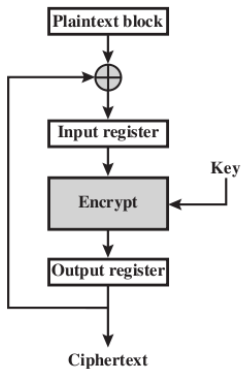
Output Feedback Mode

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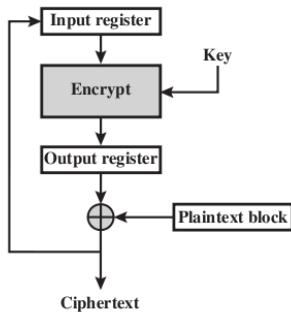
Feedback Characteristics of Modes

XTS-AES

Feedback: CBC and CFB



(a) Cipher block chaining (CBC) mode



(b) Cipher feedback (CFB) mode

Feedback: OFB and CTR

Modes

ECB

CBC

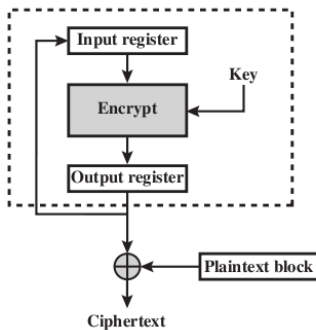
CFB

OFB

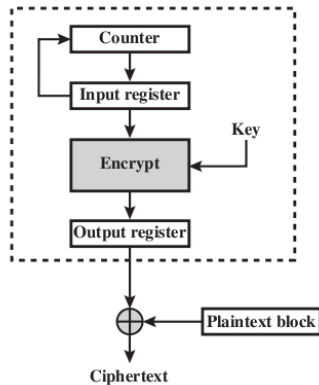
CTR

Feedback

XTS-AES



(c) Output feedback (OFB) mode



(d) Counter (CTR) mode

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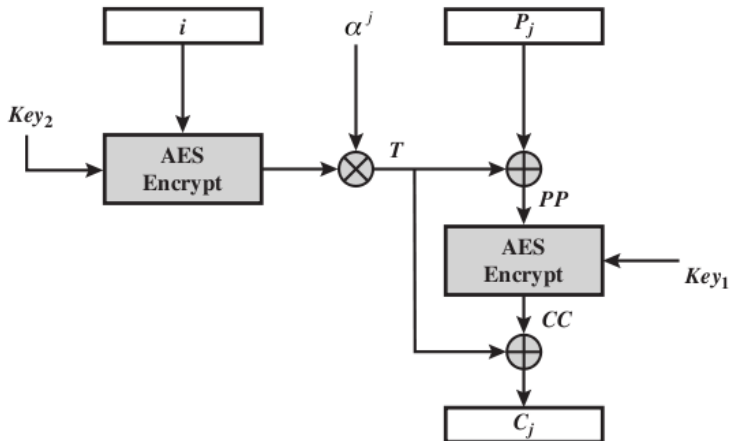
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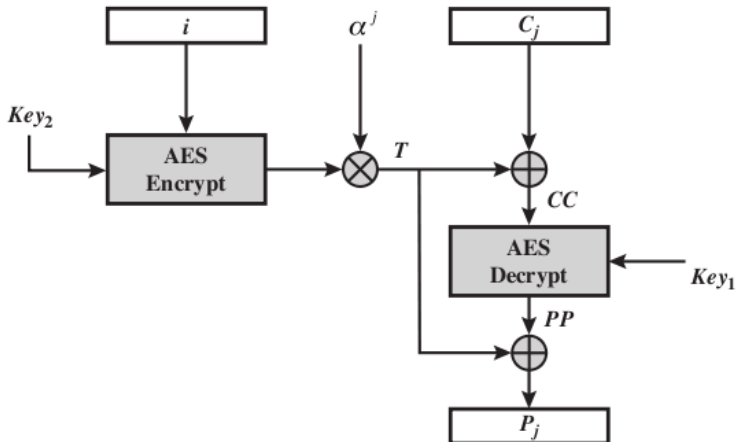
Feedback Characteristics of Modes

XTS-AES

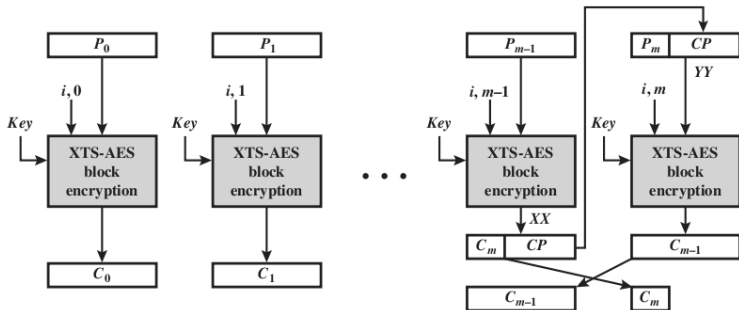
XTS-AES Encryption of Single Block



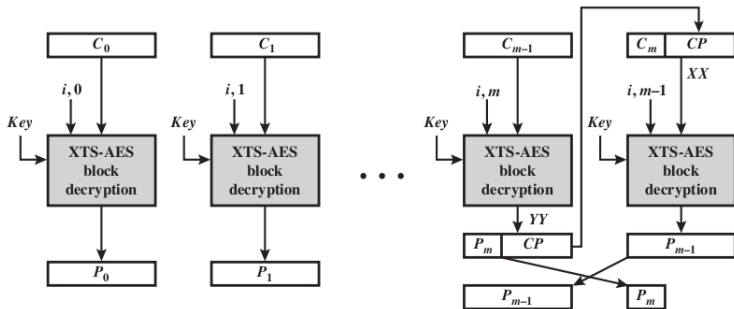
XTS-AES Decryption of Single Block



XTS-AES Encryption



XTS-AES Decryption



Encryption for Stored Data

- ▶ XTS-AES designed for encrypting stored data (as opposed to transmitted data)
- ▶ See Chapter 6.7 for details and differences to transmitted data encryption