SNS COLLEGE OF ENGINEERING

Kurumbapalayam (Po), Coimbatore – 641 107

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DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

COURSE NAME : Cryptography and Network Security

IIIYEAR /V SEMESTER

Unit 3- PUBLIC KEY CRYPTOGRAPHY

Topic : Evaluation criteria for AES – Advanced Encryption Standard-01

STANDARD

Advanced Encryption Standard - AES

- Origin of AES

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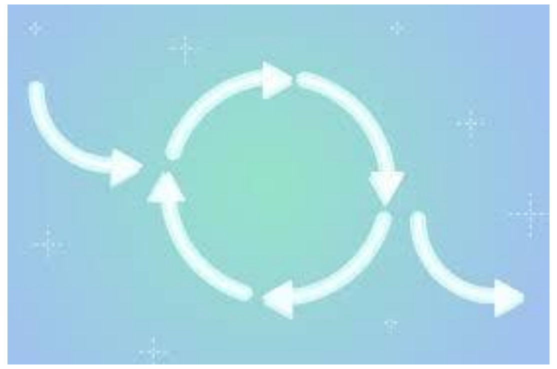
- Basic AES
- Inside Algorithm
- Final Notes



Origins

- A replacement for DES was needed
  - Key size is too small
- Can use Triple-DES – but slow, small block
- US NIST issued call for ciphers in 1997
- 15 candidates accepted in Jun 98
- 5 were shortlisted in Aug 99

AES Competition Requirements

- Private key symmetric block cipher
- 128-bit data, 128/192/256-bit keys
- Stronger & faster than Triple-DES
- Provide full specification & design details
- Both C & Java implementations

AES Evaluation Criteria

- initial criteria:
  - security – effort for practical cryptanalysis
  - cost – in terms of computational efficiency
  - algorithm & implementation characteristics
- final criteria
  - general security
  - ease of software & hardware implementation
  - implementation attacks
  - flexibility (in en/decrypt, keying, other factors)

AES Shortlist

- After testing and evaluation, shortlist in Aug-99
- MARS (IBM) - complex, fast, high security margin
- RC6 (USA) - v. simple, v. fast, low security margin
- Rijndael (Belgium) - clean, fast, good security margin
- Serpent (Euro) - slow, clean, v. high security margin
- Twofish (USA) - complex, v. fast, high security margin

- Found contrast between algorithms with
- few complex rounds versus many simple rounds
- Refined versions of existing ciphers versus new proposals

The AES Cipher - Rijndael

- Rijndael was selected as the AES in Oct-2000
  - Designed by Vincent Rijmen and Joan Daemen in Belgium
  - Issued as FIPS PUB 197 standard in Nov-2001

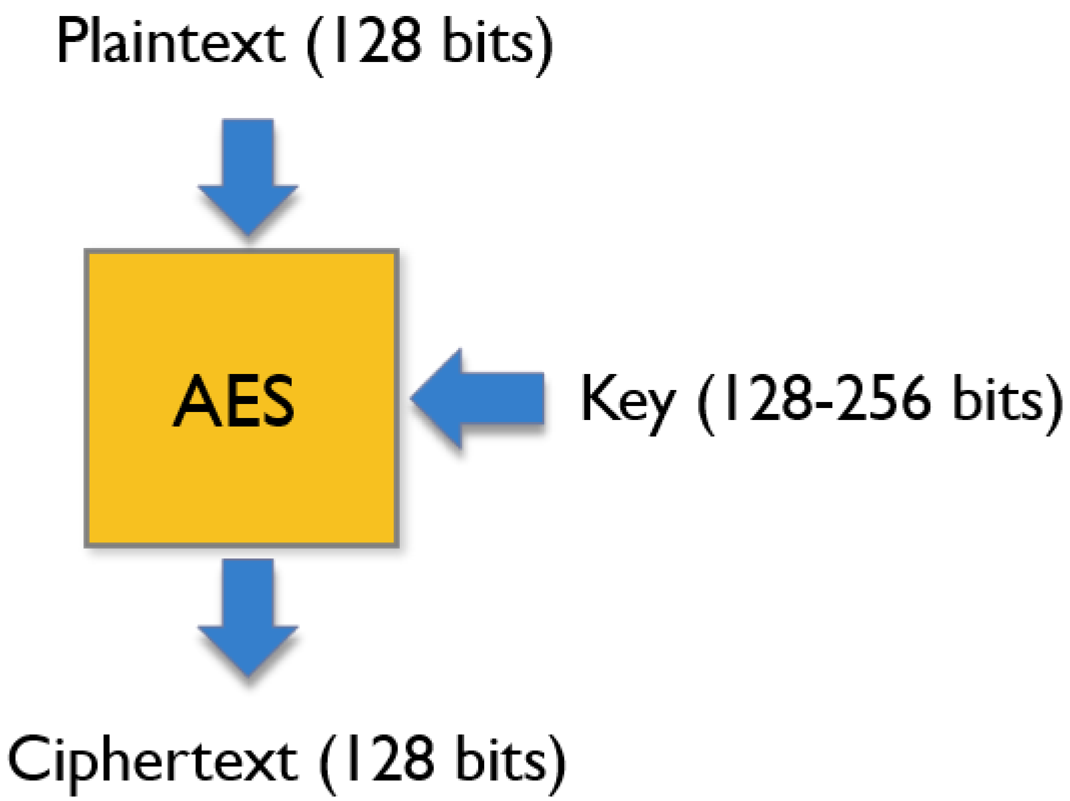
- An **iterative** rather than **Feistel** cipher
  - processes data as block of 4 columns of 4 bytes (128 bits)
  - operates on entire data block in every round

- Rijndael design:
  - simplicity
  - has 128/192/256 bit keys, 128 bits data
  - resistant against known attacks
  - speed and code compactness on many CPUs

Topics

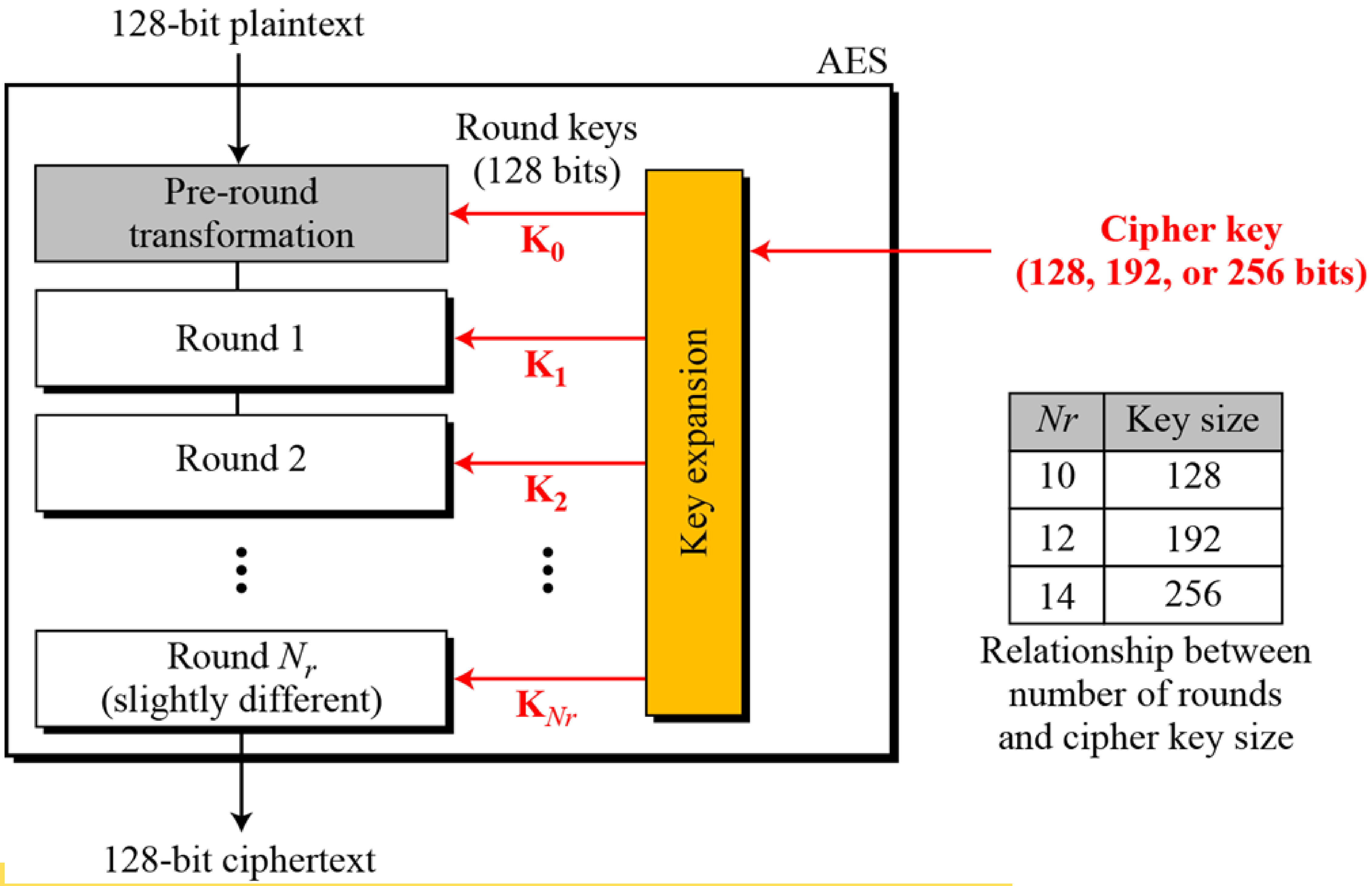
- Origin of AES
- **Basic AES**
- Inside Algorithm
- Final Notes

AES Conceptual Scheme



Multiple rounds

- Rounds are (almost) identical
  - First and last round are a little different



Nr	Key size
10	128
12	192
14	256

Relationship between
number of rounds
and cipher key size

High Level Description

Key Expansion

- Round keys are derived from the cipher key using Rijndael's key schedule

Initial Round

- AddRoundKey : Each byte of the state is combined with the round key using bitwise xor

Rounds

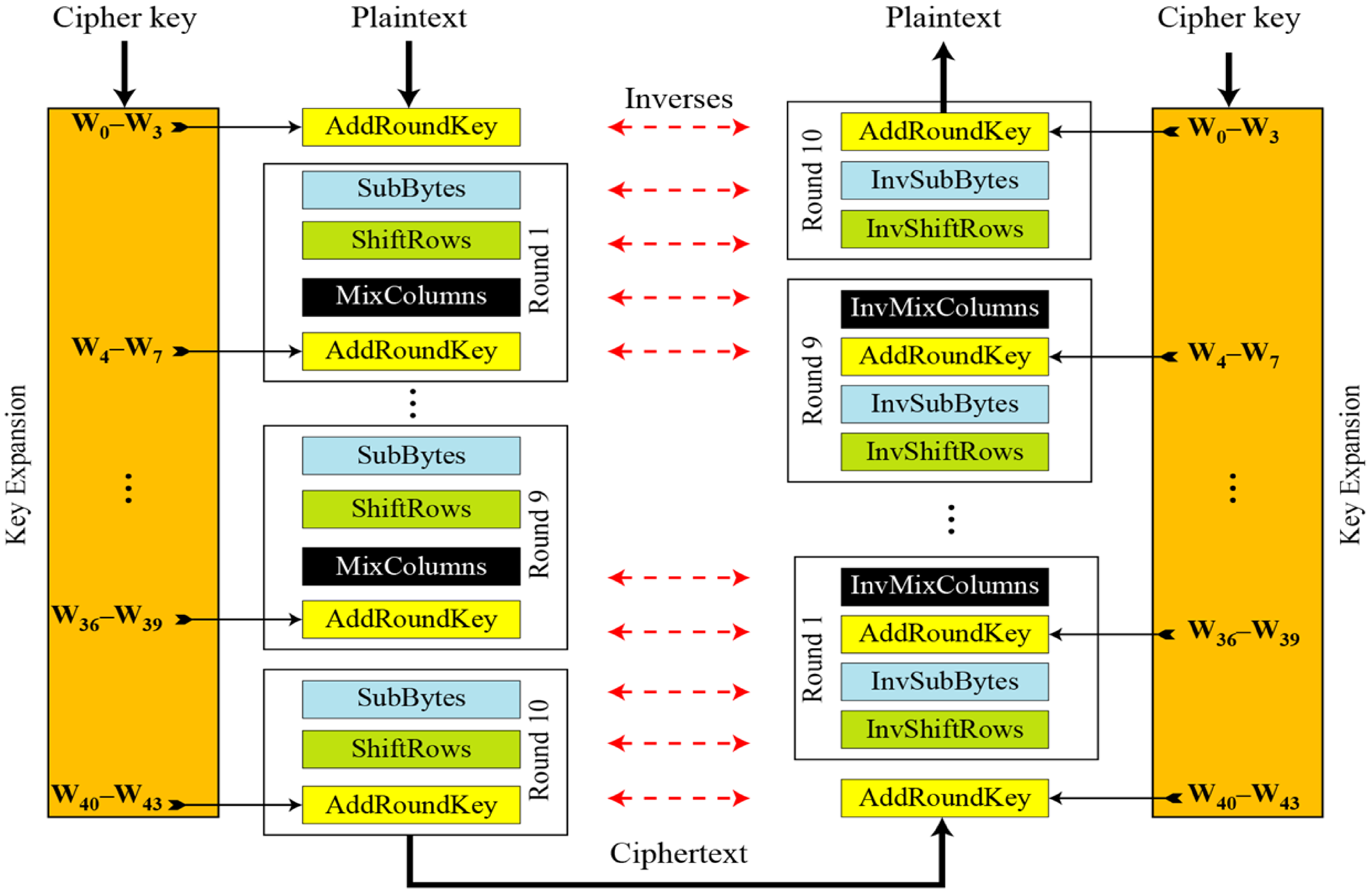
- SubBytes : non-linear substitution step
- ShiftRows : transposition step
- MixColumns : mixing operation of each column.
- AddRoundKey

Final Round

- SubBytes
- ShiftRows
- AddRoundKey

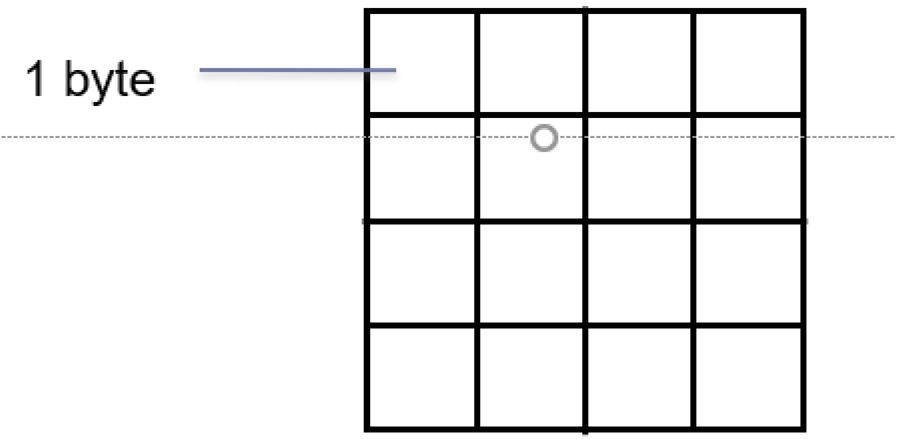
No MixColumns

Overall Structure

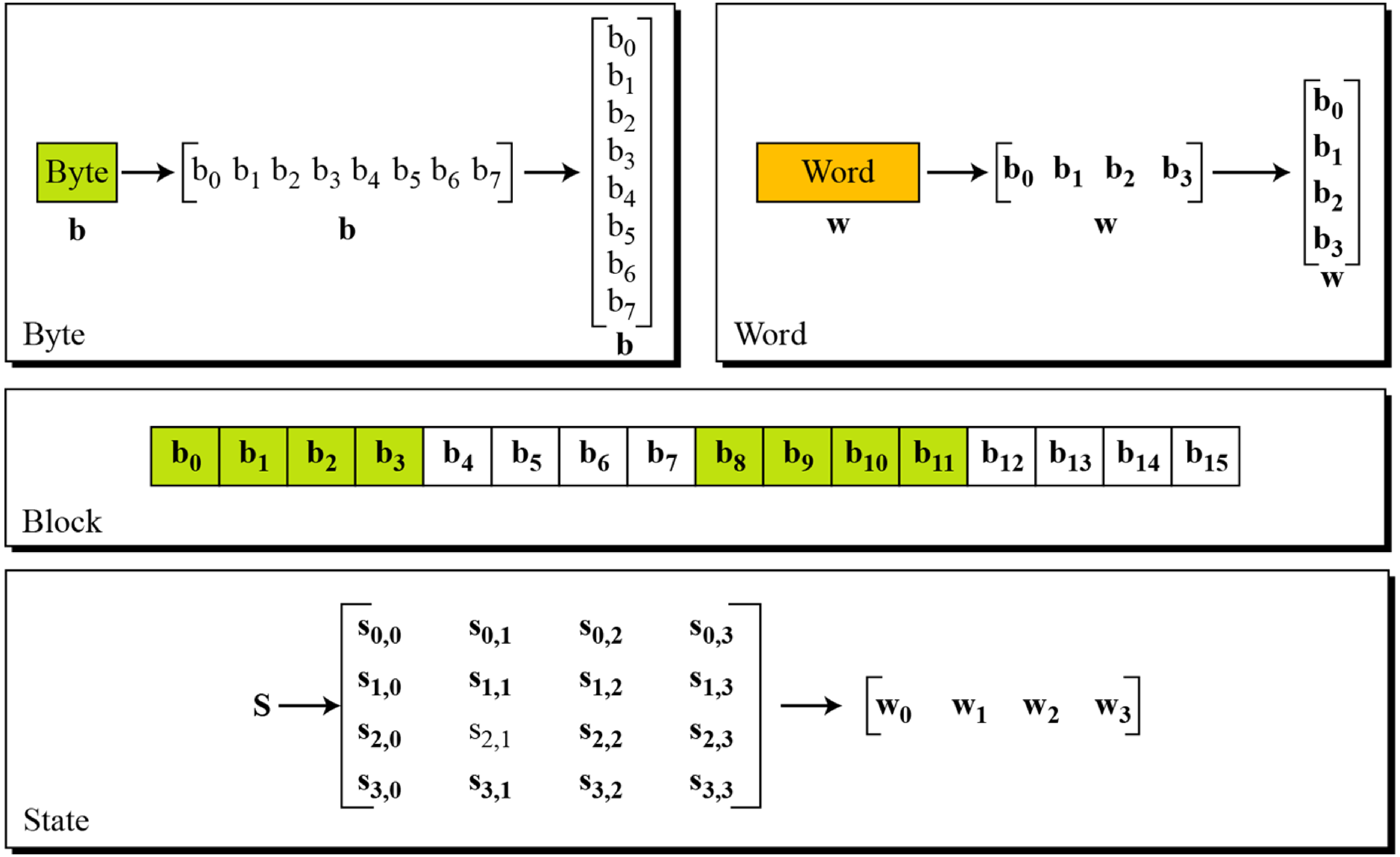


128-bit values

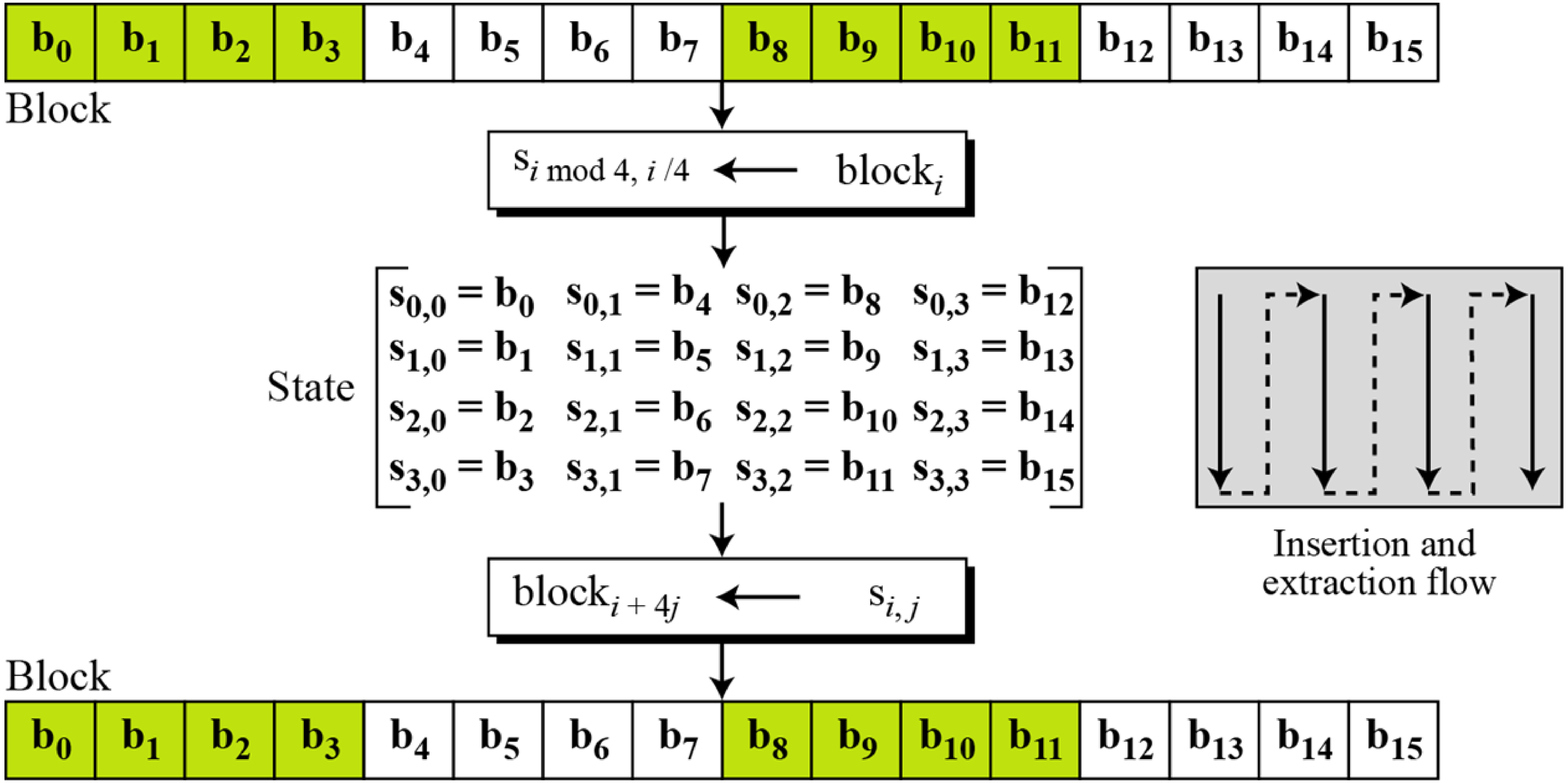
- Data block viewed as 4-by-4 table of bytes
- Represented as 4 by 4 matrix of 8-bit bytes.
- Key is expanded to array of 32 bits words



Data Unit


Byte
b
[b0 b1 b2 b3 b4 b5 b6 b7]
b
[b0 b1 b2 b3 b4 b5 b6 b7]
b
Byte
Word
w
[b0 b1 b2 b3]
w
[b0 b1 b2 b3]
w
Word
b0 b1 b2 b3 b4 b5 b6 b7 b8 b9 b10 b11 b12 b13 b14 b15
Block
S
s0,0 s0,1 s0,2 s0,3
s1,0 s1,1 s1,2 s1,3
s2,0 s2,1 s2,2 s2,3
s3,0 s3,1 s3,2 s3,3
[w0 w1 w2 w3]
State

Unit Transformation



Block

b_0	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8	b_9	b_{10}	b_{11}	b_{12}	b_{13}	b_{14}	b_{15}

$s_{i \bmod 4,\, i/4} \leftarrow \text{block}_i$

$$\text{State} \quad \begin{bmatrix} s_{0,0} = b_0 & s_{0,1} = b_4 & s_{0,2} = b_8 & s_{0,3} = b_{12} \\ s_{1,0} = b_1 & s_{1,1} = b_5 & s_{1,2} = b_9 & s_{1,3} = b_{13} \\ s_{2,0} = b_2 & s_{2,1} = b_6 & s_{2,2} = b_{10} & s_{2,3} = b_{14} \\ s_{3,0} = b_3 & s_{3,1} = b_7 & s_{3,2} = b_{11} & s_{3,3} = b_{15} \end{bmatrix}$$

$\text{block}_{i+4j} \leftarrow s_{i,j}$

Block

b_0	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8	b_9	b_{10}	b_{11}	b_{12}	b_{13}	b_{14}	b_{15}

Insertion and extraction flow

Changing Plaintext to State

Text	A	E	S	U	S	E	S	A	M	A	T	R	I	X	Z	Z
Hexadecimal	00	04	12	14	12	04	12	00	0C	00	13	11	08	23	19	19

$$\begin{bmatrix} 00 & 12 & 0C & 08 \\ 04 & 04 & 00 & 23 \\ 12 & 12 & 13 & 19 \\ 14 & 00 & 11 & 19 \end{bmatrix} \text{State}$$

Assessment 1

1 AES uses a ____________ bit block size and a key size of

a) 128; 128 or 256

b) 64; 128 or 192

c) 256; 128, 192, or 256

d) 128; 128, 192, or 256

2. Like DES, AES also uses Feistel Structure.

a) True

b) False

REFERENCES

1. William Stallings, Cryptography and Network Security, 6 th Edition, Pearson Education, March 2013.

THANK YOU