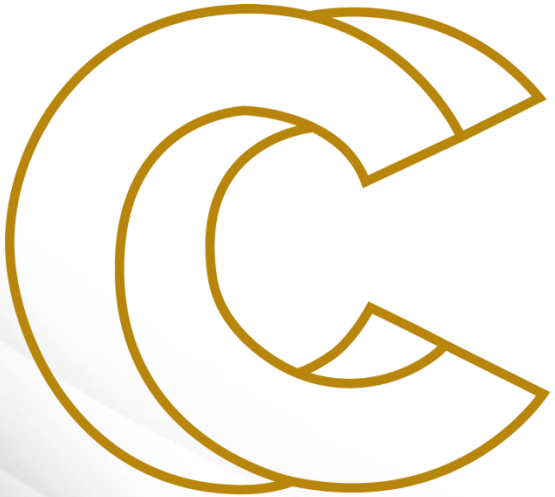

EURO 4SEE

GPU Assisted Brute Force Cryptanalysis of GPRS, GSM, RFID, and TETRA

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Lesson 3: KASUMI Block Cipher

KASUMI Block Cipher

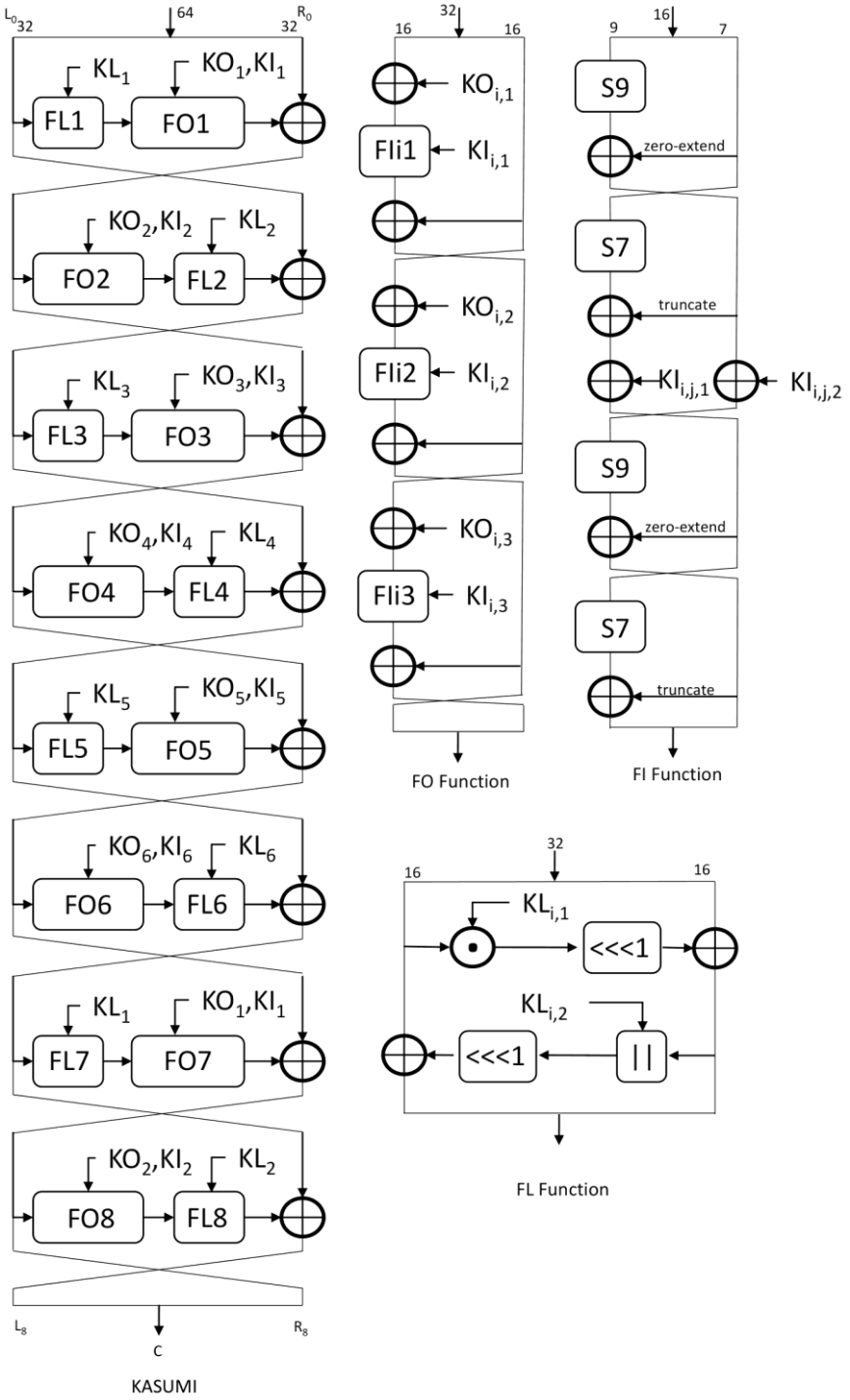
- KASUMI was designed by ETSI SAGE.
- It is a modified version of the block cipher MISTY1.
- It is a *Feistel* block cipher
  - **Number of rounds:** 8
  - **Block size:** 64 bits
  - **Key size:** 128 bits
- The key schedule of KASUMI simply consists of rotations on 16-bit values and XOR with constants.
- The round function of KASUMI contains FO and FL functions where FL function contains AND, OR, and rotation operations and FO function is also a 3-round Feistel structure which contains FI functions in each of its round.
- Moreover, FI functions is a four round Feistel structure which uses two S-boxes of sizes 7x7 and 9x9 consecutively in each round.

Lesson 3: KASUMI Block Cipher

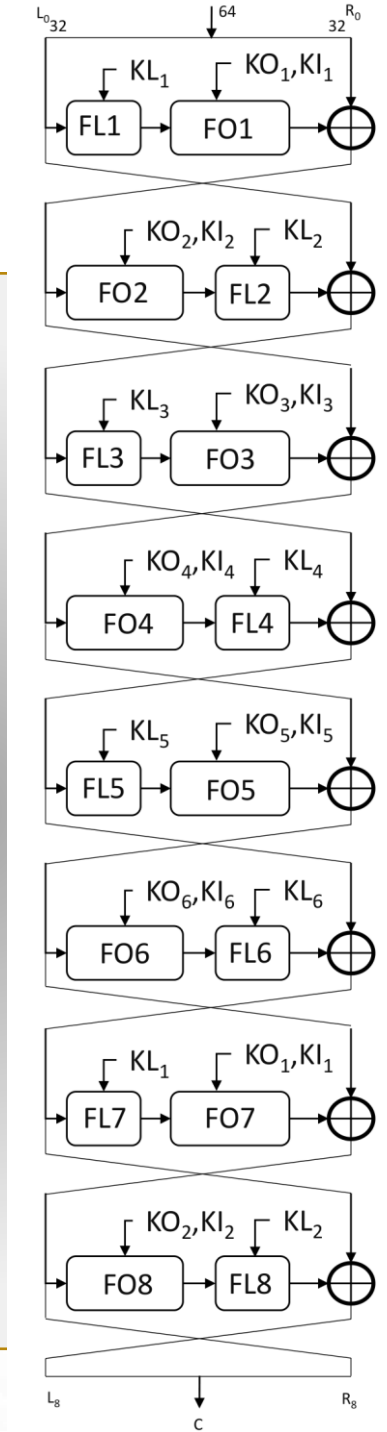
KASUMI Key Schedule

- The 128-bit key ***K*** is divided into eight 16-bit subkeys K_i:
  - $K=K_1||K_2||K_3||K4||K5||K6||K7||K8$
- Additionally a modified key ***K'***, similarly divided into 16-bit subkeys K'_i is used.
- The modified key is derived from the original key by XORing with 0x123456789ABCDEFFEDCBA9876543210
- The round keys are as follows:
  - $KL_{i,1} = ROL(K_{i,1})$
  - $KL_{i,2} = K'_{i+2}$
  - $KO_{i,1} = ROL(K_{i+1,5})$
  - $KO_{i,2} = ROL(K_{i+5,8})$
  - $KO_{i,3} = ROL(K_{i+6,13})$
  - $KI_{i,1} = K'_{i+4}$
  - $KI_{i,2} = K'_{i+3}$
  - $KI_{i,3} = K'_{i+7}$

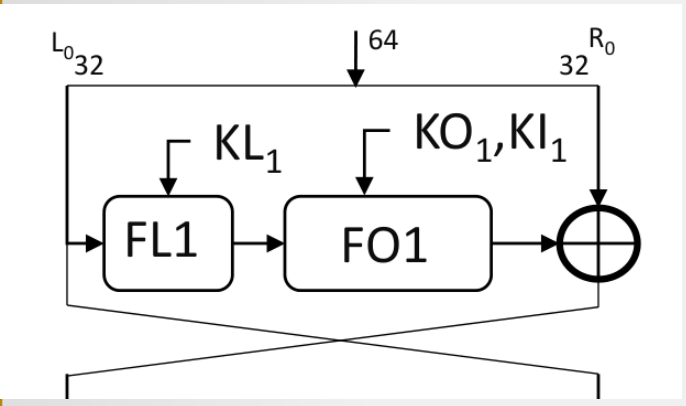
Lesson 3: KASUMI



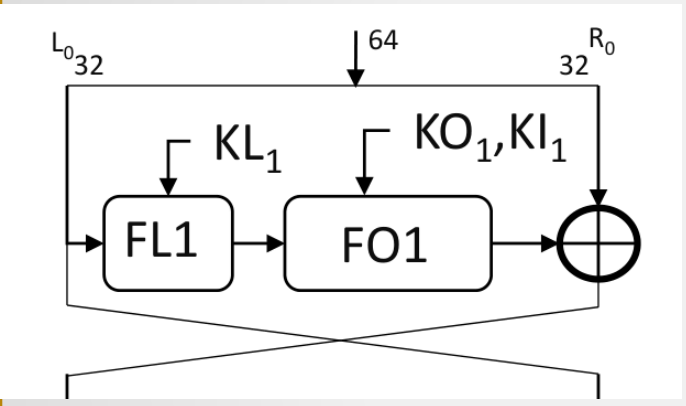
Lesson 3: KASUMI Block Cipher

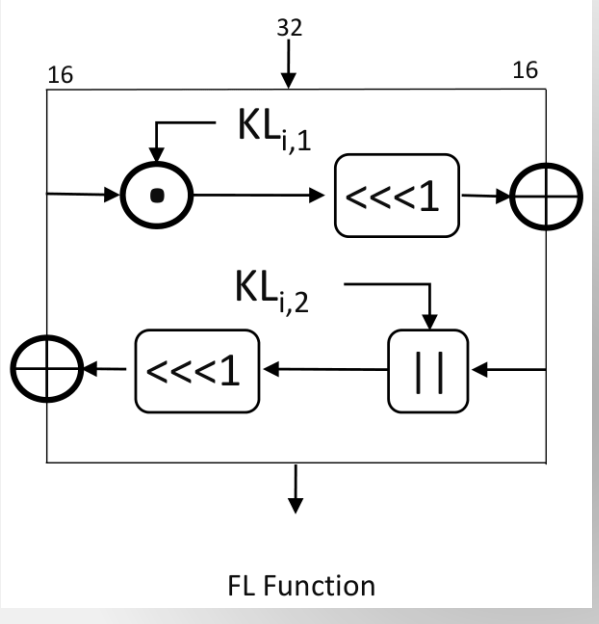


Lesson 3: KASUMI Block Cipher



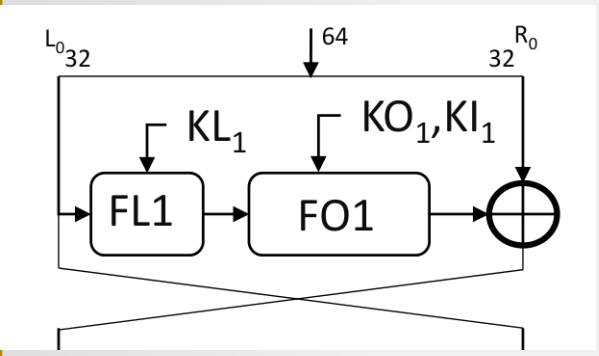
Lesson3:KASUMIBlockCipher

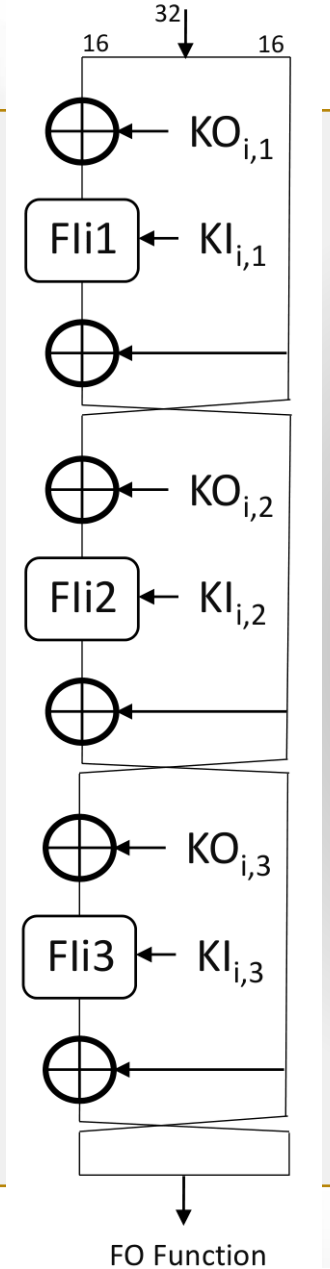




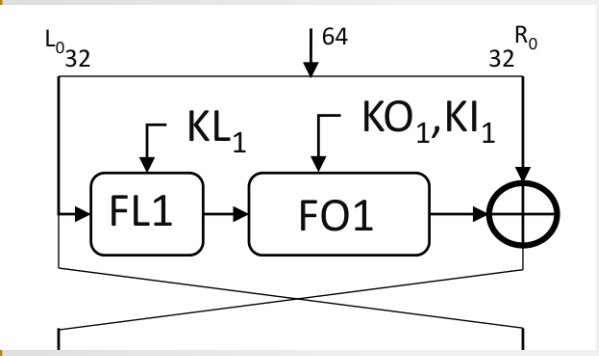
FL Function

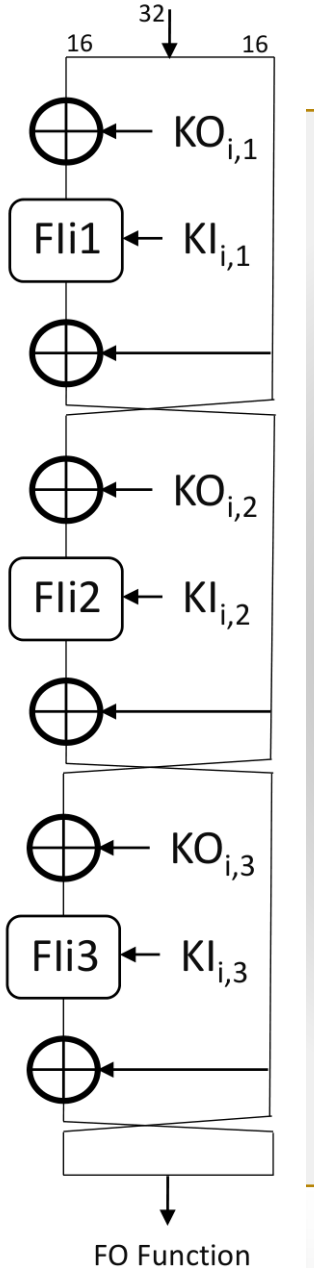
Lesson 3: KASUMI Block Cipher

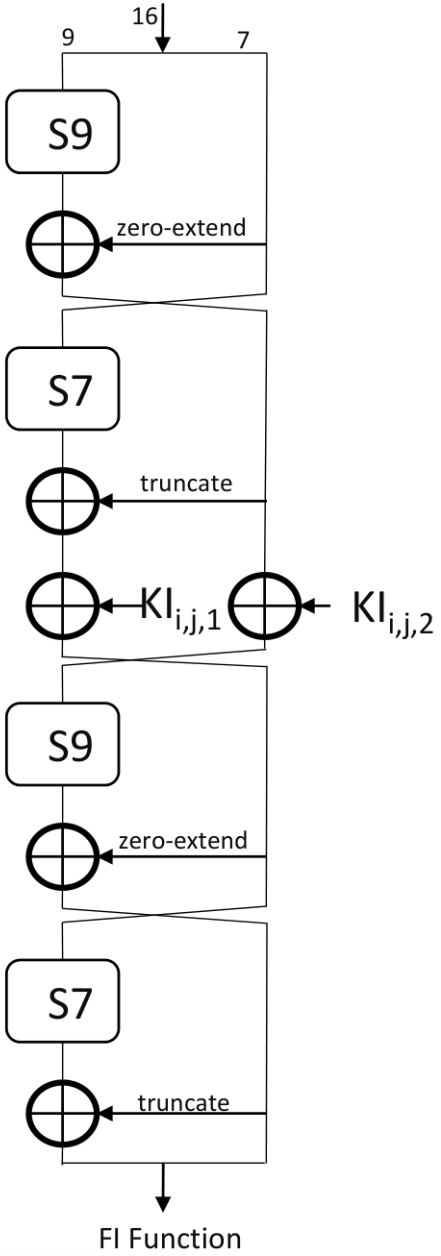




Lesson 3: KASUMI Block Cipher







Lesson 3: KASUMI Block Cipher


```
bit8 S7[128]={
        54,50,62,56,22,34,94,96,38,6,63,93,2,18,123,33,55,113,39,114,21,67,65,12,47,73,46,
        27,25,111,124,81,53,9,121,79,52,60,58,48,101,127,40,120,104,70,71,43,20,122,72,61,
        23,109,13,100,77,1,16,7,82,10,105,98,117,116,76,11,89,106,0,125,118,99,86,69,30,
        57,126,87,112,51,17,5,95,14,90,84,91,8,35,103,32,97,28,66,102,31,26,45,75,4,85,92,
        37,74,80,49,68,29,115,44,64,107,108,24,110,83,36,78,42,19,15,41,88,119,59,3
};
```

Lesson 3: KASUMI Block Cipher

```
bit16 S9[512]={
        167,239,161,379,391,334,9,338,38,226,48,358,452,385,90,397,183,253,147,331,415,340,51,362,306,500,262,
        82,216,159,356,177,175,241,489,37,206,17,0,333,44,254,378,58,143,220,81,400,95,3,315,245,54,235,218,405,
        472,264,172,494,371,290,399,76,165,197,395,121,257,480,423,212,240,28,462,176,406,507,288,223,501,407,
        249,265,89,186,221,428,164,74,440,196,458,421,350,163,232,158,134,354,13,250,491,142,191,69,193,425,152,
        227,366,135,344,300,276,242,437,320,113,278,11,243,87,317,36,93,496,27,487,446,482,41,68,156,457,131,326,
        403,339,20,39,115,442,124,475,384,508,53,112,170,479,151,126,169,73,268,279,321,168,364,363,292,46,499,393,
        327,324,24,456,267,157,460,488,426,309,229,439,506,208,271,349,401,434,236,16,209,359,52,56,120,199,277,
        465,416,252,287,246,6,83,305,420,345,153,502,65,61,244,282,173,222,418,67,386,368,261,101,476,291,195,430,
        49,79,166,330,280,383,373,128,382,408,155,495,367,388,274,107,459,417,62,454,132,225,203,316,234,14,301,91,
        503,286,424,211,347,307,140,374,35,103,125,427,19,214,453,146,498,314,444,230,256,329,198,285,50,116,78,410,
        10,205,510,171,231,45,139,467,29,86,505,32,72,26,342,150,313,490,431,238,411,325,149,473,40,119,174,355,185,
        233,389,71,448,273,372,55,110,178,322,12,469,392,369,190,1,109,375,137,181,88,75,308,260,484,98,272,370,275,
        412,111,336,318,4,504,492,259,304,77,337,435,21,357,303,332,483,18,47,85,25,497,474,289,100,269,296,478,270,
        106,31,104,433,84,414,486,394,96,99,154,511,148,413,361,409,255,162,215,302,201,266,351,343,144,441,365,108,
        298,251,34,182,509,138,210,335,133,311,352,328,141,396,346,123,319,450,281,429,228,443,481,92,404,485,422,
        248,297,23,213,130,466,22,217,283,70,294,360,419,127,312,377,7,468,194,2,117,295,463,258,224,447,247,187,80,
        398,284,353,105,390,299,471,470,184,57,200,348,63,204,188,33,451,97,30,310,219,94,160,129,493,64,179,263,102,
        189,207,114,402,438,477,387,122,192,42,381,5,145,118,180,449,293,323,136,380,43,66,60,455,341,445,202,432,8,
        237,15,376,436,464,59,461
};
```

Lesson 3: KASUMI Block Cipher

KASUMI Block Cipher

- KASUMI is an encryption standard for 3G communications.
- 2G communications initially used ***A5/1*** stream cipher which uses a 64-bit key.
- 64-bit key is too short and it is susceptible to brute-force attacks.
- Moreover, any ***A5/1*** encryption can be broken in real-time via Time-Memory Trade-off (TMTO) attacks.
- For this reason, a modified version of KASUMI which is called ***A5/3*** is added to 2G encryption standards.
- Although KASUMI supports 128-bit keys, ***A5/3*** and ***GEA-3*** both use a session key K_c of 64 bits as 128-bit $K_c \,||\, K_c$ KASUMI key for GSM and GPRS in order to have backward compatibility.

Next lecture

SPECK Family of Block Ciphers

- How SPECK works
- What are the parameters of this family of block ciphers

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Thanks!

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the European Union

EuroHPC
Joint Undertaking

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