Security Evaluations on Lightweight Cryptographic Algorithms

Lightweight Stream ciphers and their cryptanalysis

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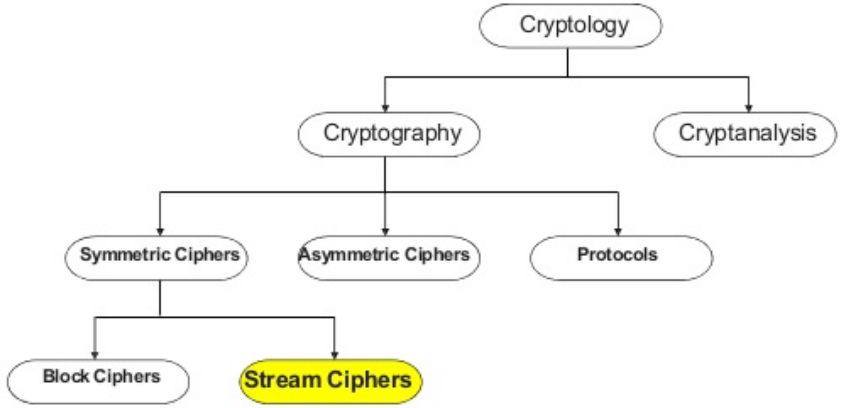
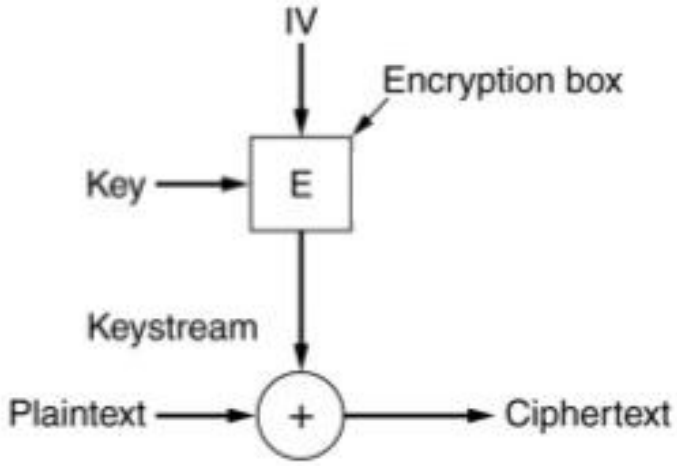
Outline

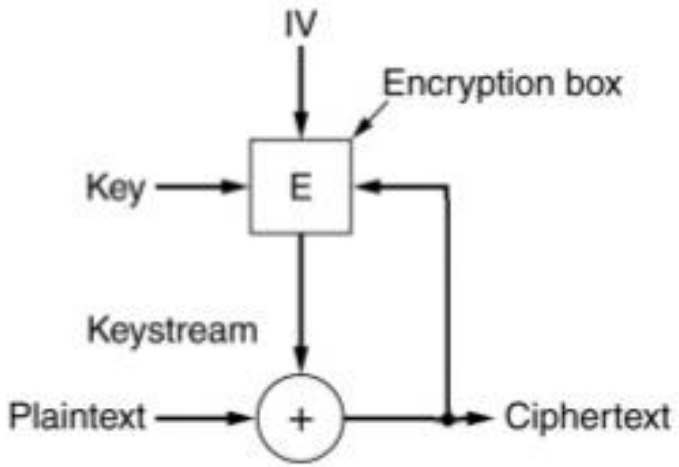
- Stream ciphers
- Lightweight Stream ciphers
- Some proposed ciphers
- The challenges
  - to design
  - to implement
- Some cryptanalysis points

Stream ciphers



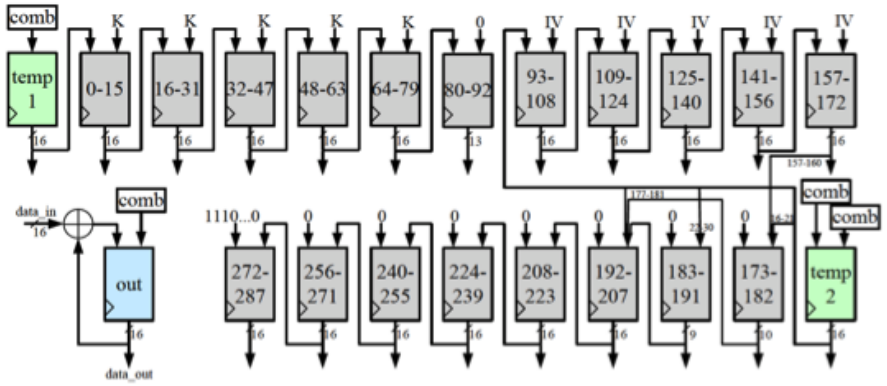
- Symmetric ciphers
  - Block Ciphers
  - Stream Ciphers (Synchronous, Asynchronous)
    - Some modes of operation transform a BC to SC

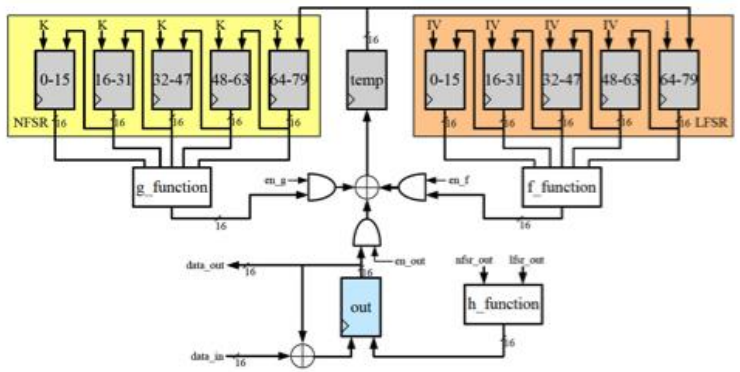




Applications

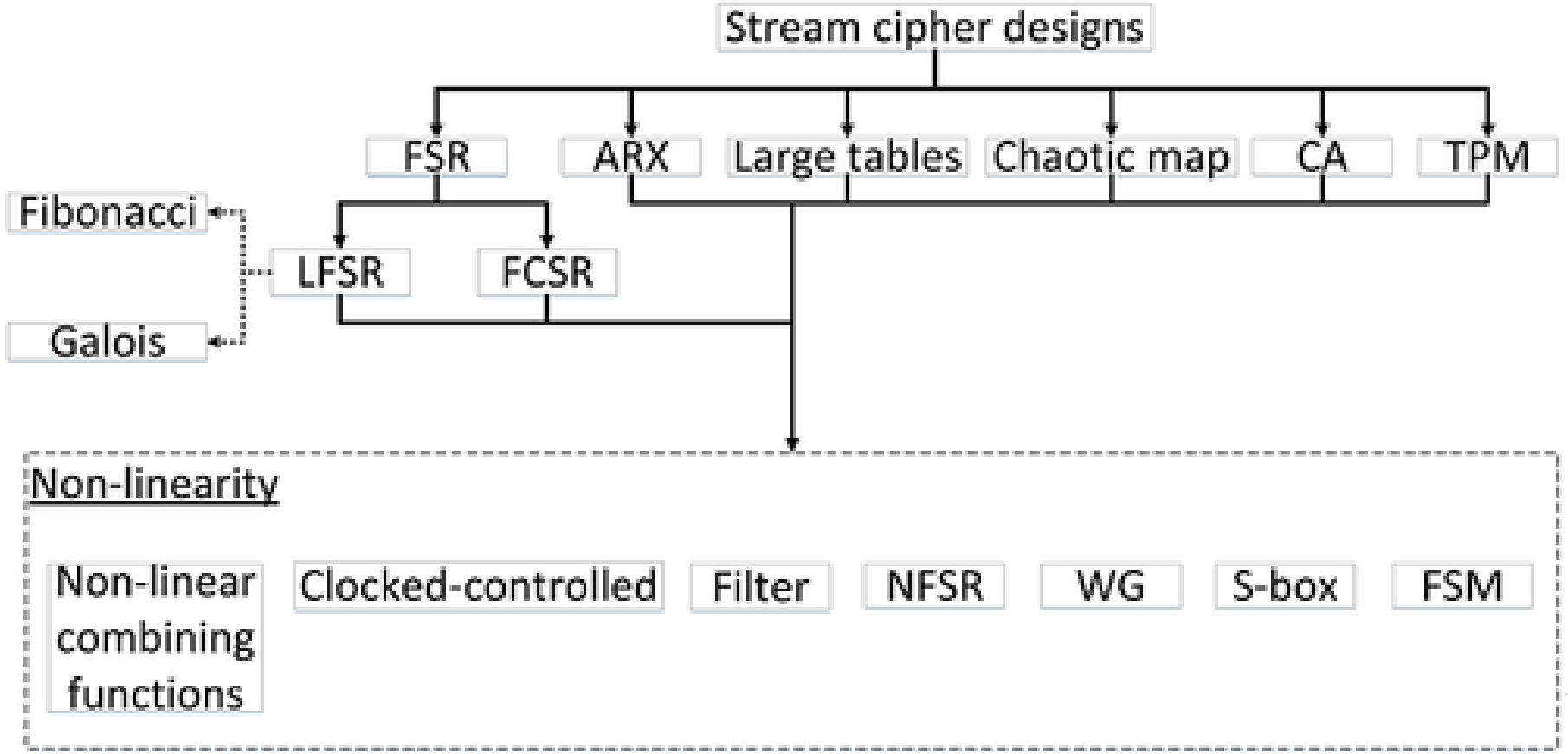
- Lightweight ciphers on RFID tags, Sensor Networks, IoT devices
- Generally
  - Encryption-Decryption are the same.
  - Faster, lighter, simpler than Block ciphers





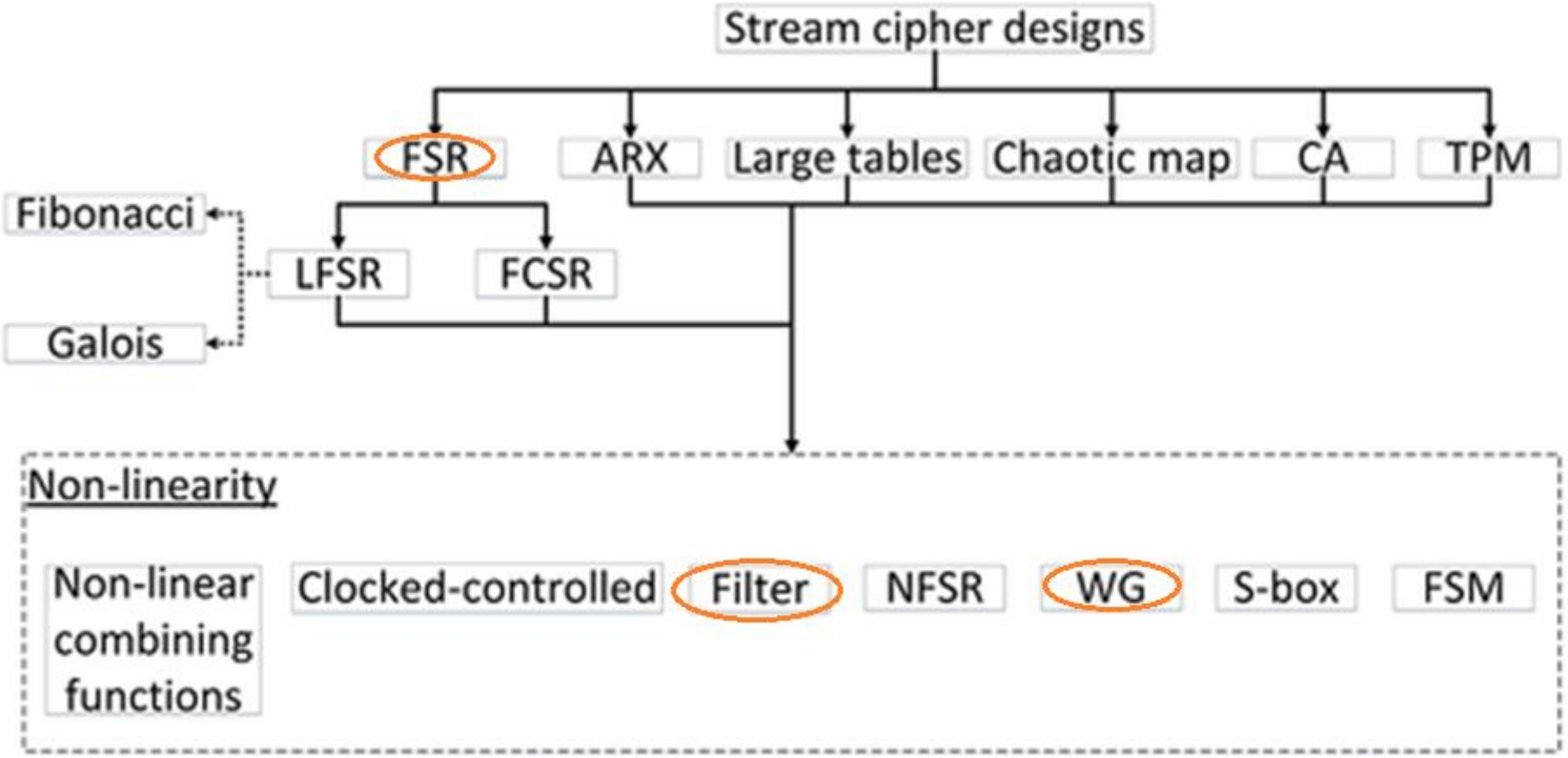
- A5/1,/2,/3, RC4, Grain, WG, …

The taxonomy



Refer to “A survey of lightweight stream ciphers for embedded systems”, Secur. Commun. Netw,2015

The taxonomy



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Lightweight Cryptography: Critical Points

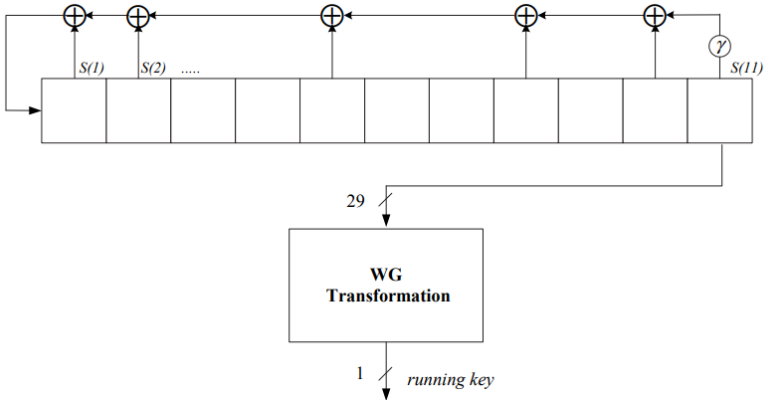
- Size:
  - Internal state (bits)
  - Key IV size (bits)
- Area (#GE)
- Power consumption
- Speed
  - Software/Hardware
- Security!
  - Mathematical Attacks
  - Implementation Attacks (countermeasures Cost)
    - Function and Protected Function (more than 2.5 times GE)

Trade off Between
Security and Lightweightness

A Case Study: WG Stream ciphers

- A Family of ciphers:
  - WG; proposed at eStream project.
  - WG-7 and WG-8; designed for encryption in resource restricted environments
  - WG-16; recommended for securing LTE applications.
  - And WG-t; uses computations in GF(2^t).

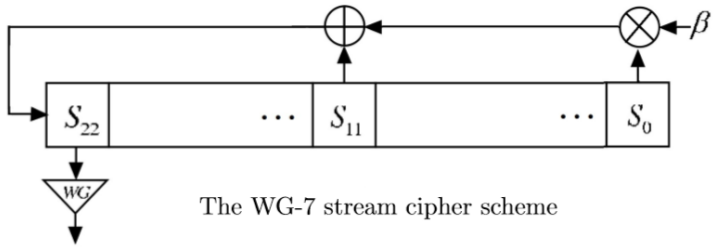
Cipher	Length of LFSR	Finite Field	The proposed application	Proposed bit-Security
$WG-7$	23	$GF(2^7)$	*RFID*	80
$WG-8$	20	$GF(2^8)$	*RFID*	128
$WG-16$	32	$GF(2^{16})$	*Communication, 5G*	128
$WG-29$	12	$GF(2^{29})$	*General Hardware*	80



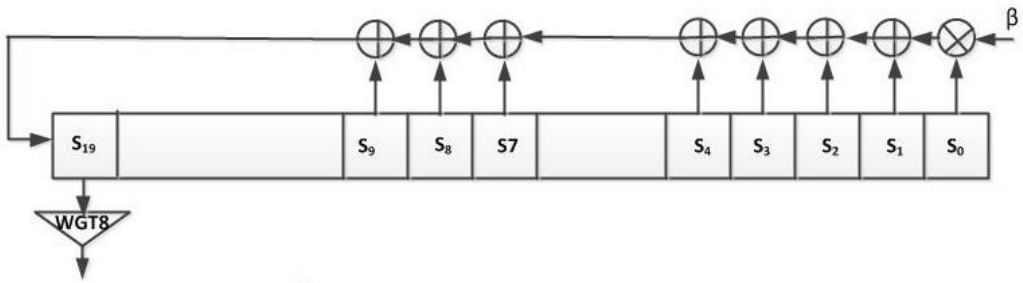
  - A filter structure
    - LFSR
    - WG transformation

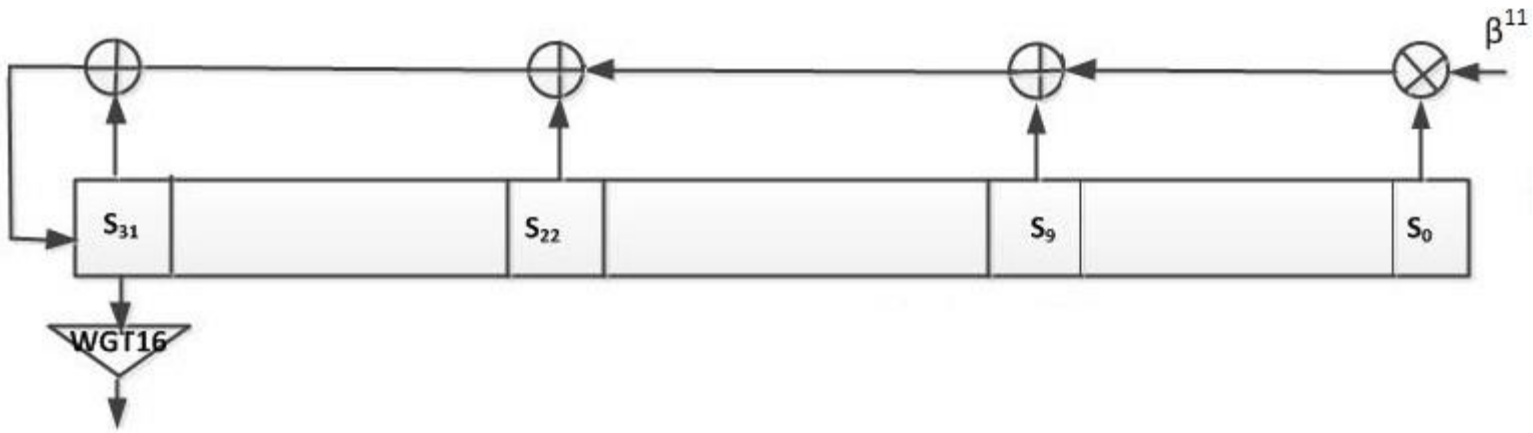
General properties

- Very simple and light cipher to be implemented
- Suitable cryptographic specifications
- Implementation points



The WG-7 stream cipher scheme





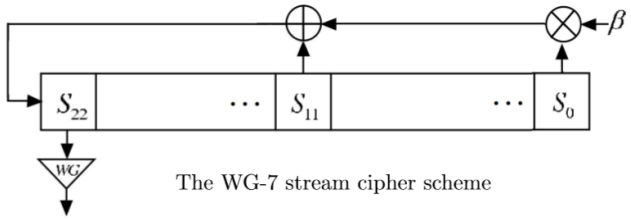
Cryptanalysis

- Distinguishing and key recovery attacks
  - Chosen IV attack on WG; Wu and Preneel (2006)
  - Algebraic attack on WG-7; Orumiehchiha, Pieprzyk, Steinfeld (2012)
  - Distinguishing on WG-8: Ding, Jin, Guan, Wang (2014)
  - Distinguishing attack; Joseph, Sekar, Balasubramanian (2016)
  - MILP-Based Cube Attack: Rohit, AlTawy, Guang Gong (2017)
  - Distinguishing on WG-8, -16: Rostami, Shakour, Orumiehchiha, Pieprzyk (2019)
- Implementation attack
  - Differential Fault Attack: Orumiehchiha, Rostami, Shakour, Pieprzyk (2020)

- Why they are still vulnerable!?

Why they are vulnerable!?

- The Filter Function
  - the algebraic properties
  - the number of input variables



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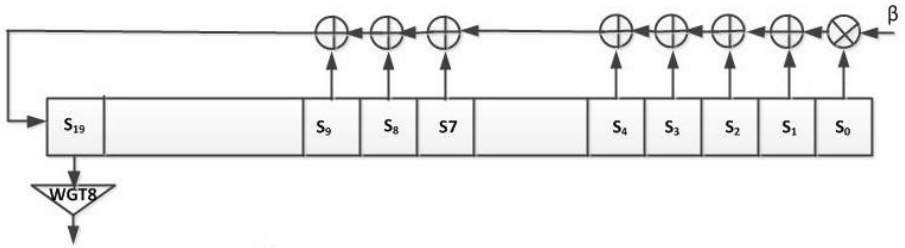
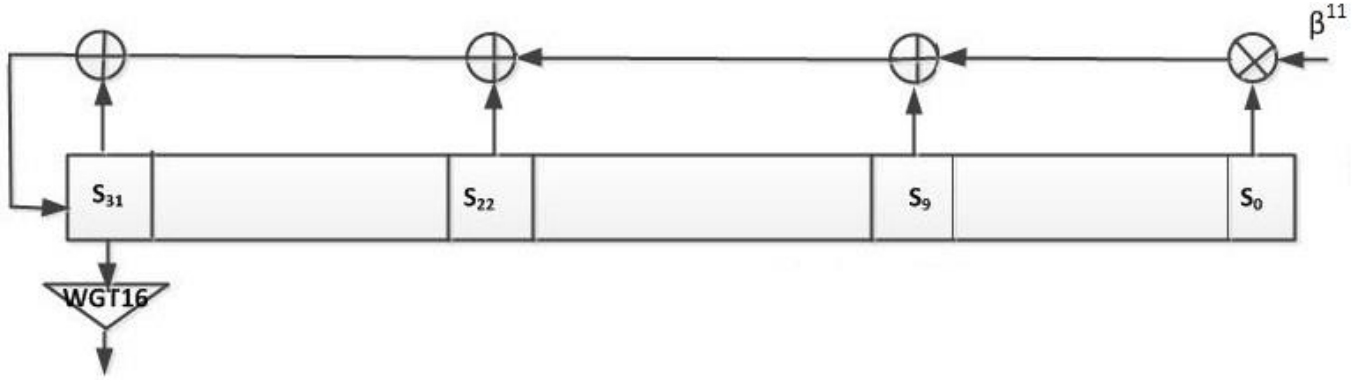


- The internal state
  - low diffusion-confusion of the state



The Challenges

- Understanding
  - the security limitations to design lightweight ciphers
  - the industry requirements for lightweight ciphers
- Need to
  - find new different security properties than what we know!
  - new recommendations to use lightweight cryptography.
  - provide crypto solutions in constrained environments.

Conclusions

- Had a look at
  - Stream ciphers as not-standard schemes to design lightweight ciphers
  - the Critical points to exploit ciphers in the constrained environments
  - a case study to see the limitations
  - Checking out the challenges

Thank you

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