FELICS – Fair Evaluation of Lightweight Cryptographic Systems

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UNIVERSITÉ DU
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Introduction

- **FELICS**
  - **F**air **E**valuation of **Li**ghtweight **C**ryptographic **S**ystems
  - open-source benchmarking framework for software implementations on constrained target devices widely used in the IoT

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  - open-source benchmarking framework for software implementations on constrained target devices widely used in the IoT
- **Motivation**
  - lack of comparative performance figures
- **Outline**
  - this talk (FELICS): the framework structure and features
  - next talk (Triathlon): evaluation of 13 lightweight block ciphers using FELICS

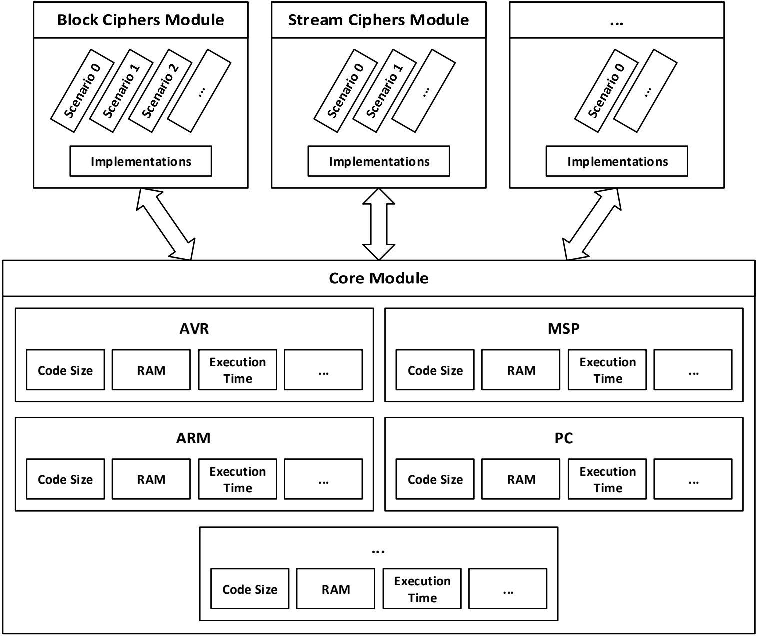
Related Work

	eBACS	ECRYPT II	BLOC	XBX	FELICS
Code Size	✗	✓	✓	✓	✓
RAM	✗	✓	✓	✓	✓
Exec. Time	✓	✓	✓	✓	✓
AVR	✗	✓	✗	✓	✓
MSP	✗	✗	✓	✓	✓
ARM	✗	✗	✗	✓	✓
PC	✓	✗	✗	✗	✓
Eval. Scen.	✗	✗	✗	✗	✓
Last Active	Nov '14	Nov '12	Jun '14	Nov '10	Jul '15

Goals

- **fair and consistent evaluation**
    - same assessment methodology for all implementations
- **accurate measurements and comprehensive results**
    - precise extraction of the metrics at operation level
- **free and open source**
    - widespread utilisation
- **flexible**
    - facilitates further development

Structure


Block Ciphers Module
Scenario 0
Scenario 1
Scenario 2
...
Implementations
Stream Ciphers Module
Scenario 0
Scenario 1
...
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...
Scenario 0
...
Implementations
Core Module
AVR
Code Size
RAM
Execution Time
...
MSP
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Code Size
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...

Core Module

- the heart of the framework
- provides the tools necessary to collect the metrics for each of the supported devices
- facilitates integration of new target devices and extracted metrics

Metric	AVR	MSP	ARM
Code Size	avr-size	msp430-size	arm-none-eabi-size
RAM	simavr avr-gdb	MSPDebug msp430-gdb	J-Link GDB Server arm-none-eabi-gdb
Execution Time	Avrora	MSPDebug	Arduino Due board

Block Ciphers Module

- same function signatures for all implementations
- template cipher implementation
- detailed implementation requirements
- implementation details in `implementation.info`

Function Signatures

```
void RunEncryptionKeySchedule(uint8_t *key, uint8_t *roundKeys);
void Encrypt(uint8_t *block, uint8_t *roundKeys);
void RunDecryptionKeySchedule(uint8_t *key, uint8_t *roundKeys);
void Decrypt(uint8_t *block, uint8_t *roundKeys);
```

Stream Ciphers Module

- same function signatures for all implementations
- template cipher implementation
- detailed implementation requirements
- implementation details in `implementation.info`

Function Signatures

```
void Setup(uint8_t *state, uint8_t *key, uint8_t *iv);
void Encrypt(uint8_t *state, uint8_t *stream, uint16_t length);
```

Target Devices

- Atmel AVR ATmega128
- Texas Instruments MSP430F1611
- Arduino Due board (ATSAM3X8E ARM Cortex-M3 MCU)

Characteristic	**AVR**	**MSP**	**ARM**
CPU	8-bit RISC	16-bit RISC	32-bit RISC
Frequency (MHz)	16	8	84
Registers	32	16	21
Architecture	Harvard	Von Neumann	Harvard
Flash (KB)	128	48	512
SRAM (KB)	4	10	96
EEPROM (KB)	4	-	-
Supply voltage (V)	4.5 - 5.5	1.8 - 3.6	1.6 - 3.6

Metrics

- three metrics:
  - code size (bytes)
  - RAM consumption (bytes)
  - execution time (cycles)
- accurate measurements
- detailed measurements ⇒ comprehensive results

Script

```
./collect_cipher_metrics.sh[{-h|--help}] [--version]
       [{-f|--format}=[0|1|2|3|4|5]]
       [{-a|--architectures}=['PC AVR MSP ARM']]
       [{-s|--scenarios}=['0 1 2']]
       [{-c|--ciphers}=['Cipher1 Cipher2 ...']]
```

Code Size

- the amount of information that is stored in the Flash memory of the target device
- the `GNU size` tool lists the section sizes and the total size in bytes for a given binary file

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   text    data     bss     dec     hex filename
    266     128       0     394     18a operation.o
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- `binary code size = size(text) + size(data)`

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- `binary code size = size(text) + size(data)`
- `text` → code
- `data` → global initialized variables
- `bss` → global uninitialized variables

RAM

- RAM consumption is split into
  - data requirement (static RAM) → the size of the constants stored in target device RAM + scenario specific data
    - size of `data` section for object files
    - block size, key size, round keys size
  - stack requirement (dynamic RAM) → the maximum value of the RAM used to store local variables and return address after interrupts and subroutine calls

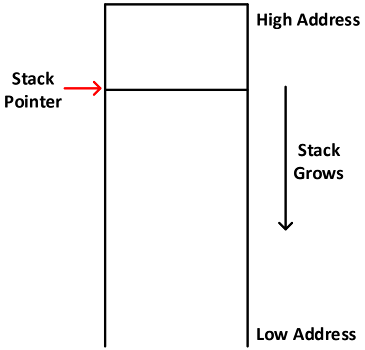
RAM

Stack

Code

```
    void BeginOperation()
→   {
        /* empty */
    }
    void Operation()
    {
        /* code */
    }
    void EndOperation()
    {
        /* empty */
    }
```

Stack



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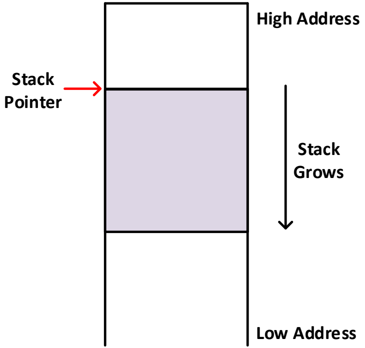

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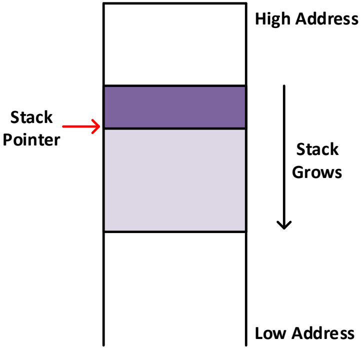

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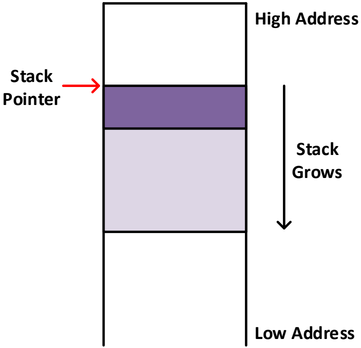

Execution Time

- the number of CPU clock cycles spent on executing a given operation
- absolute difference between the system timer number of cycles at the end of the measured operation and at the beginning of the measured operation

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Example

```
    void Operation()
→   {
        /* code */
    }
```

$t_1 \leftarrow$ cycle count value

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Example

```
     void Operation()
     {
        /* code */
→    }
```

$t_2 \leftarrow$ cycle count value

Execution Time

- the number of CPU clock cycles spent on executing a given operation
- absolute difference between the system timer number of cycles at the end of the measured operation and at the beginning of the measured operation

Example

```
void Operation()
{                          t1 ← cycle count value
   /* code */
}                          t2 ← cycle count value
```

- execution_time = $|t_2 - t_1|$

Results

Block Ciphers

- the time required to extract the metrics for 86 implementations of block ciphers in batch mode: 227 minutes
- the time required to extract each metric depends on many factors
- average values are computed for one run of each metric extraction process over all implementations

	AVR			MSP			ARM		
	Code Size [s]	RAM [s]	Exec. Time [s]	Code Size [s]	RAM [s]	Exec. Time [s]	Code Size [s]	RAM [s]	Exec. Time [s]
Scenario 0	0.85	3.78	1.54	1.05	10.85	1.06	1.38	15.53	16.40
Scenario 1	0.95	5.37	3.37	1.14	11.23	1.54	1.53	16.01	16.84
Scenario 2	0.97	3.61	1.68	1.13	8.22	1.11	1.54	13.54	15.82

Results

Stream Ciphers

- the time required to extract the metrics for 24 implementations of stream ciphers in batch mode: 30 minutes
- the time required to extract each metric depends on many factors
- average values are computed for one run of each metric extraction process over all implementations

	AVR			**MSP**			**ARM**		
	Code Size [s]	RAM [s]	Exec. Time [s]	Code Size [s]	RAM [s]	Exec. Time [s]	Code Size [s]	RAM [s]	Exec. Time [s]
Scenario 0	0.39	3.05	1.23	0.38	7.57	0.40	0.51	11.27	13.18
Scenario 1	0.39	3.11	1.31	0.37	7.57	0.40	0.50	11.25	13.17

Who can benefit?

- **designers of new ciphers**
  - understand how different components affect performance of the cipher
  - compare new algorithms with the state-of-the-art
- **software engineers**
  - select the best cipher to match the requirements of a particular application
- **standardization organizations**
  - conduct a fair and comprehensive evaluation of a large number of candidates

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  - source code
  - comprehensive results
  - FOM scripts
  - VM with all necessary tools pre-installed

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Future Work

- new modules (e.g. authenticated encryption, . . .)
- new metrics (e.g. power consumption, . . .)
- new target devices
- new evaluation scenarios
- contributions to the framework are welcome

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