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JerryScript

An ultra-lightweight JavaScript engine for the Internet of Things

Tilmann Scheller
Principal Compiler Engineer
t.scheller@samsung.com

Samsung Open Source Group
Samsung Research UK

OpenIoT Summit Europe 2016
Berlin, Germany, October 11 – 13, 2016

Overview

- Introduction
- JerryScript
- JerryScript Internals Overview
- Memory consumption/Performance
- Demo
- Future work
- Summary

Introduction

What is JerryScript?

- A really lightweight JavaScript engine
- Has a base footprint of ~3KB of RAM
- Optimized for microcontrollers
- Originally developed from scratch by Samsung
- JerryScript is an open source project released under the Apache License 2.0
- Actively developed on GitHub

Why JavaScript on microcontrollers?

- There's a huge pool of JavaScript developers
- Opens up the possibility for web developers to easily write software for embedded devices
- Performance overhead of JavaScript less of an issue for control tasks
- Increased productivity, shorter time to market
- Ability to load code dynamically over the network
- Security: Executing JavaScript code is safer than executing arbitrary native code

JerryScript

JerryScript History

- Development started in June 2014
- Released as open source in June 2015
- JerryScript passed 100% of the test262 conformance test suite in August 2015
- Rewritten compact byte code implementation landed in January 2016
- JerryScript 1.0 released in September 2016
- Current focus on usability

JerryScript

- Heavily optimized for a low memory footprint
- Interpreter-only
- Compact object representation
- Compressed pointers
- No AST, directly creating byte code
- Compact byte code heavily optimized for low memory consumption

JerryScript Portability

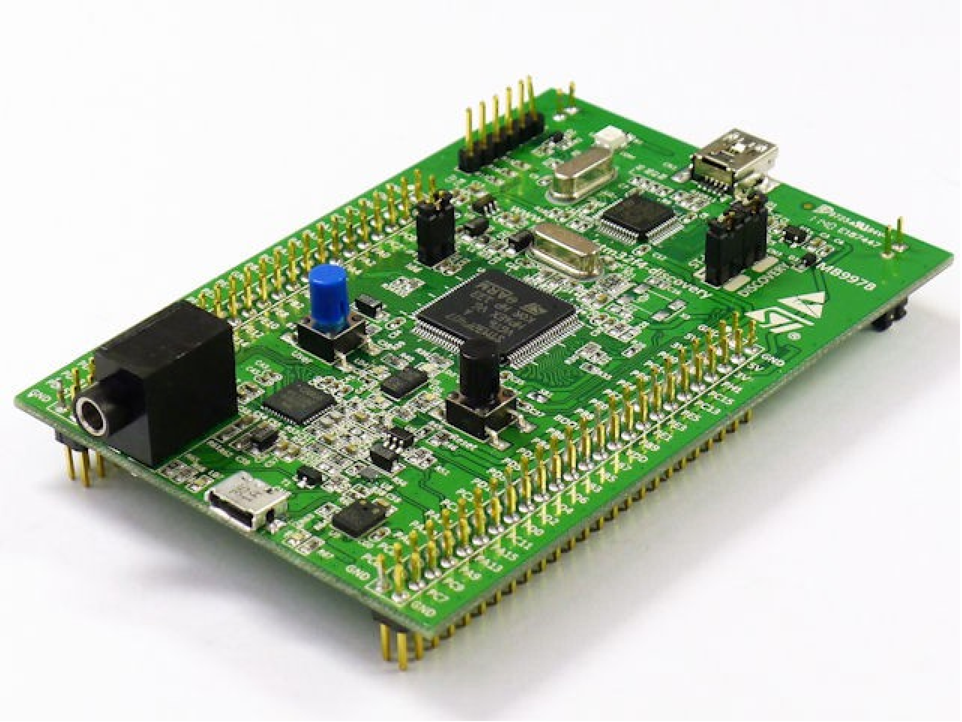
- Extremely portable
- Self-contained
- Small C library
- Can run bare-metal
- Supports the STM32F4, Arduino 101, FRDM-K64F, ESP8266 (experimental) boards
- OS support: NuttX, Zephyr, mbed OS, RIOT
- Runs on Linux/macOS as well

JerryScript

- Written in C99
- About 84KLOC
- Code size 156KB when compiled with GCC in LTO mode for ARM Thumb-2
- Implements the entire ECMAScript 5.1 standard, passes 100% of the test262 conformance test suite
- C API for embedding JerryScript
- Byte code snapshot feature

Target hardware

- STM32F4 developer board
- Cortex-M4F clocked at 168 MHz
- 192KB of RAM
- 1MB of flash memory



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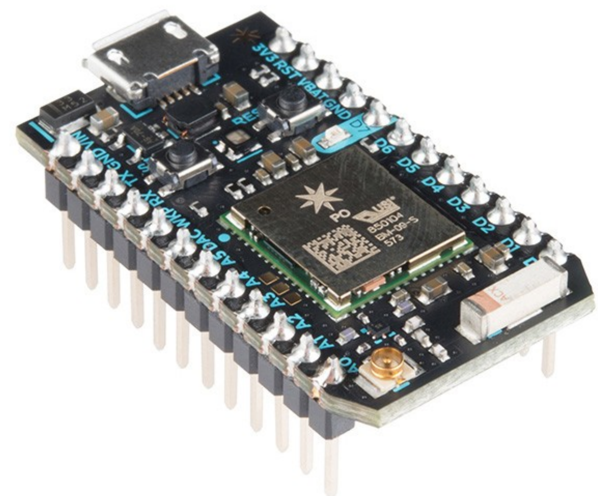
Target hardware

- Particle Photon board
- Cortex-M3 clocked at 120 MHz
- 128KB of RAM
- 1MB of flash memory
- Wi-Fi integrated
- Small footprint (37mm x 20mm)



JerryScript C API

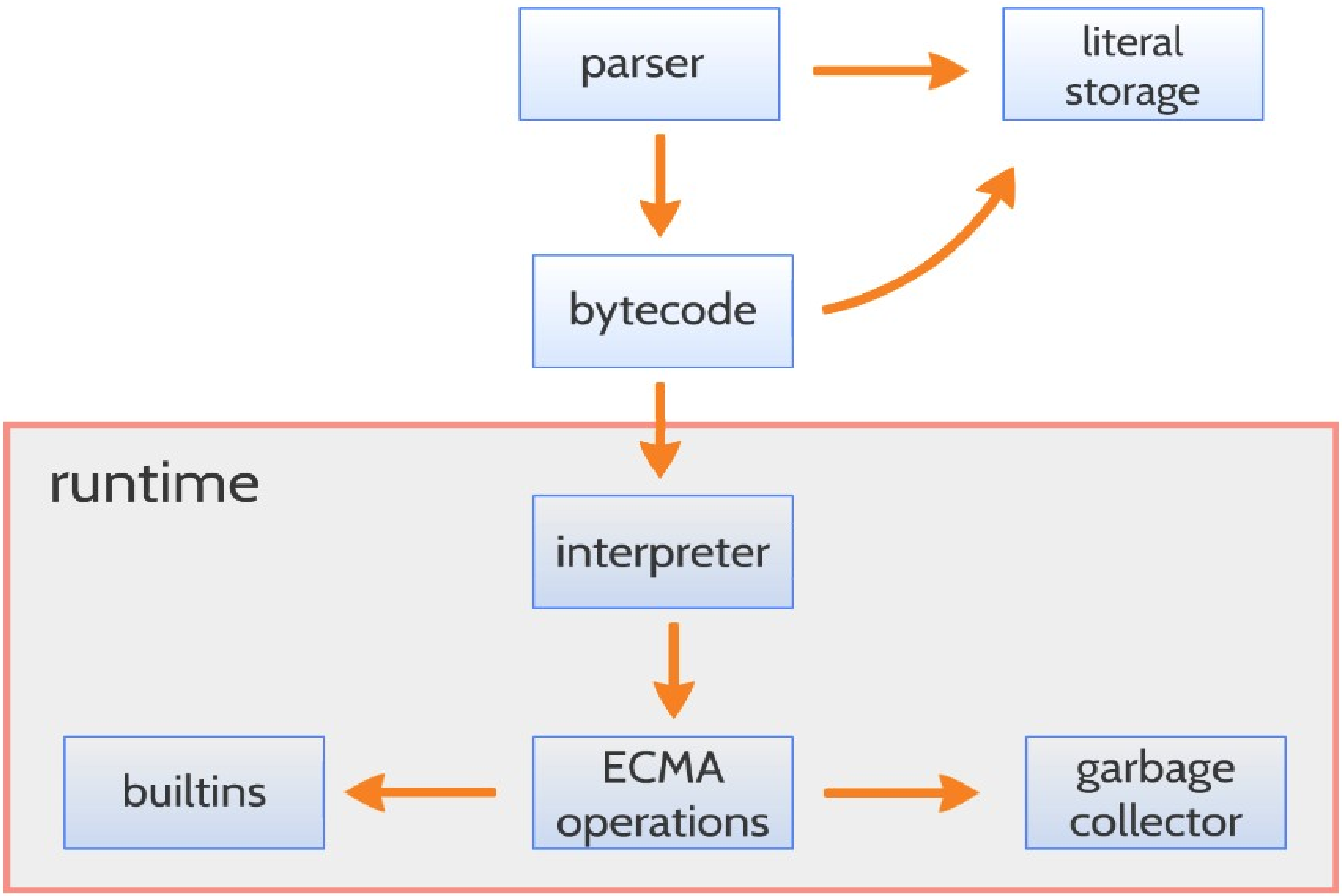

```
#include <string.h>
#include "jerry.h"

int
main (int argc, char * argv[]) {
  char script [] = "print ('Hello, World!');";

  jerry_completion_code_t code = jerry_run_simple (script,
                                                   strlen (script),
                                                   JERRY_FLAG_EMPTY);
}
```

JerryScript C API


```
int
main (int argc, char * argv[]) {
  char script1 [] = "var s = 'Hello, World!';";
  char script2 [] = "print (s);";

  // Initialize engine
  jerry_init (JERRY_FLAG_EMPTY);

  jerry_api_value_t eval_ret;

  // Evaluate script1
  jerry_api_eval (script1, strlen (script1),
                  false, false, &eval_ret);
  // Free JavaScript value, returned by eval
  jerry_api_release_value (&eval_ret);

  // Evaluate script2
  jerry_api_eval (script2, strlen (script2),
                  false, false, &eval_ret);
  // Free JavaScript value, returned by eval
  jerry_api_release_value (&eval_ret);

  // Cleanup engine
  jerry_cleanup ();
}
```

JerryScript Internals Overview

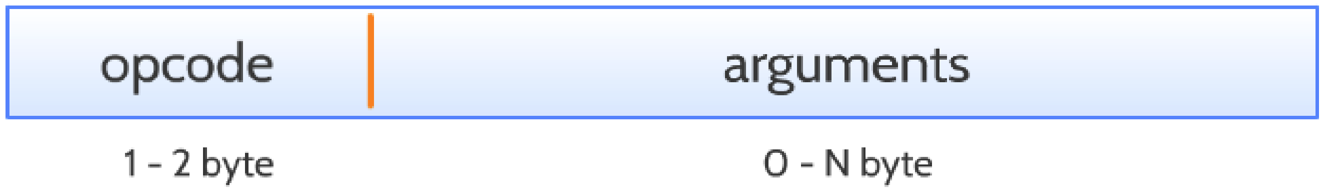
High-Level Design Overview



Parser Overview

- Optimized for low memory consumption
  - E.g. only 41KB of memory is required to parse the 95KB of concatenated IoT.js source code
    - 12.5KB byte code, 10KB literal references, 12.2KB literal storage data, 7KB for parser temporaries
- Generates byte code directly
  - No intermediate representation (e.g. AST)
- Recursive descent parser
  - The parser uses a byte array for the parser stack instead of calling functions recursively

Compact Byte Code (CBC)



- CBC is a variable-length byte code
- Currently 306 opcodes are defined
  - Majority of the opcodes are variants of the same operation
- E.g. “this.name” is a frequent expression in JavaScript so an opcode is defined to resolve this expression
  - Usually this operation is constructed from multiple opcodes: op_load_this, op_load_name, op_resolve
  - Other examples: “a.b(c,d)” or “i++”

Compact Byte Code Interpreter

- The interpreter is a combination of a register and stack machine
  - The stack is used to compute temporary values
  - The registers are used to store local variables
- Byte code decompression
  - Byte code instructions are decoded into a maximum of three atomic instructions and those instructions are executed by the interpreter

Compressed Pointers

- Compressed pointers are 16-bit values, which represent 8 byte aligned addresses on the JerryScript heap
  - Saves 50% of memory on 32-bit systems
- The JerryScript heap is a linear memory space with a maximum size of 512KB (equals to UINT16_MAX * 8)
  - UINT16_MAX is 65535
- Pointer compression can also be turned off to enable a maximum heap size of 4GB

Value Representation

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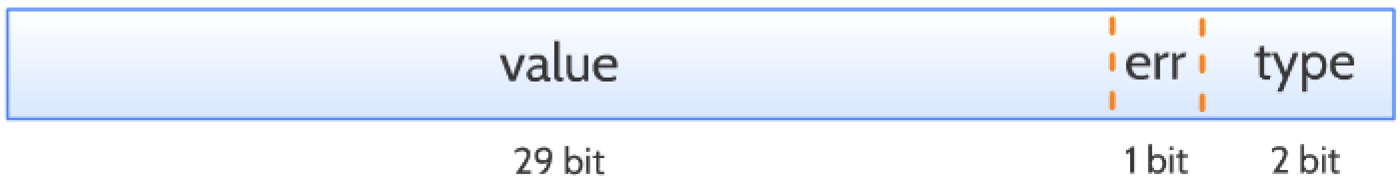
- JavaScript is a dynamically typed language
  - All values carry type information as well
- ECMAScript values in JerryScript are 32-bit wide
  - They can be primitive values (true, null, undefined, …) or pointers to numbers, strings or objects
- On 32-bit systems, 29 bits are enough to directly store any 8 byte aligned 32-bit pointer



String Representation

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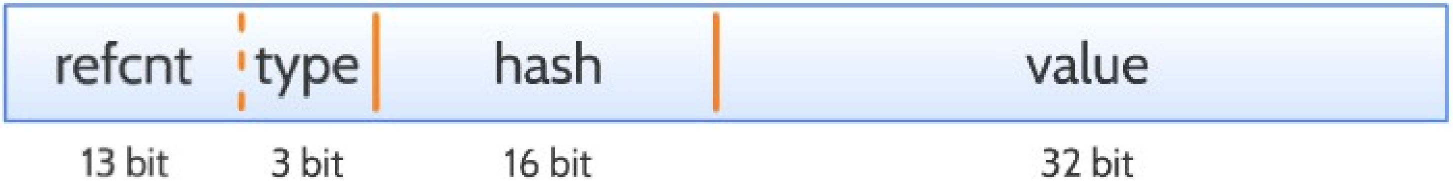
- String descriptor is 8 bytes long
- Several string types are supported in JerryScript besides the usual character array
  - Short strings: Stored in the 32-bit value field
  - Magic (frequently used) string indices



Number Representation

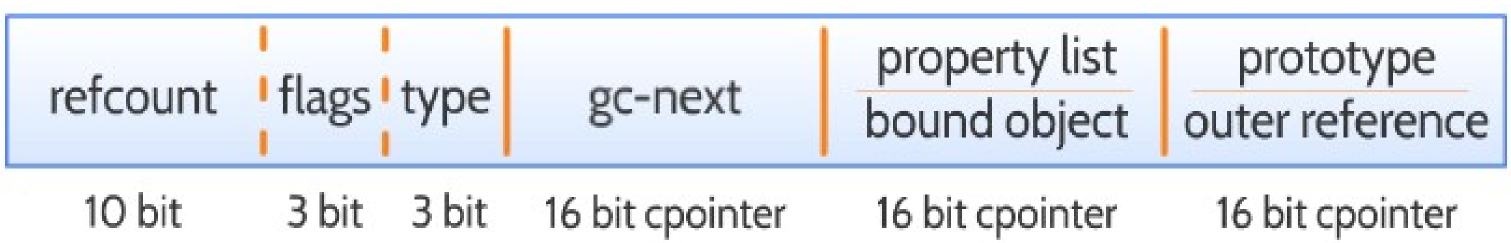
- Numbers are double precision values by default
- Optional mode for single precision values
  - Single precision numbers do not satisfy the ECMAScript requirements but can be computed faster, trading precision for performance

IEEE 754 number

32/64 bit

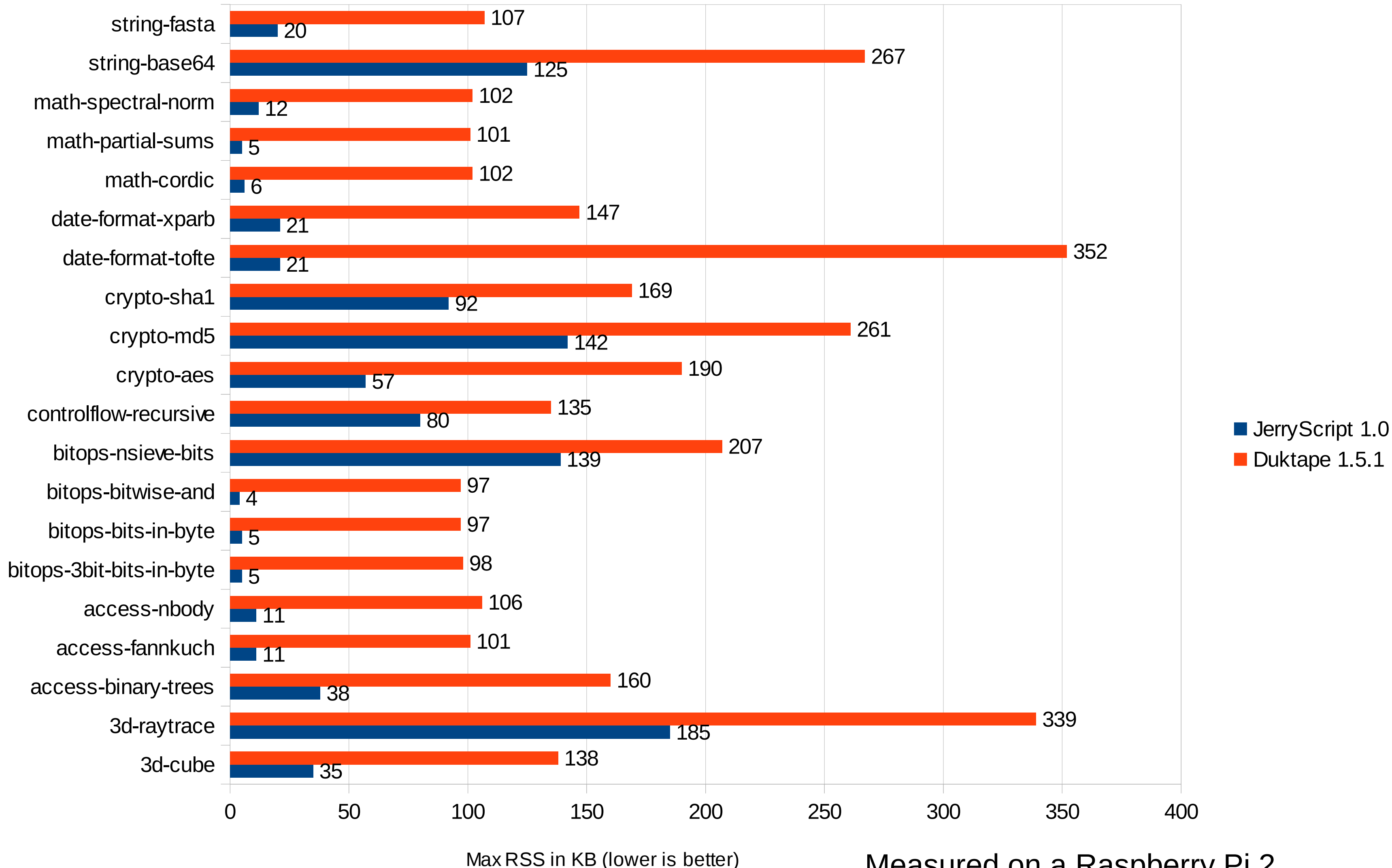
Object Representation

- Garbage collector can visit all existing objects
- Objects have a property list
  - Named data, named accessor properties
  - Internal properties
- Functions are objects in JavaScript



Memory consumption/ Performance

SunSpider 1.0.2 - Memory consumption



Measured on a Raspberry Pi 2

SunSpider 1.0.2 - Performance

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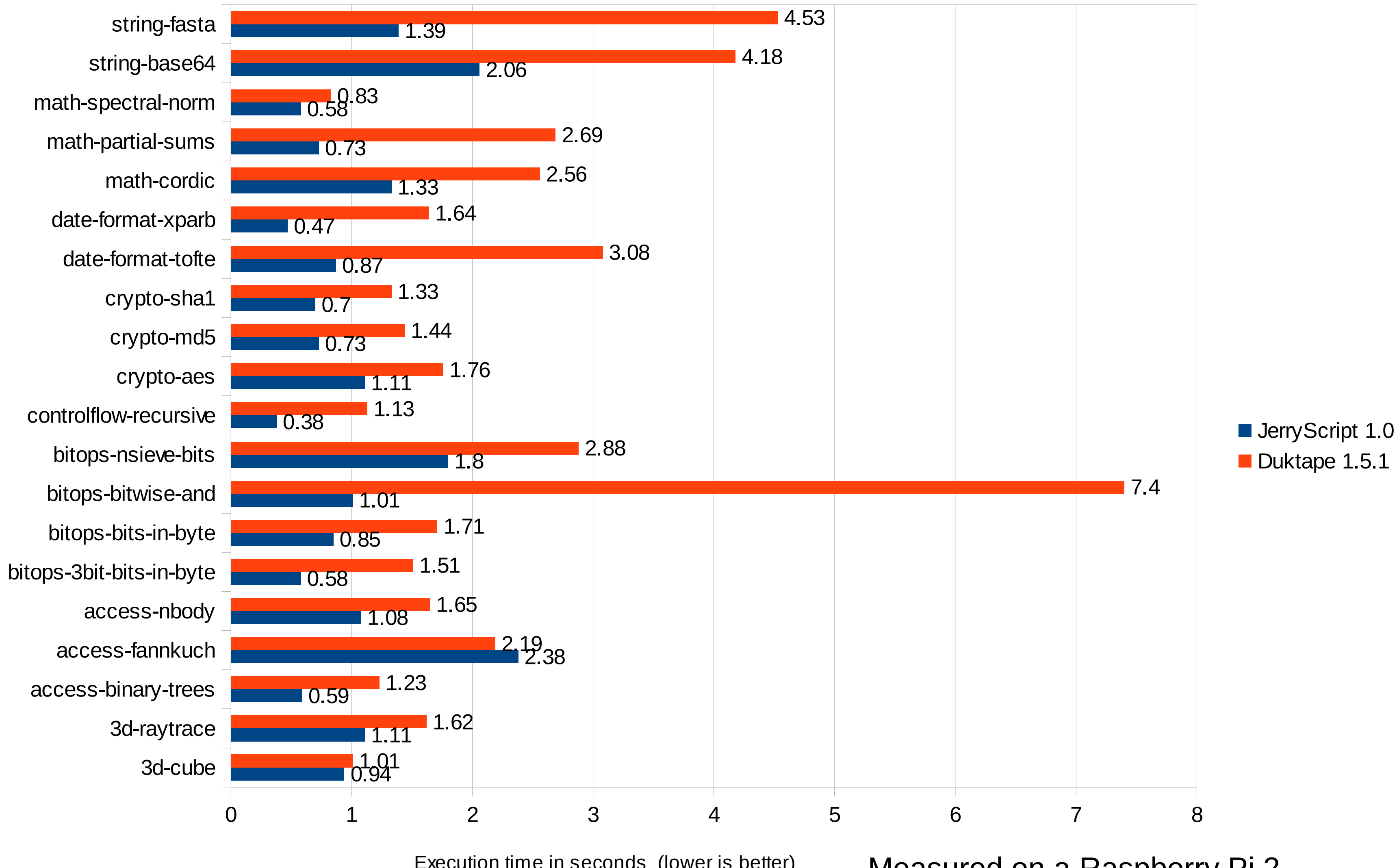


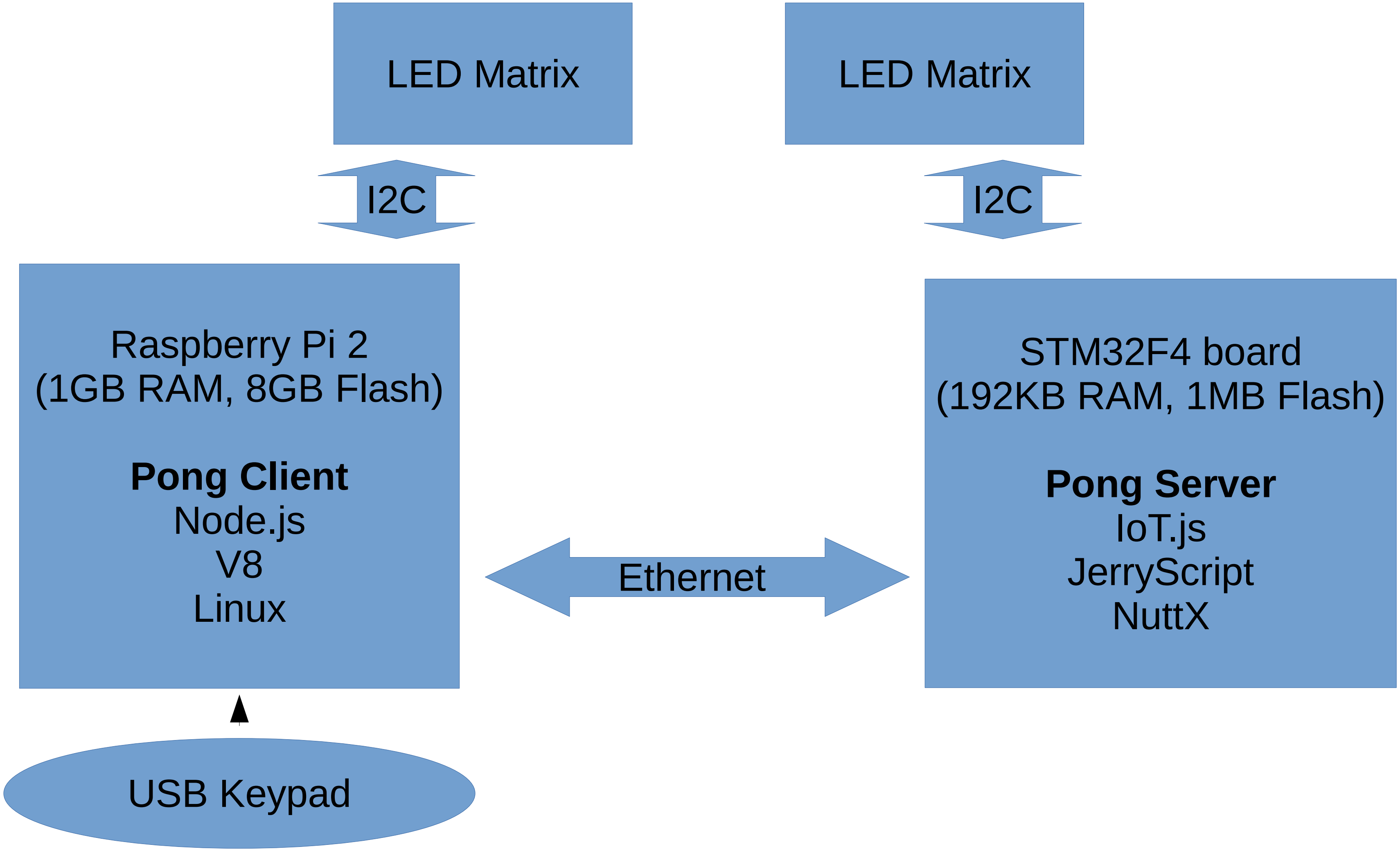
Measured on a Raspberry Pi 2

Demo

Pong Demo

- Implementation of the classic Pong game
- Display shared across two devices
- Each device drives one LED matrix
- Implemented as a Node.js module
- "AI" oppenent running on the microcontroller

Pong Demo


LED Matrix
LED Matrix
I2C
I2C
Raspberry Pi 2
(1GB RAM, 8GB Flash)
Pong Client
Node.js
V8
Linux
Ethernet
STM32F4 board
(192KB RAM, 1MB Flash)
Pong Server
IoT.js
JerryScript
NuttX
USB Keypad

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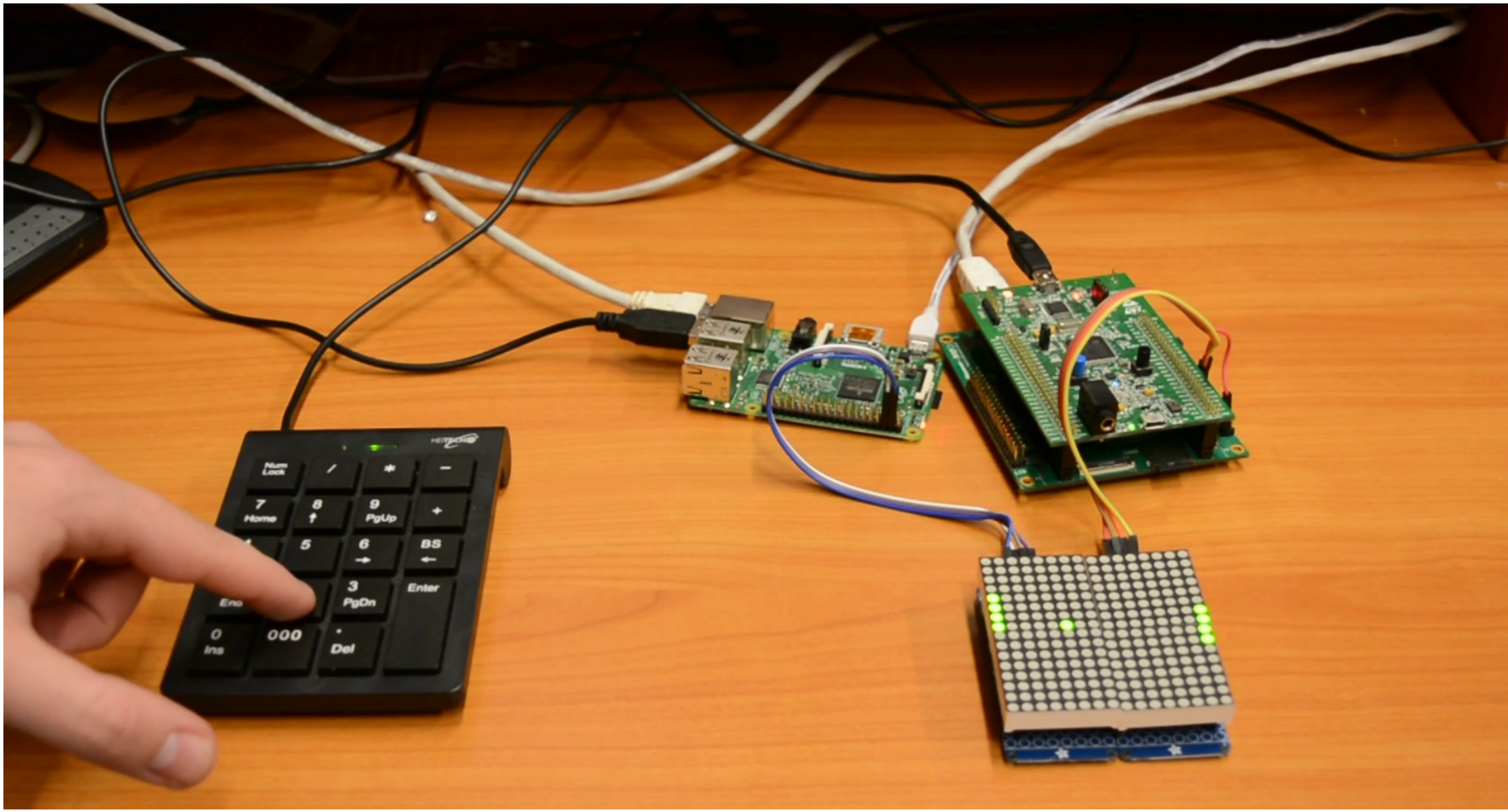
Pong Demo



JerryScript 6LoWPAN Demo

- Multiplayer implementation of the classic Pong/Tetris game
- Each device drives one LED matrix as display
- Game implemented in JavaScript
- Running on Photon boards
- Low-power wireless communication via 6LoWPAN

JerryScript 6LoWPAN Demo

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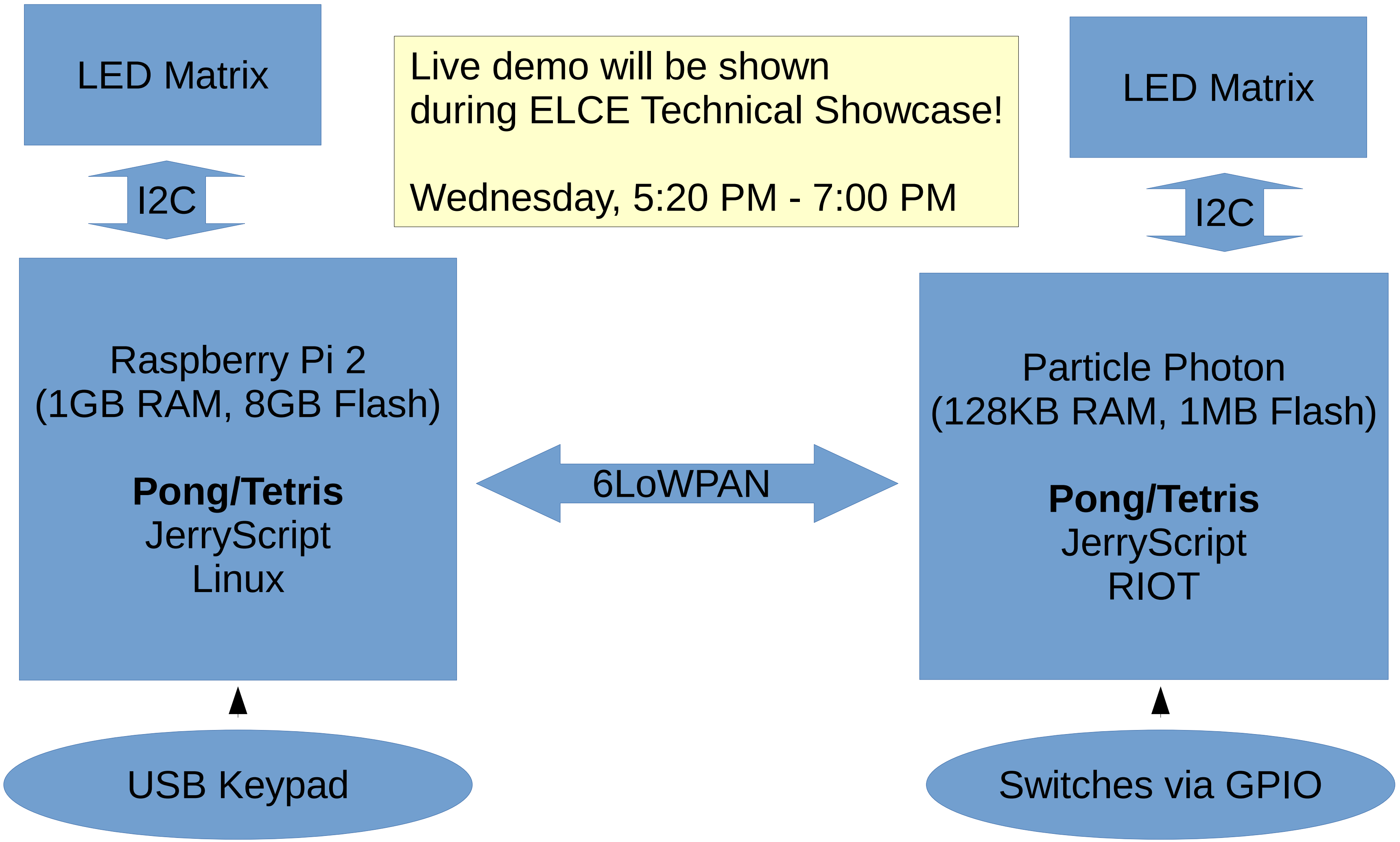
Live demo will be shown
during ELCE Technical Showcase!

Wednesday, 5:20 PM - 7:00 PM



Future work

Future work

- Further performance and memory optimizations
- Debugging support
- Memory profiling
- Selected ES6 features
- Support for more boards

Summary

Summary

- Significantly lowers barrier of entry for JavaScript development targeting heavily constrained embedded devices
- Speeds up development
- Active community
- More information on http://jerryscript.net
- Looking for bug reports and feedback

Thank you.

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Contact Information:

Tilmann Scheller
t.scheller@samsung.com

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