goto; conference aarhus

THE ACTOR MODEL APPLIED TO THE RASPBERRY PI AND THE EMBEDDED DOMAIN

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Erlang Solutions Ltd.

INTERNATIONAL SOFTWARE DEVELOPMENT CONFERENCE

gotocon.com

Agenda

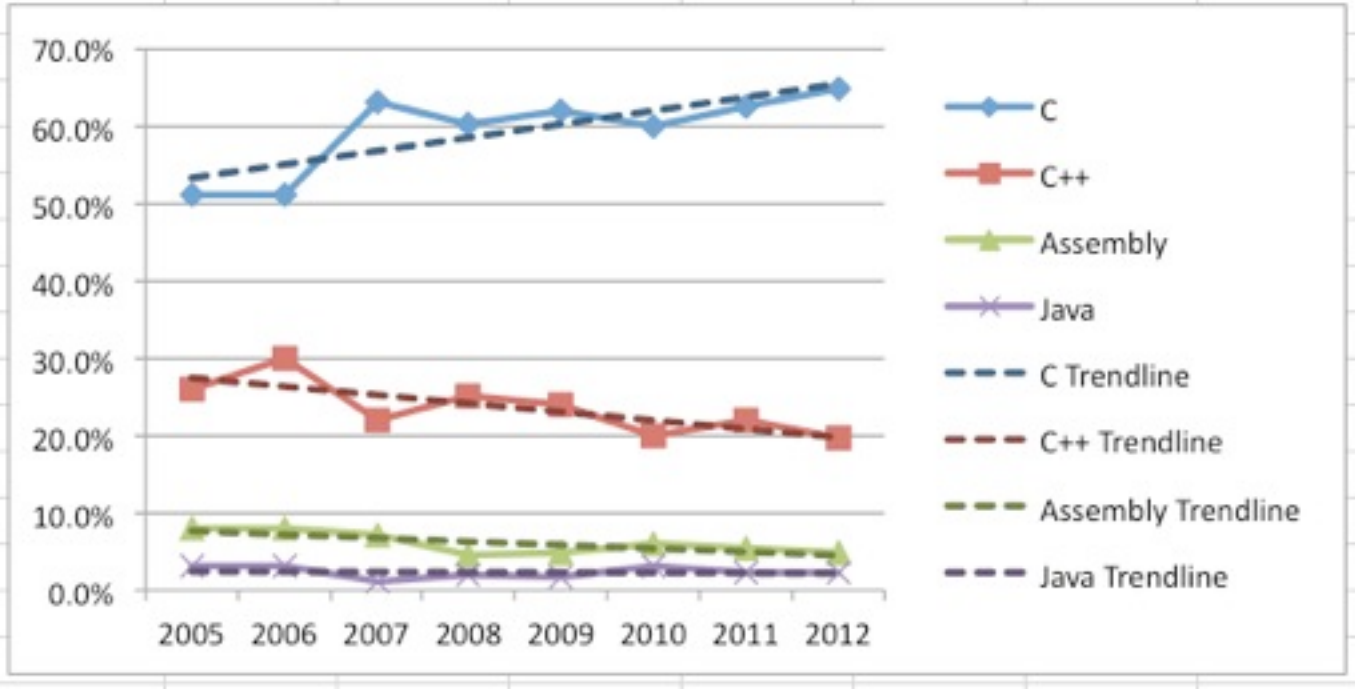
- Current state of Embedded Systems
- Overview of the Actor Model
- Erlang Embedded Project
- Modelling and developing systems using Erlang
- Experiments with the Raspberry Pi
- Future Explorations
- Q & A

Embedded Systems

> An embedded system is a computer system designed for specific control functions within a larger system, often with real-time computing constraints. It is embedded as part of a complete device often including hardware and mechanical parts. By contrast, a general-purpose computer, such as a personal computer (PC), is designed to be flexible and to meet a wide range of end-user needs
>
> – Infinite Wisdom of Wikipedia

#include "stats.h"

The four languages most often reported as the primary language for embedded projects for the years 2005 to 2012, along with linear trendlines.



Source: http://embedded.com/electronics-blogs/programming-pointers/4372180/Unexpected-trends

Current Challenges

- Complex SoC platforms
- "Internet of Things"
  - Connected and distributed systems
- Multicore and/or heterogeneous devices
- Time to market constraints

Erlang SOLUTIONS

Embedded Systems

- Bare Metal
  - No underlying OS or high level abstractions
- RTOS
  - Minimal interrupt and thread switching latency, scheduling guarantees, minimal jitter
- Embedded Linux
  - Slimmed down Linux, with hardware interfaces

Embedded Systems

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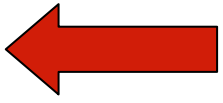
- RTOS 
  - Minimal interrupt and thread switching latency, scheduling guarantees, minimal jitter
- Embedded Linux 
  - Slimmed down Linux, with hardware interfaces

RTOS Concepts

- Notion of "tasks"
- OS-supervised interprocess messaging
  - Shared memory
- Mutexes/Semaphores/Locks
- Scheduling
  - Pre-emptive: event driven
  - Round-robin: time multiplexed

Embedded Linux

- Not a new concept, increased popularity due to abundant supply of cheap boards
  - Raspberry Pi, Beagleboard/Beaglebone, Gumstix et al.
- Familiar set of tools for software developers, new territory for embedded engineers
  - No direct mapping for RTOS concepts, expecially tasks
- Complex device driver framework
  - Here be dragons

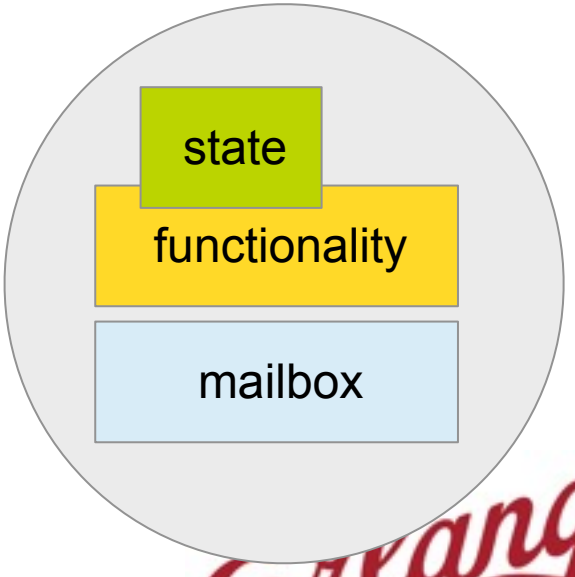
Erlang SOLUTIONS

Actor Model

- Proposed in 1973 by Hewitt, Bishop, and Steiger
  - "Universal primitives of concurrent computation"
- Building blocks for modular, distributed and concurrent systems
- No shared-state, self-contained and atomic
- Implemented in a variety of programming languages

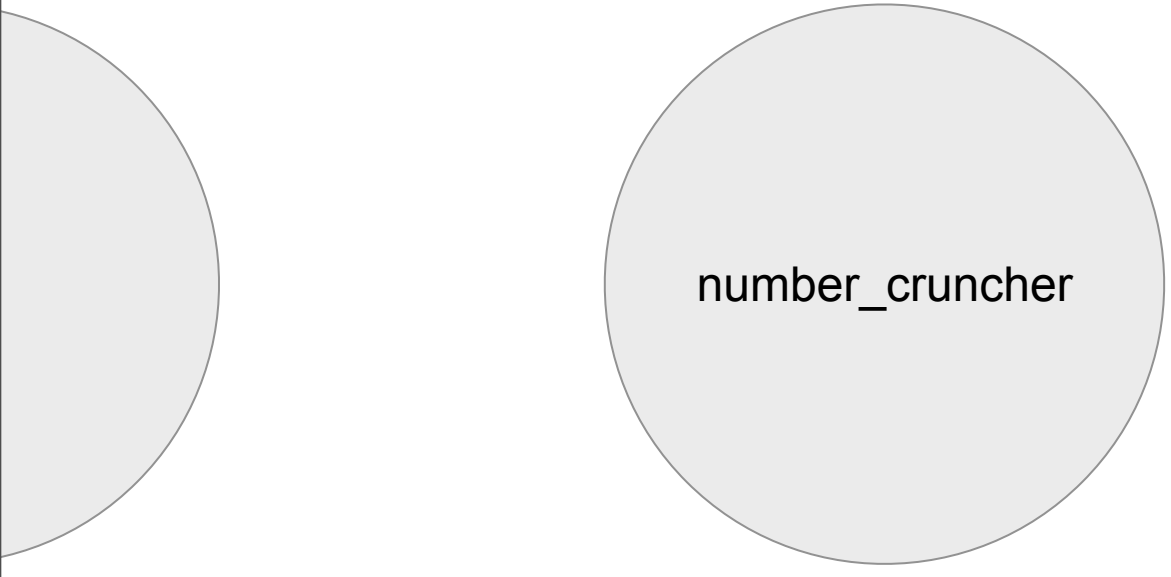
Actor Model

- Asynchronous message passing
  - Messages kept in a mailbox and processes in the order they are received in
- Upon receiving a message, actors can:
  - Make local decisions and change internal state
  - Spawn new actors
  - Send messages to other actors

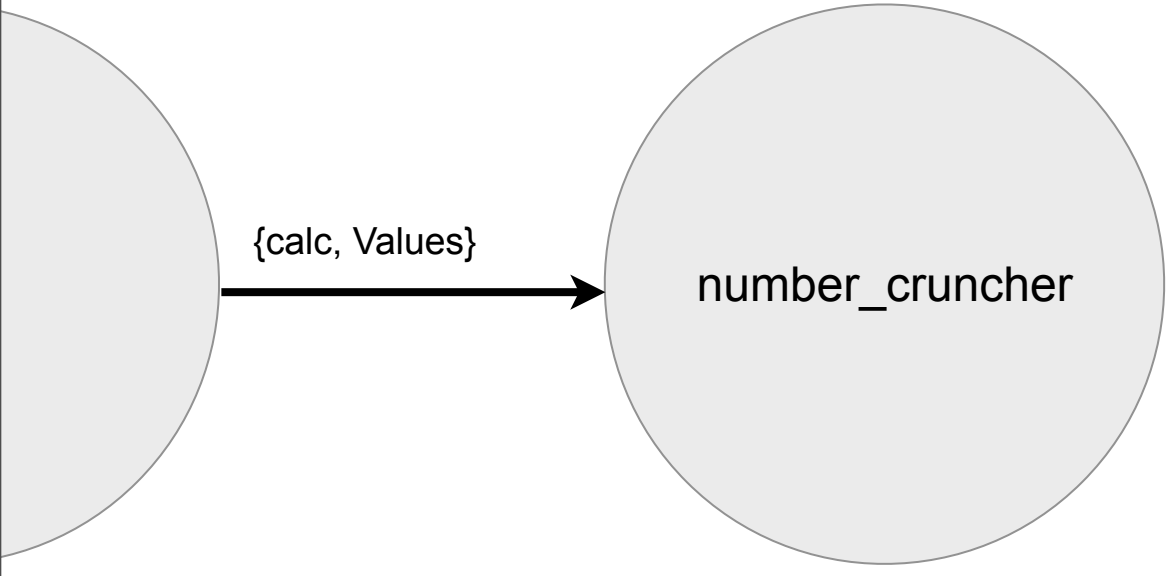


Actor Model

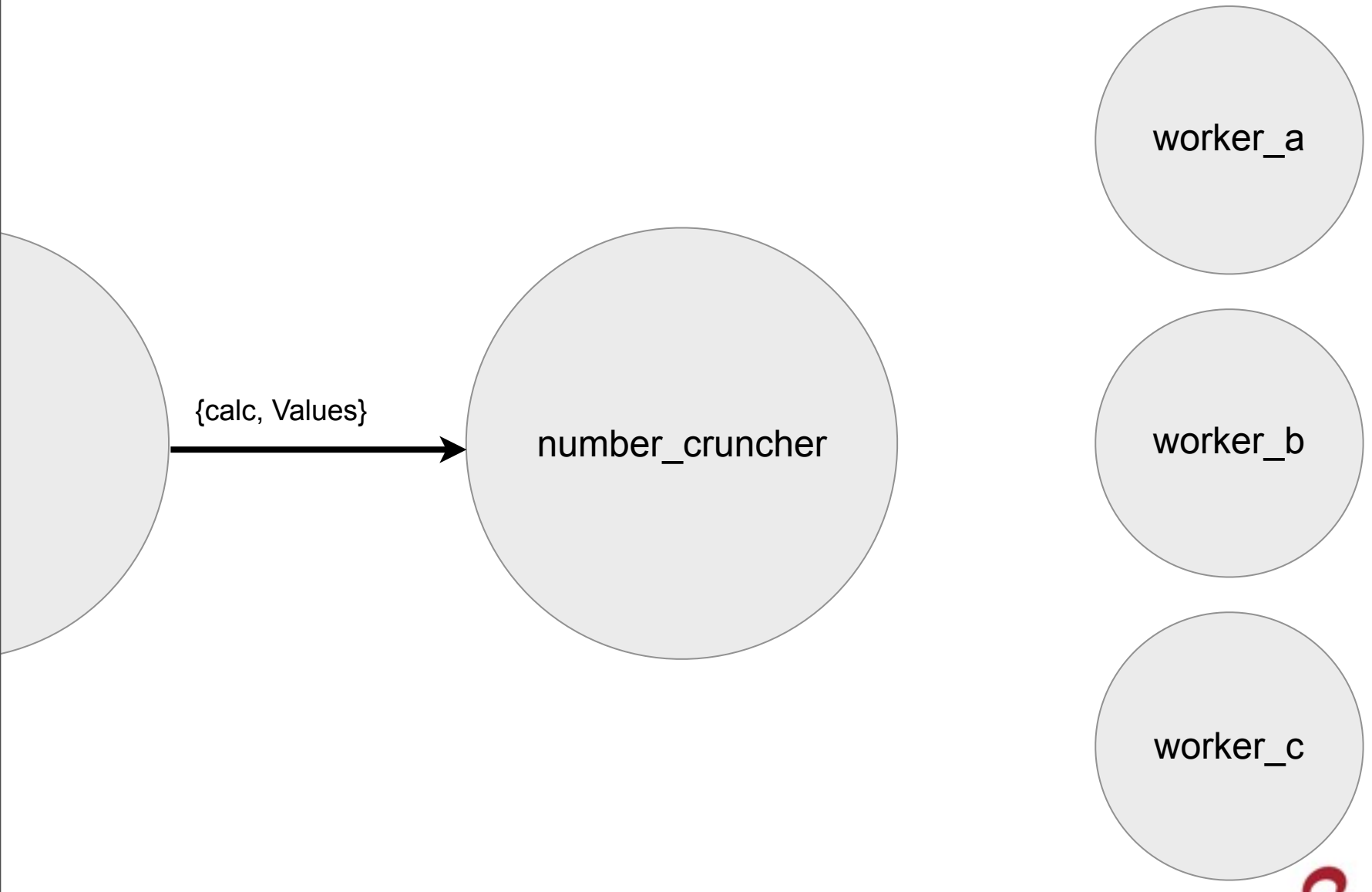
Actor Model



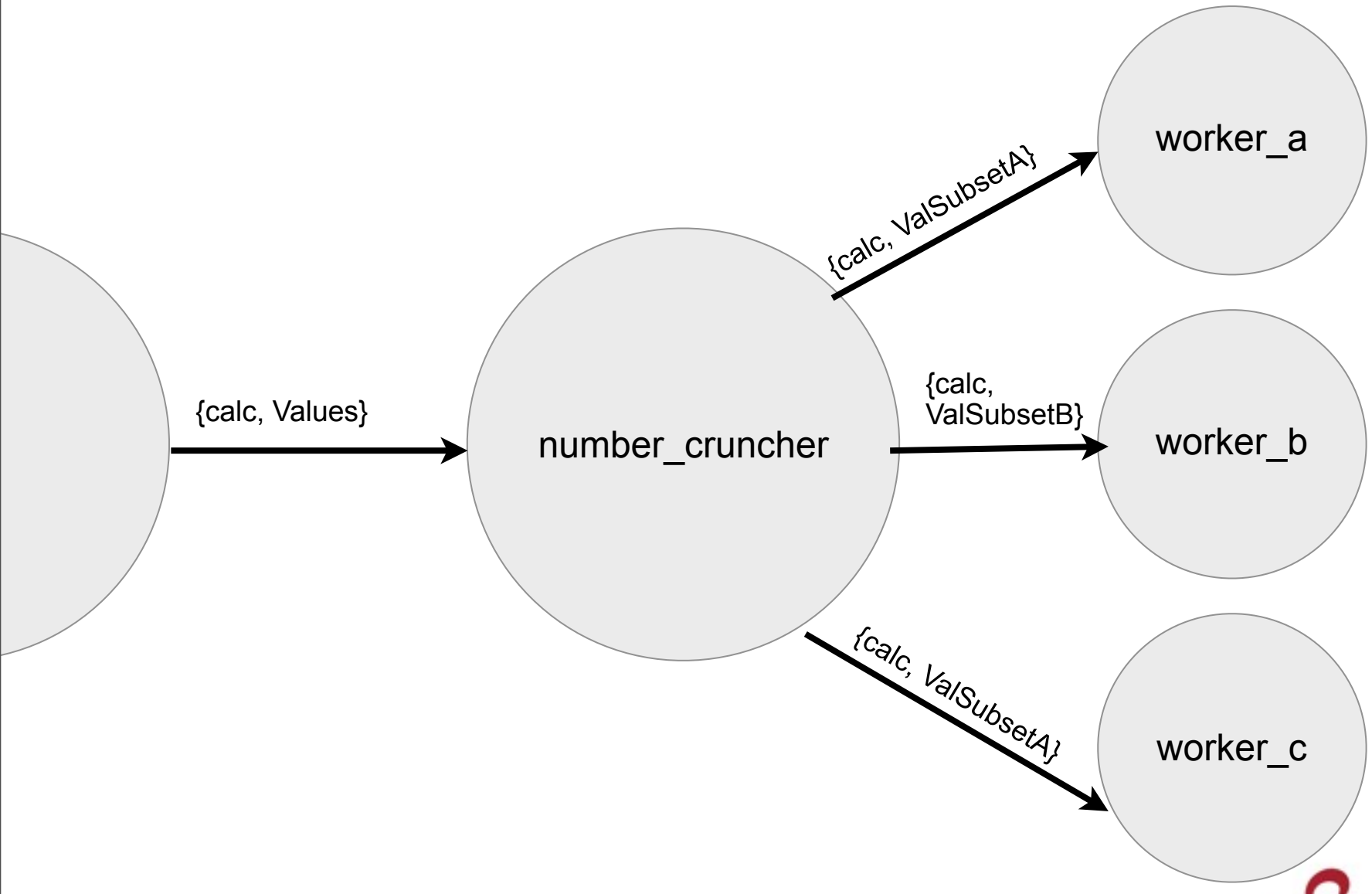
Actor Model



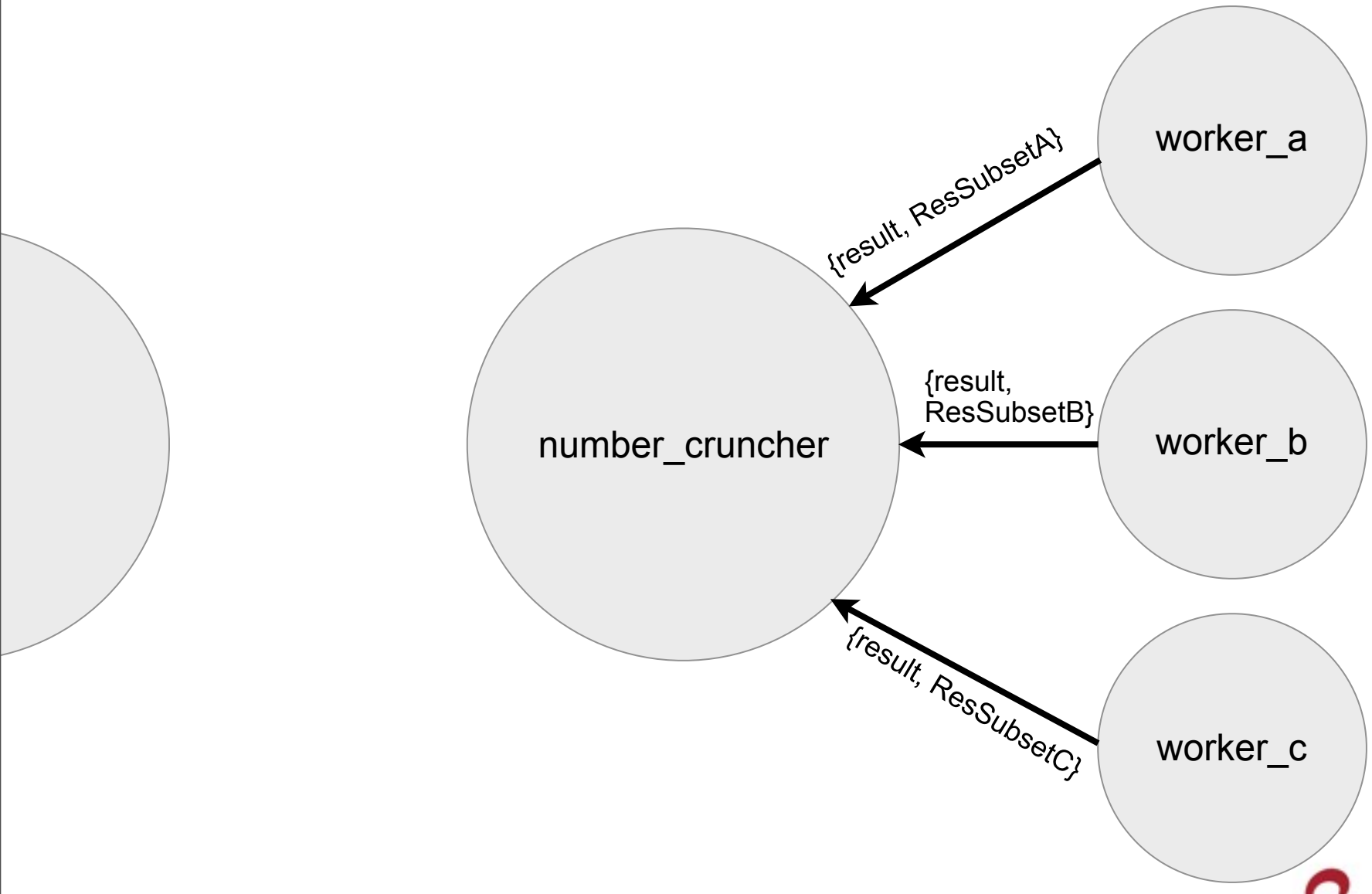
Actor Model



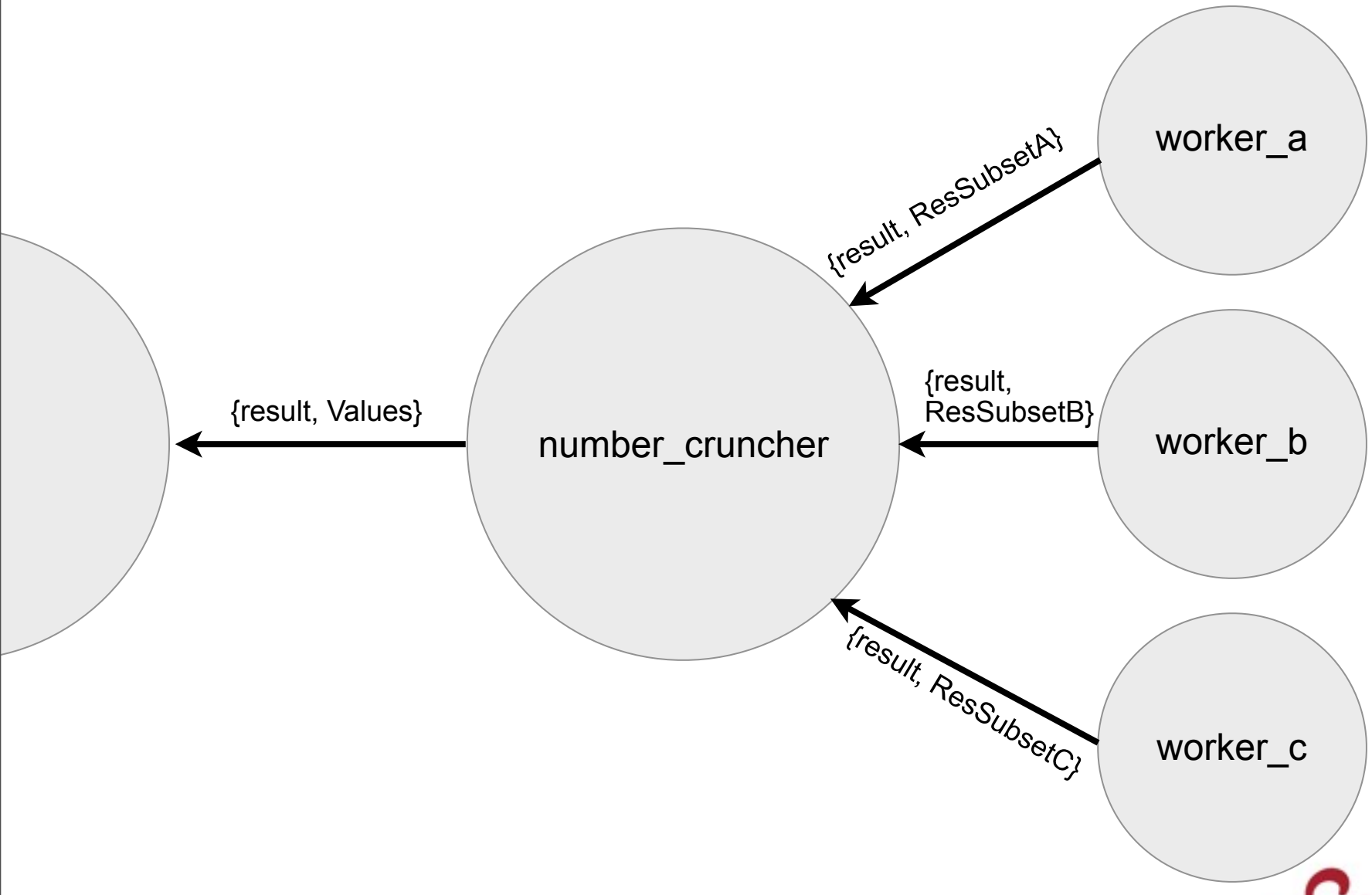
Actor Model


{calc, Values}
number_cruncher
{calc, ValSubsetA}
{calc, ValSubsetB}
{calc, ValSubsetA}
worker_a
worker_b
worker_c

Actor Model


worker_a
{result, ResSubsetA}
number_cruncher
{result,
ResSubsetB}
worker_b
{result, ResSubsetC}
worker_c

Actor Model


worker_a
{result, ResSubsetA}
{result, Values}
number_cruncher
{result, ResSubsetB}
worker_b
{result, ResSubsetC}
worker_c

Limitations of the Actor Model

- No notion of inheritance or general hierarchy
  - Specific to the language and library implementation
- Asynchronous message passing can be problematic for certain applications
  - Ordering of messages received from multiple processes
- Abstract definition may lead to inconsistency in larger systems
  - Fine/Coarse Grain

Erlang Embedded

- Knowledge Transfer Partnership between Erlang Solutions and University of Kent
  - Aim of the project: Bring the benefits of concurrent systems development using Erlang to the field of embedded systems; through investigation, analysis, software development and evaluation.
- http://erlang-embedded.com

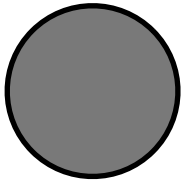
Why Erlang

- Implements the Actor model
- Battle-tested at Ericsson and many other companies
  - Originally designed for embedded applications
- Support for concurrency and distributed systems out of the box
- Easy to create robust systems
- (...and more!)

High Availability / Reliability

- Simple and consistent error recovery and supervision hierarchies
- Built in fault-tolerance
  - Isolation of Actors
- Support for dynamic reconfiguration
  - Hot code loading

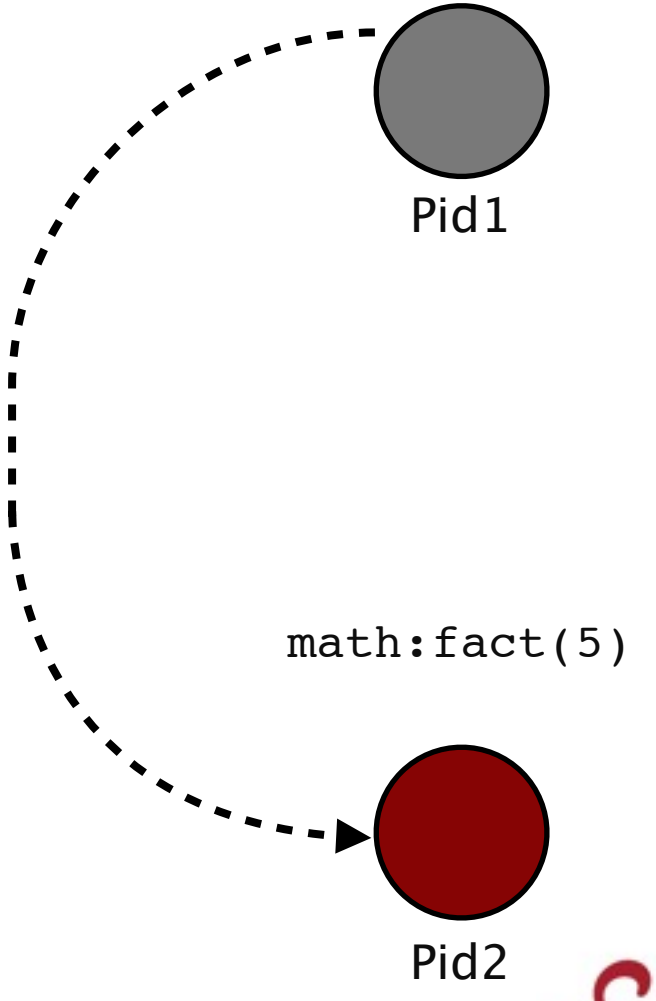
Creating an Actor




```
spawn(math, fact, [5])
```

Creating an Actor

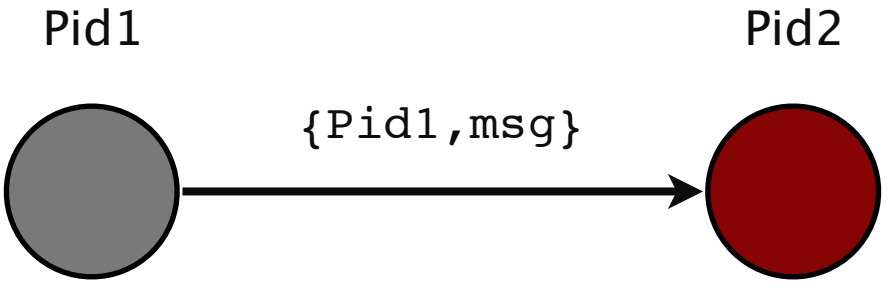
```
spawn(math, fact, [5])
```



Communication


```
Pid2 ! {self(),msg}
```

Communication




```
Pid2 ! {self(),msg}
```

Bidirectional Links

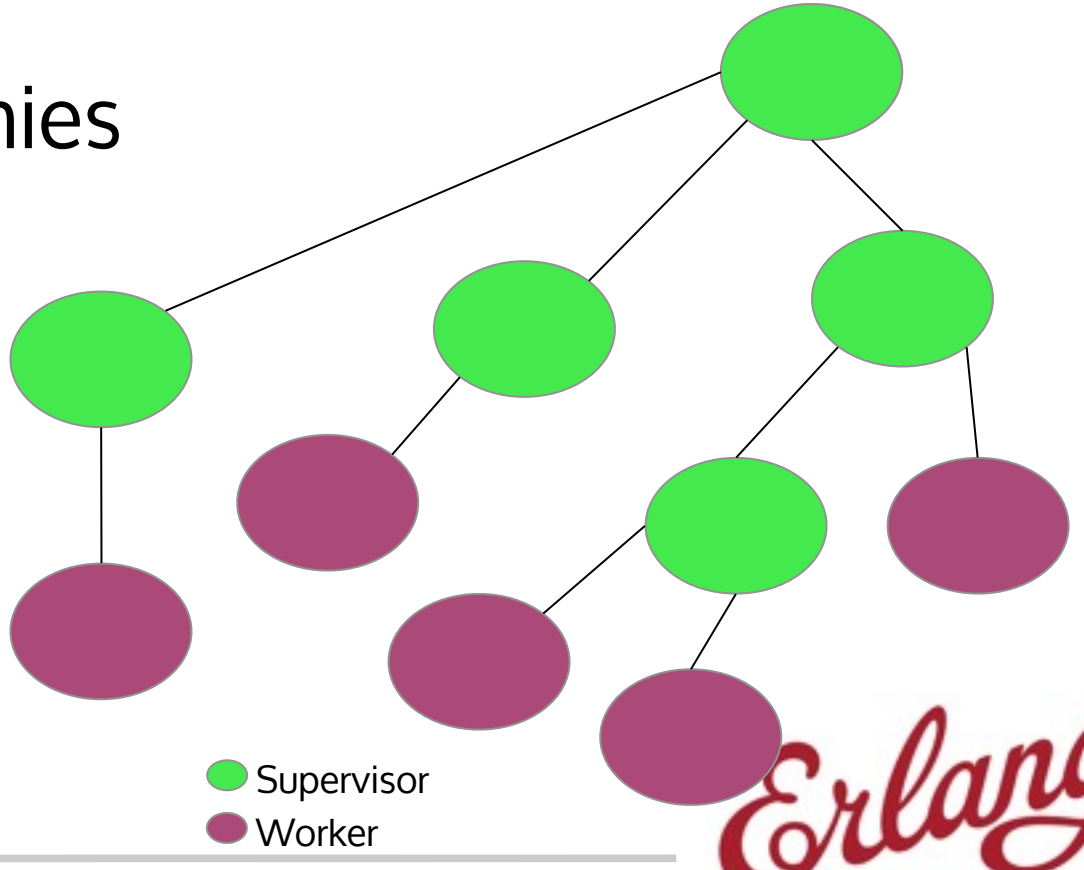

```
link(PidB)
```

Bidirectional Links

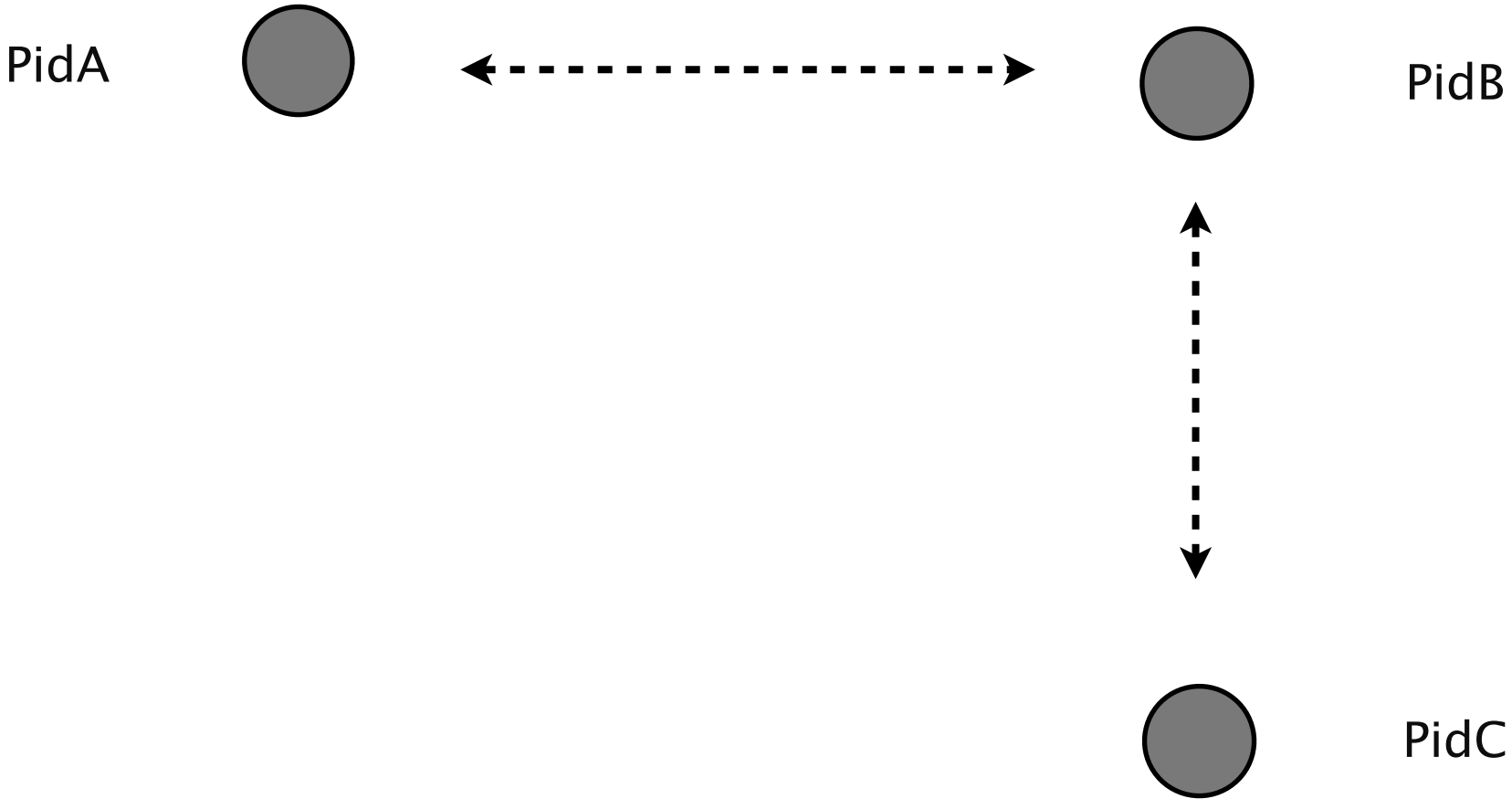

```
link(PidB)
```

Process Error Handling

- Let it Fail!
  - Abstract error handling away from the modules
  - Leaner modules
- Supervision hierarchies

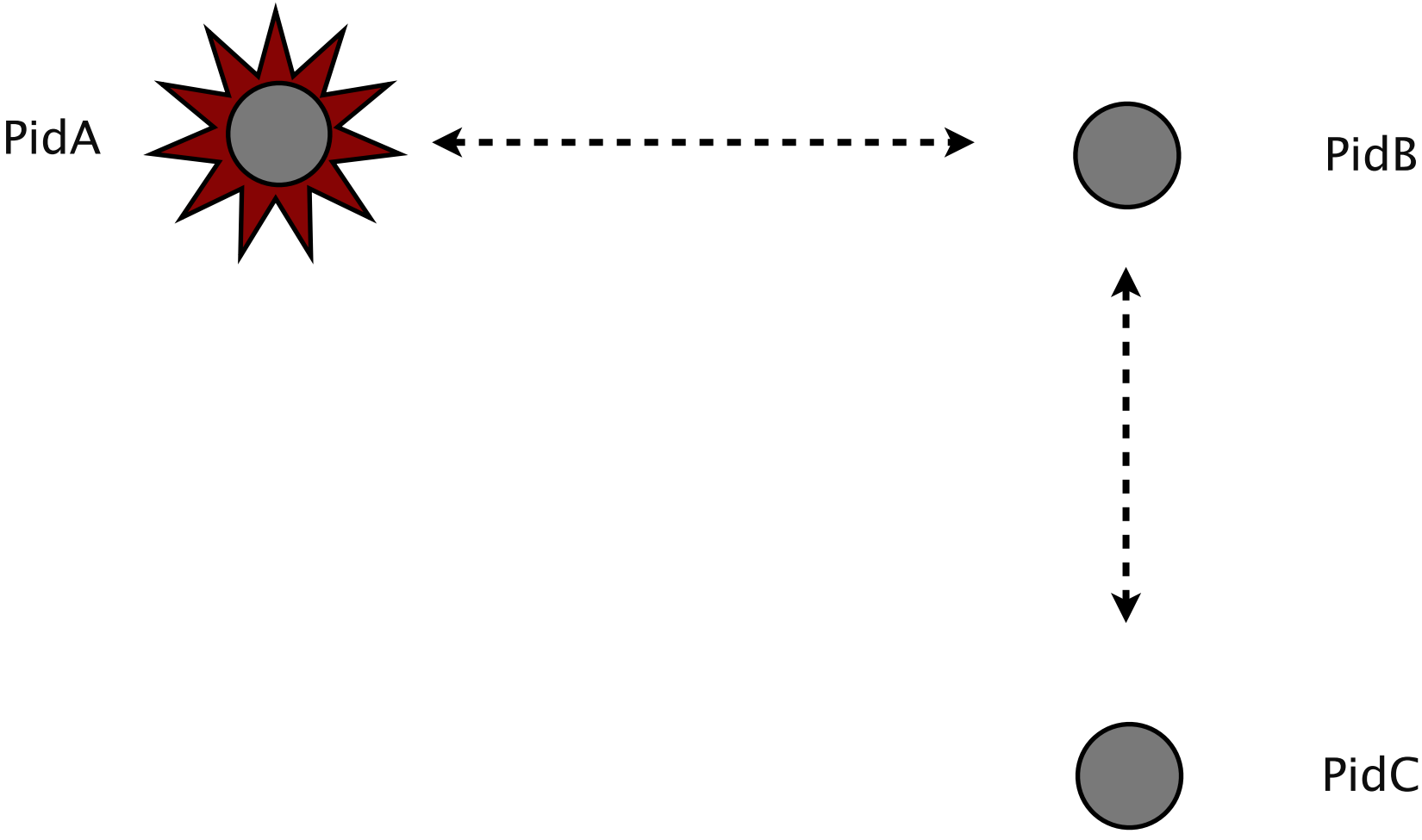


Propagating Exit Signals



Erlang SOLUTIONS

Propagating Exit Signals



Erlang SOLUTIONS

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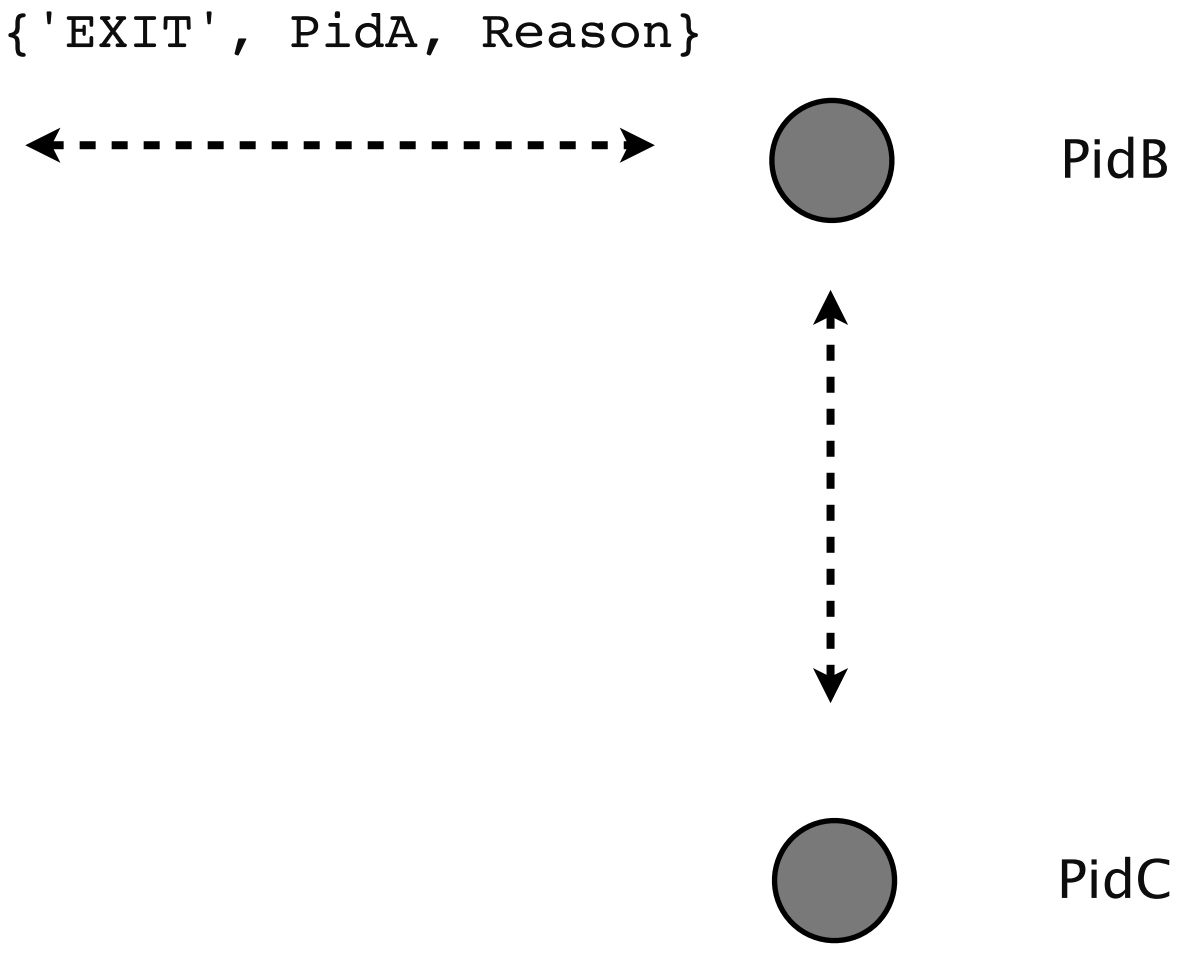

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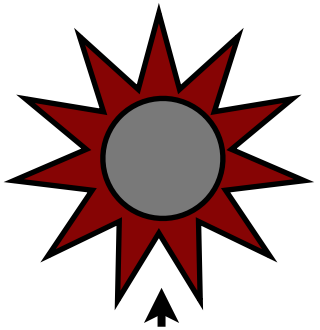
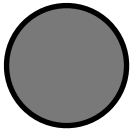


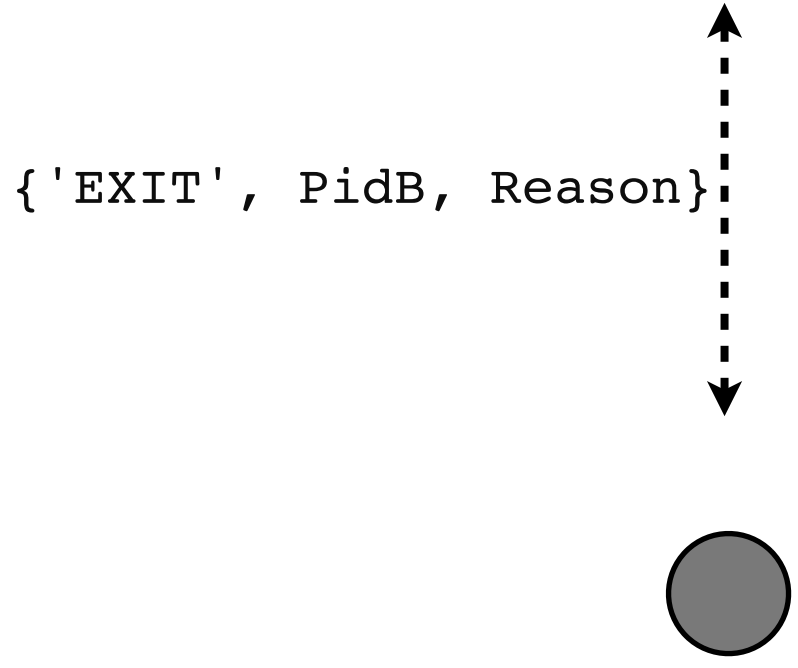
PidB



PidC

Erlang SOLUTIONS

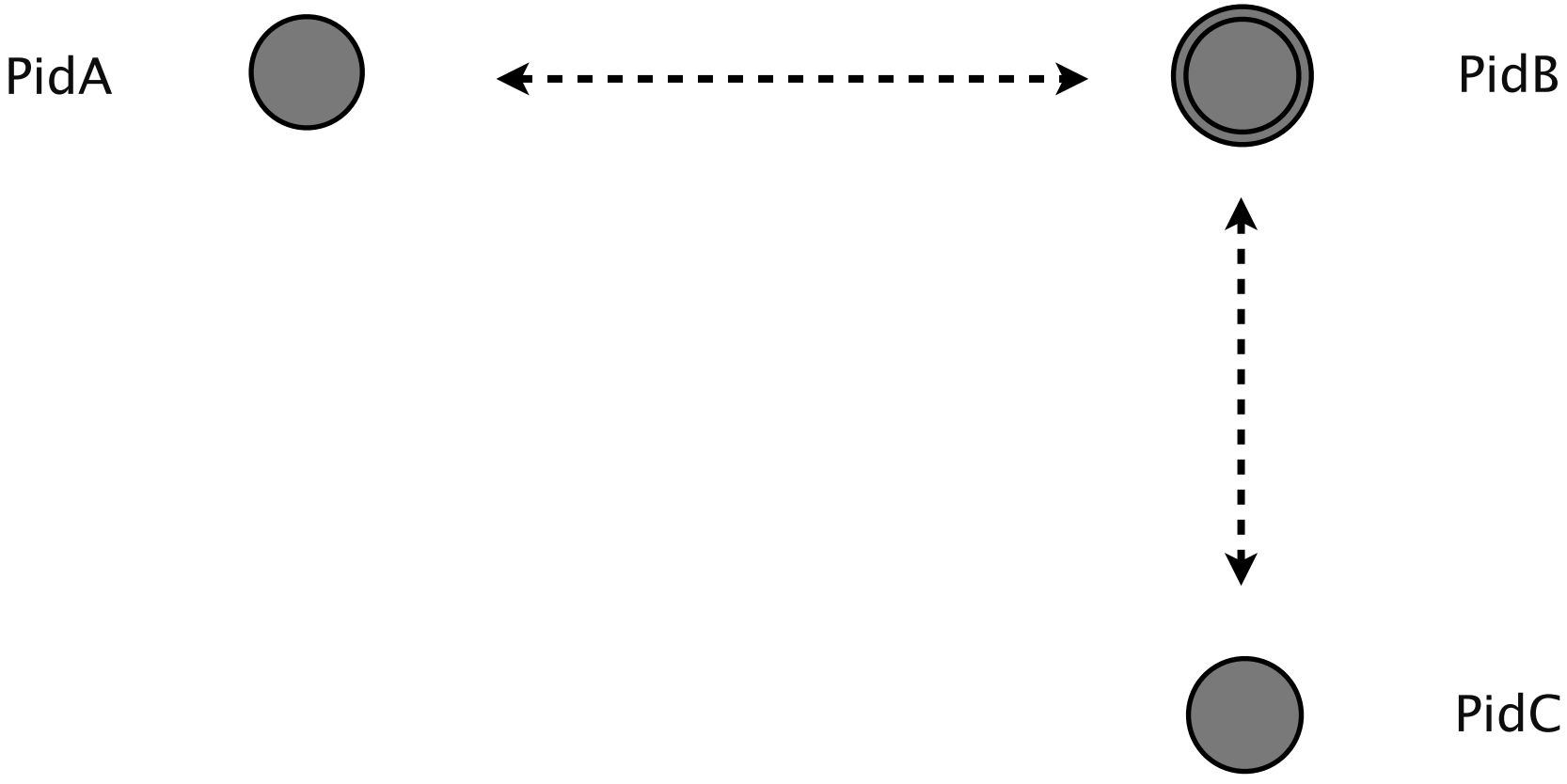
Propagating Exit Signals



Propagating Exit Signals

Erlang SOLUTIONS

Trapping Exits



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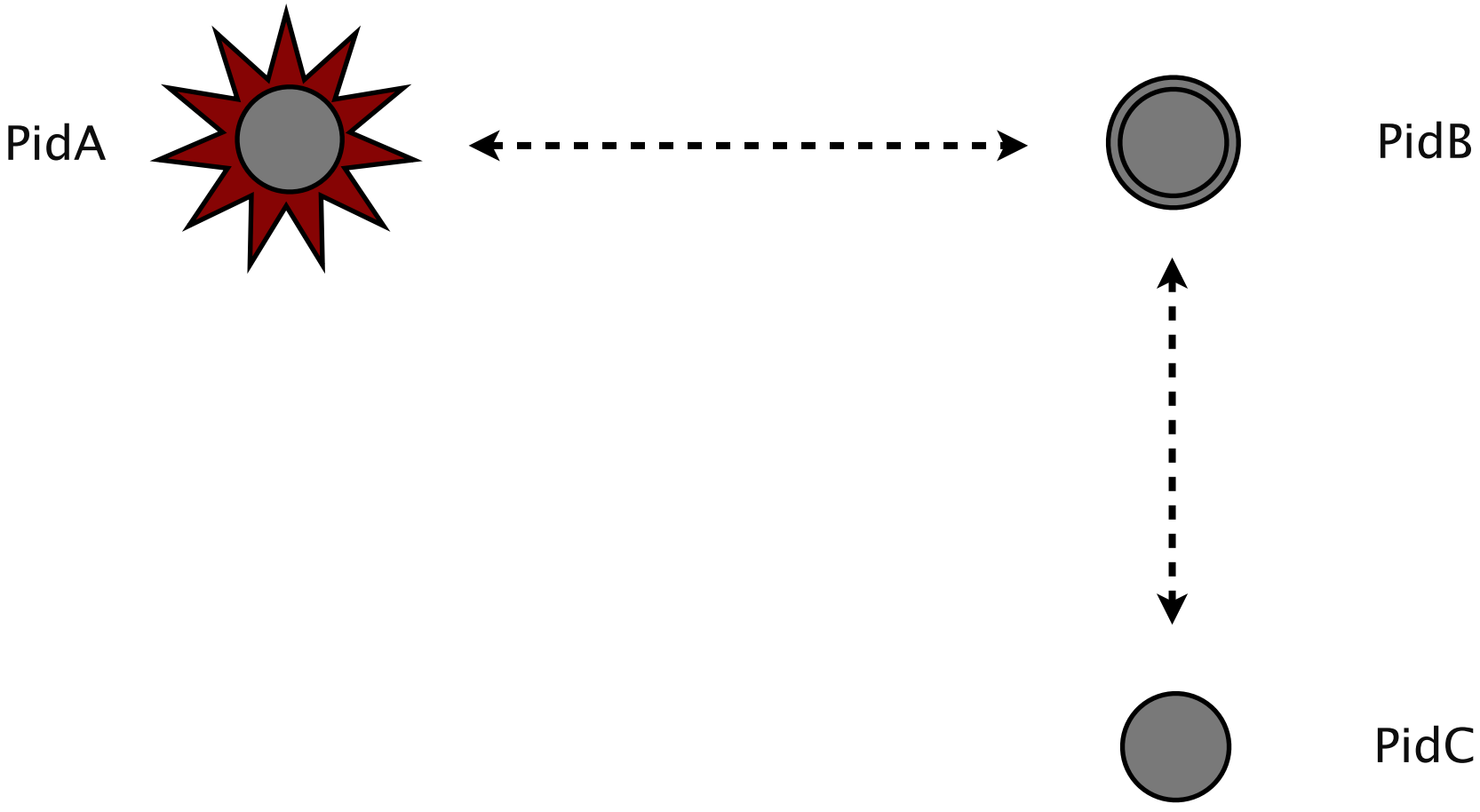

Erlang SOLUTIONS

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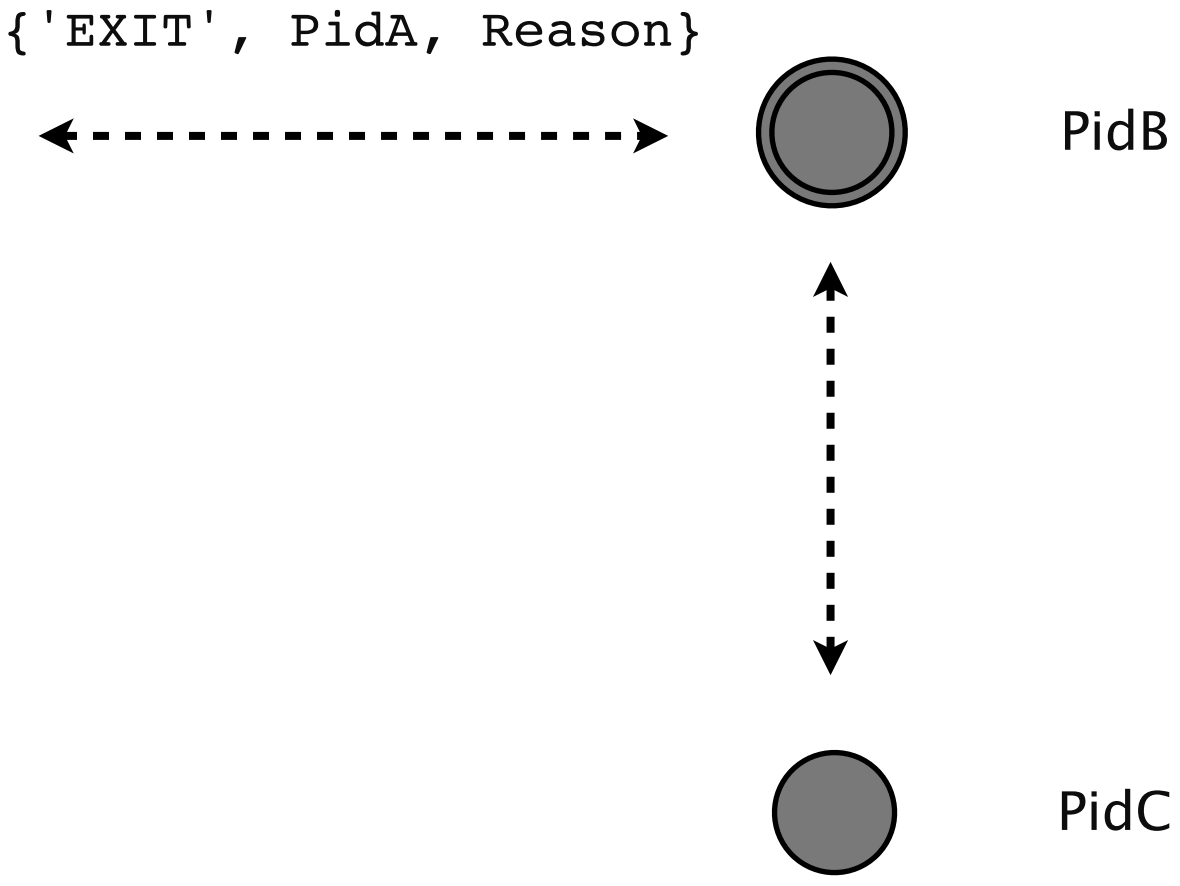

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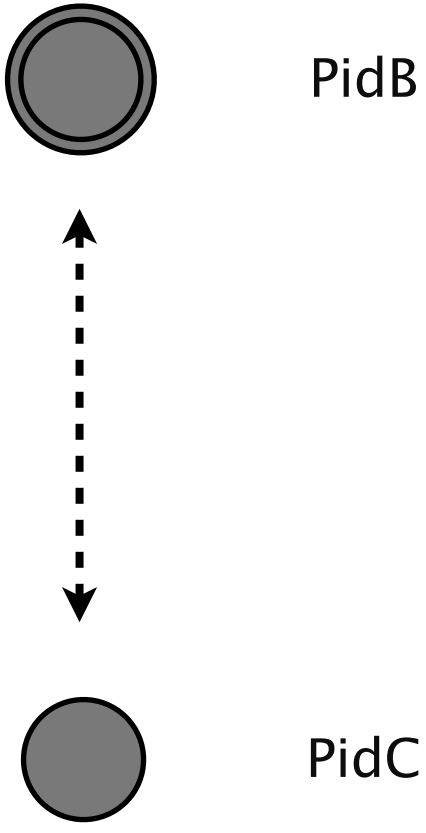
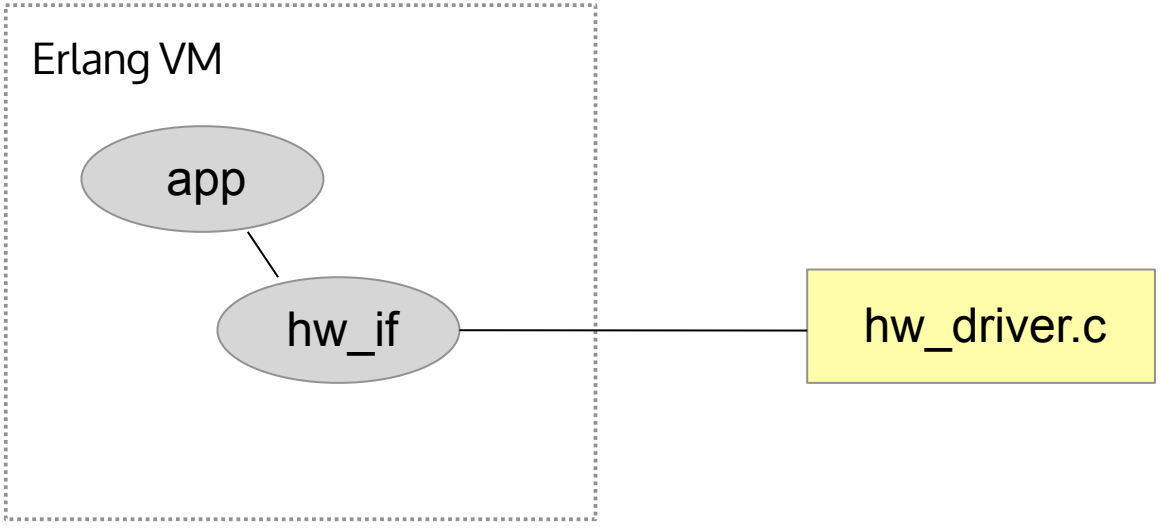


External Interfaces

- Native Implemented Functions (NIFs) and ports used to interface external world to the Erlang runtime.



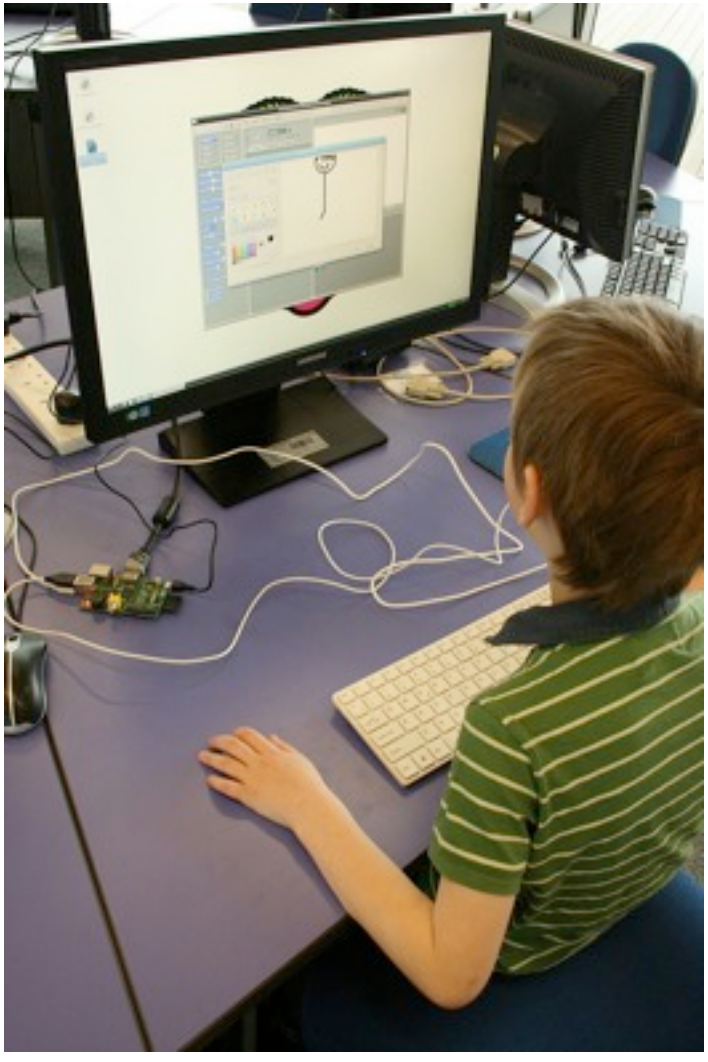
Erlang, the Maestro

(flickr/dereckesanches)

Raspberry Pi

- 700 MHz ARM11
- 256 MB DDR2 RAM
- 10/100Mb Ethernet
- 2x USB 2.0
- (HDMI, Composite Video, 3.5mm Stereo Jack, DSI, CSI-2)

Raspberry Pi in Education



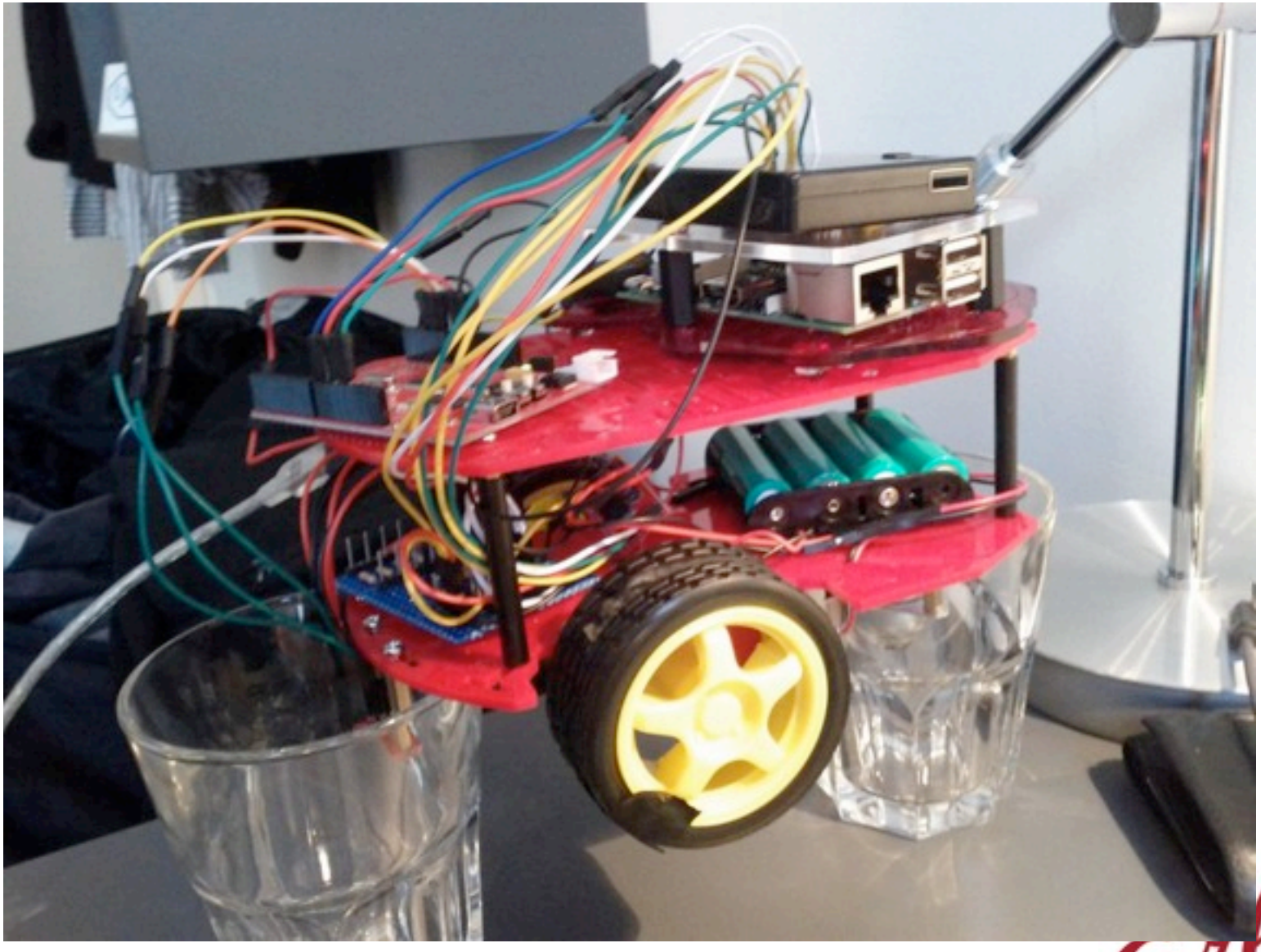
(flickr/lebeus)

- The Raspberry Pi Foundation is a UK registered charity.
- Mission statement: "...to promote the study of computer science and related topics, especially at school level, and to put the fun back into learning computing."
- Future Engineers/Programmers!

Raspberry Pi Peripherals

- GPIO
- UART
- I2C
- I2S
- SPI
- PWM
- DSI
- CSI-2

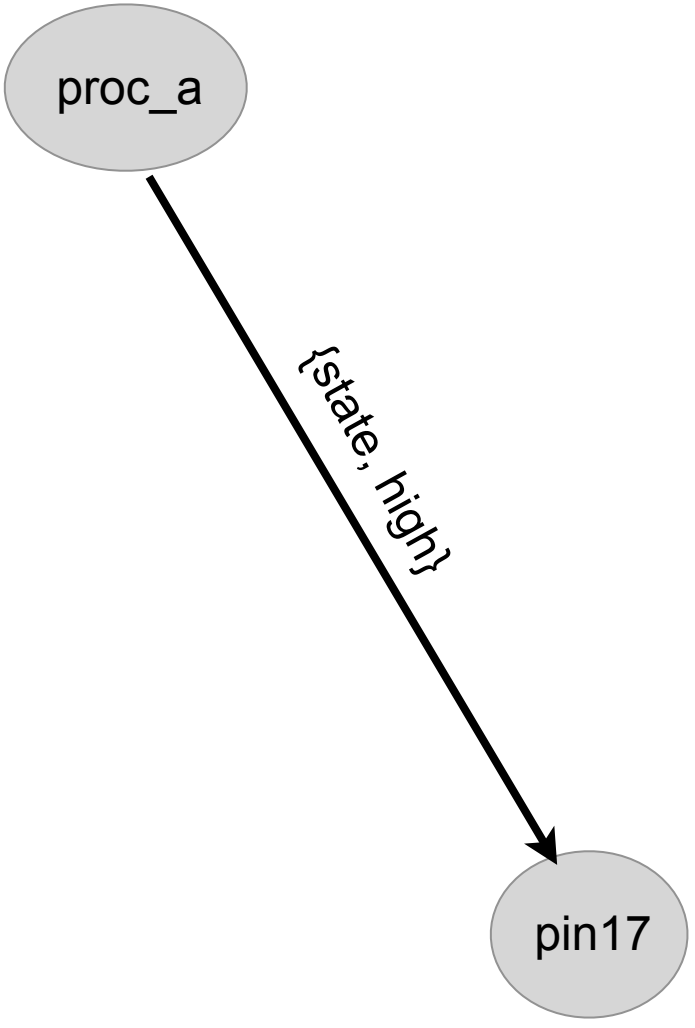
The ErlBuggy!



ErlBuggy

http://vimeo.com/48375416

Example: GPIO



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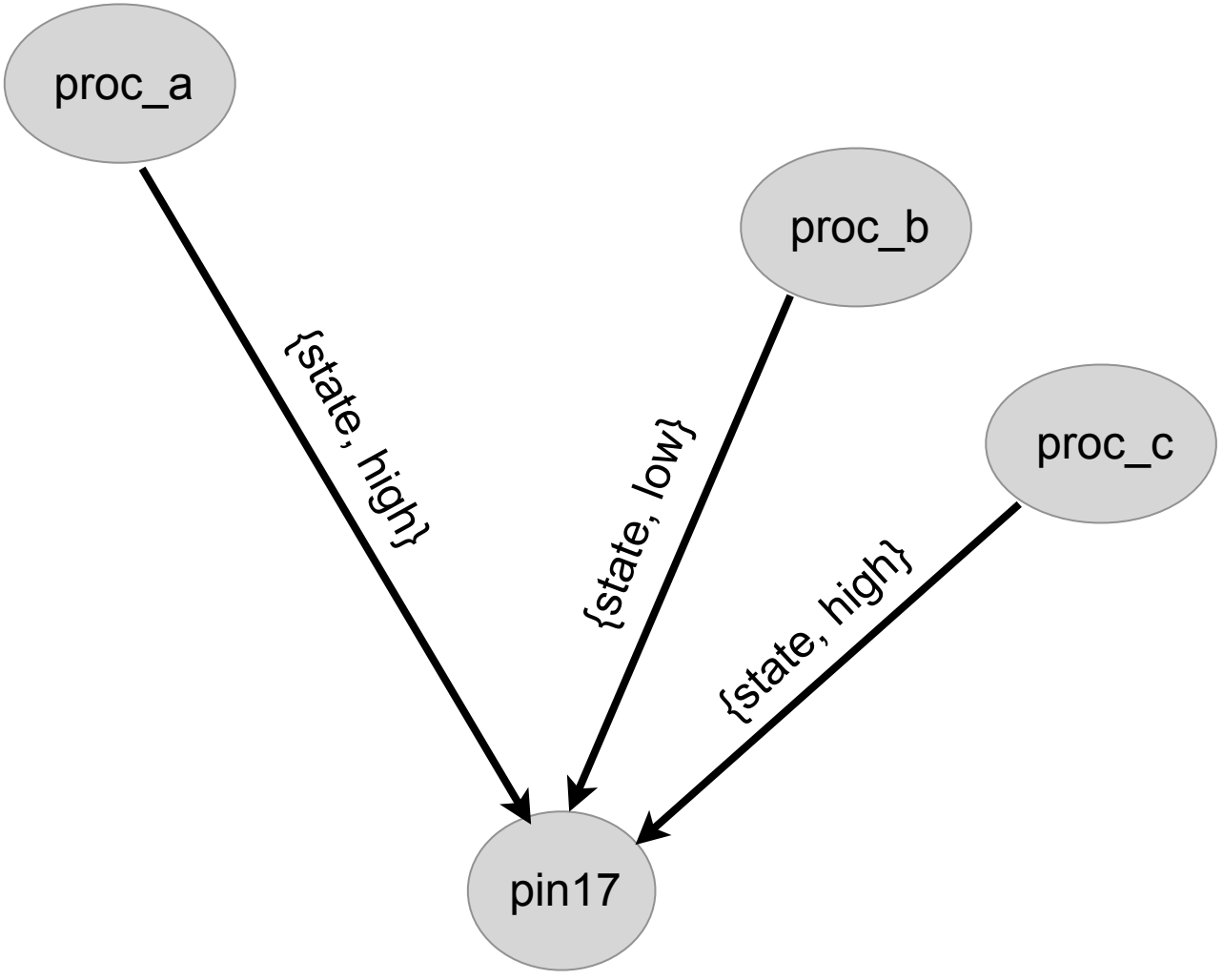

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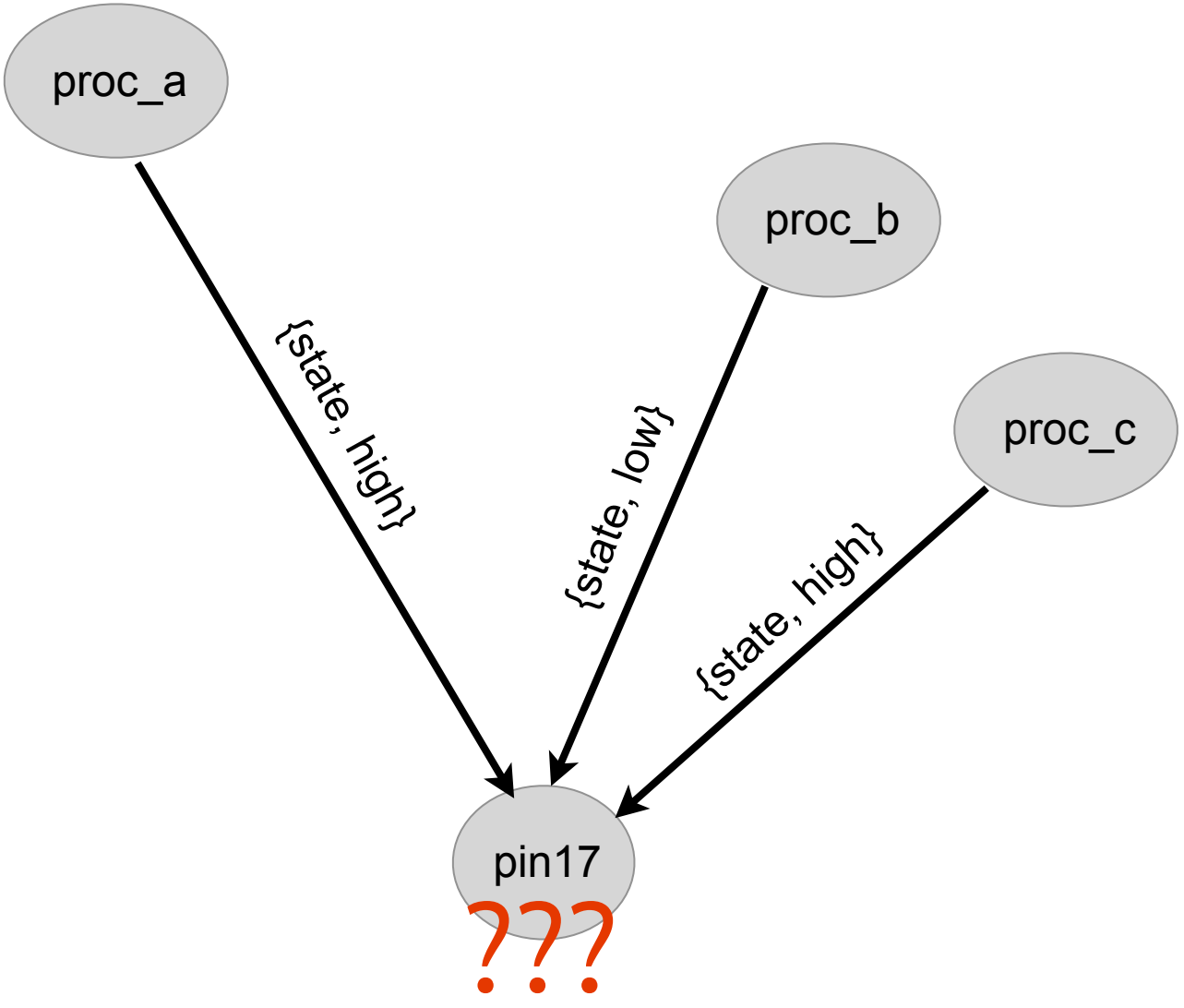

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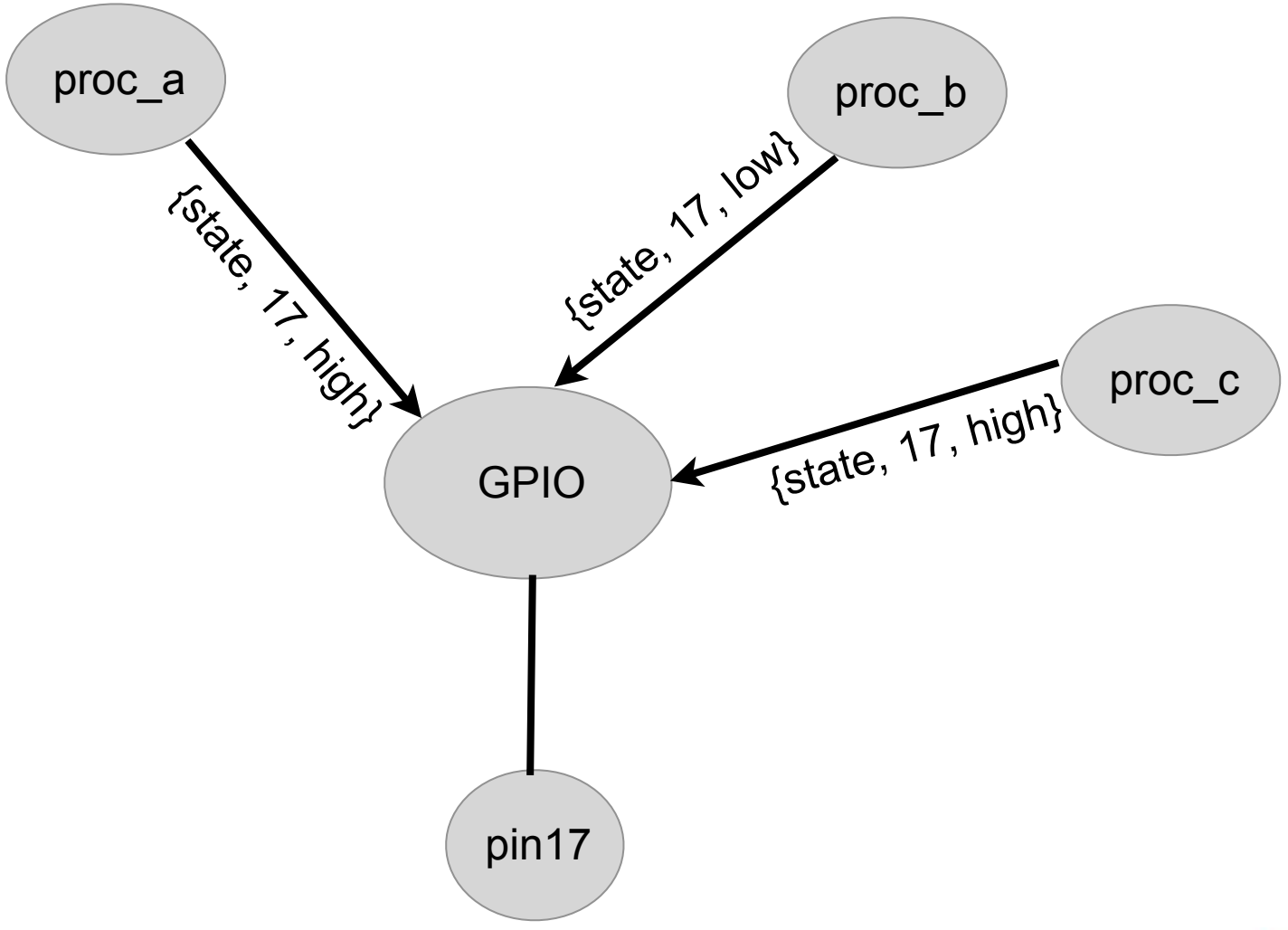


GPIO Proxy

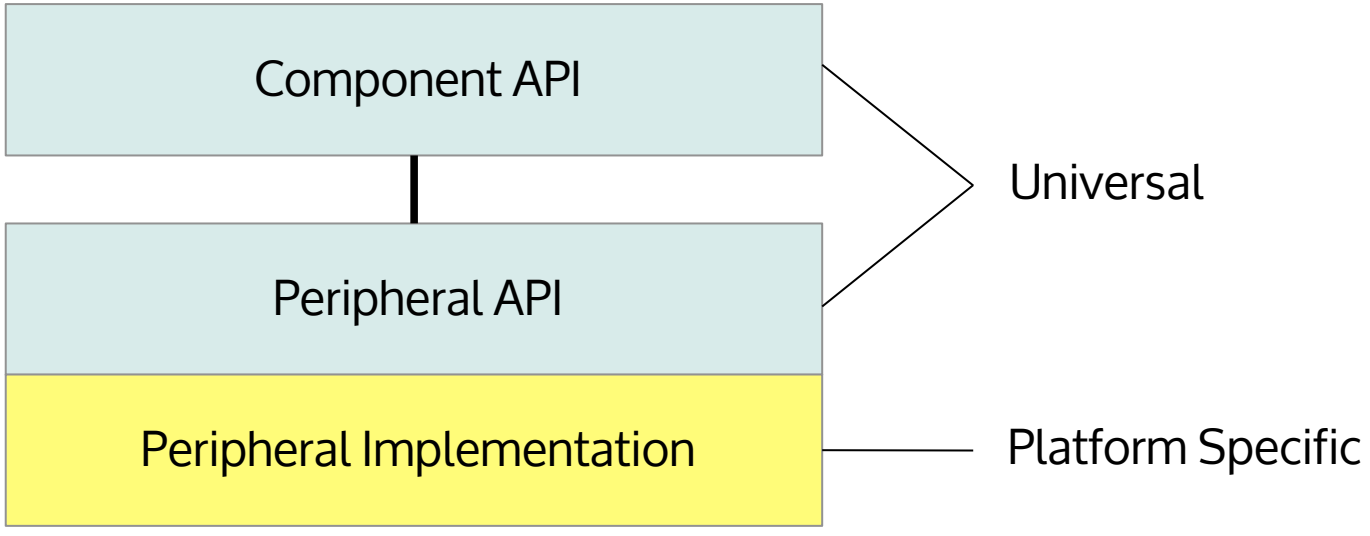
- Replaces ‘locks’ in traditional sense of embedded design
  - Access control/mutual exclusion
- Can be used to implement safety constraints
  - Toggling rate, sequence detection, direction control, etc.

Erlang SOLUTIONS

Fine Grain Abstraction

- Advantages
  - Application code becomes simpler
  - Concise and shorter modules
  - Testing becomes easier
  - Code re-use (potentially) increases
- Disadvantage
  - Architecting fine grain systems is difficult

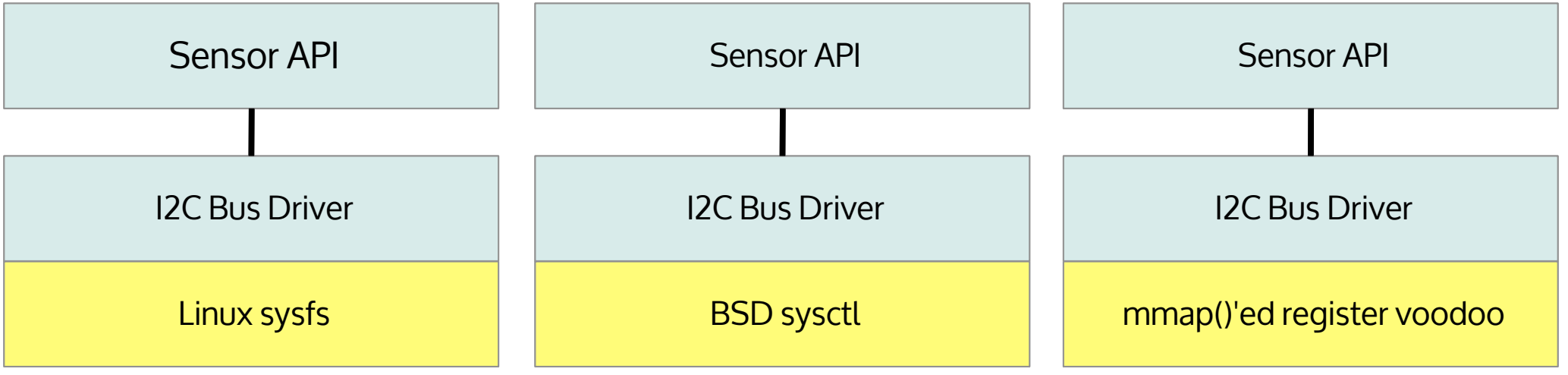
Universal Peripheral/Component Modules



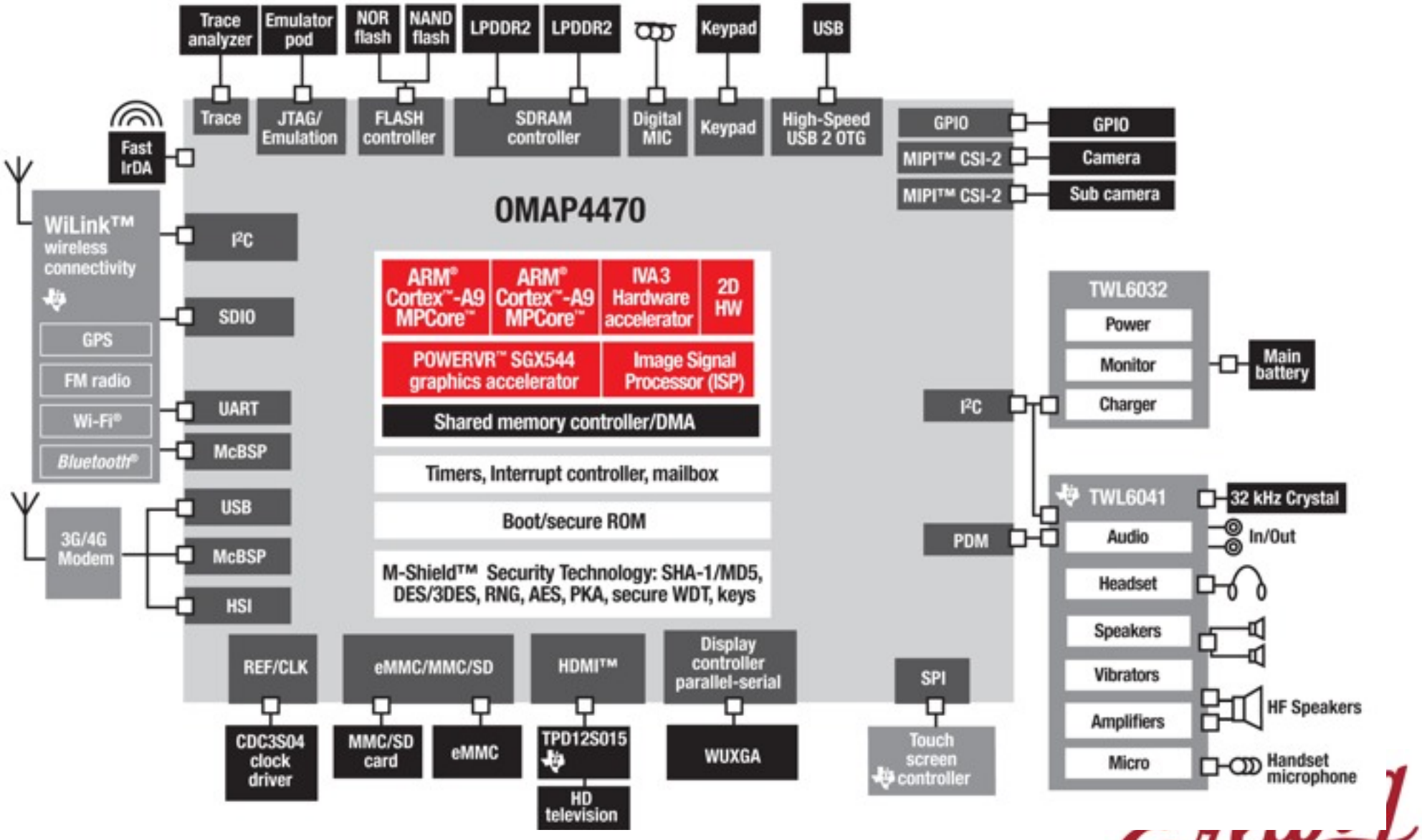
Universal Peripheral/Component Modules

An Example:

Temperature Sensor with I2C Interface



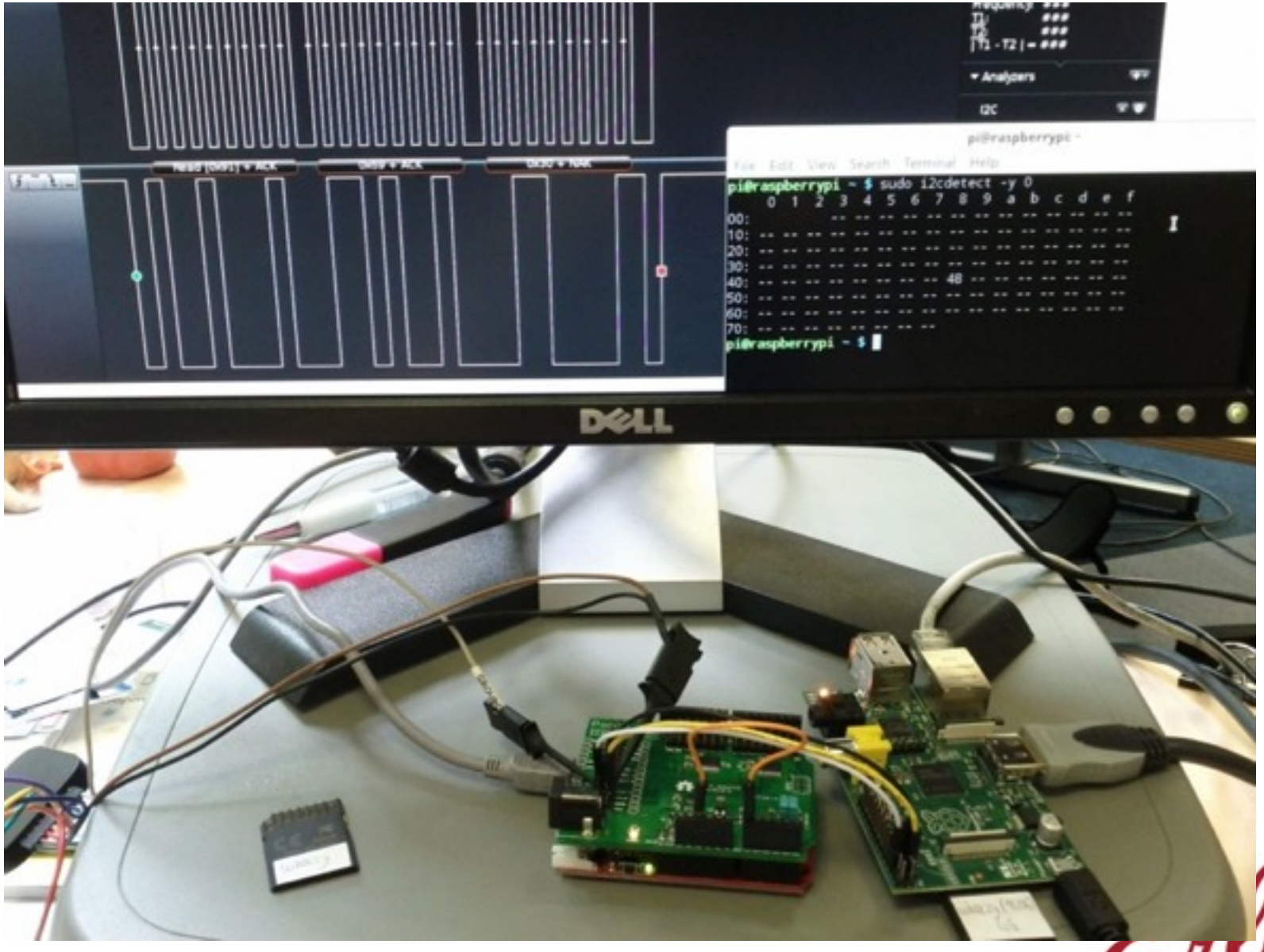
TI OMAP Reference System



Ponte Prototype

(flickr/carrierdetect)

Ponte Prototype



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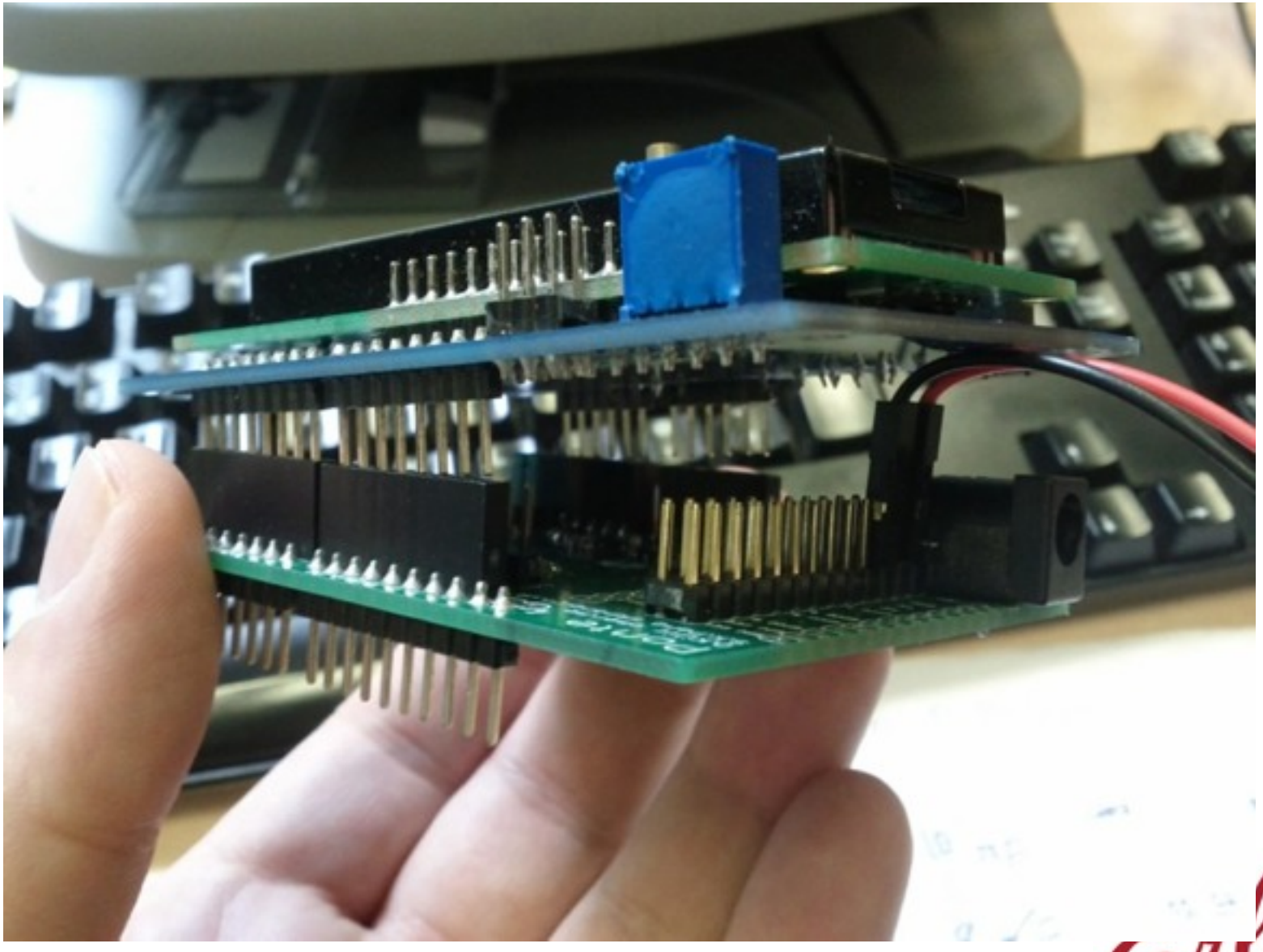
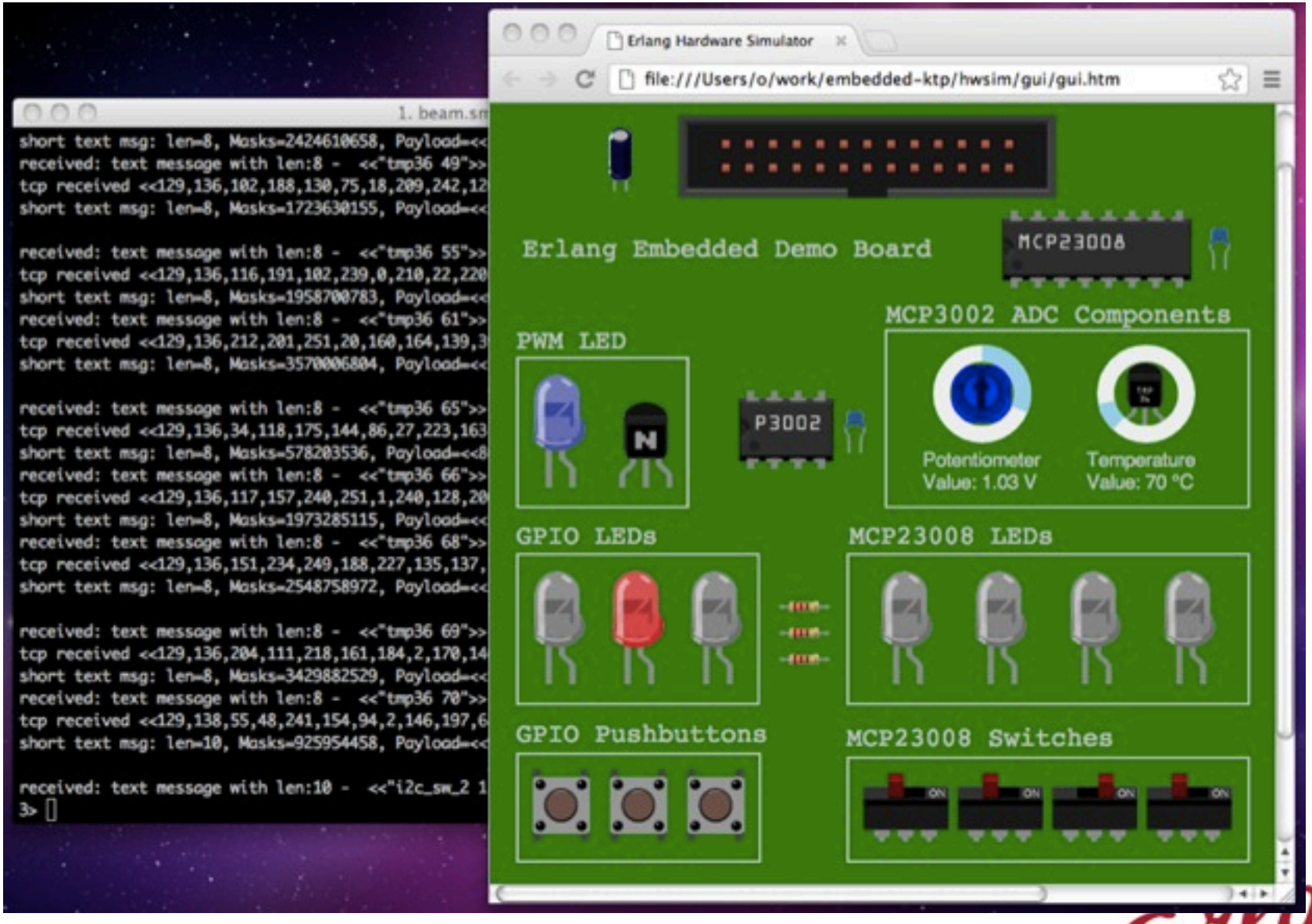
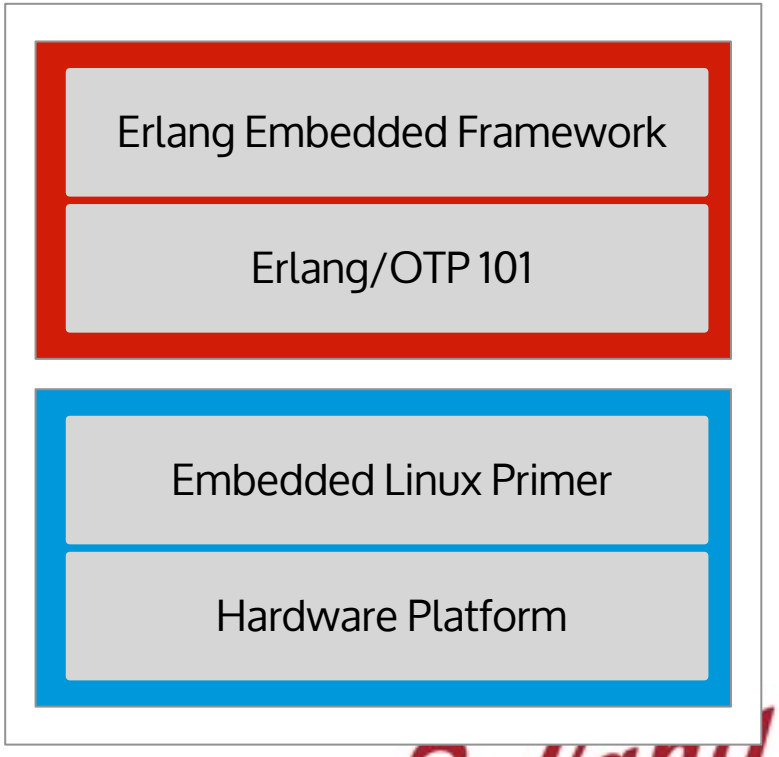


Hardware Simulator (WIP)



Erlang Embedded Training Stack

- A complete package for people interested in developing the next generation of concurrent/ distributed Embedded Systems
- Training Modules
  - Embedded Linux Primer
  - Erlang/OTP 101
  - Erlang Embedded Framework



Get in touch if you're interested.

Erlang SOLUTIONS

Thank you

- http://erlang-embedded.com
- embedded@erlang-solutions.com
- @ErlangEmbedded

> Any sufficiently complicated concurrent program in another language contains an ad-hoc, informally-specified, bug-ridden, slow implementation of half of Erlang.

– Robert Virding
Co-Inventor of Erlang