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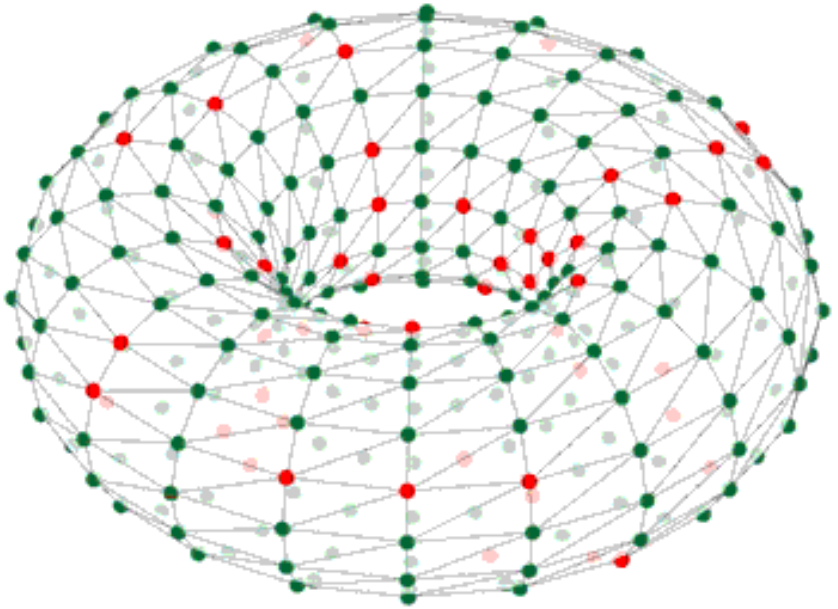
# SpiNNaker System Software



Steve Temple

SpiNNaker Workshop – Manchester – Sep 2015

erc
European Research Council
Established by the European Commission

Human Brain Project

EPSRC

SpiNNaker

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# Overview

- SpiNNaker applications and their environment
- SC&MP, *ybug* and application loading
- SARK (SpiNNaker Application Runtime Kernel)
  - Application start-up
  - SARK function library
  - Examples
  - Documentation

Please interrupt if you have a question!

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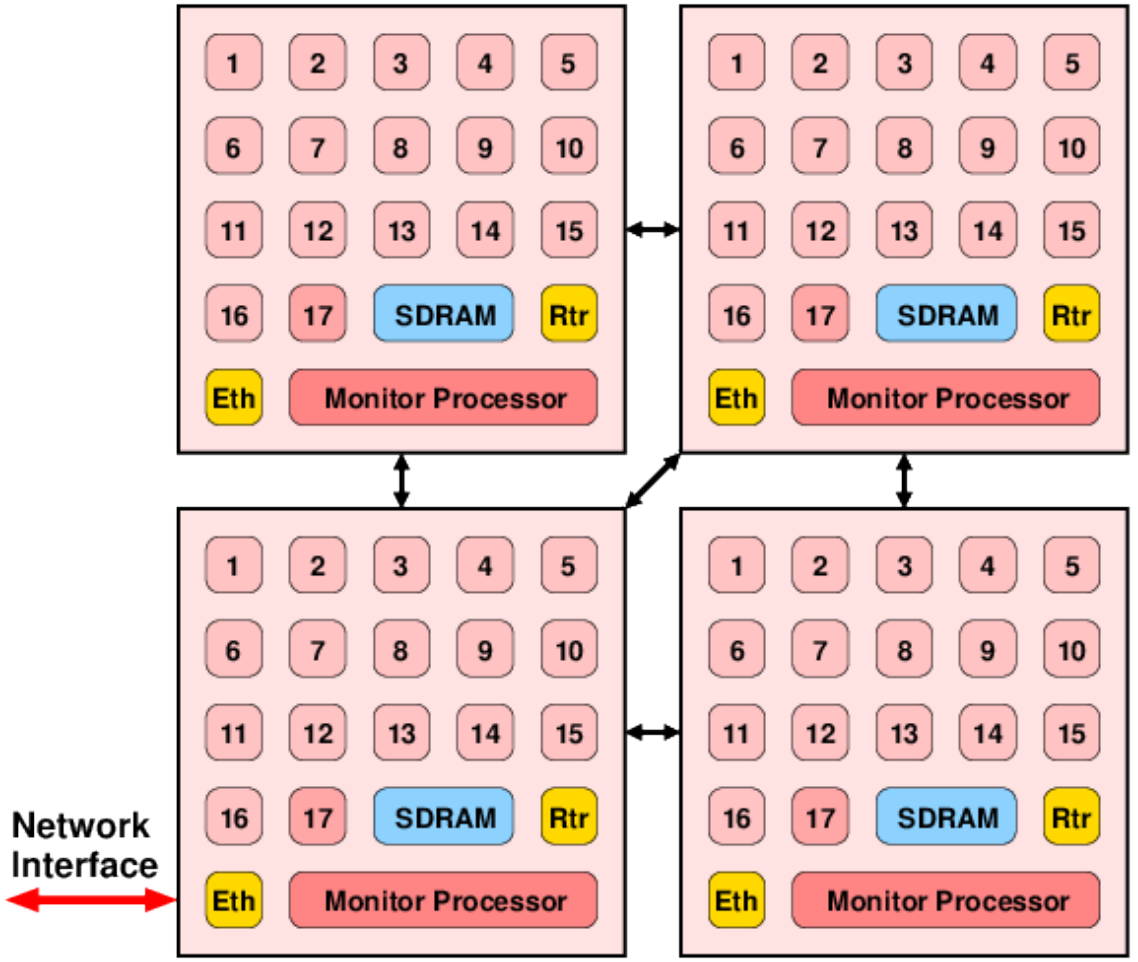
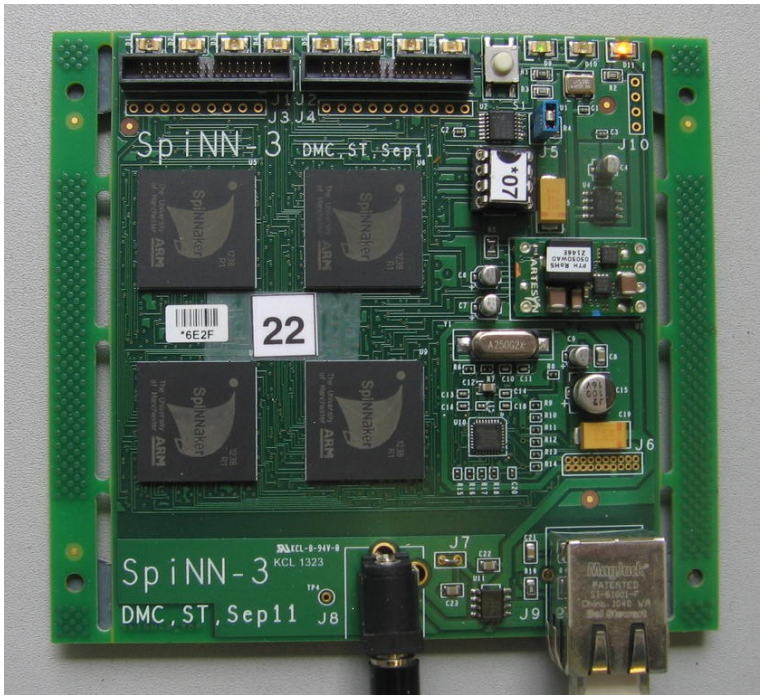
# Building Applications

- Languages – mostly C with bits of assembler
- Toolchain choice
  - ARM tools – RVDS 4 and DS-5 (free for academics)
  - GCC – Mentor Graphics Code Sourcery Lite (free)
- Library support
  - Toolchain libraries – C library functions, maths, etc
  - SARK – low-level SpiNNaker support library
  - Spin1 API – event-based application library
- Linking – support libs + application code
  - Creates application to be loaded
  - Application file format is APLX

# Execution Environment (1)



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# Execution Environment (2)

- One application per core
- Executable code (instructions) in ITCM (32 KB)
- Data (variables, stacks, heap) in DTCM (64 KB)
- Bulk and/or shared data in SDRAM (128 MB)
- Code/data access from ITCM/DTCM is fast (5 ns)
- Data access to SDRAM is slow (> 100 ns) and subject to contention
- DMA controller in each core can move bulk data between I/DTCM and SDRAM faster (~ 15 ns/word) without requiring CPU

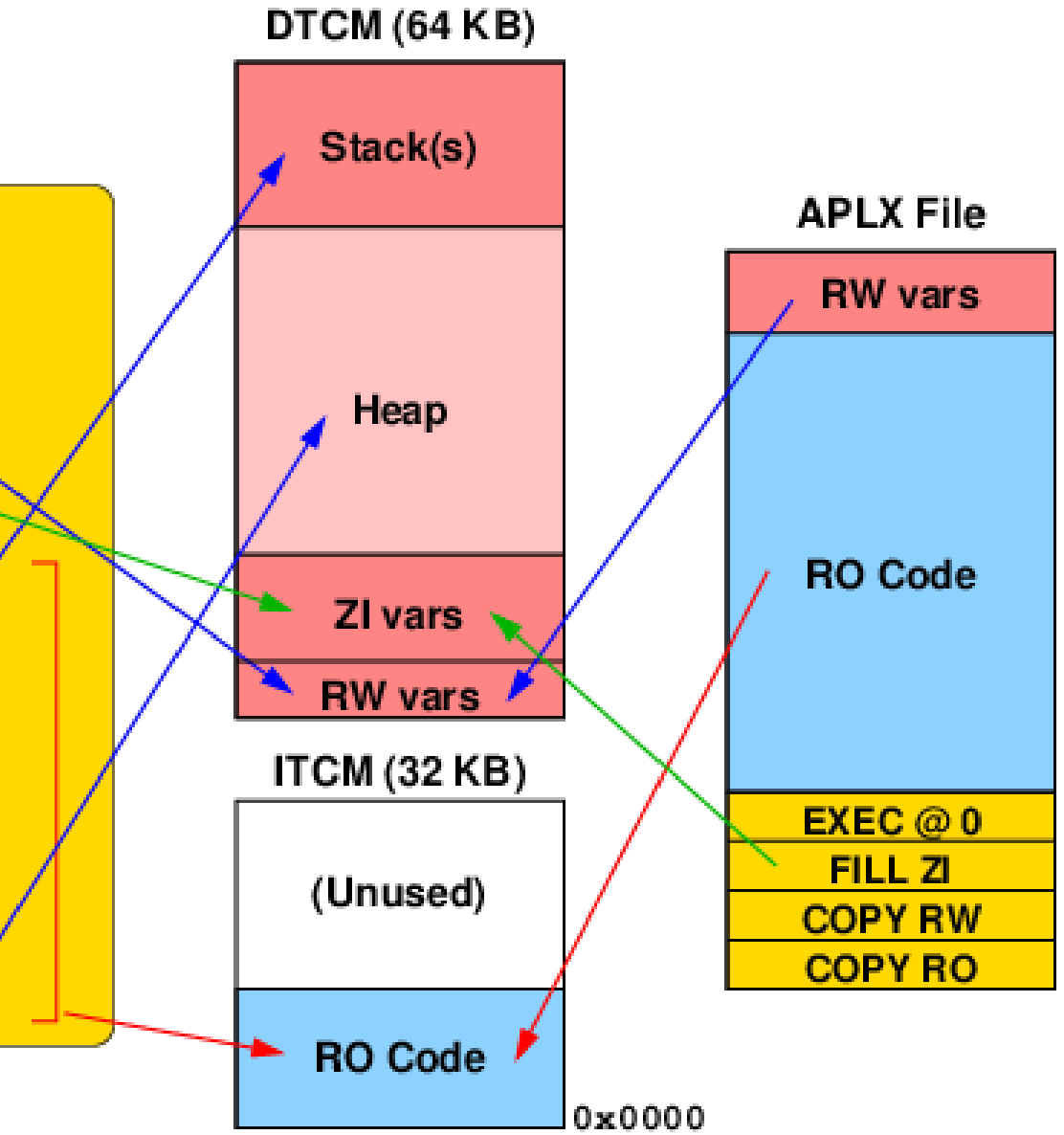
# Mapping Program to Memory

```
#include <sark.h>

uint a = 5;
uint b = 6;
uint c[30];
uint *d;

void c_main (void)
{
  uint e = 7;
  uint f = 8;
  uint g[30];
  uint *h;

  h = malloc (128);
}
```



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# SC&MP

- “SpiNNaker Control & Monitor Program”
- Loaded onto all Monitor Processors during bootstrap
- Communicates with host computer using SCP (SpiNNaker Command Protocol) over SDP
- Supervises operation of a single chip
- Allows program loading to Application Cores
- Acts as router for SDP packets between any pair of cores or with external Internet endpoints
- Flashes the LED!

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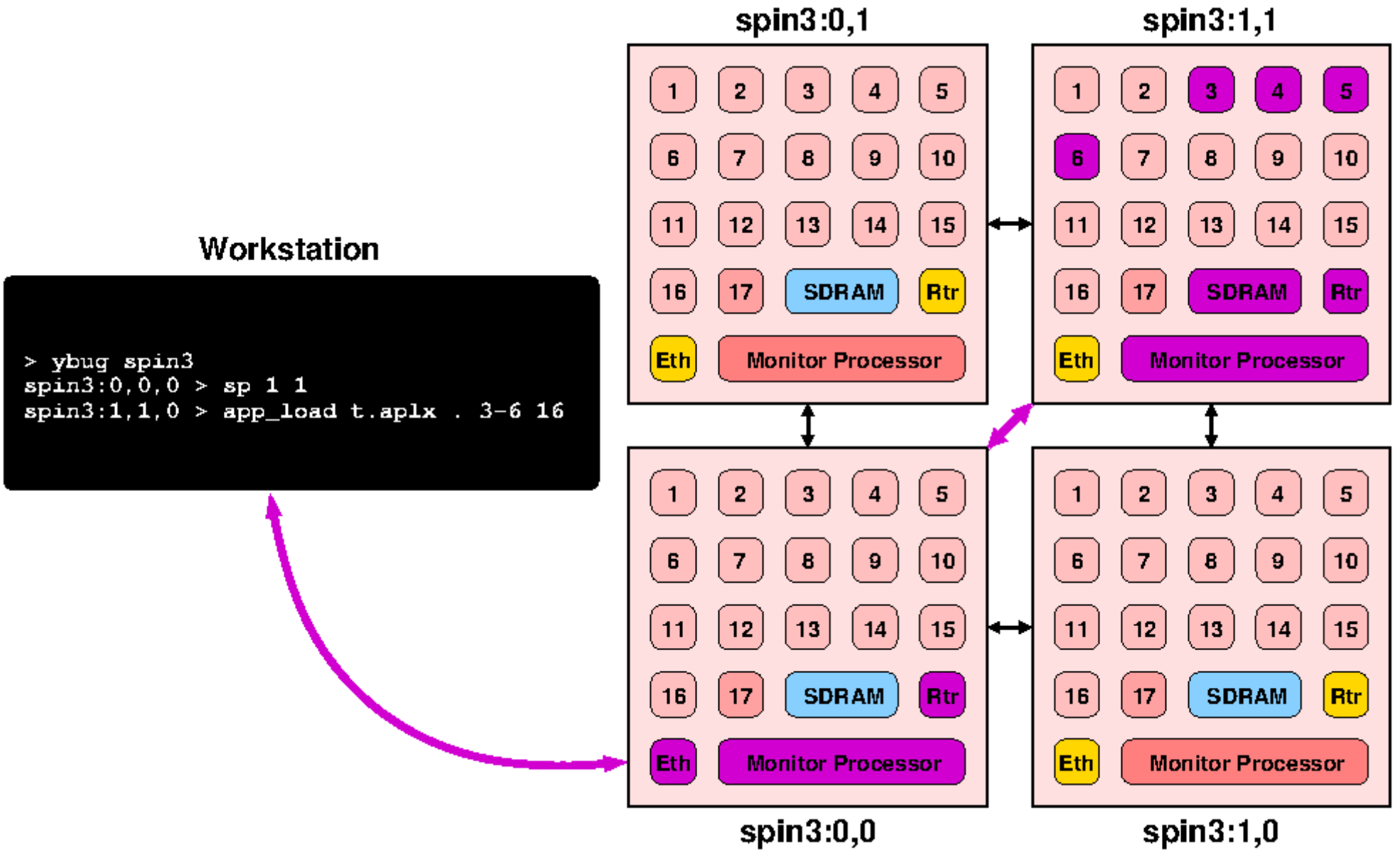
# SC&MP, SCP and *ybug*

- SC&MP provides command interface via SCP
  - `Ver` – give S/W version, etc
  - `Read (addr, length)` – read SpiNNaker memory
  - `Write (addr, length, data)` – write SpiNNaker memory
  - `Reset (core_mask)` – reset Application Cores
- Host (workstation) embeds SCP/SDP in UDP/IP to talk to SpiNNaker Monitor Processor on the Root Chip
- *ybug* is a simple command-line tool which runs on a workstation and provides an interface to SC&MP for application loading and debug

# Application Loading (1)

- *ybug* sends the application APLX to the relevant SpiNNaker chips.
- The APLX image is copied to a known place in shared memory
- *ybug* requests that the relevant Application cores are reset.
- The reset code is an *APLX loader* which loads the image according to instructions in the APLX header
- This usually results in the application being copied into ITCM and entered at address zero (the ARM reset vector)

# Application Loading (2)



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# SARK

- SpiNNaker Application Runtime Kernel
- Three main functions
  1) Application start-up
  2) Library of useful functions
  3) Communication via SDP with Monitor Processor (and hence rest of system)
- SARK is automatically linked with applications when they are built
- Occupies around 2 KB in the image

# Application Start-Up

- Start-up code at start of ITCM is SARK
  - Configures stacks for 4 ARM execution modes
  - Initialises Heap and SDP message buffers in DTCM
  - Initialises shared-memory data structure (VCPU)
  - Calls a function to do pre-application set-up
  - Calls the function **`c_main`**, the application entry point
  - Calls a function to do post-application clean-up
  - Goes to sleep!
- Some applications will never terminate
- SARK provides SDP communications with the application

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# SARK Library (1)

- CPU control
  - Interrupt disabling and enabling
  - Entering low power (sleep) mode
- Memory manipulation
  - Memory copy and fill (small footprint)
  - SDP message copying
- Pseudo-Random number generation (32-bit)
- SDP messaging
  - Message allocation in DTCM and shared memory
  - SDP message transmission

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# SARK Library (2)

- Text output via “printf”
  - Text sent to a host system using SDP packets
  - Text buffered in SDRAM
- Hardware locks and semaphores
- Memory management
  - `malloc/free` for DTCM heap
  - `malloc/free` for shared memories (eg SDRAM) with locking
  - `malloc/free` for router MC routing table
- Environment queries
  - What is my core ID, chipID, etc

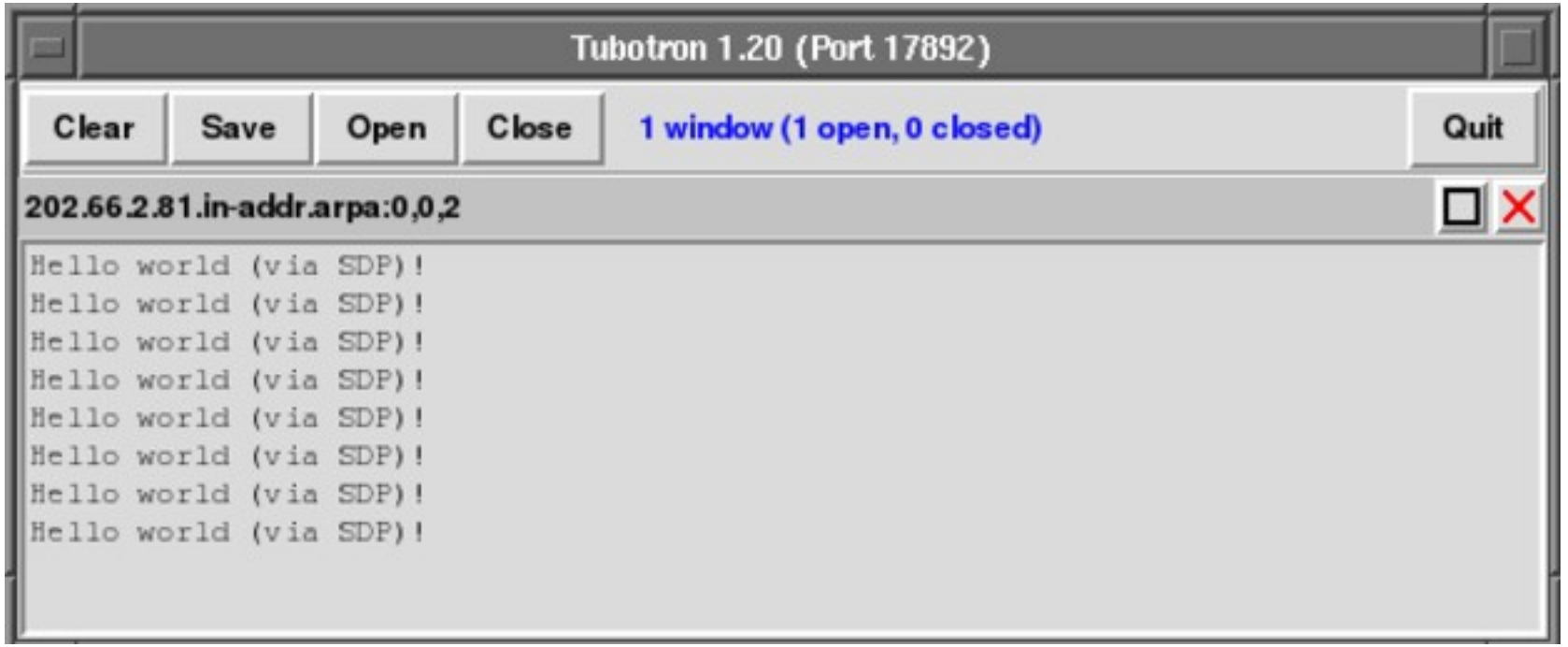
# SARK Library (3)

- Hardware interfaces
  - LED control
  - Router control – setting MC and P2P table entries
  - VIC control – allocating interrupt handlers to specific hardware interrupts
- Timer management
  - Routines to schedule/cancel events at some time in the future
- Event management
  - Routines to associate events with interrupts
  - Management of priority event queues

# SARK – Example 1

```
#include <sark.h>

void c_main (void)
{
  io_printf (IO_STD, "Hello world (via SDP)!\n");
  io_printf (IO_BUF, "Hello world (via SDRAM)!\n");
}
```



# SARK - Example 2

```
#include <sark.h>

INT_HANDLER timer_int_han (void)
{
  tc[T1_INT_CLR] = (uint) tc;      // Clear interrupt in timer
  sark_led_set (LED_FLIP (1));     // Flip a LED
  vic[VIC_VADDR] = (uint) vic;     // Tell VIC we're done
}

void timer_setup (uint period)
{
  tc[T1_CONTROL] = 0xe2;                  // Set up count-down mode
  tc[T1_LOAD] = sark.cpu_clk * period;  // Load time (us)
  sark_vic_set (SLOT_0, TIMER1_INT, 1, timer_int_han);
}

void c_main ()
{
  io_printf (IO_STD, "Timer interrupt example\n");
  timer_setup (500000);       // (0.5 secs)
  cpu_sleep ();                // Send core to sleep
}
```

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# Documentation & Help

- SARK – notes in 1.30 Software release - `sark.pdf`
- *ybug* – user guide in 1.30 Software release - `ybug.pdf`
- `"spinnaker.h"` - describes the SpiNNaker hardware – memory maps, peripheral registers...
- `"sark.h"` describes all SARK data structures and functions. Commented in Doxygen style.
- All source code is provided...
- If desperate, talk to us!