Introduction to Wireless Sensor Networks: Networking Aspects

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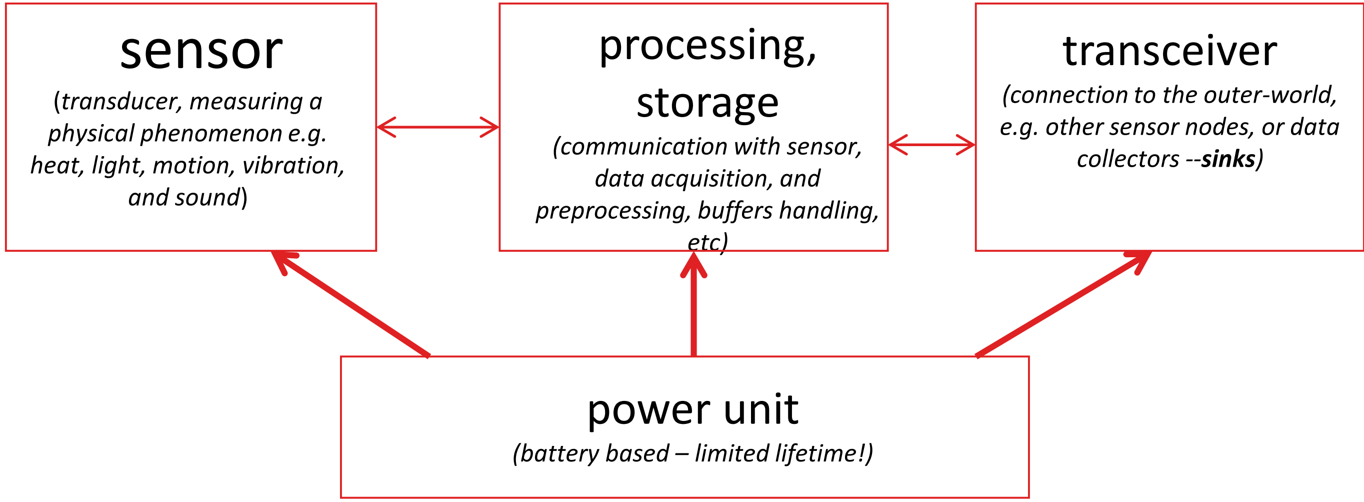
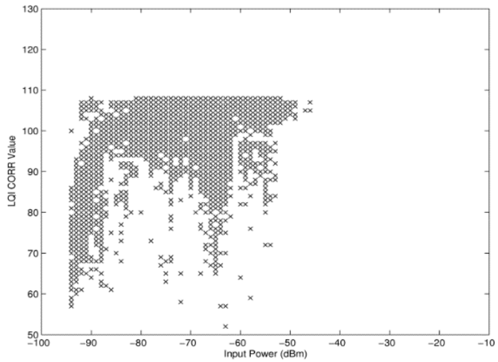
8.04.2014, 10.04.2014

Outline

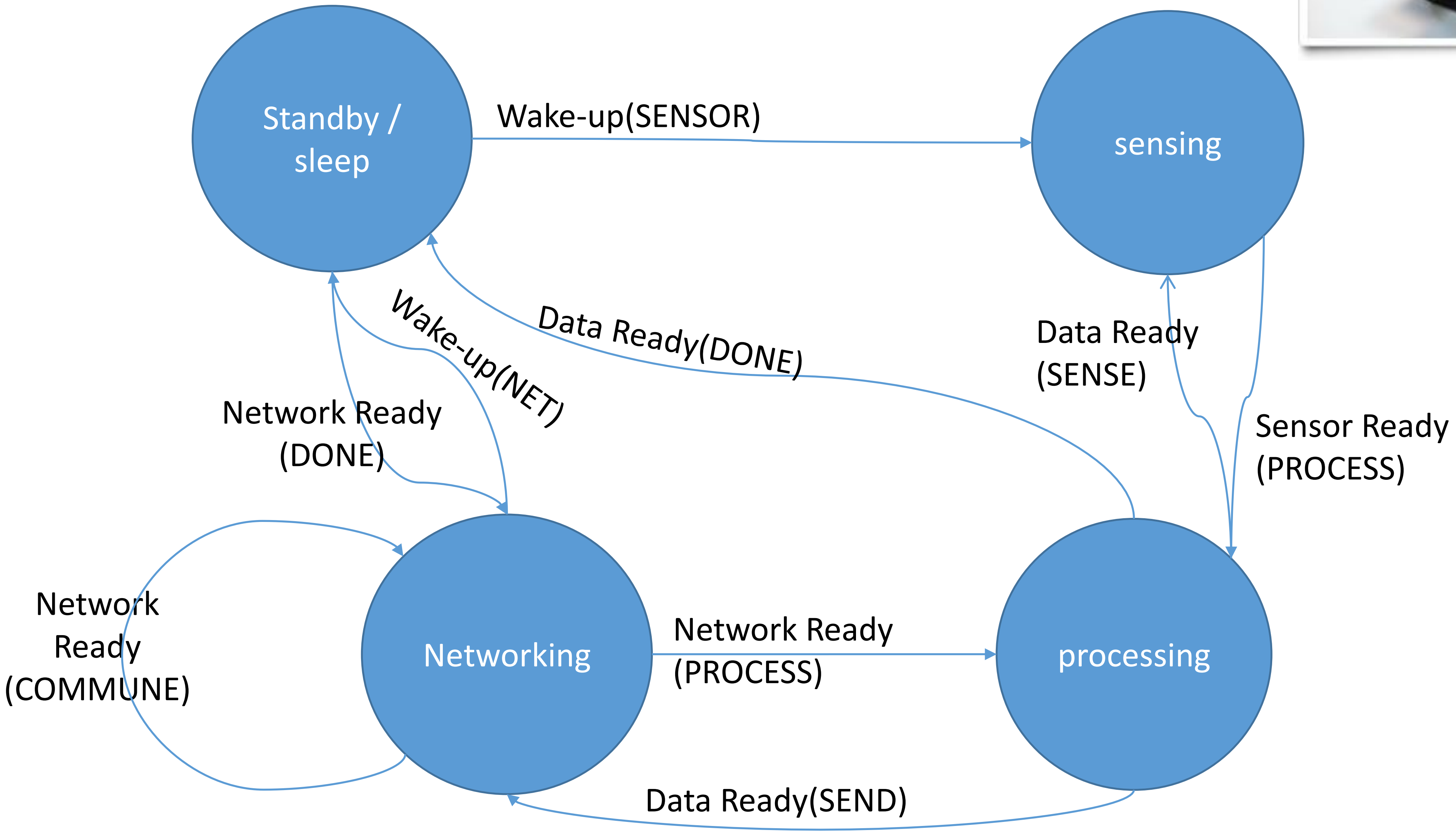
- Part 1: Applications, Standards and Protocols
    - Introduction & Reasoning of Existence
    - Sensing, Processing, and Networking Aspects
    - Standards, Topologies & Protocols
- Part 2: WSN Programming
    - WSN Core and types of nodes
    - Real-time Operating Systems
    - Examples & Hands on Session





WSN Core

Typical State Machine of a Sensor Node



Family	TRX	µProcessor	Memory	On-board Sensors	Expandability	Notes & Application areas
TELOSB	TI 802.15.4@2.4GHz (functional PHY, MAC compatible)	TI msp430-F1 (16-bit)	10KB RAM, 48KB Flash	Temperature, Humidity, Light	10 GIOs, USB programming interface	Open platform. Environmental and health structural monitoring. PoC research projects Open source software support – Active.
Mica2	**TI 802.15.4@868MHz** (functional PHY, compatible MAC)	ATMEL AVR 128L (16-bit)	4KB RAM/48 KB Flash	-	Dedicated environmental sensor board. 51-pin expansion, RS232.	One of the oldest platforms. Environmental and health structural monitoring. PoC research projects Open source software support – Active (?).
MicaZ	TI 802.15.4@2.4GHz (functional PHY, MAC compatible)	ATMEL AVR 128 (16-bit)	4KB RAM/48 KB Flash	-	Dedicated environmental sensor board 51-pin expansion, RS232.	Environmental and health structural monitoring. PoC research projects Open source software support – Active (?). **Dipole Antenna**
IRIS	ATMEL 802.15.4@2.4GHz (functional PHY, MAC compatible)	ATMEL AVR 1281	8KB RAM/48 KB Flash	-	Dedicated environmental sensor board. 51-pin expansion.	Environmental and health structural monitoring. PoC research projects Open source software support – Active. **Dipole Antenna**
Shimmer	TI 802.15.4@2.4GHz (functional PHY, MAC compatible) **Nordic BT (fully functional)**	TI msp430-F1 (16-bit)	10 KB RAM, 48 KB Flash, **2GB µSD**	3-axis accelerometer, Tilt & vibration	Expandability for Accelerometers and ECG, EMG. USB mother board.	Research platform with commercial support. Excellent support (open source tools & customized applications). **Healthcare and Sports projects (wearable computing)** Active and expanding. **Rechargeable battery (up to 8hours in fully functional mode)**
SUNSPOT	TI 802.15.4@2.4GHz (functional PHY, MAC compatible)	**ATMEL ARM (32-bit)**	1 MB RAM, 8 MB Flash	3-axis accelerometer, 3-color light.	USB. 4 GIOs.	Open platform. **JVM (very easy to program). Emulator is also available.** Fancy platform with demos for audience with no related background. Active. For hobbyists ☺ **Built in Li Battery**
Zolertia Z1	TI 802.15.4@2.4GHz (functional PHY, MAC compatible)	TI msp430-F2	8K RAM, 92KB Flash	3-axis accelerometer, temperature	52-pin expansion board. Open source community support & commercial support (excellent Wiki)	All WSN-related. One of the latest platforms. Allows the option for a dipole antenna.
XM1000	TI 802.15.4@2.4GHz (functional PHY, MAC compatible)	TI msp430-F2	8K RAM, **116 Flash,** 1MB External Flash	Temperature, Humidity, Light	10 GIOs, USB programming interface	from a family of open platforms…. **SMA connection (dipole antenna)…** All WSN-related, perhaps not for healthcare (bulky size and design). Can last up to 3 weeks on low data rate (per minute).

The WSN Core – technologies and platforms…[1-6]

The WSN Core – technologies and platforms…[1-6](cont')

Family	TRX	µProcessor	Memory	On-board Sensors	Expandability, Usability & Support	Notes & Application areas
Firefly	ATMEL ATMega128RFA1 (SoC) 802.15.4@2.4GHz (functional PHY, MAC compatible)		8 KB RAM, **128 KB Flash**	-	Dedicated environmental sensor board (inc. audio, barometric pressure, PIR sensor, liquid / relay switch). + GIOs	Research platform (CMU). Not as popular as other platforms. (?) 
WiSMote	TI 802.15.4@2.4GHz (functional PHY, MAC compatible) **2nd generation**	TI msp430-F5	16KB RAM, 128 Flash	3-axis accelerometer, temperature, light.	8 Analog, 16 GIO, mini USB	Optional support for Power-Line Communications and RS-485 (candidate for homes automation and industrial monitoring.) Research, open platform.
Xbee	**Digi 868 / 2.4GHz (SoC)**		Needs (mother board)	-	Serial communication (to µController) or host SCB (arduino, rasbery etc)	Provide wireless **end-point connectivity to devices -> plug-and-play.** **AT Commands for accessing the board.** **OTAP.** **802.1.5.4 on HW**
WaspMote	**xBee-15.4. / ZigBee** **WiFi** **BT 2.1.0 (BR / EDR)** **3G** **NFC**	ATMEL AVR 1281	8 KB RAM, 128 KB Flash, **2GB µSD**	3-axis accelerometer, temperature.	Analog, Digital, USB, I2C	Built in a torrent style – highly customizable w.r.t. the application needs. GPS optional. Commercial product – for commercial and very applied projects. **OTAP**
Jennic / NXP	Jennic 2.4GHZ (SoC) 32-bit µProcessor (ATMEL ?) PHY functional. support for MAC (HW MAC Accelerator)		128KB RAM, 128 KB ROM	-	Analog, Digital, ADC, SPI, **Digital audio interface**, UART	Closed platform. Proprietary protocol stack – ZigBee / 6LoWPAN **Pure commercial platform. Plug-and-play…**

WSN Core

What we use…

Product Name	Extras	Notes:
XM1000	Indoors RF range: ~30 m (without Line-of-Sight).	Not advisable for industrial environments due to antenna. SMA connector / Dipole antenna **is not supported**.
CM5000-SMA	Similar as XM1000, less powerfull. 5dBi dipole antenna	Advisable for industrial environments, due to antenna option. **Network compatible to XM1000**

WSN Core

When selecting motes for your applications…

- One size doesn’t fit them all.
- Support by company and open source community
- Power consumption
- Interoperability, Accessibility and tools (μProcessor toolchains, etc)
- Antenna design and antenna performance – standard-compliance &/ implementation is not panacea to RF problems….

WSN Programming

- Motes selection ↔ Programming environment.

- Open source & Research platforms: Linux-alike environments
- Plug-and-play and closed platforms: wide range of tools.

- When programming a mote → programming its μProcessor to:
  - access the peripheral devices (transceiver, leds, sensors etc)
  - handle, store, modify the acquired information.

WSN Programming

Direct µProcessor programming

Low-level / Embedded C & Assembly
Hardware specific
Faster (simplified applications & experienced programmer)
Not suitable for sophisticated applications & network topologies

Real time Operating Systems

A level of abstraction between the programmer and the hardware platform
HW Interoperability of WSN application
Allows better control on the platform
Suitable for more complex network topologies

WSN Programming

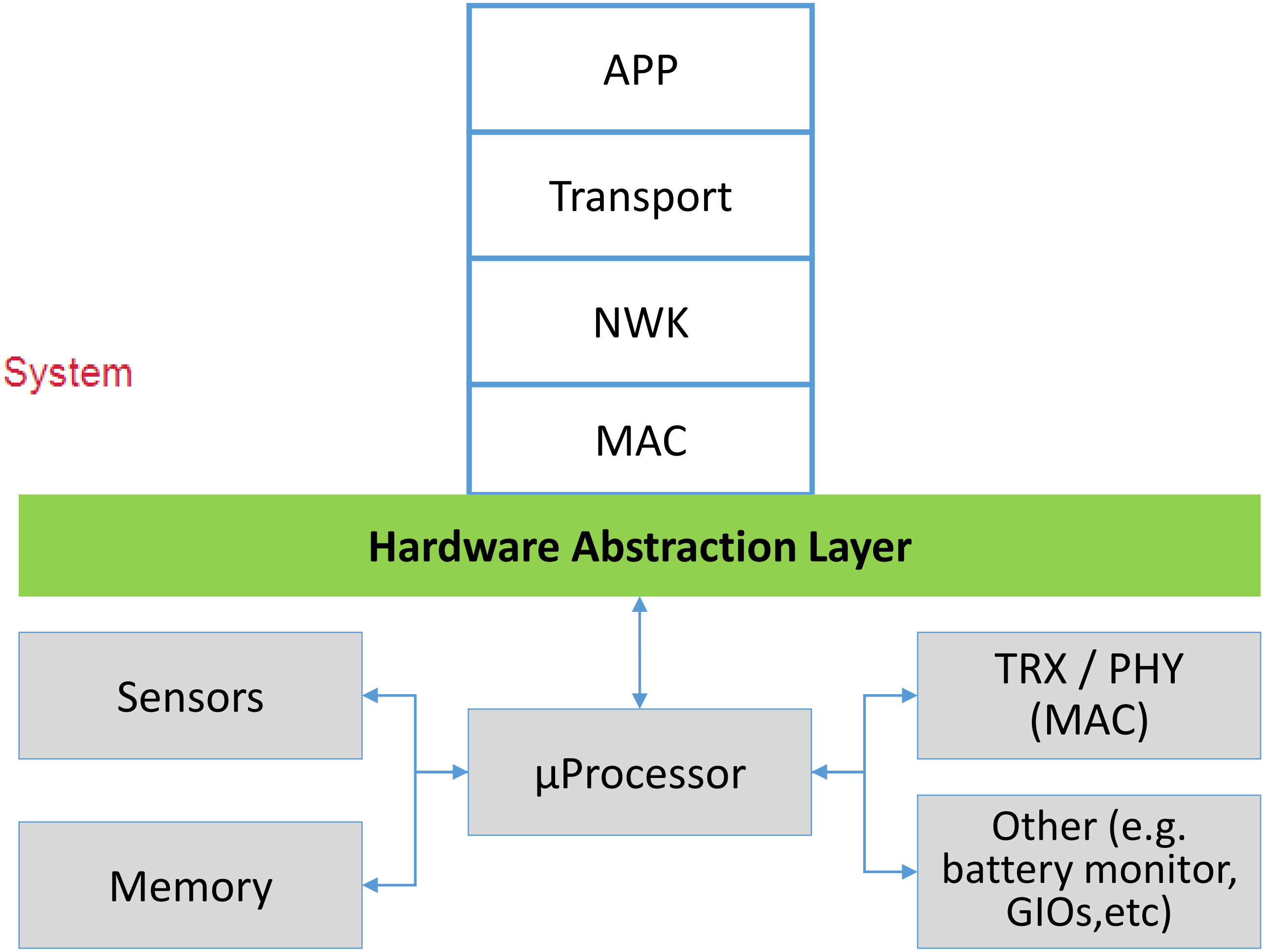
[7-10]

MANTIS
MultimodAl NeTworks of In-situ Sensors

TinyOS

Contiki
The Open Source OS for the Internet of Things

Nano-RK: A Wireless Sensor Networking Real-Time Operating System



WSN Programming

	TinyOS	Contiki The Open Source OS for the Internet of Things
First Release	1999	2005
Supported Platforms (in official distributions)	17	26
Community Support & Forums	Yes	Yes
Programming Language	nesC	C
Single / Multiple Thread	Single (multithread is optional)	Single (multithread – explicitly defined library)
Structure	Component-based	Protothreads
Simulator / Emulator	TOSSIM (python)	Cooja / MSPSIm Emulator (java)
OTAP	Yes	Yes
Protocol Stack	(802.15.4) MAC (not fully supported) Collection Tree 6LoWPAN	(802.15.4) MAC (not fully supported) Radio Duty Cycle & MAC RIME / uIP 6LoWPAN
	Great flexibility in generating highly customizable protocol stack	With default distribution: RIME or 6LoWPAN (modifiable)
Interfacing with host (Serial Communication)	Specific format (ActiveMessageC)	Flexible (but provides tools s.a. SLIP)
Documentation*	☹ ☹ ☹	☹
Debugging experience*	☹ ☹ ☹☹ ☹ ☹ ☹ ☹ ☹ ☹ ☹ ☹	☹ ☹

WSN Programming

TinyOS

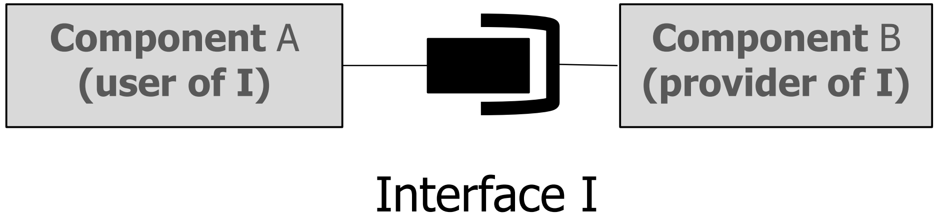
- Component-based architecture, implementing one single stack
- Event-based, non-blocking design that allows intra-mote concurrency
- Written in NesC
  - Structured, component-based C-like programming language

Programming Model:

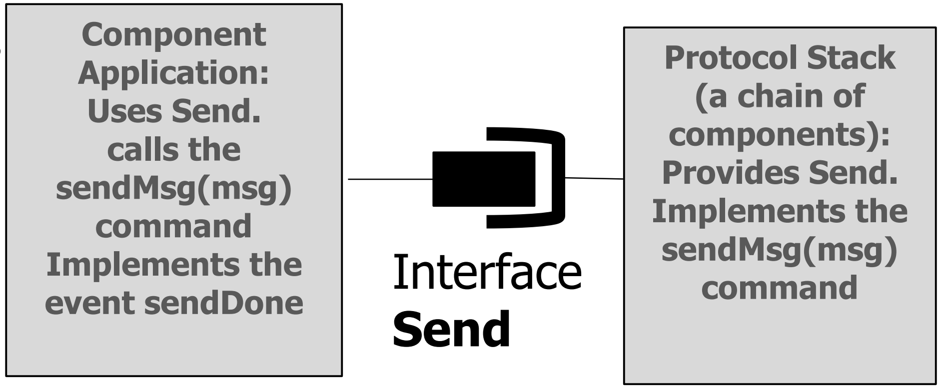
- ***Components:*** encapsulate state and processing – use or provide interfaces
- ***Interfaces*** list commands and events
- ***Configurations*** wire components together

WSN Programming

Two components are wired via interfaces.



e.g.



Components are statically linked to kernel (not reconfigurable after compiling)

The kernel is a chain of components interacting via interfaces

Interface:
The set of functions (*events* and *commands*).
Commands: the user component **may** use and the provider component **must** define and implement.
Events: the provider component **must** define and **may** implement and the user component **must** implement.

GoTo- flow

WSN Programming

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Sequential flow control while keeping a single stack

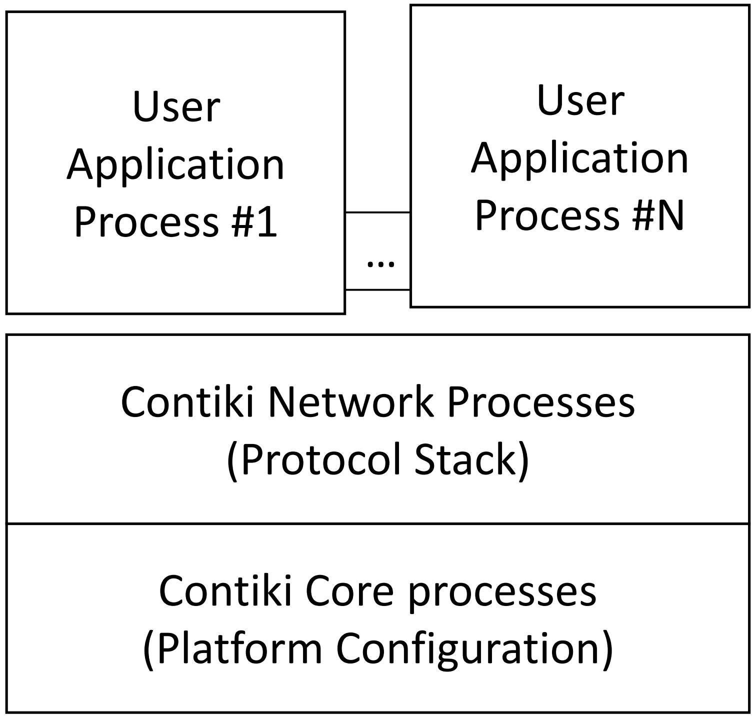
[11-12]

Event-based → Invoking processes (non-blocking)

Using protothreads: a programming abstraction that combines events and threads

Single stack and sequential flow control

Posting events or polling



WSN Programming

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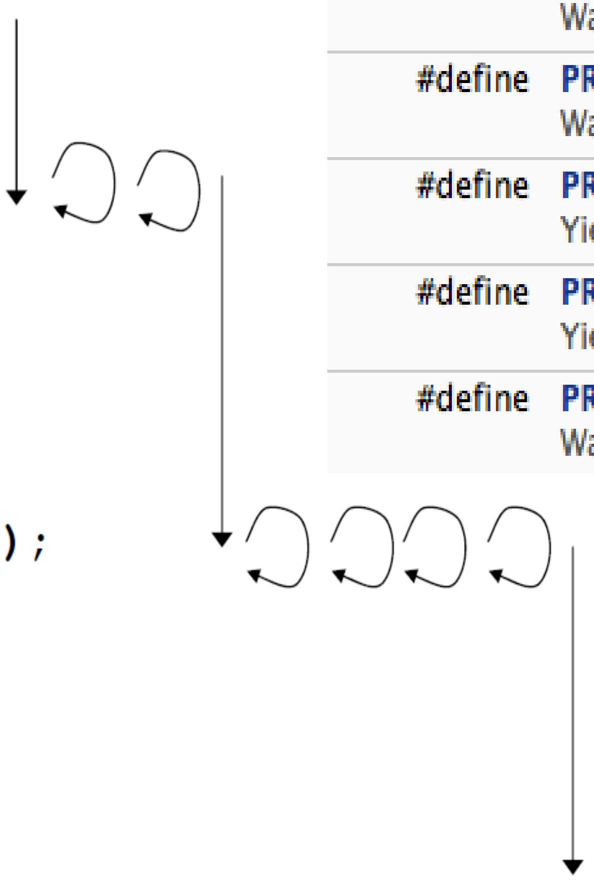
[29]

```
int a_protothread(struct pt *pt) {
  PT_BEGIN(pt);

  /* … */

  PT_WAIT_UNTIL(pt, condition1);

  /* … */

  if(something) {

    /* … */

    PT_WAIT_UNTIL(pt, condition2);

    /* … */

  }

  PT_END(pt);
}
```



Each process is essentially a protothread

#define	PROCESS_WAIT_EVENT() Wait for an event to be posted to the process.
#define	PROCESS_WAIT_EVENT_UNTIL(c) Wait for an event to be posted to the process, with an extra condition.
#define	PROCESS_YIELD() Yield the currently running process.
#define	PROCESS_YIELD_UNTIL(c) Yield the currently running process until a condition occurs.
#define	PROCESS_WAIT_UNTIL(c) Wait for a condition to occur.

WSN Programming

Hello-world in WSN programming.

A Blinking-Led Application

- Program a mote to blink a led every T seconds.

```
configuration BlinkAppC
{
}
implementation
{
  components MainC, BlinkC, LedsC;
  components new TimerMilliC() as Timer0;
  components new TimerMilliC() as Timer1;
  components new TimerMilliC() as Timer2;


  BlinkC -> MainC.Boot;

  BlinkC.Timer0 -> Timer0;
  BlinkC.Timer1 -> Timer1;
  BlinkC.Timer2 -> Timer2;
  BlinkC.Leds -> LedsC;
}
```

```
#include "Timer.h"

module BlinkC @safe()
{
  uses interface Timer<TMilli> as Timer0;
  uses interface Timer<TMilli> as Timer1;
  uses interface Timer<TMilli> as Timer2;
  uses interface Leds;
  uses interface Boot;
}
implementation
{
  event void Boot.booted()
  {
    call Timer0.startPeriodic( 250 );
    call Timer1.startPeriodic( 500 );
    call Timer2.startPeriodic( 1000 );
  }

  event void Timer0.fired()
  {
    dbg("BlinkC", "Timer 0 fired @ %s.\n", sim_time_string());
    call Leds.led0Toggle();
  }

  event void Timer1.fired()
  {
    dbg("BlinkC", "Timer 1 fired @ %s \n", sim_time_string());
    call Leds.led1Toggle();
  }

  event void Timer2.fired()
  {
    dbg("BlinkC", "Timer 2 fired @ %s.\n", sim_time_string());
    call Leds.led2Toggle();
  }
}
```

Contiki

The Open Source OS for the Internet of Things

One main.c for each platform: Core & Network processes

```
process_init();
 process_start(&etimer_process, NULL);

 ctimer_init();

 init_platform();

 set_rime_addr();

//----------------------low level api to phy-------------------------
 cc2420_init();
 {
   uint8_t longaddr[8];
   uint16_t shortaddr;

   shortaddr = (rimeaddr_node_addr.u8[0] << 8) +  rimeaddr_node_addr.u8[1];
   memset(longaddr, 0, sizeof(longaddr));
   rimeaddr_copy((rimeaddr_t *)&longaddr, &rimeaddr_node_addr);

   cc2420_set_pan_addr(IEEE802154_PANID, shortaddr, longaddr);
 }
 cc2420_set_channel(RF_CHANNEL);
memcpy(&uip_lladdr.addr, ds2411_id, sizeof(uip_lladdr.addr));

queuebuf_init();
 NETSTACK_RDC.init();
 NETSTACK_MAC.init();
```

```
#include "contiki.h"
#include "dev/leds.h"

#include <stdio.h> /* For printf() */
/
*-----------------------------------------------------------------
-----------*/
/* We declare the process */
PROCESS(blink_process, "LED blink process");

/* We require the processes to be started automatically */
AUTOSTART_PROCESSES(&blink_process);
/
*-----------------------------------------------------------------
-----------*/
/* Implementation of the process */
PROCESS_THREAD(blink_process, ev, data)
{
    static struct etimer timer;
    PROCESS_BEGIN();

    while (1)
    {
        /* we set the timer from here every time */
        etimer_set(&timer, CLOCK_CONF_SECOND);

        /* and wait until the event we receive is the one we're
waiting for */
        PROCESS_WAIT_EVENT_UNTIL(ev == PROCESS_EVENT_TIMER);

        printf("Blink... (state %0.2X).\r\n", leds_get());
        /* update the LEDs */
        leds_toggle(LEDS_GREEN);
    }
    PROCESS_END();
}
/
```

WSN Programming

The communication layers in Contiki [29-31]

- The uIP TCP/IP stack
  - Lightweight TCP/IP functionalities for low complexity µControllers
  - A single network interface (IP, ICMP, UDP,TCP)
  - Compliant to RFC but the Application layer is responsible for handling retransmissions (reduce memory requirements)

- The Rime protocol stack
  - A set of communication primitives (keeping pck headers and protocol stacks separated)
  - A pool of NWK protocols for ad-hoc networking
  - Best-effort anonymous broadcast to reliable multihop flooding and tree protocols

WSN Programming

Contiki

The Open Source OS for the Internet of Things

How does Rime work

- Rime is a software trick
- A stack of NWK layers
- Each layer is associated with a channel
- 2KB memory footprint
- Interoperability and ease in changing the protocol stack

MAC Payload			
2 Bytes	1 Bytes	N - M Bytes	M Bytes
Length N (Rime Header + Payload) + 1	Channel Number	Rime Header	Payload

WSN Programming

How does Rime work – Example

- The Collection Tree Protocol (CTP)
  - Tree-based hop-by-hop reliable data collection
  - Large-scale network (e.g. environmental or industrial monitoring)
- Reliable Unicast Bulk
  - Event-driven data transmission of a large data volume
  - Personal health-care

WSN Programming

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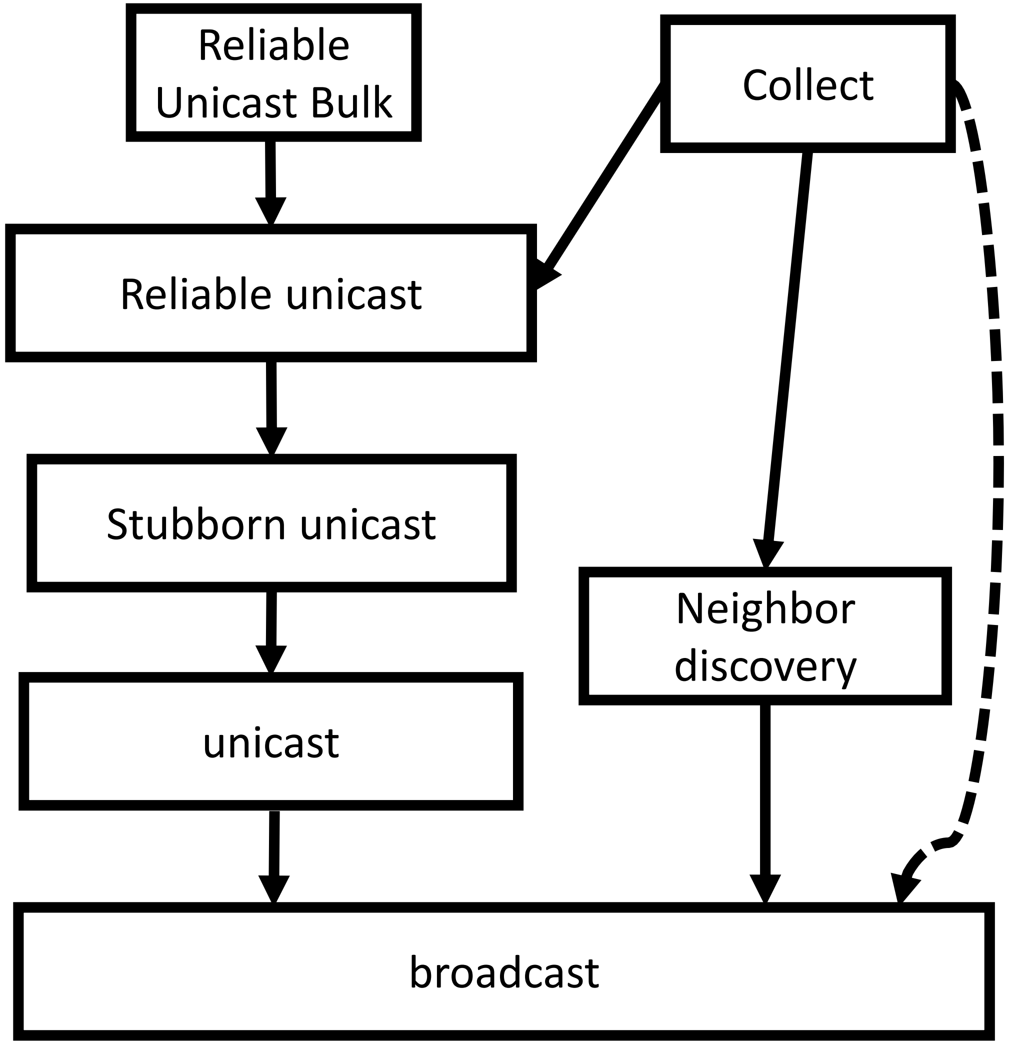
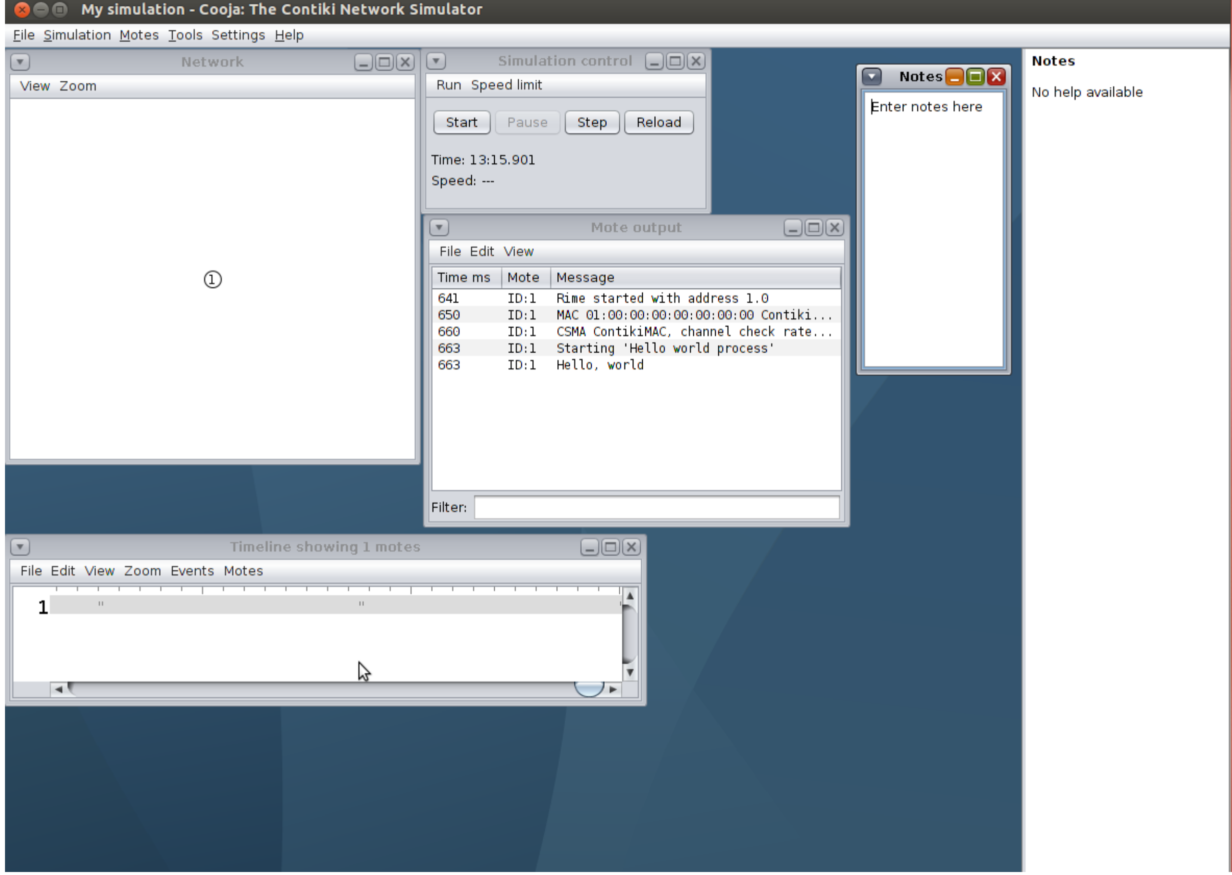
Layer	Description	Channel	Contribution to Rime Header
Broadcast	Best-effort local area broadcast	129	Sender ID
Neighbor discovery	Periodic Neighbor Discovery mechanism	2	Receiver ID, Application Channel
Unicast	Single-hop unicast to an identified single-hop neighbor	146	Receiver ID
Stubborn unicast	Repeatedly sends a packet until cancelled by upper layer		Receiver ID
Reliable Unicast	Single-hop reliable unicast (ACKs and retransmissions)	144	Packet Type and Packet ID



WSN Programming

- Cooja
  - The Contiki emulator for running WSN applications.
  - Very useful for debugging your codes – the same code you test on cooja, the same you upload to your mote
  - Evaluating the network performance (?) – has very simplifying models for radio propagation….
    - Unit disk model: Edges are instantly configured according to power attenuation w.r.t to distance & success ratio (configurable)
    - Directed graph radio medium: Considers preconfigured edges, without checking the output power.
    - Multipath ray tracer: Simulates reflection and diffraction through homogeneous obstacles (considers that all nodes have the same transmission power)



Outline

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- Part 2: WSN Programming
  - WSN Core and types of nodes
  - Real-time Operating Systems
  - **Examples & Hands on Session**

Hands on Session

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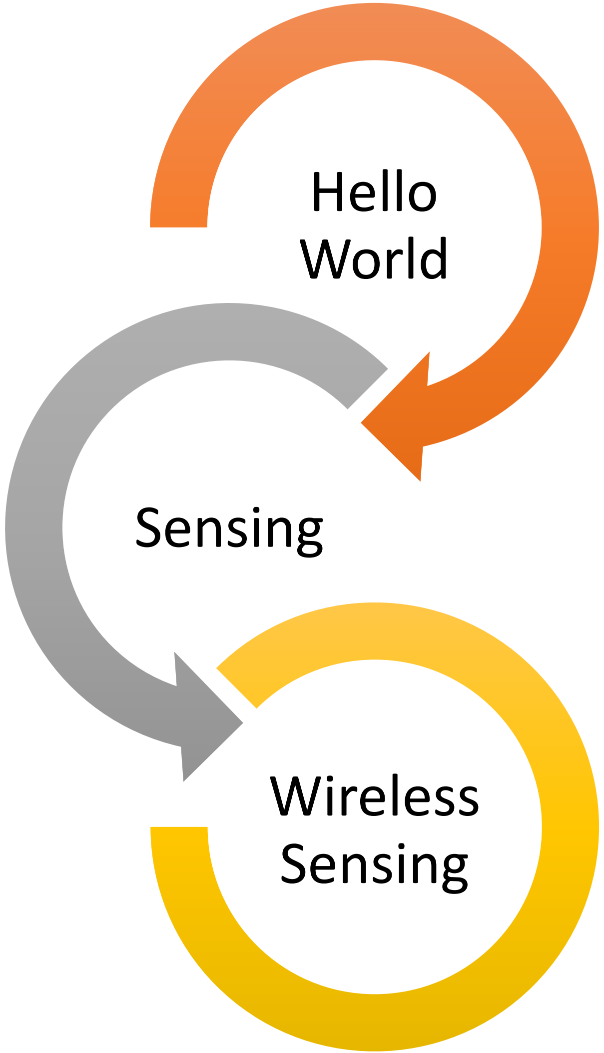
What we are going to do…



Hands on Session

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What we are going to use…in order to upload code to the motes

- FTDI drivers (for Windows machines only) – USB2Serial
- How the host computer reserves a mote:
  - COM<No> (Windows – Device Manager)
  - /dev/ttyUSB<No> (Linux) [**cat /var/log/syslog**]
  - Make sure that you have access on device (for programming it)
    chmod 777 /dev/ttyUSB0
  - Serial dump: make TARGET=sky MOTES=**/dev/ttyUSB0** login

Hands on Session at Cooja

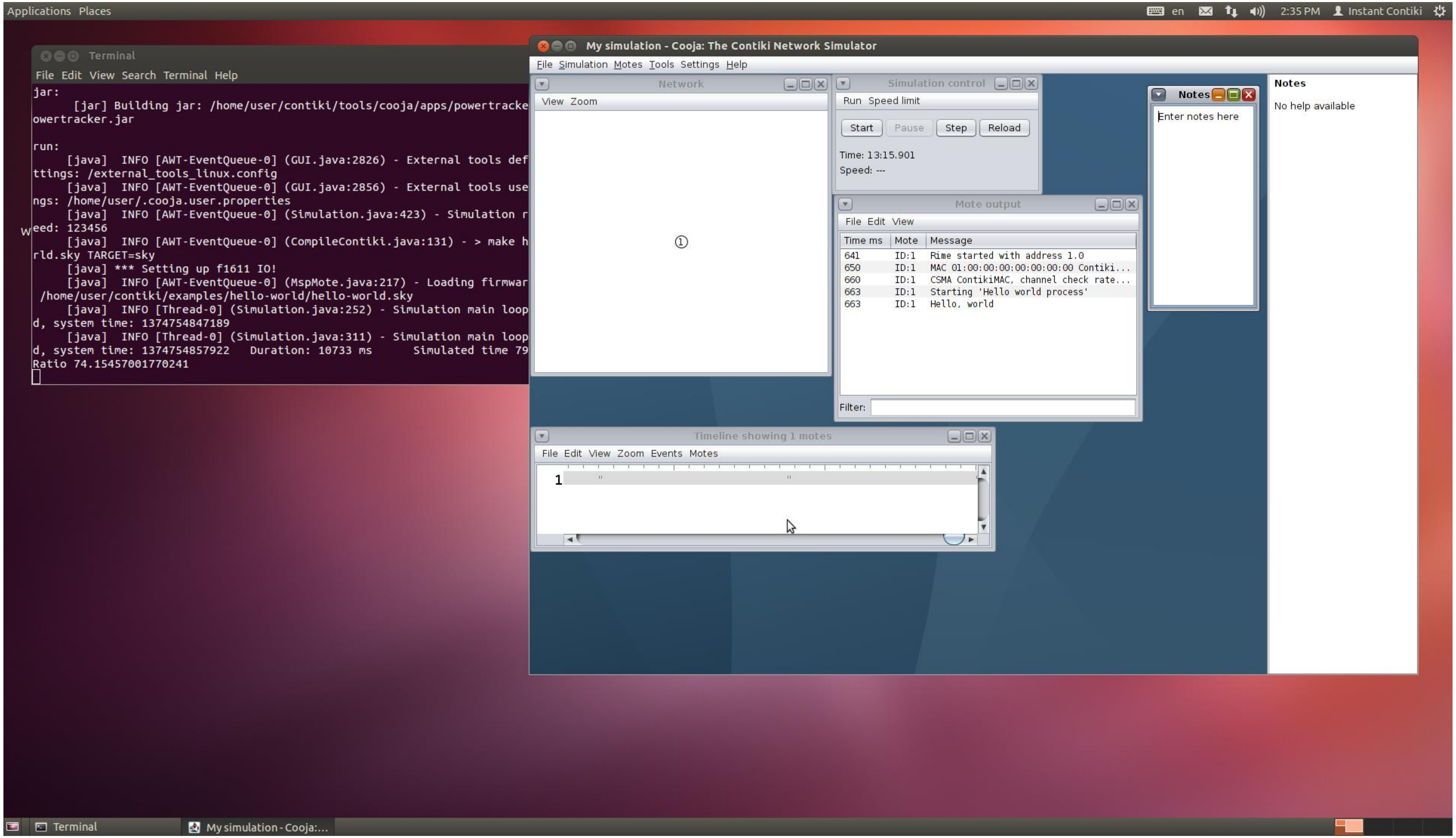
- Cooja (for emulating the motes behavior)

  Guidelines for running the codes at Cooja:

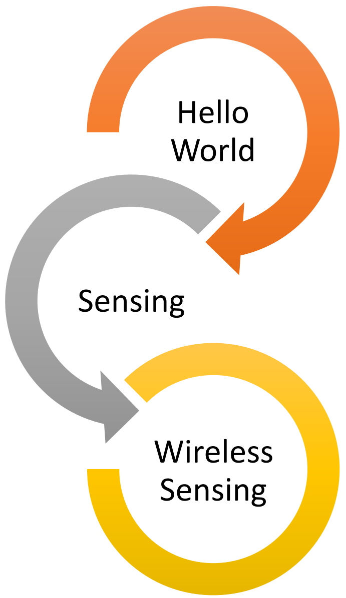
  1. From your VM / Instant Contiki run the “cooja” application
  2. Follow the instructions given at: http://www.contiki-os.org/start.html (step 3) for creating a new simulation

     Select “**sky**” as the mote type
  3. The result of the printf is shown at the “**Mote Output**” view

Hands on Session at Cooja



Hands on Session



Hello World ☺ contiki/examples/hello-world

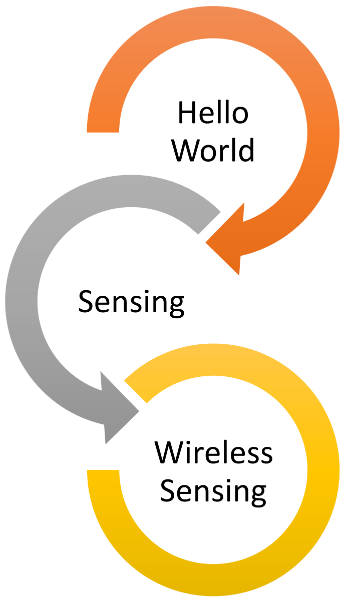
[Code structure & compile]

Hello-world.c

```
#include "contiki.h"

#include <stdio.h> /* For printf() */
/*---------------------------------------------------------------------------*/
PROCESS(hello_world_process, "Hello world process");   /**Process definition**/
AUTOSTART_PROCESSES(&hello_world_process);     /**Process Start**/
/*---------------------------------------------------------------------------*/
PROCESS_THREAD(hello_world_process, ev, data) /**Process implementation**/
{
  PROCESS_BEGIN(); /**Always first**/

  printf("Hello, world\n"); //process core

  PROCESS_END();  /**Always last**/
}
/*---------------------------------------------------------------------------*/
```

```
CONTIKI_PROJECT = hello-world
all: $(CONTIKI_PROJECT)


CONTIKI = ../..
include $(CONTIKI)/Makefile.include
```

Hands on Session



Hello World ☺ contiki/examples/hello-world
[Code structure & compile]

Program:

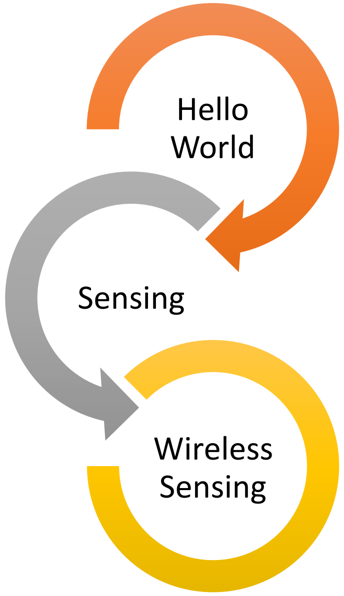
1. Open command terminal.
2. cd contiki/examples/hello-world
3. **make TARGET=<platform*> hello-world.upload** (compile and program)

Serial Dump

1. At new tab (File/Open new tab).
2. make TARGET=sky MOTES=**/dev/ttyUSB0** login

*sky/xm1000

Hands on Session



Hello World ☺ contiki/examples/hello-world

[How to trigger a process]

- How to wake up from a process

#define	PROCESS_WAIT_EVENT() Wait for an event to be posted to the process.
#define	PROCESS_WAIT_EVENT_UNTIL(c) Wait for an event to be posted to the process, with an extra condition.
#define	PROCESS_YIELD() Yield the currently running process.
#define	PROCESS_YIELD_UNTIL(c) Yield the currently running process until a condition occurs.
#define	PROCESS_WAIT_UNTIL(c) Wait for a condition to occur.

Keep on mind that:

Automatic variables not stored across a blocking wait

When in doubt, use static local variables

Hands on Session

Hello World ☺ contiki/examples/he

[How to trigger a process]

- Timers

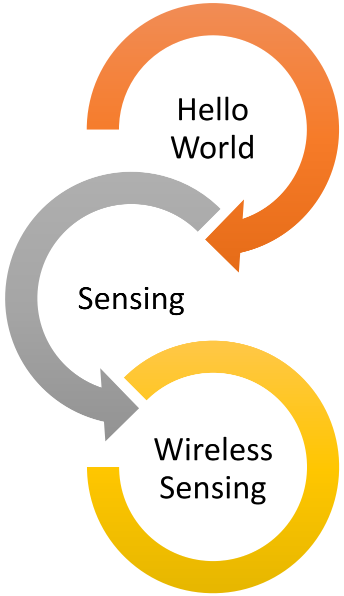
  - Event timer (etimer) : Sends an event when expired

  - Callback timer (ctimer) : Calls a function when expired – used by Rime

void	etimer_set (struct etimer *et, clock_time_t interval) Set an event timer.
void	etimer_reset (struct etimer *et) Reset an event timer with the same interval as was previously set.
void	etimer_restart (struct etimer *et) Restart an event timer from the current point in time.
void	etimer_adjust (struct etimer *et, int td) Adjust the expiration time for an event timer.
int	etimer_expired (struct etimer *et) Check if an event timer has expired.
clock_time_t	etimer_expiration_time (struct etimer *et) Get the expiration time for the event timer.
clock_time_t	etimer_start_time (struct etimer *et) Get the start time for the event timer.
void	etimer_stop (struct etimer *et) Stop a pending event timer.

void	ctimer_set (struct ctimer *c, clock_time_t t, void(*f)(void *), void *ptr) Set a callback timer.
void	ctimer_reset (struct ctimer *c) Reset a callback timer with the same interval as was previously set.
void	ctimer_restart (struct ctimer *c) Restart a callback timer from the current point in time.
void	ctimer_stop (struct ctimer *c) Stop a pending callback timer.
int	ctimer_expired (struct ctimer *c) Check if a callback timer has expired.

Hands on Session



Hello World ☺ contiki/examples/hello-world

[How to trigger a process]

From hello-world.c generate a new application (print-and-blink.c) that:

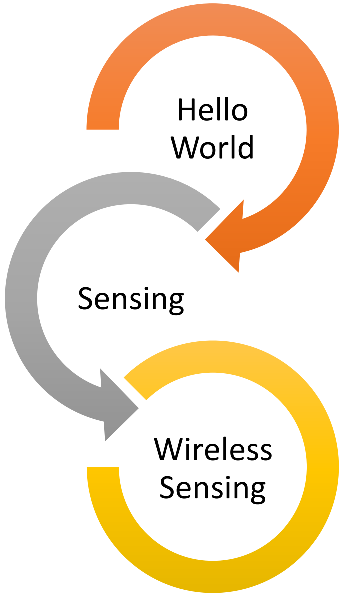
1. periodically (e.g. per second) prints a message.
2. when the message is printed a led toggles

#include “leds.h”

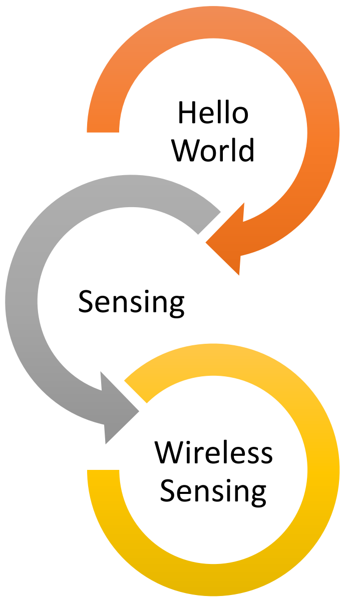
leds_toggle(LEDS_RED / LEDS_GREEN / LEDS_YELLOW)

macro for time: **CLOCK_SECOND**

```
/*---------------------------------------------------------------------------*/
PROCESS(print_and_blink_process, ”Print and blink process");
AUTOSTART_PROCESSES(&print_and_blink_process);
/*---------------------------------------------------------------------------*/
PROCESS_THREAD(print_and_blink_process, ev, data)
{
static struct etimer et;

PROCESS_BEGIN(); /**Always first**/

while(1) {

etimer_set(&et, CLOCK_SECOND);

PROCESS_WAIT_EVENT_UNTIL(etimer_expired(&et));

printf(“Echo\n”);

leds_toggle(LEDS_GREEN);

}


  PROCESS_END();  /**Always last**/
}
```



Hands on Session



Sensing ☺ contiki/examples/hello-world
[Access a sensor]

- Sensor: supported by contiki (platform/dev/<platform>)

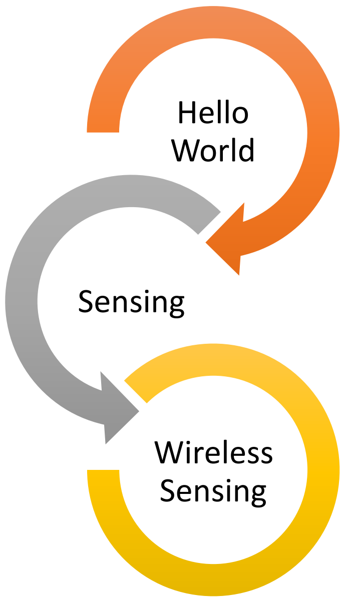
- **const struct sensors_sensor**
  - **@sky: sht11_sensor.value(type) --global**
  //type = SHT11_SENSOR_TEMP, SHT11_SENSOR_HUMIDITY

  light_sensor.value(type) --global
  //type = LIGHT_SENSOR_TOTAL_SOLAR, LIGHT_SENSOR_PHOTOSYNTHETIC

  battery_sensor.value(type) –global
  //type = 0

- ACTIVATE / DEACTIVE (<sensors_sensor>)

Hands on Session



Sensing ☺ contiki/examples/hello-world

[Access a sensor]

From the print-and-blink, generate a new application (sense-and-blink.c) that:

1. Periodically sample one or more of the on-board sensors

#include "dev/light-sensor.h” / "dev/sht11-sensor.h” / "dev/battery-sensor.h”

SENSORS_ACTIVATE(<>)

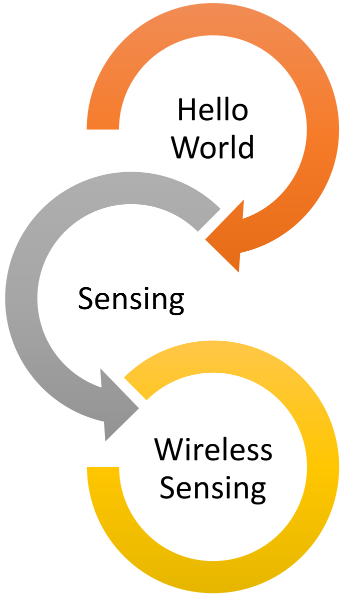
[Sample…]

SENSORS_DEACTIVATE(<>)

2. When done prints the sampled value and toggles a led

Command for serial dump: make TARGET=sky MOTES=**/dev/ttyUSB0** login

Hands on Session



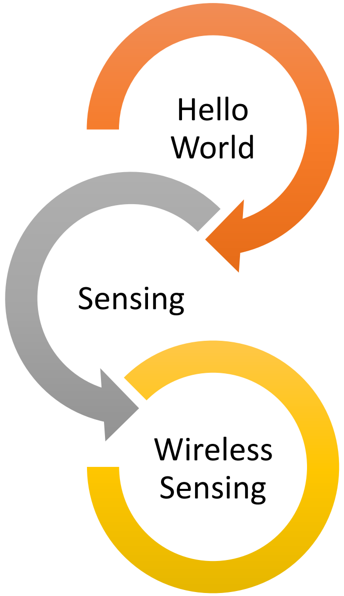
1 process

```
struct sensor_datamsg{

        uint16_t temp;
        uint16_t humm;
        uint16_t batt;

}sensor_datamsg;


PROCESS_THREAD(sense_and_blink_process, ev, data)
{
        static struct etimer et;
        static struct sensor_datamsg msg;

        PROCESS_BEGIN(); /**Always first**/

        SENSORS_ACTIVATE(sht11_sensor);
        SENSORS_ACTIVATE(battery_sensor);

while (1) {

etimer_set(&et, CLOCK_SECOND);
PROCESS_WAIT_EVENT_UNTIL(etimer_expired(&et));

msg.temp= sht11_sensor.value(SHT11_SENSOR_TEMP);
msg.humm = sht11_sensor.value(SHT11_SENSOR_HUMIDITY);
msg.batt = battery_sensor.value(0);


printf("Sensor raw values: temperature:%d, humidity: %d, battery: %d\n", msg.temp, msg.humm, msg.batt);
leds_toggle(LEDS_GREEN);



}

        SENSORS_DEACTIVATE(sht11_sensor);
        SENSORS_DEACTIVATE(battery_sensor);
PROCESS_END(); /**Always last**/
}
```

2 processes

```
PROCESS(sense_process, "Sense process");
PROCESS(print_and_blink_process, "Print and blink process");
AUTOSTART_PROCESSES(&sense_process, &print_and_blink_process);


static struct sensor_datamsg msg;
static process_event_t event_data_ready;

PROCESS_THREAD(sense_process, ev, data)
{

        PROCESS_BEGIN(); /**Always first**/

        SENSORS_ACTIVATE(sht11_sensor);
        SENSORS_ACTIVATE(battery_sensor);

        while (1) {
                ...
                process_post(&print_and_blink_process,event_data_ready, &msg);


        }
        PROCESS_END(); /**Always last**/

}
/*---------------------------------------------------------------------------*/
PROCESS_THREAD(print_and_blink_process, ev, data)
{


PROCESS_BEGIN(); /**Always first**/

while (1) {

        PROCESS_YIELD_UNTIL(ev==event_data_ready);
        printf("Sensor raw values: temperature:%d, humidity: %d, battery: %d\n", msg.temp, msg.humm, msg.batt);
        leds_toggle(LEDS_GREEN);

}
PROCESS_END(); /**Always last**/
}
```

Hands on Session



Wireless Sensing ☺ contiki/examples/hello-world

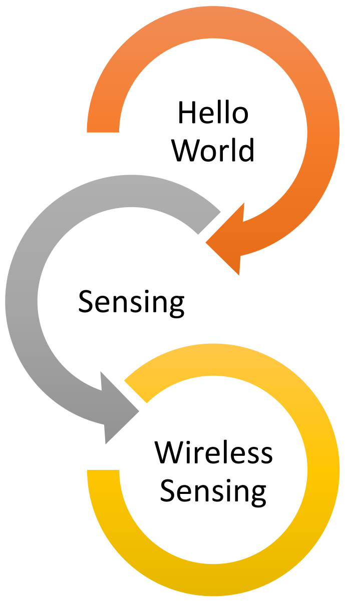
[Access a sensor & trx]

Communication:

- Each type of connection (rime / uIP / 6LoWPAN) defines a structure
- Each type of rime connection defines a struct for the callback function (rx events).

  Callback function has to have a specific definition…
- Each rime-based connection is associated with a predefined channel (>128)

Hands on Session



Wireless Sensing ☺ contiki/examples/hello-world
[Access a sensor & trx]

@ rime:

- packetbuf module for packet buffer management
- Struct rimeaddr_t for rime addressing…

```
typedef union {
        unsigned char u8[RIMEADDR_SIZE]; //=2
} rimeaddr_t;
```

@ uip:

- uipbuf module for packet buffer management
- Struct ipaddr_t

Unless otherwise specified,
IP=
176.12.RIME_ADDR[0]. RIME_ADDR[1]

The packetbuf module does Rime's buffer management. More...

Files

file	**packetbuf.c** Rime buffer (packetbuf) management.
file	**packetbuf.h** Header file for the Rime buffer (packetbuf) management.

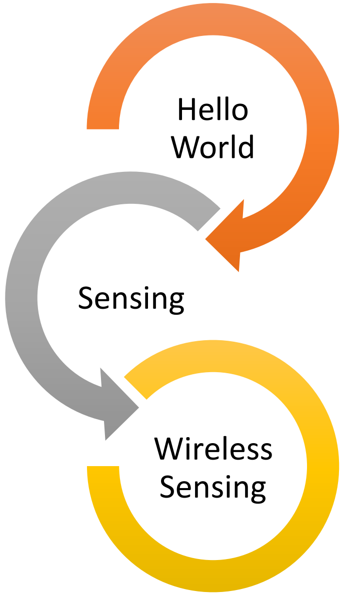
Defines

#define	**PACKETBUF_SIZE** 128 The size of the packetbuf, in bytes.
#define	**PACKETBUF_HDR_SIZE** 48 The size of the packetbuf header, in bytes.

Functions

void	**packetbuf_clear** (void) Clear and reset the packetbuf.
void	**packetbuf_clear_hdr** (void) Clear and reset the header of the packetbuf.
int	**packetbuf_copyfrom** (const void *from, uint16_t len) Copy from external data into the packetbuf.
void	**packetbuf_compact** (void) Compact the packetbuf.
int	**packetbuf_copyto_hdr** (uint8_t *to) Copy the header portion of the packetbuf to an external buffer.
int	**packetbuf_copyto** (void *to) Copy the entire packetbuf to an external buffer.
int	**packetbuf_hdralloc** (int size) Extend the header of the packetbuf, for outbound packets.
int	**packetbuf_hdrreduce** (int size) Reduce the header in the packetbuf, for incoming packets.
void	**packetbuf_set_datalen** (uint16_t len) Set the length of the data in the packetbuf.
void *	**packetbuf_dataptr** (void) Get a pointer to the data in the packetbuf.
void *	**packetbuf_hdrptr** (void) Get a pointer to the header in the packetbuf, for outbound packets.
void	**packetbuf_reference** (void *ptr, uint16_t len) Point the packetbuf to external data.
int	**packetbuf_is_reference** (void) Check if the packetbuf references external data.
void *	**packetbuf_reference_ptr** (void) Get a pointer to external data referenced by the packetbuf.
uint16_t	**packetbuf_datalen** (void) Get the length of the data in the packetbuf.
uint8_t	**packetbuf_hdrlen** (void) Get the length of the header in the packetbuf, for outbound packets.
uint16_t	**packetbuf_totlen** (void) Get the total length of the header and data in the packetbuf.

Hands on Session



Wireless Sensing ☺ contiki/examples/hello-world

[Access a sensor & trx]

From the sense-and-tx, generate a new application (sense-and-trx.c) that:

1. Periodically samples from on-board temperature sensor
2. When done broadcast the value
3. Upon the reception of a incoming packet, print its contents and the source node id

#include net/rime.h

static const struct broadcast_callbacks broadcast_call = {broadcast_recv}; -- visible outside process

Defined as: static void broadcast_recv(struct broadcast_conn *c, const rimeaddr_t *from)

static struct broadcast_conn broadcast; -- visible outside process

Inside process:

broadcast_open(&broadcast, 129, &broadcast_call); --connection -- **129: the broadcast rime channel**

packetbuf_copyfrom(const void *data, data length); --form tx buffer

broadcast_send(&broadcast); -- send to connection

Hands on Session

Send

```
PROCESS_THREAD(send_and_blink_process, ev, data)
{

static uint8_t data2send[sizeof(sensor_datamsg)];

PROCESS_EXITHANDLER(broadcast_close(&broadcast);)

PROCESS_BEGIN(); /**Always first**/

broadcast_open(&broadcast, 129, &broadcast_call);

while (1) {

        PROCESS_YIELD_UNTIL(ev==event_data_ready);


        data2send[0] = msg.temp & 255;//lsb
        data2send[1] = msg.temp >> 8;//msb

        data2send[2] = msg.humm & 255;
        data2send[3] = msg.humm >> 8;

        data2send[4] = msg.batt & 255;
        data2send[5] = msg.batt >> 8;

        packetbuf_copyfrom(data2send,sizeof(sensor_datamsg));
        broadcast_send(&broadcast);
        //printf("Sensor raw values: temperature:%d, humidity: %d, battery: %d\n", msg.temp, msg.humm, msg.batt);
        leds_toggle(LEDS_GREEN);

}
PROCESS_END(); /**Always last**/
}
```

Receive

```
static void
broadcast_recv(struct broadcast_conn *c, const rimeaddr_t *from)
{

uint8_t *appdata;
        int i;

        appdata = (uint8_t *)packetbuf_dataptr();

 printf("Data recv:[");
        for (i=0;i<packetbuf_datalen();i++)
        {
                        printf("%u ",appdata[i]);

        }


         //this is the id of the sender (as defined in compile time).
        printf("], from: %d.%d\n",from->u8[0], from->u8[1]);
        printf("\n");

}
```

References

1. http://en.wikipedia.org/wiki/List_of_wireless_sensor_nodes
2. www.advanticsys.com
3. www.shimmersensing.com
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5. http://www.libelium.com/products/waspmote/overview/
6. www.digi.com/xbee
7. http://www.nanork.org/projects/nanork/wiki
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9. www.tinyos.net
10. www.contiki-os.org
11. http://www.ee.kth.se/~mikaelj/wsn_course.shtml
12. http://contiki.sourceforge.net/docs/2.6/index.html