POLITECNICO
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ANTLAB

Internet of Things Lab

Lab 6: TinyOS (2)

Agenda

- Using the Radio in TinyOS
- TOSSIM simulation
- Advanced Examples
- **Challenge 2**

Using the Radio

Creating/Sending/Receiving/Manipulating Messages

General Idea

SENDER

Fill Message → Specify Destination → Pass Message to OS → Wait For FeedBack

RECEIVER

OS Stores Message → OS signal Msg Reception → Pass Message to Applications → Read Data

Message Buffer Abstraction

- In tos/types/messages.h

```
typedef nx_struct message_t {
        nx_uint8_t header[sizeof(message_header_t)];
        nx_uint8_t data[TOSH_DATA_LENGTH];
        nx_uint8_t footer[sizeof(message_header_t)];
        nx_uint8_t metadata[sizeof(message_metadata_t)];
} message_t;
```

- Header, footer, metadata: already *implemented* by the specific link layer
- Data: *handled* by the application/developer

Message.h file

```
#ifndef FOO_H
#define FOO_H

typedef nx_struct FooMsg {
      nx_uint16_t field1;
      nx_uint16_t field2;
      ….
      nx_uint16_t field_N;
   } FooMsg;

enum { FOO_OPTIONAL_CONSTANTS = 0 };

#endif
```

Interfaces

- Components above the basic data-link layer MUST always access packet fields through interfaces (in /tos/interfaces/).

- Messages interfaces:
  - AMPacket/Packet: manipulate packets
  - AMSend
  - Receive
  - PacketAcknowledgements (Acks)

Communication stack

- Active Message (AM) TinyOS communication technology
  - Include the communication protocol to send and receive packets
  - Each Packet is characterized by an AM Type:
    - Similar to a UDP port

Communication stack

- message_t structure:
  - Packet are represented by a message_t structure
  - To access message_t fields is must be used Packet and AMPacket interfaces:

```
interface Packet {
      command uint8_t payloadLength(message_t* msg);
      command void* getPayload(message_t* msg, uint8_t len);
      ...
}
interface AMPacket {
      command am_addr_t address();
      command am_addr_t destination(message_t* amsg);
      ...
}
```

Sender Component

AMSenderC.nc

```
generic configuration AMSenderC(am_id_t id)
{
   provides {
      interface AMSend;
      interface Packet;
      interface AMPacket;
      interface PacketAcknowledgements as Acks;
   }
}
```

Receiver Component

AMReceiverC.nc

```
generic configuration AMReceiverC(am_id_t id)
{
   provides{
      interface Receive;
      interface Packet;
      interface AMPacket;
   }
}
```

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SplitControl Interface

- Radio needs to be activated prior to be used.
  - To turn on the radio, use the split-operation start/startDone
  - To turn off the radio use the split-operation stop/stopDone

- ActiveMessageC create the communication stack on evry specific architecture
  - AMSenderC component to send messages
  - AMReceiverC component to receive messages

Example 2 – RadioCountToLeds

Create an application that counts over a timer and broadcast the counter in a wireless packet.

What do we need?

- Header File: to define message structure (RadioCountToLeds.h)
- Module component: to implement interfaces (RadioCountToLedsC.nc)
- Configuration component: to define the program graph, and the relationship among components (RadioCountToLedsAppC.nc)

Message Structure

- Message structure in RadioCountToLeds.h file

```
typedef nx_struct radio_count_msg_t {
   nx_uint16_t counter;  //counter value
} radio_count_msg_t;

enum {
   AM_RADIO_COUNT_MSG = 6, TIMER_PERIOD_MILLI = 250
};
```

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Module Component

1. Specify the interfaces to be used
2. Define support variables
3. Initialize and start the radio
4. Implement the core of the application
5. Implement all the events of the used interfaces

Module Component

- Define the interfaces to be used:

```
module RadioCountToLedsC
{
    uses interface Packet;
    uses interface AMSend;
    uses interface Receive;
    uses interface SplitControl as AMControl;
}
```

Packet Manipulation Interfaces

Control interface

- Define some variables:

```
implementation {
    message_t packet;
    bool locked; ...
}
```

Local Variables

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Initialize and Start the Radio

Events to report Interface Operation

```
event void Boot.booted() {
   call AMControl.start();
}


event void AMControl.startDone(error_t err) {
   if (err == SUCCESS) {
      call MilliTimer.startPeriodic(TIMER_PERIOD_MILLI );
   }
   else {
      call AMControl.start();
   }
}

event void AMControl.stopDone(error_t err) { }
```

Implement the Application Logic

```
event void MilliTimer.fired() {
    ...
    if (!locked) {
    radio_count_msg_t* rcm = (radio_count_msg_t*)call
    Packet.getPayload(&packet, sizeof(radio_count_msg_t));

    rcm->counter = counter;

    if (call AMSend.send(AM_BROADCAST_ADDR, &packet,
    sizeof(radio_count_msg_t)) == SUCCESS) {
       locked= TRUE; }
    }
}
```

Create and set Packet

Send Packet

Implement Events of Used Interfaces

```
event void AMSend.sendDone(message_t* msg, error_t error
{
   if (&packet == msg) {
      loked = FALSE;
   }
}
```

Must implement the events referred to all the interfaces of used components.

What about Receiving?

- We need a Receive interface

```
uses interface Receive;
```

- We need to implement an event Receive handler

```
event message_t* Receive.receive(message_t* msg, void*
   payload, uint8_t len) {
   if (len == sizeof(radio_count_msg_t)) {
      radio_count_msg_t* rcm= (radio_count_msg_t*)payload;
      call Leds.set(rcm->counter);
   }
   return msg;
}
```

- We need to modify the configuration component

```
implementation {
   ... components new AMReceiverC(AM_RADIO_COUNT_MSG); ... }
implementation {
   ... App.Receive -> AMReceiverC; ... }
```

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Configuration File

```
implementation {

   ...
   components ActiveMessageC;
   components new AMSenderC(AM_RADIO_COUNT_MSG);

   ...

   App.Packet -> AMSenderC;
   App.AMSend -> AMSenderC;
   App.AMControl -> ActiveMessageC;
   ...

}
```

RadioCountToLeds

- Let’s have a look at the files (RadioCountToLeds project)
- Let’s see how it works
- Let’s try to turn off a device

- Can you do that in Cooja?

Message Destination

- AM_BROADCAST_ADDR: for broadcast messages

  call AMSend.send(AM_BROADCAST_ADDR, &packet, sizeof(radio_count_msg_t))

Message will be handled by all receivers

- mote id: for unicast messages (e.g., 1,2 …)

  call AMSend.send(1, &packet, sizeof(radio_count_msg_t))

Message will be handled only by mote 1, even if other motes are in range

Get current mote ID

- In some cases can be useful to get the mote ID used in the simulation
- The mote ID is store in the macro **TOS_NODE_ID**

- e.g.: Program motes with different behaviours, based on mote ID

```
if ( TOS_NODE_ID == 1 ) {
    //do stuff for mote 1
 }
 else if ( TOS_NODE_ID ==2){
    // do stuff for mote 2
 }
 else{
    //stuff for other motes
 }
```

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TinyOS SIMulator

Simulate a Wireless Sensor Network with TOSSIM

Motivations

- WSN require large scale deployment
- Located in inaccessible places
- Apps are deployed only once during network lifetime
- Little room to re-deploy on errors

System Evaluation

- Check correctness of application behavior

- Sensors are hard to debug!
  - "… prepare to a painful experience" [Tinyos authors' own words]

Simulation: Pros and Cons

- Advantages
  - Study system in controlled environment
  - Observe interactions difficult to capture live
  - Helps in design improvement
  - Cost effective alternative

- Disadvantages
  - May not represent accurate real-world results
  - Depends on modeling assumptions

TOSSIM General Concepts

- TOSSIM is a discrete event simulator
- It uses the same code that you use to program the sensors
- There are two programming interfaces supported: Python and C++

Key Requirements

- Scalability
  - Large deployments (10^3 motes)
- Completeness
  - Cover as many interactions as possible
  - Simulate complete applications
- Fidelity
  - Capture real-world interactions
  - Reveal unexpected behavior
- Bridging
  - Between algorithm and implementation

Example: RadioToss

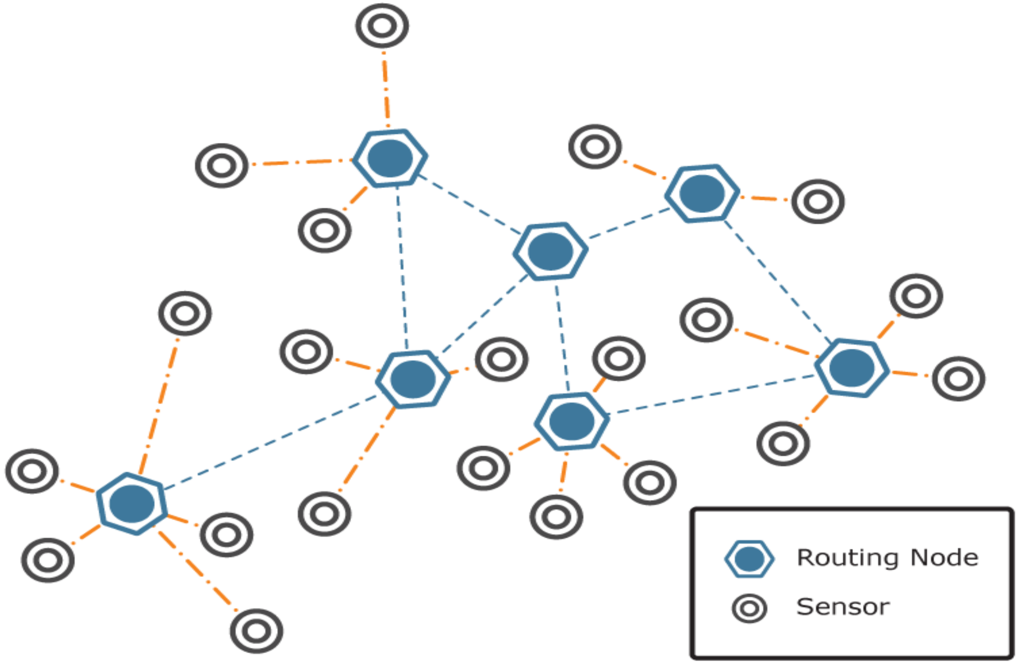
- Let's simulate the RadioCountToLeds example with Tossim
- The updated code is in the folder RadioToss
- Behaviour:
  - Send a BROADCAST message with a counter
  - Turn on/off the LEDs according to the counter

TOSSIM Files

- TinyOS Project files:
  - RadioTossC.nc
  - RadioTossAppC.nc
  - RadioToss.h
- Topology file: topology.txt
- Noise file: meyer-heavy.txt
- Simulation script: RunSimulationScript.py

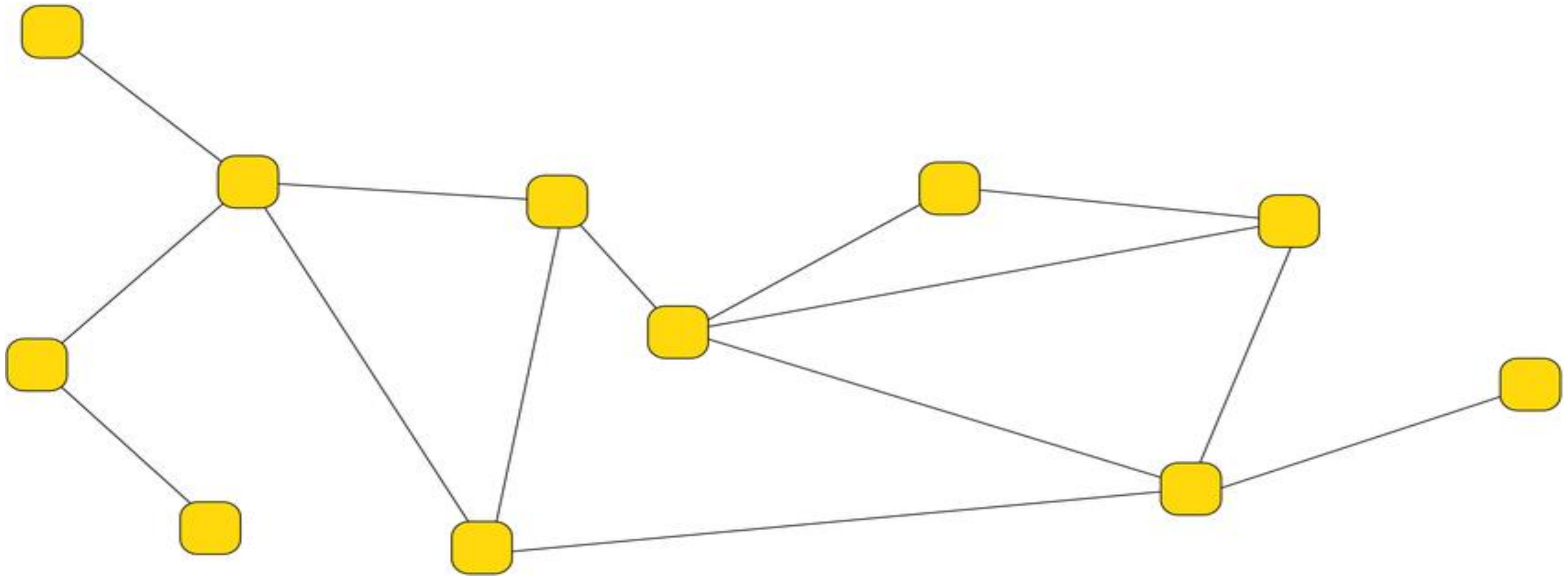
Configuring a Network

- It's easy to simulate large networks
- You must specify a *network topology*
- The default TOSSIM radio model is signal-strength based



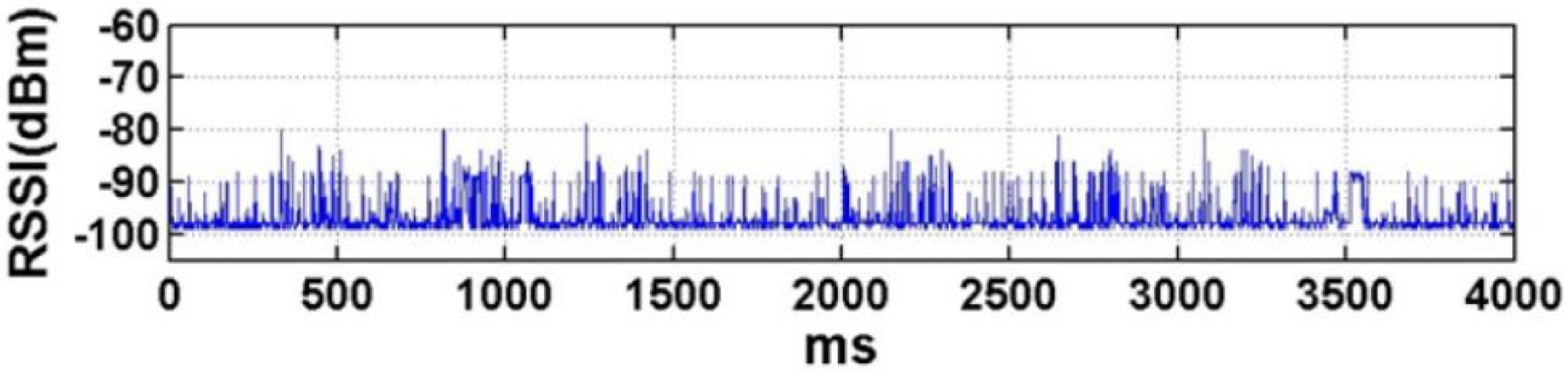
Network Topology

- You can create network topologies in terms of channel gain:
  Each entry in the topology is formatted as
  source destination gain *i.e. 1 2 -54.0*



Radio Channel

- You need to feed a noise trace (meyer-heavy.txt file)
- The directory tos/lib/tossim/noise contains some sample models
- On reception, SNR is evaluated for each bit of the message



Debugging Statements

- The output is configurable by debug channels
  - <ch> identifies the output channel
  - <text> text debugging and application variables

- dbg(<ch>,<text>) → DEBUG(ID):<text>
- dbg_clear(<ch>,<text>) → <text>
- dbgerror(<ch>,<text>) → ERROR(ID):<text>

- A channel can have multiple outputs

How to Run TOSSIM?

- To compile TOSSIM you pass the sim option to make:

```
make micaz sim
```

- To run TOSSIM use the RunSimulationScript. It must be in the same folder of the TinyOS files

```
python RunSimulationScript.py
```

Simulation

- Setup Debug Channels

```
#Add debug channel
print "Activate debug message on channel init"
t.addChannel("init",out);
print "Activate debug message on channel boot"
t.addChannel("RadioCountToLedsC",out);
print "Activate debug message on channel radio"
t.addChannel("radio",out);
print "Activate debug message on channel radio_send"
t.addChannel("radio_send",out);
print "Activate debug message on channel radio_ack"
t.addChannel("radio_ack",out);
print "Activate debug message on channel radio_rec"
t.addChannel("radio_rec",out);
print "Activate debug message on channel radio_pack"
t.addChannel("radio_pack",out);
print "Activate debug message on channel role"
t.addChannel("role",out);
```

- Number of events: increase/decrease according to your simulation

```
for i in range(0,1200):
    t.runNextEvent()
```

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Attention on RunSimulationScript

Adapt the script for the correct number of nodes

- Add noise trace for all nodes:

```
print "Reading noise model data file:", modelfile;
print "Loading:",
for line in lines:
    str = line.strip()
    if (str != "") and ( compl < 10000 ):
        val = int(str)
        mid_compl = mid_compl + 1;
        if ( mid_compl > 5000 ):
            compl = compl + mid_compl;
            mid_compl = 0;
            sys.stdout.write ("#")
            sys.stdout.flush()
        for i in range(1, 3):
            t.getNode(i).addNoiseTraceReading(val)
print "Done!";
```

Range(1,n_nodes+1)

- Create noise model for all nodes

```
for i in range(1, 3):
    print ">>>Creating noise model for node:",i;
    t.getNode(i).createNoiseModel()
```

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Exercise: temp/hum sensor

- Starting from the example in:

  IOT-examples/TinyOS/Supporting\ Files/TempHumSensor

- Simulate with TOSSIM a TinyOS application that:
  - Generate 3 motes (1, 2, 3)
  - Mote #1 is the sink
  - Mote #2 is the temperature sensor
  - Mote #3 is the humidity sensor

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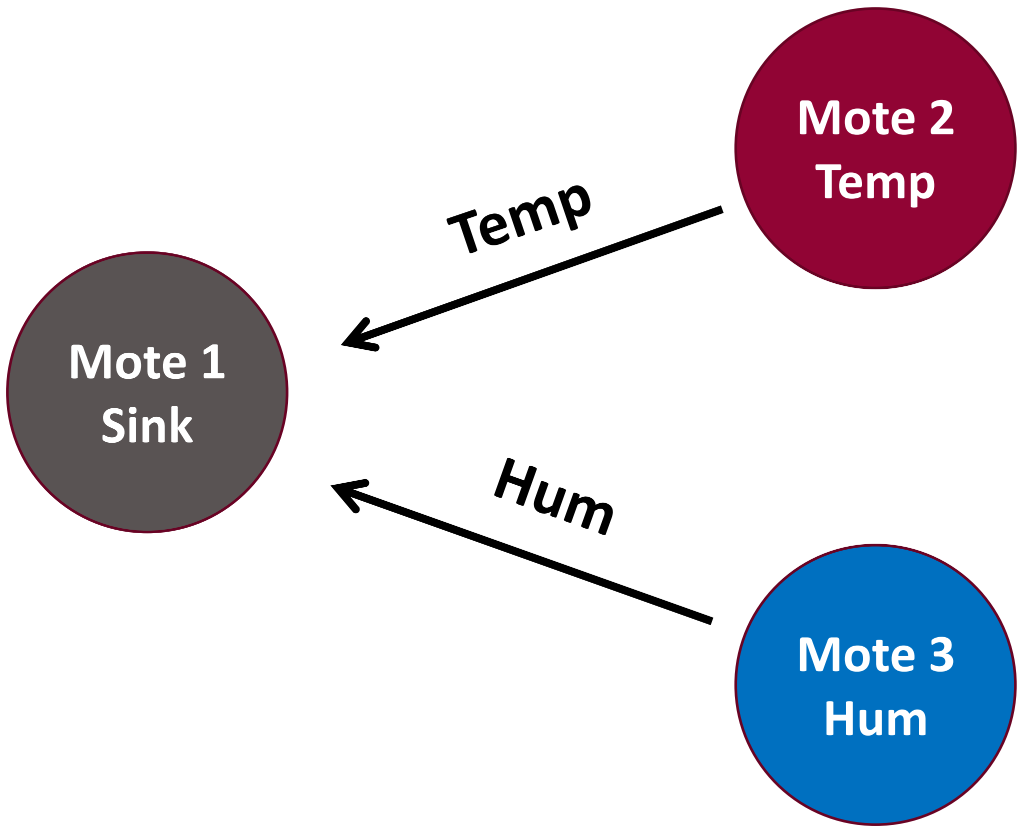
Topology



Fake temp/hum sensor

- Mote #1 only receives messages from #2 and #3
- Mote #2 sends periodic (every 1 second) messages to the sink (#1)
- Mote #3 sends periodic (every 2 seconds) messages to the sink (#1)

Message format

- Messages are composed of the following fields:
  - **Type**: 0 or 1 (0 for temperature, 1 for humidity)
  - **Data**: the value of the sensor

Challenge 3

Challenge 2

Challenge 2

Challenge 1

Challenge 1