TinyOS Applications

Advanced Computer Networks

TinyOS Applications Outline

- AntiTheft Example {done in gradual pieces}
  - LEDs, timer, booting
- Sensing Example
  - Light Sensor
  - Wiring to AntiTheft
- Single Hop Networks
  - Active Messages interface
  - Sending packets
  - Receiving packets

AntiTheft Example [List 6.1]

```
module AntiTheftC {
  uses {
    interface Boot;
    interface Timer <Tmilli> as WarningTimer;
    interface Leds;
  }
}

implementation {
  enum { WARN_INTERVAL = 4096, WARN_DURATION = 64 };
```

can only declare integer constants

AntiTheft Example [List 6.1]

```
event void WarningTimer.fired  ( ) {
  if (call Leds.get ( ) & LEDS_LED0)
   { /* Red LED is on. Turn it off, will switch on
                        again in 4096 - 64 ms. */
     call Leds.led0Off ( );
     call WarningTimer.startOneShot (WARN_INTERVAL -
                                     WARN_DURATION);
   }
  else
   { // Red LED is off. Turn it on for 64 ms.
     call Leds.led0On ( );
     call WarningTimer.startOneShot (WARN_DURATION);
   }
}
```

AntiTheft Example [List 6.1]

```
event void Boot.booted ( ) {
  /* We just booted. Perform first
                              LED transition  */
  signal WarningTimer.fired ( );
  }
}
```

interface Leds { [List 6.2]

…

```
    async command void led0On ( );
    async command void led0Off ( );
    async command uint8_t get ( );
}
```

AntiTheft configuration [List 6.6]

```
configuration AntiTheftAppC { }
implementation {
  components AntiTheftC, MainC, LedsC;
  components new TimerMilliC ( ) as WTimer;

  AntiTheftC.Boot  -> MainC;
  AntiTheftC.Leds  -> LedsC;
  AntiTheftC.WarningTimer -> WTimer;
}
```

Sensing Example

- TinyOS provides two standard interfaces for reading sensor samples:
  - Read :: acquire a single sample.
  - ReadStream :: sample at a fixed rate.

```
interface Read <val_t> {
  command error_t read ( );
  event void readDone (error_t, val_t val );
}
```

Sensing Example [List 6.8]

Anti-theft Example: detecting dark conditions

```
module DarkC {
  uses {
     interface Boot;
     interface Leds;
     interface Timer<TMilli> as TheftTimer;
     interface Read<uint16_t> as Light;
  }
}
```

Sensing Example [List 6.8]

```
implementation {
  enum { DARK_INTERVAL = 256, DARK_THRESHOLD = 200};

  event void Boot.booted ( ) {
    call TheftTimer.startPeriodic (DARK_INTERVAL);
  }
  event void TheftTimer.fired ( ) {
    call Light.read ( ); //Initiate split-phase light sampling
  }
```

samples four times per second

Sensing Example [List 6.8]

```
/* Light sample completed.  Check if it is a theft. */

  event void Light.readDone (error_t ok, uint16_t val)
  {

    if (ok == SUCCESS  &&  val < DARK_THRESHOLD)
        call Leds.led2On ( );  /* Theft Alert! Alert! */
    else
        call Leds.led2Off( ); /* Don't leave LED on */
   }
}
```

Sensor Components

- Sensors are represented in TinyOS by generic components, e.g., PhotoC for the light sensor on the mts310 board.
- A single component usually represents a single sensor:

```
generic configuration PhotoC ( ) {
  provides interface Read<uint16_t>;
}
```

AntiTheft Light Sensor Wiring [List 6.9]

```
configuration AntiTheftAppC { }
implementation {
…   /* the wiring for the blinking Red LED */
  components DarkC, MainC, LedsC;
  components new TimerMilliC ( ) as TTimer;
  components new PhotoC ( );

  DarkC.Boot -> MainC;
  DarkC.Leds -> LedsC;
  DarkC.TheftTimer  -> TTimer;
  DarkC.Light -> PhotoC;
}
```

Single Hop Networks

- TinyOS uses a layered network structure where each layer defines a header and footer layout.
- The lowest exposed network layer in TinyOS is called *active messages* (AM).
- AM is typically implemented directly over a mote's radio providing unreliable, single-hop packet transmission and reception.

Single Hop Networks

- Packets are identified by an AM type, an 8-bit integer that identifies the packet type.
- 'Active Messages' indicates the type is used automatically to dispatch received packets to an appropriate handler.
- Each packet holds a user-specified *payload* of up to TOSH_DATA_LENGTH bytes (normally 28 bytes)**.
- A variable of type message_t holds a single AM packet.

** changeable at compile time.

Platform-Independent Types

- TinyOS has traditionally used structs to define message formats and directly access messages.
- Platform-independent structs are declared with nx_struct and every field of a platform-independent struct must be a platform-independent type.

```
nx_uint16_t val ;          // A big-endian 16-bit value
nxle_uint32_t otherval;    // A litte-endian 32-bit value
```

TinyOS 2.0 CC2420 Header [List 3.32]

```
typedef nx_struct  cc2420_header_t ** {
  nxle_uint8_t  length;
  nxle_uint16_t  fcf;
  nxle_uint8_t  dsn;
  nxle_uint16_t  destpan;
  nxle_uint16_t  dest;
  nxle_uint16_t  src;
  nxle_uint8_t  type;
} cc2420_header_t;
```

The CC2420 expects all fields to be little-endian.

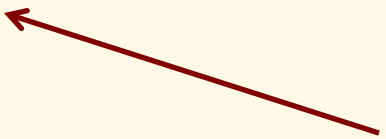
Theft Report Payload

Modifying anti-theft to report theft by sending a broadcast message

Platform-independent struct in the antitheft.h header file:

```
#ifndef ANTITHEFT_H
#define ANTITHEFT_H
typedef nx_struct theft {
   nx_uint16_t who;
} theft_t;

…
#endif
```



struct to define payload

AMSend Interface [List 6.12]

- Contains all the commands needed to fill in and send packets:

```
interface AMSend {
  command error_t send (am_addr_t  addr, message_t*
                        msg, uint8_t len);
  event void sendDone (message_t*  msg, error_t error);
  command error_t cancel (message_t*  msg);
  command uint8_t maxPayLoadLength ( );
  command void* getPayLoad (message_t* msg, uint8_t len);
}
```

Node's AM address (usually) = TOS_NODE_ID

Sending Report-Theft Packets [List 6.13]

```
uses interface AMSend as Theft;
…
message_t  reportMsg;  //theft report message buffer
bool sending;          //Do not send while a send is in progress
void reportTheft ( ) {
  theft_t* payload = call Theft.getPayload (&reportMsg,
                                            sizeof (theft_t) );
  if (payload && !sending)
    { //If Payload fits and we are idle – Send packet
      payload->who = TOS_NODE_ID;  //Report being stolen!
     //Broadcast the report packet to everyone
      if (call Theft.send (TOS_BCAST_ADDR, &reportMsg,
                                    sizeof (theft_t) ) == SUCCESS)
    }
}
```

Sending Report-Theft Packets [List 6.13]

```
event void Theft.sendDone (message_t  *msg,
                           error_t error)  {
  sending = FALSE;   //Our send completed
}
```

Called from MovingC

```
if (variance > ACCEL_VARIANCE * ACCEL_NSAMPLES)
  {
    call  Leds.led2On ( ) ;  /* Theft Alert  */
    reportTheft ( );
  }
```

Generic AMSenderC configuration

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

Communication Stack

Cannot switch itself on and off on-demand, and needs the SplitControl interface to start and stop the radio:

[List 6.14]

```
interface SplitControl {
  command error_t start ( );
  event void startDone (error_t error);

  command error_t stop ( );
  event void stopDone (error_t error);
}
```

MovingC using SplitControl

```
uses interface SplitControl as CommControl;

…
event void Boot.booted ( ) {
  call CommControl.start ( ) ;
}

event void CommControl.startDone (error_t ok) {
 //Start checks once communication stack is ready
 call TheftTimer.startPeriodic (ACCEL_INTERVAL);
}

event void CommControl.stopDone (error_t ok) { }
```

Moving C Receiving Packet

- MovingC receives a packet payload (defined as a struct contained in a header file antitheft.h) that contains acceleration settings for detecting movement of the mote:

```
typedef nx_struct settings {
  nx_uint16_t accerVariance;
  nx_uint16_t accelInterval;
} settings_t;
```

struct to define payload

AM Packet Reception

- Provided by the TinyOS Receive interface:

```
interface Receive {
  event message_t* receive(message_t*  msg,
                           void* payload, uint8_t len);
}
```

Receive.receive, as a receive "handler", receives a packet buffer which it can simply return or return as a different buffer if the handler wants to hold onto buffer.

MovingC Receiving Packet [List 6.16]

```
uses interface Receive as Setting;
…
uint16_t accelVariance = ACCEL_VARIANCE;

event message_t* Settings.receive (message_t  *msg,
                    void *payload, uint8_t len)  {
  if (len >= sizeof (settings_t))  //Check for valid packet
    { /* Read settings by casting payload to settings_t,
         reset check interval */
      settings_t  *settings = payload;
      accelVariance  = setting->accelVariance;
      call TheftTimer.startPeriodic (setting->accelInterval);
    }
  return msg;
}
```

Selecting a Communication Stack

- Need to wire to the components representing the desired communications stack.

```
configuration ActiveMessageC {
  provides interface SplitControl;
  …
}
generic configuration AMSenderC (am_id_t id) {
  provides interface AMSend;
 …}
generic configuration AMReceiverC (am_id_t id) {
  provides interface Receive;
 …}
```

TinyOS Applications Summary

- AntiTheft Example
  - LEDs, Timer, Boot
  - get, enum
- Sensing Example
  - Light Sensor
  - Read (split-phase)
  - Wiring to AntiTheft
  - Two Timer instances

TinyOS Applications Summary

- Single Hop Networks
  - Active Messages, typed messages
  - Platform-independent types
- Sending packets
  - AMSenderC generic configuration
  - SplitControl of Radio Stack
  - Structs for packet payloads
- Receiving packets
  - Implemented as a receive event handler.