SimpliciTI
by Texas Instruments

- Low Power
- Simplicity
- Low Cost
What is it?

- SimpliciTI is
  - Low Power: a TI proprietary low-power RF network protocol
  - Low Cost: uses <4K / 8K FLASH, < 512 bytes / 1K RAM
  - Flexible: simple star w/ extendor and/or p2p communication
  - Simple: Utilizes a very basic core API
  - Versatile: MSP430+CC1100/2500, CC1110/2510, and DSSS parts
  - Low Power: Supports sleeping devices
Application Areas?

SimpliciTI supports:

- alarm & security: occupancy sensors, light sensors, carbon monoxide sensors, glass-breakage detectors
- smoke detectors
- AMR: gas meters, water meters, e-meters
- home automation: garage door openers, appliances, environmental devices
- and many more...
Networking Basics

- **Device Configurations**
  - Access Point (AP)
  - Repeater (RE)
  - Sleeping Device (SD)
  - Device (D)
  - TX-Only Device (TD)

- **Topologies**
  - AP Star
  - AP Star w/ Repeaters
  - Peer2Peer
SimpliciTI Network topology: wireless sensing application

- Range can be extended through repeaters.
- The circles represent range of gateway and extended range of repeaters.

Examples message flows:
- Peer2Peer message
- Message to Access point
- Message repeated through range extenders
SimpliciTI network topology: Active RF tags

- Active RF tags typically enter and exit the network ad-hoc.

- They must be able to quickly associate to the network while maintaining low power consumption.
SimpliciTI Smoke Detector System

Optional Access point
Sensor / Extender
Alarm Triggered Device

Examples message flows

Flooded Alarm Message
Hardware Support

- Initial release using Experimenter’s Board
  - (MSP430FG4619) w/ Chipcon Socket Interface for CC1100 / CC2500

- Future support
  - SOC (CC2510 / CC1110)
  - DSSS (MSP+CC2420, CC2430)
## SimpliciTI vs. ZigBee

<table>
<thead>
<tr>
<th>TI protocol software:</th>
<th>SimpliciTI</th>
<th>ZigBee</th>
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<tbody>
<tr>
<td><strong>Network properties:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mesh network</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Typical number of nodes</td>
<td>from 2 to ~30</td>
<td>from 2 to hundreds</td>
</tr>
<tr>
<td>Point-to-point and star network</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Hardware and software:</strong></td>
<td></td>
<td></td>
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<tr>
<td>Hardware</td>
<td>Any MSP430 + CC TRX or 8051 SoC</td>
<td>MSP430F2418 + CC2420, CC2430</td>
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<tr>
<td>Frequency &amp; modulation</td>
<td>Any TI radio: <strong>sub 1GHz, 2.4GHz</strong>, standard or proprietary</td>
<td>IEEE 802.15.4 DSSS, 2.4GHz</td>
</tr>
<tr>
<td>SW object distribution</td>
<td>Free download</td>
<td>Free download</td>
</tr>
<tr>
<td>SW source code</td>
<td><strong>Free download</strong></td>
<td>Not required for development.</td>
</tr>
<tr>
<td>Compiled code size on MSP430</td>
<td>~4k depending on configuration</td>
<td>50-60k depending on configuration</td>
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<tr>
<td>Interoperability between vendors:</td>
<td>No</td>
<td>Optional</td>
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<tr>
<td>Encryption</td>
<td>Yes, 128bit AES on enabled HW Devices, other in software.</td>
<td>Yes, 128bit AES</td>
</tr>
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</table>
Architectural Overview

• Layers
  – LHAL (BSP)
  – NWK
  – nwk Apps (modules)
  – customer apps

• Network Support
  – init
  – ping
  – link / linklisten
  – nwk mgmt
  – security
  – freq agility
  – send / receive
  – I/O
**Architectural Highlights**

- no timers
- no osal
- simple bsp (no formal HAL)
- no formal PHY or link layer
- nwk manages
  - Radio, Rx / Tx, queuing, demux (ports)
- modular optional security

- *Architecture is designed to ensure compact code size!*
- *Full flexibility for the application programmer since no timers are used!*
Only 6 API calls

- **Initialization**
  
  ```c
  smplStatus_t SMPL_Init(void);
  ```

- **Linking** (bi-directional by default)
  
  ```c
  smplStatus_t SMPL_Link(linkID_t *linkID);
  smplStatus_t SMPL_LinkListen(linkID_t *linkID);
  ```

- **Peer-to-peer messaging**
  
  ```c
  smplStatus_t SMPL_Send(lid, *msg, len);
  smplStatus_t SMPL_Receive(lid, *msg, *len);
  ```

- **Configuration**
  
  ```c
  smplStatus_t SMPL_ioctl(object, action, *val);
  ```
Simple Configuration

/* FROM smpl_config.dat */

// Number of connections supported
-DNUM_CONNECTIONS=4

// Maximum size of application payload
-DMAX_APP_PAYLOAD=20

// size of low level queues for sent and received frames.
-DSIZE_INFRAME_Q=2
-DSIZE_OUTFRAME_Q=2

// default Link token
-DDEFAULT_LINK_TOKEN=0x01020304

// default Join token
-DDEFAULT_JOIN_TOKEN=0x05060708

// this device's address.
-DTHIS_DEVICE_ADDRESS="{0x79, 0x56, 0x34, 0x12}"

// device type
-DEND_DEVICE

// for End Devices specify the Rx type.
//-DRX_LISTENS
//-DRX_POLLS
//-DRX_NEVER
-DRX_ALWAYS

- operational mode (type)
- power mode (sleep support)
- topology
- addressing / identification
- RAM allocation
  – packet size
  – buffer sizes
  – # supported links (connections)
- security tokens
- messaging (hop ct, repeaters)
- radio (freq, crypto key, modulation, CCA parameters)
## Runtime Configuration

- radio frequency
- encryption key
- app access to frame header
- app access to radio controls
- AP nwk mgmt control

<table>
<thead>
<tr>
<th>Object</th>
<th>Description</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>IOCTL_OBJ_FREQ</td>
<td>Get/Set radio frequency</td>
<td>Frequency agility. May be used by APP or NWK.</td>
</tr>
<tr>
<td>IOCTL_OBJ_CRYPTKEY</td>
<td>Set encryption key</td>
<td>Customer may provide external means for user to set a non-default key. Requires reset to take effect.</td>
</tr>
<tr>
<td>IOCTL_OBJ_RAW_IO</td>
<td>Application layer access to the frame header to directly send or receive a frame.</td>
<td>This object is used for example to ping another device where the network address of the target device is supplied directly and not done through the connection table.</td>
</tr>
<tr>
<td>IOCTL_OBJ_RADIO</td>
<td>Application layer access to some radio controls.</td>
<td>Limited access to radio directly. For example, sleeping and awakening the radio and getting signal strength information.</td>
</tr>
<tr>
<td>IOCTL_OBJ_AP_JOIN</td>
<td>Access Point join-allow context</td>
<td>Interface to control whether Access Point will allow devices to join or not.</td>
</tr>
</tbody>
</table>

Table 7: Customer configurable run-time objects
Example: How to configure Access Point

- star hub in the network (1 / net)
- always-on (acts as range extender)
- store and fwd for sleeping devices
- linking and token (link and join) mgmt
- AP can implement end device functionality (link listen, receive)

// Initialize the HW/Radio
HAL_HWInit(); // initialize the BSP (API subject to change)
SMPL_Init();

// Handle Linking
SMPL_LinkListen(&linkID1);

// Receive Messages
While (1) {
    while((SMPL_SUCCESS == SMPL_Receive(linkID1, msg, &len) { 
        // do something
    }
}
Example: How to configure Range Extender

• always-on device
• repeats received frames (with limitations)
• limited to 4 / net (although flexible in design)

```c
// Initialize the HW/Radio
HW_Init();
SMPL_Init();

// No Linking or application level functionality
```
Example: How to configure End Device

- poll for data
  - polling is Port specific
  - no data results in blank (empty) response
- API e.g. Sequence
  - Init (and Join)
  - Link (assumes listen)
  - Sample Temp
  - Send
- option to sleep

```c
void main()
{
    linkID_t linkID;
    uint32   temp;

    // Initialize the board's HW
    HW_Init();
    SMPL_Init();
    // link.
    SMPL_Link(&linkID);

    while (TRUE)
    {
        // sleep until timer. read temp sensor
        MCU_Sleep();
        HW_ReadTempSensor(&temp);
        if (temp > TOO_HIGH)
        {
            SMPL_Send(linkID, "Hot!", 4);
        }
        if (temp < TOO_LOW)
        {
            SMPL_Send(linkID, "Cold!", 5);
        }
    }
}
```
Addressing and Communication

- net address = hw addr (4 byte) + app port
  - statically assigned hw addr
  - no address resolution mechanism
- byte 1: 0x00, 0xFF – reserved for broadcast
- communication topologies:
  - direct peer-2-peer
  - direct p2p through RE
  - store and fwd p2p through AP
  - store and fwd p2p through RE and AP
### Packet Format

<table>
<thead>
<tr>
<th>PREAMBLE</th>
<th>SYNC</th>
<th>LENGTH</th>
<th>DSTADD</th>
<th>SRCADD</th>
<th>PORT</th>
<th>DEVICE INFO</th>
<th>TRACTID</th>
<th>App Payload</th>
<th>CRC</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>n</td>
<td>2</td>
</tr>
</tbody>
</table>

- Preamble: hw sync
- Sync: hw sync
- Length: bytes non-phy
- Dstaddr: hw filter 1 byte
- Srcaddr
- Port: app port number
- Dev info: capabilities
- Tractid: transaction nonce or seq num
- App pyld: 0 <= n <= 52 byte
- Crc: must be valid

**SW Encryption**

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Technology for Innovators

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Additional Details

- IAR development environment
- minimal hw abstraction
- no driver support (UART, SPI, LCD, Timers)
- no heap utilization
- no runtime (nwk) context storage
- single thread (app), no tasks or scheduling
- no nwk callbacks – app must poll nwk layer
- nwk api is synchronous (does not return until operation is complete)
- retries and acks must be managed by app
Downloads simpliciTI today to learn more!
It is a free download and full source code is included!

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Description</th>
<th>Weblink</th>
</tr>
</thead>
<tbody>
<tr>
<td>simpliciTI</td>
<td>Network protocol software</td>
<td><a href="http://www.ti.com/simpliciti">www.ti.com/simpliciti</a></td>
</tr>
<tr>
<td>MSP430 code library</td>
<td>Code library for communication between MSP430 and CC RF-ICS</td>
<td><a href="http://www.ti.com/ccmsplib">www.ti.com/ccmsplib</a></td>
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<tr>
<td>Ultra Low-Power MSP430 MCUs</td>
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<tr>
<td>Low-Power RF ICs</td>
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