Wireless Communication

CS 447– Wireless Embedded Systems
Outline

• 802.11 - Wi-Fi
• Bluetooth
• WiMAX
• Cellular
• Satellite
• 802.15.4
802.11 – WiFi

- **WLAN** – wireless local area network
- 2.4 GHz radio band (most typical)
- 14 channels
- Media Access Control (**MAC**), Physical Layer (**PHY**) standards

January 31, 2018
802.11 – WiFi

- **Access point** – allows WiFi device to connect to wired network
- APs support multiple connected devices
802.11 – WiFi

• Ad-hoc – allows direct communication between devices without an intermediary access point
• Aka “ad-hoc WiFi”
802.11 – WiFi

Wi-Fi has many more details
- Encryption
- SSID
- Range extenders
- ...

IoT Lab has **Xbee WiFi** modules you can rent
- Configuration can be challenging..
Outline

• 802.11 - Wi-Fi
• Bluetooth
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Bluetooth

- Intended for short distances
- 2.4 GHz radio band
- PAN – Personal Area Network
- IEEE 802.15.1 standard (historical)
- 79 designated channels
- Data rate: ~25 Mbits / second
- Range: ~10 meters
Bluetooth

- Master / Slave architecture
- Master can communicate with up to 7 devices
- **Piconet** – ad-hoc network using Bluetooth technology
- **Round-robin** scheduling of slave comm
- Has broadcast mode (little used)

Many Bluetooth “breakout” modules available
- E.g., Sparkfun BlueSMiRF Silver ~$25
Outline

• 802.11 - Wi-Fi
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• **WiMAX**
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WiMAX

- **Worldwide Interoperability for Microwave Access**
- IEEE 802.16 standard for PHY, MAC layers
- “Last mile wireless broadband access”
- Not a replacement for WiFi
- Alternative to cable or DSL
- Data rate: ~30 Mbit / sec
- Range: ~10 miles
- Does NOT require line of sight (LOS)
WiMAX

Usages:

• **Backhaul** service to transfer data within an ISP network

• Provide internet access for users in remote locations (laying cable too expensive)

• Form of mobile internet access (competes w/ cellular, satellite)
WiMAX

How to use:
• Base stations – installed by service providers
• Receivers – installed within clients
Outline

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Cellular

- 2G, 3G, 4G => 800 MHz frequency band
- Data rate (4G): 100 Mbits / sec (max) for high mobility
- Data rate (4G): 1 Gbit / sec (max) for low mobility
- Many protocols: GSM, LTE, GPRS

Many cell modems available:
- E.g., adafruit FONA 3G + GPS

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Cellular

GSM: Global System for Mobile (Communication)
• European standard
• 2nd generation digital cell network protocol
• >90% market share
• 190+ countries
Cellular

LTE: Long-Term Evolution

• Commonly marketed as 4G LTE
• Goal: increase capacity and speed of wireless data networks
• Utilizes digital signal processing techniques and modulations
• LTE incompatible with 2G and 3G networks
  • Must be on separate radio spectrum
Cellular

GPRS: General Packet Radio Service

• Packet oriented mobile data service
• 2G and 3G networks
• Extends GSM
  • SMS messaging (up to 30 per minute)
  • “always on” internet

• E.g., Sparkfun GSM/GPRS Module
Outline

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Satellite

E.g., Iridium Network

• 66 active satellites
• Transceivers anywhere on earth’s surface
• Voice and data coverage for satellite phones
• ~$1.00 per minute of phone use
• Supports TCP/IP
Satellite

E.g., Iridium 9603
• Transceivers are power hungry (~1.3 Amps in transmit mode)
• Relatively slow data rates (~3 kbits/sec)
• ~1 second round-trip latency

E.g., Sparkfun RockBLOCK Mk2
• Iridium 9602 broken out
Outline

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802.15.4

- Radios you’ll use
- Reliable
- Power efficient
- Low data rate
- Designed for wireless sensor networks (WSNs)
- IEEE 802.15.4 standard for MAC and PHY
802.15.4

- 900 MHz or 2.4 GHz frequency bands
- 16-bit addressing (short)
- If needed, 64-bit extended addressing
- Link quality metrics
- Carrier Sense Multiple Access w Collision Avoidance (CSMA-CA)
- Built-in acknowledgements (acks) for transfer reliability
802.15.4

**Star topology:**
- Communication established between devices and single central controller (PAN coordinator)
- Controller routes packets to end points (via addressing)
Peer-to-Peer topology:
- Any device able to communicate with any other device within range
- P2P allows complex network formations (e.g., mesh network)
- Allows multiple hops to route messages (application layer)
PHY – Physical Layer
• Enables transmission / reception of PHY protocol data units (PPDUs) across physical radio channel

Features:
• Activates / deactivates of radio transceiver
• Energy detection
• Channel selection
• Clear channel assessment
• LQI – link quality indicator (for RSSI)
MAC sublayer
• Enables transmission / reception of MAC protocol data units (MPDUs) across the PHY data service

Features:
• Beacon management
• Channel access
• Frame validation
• Ack
• Hooks for application-layer security
802.15.4

Xbee 802.15.4 Series 1
- Indoor range: 200’
- Outdoor range: 4000’
- Data throughput: up to 96,000 bits / second
- UART data rate: 57,600 baud (typical)

- Transmit current: ~50mA peak
- Receive current: ~30mA
- Operating voltage: 3.3V
802.15.4

Xbee 802.15.4 Series 1

• "Transparent" operating mode (default)
• Acts like invisible wire

Other modes include API and Command (advanced)

• API mode allows more advanced operations
• E.g., addressing specific radio modules
802.15.4

Xbee 802.15.4 Series 1
• This class: application layer addressing
• Base station radio “broadcasts”
• All end-points receive packet
• Uses application level logic to determine addressing...
802.15.4

Xbee 802.15.4 Series 1
• Will connect Xbee radio to computer via USB dongle
• Computer will act as base station
802.15.4

Xbee 802.15.4 Series 1

• Will Connect Xbee to Arduino with shield
• Arduino(s) act as end point devices for WSN
• Shield has switch: **DLINE, UART**
  • *DLINE* – communicate b/t computer and Arduino USB
  • *UART* – communicate b/t Xbee radio
802.15.4

Xbee 802.15.4 Series 1
• You MUST configure the radios before using
  • X-CTU software package from Digi
    • https://www.digi.com/products/xbee-rf-solutions/xctu-software/xctu

Must set following parameters:
• **CH** – radio channel
• **ID** – PAN ID
• **MY** – unique 16-bit address for each radio
• **DL** – 16-bit destination address for each radio
• **BD** – serial baud rate
802.15.4

XCTU software primer –
- Connect Xbee radio to Xbee USB dongle
- Connect USB dongle to computer
- Download / open **XCTU**
Click "Discover Devices"
Select the ports to be scanned:

- Bluetooth-Incomo-Port
- usbserial-DN01J60D

Select port

Click Next >
Select multiple Baud Rates: 9600, 57600, 115200
Click Finish
XCTU will search for connected radios...
Radio found, select and click “Add selected devices”
Device has been added..

Click on it to configure.

Select a radio module from the list to display its properties and configure it.
Parameters that can be configured...

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name:</td>
<td>XBEE PRO 802.15.4</td>
</tr>
<tr>
<td>Function:</td>
<td>XBEE PRO 802.15.4</td>
</tr>
<tr>
<td>Port:</td>
<td>usbserial-DN0.../B/N/1/N - AT</td>
</tr>
<tr>
<td>MAC:</td>
<td>0013A200415E0E22</td>
</tr>
<tr>
<td>CH Channel</td>
<td>D</td>
</tr>
<tr>
<td>ID PAN ID</td>
<td>1337</td>
</tr>
<tr>
<td>DH Destination Address High</td>
<td>0</td>
</tr>
<tr>
<td>DL Destination Address Low</td>
<td>FFFF</td>
</tr>
<tr>
<td>MY 16-bit Source Address</td>
<td>BACE</td>
</tr>
<tr>
<td>SH Serial Number High</td>
<td>13A200</td>
</tr>
<tr>
<td>SL Serial Number Low</td>
<td>415E0E22</td>
</tr>
<tr>
<td>MM MAC Mode</td>
<td>802.15.4 + MaxStream header w</td>
</tr>
<tr>
<td>RR XBe Retries</td>
<td>0</td>
</tr>
<tr>
<td>RN Random Delay Slots</td>
<td>0</td>
</tr>
<tr>
<td>NT Node Discover Time</td>
<td>19  x 100 ms</td>
</tr>
<tr>
<td>NO Node Discover Options</td>
<td>0</td>
</tr>
<tr>
<td>CE Coordinator Enable</td>
<td>End Device [0]</td>
</tr>
<tr>
<td>SC Scan Channels</td>
<td>1FFFE Bitfield</td>
</tr>
<tr>
<td>SD Scan Duration</td>
<td>4 exponent</td>
</tr>
</tbody>
</table>
E.g., click the ID text field to edit configure the PAN ID of your WSN...
Click Write to configure the radio.
Repeat for CH, MY, DL, BD

NOTE: You’ll have to configure all radios in your WSN
802.15.4

CH – channel
• same for all radios in WSN

ID – PAN ID
• same for all radios in WSN
• unique for your team

BD – baud rate
• same for all radios in WSN (e.g., 57600)
802.15.4

MY – 16-bit source address

- Each radio in WSN must have unique MY address, e.g.,
  - 0xBACE for base station radio
  - 0x0001 for wireless node #1
  - 0x0002 for wireless node #2
  - 0x0003 for wireless node #3
802.15.4

DL – 16-bit destination address

• Base station radio must broadcast (0xFFFF)
• Wireless nodes match base station’s MY address (e.g., 0xBACE)