



Applying 802.15.4 to embedded solutions

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Agenda

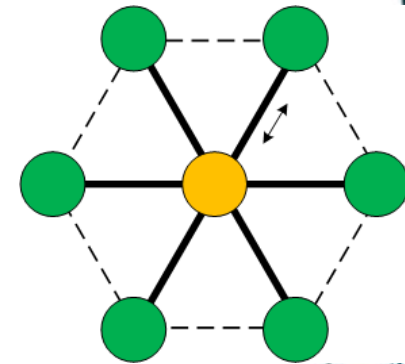
- Characteristics of 802.15.4
- Design questions
- Protocols and implementations
- Incorporating chips and modules
- Antennas and Agency compliance

802.15.4 Characteristics

- Designed to be a PAN
 - Lower power than MAN, LAN technologies
 - Ability to sleep
 - Simple
 - MAC and PHY layers
 - Point to point, Point to Multipoint, Peer-to-peer
 - Coordinator possible, but not required
 - Broadcast and Unicast modes
 - Low data rate
 - Not necessarily an “internet” technology

802.15.4 MAC

802.15.4 PHY



802.15.4 Characteristics

802.15.4 PHY

IEEE
Std 802.15.4-2006

LOCAL AND METROPOLITAN AREA NETWORKS—PART 15.4:

Table 1—Frequency bands and data rates

PHY (MHz)	Frequency band (MHz)	Spreading parameters		Data parameters		
		Chip rate (kchip/s)	Modulation	Bit rate (kb/s)	Symbol rate (ksymbol/s)	Symbols
868/915	868–868.6	300	BPSK	20	20	Binary
	902–928	600	BPSK	40	40	Binary
868/915 (optional)	868–868.6	400	ASK	250	12.5	20-bit PSSS
	902–928	1600	ASK	250	50	5-bit PSSS
868/915 (optional)	868–868.6	400	O-QPSK	100	25	16-ary Orthogonal
	902–928	1000	O-QPSK	250	62.5	16-ary Orthogonal
2450	2400–2483.5	2000	O-QPSK	250	62.5	16-ary Orthogonal

Design Questions

- What maximum required bandwidth?
 - 250 kbps over the air, but 125 kbps *max*
 - 38.8 kbps more typical for PtP and PtMP networks
 - Slower for mesh technologies
- How much range do you need?
 - Frequency considerations
 - Environmental considerations
 - Output power in Europe ~10dBm (10mW)
 - For 0 dBm...30m indoor, 100m outdoor
 - For 10dBm w/ LNA...60m indoor, 1km outdoor

Design Questions

- How often is data transmitted?
 - Effects sleep mode and battery life
 - Determining factor in whether or not mesh can be used

Design Questions

- Battery life calculation example

Current in TX (mA)	40	Alkaline AA	
Current in RX (mA)	45	Battery life (hours)	30551.63
Sleep current (mA)	0.035	days	1272.984
Time interval (min)	60	years	3.487629
time in TX (ms)	3000		
Time in RX (ms)	2000	Lithium	
		Battery life (hours)	32159.61
% Duty Cycle in TX	0.08%	days	1339.984
% Duty Cycle in RX	0.06%	years	3.671188
% Duty Cycle in sleep	99.86%		
Avg current draw	0.093285	Alkaline D	
		Battery life (hours)	128638.4
		days	5359.934
		years	14.68475
Battery Capacities			
AA Alkaline mAh	2850		
AA NiMH	2500		
Lithium	3000		
D Cell Alkaline (typ)	12000		

Design Questions

- General Considerations
 - Power supply (Voltage, current)
 - Battery types
 - Antenna placement/enclosures
 - Data format (transparent/API)
 - Data backhaul or local network?
 - Network Topology

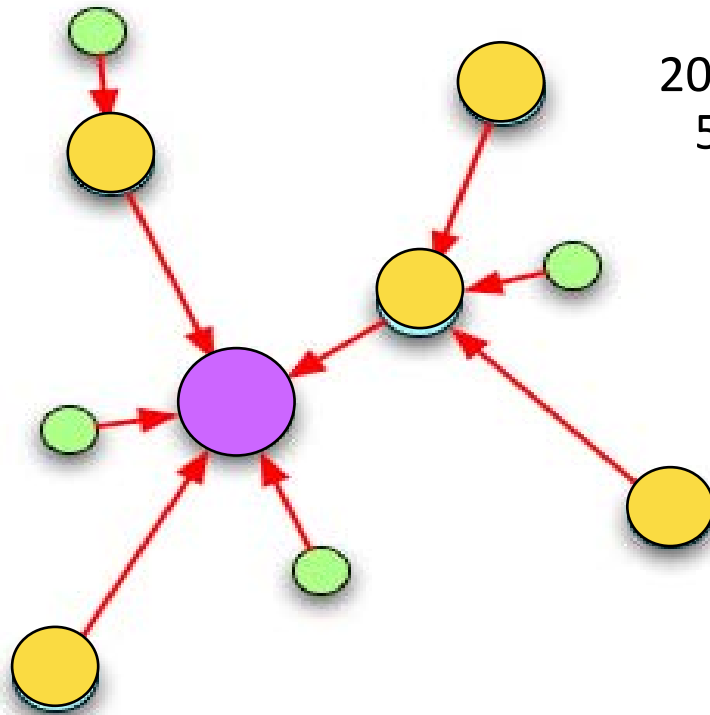
Zigbee





Key Characteristics

- Built on top of 802.15.4 – DSSS in 2.4 GHz
 - End points sleep, Routers don't
 - Coordinator needed to start network
- 2006 vs. 2007
 - Zigbee 2006 had significant limitations
 - Zigbee 2007 includes frequency agility, message fragmentation, enhanced security
- Routing
 - AODV style route discovery
 - Cluster-Tree routing – short routing time, but knowledge of lots of routes

Zigbee

2007 Practical Size:
500+ routers, 32 end points per router



-  ZigBee Coordinator
-  ZigBee Router
-  ZigBee End Device
-  Network association

Zigbee

Strengths

- Very low power end devices – because they are subservient to parental routers
- Cluster-Tree routing = quick knowledge of routes
- With 2007
 - Frequency agility switches from problem channels
 - Supports message fragmentation
 - Separated key security
- Network can scale to be very large

Zigbee

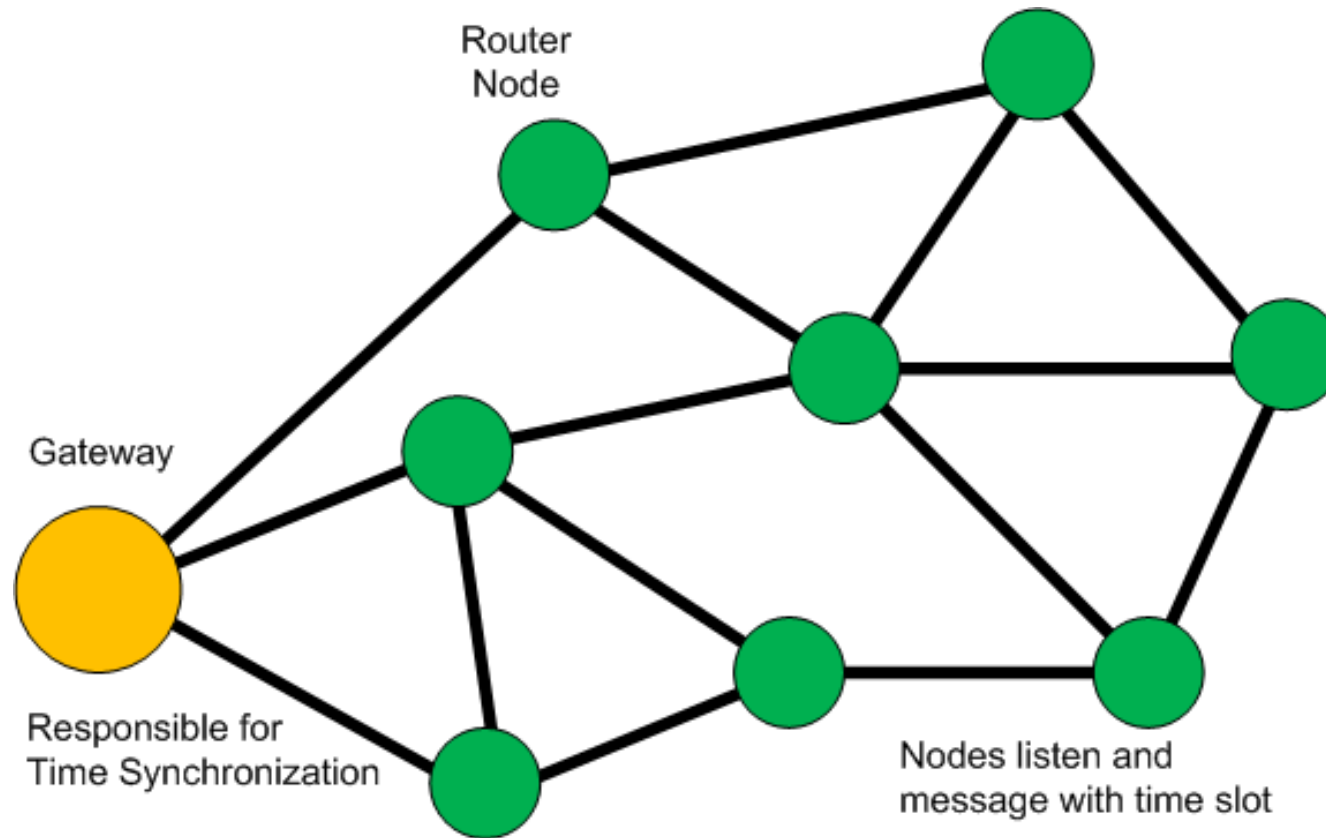
Limitations

- Routers must be powered – they can never go to sleep
- Network changes mean a lot of route discovery traffic
- Heavy traffic volume means lots of collisions – potential message loss
- Coordinator needed to start network and manage network

Wireless HART

- Time Synchronized Mesh Protocol (TSMP)
 - Access uses TDMA (Time Slots)
 - Optimized for low power, sleeping routers
 - Every node is a router
 - Gateway (coordinator) keeps network synchronized
 - Time synchronized sleeping and waking
- Built on top of 802.15.4 DSSS – but adds Frequency Hopping
- Security includes encryption and authentication

Wireless HART



Wireless HART

Strengths

- Every node is a router at very low power consumption
- Very reliable – every message acknowledged
- Security
- Networks scale to moderate level – 1000 nodes
- Frequency Agility

Wireless HART

Limitations

- Latency long and non-deterministic
- Expensive end nodes, very expensive gateway
- Requires powered gateway (coordinator) for network to stay functioning
- Limited throughput

Digi Mesh

Key Characteristics

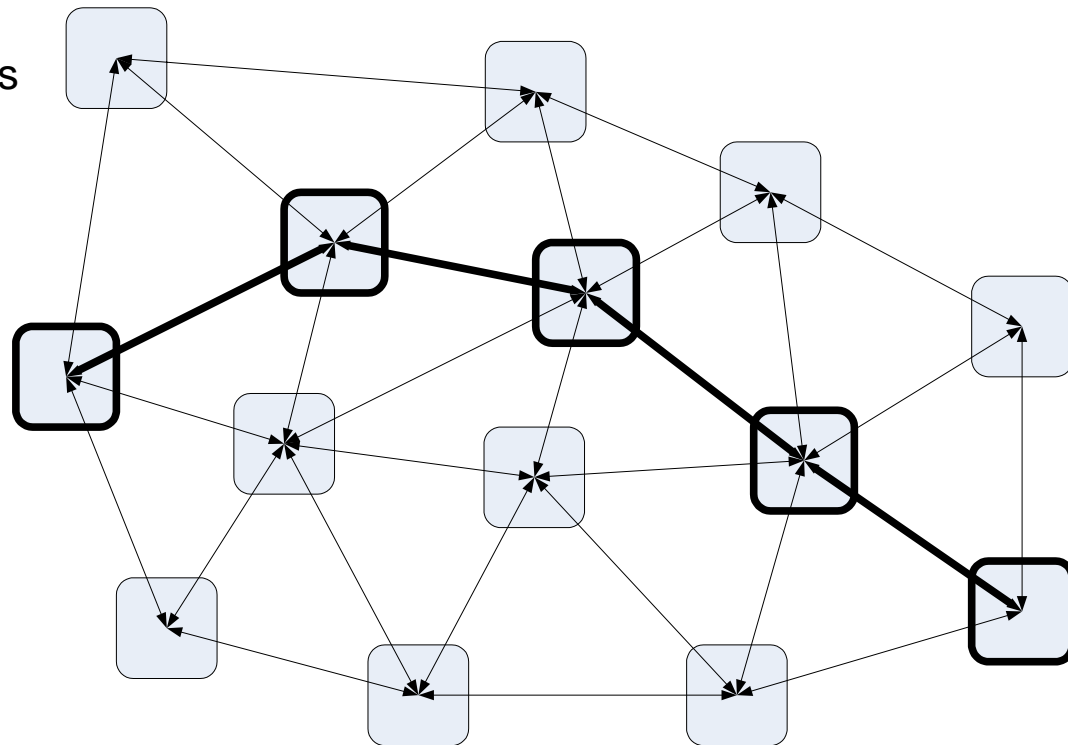
- Available in Multiple Frequency bands
 - 2.4 GHz DSSS
 - 900 MHz FHSS
- AODV Routing and Discovery
 - Routing tables built for only for needed destinations
 - Peer to Peer Mesh – No coordinator needed
- Nodes
 - All nodes can be routers
 - Sleeping Router Support – Time Synchronized
- Full Security Suite

Digi Mesh

Network Architecture

DigiMesh Nodes

- No parent-child relationships
- All nodes can route
- Nodes are interchangeable
- All can be low power



Digi Mesh

Strengths

- Every node is a router at very low power consumption
- Very reliable – every message acknowledged
- Frequency Agility
- Security
- Efficient route discovery and routing – only learns routes that actually get used (AODV)
- Larger Payloads plus fragmentation support very high reliability

Digi Mesh

Limitations

- Latency long and non-deterministic
- Limited throughput depending on loading and discoveries
- Network can scale to a moderate size of around 500+ nodes
 - Can be very large if traffic is light and message flow doesn't change much.

Antennas

- Limited by FCC and CE regulations
 - FCC 15.247, EN 300 328
- Antenna types
 - Monopole
 - Requires ground plane
 - Chip
 - Nice mechanically
 - Lowest range
 - Dipole
 - No ground plane required
 - Generally the best range of the omni antennas



Chip vs. Module

- Chip solution
 - Cheaper for large volumes
 - Greater control of size/mechanical features
 - Longer time to Market
 - RF Layout and agency certifications
- Module
 - Agency certified
 - No antenna or RF design required
 - Simple interface
 - Options for interchangeability



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Questions



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