Bluetooth

Why do we need Bluetooth and Zigbee

- Bluetooth wireless technology
  - Well focused towards voice applications and higher data rate applications (cell phones, headsets, etc.)
- ZigBee technology
  - Best suited for control and monitoring applications
  - L3: Low data rates, Low power, Low costs
  - Ease of use (remote controls, sensor nets, etc.)

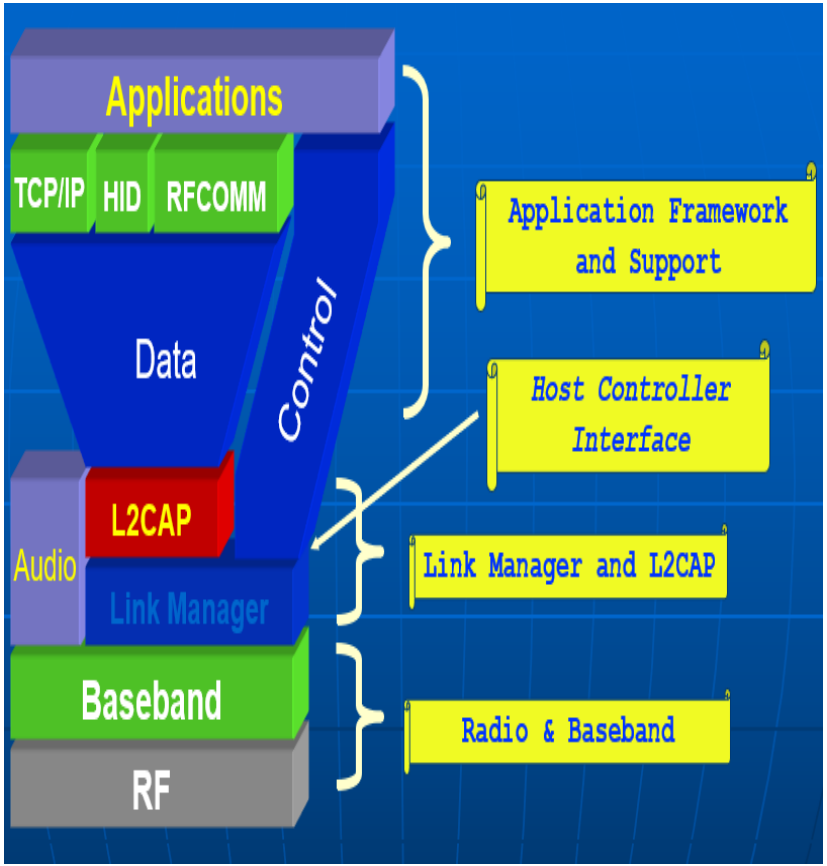
Bluetooth Overview

- Wireless technology for short-range voice and data communication
- Low-cost and low-power
- Provides a communication platform between a wide range of “smart” devices
- Not limited to “line of sight” communication

Applications

- Automatic synchronization between mobile and stationary devices
- Example:
  - Walk into office and have your PDA synch with your laptop on your desk without even taking your PDA out of your briefcase
- Connecting mobile users to the internet using bluetooth-enabled wire-bound connection ports
- Dynamic creation of private networks

Bluetooth Protocol Stack



Bluetooth Radio

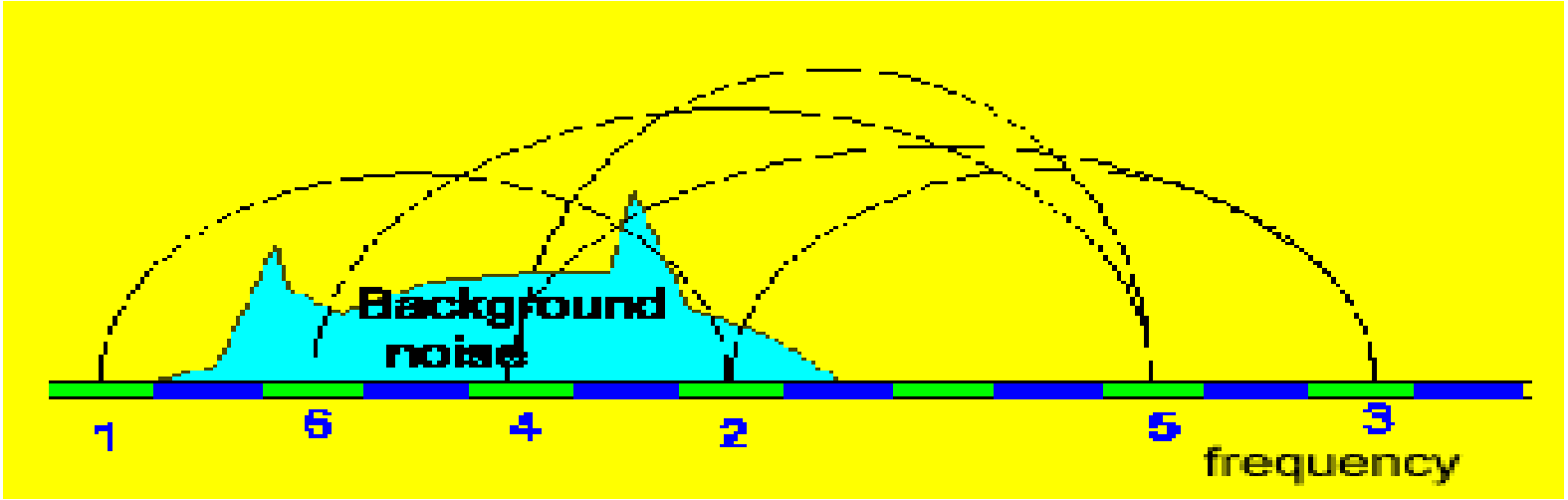
- Uses 2.4 GHz ISM band spread spectrum radio (2400 – 2483.5 MHz)
- Advantages -Free, Open to everyone worldwide
- Disadvantages-Can be noisy (microwaves, cordless phones, garage door openers)

Baseband Layer

- Handles Frequency Hop Sequences for Synchronization and Transmission (1600 hops/s)
- Establishes Links
  - Synchronous Connection Oriented (SCO)
  - Asynchronous Connection-Less (ACL)
- Provides functionality to determine nearby Bluetooth devices

Frequency Hopping

- In order to mitigate interference, Bluetooth implements frequency hopping
- 1600 hops per second through 79 channels, 1 MHz each.
- Spreads Bluetooth traffic over the entire ISM band
- All slaves in piconet follow the master for frequency hop sequence



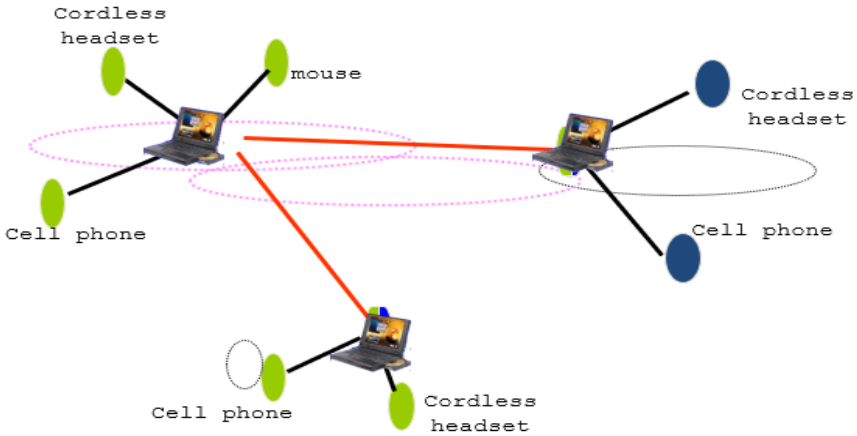
Establishing Piconet

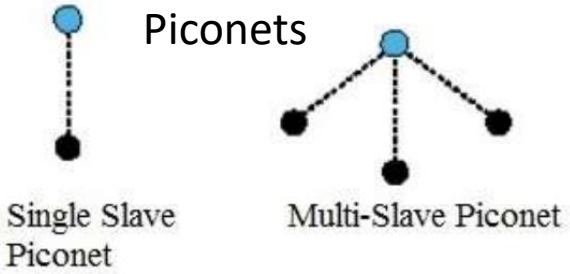
- Whenever there is a connection between two Bluetooth devices, a piconet is formed
- Always 1 master and up to 7 active slaves (> 200 could be parked)
- Any Bluetooth device can be either a master or a slave
- All devices have the same timing and frequency hopping sequence
- Master determines hopping pattern, slaves have to synchronize
- Each piconet has a unique hopping pattern
- Participation in a piconet = synchronization to hopping sequence

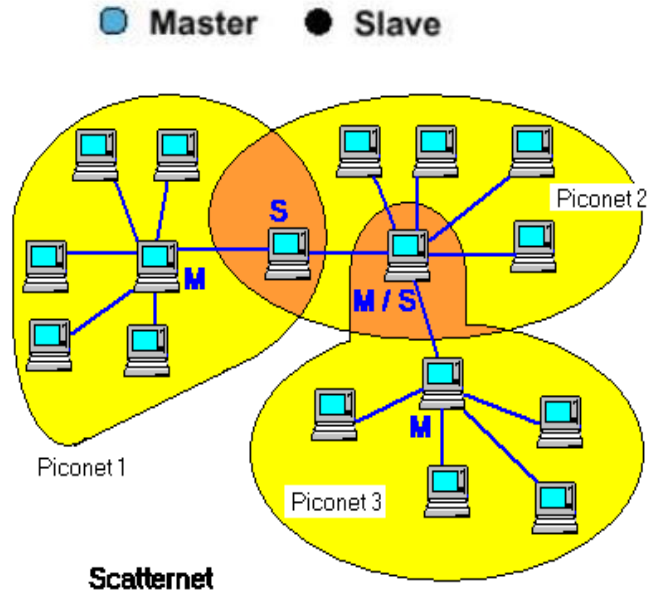
- All devices in a piconet hop together
  - Master gives slaves its clock and device ID
    - Hopping pattern: determined by device ID (48 bit, unique worldwide)
    - Phase in hopping pattern determined by clock
- Addressing
  - Active Member Address (AMA, 3 bit)
  - Parked Member Address (PMA, 8 bit)

Piconets and Scatternets

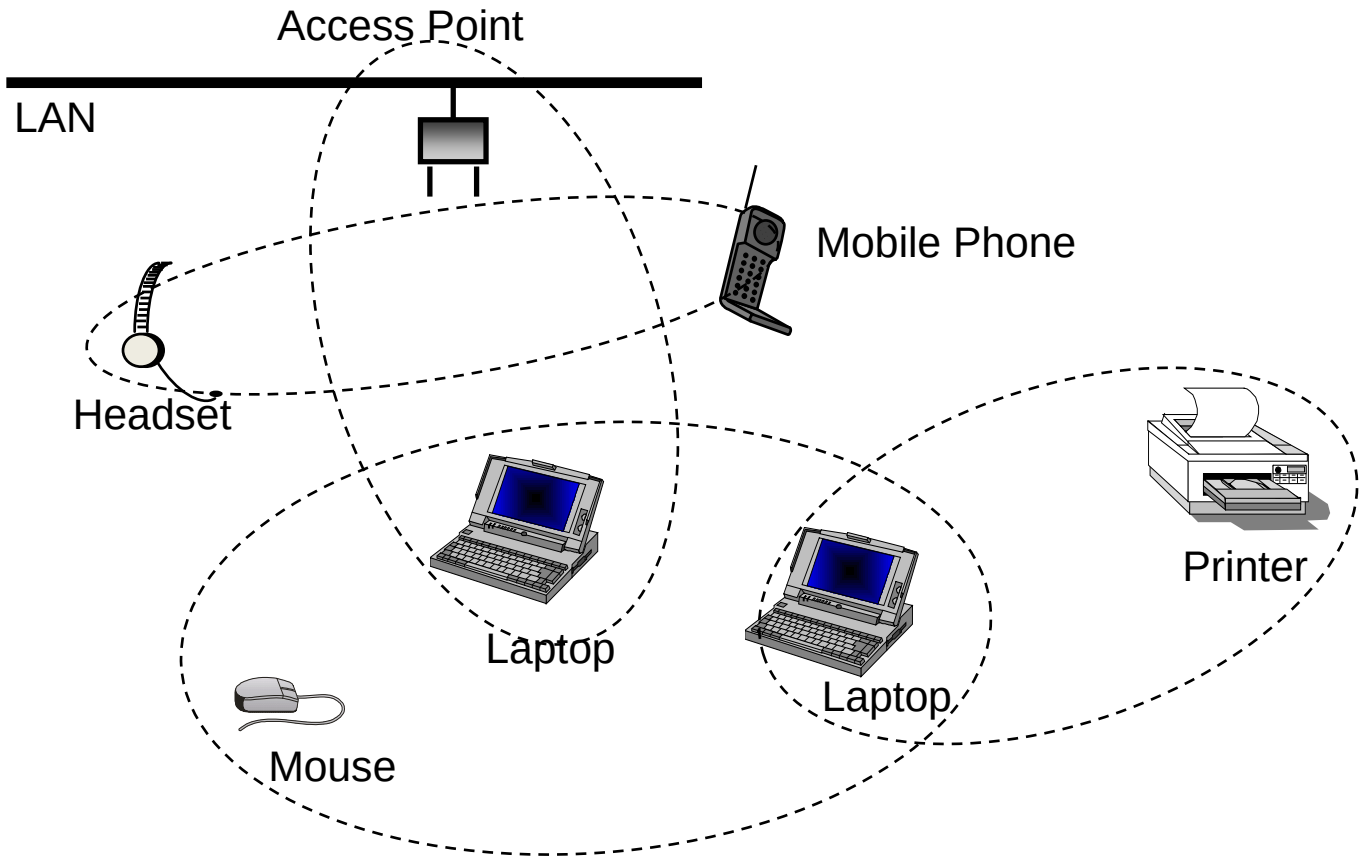
- Piconet-Basic unit of **bluetooth** networking. Devices function as master and slave in piconet.
- Scatternet-Formed by two or more Piconets
- Master of one piconet can participate as a slave in another connected piconet
- No time or frequency synchronization between piconets





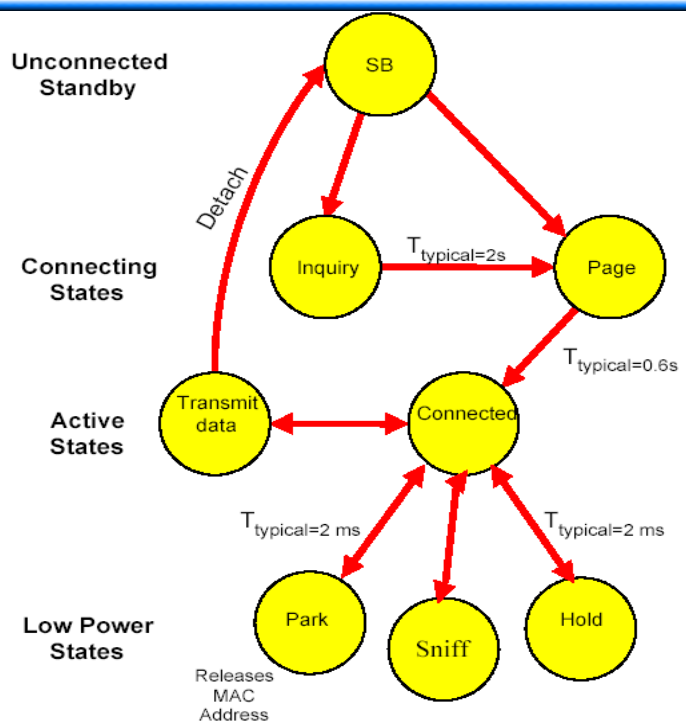


Interconnected Piconets- Scatternets



Connection Management

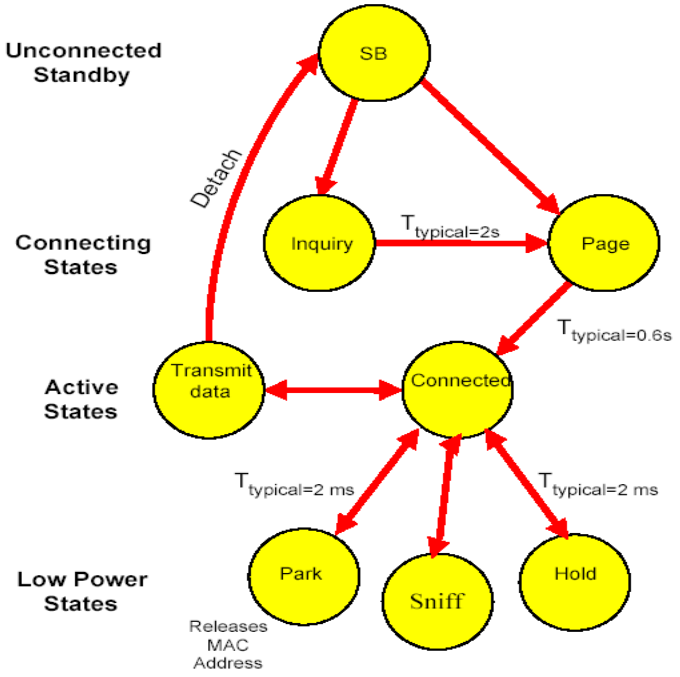
- In the beginning of the formation of a piconet, all devices are in SB mode, then one of the devices starts with an inquiry and becomes the “M” (Master) terminal.
- During the inquiry process, “M” registers all the SB terminals that then become “S” (Slave) terminals. After the inquiry process, identification and timing of all “S” terminals is sent to “M” using FHS packets.
- The “M” terminal starts a connection with a PAGE message including its timing and ID to the “S” terminal.
- When the connection is established, the communication takes place, and at the end, the terminal can be sent back to SB, Hold, park or Sniff states.



Standby (SB): do nothing
Inquiry: search for other devices
Page: connect to a specific device
Connected: participate in a piconet

Connection Management

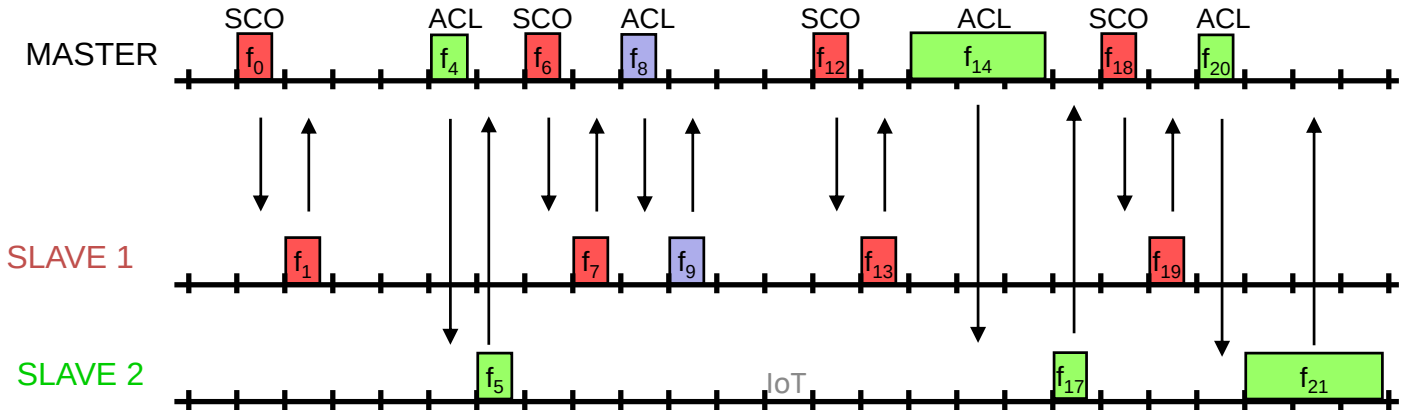
- Hold, Park and Sniff are power-saving modes.
- The Hold mode is used when connecting several piconets or managing a low-power device.
- In the Hold mode, data transfer restarts as soon as the unit is out of this mode.
- In the Sniff mode, a slave listens to the piconet at reduced and programmable intervals according to the applications needs.
- In the Park mode a device gives up its MAC address but remains synchronized with the piconet.
- A Parked device does not participate in the traffic but occasionally listens to the traffic of "M" to resynchronize and check on broadcast messages.



Park: release AMA, get PMA
Sniff: listen periodically, not each slot
Hold: stop ACL, SCO still possible, possibly participate in another piconet

Polling Based Transmission

- Polling-based TDD packet transmission--625µs slots, master polls slaves
- SCO (Synchronous Connection Oriented) – Voice
  - Point to Point Connection between only one master and only one slave.
  - Periodic single slot packet assignment, 64 kbit/s full-duplex, point-to-point
  - Slot reservation at fixed intervals
- ACL (Asynchronous Connection Less) – Data
  - Multipoint connection between one master and many slaves
  - Variable packet size (1,3,5 slots), asymmetric bandwidth, point-to-multipoint
  - Polling access method



Data Transmission

•If there is no data to be sent on the ACL link and no polling is required, no transmission shall take place.

•If a slave fails to decode the slave address in the packet header, it is not allowed to transmit in the next slot.

•However, on an SCO link, the slave can go ahead and transmit in its allocated slot even if the decoding fails in the preceding slot.

•SCO slave shall not transmit in its allocated slot if a different slave was addressed in the previous master-to-slave slot.

•A collision can happen when a slave incorrectly decodes a packet addressed to another slave and responds

Challenges facing Bluetooth

- Interoperability
  - Always a challenge for any new technology
- Hyped up expectations
- Out of the box ease of use
- Cost target $5
- RF in silicon
- Conflicting interests – business and engineering

Zigbee and Bluetooth

Optimized for Different Applications

ZigBee

- Smaller packets over large network
- Mostly Static networks with infrequently used devices
- Home automation, toys, remote controls, etc.

Bluetooth

- Larger packets over small network
- Ad-hoc networks
- File transfer
- Screen graphics, pictures, hands-free audio, Mobile phones, headsets, PDAs, etc.

Address Different Needs

ZigBee

- Is better for devices Where the battery is 'rarely' replaced
- Targets are :
  - Tiny fraction of host power
  - New opportunities where wireless not yet used

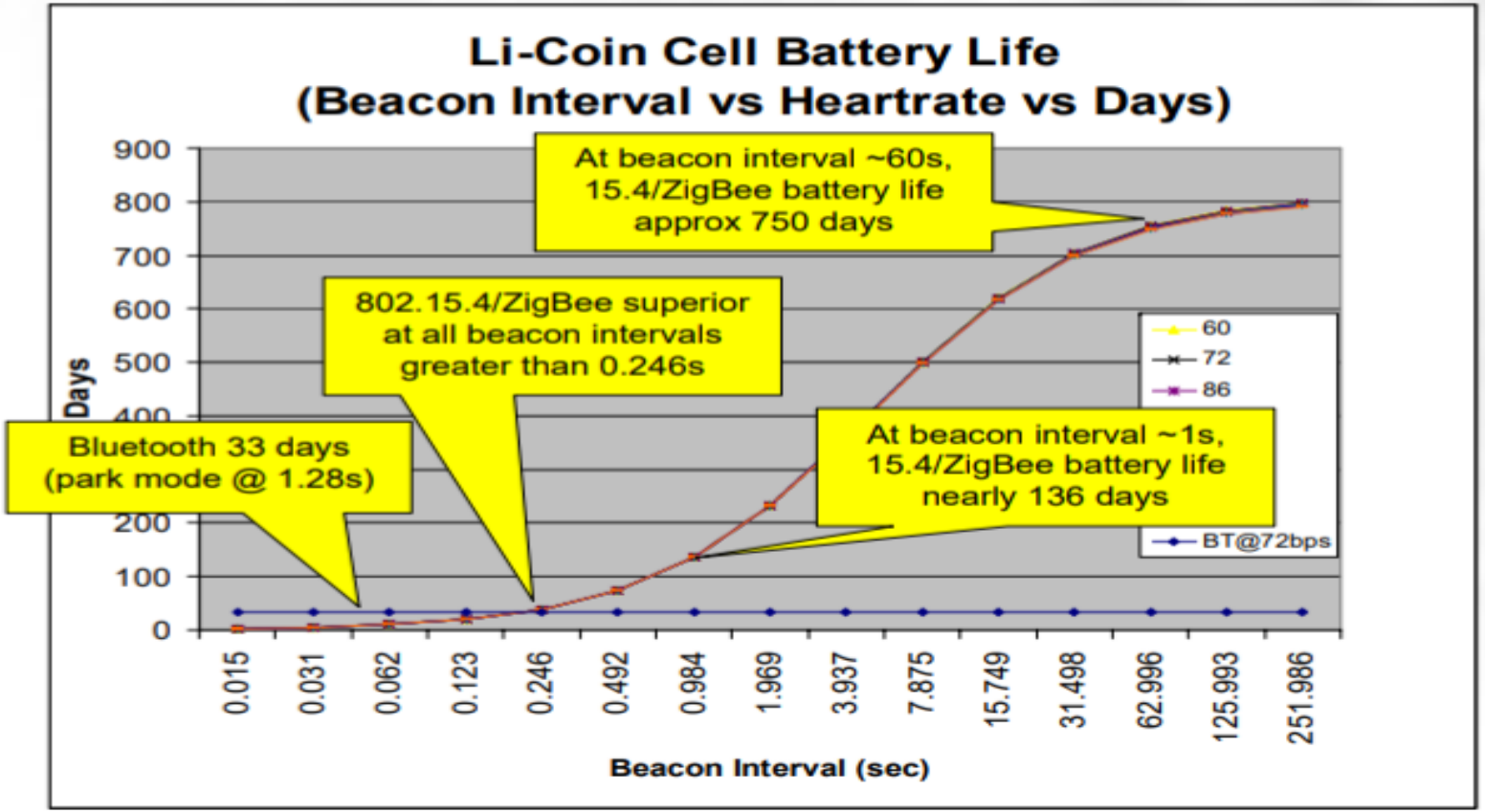
Bluetooth

- Is a cable replacement for items like Phones, Laptop Computers, Headsets
- Expects regular charging
- Target is to use <10% of host power

Zigbee and Bluetooth

	Bluetooth	ZigBee
AIR INTERFACE	FHSS	DSSS
PROTOCOL STACK	250 kb	28 kb
BATTERY	rechargeable	non-rechargeable
DEVICES/NETWORK	8	255
LINK RATE	1 Mbps	250 kbps
RANGE	~10 meters (w/o pa)	~30

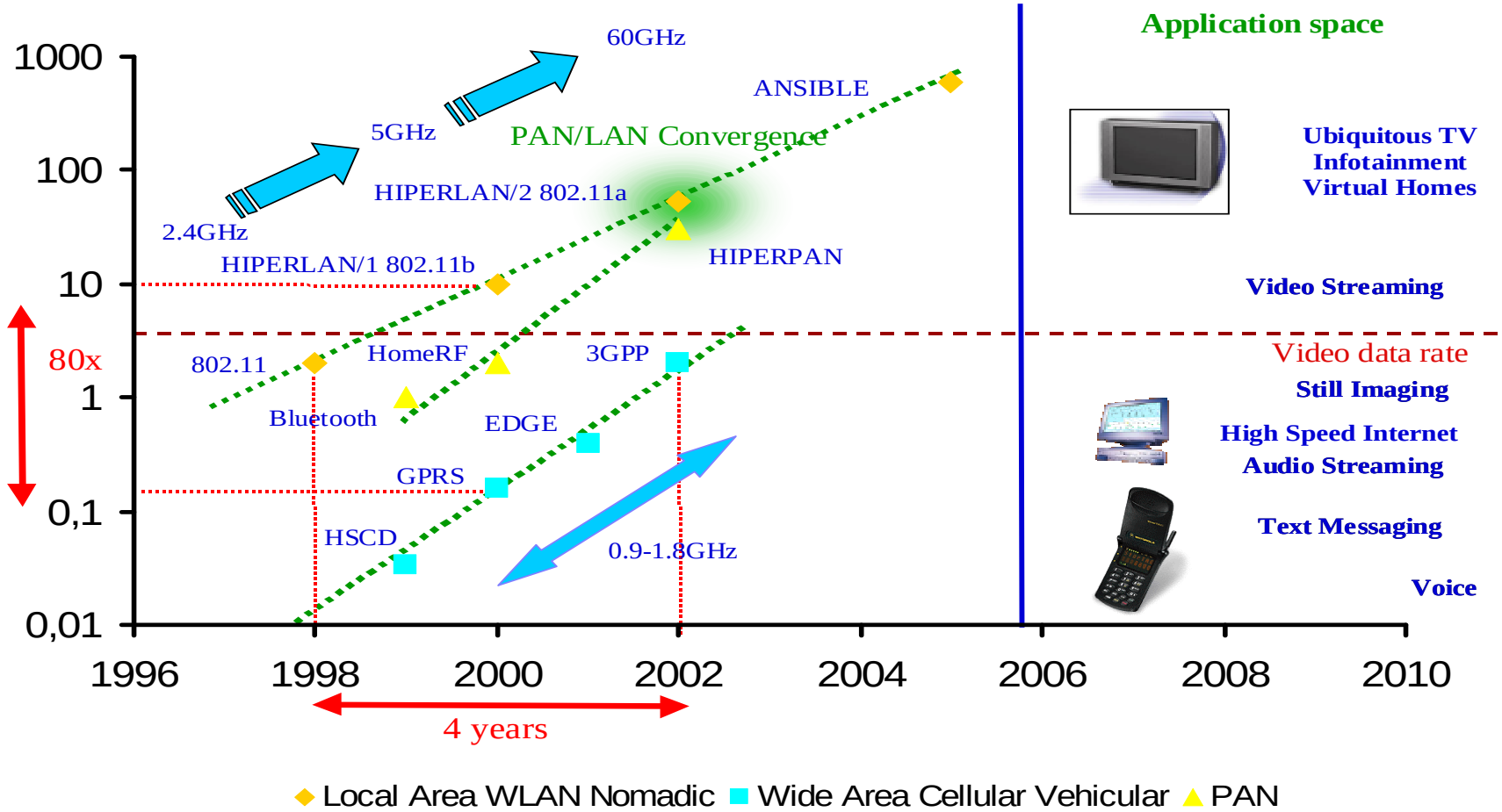
Lifespan


Li-Coin Cell Battery Life
(Beacon Interval vs Heartrate vs Days)
At beacon interval ~60s, 15.4/ZigBee battery life approx 750 days
802.15.4/ZigBee superior at all beacon intervals greater than 0.246s
Bluetooth 33 days (park mode @ 1.28s)
At beacon interval ~1s, 15.4/ZigBee battery life nearly 136 days
Days
900
800
700
600
500
400
200
100
0
60
72
86
BT@72bps
0.015
0.031
0.062
0.123
0.246
0.492
0.984
1.969
3.937
7.875
15.749
31.498
62.996
125.993
251.986
Beacon Interval (sec)

Comparison

Feature(s)	IEEE 802.11b	Bluetooth	ZigBee
Power Profile	Hours	Days	Years
Complexity	Very Complex	Complex	Simple
Nodes/Master	32	7	64000
Latency	up to 3 secs	up tp 10 secs	30ms
Range	100 m	10m	70m-300m
Extendability	Roaming possible	No	YES
Data Rate	11Mbps	1Mbps	250Kbps
Security	Authentication Service Set ID (SSID)	64 bit, 128 bit	128 bit AES and Application Layer user defined

Convergence Scenario



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