Application-Optimized Wireless Sensor Network Interfaces

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What is a Body Area Network?

- A Body Area Network (BAN) is defined as:
  - A communications technology that is optimized for low power consumption and operates in, on or around the human body to enable a variety of applications including medical, consumer electronics and personal entertainment

- Example of a medical BAN:

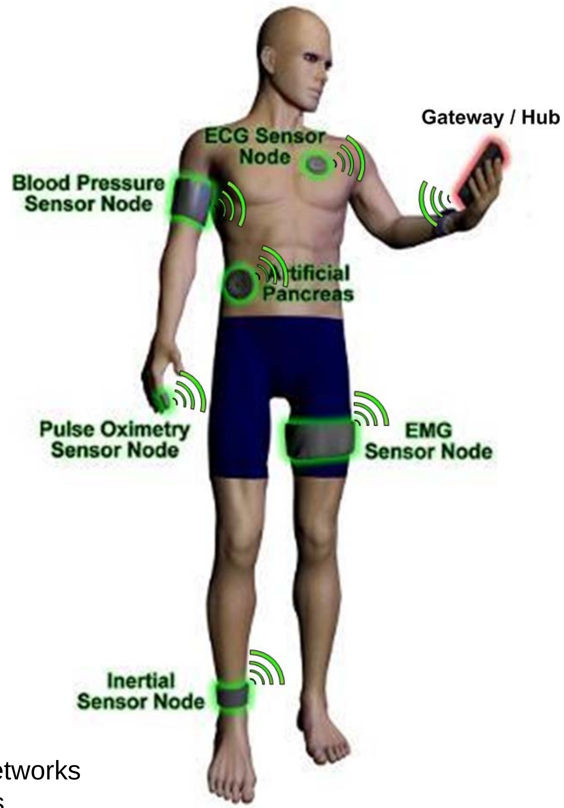


Figure source: University of Virginia Engineering – Body Area Sensor Networks
inertia.ece.virginia.edu/engineering-research/body-area-sensor-networks

Example Sensors

- BAN must support a wide-range of sensors/applications:

Sensor	Data Type	Bits/Sample	Sample Rate	Date Rate (kbps)	Priority (Qos)	Encryption	Battery Life
5/6-lead ECG	Streaming	72	500 Hz	36	High	Yes	1 week
SpO2	Streaming	40	76 Hz	3.04	High	Yes	1 week
Accelerometer (3-axis)	Streaming	30	50 Hz	1.5	Medium	No	6 months
Blood Pressure	Episodic	80	1 – 10 / day	–	Medium	Yes	3 – 6 months
Weight Scale	Episodic	16	1 / day	–	Low	No	1 – 2 years

- Diverse requirements:
  - Throughput
  - Streaming vs. episodic
  - Data robustness: reliability, latency and jitter requirements
  - Security / encryption
  - Peak / average power consumption

Requirements for BAN Standard

- General:
  - Sensors located inside or on body
  - Low-cost and disposable
- PHY:
  - Range: $\geq$ 3 meters
  - Data rates: 100 kbps – 1 Mbps
  - **Peak-power consumption $\leq$ 3-5 mA** (note: radio is 80-90% of total power)
  - Robust in noisy and interference-limited environments
  - Coexist with legacy devices
- MAC and Security:
  - Star topology
  - Support for streaming and episodic data
  - Simple setup mechanism with short access times
  - Support for QoS
  - **Efficient power management – micro and macro sleep intervals**
  - Support for alarms
  - **Support for strong security**

IEEE 802.15.6 Narrowband PHY/MAC meets these requirements

IEEE 802.15.6 Low-Power PHY

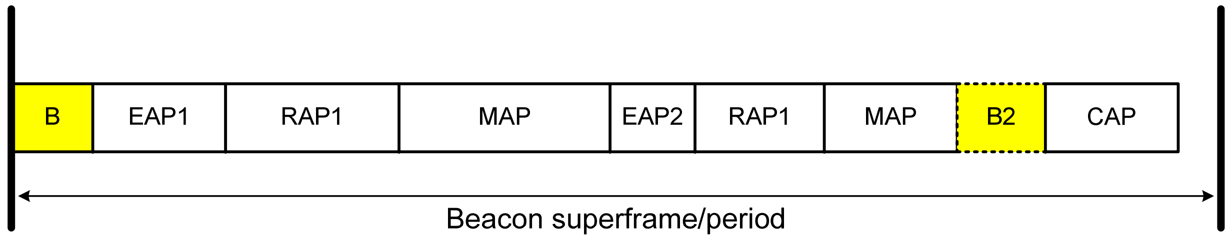
- Standard designed for a low peak-power implementation of narrowband PHY
- Relaxed RF requirements:

Feature of Standard	PA	TX VCO	LNA	RX VCO	RX Channel Filters	ADC
TX power (–10 dBm)	✓					
SNR requirement		✓		✓		✓
High noise figure			✓			
Multiple preambles					✓	
Relaxed ACI specs				✓	✓	✓
D-BPSK and D-QPSK		✓				

- Relaxed digital baseband requirements:
  - Differential PSK + powerful m-sequence minimizes complexity of packet detection
  - Differential PSK eliminates the need for a channel estimation block
  - FEC is based on a simple, binary, 2-bit error correcting BCH code
  - Number of data rates and options are kept to a minimum

IEEE 802.15.6 Protocol Power Savings

- An efficient protocol can lead to significant (average) power savings



B: Beacon
EAP: Emergency access phase

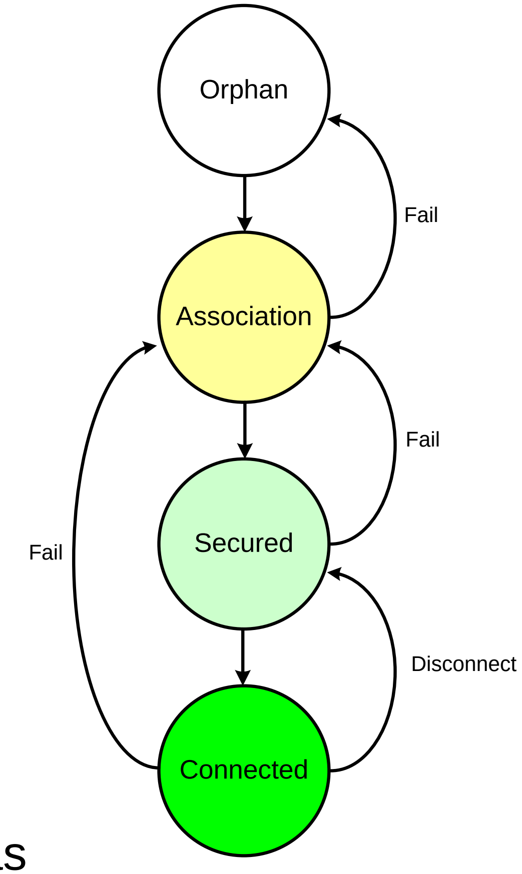
RAP: Random access phase
MAP: Managed access phase
CAP: Contention access phase

- Streaming applications:
  - Scheduled access: nodes wake up at pre-negotiated time to transmit / receive frames
  - Nodes sleep between packets and conserve power
  - Depending on clock accuracy and guard times requirements, nodes can skip multiple beacons, allowing nodes to sleep even longer
- Episodic applications:
  - Random access: allows a node to transmit data only when it is available
  - Node wakes up prior to arrival of a beacon to synchronize timing with network

IEEE 802.15.6 Security

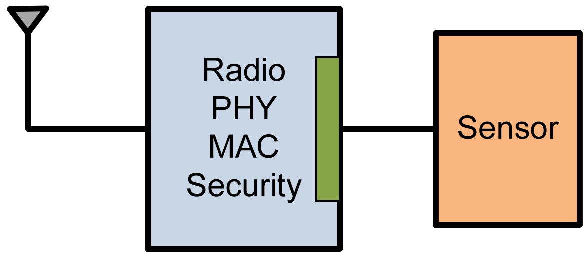
- Standard was developed using the security model shown to the right
  - MAC protocol was built on top of this security model
  - For comparison, traditional approach starts with the association model and build security on top of it
  - Security is sometimes an afterthought

- IEEE 802.15.6 approach leads to a more robust security mechanism at the MAC layer:
  - Better protection for higher layers
  - Less energy consumed because the number of messages exchanged is reduced
  - Example: 11 messages are needed for BLE, whereas only 4 messages are needed for 802.15.6



Smart Sensors

- Example wireless sensor platform:



- Sensors need to be "smart enough" to efficiently use the radio:
  - Minimize data to be transferred by implementing local processing at the sensor
  - Sensors should only be on when collecting data → duty cycling
  - When enough data has been collected, or QoS requirements have been met, only then should data be pushed to the radio
- Take a "systems-view" when designing the radio, sensor and sensor interface, goal should be to minimize overall power consumption, not just radio power
- Key to proliferation of wireless medical sensors is to standardize the interface between the sensor and radio: *Goal is to support multiple sensors using a single radio*