Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [Topological Considerations for BAN]
Date Submitted: [May 13, 2008]
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Abstract: [This document presents the topological considerations for BAN. It highlights pros and cons of star, mesh, tree and hybrid topologies from BAN perspective]

Purpose: [To stimulate discussion on BAN topology]

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Introduction

- Network topology/architecture is a key design issue
- Network topology determines the way devices are interconnected
- Network topology considerations plays a central role in MAC protocol design
  - Mesh, star, tree, peer-to-peer, master-slave
- Network topology should be derived from application requirements

BAN Device Types by Location

- On the body
  - Distance of the device is less than a few cms from body
  - ECG, EEG, EMG, Blood pressure, Temperature, SpO_2 sensors, Hearing aids, Head phones
- Around/near the body
  - Distance of the device is greater than a few cms from body
  - Bedside patient monitoring devices, Gaming console
- Deep-inside the body
  - Camera pills, Implanted Cardiac Defibrillators (ICD), Deep brain stimulators, Nerve stimulators, Retina implants, Cochlear implants
- Marginally-inside the body
  - Subcutaneous devices
  - Glucose sensor and insulin pump

BAN Device Types by Energy Supply

- Replenishable
  - ECG, EEG, EMG, Temperature, Blood pressure, SpO_2 sensors, hearing aids, head phones
- Non-replenishable
  - Implants
  - Camera pills, ICDs, Deep brain stimulators, Nerve stimulators, Retina implants
- Mains powered
  - Bedside monitors
- Self-powered
  - Based on energy scavenging techniques

BAN Device Types by Function

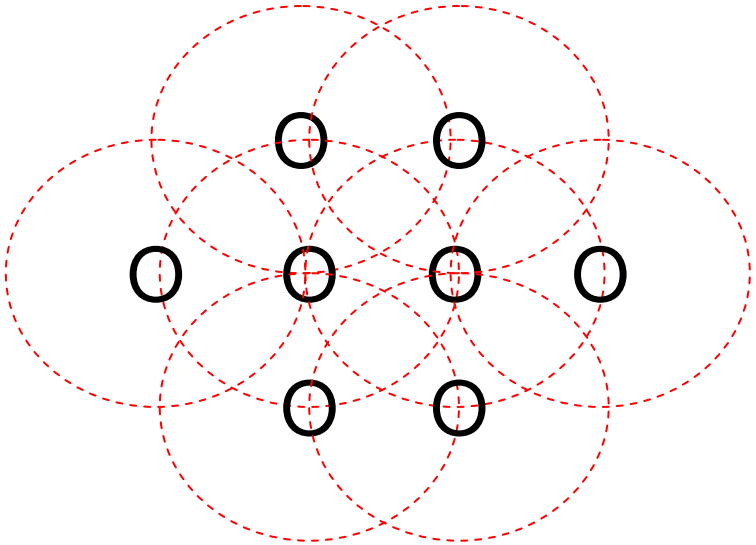
- Sensors
  - ECG, EEG, EMG, Blood pressure, SpO_2 sensors, Glucose sensor, pH sensor, image sensor
- Actuators/Stimulator
  - Drug pump, Nerve stimulator, Brain stimulator, ICDs
- Data collectors/aggregator
  - Bedside monitor, Image collector for camera pill, ECG collector, EEG collector, EMG collector, ICD data collector
- Controller/programmer/tuner
  - ICD controller, Nerve stimulator controller, EMG controller
- Gateway/Access point
  - Gateway to outside world
    - Cell phone, PDA, Wi-Fi access point
    - Translate BAN protocol to other protocols

BAN Device Type by MAC functions

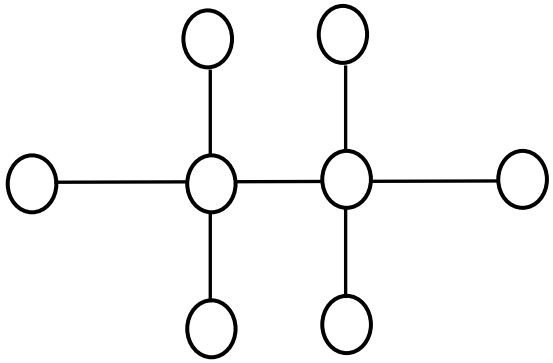
- Anchor/BAN coordinator
  - Starts and maintains BAN
  - Selects suitable frequency channel for operation
  - Authenticates devices
  - Stores keys
- Masters/Parents/Coordinators/Full Function Devices
  - Heavy duty/complex devices
  - Assist in network formation, management and routing
  - Send and receive data
  - Forms the backbone of the network
- Slaves/Children/Reduced Function Devices
  - Light duty/simple devices
  - Low cost energy efficient devices
  - Send and receive data

Network Topology

- Physical topology
  - The way devices are physically interconnected
  - PHY layer
- Logical topology
  - Communication (data) flow path
  - MAC and Network layer



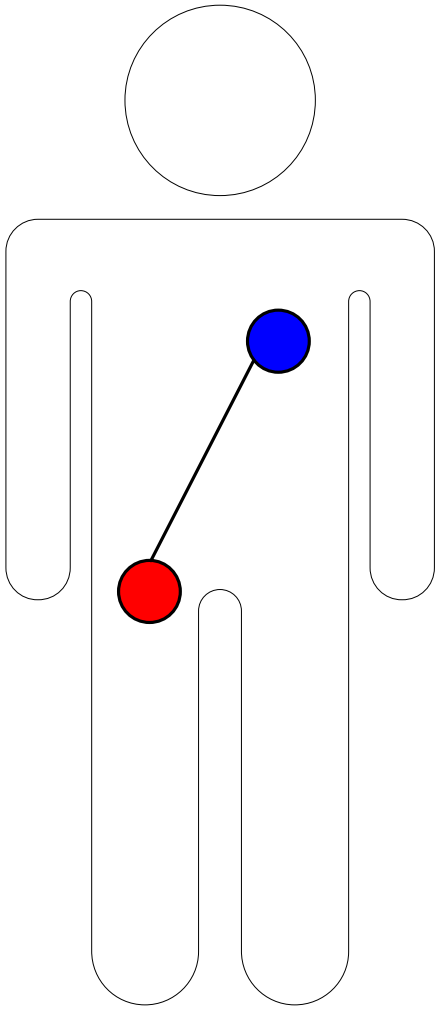
Physical Topology



Logical Topology

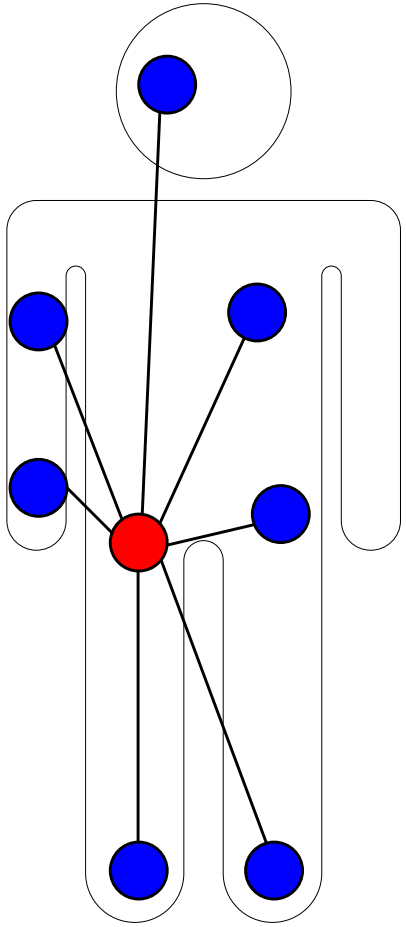
Point to Point

- Simplest topology
  - Connection between a pair of devices
- Example applications
  - Implanted ICDs, camera pills, drug-pill, glucose monitor, Nerve stimulator, Brain stimulator, retina implants
- MICS band only allows communication between an implanted device and an external programmer/controller



Star (Spoke and hub)

- Central coordinator surrounded by peripheral (slave) devices
- Indirect communication between slaves via coordinator
- Example Applications:
  - ECG, EEG, Blood pressure, SpO_2, Temp, Heart rate, Patient monitoring

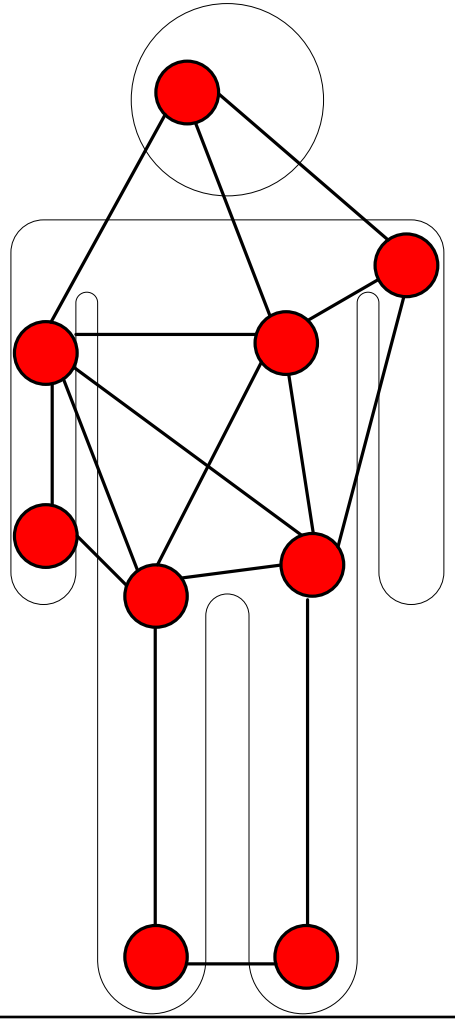


Star (Cont'd)

Advantages	Disadvantages
• Simplicity • Ultra-low power operation of slave nodes • Easy configuration • Centralized management	• Complex central coordinator node • Higher power consumption of central coordinator • Limited coverage area • Single point of failure • Not scalable • Indirect communication between neighboring slave nodes

Mesh (Peer-to-peer)

- Any two devices within the transmission range can communicate
- Example Applications
  - ECG, EMG, Blood pressure, SpO_2, Temp, Heart rate, Patient monitoring, extreme sports safety, vital signs monitoring for firefighter and soldiers

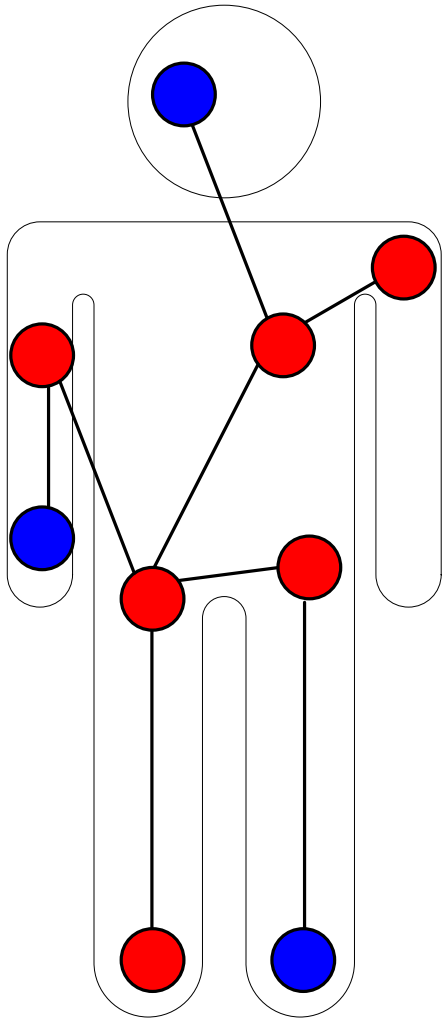


Mesh (Cont'd)

Advantages	Disadvantages
• Robust • Reliable • Scalable • Fault-tolerant • Extended coverage • Nodes can have identical functionality and balanced energy consumption • Short and efficient communication paths • Low latency	• Functionally identical node may not be required in many applications • Increased cost • Complex routing

Tree

- Root forms the tree
- Nodes on the tree have parent-child relationship
- Route between two devices go through common parent
- Example Applications:
  - ECG, EMG, EEG, Blood pressure, SpO_2, Temp, Heart rate, Patient monitoring

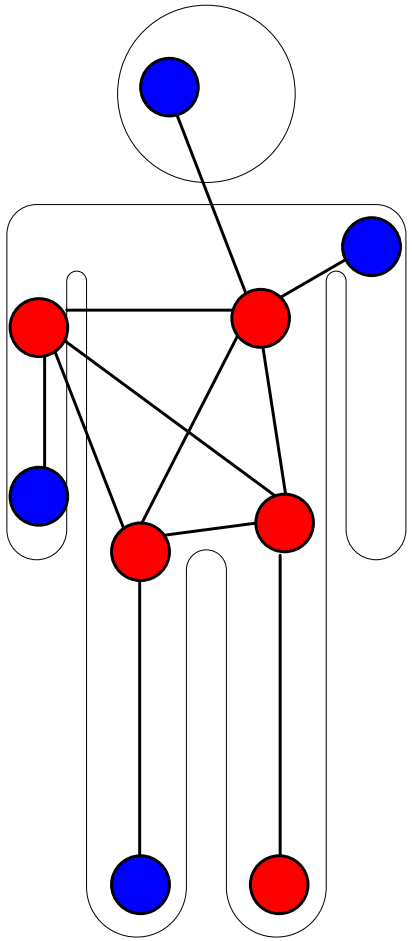


Tree (Cont'd)

Advantages	Disadvantages
• Low complexity • Ultra-low power operation of leaf nodes • Easy configuration • Centralized management • Large coverage area	• Complex root node • Higher power consumption of parent nodes • Single point of failure • Poor reliability • Limited scalability • Indirect communication between neighboring leaf nodes • Longer routes • Higher latency • Root is the bottleneck

Hybrid (Star+Mesh)

- Combines robustness and flexibility of mesh with simplicity and low-power operation of star
- End/leaf nodes can be slaves and save energy
- Example applications:
  - ECG, EMG, Blood pressure, SpO_2, Temp, Heart rate, Patient monitoring, extreme sports safety, vital signs monitoring for firefighter and soldiers

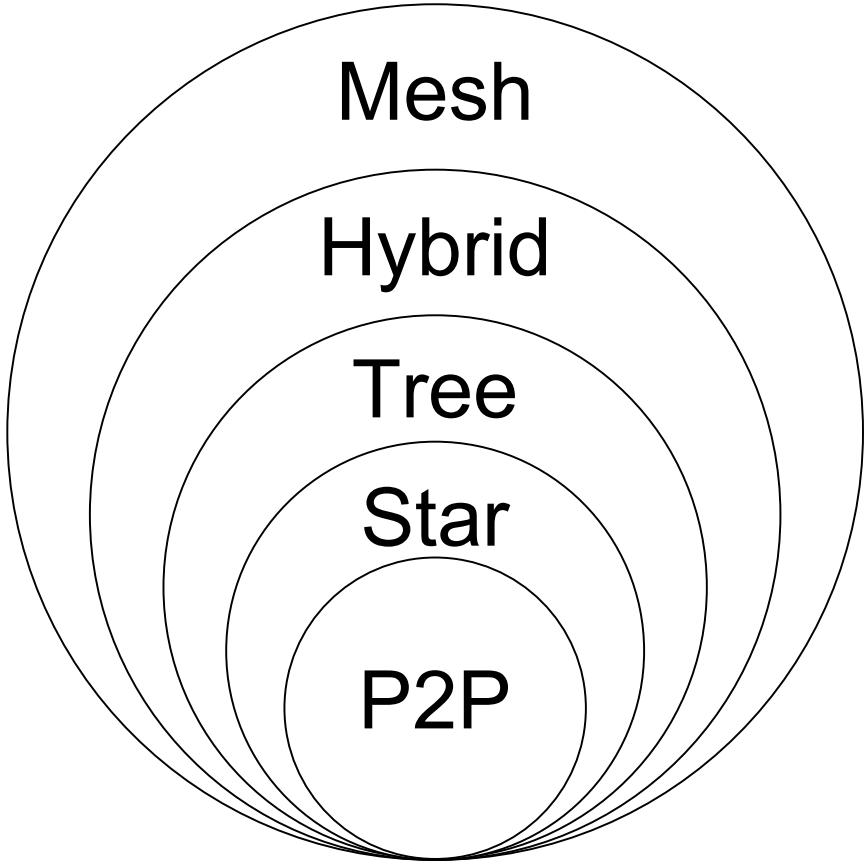


Hybrid (Cont'd)

Advantages	Disadvantages
• Medium complexity • Ultra-low power operation of leaf nodes • Inexpensive leaf nodes • Large coverage area • Low latency • Robust and reliable • Scalable	• Higher power consumption of parent nodes • Indirect communication between neighboring leaf nodes • Asymmetric power consumption between parent and child

Topology

- Questions for the group:
  1. Which topologies shall we support?
  2. Can we design a MAC protocol that is flexible enough to construct any kind of topology?



Conclusion

- Topology is a key design issue
- Application requirements, topology and MAC protocol design are interwoven
- Reliability, fault-tolerance, scalability and QoS key design goals for BAN which tend to favor mesh
- On the other hand full mesh topology can be overkill for many applications
- The challenge for the TG6 is to strike right balance between reliability, scalability and complexity

Reference

Javier Espina, Thomas Falk and Oliver Mulhens "Network Topologies, Communication Protocols and Standards" book chapter in Body Sensor Networks, Springer-Verlag, London 2006