Cooperative Communications and Wireless Body Area Networks

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**Wireless Body Area Networks**
- Applications
- Network architecture of WBANs
- MAC and Route Protocols
- Interworking

**Cooperative Communications**
- Features of Cooperative Communications
- Cooperation Mechanisms
- Cooperative communications in WBANs
Applications: Definition

• WBAN will provide short range, low power and highly reliable wireless communication for use in close proximity to or inside body.

Date rate: up to 10Mbps
• Date rate: up to 10Mbps
• Range: 2m or extended to 5m
Applications: Usage

Healthcare application such as Telemedicine, physiological monitoring and emergency response

Wellness application such as interactive gaming, CE
Applications: HBC

- MPEG
- Photo
- Display Photo
- Play MPEG
- Display Documents

'Ve Touch and Play'!!
Applications: System architecture

Figure 1 Health Monitoring System Network Architecture
Applications: Traffic Classification

• Medical and non-medical Sensors can be classified as in-body, on-body and around body sensor; or classified as biosensor and motion sensor

• Traffic is classified as wave-form real time stream, real-time parameter measurement stream, and video stream
Applications: Uniqueness for Healthcare Application

• Medical information has higher priority in communication networks
• Veridical and time-accurate acquisition of physiological data is extremely important
• Patient mobility and Channel Characterization give rise to a dynamic, time-varying environments
• Un-compressed video for ECG, robot control
• Movement of limbs and various postures of human body
Network Architecture

- Definition: a logical connection of communication
- Types: star, multihop and cluster-based architecture
- Performance metrics: PDR, ANR, network lifetime and inter-user interference
- Considerations: power limited, transmission delay, reliability, tissue protection
Network Architecture: Spectrum Regulations

- WMT Frequencies: 608-614MHz, 1395-1400MHz, 1427-1432MHz
- ISM  UWB  MICS (Implant medical sensors)
Network Architecture: Issues

- How to design network architecture to satisfy medical QoS requirements in a dynamic and time variant environment with the constraint of energy-efficiency, low radiation and low inter user interference
- How to maximum network lifetime while satisfying QoS requirements
MAC and Routing Protocol

- No existing standard for WBAN MAC protocol
- Referring WPAN standards: IEEE 802.15.1/Bluetooth, IEEE 802.15.4/Zigbee
- Future WBAN standard: IEEE 802.15.6
  - NICT MAC proposal (Nov/2009)
  - MedWiN MAC and Security Proposal (Sep/2009)
  - Two Protocols Merged in 2010
MAC and Routing Protocol: Cont’d

- Many new proposed MAC and route protocols have been studied
- CICADA (Cascading Information Retrieval by Controlling Access with Distributed Slot Assignment)
- Battery-Dynamics Driven TDMA
- DQBAN (Distributed Queuing Body Area Network): Hybrid slotted TDMA/CSMA
- CCA/TDMA
MAC and Routing Protocol: MedWiN

MAC-Network Topology

**Subnet 1**
- H1
- N1a
- N1b
- N1c
- N1d

**Subnet 2**
- H2
- N2a
- N2b
- N2c
- N2d
- N2e

H = hub
N = node

Interference mitigated between subnets
MAC and Routing Protocol: Issues

- How to design network MAC protocols enabling WBANs adaptively and intelligently balance the QoS requirements and unique constraints
- How to design cooperative communication protocols for WBANs
- How to combine minimum energy route and low duty cycle scheduling to maximum network lifetime of WBANs while satisfying QoS requirements is a challenging issue.
Interworking
Internetworking: Issues

• The research shows that How to efficiently allocate bandwidth when integrating heterogeneous wireless networks is obviously a challenge.

• Consistency medical QoS providing over integrated WiFi/WiMax wireless networks is a challenge research.

• Efficient radio resource management, scheduling and connection admission control are still open issues in WiMax networks, they are also crucial in integrated WiFi/Wimax wireless networks for E-health services.
Internetworking: Issues

- Handover management for seamless integration of wireless networks and for providing continuous E-health service for mobile users may be one of the most challenging issues, due to the transfer of vital medical information through dynamic wireless channels and networks.
- How to efficiently manage the spectrum to accommodate different application by using cognitive radio technology is a challenge issue.
- How to design a resource-aware secure mechanism within WBAN and with heterogeneous networking
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• Cooperative communications in WBANs
Features of Cooperative Communications: concepts

- A derivative of MIMO systems which can increase spectrum efficiency through spatial multiplexing and improve the robustness/range of wireless link for a given data rate through space-time coding and beamforming.
- Cooperation means that multiple nodes in a wireless network work together to form a virtual antenna array to exploit the spatial diversity of the traditional MIMO techniques without each node necessarily having multiple antennas.
- It is fundamentally different from multihop communications, in which the destination only receives one version of the message from the source.
- It utilizes the broadcast nature of wireless signals, where relays, partners or helpers can overhear the communications between a source and a destination.
Features of Cooperative Communications: performance metric


\[ P_e(SNR) \approx \frac{3}{16} SNR^{-2}, \quad P_e(SNR) \approx \frac{1}{4} SNR^{-1}. \]
Features of Cooperative Communications: Benefits

- Higher spatial diversity: resistance to both small scale and shadow fading
- Reduced interference/low transmitted power: better frequency reuse in a wireless networks
- Adaptability to network conditions: opportunistic use and redistribution of network energy and bandwidth
Features of Cooperative Communications: tradeoff

Spatial Multiplexing gain

\[
\lim_{\text{SNR} \to \infty} \frac{R(\text{SNR})}{\log \text{SNR}} = r
\]

Diversity gain

\[
\lim_{\text{SNR} \to \infty} \frac{\log P_e(\text{SNR})}{\log \text{SNR}} = -d.
\]

Trade off

\[
d^*(k) = (m - k)(n - k).
\]

Cooperation Mechanisms

With the dimensions DF and AF:

• Fixed relaying
• Selection relaying
• Incremental relaying
• Incremental transmission relay selection (ITRS)
• Multi-hop with relay selection (MHRS)
Cooperative communications in WBANs: Driven forces

Driven forces from WBANs and other sensor networks:

• high path loss
• Extreme low transmission power
• Limiter energy consumption
• High reliability and QoS requirements
Cooperative communications in WBANs: Driven forces

Driven forces from WBANs and other sensor networks:

• high path loss
• Extreme low transmission power
• Limiter energy consumption
• High reliability and QoS requirements
• Coordinating mission tasks
• Automatic and self organization
Cooperative communications in WBANs: Preliminary Results

The graph shows the overall energy consumption per bit (nJ) for different body positions. The positions include:
- Left ear
- Right ear
- Left wrist
- Right wrist
- Right waist
- Left ankle
- Right ankle

The bars indicate the energy consumption under two scenarios:
- Direct
- Cooperative

The x-axis represents the body positions, while the y-axis shows the energy consumption in units of $\times 10^4$ nJ.
Cooperative communications in WBANs: Preliminary Results

![Graph showing path loss in posture one (dB) vs. overall energy consumption per bit (nJ) for direct and cooperative communication.]
Cooperative communications in WBANs: Challenges

- No cooperative protocol has been designed for WBANs
- Cooperative Networking: to integrate WBANs or sensor networks to other heterogeneous networks such as cellular/WiFi networks in ubiquitous computing
Thanks for your attention

Q&A?