Body Area Networking Standardization: Present and Future Directions

Carlos Cordeiro
Philips Research N.A.
345 Scarborough Road
Briarcliff Manor, NY 10510
carlos.cordeiro@philips.com

Maulin Patel
Philips Research N.A.
345 Scarborough Road
Briarcliff Manor, NY 10510
maulin.patel@philips.com

ABSTRACT

Body Area Networks (BAN) designed for medical, lifestyle and entertainment applications have drawn the attention of many researchers and industry players alike. This is primarily due to the surge in the number of personal electronic gadgets, new sensing and monitoring devices for in-body and near-body use, device miniaturization, and technological advances in Wireless Sensor Networking (WSN). BAN enables the convergence of these technologies by providing a single unified solution for connectivity in and around the body towards providing the connected consumer experience.

BAN brings about new set of challenges such as scalability (in terms of data rate, power consumption and number of devices), integration of in and around the body networking, interference mitigation, coexistence, QoS, and ultra-low power protocols and algorithms. Moreover, effects on human body have to be considered and several regulatory requirements have to be met. On the standardization side, the IEEE 802.15 Study Group on BAN (SG-BAN) has recently been formed to lead the initiative of developing a single unifying BAN standard that addresses these challenges.

In this paper we study the applications, functional and technical requirements that are at the center of the first BAN specific standards making process. We compare and contrast these requirements with existing low power low data rate WPAN standard called ZigBee. Our goal is to highlight the core set of requirements and research challenges which must be addressed by a BAN standard for it to become ubiquitous and pervasive technology.

Categories and Subject Descriptors

C.2.1 [**Computer-communication Networks**]: Network Architecture and Design —*Wireless Communication*

Keywords

Body Area Networks, wireless, standard

1. INTRODUCTION

Recent advances in Wireless and Micro-Electro-Mechanical technologies and the proliferation of electronics gadgets in, on and around human body provide a unique opportunity for building next generation wireless BAN technology targeted at medical and consumer applications. BAN is seen as the key technology that will provide a single unified solution for connectivity in and around the body, and which is intended to support a wide range of medical applications such as wellness monitoring, deep brain stimulation, electronic pills, and implanted drug delivery, as well as lifestyle applications including ambient intelligence (e.g., home, office, car), gaming, entertainment, and consumer electronics.

Despite significant technical advanced in WSN technology, BAN poses unique technical challenges primarily due to diversity of applications and their stringent requirements as can be seen from Table 1. Developing a single unifying BAN standard that addresses these complex set of functional requirements is an important first step toward achieving interoperability and economics of scale. With that in mind, the IEEE 802.15 Study Group on BAN (SG-BAN) has been formed in November 2006 [3].

Table 1: Functional requirements of BAN Apps

Application	Data Rate	Latency	BER
Capsule Endoscope	1 Mbps	-	$< 10^{-10}$
ECG	192 Kbps (6 Kbps, 32 channels)	$< 250ms$	$< 10^{-10}$
EEG	86.4 Kbps (300Hz sample, 12-bit ADC, 24 channels)	$< 250ms$	$< 10^{-10}$
EMG	1.536 Mbps (8kHz sample, 16-bit ADC, 12 channels)	$< 250ms$	$< 10^{-10}$
O_2, CO_2, Glu. Monitor	1 Kbps	$< 20ms$	$< 10^{-5}$
Audio, Video, Med. Imaging	$<$ 10 Mbps (e.g. SD)	$< 100ms$	$< 10^{-3}$
Voice	50 - 100 Kbps/flow	$< 10ms$	$< 10^{-3}$

2. FUNC. & TECH. REQUIREMENTS

Table 1 shows the functional requirements of a few typical BAN applications. Notice the wide variation in data rate, BER and delay tolerance which requires scalable solutions with QoS provisions.

Table 2 identifies core technical requirements that should be addressed by a BAN standard and compares these requirements with existing low power, low data rate wireless sensor network standard called ZigBee [2]. ZigBee defines network, transport and application layers on the top of phys-

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Table 2: BAN Technical Requirements

Characteristic	Technical Requirement	ZigBee/802.15.4
Supported applications	Medical, Consumer electronics, Entertainment, Gaming, Interactive, Ambient intelligence.	Home, Industrial & Plant automation, Lighting, Meter reading.
Operating space	In, on, or around the body. Up to 3 m.	10m to 100m.
Network size	Modest; < 256 devices per BAN	Huge; Up to 65K devices.
Data rate	Scalable from sub Kbps up to 10Mbps (see Table 1).	20, 40 or 250 Kbps.
Device duty cycle	Scalable from 0.01% to 100%. Between 0.01-1% in stand-by mode & Up to 100% in fully active mode.	Full function devices 100% & Reduce function devices <100%.
Target frequency bands	Unlicensed and Medical approved bands e.g. MICS, MEDS, ISM, WMTS. (Consumer Electronics applications confined to ISM bands.)	868, 915 or 2400 MHz
Power consumption	Scalable from 0.01 mW to 40mW. Between 0.01-1mW in stand-by mode and Up to 40mW in fully active mode.	Tx 25-35 mW; Rx 25-40 mW in 2.4GHz band.
Radiated power	Meet local regulatory requirements. E.g. SAR (RF energy absorbed into human tissue) limit imposed in US by the FCC is 1.6W/kg averaged over 1g of tissue for the General Population[1]. Canada and Australia use this limit as well. The SAR standard adopted by the European Union is 2W/kg averaged over 10g of tissue for the General Population [4].	1-100mW (Europe) and 1W (USA).
Coexistence	Coexistence with legacy devices such as WLAN, WPAN, Bluetooth and Self-coexistence. Simultaneous collocated operation of up to 256 devices belonging to different BANs.	Supports multiple collocated ZigBee devices belonging to different PAN.
QoS support	BER: from 10^{-10} to 10^{-3}, Latency: from $10ms$ - $250ms$.	None
QoS differentiation	Hard Real-time, Soft Real-time, Guaranteed delivery, Battery saving mode, Acks, In order delivery, Asymmetric links.	Acks, Best effort.
Security	Privacy, Encryption, Authentication, Message Integrity. MAC, Network and Application security.	AES 128 bit encryption, MAC, Network and App. security.
Safety, Bio-friendly	Meet regulation requirements for SAR and HIPPA.	Outside the scope of standard.
Location information	Localization within a radius of 10 cm for 67% of the cases and within 30 cm for 95% of the cases.	Outside the scope of standard.
MAC	Scalable, robust, reliable, low-complexity MAC.	CSMA-CA, Best effort service.
Routing	Simple; Wearable devices: direct communication. Implanted devices: indirect communication via a wearable device.	Multi-hop, Tree: simple, Mesh: complex.
Robustness, Fault tolerance	Ability to isolate failures (Node, H/W, S/W) and to recover from failures. Avoid single point of failure. Zero maintenace.	Outside the scope of standard.
Synchronization	Synchronize sleep and wake up schedules for energy savings.	Only leaf nodes can sleep.
Ergonomic consideration	Non-invasive, Non-obstructive, Small size, weight, form-factor, Nomadic, Ambient intelligence, Context awareness.	Outside the scope of standard.
Reprogramming	Ability to reprogram implanted devices wirelessly.	Outside the scope of standard.
Remote calibration	Ability to calibrate implanted devices remotely.	Outside the scope of standard.
Network setup time	Up to 1 sec.	50 ms

ical and MAC layers defined by IEEE 802.15.4. The fact that ZigBee does not address majority of core technical requirements of BAN highlights the need for a standard specifically designed for BAN.

3. RESEARCH CHALLENGES

As can be seen from the requirements, a number of research challanges have to be addressed in designing a BAN standard. For example, a 400MHz MICS band PHY is suitable for implanted devices because of a path loss in the order of 100-120dB. However, 400 MHz band PHY is not suitable for wearable devices because of limited throughput. 2.4GHz-ISM band PHY is suitable for wearable devices but it will have very limited range if used for implanted devices. In addition, extensive research and thorough insight are required in the areas of ultra-low power protocols and algorithms, coexistence and interference mitigation, cross-layer design, security and privacy, channel models, to name a few, in order to converge on the most suitable approaches for BAN.

4. CONCLUSION

BAN is a promising technology which can revolutionize next generation healthcare and entertainment applications. Developing a unifying BAN standard which addresses the core set of BAN requirements is the quintessential step to unleash the full potential of BAN, and is currently under discussion in the IEEE 802.15 SG-BAN.

5. REFERENCES

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