Evaluating the IEEE 802.15.6 2.4GHz WBAN Proposal on Medical Multi-Parameter Monitoring under WiFi/Bluetooth Interference

Yufei Wang, Qixin Wang
{csyufewang, csqwang}@comp.polyu.edu.hk
Department of Computing
The Hong Kong Polytechnic University
Outline

- Introduction
- Overview of IEEE 802.15.6 2.4GHz WBAN proposal
- PER analysis of 2.4GHz WBAN
- Case study of ECG monitoring WBAN
- Conclusion
Introduction
Crisis of wired BAN

- Cause frequent falling off of medical sensors
- Limit the movement of patients
- Make medical unit untidy
WBAN Solves the problems of wired BAN

- Sensors unlikely fall off
- Patient feel more comfortable
- Medical units are more tidy
Characteristics of medical WBAN

- Low duty cycle
  - Typical sampling rate < 100Hz[Physionet]
  - Wakeup on demand

- Low data rate
  - The typical rate is 500Kbps[15.6NB][15.6UWB]

- Low power
  - The typical transmit power < 1mW[15.6NB][15.6UWB]

- Versatile latency
  - *ElectroCardioGraph* (ECG) can not tolerate a delay more than 500ms[Chevrollier05]
  - Body temperature monitoring can tolerate several second delay[Chipara10]
IEEE 802.15.6 is making WBAN Standard

- It includes many RF bands, such as 400MHz, 2.4GHz, 3.1G~11.2GHz
- It includes many modulation schemes, such as BPSK, GMSK, IR-UWB, FM-UWB.
- Among them, 2.4GHz proposal is the most mature.
Overview of 2.4GHz WBAN Proposal
RF Channels

- The center frequency $f_c$, for the $n_c$th channel ($n_c = 0, 1, ..., 78$), is $2402.00 + 1.00 \times n_c$ MHz.
- While for WiFi, the center frequency $f_c$, for the $n_c$th channel ($n_c = 1, 2, ..., 13$), is $2407.00 + 5.00 \times n_c$ MHz.
- For Bluetooth, the center frequency allocation is the same as 802.15.6 2.4GHz proposal.
PLCP Preamble and PLCP Header use DBPSK; PSDU may use DBPSK or QPSK. In any case, the symbol rate is 600K.

PLCP Header uses a 19/31 BCH coding and 4 repetitions; PSDU uses a 51/63 BCH coding.
PER Analysis of 2.4GHz WBAN
BER and PER are obtained by:

$$P_{ber} = \frac{1}{2} \exp\left(-\frac{E_b}{N_0}\right)$$

- Where $E_b$ is the per bit energy, $N_0$ is the \textit{Power Spectrum Density} (PSD) of thermal noise, $I$ is the PSD of WiFi interference in this 15.6 Channel

$$P_{ber} = \frac{1}{2} \exp\left(-\frac{E_b}{N_0} G\right)$$

- Where $G$ is the equivalent channel coding gain

$$P_{per} = 1 - \left(1 - P_{ber}\right)^L$$

- Where $L$ is the packet length
More accurate PER is obtained by:

- \[ P_{\text{per}} = (1 - P_{\text{preamble}})(1 - P_{\text{plcp_hdr}})(1 - P_{\text{psdu}}) \],
- where \( P_{\text{preamble}} \) is the error rate of preamble (synchronization error rate); \( P_{\text{plcp_hdr}} \) is the error rate of PLCP Header; \( P_{\text{psdu}} \) is the error rate of PSDU.
- Fig.[PKT] shows that different parts of a packet use different modulation schemes, coding rate and repetition times.
Model Interference

- The bandwidth of WiFi (i.e. 20MHz) is much bigger than that of WBAN (i.e. 1.2MHz), so it is natural to regard WiFi interference as white noise[Golmie03][Shin05].

- While, modeling Bluetooth interference is more difficult, as the bandwidth of Bluetooth (1MHz) is similar to that of WBAN (1.2MHz).

- We let Bluetooth pass band samples pass the down conversion circuit of WBAN to generate base band interference samples. Then, we use these interference samples in Mote-Carlo simulation to get BER of WBAN.
Case Study of ECG Monitoring WBAN
ECG monitoring WBAN consists of a monitor and 4 ECG electrodes.

A Mobile Station (MS) is doing FTP
Polling based MAC

- Monitor broadcasts beacon periodically
- Upon detecting beacon, electrodes upload the samples in assigned time slot
- In assigned slot, electrode may use repetition

- Sampling rate: 100Hz
- Super frame: 10ms
- Slot: 2ms
- Packet duration: 600us
- Data rate: 500Kbps
Mean Time To Failure (MTTF) definition

$$MTTF = \frac{1}{f_s \times P^{WBAN}}$$

- Where $f_s$ is the sampling rate, $P^{WBAN}$ is error rate of whole WBAN
- $P^{WBAN}$ depends on Packet Error Rate (PER) of single packet and super frame structure
- PER depends on Bit Error Rate (BER) and packet length
PER of WBAN under WiFi interference
PER of WBAN under Bluetooth interference
Fig. [MW] MTTF of WBAN under WiFi interference
Fig.[MB] MTTF of WBAN under Bluetooth Interference
Conclusion
WiFi is a big threat; while Bluetooth is not.

- Fig.[MW] shows that: when WBAN base station (monitor) and WBAN client (electrode) is 2m away, the WiFi interferer must be 14m away to ensure a 3 hours MTTF (a safe value).

- Fig.[MB] shows that: when WBAN base station (monitor) and WBAN client (electrode) is 2m away, the Bluetooth interferer need be only 3.1m away to ensure a 3 hours MTTF.
reference


