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

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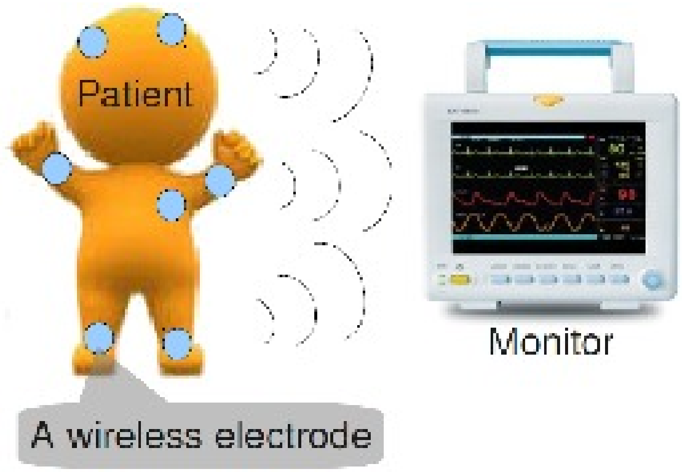
Introduction

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

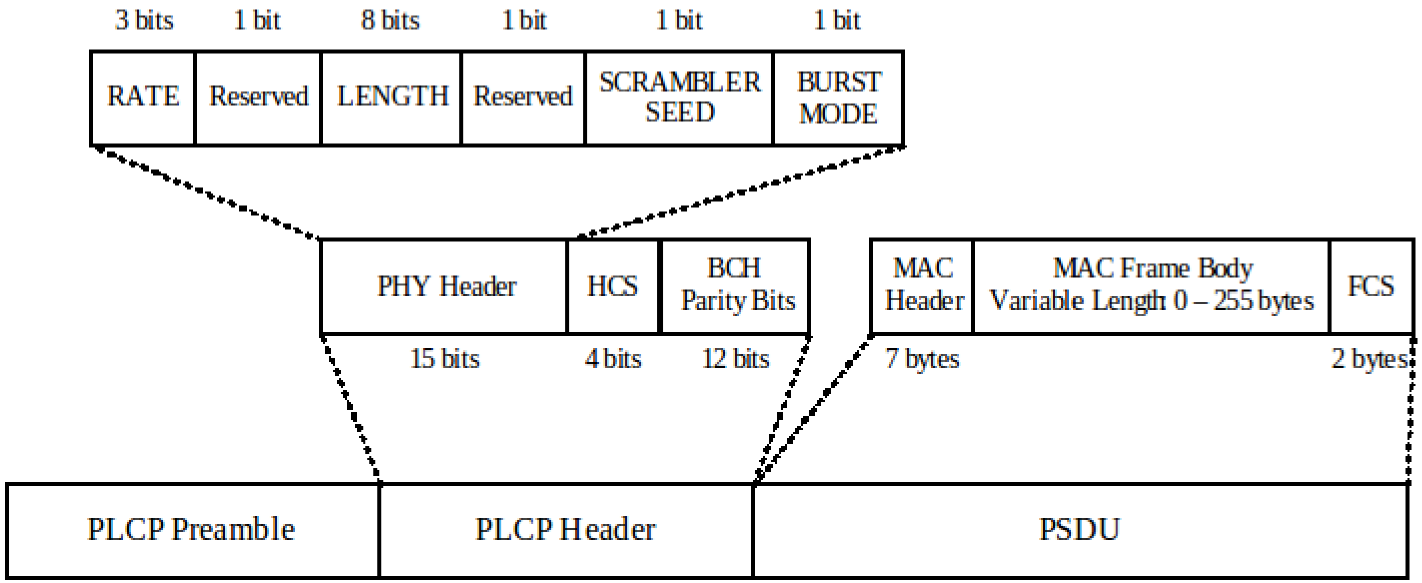
- It includes many RF bands, such as 400MHz, 2.4GHz, 3.1G~11.2GHz
- It includes many modulation schemes, such as BPSK, GMSK, IR-UWB, FM-UWB.
- Among them, 2.4GHz proposal is the most mature.

Overview of 2.4GHz WBAN Proposal

RF Channels

- The center frequency f_c , for the n_cth channel ($n_c = 0,1,\ldots, 78$), is $2402.00+1.00 \times n_c$ MHz
- While for WiFi, The center frequency f_c , for the n_cth channel ($n_c = 1,2,\ldots,13$), 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

Fig.[PKT]: Packet Format[15.6NB]



- 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:

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

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

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

- Where G is the equivalent channel coding gain

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

- Where L is the packet length

More accurate PER is obtained by:

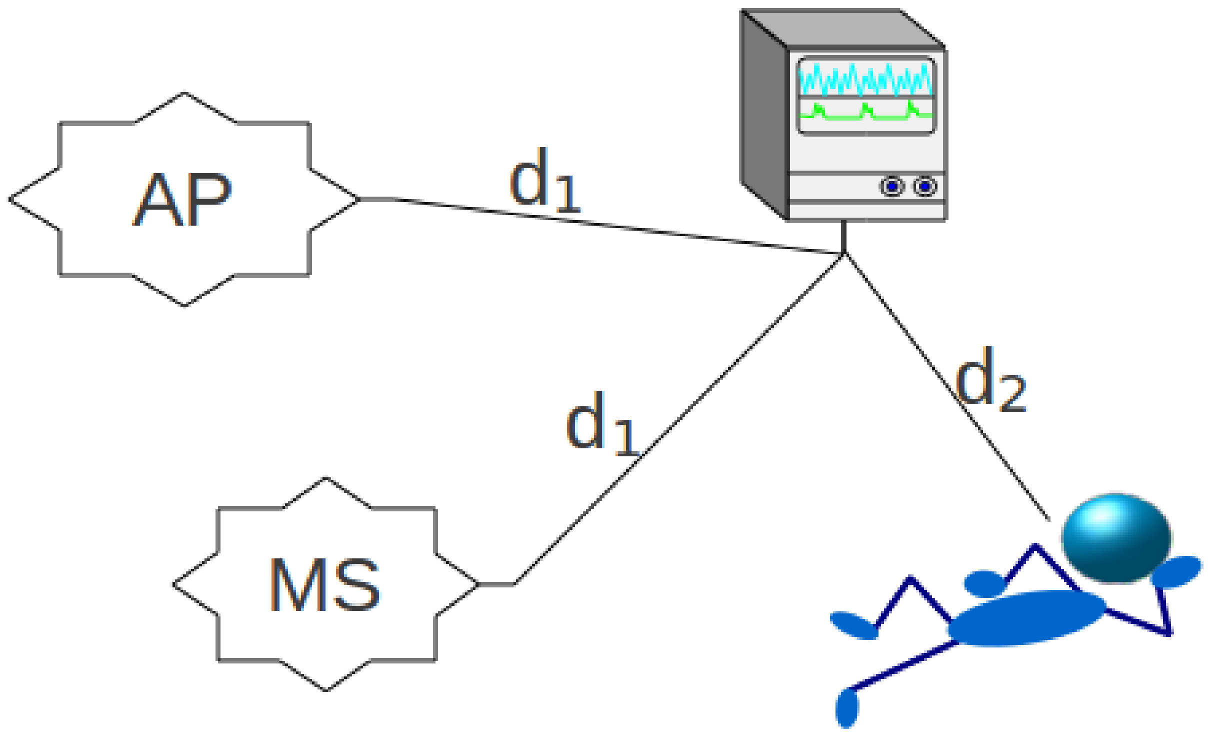
- $P_{per} = (1 - P_{preamble})(1 - P_{plcp\_hdr})(1 - P_{psdu})$,
- where $P_{preamble}$ is the error rate of preamble (synchronization error rate); P_{plcp_hdr} is the error rate of PLCP Header; P_{psdu} is the error rate of PSDU.
- Fig.[PKT] shows that different parts of a packet use different modulation 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.

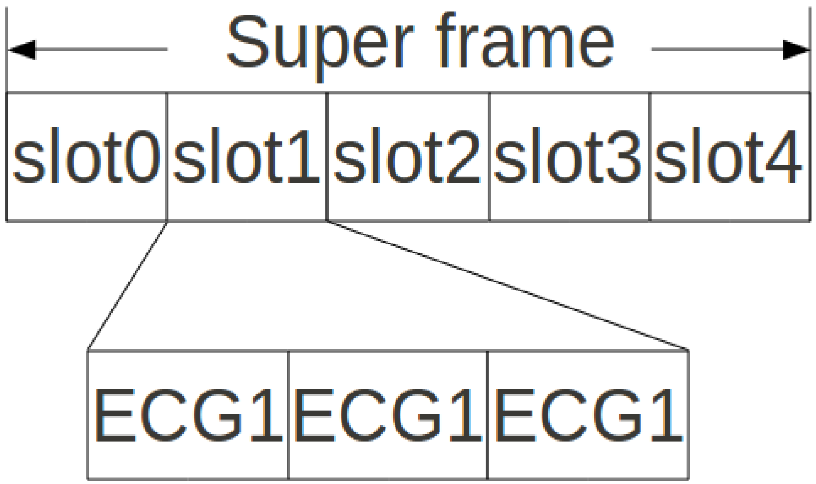
Case Study of ECG Monitoring WBAN

Simulation layout



- ECG monitoring WBAN consists of a monitor and 4 ECG electrodes.
- A *Mobile Station* (MS) is doing FTP

Polling based MAC



- Sampling rate: 100Hz
- Super frame: 10ms
- Slot: 2ms
- Packet duration: 600us
- Data rate: 500Kbps

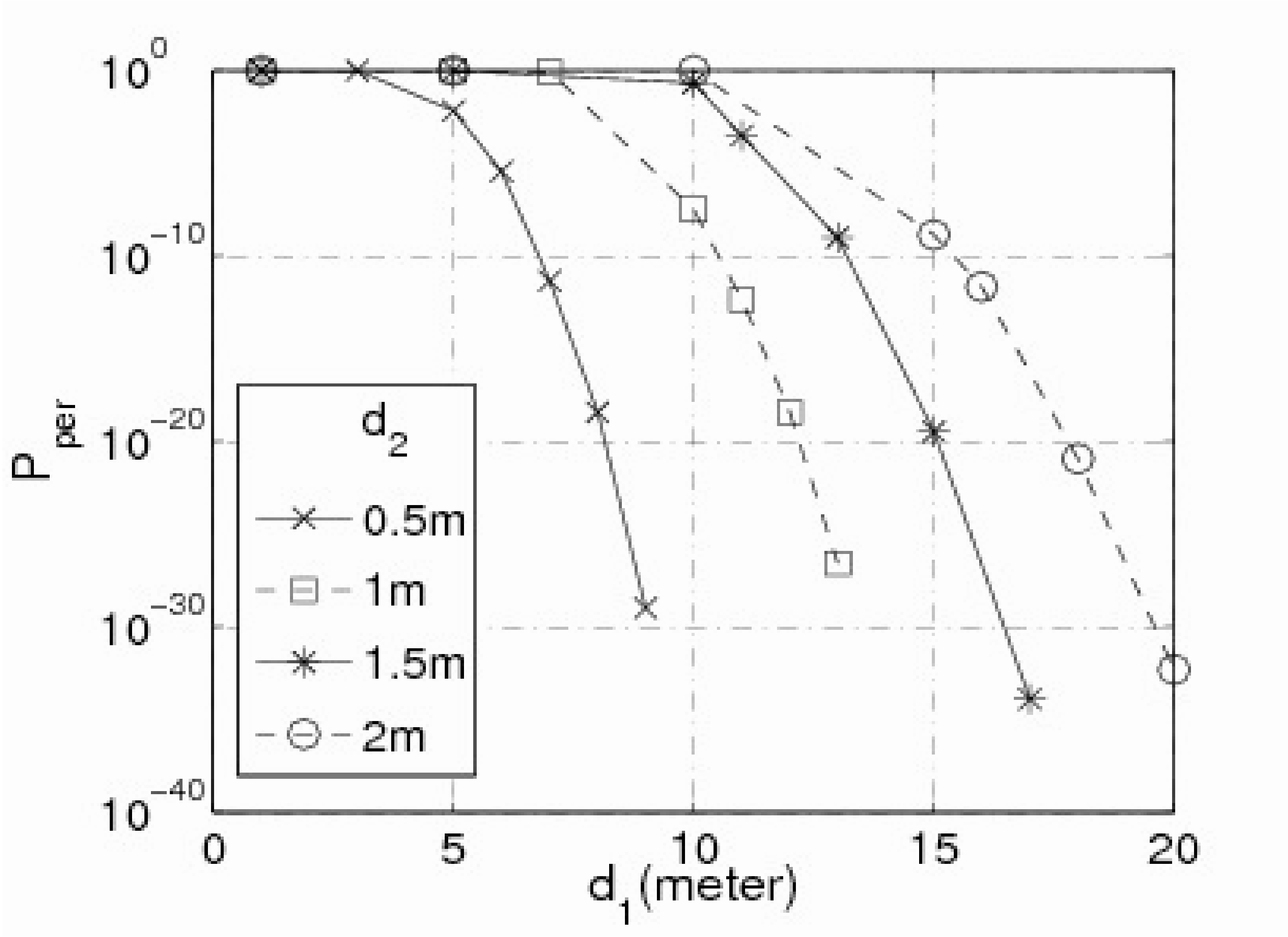
- Monitor broadcasts beacon periodically
- Upon detecting beacon, electrodes upload the samples in assigned time slot
- In assigned slot, electrode may use repetition

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

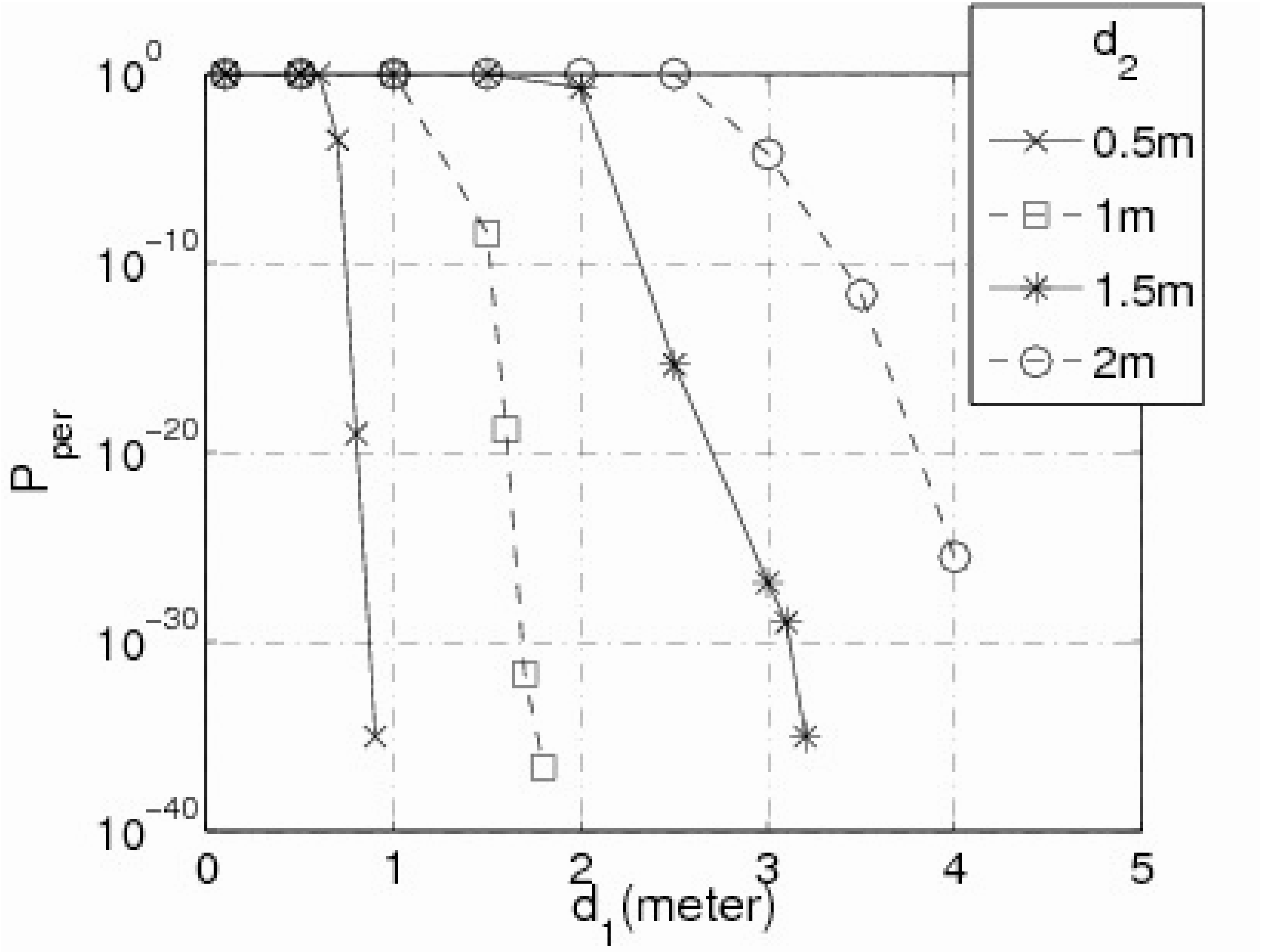


Fig.[MW] MTTF of WBAN under WiFi interference

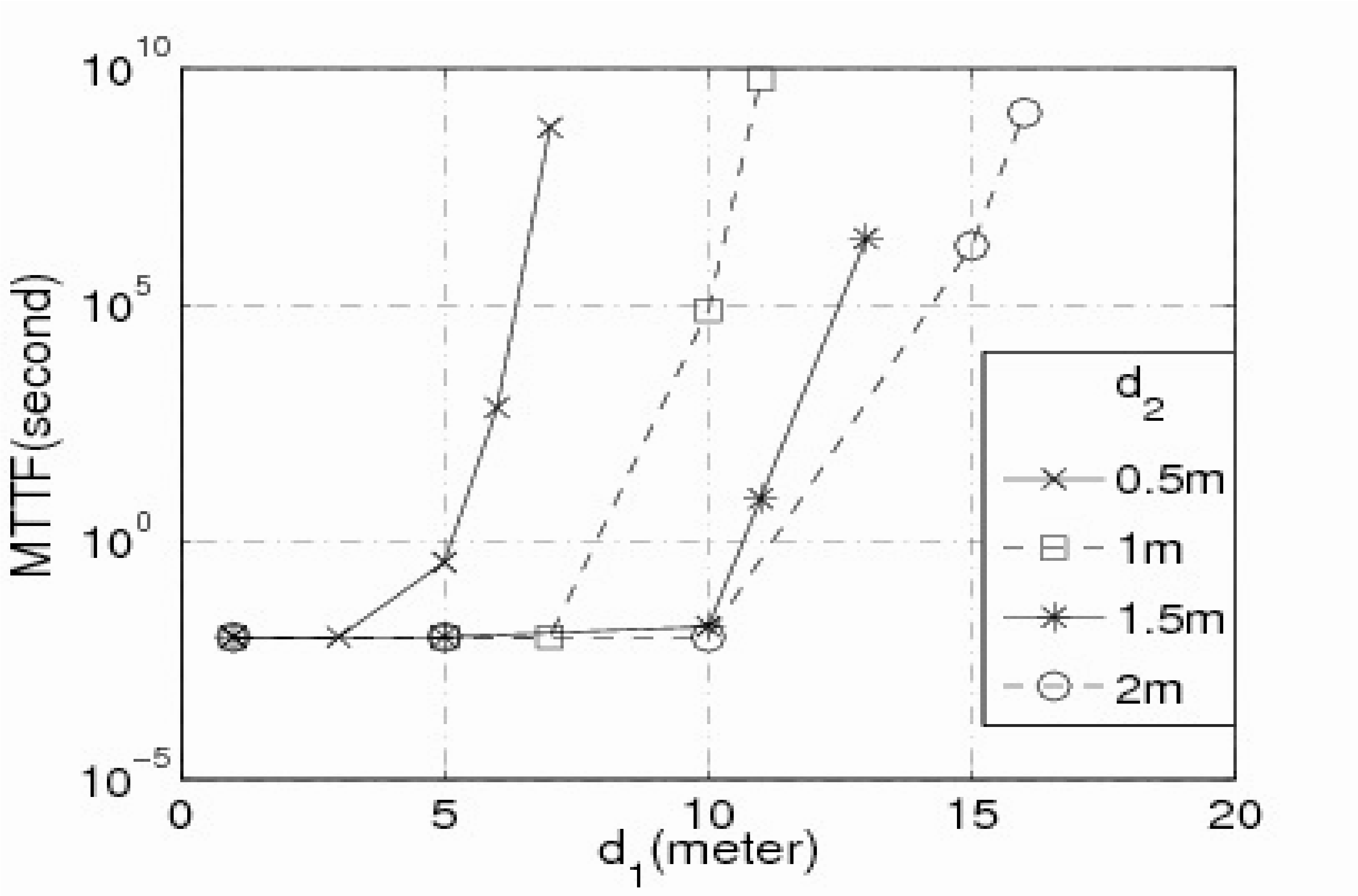
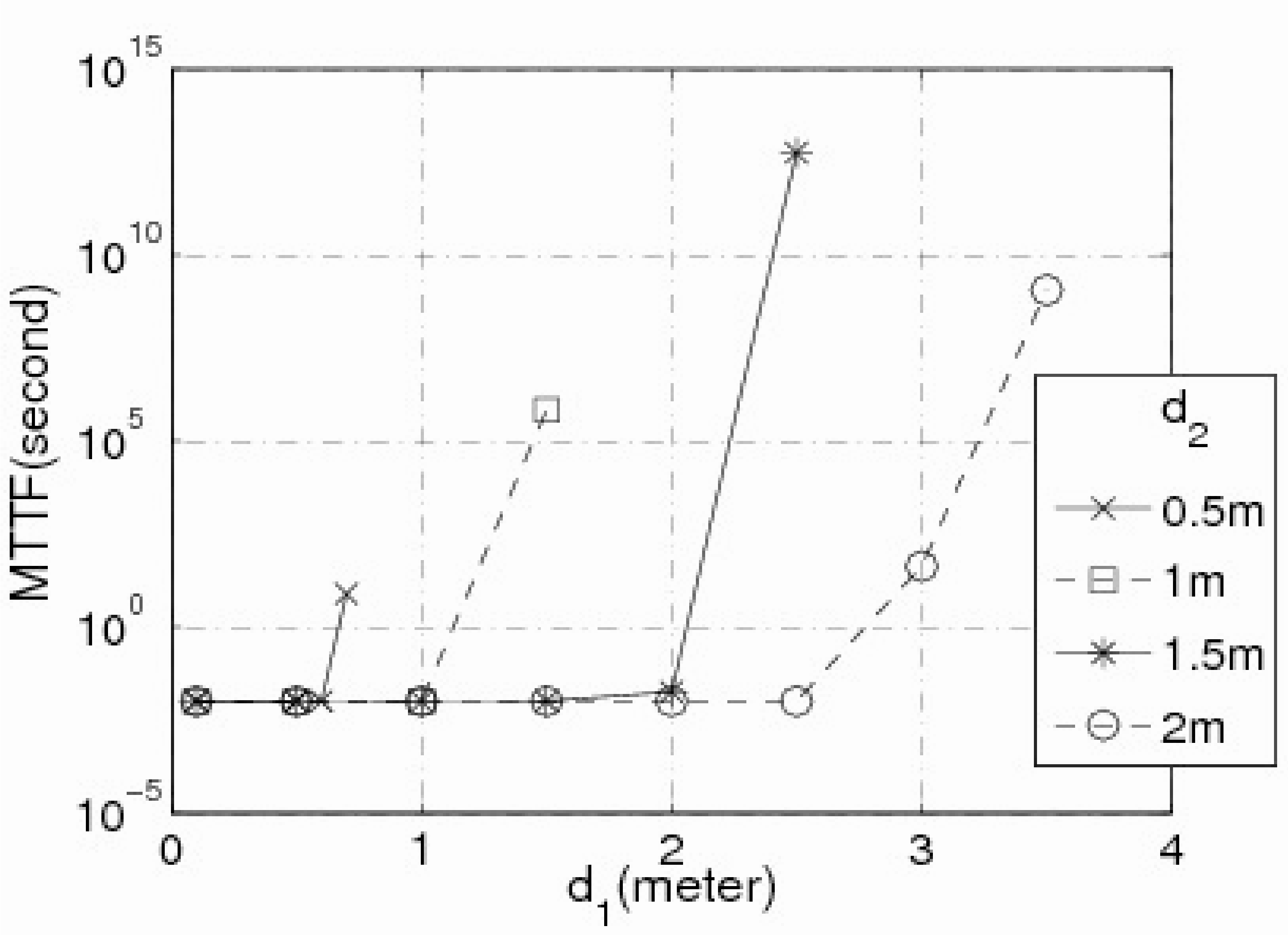


Fig.[MB] MTTF of WBAN under Bluetooth Interference



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 interfere need be only 3.1m away to ensure a 3 hours MTTF.

reference

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