Analysis of Interference in WBANs

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ABSTRACT

Healthcare applications, Body monitoring are just some of the BAN applications. Lately WBAN deployments have been based on ZigBee links operating on the ISM band, sharing the spectrum with many other technologies, widely deployed as well, such as WLAN.

WBANs, based on WSN using ZigBee, usually share the ISM band with other communication standards. Interference is then one of the main issues to be addressed. The amount of traffic present on one WSN link might be very small when compared with other technologies, nevertheless the integrity of the delivered information might be vital in some applications.

Performance regarding throughput in WBAN links using ZigBee, in presence of other widely deployed technologies, are presented in this work in order to get a vision of the interference in each one of the cases.

WBANs promise inexpensive and effective solutions, on most of their applications. Interference might be a problem though. An arrangement on the placement of other technologies in the domestic environment has to be reached in order to avoid interference that can be very critic.

1. INTRODUCTION

WBAN Healthcare applications can be considered very challenging for a lot of aspects. The continuous monitoring that is expected to be reached on a single patient health is perhaps the most attractive feature of WBAN based on ZigBee links between the nodes. It can be deduced that the reliability of the information transmitted on everyone of these links, and their correct operation, can be vital when it comes to the monitoring of a patient health.

In these WBAN, information such as the heart beat, motion, blood and sweat analysis is expected to be carried and to be delivered in a successful and trustable way to the destination, so that further actions based on them can be taken.

Now thinking of WIFI, Bluetooth, Microwave Ovens and Video Senders, it is important to clarify what they have in common. First of all, they are widely deployed in many of the houses and offices, and sometimes some environment can be found where they are present all together. But besides this important characteristic, another important one is the fact that, working on the ISM band, they all share or interfere on the same spectrum. The 2.4 GHz band, since unlicensed, is widely used, and is expected to be used by all these kind of technologies [1], over which small networks, or domestic applications can be deployed.

A picture of this problem is provided in the Figure 1 presented here:

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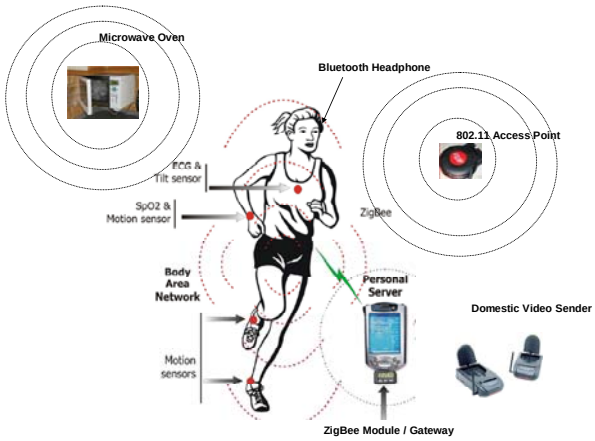

Figure 1. Expected Scenario

In Figure 1 what it can be appreciated a representation of what is expected to be a typical scenario of WBAN in the coming future. Monitoring of human health, sometimes monitoring vital variables such as the heart beat. A very possible scenario is the one over which all these A problem will occur for instance, if there is an anomaly in the heart beat of a patient, and because of interference the information does not reach, or at least in a proper way, the gateway. Vital information could be lost, with very serious consequences.

Speaking of Interference it is important to understand what impact it can bring to a WBAN and measure it. At a very first analysis, one can say that none of these technologies occupies the totality of the ISM spectrum. So that a possible switching channel information can be exchanged. Bluetooth Transmission for instance, switching 1600 times a minute frequencies, uses de FHSS (Frequency Hopping Spread Spectrum) technique so intuitively the interference due to this technology can be expected to be minimum, since the probability of choosing the same frequency of a ZigBee channel is very low. But what happens with WIFI for instance, when the used channel is wider and higher emitted power. One can say that there will be always time in between for in which some changing channel information could be exchanged. But what happens when the kind of WIFI traffic is UDP in which the inter packet time decreases significantly?

Another important source of interference to be considered in the ISM band is the Microwave Oven. Specially because of its unpredictable behaviour in frequency the Microwave Oven represents an interfering element emitting peaks of unmodulated power over a number of frequencies that can vary according to the time usage, the brand of the Oven etc.

In this paper we try to present a study of these interferences that clearly affect WBANs, and try to present how significant their effect can be on ZigBee transmissions.

2. SOURCES OF INTERFERENCE

When thinking about bodynets it is clear that the user can be any person, which implies that they are going to be present in any environment. Considering this, the most relevant technologies working on the ISM band were considered for this work. Bluetooth is one of the technologies but since its FHSS (Frequency Hopping Spread Spectrum) characteristic, it is expected that the interference caused by this technology can be omitted. Jumping 1600 times a minute over 79 channels the probability of overlapping in frequency with other technology is very low, based on the random choice of the channel in the Bluetooth transmission [1].

IEEE 802.11 is working on the ISM band as well over 11 channels each one of them with a bandwidth on average 5 times wider than the bandwidth of a IEEE 802,15.4 (ZigBee PHY) channel. And it has to be considered that in most of the cases the channel is not changed but it is hold from the moment the device using 802.11 is switched on until it is switched off again by the user. A visual of the IEEE 802.11 frequency behaviour in comparison with IEEE 802.15.4 is given in Figure 2.

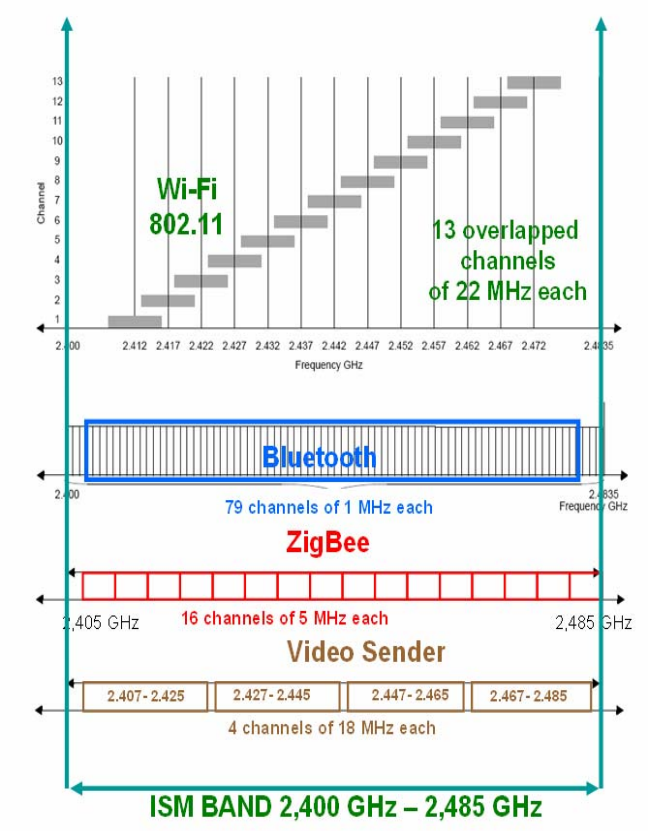

Figure 2. ISM band use

In Figure 2 can be appreciated how 802.15.4 (PHY and MAC layer of ZigBee) is working over 16 channels in comparison with the other ISM technologies. When it comes to the power delivered by an Access Point using IEEE 802.11 (a device that is present not only in offices, but also in domestic environments) generally it is set around 24 mW while a transmitter in WSN using ZigBee usually operates at 1mW.

The Microwave Oven present in most of the houses has become a very important device in any domestic environment. It works on the ISM band as well. Its frequency behaviour is not predictable. It varies according to the model of the Oven, the Brand, and the use time. The Microwave Oven in most of the cases is emitting peaks of power mainly coming from the front door, all over the 2.4 GHz Band..

Since it varies from one Oven to another it makes really difficult to try to predict the effect of this interference. It can be very critical from a WBAN point of view depending on how big is the peak of power emitted and how wide it is [4]. In order to provide a visual of this unpredictable behaviour of the Microwave Oven Figure 3 presents the Frequency Behaviour of 4 different Microwave Ovens working on the 2.4 GHz Band.

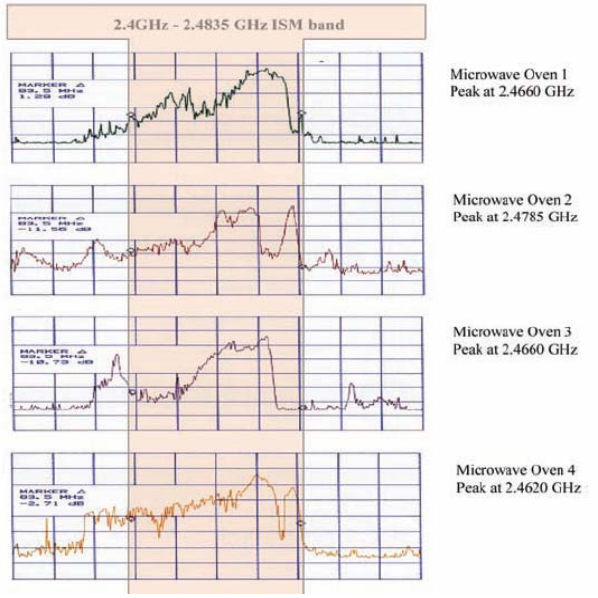

Figure 3. Microwave Oven Frequency Behaviour

Video Sender devices are present in many of our homes. Pay per View TV providers often give them to users in order to broadcast signal all over the house. They work on the ISM band as well. These devices usually work in a continuous mode. There are not empty spaces in time in which the transmission is not taking place. In most of these devices, the user can choose 1 over 4 channels in the ISM band 20 MHz wide on average.

3. MEASUREMENTS

Using two WBAN nodes and IEEE 802.15.4 standard, traffic at 125 Kb/s was generated between them in order to study the variations in the throughput when in presence of other ISM technologies. The measurements were carried out in a shielded room in order to avoid external interference, and appreciate the interference effect from the source of the traffic in each one of the cases. A representation of the Lab scenario that was used for every one of the interfering elements is presented in Figure 4.

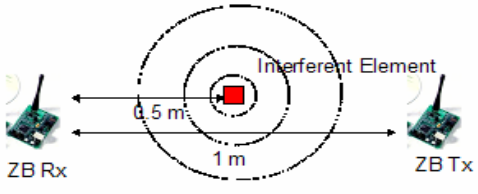

Figure 4. Lab Scenario

The throughput between these two WBAN nodes was 125 Kb / s with no interference. The degradation of this parameter was measured with the different interfering transmitters from other ISM technologies, and taking a look at the variation in the throughput the interference effect of everyone of the technologies can be rated. The throughput between the two WBAN nodes was measured in each one of the cases over the 16 channels of IEEE 802.15.4, in order to measure the effect of the interference on each one of them.

3.1 ZigBee and Bluetooth

Starting with Bluetooth the obtained results were not so far from the ones expected. In the Figure 5 it is presented the throughput over the between the two ZigBee nodes, and the same parameter measured over the 16 channels when a Bluetooth data transmission is taking place between a Laptop and a cellular phone.

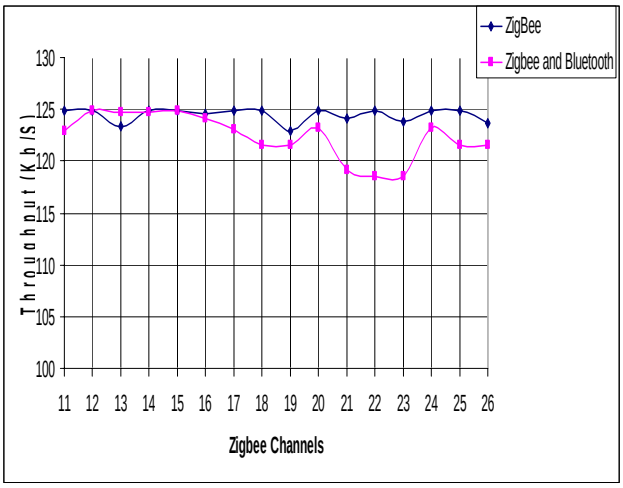

Figure 5. ZigBee (WBAN) in presence of Bluetooth

As expected, mainly due to the FHSS feature of the Bluetooth transmission the degradation on the throughput is not very relevant, since the probability of colliding once in the same channel and then colliding again on the second attempt are very low, since in case of collision, when the 802.15.4 attempts to retransmit for the second time, the probability that the same channel is going to be occupied by the Bluetooth transmitter is very low.

3.2 ZigBee and IEEE 802.11

For the IEEE 802.11 study of interference a WIFI access point was used, working on channel 6 and transmitting UDP traffic to a personal computer. UDP traffic was selected as the worse case for transmissions with minimum interframe spaces turning the situation very critical. A visual of the throughput degradation is given in Figure 6.

It can be appreciated how, when the two IEEE 802.15.4 nodes operate on the same channel the WIFI Access Point is operating the throughput falls down to 10 Kb/s. It can be noticed, that there is still some exchange of information taking place, allowing an eventual “change channel” in the WBAN Transceivers in order to avoid the interference by switching the transmission to another frequency.

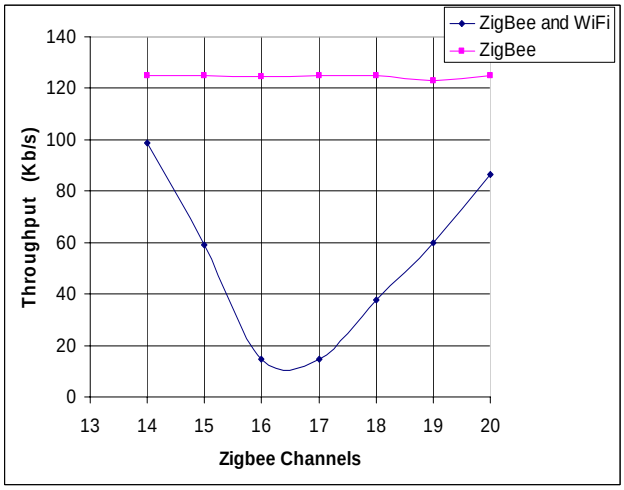

Figure 6. ZigBee (WBAN) in presence of WIFI.

In Figure 2, it can be appreciated how channels are placed in these two technologies. It can be also seen that in channel 15 in the IEEE 802.15.4 technology there is only a partial overlapping over this channel. So it can be a good solution when in presence of more than one Access Point.

3.3 ZigBee and Video Sender

The Video Sender can be considered as a very serious issue when it comes to WBAN links. Speaking of the results getting from the measurements Video Sender devices represent a huge concern for WBANs, especially when these transport data that can be vital for the subject. During the experiments when the the 802.15.4 WBAN nodes were working on the same channel as the Video Sender or in the nearby zone, there was a very significant decrease in the throughput performances and sometimes, there was not throughput at all. The association between the nodes was forced by turning off the Video sender, associating the two devices and then, turning back on the Video Sender and appreciating the interference effect. A graph of this measure is given in Figure 7.

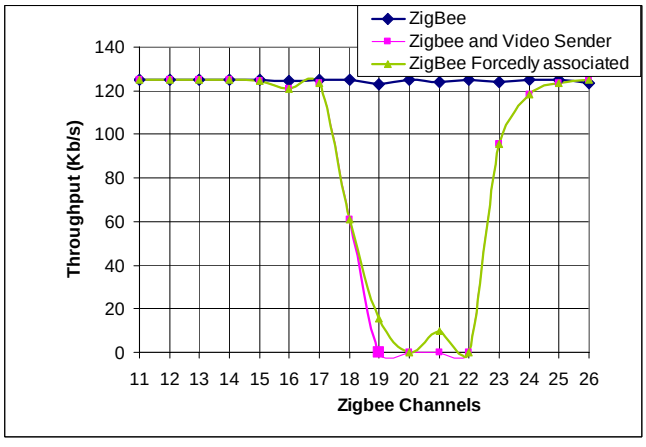

Figure. 7. ZigBee (WBAN) in presence of Video Sender Device.

The Video Sender is set to operate on channel 2 (2452.8 MHz). It can be appreciated how through 4 channels on the band, normal association is not even possible, when the Video Sender

was on. It has to be remarked since WBANs in many of their applications carry information that can be vital for the subject and how, at times in this experiment, exchange of information was basically inexistent between the two nodes. It is an important result since an eventual "change channel" message between the two nodes, in order to continue with the exchange of information, wouldn't be possible.

3.4 ZigBee and Microwave Oven

The microwave Oven is one of the pending issues in the WSN world. Working it the ISM band, and not having a predictable behaviour regarding the power emitted across the band, it represents one of the devices that causes more worries for the expected deployment of WSNs. In Figure 8 it is shown how the Throughput varies in every one of the channels when in presence of a Microwave Oven while heating.

It is important to remember how the frequency behaviour in Microwave Ovens varies according to the brand and the usage time. For this Microwave Oven the throughput between the two nodes decreases but in a way in which the exchange of information is still possible, and in the case the throughput falls to a value below a certain threshold, an eventual change of the channel could be carried out.

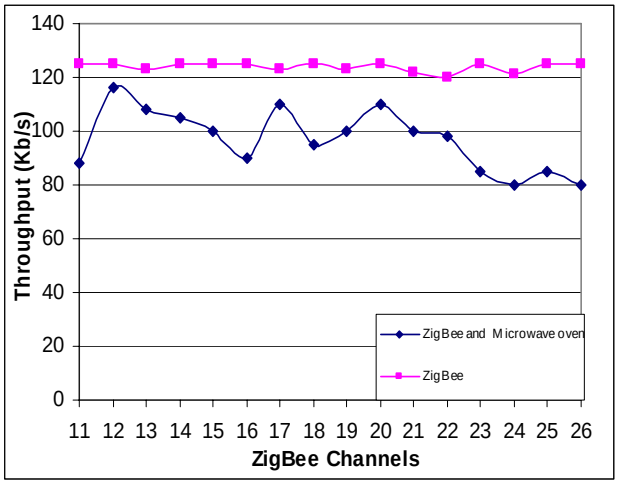

Figure 8. ZigBee (WBAN) in presence of Microwave Oven

4. CONCLUSIONS

The test results show that reliable ZigBee- Bluetooth and even in the case ZigBee–Microwave Oven coexistence is possible without affecting in a significant way the running application. In ZigBee-WiFi case, whether overlapped channels are used by the two technologies, the coexistence could be effectively reached by implementing frequency agility technique in ZigBee devices.

Moreover the presence of a 2.4 GHz Video Sender can abruptly interrupt the communication on a ZigBee link and a possible solution would be to keep a spatial separation between the Video Sender device and the ZigBee nodes and again enable frequency agility in order to perform an eventual change in the channel.

Frequency agility, and how to perform it, seems to be the solution in the interference problem, with the existent technologies, and those supposed to appear in the scene of the ISM band.

Future work is planned to define proper distributed algorithms for interference detection (it is worth to remind that, in general, just a subset of the network nodes are subject of an interference) and distributed coordination algorithms that allow to apply proper countermeasures and exploit the frequency agility feature which is currently under study by the ZigBee Alliance [5].

Lastly, as a follow up of these activities it is expected to obtain detailed information regarding the degradation of the different signals due to the interference for more than a couple of technologies at the same time, finding alternatives and possible solutions to overcome the unwanted effects that, in the case of wireless body area network, they could be dangerous.

5. REFERENCES

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