Comparative Study of IEEE 802.15.4 and IEEE 802.15.6 for WBAN-based CANet

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***Abstract*— In this paper, we present an overview of IEEE 802.15.4 and 802.15.6 standards. Thereafter, in view of their various strengths and many similarities, we study the possibility of using one of these two norms to implement the body area network (WBAN) of CANet (an innovative ehealth project) scenario according to the nature of the studied sensors.**

To do so, we considered an hybrid differentiation layer, previously proposed, based on 802.15.4 and we made a classification of CANet ehealth sensors based on IEEE 802.15.6 native superframe periods and priority and service differentiation systems. Each choice between them has its advantages and disadvantages. Thus, it will be necessary to analyze in detail the simulation and prototyping results of 802.15.4 and 802.15.6 norms once implemented in CANet context in order to decide about the standard providing the optimal QoS.

Keywords—Wireless body area networks (WBANs); E-health, CANet project; IEEE 802.15.6; IEEE 802.15.4;

I. INTRODUCTION

Wireless sensor networks (WSNs) [1] became one of the most leading strength to improve human being existence and lifestyle through using the varied and great features provided by emergent communication technologies. This kind of microelectronic networks will be in the near future, much more present in several domains including the health monitoring remotely, known as e-health [2].

Several projects have been developed in the context of e-health monitoring and discussed many problematics related to the specific needs of patients (concerned persons) such as targeting Parkinson's disease, Alzheimer, etc.

We are interested by CANet [3], an innovative ehealth project, targeting the general needs common to the majority of the elderly, and proposing a walking cane provided with several sensors.

These small devices (sensors) watch the health state and vital parameters of the elderly person and send periodically or if necessary the related informations to a network coordinator. The latest is responsible for forwarding these data via a network of higher range (such as Internet) to the family doctor or a family member.

WSN networks destined for short-range and large data rates, known as wireless body area networks (WBANs) [13, 14, 15], were discussed in the literature through the use of various technologies mainly IEEE 802.15.4 [4] and 802.15.6 [5] standards.

IEEE 802.15.4, originally intended to wireless personal networks (WPANs), did not satisfy the increasing requirements of emerging WBANs since it does not support high data rate applications.

There are also situations (eg, co-existence with and multimedia heavy data traffic) in which IEEE 802.15.4 can't provide an acceptable compromise between power consumption and QoS needs simultaneously.

For those various reasons, hybrid solutions, based on IEEE 802.15.4 enhancement, have been proposed such as [6] including a mechanism of service differentiation.

IEEE 802.15.6 has been also designed to provide a great use flexibility of WBANs in the ehealth field and a specifically integrated native priority system. We used these 802.15.6 features and proposed an assignment of priorities and superframe periods of transmission for each CANet sensor.

Some comparative studies between these two norms 802.15.4 and 802.15.6 exist in the literature, such as [18].

However, to our best knowledge, this study is the first to compare these standards for a real situation (the ehealth project CANet), and which discusses, in this context, the contribution of [6] to 802.15.4 so it can support an approach of service differentiation, natively contained in 802.15.6.

The remainder of the paper is organized as follows:

In the second section, we describe exhaustively the CANet project, the integrated sensors into it and the traffic types, etc. The section 3 contains an overview of IEEE 802.15.4 and an explication of the improvement proposed by [6] especially the use of IEEE 802.15.4 and the differentiation of service simultaneously in CANet project. We present in section 4 the main characteristics of the IEEE WBANs standard: IEEE 802.15.6 and its native service differentiation system (through user priorities UPs). In section 5, we explain the uses of 802.15.4 and 802.15.6 features for the CANet scenario. Analyzing and comparing the two technologies, we discussed in this section the possibilities of CANet implementation. The final section (section 6) concluded our study and introduced the perspectives of our work.

II. CANET PROJECT

The CANet (Cane Network) project consists on designing and implementing a monitoring system of elderly integrated into an equipment which is usable to the everyday life: their walking cane!

The smart cane would thus allow leading an easier life (it will not be necessary any more to stay in a hospital or a medical center to be watched all the time) while avoiding possible risks to which is exposed the concerned elderly person (falls, suffocation, fire, etc.).

In order to grow old serenely and healthy, many embedded sensors in/on the cane will ensure an active and optimized monitoring of the elderly, according to the health of the concerned person, and chronic diseases from which he suffers, etc. (Fig. 1).

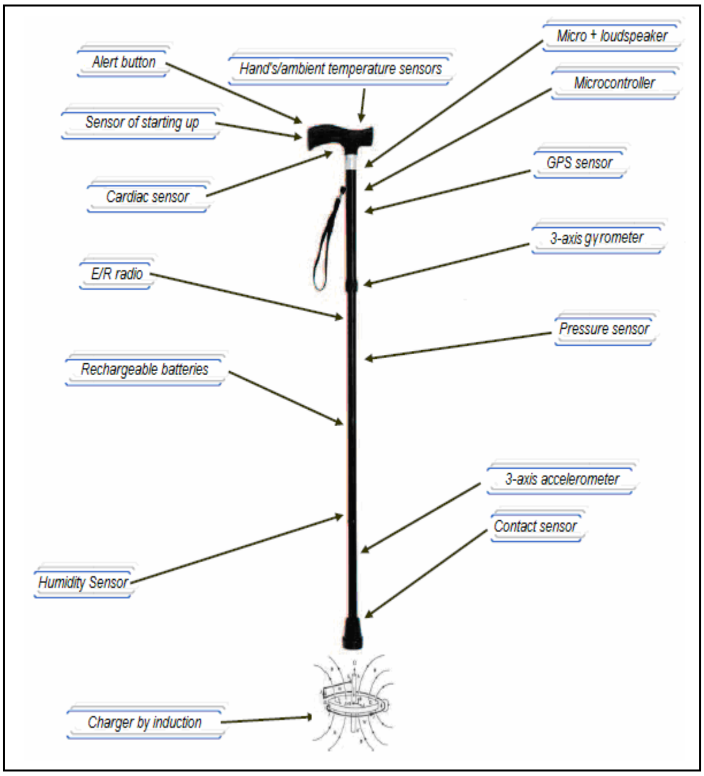

Fig. 1. Various sensors proposed in CANet project [3]

To better understand the characteristics of different sensors and their requirements in terms of QoS, data rate, frequency, etc., we will present a general definition of each proposed sensor in the CANet project:

- *A starting up sensor :* Allowing to start up (to activate) the completeness of the monitoring system, embarked on the cane ;
- *A hand's temperature sensor :* Measuring periodically the temperature of the hand and making sure it does not exceed a certain range of values ;
- *A battery charge sensor :* integrated into the body of the cane ;
- *Digital sensor AON (all or nothing) for detecting the action of the cane on the ground :* It is a sensitive sensor to the contact of the cane with the ground when walking, to estimate the traveled distance, the rest periods, etc. ;
- *The combination (microphone, loudspeaker) :* A couple microphone / loudspeaker for the interactive dialogue with the concerned person ;
- *A 3- axis accelerometer :* Assisting in the location and detection of falls ;
- *A 3- axis gyrometer :* The 3-axis gyrometer, coupled with a magnetometer, measures the angular speed and gives interesting informations about the rotation movements of the cane ;
- *An emergency call button ;*
- *A localization system :* Intended for the localization of the cane indoor/outdoor (via the considered wireless network) ;
- *Cardiac sensor :* This sensor records and watches the heart rhythm;

An alert frame is sent at the instant of press on the alert frame, in the case of extreme urgency;

Any sensor can also move to the critical state in case of detection of abnormal or even alarming values of a given vital sign to be watched [3].

A. Communication

In order to overcome the CANet problems of network range, data rate and energy consumption, [6] proposed a multi-tier topology.

Thus, the communication between the cane sensors and the center of data collection passes by several connections.

This global topology proposed for CANet project consists of three, four or five levels according to the implementation context (at home, in a medical center, etc.).

- *Level 1 - mandatory level - : links between the cane and the sensors placed on the human body:*

  At this level, it comes to establishing connections between nodes of a WBAN: two proposals were selected for the CANet project as illustrated in Fig. 2 (a) and (b).

In the first one (Fig. 2 (a)), we propose to place the hub on a necklace worn by the concerned person to prevent it from loss while all the other nodes are integrated into the cane.

In the second proposition (Fig. 2 (b)), [6] indicated that the hub can also be placed into the cane while the various sensors are situated on the body of the monitored person.

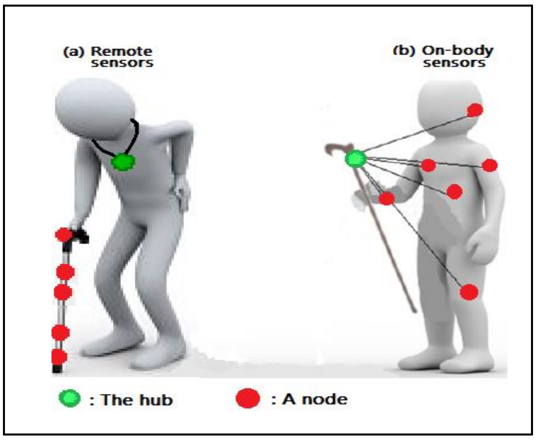

Fig. 2. Propositions of WBAN structure for CANet project [6]

- *Level 2 - optional level -: direct links between canes:* This level is necessary when the system has to support traffics generated by several canes particularly in the case of a hospital or a health center for example, where cohabit several elderly;
- *Level 3 - mandatory level - : links between canes and access point (AP):* In the case of a system containing a single cane, the access point refers to the WBAN hub;
- *Level 4 - mandatory level - : links between APs*
- *Level 5 - mandatory level - : link with a data collection center* links between AP and data collection center.

The representation of the different system levels is detailed in Fig. 3.

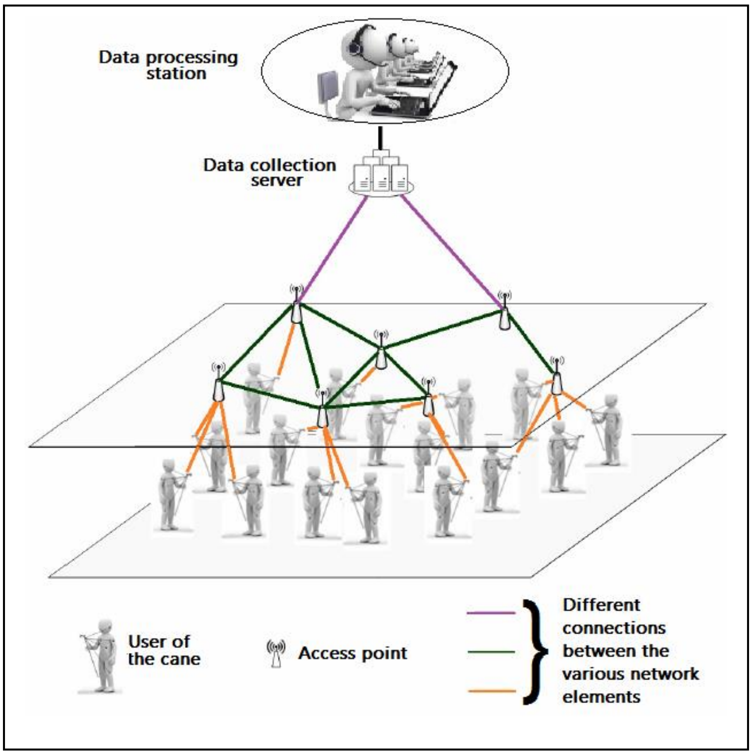

Fig. 3. Global topology of the CANet system [6]

B. Characteristics of data traffics

The proposal of general criteria for traffics classification is a necessity to allow simplification of the MAC layer processing made according to each sensor type (such as favoring the traffics with high priority).

According to the study done by the authors of [6], the most relevant criteria common to all the CANet sensors are: periodicity, data rate, priority, and the real-time aspect.

- *Data periodicity:* The data periodicity represents the duration of transmission cycle for each sensor. This duration varies according to the information type and the useful period which allows the detection of significant information.
  - *Pseudo-periodicity:* It comes to traffics not always present and therefore unpredictable, which are subject to a period but for irregular cycles, as emergency information and data sent in real time ;
  - *Low periodicity:* This category is intended for sensors generating data with high frequency (very short duration between two successive transmissions). In this family, we find, for example, the cardiac sensor;
  - *Average periodicity:* In this category, the period between two successive transmissions is of few minutes;
  - *Long periodicity:* For the sensors of this category, the duration between two successive transmissions exceeds that of the family of average periodicity.
- *Data rate :*
  - *Low data rate:* For data rates of few bytes per second at the most ;
  - *Average data rate:* This category is generally related to informations for 2D or 3D representation such as GPS location data ;
  - *High data rate:* Usually this kind of traffic contains data of a voice message and requires a large bandwidth.
- *Priority :*
  - *Low priority:* For the data without particular requirements of transmission/reception time or of QoS ;
  - *High priority:* includes the real-time data ;
  - *Very high priority:* This category is intended for alert data.

III. USAGE DE IEEE 802.15.4 FOR CANET PROJECT

A. IEEE 802.15.4 overview

IEEE 802.15.4 was proposed as a standard for low-rate wireless personal area networks (LR-WPANs). It defines mainly the characteristics of the physical and MAC layers for data communication devices using low data rate, low power, low complexity, and short-range radio frequency (RF) transmissions [7]. The network topologies supported under IEEE 802.15.4 are star and peer-to-peer. The first topology is the most commonly used one. As shown in Fig. 4, two different device types can participate in an LR-WPAN network; a full function device (FFD) and a reduced-function device (RFD) [7].

- *Full Function Device (FFD):* This kind of devices can be either a coordinator, a coordinator of a WPAN or a simple device. It works under all topologies and communicates with all types of devices.
- *Reduced Function Device (RFD):* An RFD can't be a WPAN coordinator. It can be defined as a final device which can communicate only with an FFD.

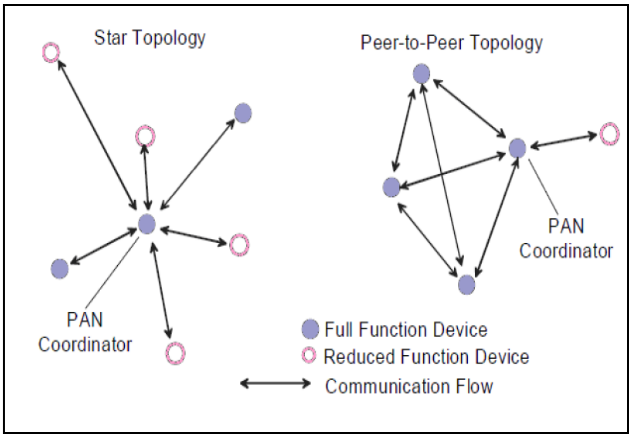

Fig. 4. IEEE 802.15.4 network topologies and device types

The 2.4 GHz ISM band is the most used one for IEEE 802.15.4 since it affords a data rate of 250 kbits/sec and it's the only one available worldwide. This frequency band offers also the best performance with the use of spread spectrum modulation technique DSSS (Direct Sequence Spread Spectrum) and the digital modulation scheme O-QPSK (offset Quadrature Phase-shift keying) [6].
The standard MAC layer tolerates two modes of transmission: beacon-enabled mode and non beacon-enabled mode. In beacon mode, the WPAN coordinator manages the network communication, mainly the access to the channel, through a superframe, which the structure is illustrated in Fig. 5. The interaction between the coordinator and network nodes is authorized only during the active part which consists of a contention access period (CAP; 9 slots of equal duration), and a contention free period (CFP; 7 slots) [8]. The slotted CSMA/CA and slotted aloha mechanisms are used during CAP periods while GTs (Guaranteed Time Slots) are used for CFP phases to exchange information between the coordinator and its network devices.

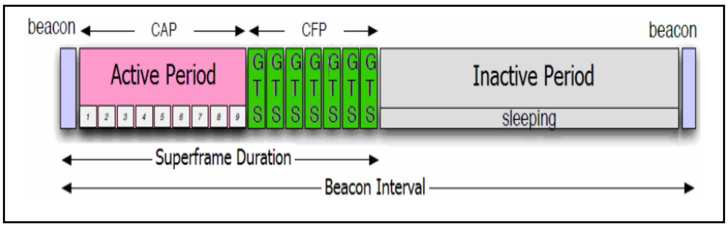

Fig. 5. IEEE 802.15.4 superframe structure in Beacon enabled mode

B. Hybrid solution for an IEEE 802.15.4-based CANet WBAN

The recent improved versions of 802.15.4 are increasingly used in industrial sensors and many other domains of Internet of Things (IoT) [9].

However the performance of this standard still has several weaknesses especially the lack of any measures to classify traffics based one to their urgency.

Therefore, the authors of [6] suggested adding a service differentiation layer between the MAC and the application layers as explained in Fig. 6.

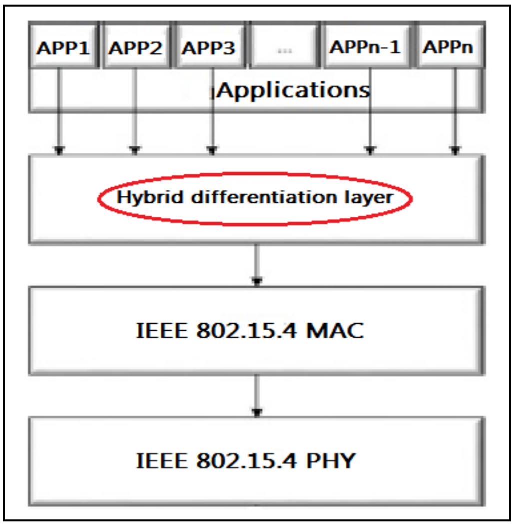

Fig. 6. The position of the proposed differentiation layer [6]

The various CANet sensors have been classified into a set of profiles according to criteria defined above.

The critical state represents the transition to a situation of extreme control after detecting an abnormal variation in the information detected by the sensors. The alert state represents the user's request to establish a vocal communication to ask for help.

These profiles (defined in table I) will be used by all the sensors during the existence of a critical condition, upon detection of an anomaly or when sending an alert, which indicates the existence of a medical problem.

TABLE I. IEEE 802.15.4-BASED PROFILES MAPPING PROPOSED BY [6]

Profile	Periodicity	Data rate	Priority
Profile 1	Pseudo	Low	Low
Profile 2	Long	Low	Low
Profile 3	Average	Low	Low
Profile 4	Pseudo	High	High
Profile 5	Low	Average	High
Profile 6	Pseudo	Low	High
Profile 7	Low/Average	Average	High
Profile 8	Low	Low	Low
Profile 9	Pseudo	Low	Very high
Profile 10	Low	-	Extremely high

As for the sensors of the profile 10, they have the right to choose the transmission parameters they need quite freely since their sent informations are of the most priority.

Certainly, the proposed hybrid layer solution for the 802.15.4-based WBAN which can be used in CANet makes it much more reliable.

However, even if CAP period is used for contention access to the channel and CFP is specifically destined to support QoS requirements such as low latency and specific data bandwidth, etc. through the use of up to seven GTSs [9], there is no explicit prioritization concept initially considered by the standard.

So all the enhancements destined to it will always present important limits as data rates relatively low and insufficient QoS for heavy traffic like voice transmission.

Thus, IEEE 802.15.6 can be a better solution.

IV. USAGE DE IEEE 802.15.6 FOR CANET PROJECT

A. IEEE 802.15.6 overview

IEEE 802.15.6 standard was specifically designed to provide an international norm supporting low complexity, low cost, ultra-low power consumption, and extremely reliable wireless communication. The main goal of this standard is to give a solution to service differentiation for short range communication between tiny devices within the surrounding area of the human body. IEEE 802.15.6, operating on PHY and MAC layers, proposes two topology types, as shown in Fig. 7, one-hop and two-hop star topologies. An IEEE 802.15.6-based WBAN is composed of one and only one coordinator (also named a hub) and a number of connected nodes, which varies from 0 to 64 nodes [5].

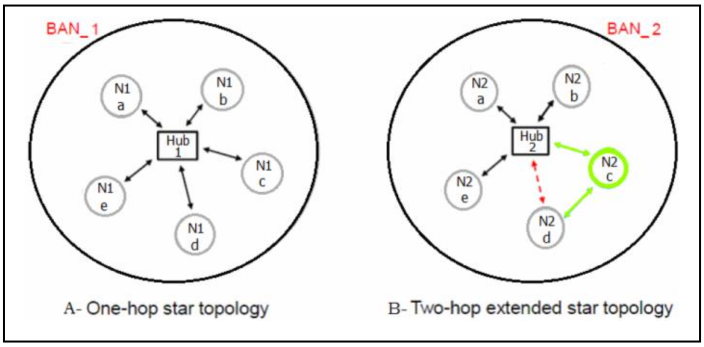

Fig. 7. IEEE 802.15.6 network topologies

The standard suggests the use of one of three PHY layers for a unique 802.15.6 MAC layer: Narrowband (NB), Human Body Communications (HBC) and Ultra wideband (UWB) PHY.

The choice between these PHY layers is done essentially according the application nature, the required data rates and the available frequency bands.

- *NB PHY layer:* operates in the [402 MHz, 2483.5 MHz] interval and tolerates up to 971.4 kbits/s ;
- *HBC PHY layer:* operates between 5 and 50 MHz and supports up to 1312.5 kbits/s ;
- *UWB PHY layer:* operates in [3100 MHz, 10 600 MHz] and is efficient for different data rates, according to the modulation, up to 1114 kbits/s.

With the aim of satisfying the different natures of WBANs based applications, 802.15.6 MAC integrated three modes of channel access: beacon mode with superframes, non-beacon mode with superframes and non-beacon mode without superframes.

In each of these modes, a superframe structure was defined to better serve specific requirements of the targeted application.

When used for vital ehealth applications such as CANet, 802.15.6 has to handle in a special way urgent traffics, to ensure the sequencing of received informations, and to guarantee a good QoS through various appropriate periods of time.

These needs are satisfied optimally through the beacon mode with beacon periods since it defines a time base and high-flexible superframe periods as shown in Fig. 8.

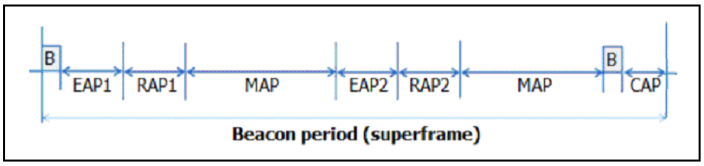

Fig. 8. IEEE 802.15.6 superframe structure in Beacon mode with superframes

EAPs (Emergency Access Phases), RAPs (Random Access phases) and CAP (Contention Access Phase) are the superframe parts during which the contention access to the channel is performed while MAP period (Managed Access phase) supports polling / posting (at the request of the hub) and scheduled accesses.

The main characteristics of these different parts of the 802.15.6 superframe are illustrated in table II.

TABLE II. CLASSIFICATION OF IEEE 802.15.6 STD SUPERFRAME PERIODS [5, 11, 12]

Period	Periodicity	Data rate
MAP	Regular traffic	Scheduled access
	Unscheduled and improvised access	On-demand (Polling/Posting)
EAP	Urgent high priority traffic only	Contention access
RAP	Random traffic (urgent or classic)	
CAP	Regular traffic only	

B. Implementation of an IEEE 802.15.6-based CANet WBAN

A priority management system has been implemented for the IEEE 802.15.6 MAC layer in order to differentiate the various types of traffic.

To do so, different data rates have been defined for each physical layer and for each UP so as to have increasing data rates by increasing the priority level.

Seven priority levels in total are taken into consideration by the norm as shown in the table III.

The traffic with low UP is generally of long periodicity, the average user priorities are associated to average and low periodicities. The highest UP 7 is used for pseudo-periodic traffic.

Other mechanisms of service differentiation are also defined by 802.15.6 for competitive access to the channel (contention access) depending on the selected access mechanism: CSMA / CA and slotted Aloha.

As illustrated in the following table (table III), the choice of backoff intervals [CWmin, CWmax] for CSMA / CA is predefined by the standard.

The slotted aloha mechanism had also been adapted to the differentiation requirements through the definition of appropriate contention probability thresholds CPmin and CPmax for each user priority (UP).

TABLE III. PRIORITY MAPPING PROPOSED BY IEEE 802.15.6 [5, 10]

Priority class	User priority	Traffic designation	CSMA/CA		Slotted Aloha	
			CW min	CW max	CPmax	CPmin
Low	0	Background (BK)	16	64	1/8	1/16
	1	Best effort (BE)	16	32	1/8	3/32
Average	2	Excellent effort (EE)	8	32	1/4	3/32
	3	Video (VI)	8	16	1/4	1/8
	4	Voice (VO)	4	16	3/8	1/8
High	5	Medical data Or network control	4	8	3/8	3/16
	6	High-priority Medical data Or network control	2	8	1/2	3/16
	7	Emergency or medical implant event report	1	4	1	1/4

V. COMPARISON BETWEEN 802.15.4 AND 802.15.6 FOR CANET WBAN

So, both choices we considered in this work are: 802.15.4 used for the profiles proposed by the authors of [6], as detailed in sub-section (III-B) and the approach we propose according to what is natively available in 802.15.6.

To compare them objectively and effectively, we listed the approaches of each choice aiming to guarantee an efficient differentiation of service and a good QoS especially for vital (urgent) traffics. To achieve the objectives mentioned above, [6] proposes essentially:

- The definition of 10 profiles and different characteristics for each defined profile.
- To satisfy every profile sensors, one of the major contributions of [6] is the proposal of a differentiation layer (Fig. 6 in sub-section (III-B)).

  This layer has the needed differentiation methods to recognize the profiles and the processing to be performed for each message sent by different application layers related to the CANet sensors. It also allows the classification of the received messages according to the period of transmission used for every profile. This hybrid layer is also able to detect the presence of critical traffic and emergency situation.

To reach the same purposes, the 802.15.6 standard provides natively:

- The definition of an EAP period exclusively intended to urgent traffics.
- It sets the bounds of [CWmin, CWmax] intervals for the use of CSMA / CA (and) as well as [CPmin, CPmax] intervals for the slotted aloha access mechanism by favoring the traffics with high priority.
- It provides various data rates for each priority class by assigning much higher data rates for urgent traffics.
- The main contribution of our present work is essentially the assignment of adequate 802.15.6 priorities and transmission periods to each sensor of CANet project using 802.15.6 suggestions, by analogy to those proposed by [6] based on 802.15.4.

The analogy that we made between the contribution of [6] based on 802.15.4 and what we propose for CANet project based on 802.15.6 is exhaustively explained in the table IV.

So we exposed in this section the mechanisms provided by each considered approach to manage optimally the WBAN traffics of CANet scenario.

However, it is still early to conclude on the choice to make between 802.15.4 and 802.15.6 because we'll need to observe the performances of each of these technologies under the same simulation and prototyping conditions.

VI. CONCLUSION AND PERSPECTIVES

Through this work, we used the IEEE standards destined to wireless sensor networks, 802.15.4 and 802.15.6, to make an analogy between them once applied to CANet project. To do so, we considered the proposition of [6] based on 802.15.4 since this standard does not support natively priorities and service differentiation. In addition, we proposed an assignment of adequate IEEE 802.15.6 priorities and superframe periods to all the sensors proposed for CANet.

In a future work, we aim at investigating the performances of IEEE 802.15.4-based and 802.15.6-based CANet WBANs in the same conditions and for the same parameters values. Through this approach, we will be able of determining the ideal standard to be used, the values of parameters, the choice of the transmission mode and the appropriate access method that ensure an optimal differentiation of the traffic and the maximal values of different QoS metrics in the considered WBAN. Other challenges can be considered too, such as the risk of interference [16] when using simultaneously the both studied standards for different CANet sensors in the same frequency band.

It would be also interesting to prototype and test the CANet scenario on a real testbed such as WiNo prototypes [17].

TABLE IV. CORRESPONDANCE BETWEEN IEEE 802.15.6 NATIVE UPS AND IEEE 802.15.4 PROPOSED PROFILES BY [6]

<table>
<tr><th>Sensors</th><th>IEEE 802.15.4 proposed profiles</th><th>IEEE 802.15.4 superframe used periods</th><th>IEEE 802.15.6 proposed priorities</th><th>IEEE 802.15.6 superframe used periods</th></tr>
<tr><td>Starting up sensor</td><td>1</td><td rowspan="8">CAP</td><td>1</td><td>RAP, CAP</td></tr>
<tr><td>Hand’s temperature sensor</td><td>2</td><td>6</td><td rowspan="5">EAP, RAP</td></tr>
<tr><td>Outside temperature sensor</td><td>2</td><td>6</td></tr>
<tr><td>Battery charge sensor</td><td>2</td><td>5</td></tr>
<tr><td>Humidity body sensor</td><td>2</td><td>6</td></tr>
<tr><td>Outside humidity sensor</td><td>2</td><td>6</td></tr>
<tr><td>Digital sensor AON (all or nothing)</td><td>3</td><td>2</td><td>RAP, CAP</td></tr>
<tr><td>Cardiac sensor</td><td>8</td><td>6</td><td rowspan="2">EAP, RAP</td></tr>
<tr><td>The combination (microphone, loudspeaker)</td><td>4</td><td rowspan="3">CFP</td><td>5</td></tr>
<tr><td>3-axis accelerometer</td><td>5</td><td>2</td><td rowspan="2">RAP, CAP</td></tr>
<tr><td>3-axis gyrometer</td><td>5</td><td>2</td></tr>
<tr><td>Emergency call button</td><td>6</td><td>CAP and CFP</td><td>6</td><td>EAP, RAP</td></tr>
<tr><td>Localization sensor (inside and outside)</td><td>7</td><td>CFP</td><td>2</td><td>MAP, CAP</td></tr>
<tr><td>Alert frame</td><td>9</td><td>CAP and CFP</td><td>6</td><td rowspan="2">EAP, RAP</td></tr>
<tr><td>Critical state</td><td>10</td><td>Whenever (CAP and CFP)</td><td>7</td></tr>
</table>

REFERENCES

[1] P. Rawat, K.D. Singh, H. Chaouchi and J.M. Bonnin, “Wireless sensor networks: a survey on recent developments and potential synergies”, The Journal of Supercomputing, Volume 68, Springer, 2014.
[2] O. Hamdi, M.A. Chalouf, D. Ouattara and F. Krief, “eHealth: Survey on research projects, comparative study of telemonitoring architectures and main issues”, Journal of Network and Computer Applications, Volume 46, Elsevier, 2014.
[3] T. Val, E. Bougeois, A. Van Den Bossche, N. Cazenave, L. Redon, A. Soveja and T. Villemur, “Projet CANet : un système de suivi de personnes à mobilité réduite grâce à leur canne de marche”, revue EsprIUT, Numèro spécial Recherche, Volume Hors-série, p. 10-11, february 2013.
[4] IEEE Standard for Local and metropolitan area networks part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs), 2011.
[5] IEEE Standard for Local and metropolitan area networks part 15.6: Wireless Body Area Networks: IEEE Std 802.15.6-2012, 2012.
[6] S. Khssibi, “Utilisations des réseaux de capteurs de canne pour les applications de surveillance de personnes”, Ph.d thesis report, University of Toulouse 2, 2015.
[7] R. H. et al., Ieee standards part 15.4: Wireless medium access control (mac) and physical layer (phy) specifications for low-rate wireless personal area networks (lr-wpans), 2003.
[8] K.A. Ali, J.H. Sarker and H.T. Mouftah, “Urgency-based MAC Protocol for Wireless Sensor Body Area Networks”, IEEE International Conference on Communications Workshops (ICC), 2010.
[9] M. Khanafer, M. Guennoun and H.T. Mouftah, “A Survey of Beacon-Enabled IEEE 802.15.4 MAC Protocols in Wireless Sensor Networks”, IEEE Communications Surveys and Tutorials, Volume 16, IEEE, 2014.
[10] O. Ekundayo, “Body Area Network Standardization, Analysis and Application”, Ph.d thesis report, SAVONIA University of Applied Sciences, 2013.
[11] A. Al-Mazroa and N. E. Rikli, “Performance Evaluation of IEEE 802.15.6 MAC in WBANs - A case Study”, International Conference on Information Technology and Multimedia (ICIMU), Malaysia, 2014.
[12] C. Tachtazis, F. Di Franco, D.C. Tracey,N.F. Timmons and J. Morrison, Chapter: “An Energy Analysis of IEEE 802.15.6 Scheduled Access Modes for Medical Applications”, D. Simplot-Ryl, M. Dias de Amorim, S. Giordano and A. Helmy, Ad Hoc Networks, Springer Berlin Heidelberg, 2012.
[13] R. Cavallari, F. Martelli, R. Rosini, C. Buratti and R. Verdone, “A Survey on Wireless Body Area Networks: Technologies and Design Challenges”, IEEE Communications Surveys and Tutorials, Volume 16, IEEE, 2014.
[14] S. Movassaghi, M. Abolhasan, J. Lipman, D. Smith and A. Jamalipour, “Wireless Body Area Networks: A Survey”, IEEE Communications Surveys and Tutorials, Volume 16, IEEE, 2014.
[15] G.K. Ragesh and K. Baskaran, “A Survey on Futuristic Health Care System: WBANs”, Procedia Engineering, Volume 30, Elsevier, 2012.
[16] T. Hayajneh, G. Almashaqbeh, S. Ullah and A.V. Vasilakos, “A survey of wireless technologies coexistence in WBAN: analysis and open research issues”, Wireless Networks, Volume 20, Springer, 2014.
[17] A. van den Bossche and T. Val, “WiNo : une plateforme d’émulation et de prototypage rapide pour l’ingénierie des protocoles dans les réseaux de capteurs sans fil”, Journées francophones Mobilité et Ubiquité (UBIMOB), France, 2013.
[18] R. Huang, Z. Nie, C. Duan, Y.Liu, L.Jia and L.Wang, Chapter: “Analysis and Comparison of the IEEE 802.15.4 and 802.15.6 Wireless Standards Based on MAC Layer”, X. Yin et all., Health Information Science, Springer International Publishing, 2015.
[19] K. Elissa, “Title of paper if known,” unpublished.