An Effective Approach for Energy Aware in Wireless Sensor Network

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***Abstract*—In wireless communication, energy present very serious problem which could be easily affect the lifetime of all the network. The increasing of the wireless connected object lead to the appearance of a new notion which is the Internet of Thing. The growth of network size produce very important quantity of data as a result which request more quantity of energy to consume. The technology of the IEEE 802.15.4 present very powerfull solution for all application dedicated to low energy consumed which justify our choice for it to study. This paper investigate an approach used to postpone the fault energy of node in the network. So we get the energy consumed by every node then we detect the node with lack of power. After that we propose a specific manner to get both the Superframe Order (SO) and the Beacon Order (BO) for this node in order to more maintain the little power lasted in its battery. We use in our work the topology of tree with the mode of beacon enabled for Wireless Sensor Network (WSN).**

***Keywords*—The Standard of IEEE 802.15.4, WSN, The Beacon Enabled Mode, BO, SO**

I. INTRODUCTION

Wireless Sensor Network (WSN) succeed in gaining a great regard from both researchers and engineers thanks to its increased demand in different areas. So many studies were developed to solve the main trouble of it which is the energy efficient. Divers protocols were invented to reduce energy consumption in WSN such as in [1]. In addition to that fault detection present very serious problem for WSN because of the limited resources of the nodes. Multiples methods were assumed to solve that [2],[3].

The standard of the IEEE 802.15 Personal Area Network (PAN) is formed by divers protocols destined for little power communication. The IEEE 802.15.4 is considered as sub branch of PAN standard [4].

This technology is included in the most popular technology which is destined for law data rate. It is increasingly used in many fields blessing to its different benefits. LRWPANs have many important characteristics which are the short-range operations, the facility of installation, the honest data transfer, cheap cost, objective battery life and the maintain of uncomplicated protocol. The technology of IEEE 802.15.4 is manipulated in many kinds of networks such as ZigBee, 6LoWPAN and ISA100.11a [5].

The LRWPANs is used in many applications and many fields such as agriculture, environment monitoring, security purposes, military, sports ([6], [7]) as well as entertainments [8]. In healthcare fields [9], the technology of IEEE 802.15.4 is so used in order to supervise the humans parameters [10] like the cardiac patients monitoring [11]. In ([12], [13]) the authors study the case of wearing a WBAN by patient. So they offers a continuous monitoring for him. However, sensor nodes send periodically certain parameters to the PAN coordinator to prove the best operation of the node in which it is implemented.

WPAN is used also in military field. The dress uniform wearing by the battle could consist of a BAN which is a bearable network. This BAN could include so many electronic devices such as support sensors in order to protect the connection of the soldiers wearable computer [14]. In addition to that, in sport field the body of players is implemented by sensors in order to detect the players movement. It is destined to explore a new manner to conserve energy and increase the performance of the player to the top of altitude over a long era of time [14]. The WPAN is used also in other different domains such as in entertainment. Although the multiple advantages of the technology of IEEE 802.15.4 that person could not ignored, this standard presents many drawbacks such as its restricted communication authenticity, the absence of protection on front of interferences and Powered relay nodes as well as Unbounded Delay. For all theses raisons the IEEE 802.15.4 is not the right choice in terms of accuracy, latency or performing in inaccessible environments [15]. For the reason to exceed such restriction, a Research Group named 802.15 Task Group 4e was lanced in 2008. Consequently, the standard of the 802.15.4e was developed in 2012 [15]. Many other functionality was added in the first standard.

This new standard gives us more opportunity such as the Time Slotted Channel Hopping (TSCH). Also an other extension of Multi-channel was added with its Deterministic and Synchronous (DSME) characteristics [15]. Moreover the technology of 802.15.4e is identified by its Low Latency Deterministic Network (LLDN) [15]. So it presents five new

MAC protocols destined for distinct operation field and some general application enhancements.

We interest in our paper to this standard (IEEE 802.15.4). Our approach has for purpose to postpone the fault energy of node in the network. We start by calculating the energy consumed by every node. Then we detect the node wich suffer from the lack of power. However, we propose a specific manner to get the Superframe Order (SO) and the Beacon Order (BO) for this node to maximize the lifetime of the network.

Our paper is organised by the way that section 2 presents some related work about the adjustment of the Beacon Interval (BI) and the Superframe Duration (SD). Then we detail an overview about the standard IEEE 802.15.4. Section 4 explains the different methods used to calculate the divers forms of energy consumption. However section 5 provides the way used to adjust the standard parameters. Moreover we introduce our results of simulation in the next section and in the last part we conclude this paper.

II. Related work

Since both Beacon interval and super-frame duration have a direct link with the period of activity of the node. So it contributes directly in the lifetime of the node as well as the network. Many works were developed in this field. Some research groups were interested in only the Beacon Interval adjustment other were interested to adjust the Super-frame Duration. Although other tried to access to both the BI and the (SO).

The change of Beacon interval is considered as the most attractive case for research. In [16], the writers use a defined amount of (SO) and modify (BO) value. This modification affects directly the duty cycle of the network. This adjustment depends essential from the traffic store of the network. If the data traffic increase then (BO) value become lower however if sleeping period decrease (BO) increase.

In [16], the authors proposed a new algorithm called the Beacon Order Adaptive Algorithm (BOAA) which is destined for networks with star topology. The technique intervene only in the(BO) parameter of the superframe structure. It's about a technique which recalculate just (BO) parameter.

The second case is to change just the Super-frame Order SO value and to conserve the Beacon frame Order (BO) fixe. In [17], the searchers develop an original approach named the Dynamic Super-frame Adjustment Algorithm (DSAA). They have a very clear objectives which is the reduction of the energy usage and to boost the canal exploitation. So the coordinator begin by calculating the superframe activity and collision percentage. The first one characterise the period in which the PAN is engaged in collecting or sending information. Despite, the occupation rate is get according to the received data at the PAN coordinator who compares after that theses values to other considered as a thresholds then it selects the Super-frame Order.

There are many other parameters taken into account to choose the most perfect value of (SO) in the network such as throughput during the Contention Access Period (CAP), the queue state as well as the idle period in the technique of Adaptive Duty Cycle Algorithm (ADCA) [18]. The PAN node make a decision based on the duration of the idle period. If it exceeds the half of the CAP, the value of (SO) will be decreased. In the case that it is is fewer than 50 percent of the CAP part, then the PAN go over to examine the number of packets collected and the number of suspended packets over the CAP. In the case that suspended packets are higher than collected packets, the (SO) will be developed for the next Beacon Interval.

An other very different methods used for the adjustment of the (SO) value which is presented in [19],[20]. It is about Markov-base theoretical analysis. The main idea of this technique is based on a mathematical models used. The value of (SO) is manipulated based on network conditions.

In the third case both (BO) and (SO) are adapted simultaneously to gain more fluently. In [21], the approach of Duty cycle Self-Adaptation Algorithm (DBSAA) was developed based on the duty cycle value. The adjustment depend from four parameters: the Collision Rate (CR), the source nodes number, superframe Occupation Ratio (OR) as well as message collected by the coordinator.

III. The IEEE 802.15.4 Overview

The technology of the IEEE 802.15.4 is an unwired network standard which is widely used for the low power environment. It defines the two first layers of the Protocol Stack which are the Physical layer and Medium Access Control layer. This technology gives as the choice of frequency bands from the available one which are 868 MHz, 915 MHz and 2.4 GHz with multiple canals of transmission in every band but the most used band is the 2.4 GHz band. In which a big problem could be lived which is the interference trouble. Two kinds of interferences are presented in this band: internal interference and external interference. In the first one it is simply the mutual interference of WBANs over each other although in the second one always he intervention of an external technology is the responsible for example WiFi or Bluetooth over WSNs [22], [23]. Also this standard give as the opportunity to choose between three data rates 250 kbps, 40 kbps and 20 kbps. In the Personal Area Network, (PAN) coordinator sets the main practical parameters which could be the duty cycle or the band of frequency. This standard presents two functional status which are the non-Beacon-enabled mode and Beacon-enabled one. In first mode, the MAC method used is the well known protocol Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA). So the Clear Channel Assessment CCA is employed before sending data on the medium. Then a decision is made according to its state. If it is not clear, it stays waiting for a period of time before the next attempt. The energy consumed in this mode is very important, showed by figure 1. In the Beacon-enabled mode, the coordinator transmit beacon frame every period for all members of the network in order to synchronise it. Two successive frames (Beacons) represent the Beacon Interval (BI) which its expression is given by equation (1). This period of time is composed by an operating duration and an optional inactive duration. The Superframe Duration (SD) present the first part. It is formed by two parts: (CAP) and the Contention Free Period (CFP), showed by figures 1. The slotted version of CSMA/CA mechanism is employed for channel access in first part whereas in CFP an scheduled TDMA mechanism manage the network. While in the inactive duration, nodes have the chance to enter in sleep station in order to save the battery power.

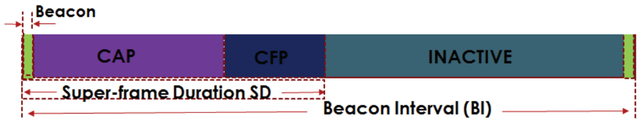

Fig. 1. The frame of IEEE 802.15.4

The BI Beacon Interval is defined by (1).

$$BI = aBaseSuperframeDuration * 2^{BO}; 0 \leq \text{BO} \leq 14 \quad (1)$$

BI depends from the value of $aBaseSuperframeDuration$ which is presented by equation (2).

$$aBaseSuperFrameDuration = aBaseSlotDuration * anumSuperframeSlot \quad (2)$$

The relation (2) gives as the definition of the $aBaseSuperframeDuration$ in the technology of IEEE 802.15.4 which is in direct relation with $aBaseSlotDuration$. The $aBaseSlotDuration$ is defined with equation (3).

$$aBaseSlotDuration = 60 * symbols \quad (3)$$

The Superframe Duration SD is defined by equation (6).

$$SD = ABaseSuperframeDuration * 2^{SO} \quad (4)$$

$$0 \leq \text{SO} \leq \text{BO} \leq 14 \quad (5)$$

IV. Energy efficient

Energy stay again very attractive field for research that is why many works were developed in order to calculate it with more efficiency.In my case i will use some special manner to calculate some kinds of energy which are characterised by theirs link with the parametric of the protocol used to enhance to the canal of transmission which is the CSMA/CA protocol. The emission energy E_{em} is giving by equation (6).

$$E_{em} = (nbt_{sd} * Ttt * Eb) + 2 * U * I * CCA * Tp_{back} \quad (6)$$

Ttt present the size of frame. Eb is binary energy,nbt_{sd} represent the number of data frame present in SD, CCA is the Clear Channel Assessment, U is the Voltage value as well as I expressed current value.
Although Tp_{back} is presented by equation (12).

$$Tp_{back} = (2^{cst_{back}} - 1) * 20symbol \quad (7)$$

With cst_{back} characterise the backoff period.
Concerning energy of collision E_{col}, it is get by expression (13).

$$E_{col} = Tatt * U * I * Nbpk \quad (8)$$

$Tatt$ is among of time to access to the transmission canal. $Nbpk$ is the number of try to transmit information without receiving any acknowledge from destined node.
The energy consumed in overhearing and overmitting phase, is mentioned by equation (14).

$$E_o = nbr_{tr} * dtra * Eb * PER \quad (9)$$

$dtra$ present the size of frame (bit). Eb is show the binary energy. PER is the error rate with is obtained as the average of packet transmitted without being well received.
Received energy Erc is giving by formula (15)

$$E_{rc} = nbr_{SD} * Eb \quad (10)$$

With nbr_{SD} show the number of bit received in SD period. The energy in sleep period E_{SLP} is giving by formula (16).

$$E_{SLP} = Eb * (BI - SD) \quad (11)$$

The objective of our work is to make an extension in the survival period of the network via extending the career of the node by more exploit the quantity of energy remaining E_R lasted in the battery of the node.
The remaining energy E_R is showed by expression (12) .

$$E_R = Eini - Ec \quad (12)$$

Ec is always the som of all types of energy consumed. It is giving by equation (13).

$$Ec = E_{em} + E_{col} + E_o + E_{idl} + E_{rc} \quad (13)$$

V. IEEE 802.15.4 Parameters adjustment

Our work is based on the adjustment of both the Beacon frame Interval valor and the Superframe Duration. So the PAN coordinator receive the energy consumed by every node EC than try to select if there is a node in which the battery level is less then the energy threshold ET. In this case, a new value of BON and SON will be calculated and be send to this node in order to decrease its duty cycle and maximize its lifetime as mentioned in figure 2.

We suppose that E_{BI} the energy wasted in the Superframe duration is giving by relation (14).The (E_R) present the Energy Remaining, (BI) is the size of Beacon Interval period, (T_{tt}) is the frame length, (E_T) is the Energy of frame as mentioned above.

$$\text{E\_\{BI\}} = \frac{\text{BI}}{\text{T\_\{tt\}}} * \text{E\_T} \quad (14)$$

We suppose that energy consumed in BI is always less then the energy remaining in the battery (15)

$$E_{BI} \leq E_R \quad (15)$$

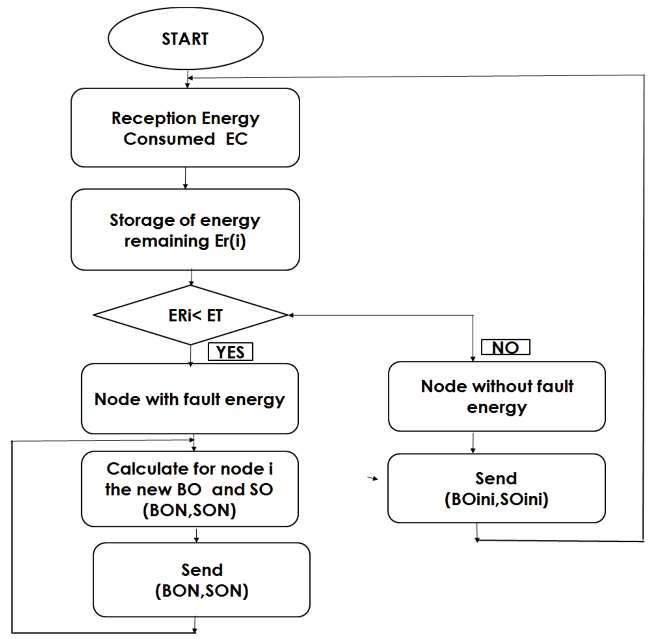

Fig. 2. Method description

The relation (16) is expressed used both relations (14) and (15),

$$\frac{BI}{T_{tt}} * E_T \leq E_R \quad (16)$$

As BI is calculated by relation (17).

$$BI = 15,36 * 10^{(-3)} * 2^{BO} \quad (17)$$

Equation (16) become by this way (18).

$$(15,36 * 10^{(-3)}) * \frac{2^{BO}}{T_{tt}} * E_T \leq E_R \quad (18)$$

We calculate 2^{BO} relation (19).

$$2^{BO} \leq \frac{E_R * T_{tt}}{15,36 * 10^{(-3)} * E_T} \quad (19)$$

That is why BO is mentioned by the formula (23).

$$BO = \frac{log(\frac{E_R * T_{tt}}{15,36*10^{(-3)}*E_T})}{log(2)} \quad (20)$$

We propose that we use just 10% of the energy remaining in the node E_{R1} in order to well exploit it, giving by relation (21).

$$E_{R1} = E_R * 0.1 \quad (21)$$

Therefore BO become (22):

$$BO = \frac{log(\frac{0.1*E_R*T_{tt}}{15,36*10^{(-3)}*E_T})}{log(2)} \quad (22)$$

For the case of the Superframe Duration SD we just use the 70% from the BI period. So SO it is expressed by relation (23)

$$SO = 0.7 * \frac{log(\frac{0.1*E_R*T_{tt}}{15,36*10^{(-3)}*E_T})}{log(2)} \quad (23)$$

VI. Simulation Results

Our work was implemented using INET-MANET/OMNET++ tools as shown by figure 3. INETMANET is a Wireless Sensor Network simulator based on the OMNet++ platform [24]. OMNeT++ simulator is adaptable and its components are based on C++ library. Despite, there are many simulators available for Wireless sensor network such as Castalia [25], NS2 [26], NS3 [27] but INETMANET/OMNET++ present the most realistic wireless environment and mote behaviors.

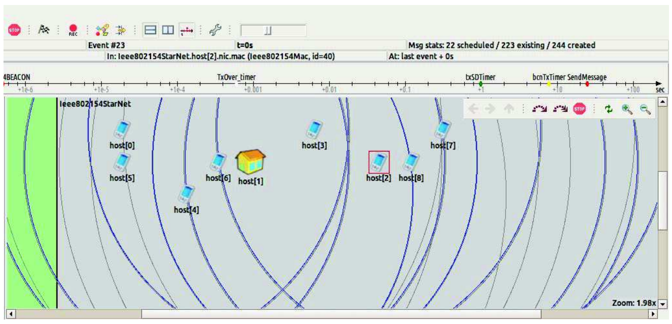

Fig. 3. Network node

Our features of simulation are defined in table I.

TABLE I. Simulation Features

Parameters	Values
Simulation time	18000 s
Network size	(400,200)
E initial	18720J
Nodes number	9
Channel frequency	2.4 GHz
Radio Type	IEEE 802.15.4 radio
dispersion	rondom

The figures 4, 5, 6, 7 as well as 8 show as the simulation results for all kinds of energy that we calculated which are energy of reception, energy of transmission, energy of overhearing-overmitting and energy consumed in sleep state. All the figures decrease by the same way as a result of the decrease of the Duty Cycle (DC). After intervention the BO decrease from 10 to 7 and the SO decrease also from 8 to 4. Therefore the duty cycle DC is reduced from 25% to 12,5%. The (DC) is calculated by formula (24).

$$2^{(SO-BO)} * 100 = \frac{1}{2^{(10-8)}} * 100 = \frac{1}{2^2} * 100 = 25 \quad (24)$$

$$2^{(SO-BO)} * 100 = \frac{1}{2^{(7-4)}} * 100 = \frac{1}{2^3} * 100 = 12,5 \quad (25)$$

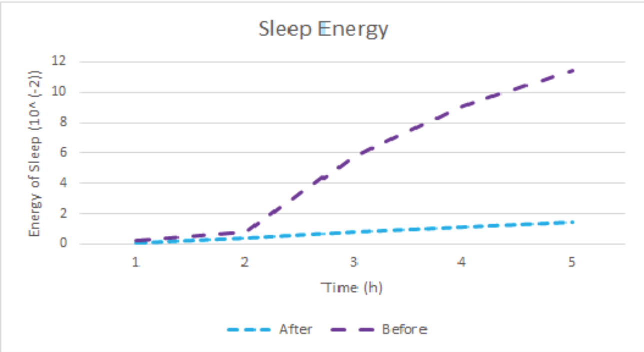

Fig. 4. SLEEP Energy

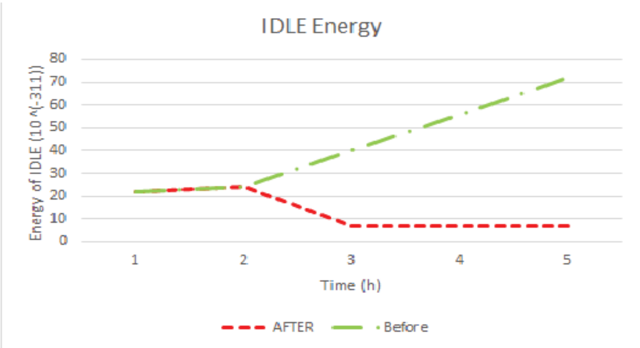

Fig. 5. IDLE Energy

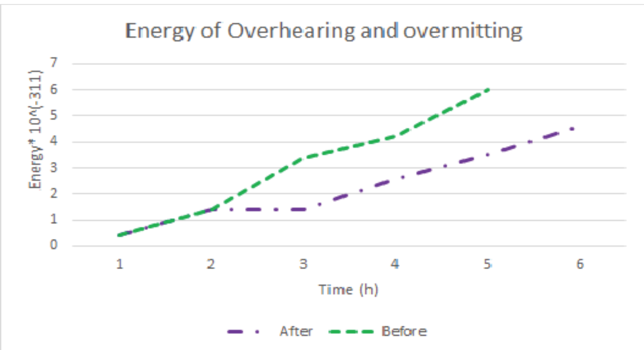

Fig. 6. Overhearing and Overmitting Energy

VII. Conclusion

Our objective in this work is to postpone the fault of energy in the network. So we are trying to calculate every kinds of energy that could be consumed by the node. Then we detect the node with fault energy. After that we propose a specific manner to get the Beacon Order and the Superframe Order for this node in order to more maintain the little power lasted in the battery. As perspective to this work, it will be very interested if we derive this work to very extended network with mesh topology.

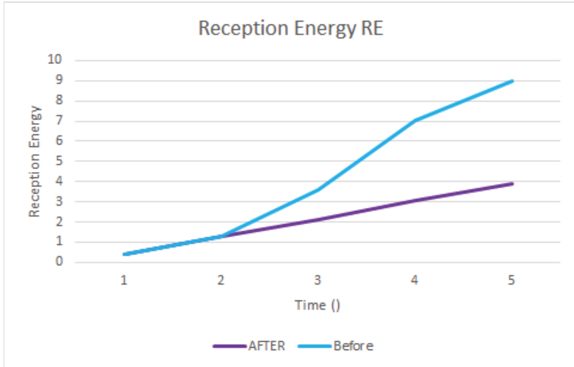

Fig. 7. Reception Energy

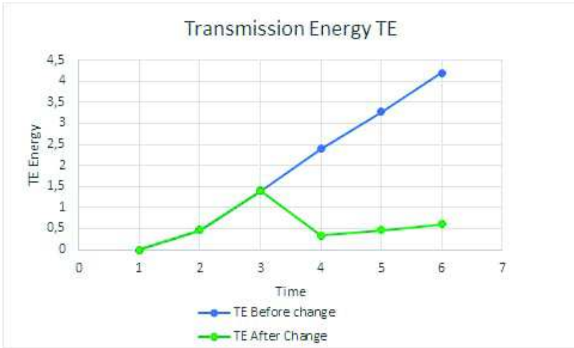

Fig. 8. Transmission Energy

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