Conférence Internationale en Automatique & Traitement de Signal (ATS-2017)
Proceedings of Engineering and Technology – PET
Vol.23pp.5-11

Data collection from the mobile sink in WSN by the communication management of the UDP protocol

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***Abstract*- Today in the field of objects connected to the Internet, there is a great interest for wireless sensor networks (WSN) where each sensor can be used in various areas such as health, intelligent habitat, environmental monitoring, industrial control, etc. However, given that the sensors are limited in energy, the data are sent by UDP, a communication protocol that does not guarantee their delivery. The mobility of nodes can, for example, cause the loss of these data. It is for this reason that the management of data transmission through UDP requests is required. In this article, we study, in WSN, the impact of various methods of communication management by UDP on the delivery of data to a mobile sink. The objective of this study was to determine which method best meets the constraints of this network.tyt**

***Key words*- WSN, mobile sink, data collection, 6LoWPAN, ContikiOS.**

I. Introduction

The Internet of Objects (IoT: Internet of Things) [1] is a technology which designates the connection of communicating devices with their environment to the Internet. Despite the limitations of energy in WSN, this technology is integrated to sensors through the standard 6LoWPAN (IPv6 Low Power Wireless Personal Area Networks) [2, 3]. This standard has allowed the sensors to adapt to IPv6 protocol and to participate in the Internet.

Generally, the RPL protocol (RPL: IPv6 routing protocol for Low Power and lossy networks) [4] is used in WSN using 6LoWPAN (IPv6 Low Power Wireless Personal Area Networks). This protocol is a routing protocol that manages the mobility. It builds in WSN a tree with the sink as the root node and sensors as nodes. This root collects data from sensors. The transport of these data is done by UDP (User Datagram Protocol). This protocol is used by the Internet and where the transmission of packets is without connection and without acknowledgment. In view of these facts, UDP is adapted to the constraints of WSN, but it is not reliable for the delivery of data when the sink is mobile. It is for this reason, that the management of data transmission through UDP requests is necessary in this network.

This article is structured as follows. Section 2 introduces 6LoWPAN protocol stack. Section 3 presents the process of data collection by mobile sink in WSN. This section explains the operation of the RPL protocol and the communication management by UDP. Section 4 presents simulation scenarios and analyzes the obtained results. Section 5 presents a conclusion with prospects.

II. 6LoWPAN protocol stack

Application (CoAP)
Transport (UDP)
Network (IPv6, RPL)
Adaptation (6LoWPAN)
MAC (CSMA)
Duty-cycle (ContikiMAC)
Physical (IEEE 802.15.4)

Fig. 1 6LoWPAN protocol stack

A WSN is a set of sensors scattered in a field of sensors. These sensors are autonomous, able to communicate between them and transmit data to one or more sinks. However, the limitations of sensors in energy, computational capacities and memory, make it difficult that such a network can meet the requirements of the quality of service (QoS) without that its nodes are greedy in energy. In order to limit the constraints related to WSN, standards and protocols have been specially designed to guarantee him the QoS (see figure 1) [2].

IEEE 802.15.4 [5] is a standard that defines the physical layer and the MAC layer (Media Access Layer). It is designed to meet the limitations of WSN.

6LoWPAN is a standard based on IEEE 802.15.4. It is located in the adaptation layer between the network layer and the MAC layer. This standard has allowed the routing of packets IPv6 for the participation of objects limited in energy to the IoT.

The main protocols described in 6LoWPAN protocol stack:

- The protocol ContikiMAC [6] is a protocol that uses the technique of duty-cycle which consists of that sensors are between the active mode and the sleep mode in order to preserve the energy and prolong the life of the network. In this Protocol, the sender repeat the transmission of a packet until the receipt of acknowledge message or during any its active period.
- The RPL protocol is a routing protocol used byIPv6 which allows the construction of a DODAG (Destination Oriented Directed Acyclic Graph). The destination is the sink.
- The UDP protocol is a transport protocol used by the Internet for the transmission of packets without connection and without acknowledgment.

ISSN 2356-5608

III. Data collection by the mobile sink in WSN

The main steps of data collection by a sink in WSN [2]:

- In a first time, the RPL protocol will allow the nodes to exchange ICMPv6 packets (Internet Control Message Protocol Version 6) for the construction of a DODAG.
- In a second time, the UDP protocol will allow the sensors to transmit, in the DODAG, UDP packets to the sink [2]. The data are contained in these packets.

A. The operation of the RPL protocol

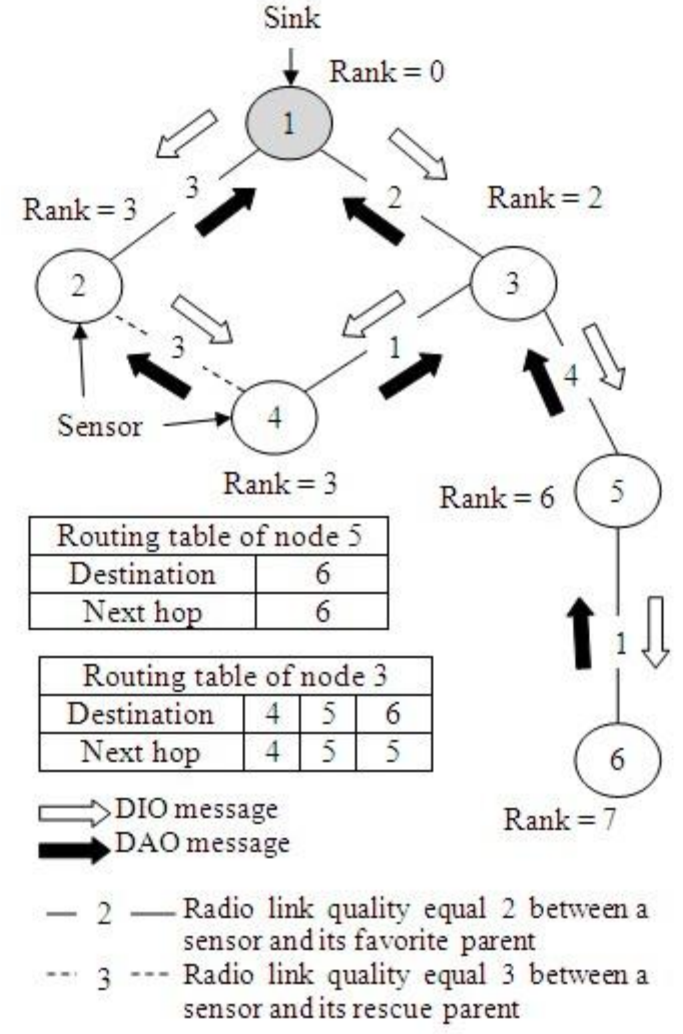

Fig. 2 The operation of the RPL protocol in storing mode with the radio link quality as routing metric

In network layer, the RPL protocol is a routing protocol used by IPv6. It uses four types of ICMPv6 packets for the construction of a DODAG:

- DIO (DODAG Information Object): This message allows a sensor to calculate its rank in DODAG and maintain the roads. It contains information such as the rank of the sender and the objective function to use to construct the DODAG.
- DIS (DODAG solicitation information): A DIO message can be requested by this message.
- DAO (Destination Advertisement Object): This message allows the sensors to indicate their choices of preferred parent and secour parents, as well as to build routing tables.
- DAO_ACK (Destination Advertisement object acknowledgment): A DAO message may be acquitted by this message.

The RPL protocol follows the following steps for the construction of a DODAG (see figure 2):

1. The Sink broadcasts a DIO message to the neighbor sensors.
2. Each sensor that receives the DIO message, calculates its rank by using the objective function specified in this message. This function defines the routing metric (energy, number of hops, radio link quality…) to choose the preferred parent. Thus, the sensors will attribute a rank equal to the addition of the rank of its preferred parent and the cost of this metric. In figure 2, the routing metric is the radio link quality; the sensors attribute small costs to the best radio links.
3. After the sensor has calculated rank, it broadcasts a DIO message to the neighbor sensors.
4. The sensor selects as preferred parent, the neighbor with which it has the smallest rank. It also selects as secour parents, the neighbors with which it has had the smallest ranks. Subsequently, it informs its parents of its choices by DAO messages.
5. For the construction of roads between nodes in a DODAG, the RPL protocol works in storing mode where sensors inform parents of its descendants by DAO messages. Thus, each parent is saved in its routing table, its descendants and the next hops to routing data. The sink and the leaf nodes do not manage routing table, they emit their packets to the intermediate nodes for routing them to their destinations.

The sink and the sensors send periodic DIO messages to maintain the roads in the DODAG. These messages are sent according to the Trickle algorithm that defines mainly two things:

- If the sensor receives a DIO message not indicating a change in the topology, it double the period of sending DIO messages.
- If the sensor receives a DIO message indicating a change in the topology, it resets the period of sending DIO messages to its smallest value.

In WSN using the RPL protocol, a mobile sink is a sink embedded in mobile objects (human, car, robot…). Thus, it can move in a random manner or in a controlled manner. The advantages of this network are the possibility to expand and the possibility to minimize, in a DODAG, a road in number of hops, collisions, loss packets, etc. The disadvantage is the frequent breakdown of the links between nodes which result the non-reliability of roads, the loss of packets, the interruption of traffic, the increase of the overhead, the increase of the duty-cycle, the difficulty of locating the nodes that change position, etc.

B. The communication management by UDP

We considered that a sensor join the DODAG when it sends a DAO message to its parent. We considered that a sensor join WSN when it sends its data in the DODAG to the sink (sensor must participate in the routing of data). To resolve some problems of mobility of the sink in WSN, the management of data transmission through UDP requests is required. We note,

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in our application, that to ensure the reliability of data transmission, the duration of the transmission of the UDP message between a node and its neighbor is generally less than a second. In our study, the data collection in WSN is carried out according to one of the following methods that we will describe by sequence diagrams [7]:

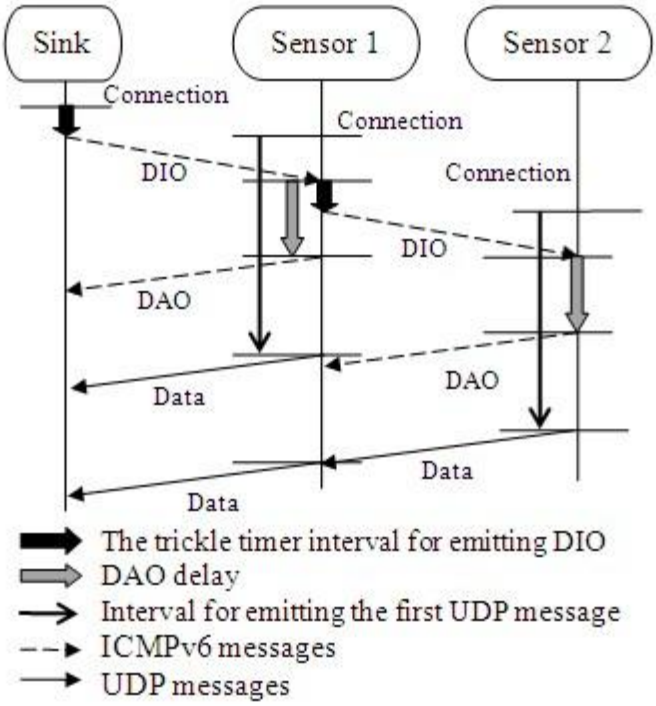

Fig. 3 Data collection by the sink, in WSN, according to the first method of communication management by UDP

Figure 3 shows a DODAG where the sink is the parent of the sensor 1, and this sensor is the parent of the sensor 2. The operation of the first method of communication management of UDP, in this DODAG, consists of:

- Role of the sink: The sink receives data from the sensors.
- Role of the sensor: The sensor will periodically emit its data.

The impacts of the first method of communication management by the UDP protocol in WSN with mobile sink:

- This method will not take into account the mobility of the sink, and then much data will be lost.
- This method allows the sensors to emit UDP packets through the DODAG built by ICMPv6 packets.
- This method minimizes the displacements of the sink. In fact, the sensors use the roads of the DODAG.

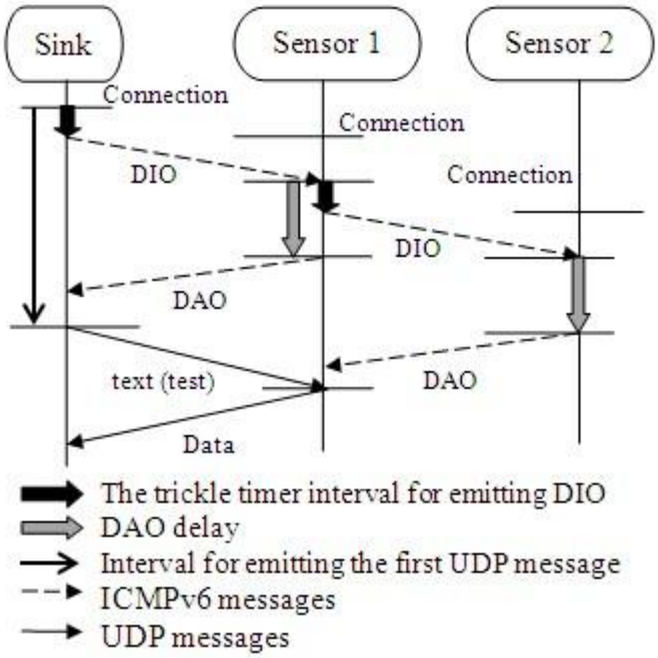

Fig. 4 Data collection by the sink, in WSN, according to the second method of communication management by UDP

Figure 4 shows a DODAG where the sink is the parent of the sensor 1, and this sensor is the parent of the sensor 2. The operation of the second method of communication management of UDP, in this DODAG, consists of:

- Role of the sink: The sink is unlimited in energy. It periodically emits a text message "test" to the sensors.
- Role of the sensor: When a sensor receives the text message "test", it will emit its data to the sink.

The impacts of the second method of communication management by the UDP protocol in a WSN with mobile sink:

- This method takes into account the mobility of the sink, and then a small number of data will be lost generally due to the collisions.
- Since the sink does not manage routing table, it collects the data from the sensors in its radio range. In effect, the sink transmits the text message "test" to its neighbors without indicating to which transmit this message.
- In this method, the sink collects the data from the sensors in its radio range. Thus, maximization of the displacements of the sink.

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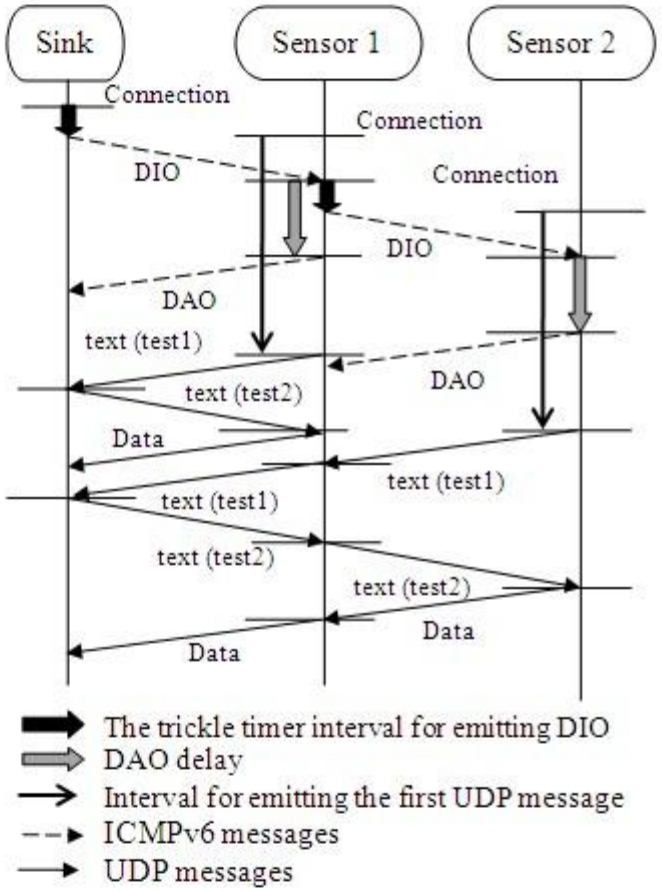

Fig. 5 Data collection by the sink, in WSN, according to the third method of communication management by UDP

Figure 5 shows a DODAG where the sink is the parent of the sensor 1, and this sensor is the parent of the sensor 2. The operation of the third method of communication management of UDP, in this DODAG, consists of:

- Role of the sink: The sink will emit a text message "test2" to the receipt of a text message "test1" on the part of a sensor. The text message "test2" means for the sensor that the sink is available in the collection of data.
- Role of the sensor: A sensor will periodically emit a text message "test1" to the sink. At the reception of the message text "test2" on the part of the sink, the sensor sends its data to the sink.

The impact of the third method of communication management of the UDP protocol in WSN with mobile sink:

- ➢ This method takes into account the mobility of the sink, and then a few data will be lost generally due to the collisions.
- ➢ This method has allowed the sensors to emit UDP packets through the DODAG built by ICMPv6 packets.
- ➢ This method minimizes the displacements of the sink. In fact, the sensors use the roads of the DODAG.
- ➢ The disadvantage of this method is that the sensors must have a significant capacity of energy, storage and computational capacities.

IV. Simulation and Analysis

A. The scenarios of simulation

TABLEAU I
THE PARAMETERS OF WSN SIMULATION

Parameter	Value
ContikiOS	Contiki-2.7
Transport protocol	UDP
Routing protocol	RPL protocol in storing mode
Objective function	MRHOF (Minimum Rank with Hysteresis Objectif Function) with ETX (Expected Transmission Count) as routing metric
Protocol of the adaptation layer	6LoWPAN
MAC protocol	CSMA
Duty-cycle	ContikiMAC
Standard of the physical layer and the MAC layer	IEEE 802.15.4
Topology	DODAG
The nodes	One sink and14 sensors
Radio range of each node	100 meters
The mobility of sink	Moving between positions
Simulation delay	8 minutes
The duration of data collection by the sink in one zone	2 minutes
The interval for emitting the first UDP message	20 seconds
The minimum interval for emitting the DIO message	4.096 seconds
The maximum interval for emitting the DIO message	1048.576 seconds

ContikiOS [8, 9] is an operating system designed specifically for WSN. It provides the Cooja simulator (Contiki OS Java Simulator) which allows to simulate WSN described in table 1.

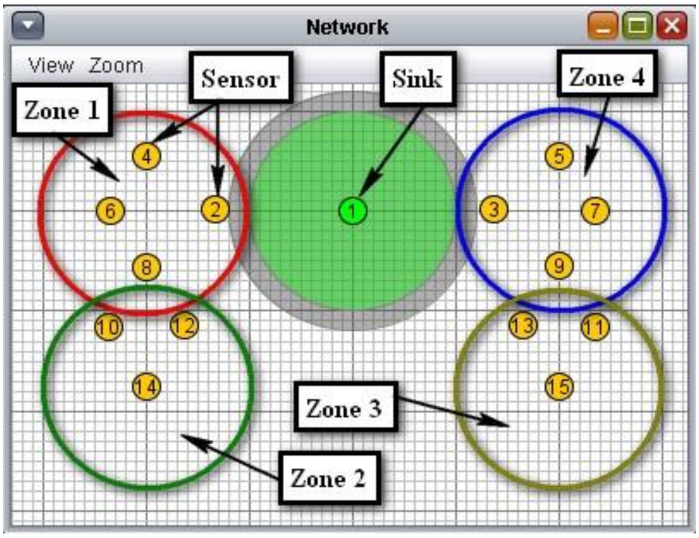

Fig. 6 The topology of WSN

TABLEAU II
THE SCENARIOS OF WSN SIMULATION

Scenario	Method of communication management of UDP	Zones in order visited periodically by the sink to cover WSN

ISSN 2356-5608

Conférence Internationale en Automatique & Traitement de Signal (ATS-2017)
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Scenario 1	First method	Zones 1 and 4
Scenario 2	Second method	Zones 1, 2, 3 and 4
Scenario 3	Third method	Zones 1 et 4

To show the impact of mobility of the sink in WSN, we simulated our scenarios according to the input parameters in table 1 which describes the characteristics of the studied network. Our scenarios are described in table 2.

Figure 6 represents the topology of the studied WSN. The green zone represents the radio coverage of the sink, and the gray zone represents the interference zone of the sink. In WSN, one of the applications that require the mobility of sink is the data collection between two zones A and B which are not in the same radio coverage. Instead of using sensors to connect these two zones, the use of a mobile sink which moves between zones A and B, seems to be a better solution for the energy consumption by the sensors and to expand of the network. The topology of WSN that we study looks like this application. As figure 6 shows, the mobility of the sink is to move at most between four positions. Thus, it creates by its radio range four zones 1, 2, 3 and 4. This mobility corresponds to the industrial control applications. In this type of application, the sink is active in the position of the creation of the zone. This is the reason for which we have neglected its movement between two zones.

B. Simulation results

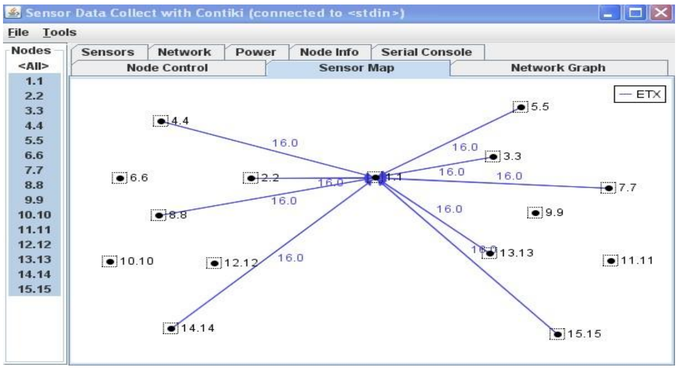

Fig. 7 Data routing in DODAG at the end of the simulation of scenario 1

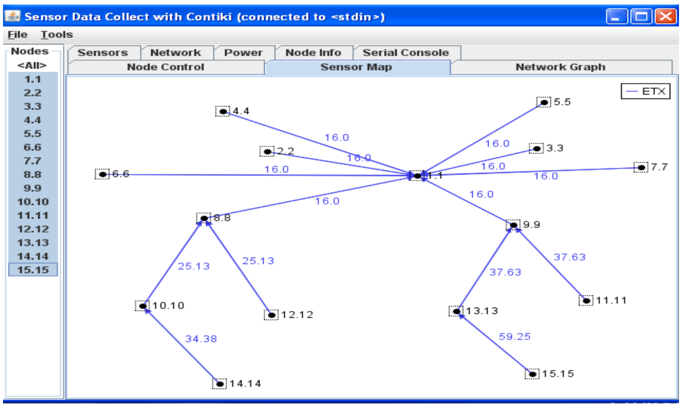

Fig. 8 Data routing in DODAG at the end of the simulation of scenario 3

TABLEAU III
EVALUATION PARAMETERS OF THE CONSTRUCTION OF THE DODAG

Scenario	**Number of Sensors having joined WSN at the end of the simulation**	**Time for all sensors join WSN**
Scenario 1	14	2 min 39 sec
Scenario 2	9	-
Scenario 3	14	2 min 39 sec

We considered that a sensor join the DODAG when it sends a DAO message to its parent. We considered that a sensor join WSN when it sends its data in the DODAG to the sink. Thus, the topology of WSN contains the sensors having joined this network (see figures 7 and 8). The results of the analysis of the topologies in each studied scenarios, are described in table 3 and figures 7 and 8. We note at the end of the simulation:

- In scenario 2, all sensors have not joined WSN. The reason is that the sink collects data from the sensors in its radio range. In addition, these sensors can be in the sleep mode during the collection.
- In scenarios 1 and 3, all sensors have quickly joined WSN. The reason is the routing of UDP packets in the DODAG.

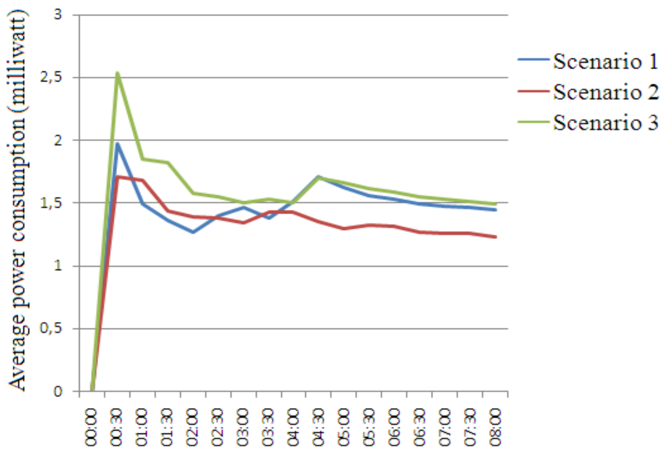

Fig. 9 The average energy consumption of the sensors in each scenario

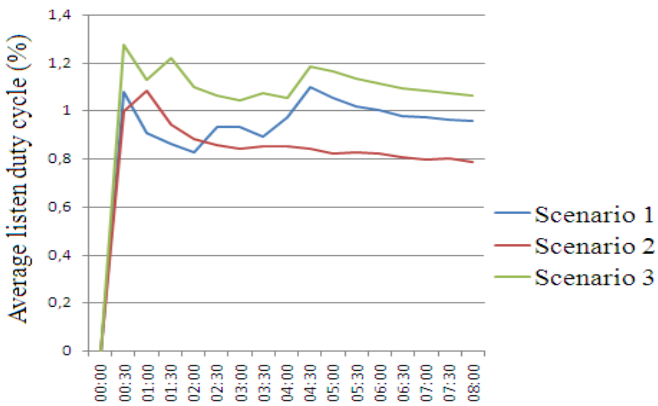

Fig. 10 The average listen duty-cycle of the sensors in each scenario

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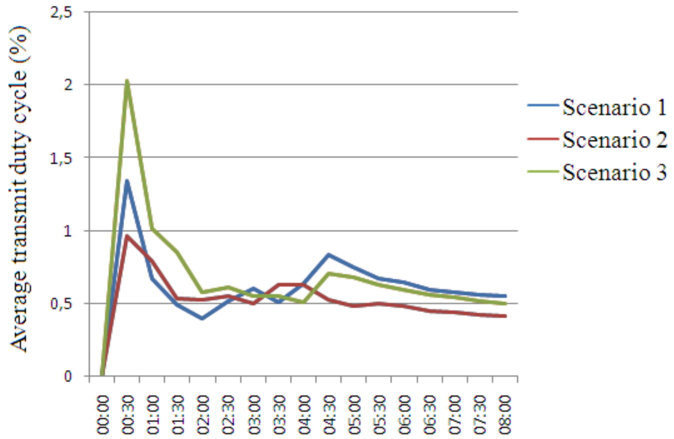

Fig. 11 The average transmit duty-cycle of the sensors in each scenario

In the course of the simulation, we have obtained results of the following metrics:

- The energy consumption by the sensor.
- The duty-cycle that is the cycle where the sensor goes between the sleep mode and the active mode. When the sensor is in the active mode, it has a period of listening and a period of transmission.

In this application, we evaluate the sensors which arrive to send data to the sink in the DODAG. We note that the sink is not taken into account, given that we considered it unlimited in energy and always being in active mode (100% duty-cycle). From the results obtained, we have traced the curves in the figures 9, 10 and 11:

- In the first minute, we note in the curves of the three figures a significant increase of energy consumption and the active periods of duty-cycle. The reason is the connection of the nodes to the WSN.
- The variations of the curves in these three figures are almost similar. The explanation is that a high energy consumption of few sensors implies major periods of listening and transmission, which implies a large traffic of packets.
- In the course of the simulation, we see that the sensors have consumed the most of energy in scenarios 1 and 3. This consumption decreases more in scenario 2. The explanation is that more traffic is large, more the energy consumption is.

TABLEAU IV
AVERAGE UDP PACKETS IN EACH SCENARIO

	UDP packet	
Scenario	**Average received data packets**	**Average loss data packets**
Scenario 1	11,571	2,714
Scenario 2	2,111	0
Scenario 3	12,357	0

At the end of the simulation, we note in table 4 which shows the average of UDP packets in each scenario:

- The WSN of the scenario 1 does not guarantee the reliability of data transmission. The reason is that the sensors do not verify the availability of the mobile sink.
- The number of data collected is small in scenario 2. The reason is that the sink collects thedata from the sensors in its radio range. In addition, these sensors can be in the sleep mode during the collection.

TABLEAU V
AVERAGE ICMPV6 PACKETS IN EACH SCENARIO

	ICMPv6 packet		
Scenario	**Average DIO packets**	**Average DAO packets**	**Average DIS packets**
Scenario 1	117,666	167,714	20,357
Scenario 2	88,8	57,8	58
Scenario 3	130,6	254,642	20,357

At the end of the simulation, we note of table 5 which shows the average of the ICMPv6 packets in each scenario:

- The collection of data from the sink implies the use of roads in DODAG. Thus, more the number of UDP messages is bigger, more the number DIO and DAO messages is [2]. This explains the results obtained in the Scenario 2.
- We note a big number of DIS packets in scenario 2. The first reason is that the decrease of DIO packets increases the DIS packets. The second reason is the long absence of the sink to a zone.

V. CONCLUSION AND PROSPECTS

In WSN using the RPL protocol, the communication management by UDP requests ensures the reliability of the transmission of data. The data collection of sensors at the request of the sink, ensures minimal energy consumption on the part of sensors, but decreases the number of collected data. The data collection by the sink at the requests of sensors to deliver their data, ensures the collection of a big number of data, but increases the energy consumption in the network.

The problems of mobility of the sink in WSN that we seek to resolve in our future works consist of reducing the energy consumption, the duty-cycle, the overhead, etc.

The end of this article proposes a search of roads taking into consideration the QoS in WSN, for the applications that require a mobile sink.

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