Optimizing Coverage in a Wireless Sensors Network by Selecting the Best Sensors

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Abstract. The challenges imposed by wireless sensor networks can be attributed to several factors such as a severe energy constraints, the limited processing and communication capabilities, the dynamic deployment of the environment, the unique data dissemination model, and the quality of service required at the application level. The routing protocol is considered as an important service. It allows to the routing of data packets captured to shift from the sensors to the base station. The choice of the path taken is made according to the performance standards such as energy consumption, reliability, transmission delay, etc. In this work, we will look for the best sensors and the best path to choose in order to set up our sensor network properly. As well, we will optimize the type of sensors for purchasing and the routing of the packets as far as possibility. And consequently, we use a multi-objective function for this purpose. The first part will consist of making the choice between different sensors. As a result, we have the group of sensors which has a minimum communication radius with a cheaper cost, a high throughput, and low-energy consumption. Our results are more optimal in terms of cost, energy, and transfer rate compared to other approaches. The optimization results obtained give us a minimum value for the cost of sensor deployment in the area equal to 218586 FCFA, a minimum value of 1609120 W/h, and a maximum value for the transmission rate equal to 47.82 bit/s. This optimization ensures 91.03% coverage with the square octagon network model.

Keywords: Routing protocol · Optimization · Wireless Sensors Network · Coverage

1 Introduction

Advances in microelectronics, micromechanics, and wireless communication technologies over the past few decades have made it possible to produce components with a volume of just a few cubic millimeters at reasonable cost. These components, known as microsensors, contain a sensing unit that detects physical

K. Cheikh M. F. Kebe et al. (Eds.): InterSol 2024, LNICST 610, pp. 71–86, 2025.
https://doi.org/10.1007/978-3-031-86493-3_7

quantities (heat, humidity, and vibration) and converts them into digital data. Sensors are thus true embedded systems. A wireless sensor network is the use of a large number of battery-powered sensors to autonomously collect and transmit environmental data to one or more collection points. They are becoming increasingly popular in a variety of fields. Despite their many advantages, wireless sensor networks are limited by the battery power, processor power, and communication capacity of the sensors.

Therefore, it's important to make an optimal choice of sensor types and how to deploy them in a wireless sensor network. In our work, we present the best sensor available on the market based on a set of criteria. We made a comparative study of a set of sensors based on their energy, communication range, transmission power, and price. The result is a set of sensors with minimum communication range, lower cost, higher throughput and lower energy consumption. For each optimization case, we implemented a sensor deployment pattern in square, hexagon and square-octagon shapes. In this way, we optimized the network while ensuring maximum coverage in the working area. The results are shown in Fig. 5, Fig. 6, and Fig. 7.

2 State of the Art of Routing Protocols in Wireless Sensors Networks

The routing in wireless sensor networks, is a field which is very much explored by researchers. They give specific characteristics of this type of network. The energy and computing limits of power of the sensors require consequently a new generation of protocols completely different from those of wired and wireless networks. This difference is explained by the fact that the sensors have limited energy in computing power and in storage capacity which one requires an efficient management of resources. As for the literature's side, there are several researchers who have oriented their works in this same field. We can name among them, [1–10]. Afterward, in this part, we will then lay out the different types of routing protocols, the importance energy and quality of service in wireless sensor networks.

2.1 Routing Protocols in WSNs

According to the sensor network topology, Mammeri and al have developed three types of routing protocols in theirs work [11] which are listed as the flat routing protocol, the hierarchical routing protocol and the geographic routing protocol. In theirs works [5] and [12], the authors have explained that hierarchical routing is the most effective in terms of energy efficiency. In fact, it is based on the concept of standard node, master node and base station. The standard nodes itself routes the messages to the masters ones, which then route the standard nodes through the network via others master nodes until the base station called (sink). Among the hierarchical routing protocols, there are those that follow the hierarchy in a grouped manner called (clustering) that are elaborated in work

[5] done by AnnushaKumar and al. In addition, there are those that follow the routing protocols which are in the chained hierarchy which is established in work [1] done by Es-Sabery and al.

Hierarchical Routing Protocols. In the work [8], by Seedha Devi and al, they have established the technique of hierarchical system which is usually divided the network into subsets in the purpose of facilitating its management and typically to optimize the routing which is carried out at several levels. In this type of protocols, we distinguish two types of node groups where the network's architecture is situated named the zone and the cluster. Malisetti and al. have defined a cluster in work [13] as a set of nodes which has a node named node-head or Cluster Head (CH) and the role of the CH is to be a relay directly between the nodes of the cluster and the base station or others CHs. Generally, the CH has greater energy resources than the other nodes in the network. Then, Vinitha and al have shown in their work [10] that the CH is elected according to different criteria and information on the network. Which are the energy level of a sensor, the connection with other sensors and the geographical position, etc. So every area is defined by a set of nodes which does not have a head node (or CH). Thus, obviously a cluster is a subclass of an area.

Figure 1 this technique presented the Hierarchical topology.

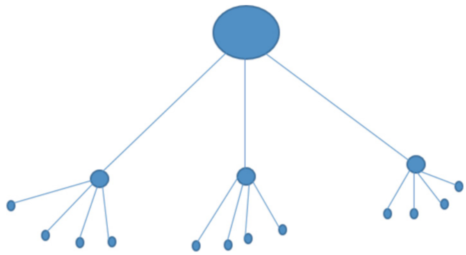

Fig. 1. Hierarchical topology.

2.2 Transmission Algorithms in WSN

The approach proposed in work [14] by Yemeni and al. have run the Kalman filter for redundancy reduction. The Kalman filter is an infinite impulse response filter which estimates the states of a dynamic system from a series of incomplete or noisy measurements. The technique based on the traveling salesman problem and clustering is presented by Velusamy and al in work [6]. In order to ensure low-power consumption for data transmission in sensor networks. A quantum annealing approach is used in work [15] by Nikouei and al in order to improve the cost of system deployment by minimizing the number of sinks and SDN controllers needed. In work [8], Seedha Devi and al. have elaborated a data aggregation scheme based on cluster heads to reduce latency and packet's loss. They also placed an aggregation system directly at the base station. The work of Vinitha and al. in [10] addressed the issue regarding energy and provided energy efficient multi-hop routing in WSNs. The author have used an energy-efficient multi-hop routing named Taylor which in based on Cat Salp Swarm Algorithm (Taylor C-SSA) by shifting the C-SSA with Taylor series.

The work of AnnushaKumar and al. in [5] address the issue of energy and provide an efficient Clustering-like routing protocol for sensor energy conservation and lifetime with high throughput. The authors used a new routing protocol based on the hybrid cuckoo search algorithm combined with the genetic algorithm. In work [9], Singh and al. proposed an application of three algorithms:

- Algorithms 1: Consisted of the placement of the receiver node (sink) by optimizing the swarm of particles.
- Algorithms 2: the route between the sensors and the sink uses the tree of minimum range (spanning tree), which is then optimized by the technique of bee colonies.
- Algorithms 3: it is about the opportunistic transmission of packets to neighbors.

In work [8], Seedha Devi and al propose latency reduction and packet loss in WSNs. They propose a data aggregation scheme based on clusters and consists two phases.

- Phase 1: Each cluster head applies compressional aggregation. Then, the aggregation tree is built by the receiver using the minimum spanning tree.
- Phase 2: The Packet loss rate and the latency are considered when prioritizing and allocating time slots.

As for the maintenance and adjustment of knots, the work of Ouyang and al. in [7] showed a drone-based scheme with automatic transmission and reception. This system is based on a special drone coupled with the GNSS-RTK platform (Global Navigation Satellite System, Real - Time Kinematic). Table 1: compares the algorithms covered at the level of the state of the art with full respect for the working criteria. Which are the deployment strategy, the structure of the network, the type of routing, the transmission protocol used and lastly the objective expected.

Table 1 compares the algorithms covered at the level of the state of the art with respect to the working criteria which are: the deployment strategy, the structure of the network, the type of routing, the transmission protocol used and the objective expected.

3 Preliminaries

In order to simplify the presentation of our approach, we start by introducing some key models that we use in the rest of our document such as: network model, energy model and radio model.

Table 1. Comparison of approaches

Protocol approach	Deployment strategy	Network structure	Routing type	Sensor node	Transmission protocol	objectif
[14]	random on square grids	Flat topology	end-node level and sink-node level	Active and passive	Kalman filter	Reduces data redundancy
[6]	Polygons (vorony diagram)	hierarchical	UAVs	CH, NCH, VCH	Trade Seller (ESDCS	Reduces energy
[15]	Dynamics (methaheuristics)	hierarchical	multi-sink multi-controller node	SDN	quantum annealing	Reduce the cost
[10]	Random	hierarchical	multi hop routing	CH	Taylor C-SSA (LEACH)	Reduce energy, delay
[5]	random	hierarchical	clustering	CH level 1 and level 2	Cuckoo combined with GA(TEEN)	Long life, high throughput
[16]	Deployment in hexagon	hierarchical	Clustering	CH, target nodes	CSMA/CA	Fusion of real-time data, collision, energy
[17]	dynamic	hierarchical	multi-hop def routing	SDN	Mobile well(ODGRP)	Reduces energy
[9]	random	hierarchical	multi-hop and multi-sink	CH	coding, spanning tree	Reduces redundancy, energy
[8]	-	hierarchical	multi hop routing	multi-level CH	spanning tree, slot	Reduce pck loss
[7]	By point of interest	hierarchical	UAVs	Asset	3G 4G 5G	-

3.1 Network Model

We assume that each sensor is omnidirectional and has 360° coverage. Each sensor is represented by a circle with center I and radius R which mean the communication radius of the sensor. A defined number of sensors will be placed in the search area. It is divided into square-octagon patterns. Each pattern consists of two octagons and a square with equal sides. Thus, each sensor is placed in the center of each octagon (see Fig. 2).

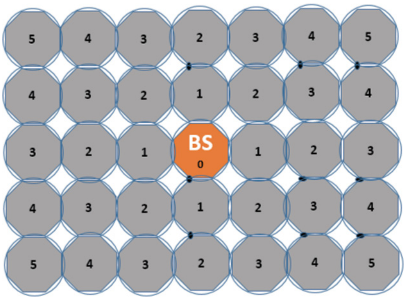

Fig. 2. Cutting in a square-octagon pattern.

The network topology is centralized. Each sensor node is identified by its label number and its position within frame which takes as its origin from the center of the base station. In our architecture, the distance between two consecutive sensors is identified by the Euclidean distance between the center of two consecutive sensors. Then The value is equal twice the communication radius of the sensor presented by Lecor al. in [18]. The author defines the value d of the Euclidean distance between two consecutive sensors in (1). The author also defines the network cost as a function of R in Eq. (2).

$$\begin{cases} d = 2 * R * \cos(T) \\ T = \frac{2\pi}{8} \\ d = 2 * R * \cos(\frac{\pi}{4}) \\ d = R * \sqrt{2} \end{cases} \tag{1}$$

$$Cost(N, x) = a(N) * \frac{1}{3.82 * R(x)^2} * price(x) \tag{2}$$

The cost equation takes as input a network N and sensors x. We have $a(N)$ the total area of the network, *price* the price of a sensor and $\frac{1}{3.82*R(x)^2}$ the area of an octagon containing a sensor x.

3.2 Energy Model

The sensor node consumes energy to perform three main tasks which followed: detection, communication and data processing. In [1], Es-Sabery and al show that the energy used for revealing the physical phenomenon is negligible. Besides, the energy used for processing is less than the communication's energy. In [19], Sharma and al show that energy's efficiency represents a significant metric performance because it straightly influences the durability of the network. In [13], Malisetti and al systematically underline that the radio model is used to communicate the information between the receiver and the transmitter. The energy is conveyed by the transmitters to operate the power amplifier and the electronic circuits of the transmitter and the receiver in Fig. 3. The power's consumption at the time when the data bits are received and transmitted and at any distance between the transmitter and the receiver, is represented by Eq. (3) and Eq. (5).

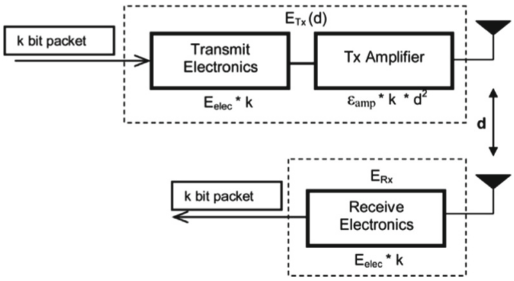

Fig. 3. Energy consumption model [3].

In the energy model, Wang and al showed in [20] that the energy used by each node to transmit, is proportional to d^2 if the distance between the transmitter and the receiver is less than the threshold distance d_0, otherwise it is proportional to d^4. The total energy required by each node to transmit $k - bit$ data is:

$$E_{tx}(k,d) = \begin{cases} k[E_{elec} + E_{amp} * d^2] & \text{si } d < d_0 \\ k[E_{elec} + E_{amp} * d^4] & \text{si } d > d_0 \end{cases} \tag{3}$$

$$d_0 = \sqrt{\frac{e_{fs}}{e_{mp}}} \tag{4}$$

$$E_{rx}(k,d) = E_{elec} * k \tag{5}$$

With a full consideration of k the number of bits to be transmitted, d being the Euclidean distance between the transmitter and the receiver, and E_{elec} is a hardware parameter of energy consumed during the operation of the transmission channel. It amplifies energy for the free space model e_{fs} and for the multi-path model e_{mp}, which are two parameters of energy consumption by the amplifier E_{amp} and d_0 which is a distance threshold between two successive nodes.

3.3 Wireless Model

In their work titled [21], Gungor and al showed that the wireless channel is modeled using a log-normal path loss model by shading and combining analytical and empirical methods. This model is used for large and small coverage systems and for indoor wireless environments with obstructions. In this model, the signal-to-noise ratio $S_B(d)$ at a distance d from the transmitter is given by Eq. (6):

$$S_B(d)_{dB} = P_t - P_l(d_0) - 10 * n * \log_{10}(\frac{d}{d_0}) - X_\alpha - X_n \tag{6}$$

where P_t is the transmit power in dBm, $P_L(d_0)$ is the path loss at a reference distance d_0, n is the path loss exponent, X_α is a variable zero-mean Gaussian random with standard deviation α, and P_n is the noise power in dBm. In [22], Shannon gave in 1998 the formula for the transmission capacity of the communication channel of k bits over a distance d by Eq. (7)

$$C_{tx}(k,d) = W * \log_2(1 + S_B) \tag{7}$$

With W the bandwidth, $S_B(d)$ the signal to noise ratio, k is the number of bits to be transmitted over a distance d.

3.4 Communication Model

This section introduces the Bluetooth, UWB, ZigBee, and Wi-Fi protocols, which correspond to the IEEE 802.15.1, 802.15.3, 802.15.4, and 802.11a/b/g standards respectively. The main objective of this part is to set forth a comparison of the four main short-range wireless networks in Fig. 4.

Standard	Bluetooth	UWB	Zigbee	Wi-Fi
IEEE spec..	802.15.1	802.15.3a	802.15.4	802.11a/b/g
Frequency band	2.4GHz	3.1-10.6 GHz	868/915 MHz; 2.4 GHz	2.4 GHz; 5 GHz
Max signal rate	1 Mb/s	110Mb/s	250kb/s	54Mb/s
Nominal range	10 m	10 m	10-100 m	100 m
Nominal TX power	0 - 10 dBm	-41.3 dBm/MHz	(-25) - 0 dBm	15 - 20 dBm
Number of RF channels	79	(1-15)	1/10;16	14(2.4GHz)
Channel bandwidth	1MHZ	500MHz-7.5GHz	0.3/0.6 MHz; 2 MHz	22MHz
Modulation type	GFSK	BPSK, QPSK	BPSK (+ ASK), O-QPSK	BPSK, QPSK COFDM, CCK, M-QAM
Spreading	FHSS	DS-UWB, MB-OFDM	DSSS	DSSS, CCK, OFDM
Coexistence mechanism	Adaptive freq. hopping	Adaptive freq. hopping	Dynamic freq. selection	Dynamic freq. selection transmit power control (802.11h)
Basic cell	Piconet	Piconet	Star	BSS
Extension of the basic cell	Scatternet	Peer-peer	Cluster tree-mesh	ESS
Max number of cell nodes	8	8	> 65000	2007
Data protection	16-bit CRC	32-bit CRC	16-bit CRC	32-bit CRC

Fig. 4. Comparison table of the main short-range wireless networks [23].

Bluetooth and ZigBee are protocols intended for low-speed and short-range portable products. They have a limited energy life (battery). Therefore, the power's consumption must be very low. UWB is offered for short-range and high-speed applications. And Wi-Fi is designed for longer range connection and supports devices with power supply. Bluetooth and ZigBee protocols consume less power than UWB and Wi-Fi protocols. To conclude, Bluetooth and ZigBee are suitable for low data rate applications with limited battery (such as mobile devices and sensor networks running on battery), due to their low-power consumption which gives them a long service life. While, for high-speed applications (like audio/video surveillance systems), UWB and Wi-Fi would be better solutions.

4 Approach

In our approach, we note that there are several categories of sensors on the market with different performances. These differ on criteria such as: cost, power to transmit captured data, coverage and collection radius, and energy. It is necessary to make a good choice of these sensors in order to optimize the coverage and performance of our WSN. The main goal of our work is to choose the least expensive sensors in terms of energy and transmission power to ensure coverage and data transmission in our wireless network. To optimize the network paths, we need to find the minimum distance between two consecutive sensors. To do this, we use three functions representing cost, energy, and transmission rate, respectively. These three functions have in common a variable called d, which is the Euclidean distance between two consecutive sensors. In our approach, the network topology we use defines the d value of the distance between two sensors. This value is defined in Eq. (8).

$$d = 2 * R * \cos(\frac{\pi}{4}) = R * \sqrt{2} \tag{8}$$

4.1 Formalization of the Problem

Given:

- N a network with an area denoted by $a(N)$
- $\mathcal{S}$ a set of sensors where each sensor x in $\mathcal{S}$ is characterized by its price, denoted by $price(x)$, its communication radius, denoted by $R(x)$, its electrical energy, denoted by $E_{elec}(x)$, its amplification energy, denoted by $E_{amp}(x)$, its width of bandwidth, denoted by $W(x)$ and its transmission power, denoted by $Pr(x)$.
- E_{tr}: a maximum energy threshold not to be exceeded
- C_r: a maximum network cost threshold not to be exceeded
- D_r: a minimum threshold of the transmission rate
- K: the number of bits to transmit

We are looking for the sensor that minimize the following function.

$$\min_{x \in \mathcal{S}} \text{Cost}(N, x, E_{tr}, D_r, K)$$

such that:

$$\begin{cases} \text{Cost}(N, x, E_{tr}, D_r, K) \leq C_r \\ \text{EnergyTotal}(x, K) \leq E_{tr} \\ \text{TransmissionRate}(N, x) \geq D_r \end{cases}$$

With

$$\begin{cases} Cost(N, x) = a(N) * \frac{1}{3.82 * R(x)^2} * price(x) \\ EnergyTotal(x, K) = K * [2E_{elec}(x) + E_{amp}(x) * (2R(x)\cos(\frac{\pi}{4}))^2] \\ TransmissionRate(x) = W(x) * \log_2(1 + S_B(x)) \\ S_B(x) = 10^{\frac{(P_t(x) - 20 * \log_{10}(\frac{4\pi * d(x)}{\lambda}))}{10}} \end{cases} \tag{9}$$

Details on these formulas are given in the next section.

4.2 Network Cost Function

It evaluates the cost of all the sensors that are placed in the network. Each sensor node has a price and all the nodes in the network have a total cost. It takes as variable R the communication radius of the sensor x.

$$Cost(N, x) = a(N) * \frac{1}{3.82 * R(x)^2} * price(x) \tag{10}$$

According to our working criteria, the cost of the network must not exceed the threshold value C_r. Therefore, the communication radius of a sensor is given by the following equation.

$$R(x) \geq \sqrt{\frac{a(N) * price(x)}{C_r * 3.82}} \tag{11}$$

4.3 Network Energy Function

It evaluates the transmission energy and the reception energy between two neighboring sensors. When a sensor transmits data to another sensor, they provide transmit energy and receive energy. The sum of these two energies is called $EnergyTotal$. It takes as variable R the communication radius of a sensor x.

$$EnergyTotal(x, k) = k * [2 * E_{elec}(x) + E_{amp}(x) * (2 * R(x) * \cos(T))^2]$$

$$EnergyTotal(x, k) = k[2E_{elec}(x) + E_{amp}(x) * (R(x)\sqrt{2})^2] \tag{12}$$

4.4 Network Transmission Rate Function

It evaluates the transmission power between two consecutive sensors of the network at a distance d. It takes as variable $R(x)$ the communication radius of the sensor x.

$$TransmissionRate(N, x, S_B(x)) = W * \log_2(1 + S_B(x)) \geq D_r$$

$$S_B(x) = P_t(x) - P_L(x)$$

$$P_L(x) = 20 * \log_{10}(\frac{4\pi * d(x)}{\lambda})$$

$$S_B(x)(d)_{dB} = P_t(x)_{dB} - 20 * \log_{10}(\frac{4\pi * d(x)}{\lambda})$$

$$S_B(x)(d) = 10^{\frac{(P_t(x)_{dB} - 20 * \log_{10}(\frac{4\pi * d(x)}{\lambda}))}{10}}$$

$$TransmissionRate(N, x, S_B(x)) = W(x) \log_2(1 + S_B(x)(d)) \tag{13}$$

5 Case Studies

- Given the wireless transmission modules with their characteristics in the table below Table 2.

$$\min_{x \in \mathcal{S}} \text{Cost}(N, x, E_{tr}, D_r, K)$$

such that:

$$\begin{cases} \text{Cost}(N, x, E_{tr}, D_r, K) \leq C_r \\ \text{EnergyTotal}(x, K) \leq E_{tr} \\ \text{TransmissionRate}(N, x) \geq D_r \end{cases}$$

Table 2. Sensor choice minimize $\text{Cost}(N, x, E_{tr}, D_r, K)$

Sensor/data	N	$Price(x)$	$R(x)$	$P_t(x)$	$E_{elec}(x)$	$E_{amp}(x)$	$W(x)$	C_R	K	E_{tr}	λ	Dr
Digi XBee Cellular 3G	(200,100)	77185.9	100	3.3*0.702	8333.69	0.0013	2.4	40411	2	30	0.125	250M
Bluetooth V3 module TEL0026	(200,100)	14.630	10	3.6*0.05	648	0.0013	2.4	765960	2	2.59	0.125	2M
ESP8266 Wi-Fi IoT	(200,100)	31675	50	3.3*0.5	5940	0.0013	2.4	66335	2	25	0.125	54M
Digi XBee 3 Zigbee	(200,100)	22260	20	3.6*0.04	518.4	0.0013	2.4	296596	2	2.07	0.125	250k
RF ZigBee ETRX357	(200,100)	16700	20	3.6*0.031	648	0.0013	2.4	218586	2	2.59	0.125	250k

- Given the wireless transmission modules with their characteristics in the table below Table 3.

$$\min_{x \in \mathcal{S}} \text{EnergyTotal}(x, K)$$

such that:

$$\begin{cases} \text{EnergyTotal}(x, K) \leq E_{tr} \\ \text{Cost}(N, x, E_{tr}, D_r, K) \leq C_r \\ \text{TransmissionRate}(N, x) \geq D_r \end{cases}$$

Table 3. Sensor choice minimize $TotalEnergy$

Sensor/data	N	$Price(x)$	$R(x)$	$P_t(x)$	$E_{elec}(x)$	$E_{amp}(x)$	$W(x)$	C_R	K	E_{tr}	λ	Dr
Digi XBee Cellular 3G	(200,100)	77185.9	100	3.3*0.702	8333.69	0.0013	2.4	40	2	33361120	0.125	250M
Bluetooth V3 module TEL0026	(200,100)	14.630	10	3.6*0.05	648	0.0013	2.4	40	2	2594080	0.125	2M
ESP8266 Wi-Fi IoT	(200,100)	31675	50	3.3*0.5	5940	0.0013	2.4	40	2	23762080	0.125	54M
Digi XBee 3 Zigbee	(200,100)	22260	20	3.6*0.04	518.4	0.0013	2.4	40	2	2074080	0.125	250k
RF ZigBee ETRX357	(200,100)	16700	20	3.6*0.031	648	0.0013	2.4	40	2	1609120	0.125	250k

- Given the wireless transmission modules with their characteristics in the table below Table 4.

$$\min_{x \in \mathcal{S}} \text{TransmissionRate}(N, x)$$

such that:

$$\begin{cases} \text{EnergyTotal}(x, K) \leq E_{tr} \\ \text{Cost}(N, x, E_{tr}, D_r, K) \leq C_r \\ \text{TransmissionRate}(N, x) \geq D_r \end{cases}$$

Table 4. Sensor choice maximize *TransmissionRate*

Sensor/data	N	$Price(x)$	$R(x)$	$P_t(x)$	$E_{elec}(x)$	$E_{amp}(x)$	$W(x)$	C_R	K	E_{tr}	λ	$Dr(b)$
Digi XBee Cellular 3G	(200,100)	77185.9	100	3.3*0.702	8333.69	0.0013	2.4	40	2	33.4	0.125	1.91
Bluetooth V3 module TEL0026	(200,100)	14.630	10	3.6*0.05	648	0.0013	2.4	40	2	2.5	0.125	191.31
ESP8266 Wi-Fi IoT	(200,100)	31675	50	3.3*0.5	5940	0.0013	2.4	40	2	23.7	0.125	7.65
Digi XBee 3 Zigbee	(200,100)	22260	20	3.6*0.04	518.4	0.0013	2.4	40	2	2.07	0.125	47.82
RF ZigBee ETRX357	(200,100)	16700	20	3.6*0.031	648	0.0013	2.4	40	2	1.6	0.125	47.82

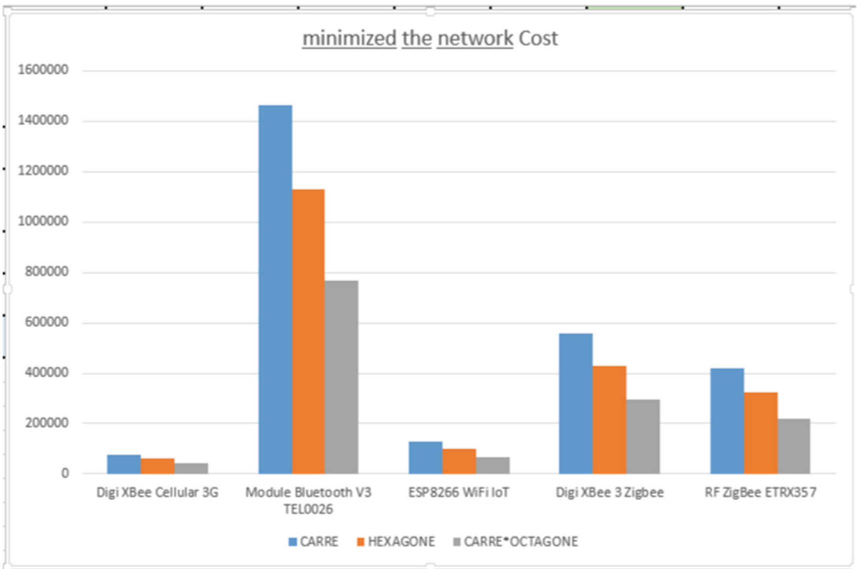

Fig. 5. Minimized the network *Cost*.

Based on optimization criteria, Fig. 5 shows that network cost is highest with Bluetooth, 3G and WiFi are cheaper and Zigbee is average.

According to the optimization criteria, Fig. 6 shows that the energy consumed in the network is highest with 3G followed by WiFi, Bluetooth consumes less energy and transmission with Zigbee requires low energy.

According to the optimization criteria, Fig. 7 shows that the transmission rate is lower with 3G and WiFi, Zigbee has an average rate and Bluetooth uses the highest transmission rate.

5.1 Assessment

We evaluated a number of sensors on the market for different scenarios. This multi-objective study was based on three basic functions. They have a common variable called d, which is the Euclidean distance between two consecutive sensors. The functions we used are: the $Cost$ function, the $EnergiTotal$ function, and the $TransmissionRate$ function. We maximized the network $TransmissionRate$ function and minimized the network $Cost$ and $EnergiTotal$ functions. After a comparative study of a set of sensors based on our three functions, we obtained as results three tables presented in Tables 2, 3, 4.

The analysis of our results shows that sensors using the IEEE 802.4 communication protocol and the ZIGBEE ETRX357 RF type offer better performance than other sensors. So we'll use this type of sensor to improve the performance of our data sensor network.

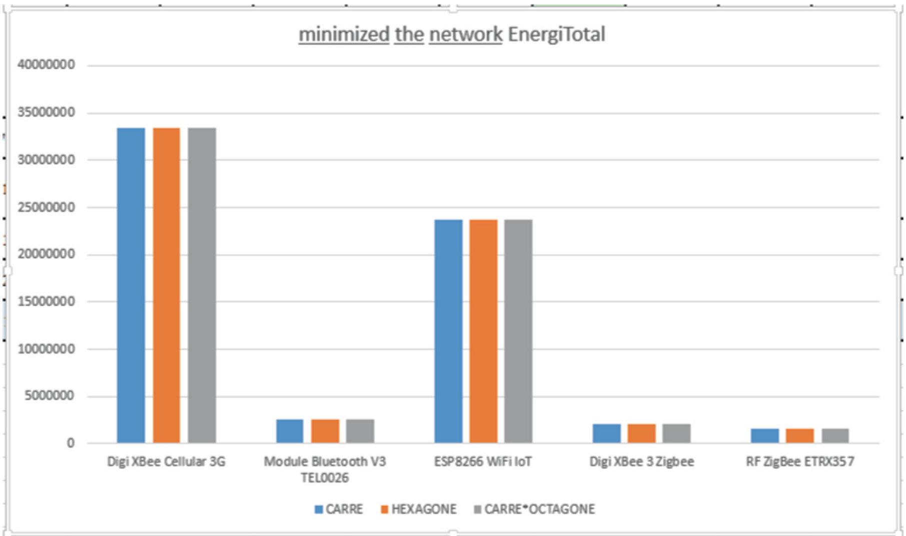

Fig. 6. Minimized the network $EnergiTotal$.

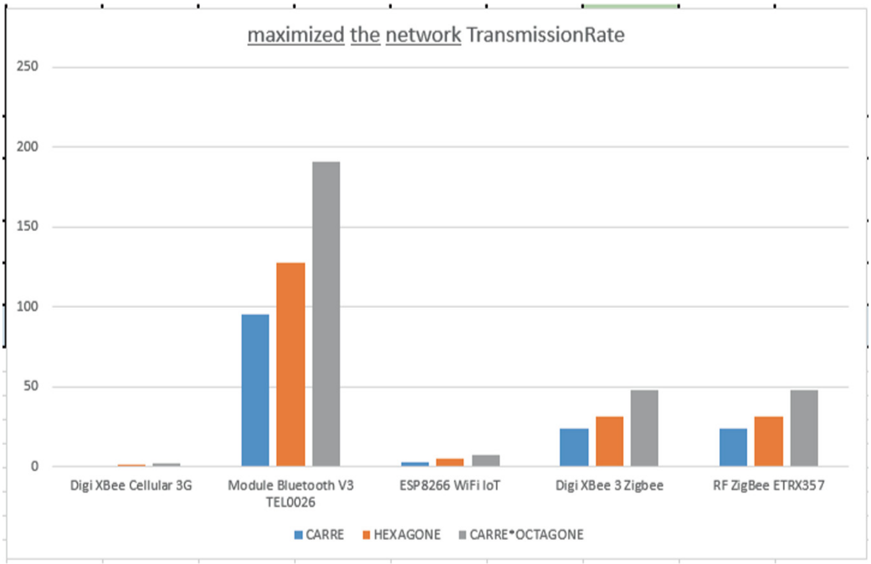

Fig. 7. Maximized the network *TransmissionRate*.

6 Conclusion

In summary, we conducted a comparative study of a number of sensors on the market. This multi-objective study was based on a number of criteria. Each constraint is represented as a function, so we used three functions. We have a function that represents the cost of the network, we also have a function that represents the total energy of the network and finally we have the function that gives us the transmission rate of the network. In summary, ZIGBEE ETRX357 RF sensors with IEEE 802.4 protocol will be implemented in our wireless sensor network. Again with the aim of increasing network performance, we will propose a linear routing algorithm for data packet transmission in our WSN.

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