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RESEARCH ARTICLE

The effects of LT-SN on energy dissipation and lifetime in wireless sensor networks

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ABSTRACT

Wireless sensor networks (WSNs) still attract the attention of researchers, users and the private sector despite their low power and low range tendency for malfunction. This attraction towards WSNs results from their low cost structure and the solutions they offer for many prevalent problems. Many conditions, which remain unforeseen or unexpected during the design of the system, may arise after the initialization of the system. Similarly, many situations where security vulnerabilities take place may emerge in time in WSNs operating normally. In this study, we called nodes which enter sleeping mode without any further waking up and causing a sparser number of nodes in the network without any function in data transmission as Long-Term Sleep Nodes (LT-SN); and considered energy spaces caused by such nodes as a problem; and established two Linear Programming (LP) models based on the efficiency of the present nodes. We offered two different models which present the effect of sensor nodes, which were initially operating in wireless sensor network environment and did not wake up following sleep mode, on network lifetime. The results of the present study report that as the number of LT-SN increases, the lifetime of the network decreases.

1. Introduction

Technological developments in Wireless sensor networks (WSNs) field are indicating that WSNs will be much more prevalently utilized in the future. Important advancements were made regarding the solution of many bottlenecks thanks to studies carried out on WSNs until now [1]. However, many more studies have to be carried out in order to provide solutions for the energy efficiency and high lifetime bottlenecks [2]. There are more challenges (i.e., computation/communication, save energy, balance energy, maximize network lifetime, minimize energy consumption, minimizing processing time, communication and message complexity, optimized and select the best transmission routes, query huge amount of data) to be overcome in WSNs.

When a node's energy is a critical level, it cannot provide sensor data to the network, and it cannot forward data from other nodes. This situation leads to the formation of energy gaps in the network and higher energy consumption. Due to these holes, both security vulnerability occurs and more load is put on the rest of the nodes [3]. Hence, this affects the network lifetime adversely [4]. Problems like this have their negative effects on network robustness and stability [5]. Energy is one of the main sources that has to be used effectively in WSNs. In the present case, since studies related to the wireless charging of the sensor nodes have not reached a sufficient level yet [6], our primary objective is the best utilization of the battery energy in the nodes of the sensor network. By using the energies of the nodes in the network more effectively, the lifetime of the networks is extended and more long term operation can be maintained. Therefore, it can be inferred that a linear relationship is present between the lifetime of the network and effective use of the energy. Spaces are forming in a sensor network with full initial coverage area due to nodes entering sleeping mode and losing connection with the network over time. These spaces both cause security issues and more workload on the remaining nodes which are required to protect and observed the same related area. This naturally causes high level energy consumption due to the forming spaces and as a result of excessive energy

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consumption, the lifetime of the network is negatively affected due to this fact.

In this paper, we accepted the effects on the lifetime of the network and the consumed energy due to the energy spaces caused by LT-SN nodes, which are not participating in data transmission, as a problem. Our purpose was the most efficient lifetime extension of the network and minimization of the consumed energy by using program codes written in a mathematical programming and optimization environment and compatible with the configured mathematical model despite the presence of LT-SN nodes with known locations in the network environment which are not performing sensing duties.

We can define the contribution of this paper to the literature as follows: (1) introducing the LT-SN concept to wireless sensor networks and developing a model compatible with this concept, (2) configuration of the same area in the most optimal way with the remaining nodes for observation by using two different algorithms and (3) analysing the performance of the suggested LP mathematical model related to the researched problem via the performed simulations.

The remain of this paper is organized as follows: The Section 2 gives a brief review of the literature review efforts on minimizing energy and maximizing the lifetime WSN. Section 3 gives system model, and LP formulations. Analysis based on LP models are given in Section 4. Section 5 gives the conclusion of the paper.

2. Literature review

In this section, we shortly summarize related research efforts on minimizing dissipation energy, and maximizing the lifetime of WSN, which involves looking at the mathematical LP formulation of the impact LT-SN on dissipation energy, and maximum lifetime. Recently, significant efforts have been made on reducing the energy consumed by node or to extend the lifetime of the network [7,8]. Bulut and Korpeoglu [7] proposed a novel model named dynamic sleep scheduling protocol (DSSP), for extending the lifetime by keeping only a necessary set of sensor nodes active. Singh and Bharti [8] proposed a sleep management protocol which support sleep or awake mode to conserve energy consumption. Jurdak and Ruzelli [9] proposed a node energy model which includes energy components for radio transmission, reception, listening, and sleeping mode. Despite the fact that some previous studies have investigated the impact of short-term sleeping node on network lifetime in wireless sensor network [10,11], the impact of LT-SN on the network lifetime has not been fully investigated. Wang et al [10] proposed a scheduling algorithm, namely, energy-consumption-based CKN, to prolong the network lifetime. Chachra and Marefat [11] proposed several distributed algorithms to perform sensor and radio sleep scheduling in WSNs. Saraswat et al. [12] proposed a scheme and the lifetime of the nodes based on overall energy consumption is estimated and studied the effect of duty cycle on expected energy consumption was studied. Pagar et al. [13] proposed radio power modes which dynamically change according to current traffic situation in the network. They addressed deep sleep mode pulled low current, but it caused more energy costs due to delays. Mahani et al. [14] studied the multi-mode structures from credibility viewpoint of the sleep modes. They showed sleep modes lead to long path length from source to sink and so decreased the message credibility. In this study, we tried to draw the attention of researchers especially to the observation and sensing requirement of the emptied areas caused by LT-SN nodes as well as the required extra energy. This study carries similarities with Cardei et al. [15] if considered regarding the coverage or protection, however differs completely with the LT-SN concept. This is because they aim to increase the energy efficiency by holding one part of the nodes in sleeping mode while sustaining the other part in a waked state. In our study however, the nodes entering sleeping modes do not wake up again, therefore they have no role in data production or data transmission. As time passes, the remaining nodes which have the objective of protecting the area are facing an increased data transmission load and are consuming more energy caused by the disappearance of the LT-SN nodes in some sense. Yuksel et al. [16] researched the most critical node in network environment by resolving the LP problem which maximizes lifetime parameter. Our present study is in parallel with the study of [16] both in terms of investigating the effects of network on general life when certain nodes are out-of-service and with regard to LP model. Pala et al. [17] investigated the excess energy due to nodes in partial sleeping mode, which are only able to transmit the sensed data to the center or which have no source or in-between node role at all. Our present study differs from in [17] study in three regards: (i) two different LP models which are more advanced, maximizing the lifetime and minimizing the power consumptions were used. (ii) the LT-SN in this present model are not used as a source or node in-between in any way. (iii) the present model is able to transmit data, produced by single as well as multiple sources, to the target.

3. Concept and model

Throughout this research paper, our main aim is to investigate the effects of LT-SN that are not served during the data transfer [18] on energy dissipation characteristics of sensor nodes. In this section, we clarify the assumptions, define our system model, and formulate the optimization problem. By using the developed model, we formulate minimizing consumed energy and maximizing lifetime in the network as an LP framework.

3.1. System model

Network topology is a G (W, A) diagram which is complete and directional. W is the set of all sensors including the base station. V is indicating the set of sensor nodes excluding base station (BS) V=W \ {1}.

A = {(x, y): x ∈ V, y ∈ W-x} is the cluster of all border points.

All messages that will be sent from node N_x to node N_y during network lifetime are referred as β_{xy}.

All system notations used in this study are presented in Table 1.

Table 1. Summary of notation

Variable	Description
A	Set of arcs
W	The set of nodes including the base station (BS)
V	The set of nodes excluding the BS
S_x	The data generated by node N_x
N	The number of nodes in a network environment
N_S	Number of source nodes
$N_{LT\text{-}SN}$	Number of long-term sleep nodes
V_A	Deployment area
N_{SRC}	Source node
U	Set of source nodes
ε	Transmitters efficiency
ρ	The energy consumed in the electronic circuit
α	Transmission path loss exponent
e_x	The battery power of each node in a network environment
β_{xy}^{z}	Data flow from node N_x to node N_y (z-source data stream)
E_{rx}	The amount of consumed energy for receiving data
E_{tx}	The amount of consumed energy whereas transmitting one bit of data form node N_x to node N_y
d_{xy}	The distance between two nodes
L	Network lifetime (s)

Throughout this study, we use the first order radio parameters given in [19].

$$E_{Tx,xy} = \rho + \varepsilon (d_{xy})^{\alpha} \quad (1)$$

$$E_{Rx} = \rho \quad (2)$$

$$d_{xy} = \sqrt{(x_2 - x_1)^2 + (y_2 - x_1)^2} \quad (3)$$

Eq. (1) and Eq. (2) illustrate the amount of energy for transmission (from node N_x to N_y) and reception of a bit, respectively.

Where ρ models the energy dissipation on electronic circuitry (ρ = 50 nJ), ε indicate the transmitter's efficiency (ε = 100 pJ), α represents the path loss exponent, and d_{xy} is the distance between N_x and N_y, based on Euclidean distance as shown in Eq. (3).

The Euclidean distance is calculated between each sensor node and BS.

In this study, the life of the network is considered as the duration between the time network starts operation and the time when the first node in the network consumes entire its energy and dies [20].

On the same network area 100 nodes, 50 nodes and 25 nodes network topologies were used.

The placement of the nodes in the network environment was different for each topology.

In each simulation, which carried out the node placement is kept constant.

The only thing that varies in each simulation was randomly selected source nodes.

3.2. LP framework

Equations of the LP optimization problem which are minimizing the battery energy of the sensor nodes are given in the Eq. (4)-Eq. (11) interval, while the equations of the LP optimization problem which are extending the lifetime are given in the Eq. (12)-Eq. (19) interval [21].

If the given model equations are solved with the optimization program, the data produced by the sources is sent to the collecting node via the most ideal way and lowest energy utilization possible, dependent on the obtained data transmission model. The multiple to single (convergecast) transmission mode was used during data transmission.

All nodes except the source node, collection node and LT-SN nodes are able to operate as a relay (in-between node).

In scenarios multiple sources are used (double, triple, quintet), each source is programmed in such a way that they can operate as a potential relay node for the other source nodes.

For example, three of 100 randomly distributed nodes with the purpose of observing a disc shaped area with a radius of R=100 m shall act as source nodes (N_{15}, N_{21} and N_{95}) and 5% (N_2, N_{13}, N_{33}, N_{59} and N_{66}) shall be LT-SN. The LP model accepts all nodes as in-between nodes except the LT-SN and the target and sends data produced in three separate to the target node in an energy minimizing fashion.

Each node that is producing data is able to act as a potential relay node for the other data producing nodes.

The objective function of optimization problem is to minimize the $\mathbf{e}_x$ parameters as given below:

Minimize e_x

Subject to the following constraints:

$$\beta_{xy} \geq 0 \ \forall (x, y) \in W \tag{4}$$

$$\beta_{xy} = 0, if\, N_x = N_y \text{ and } N_x = N_1 \ \forall (x, y, z) \in W \tag{5}$$

$$\beta_{xy} = 0, if\ N_y = N_{LT-SN} \ \forall y \in U_{LT-SN} \tag{6}$$

$$\beta_{xy} = 0, if\ N_x = N_{LT-SN} \ \forall x \in U_{LT-SN} \tag{7}$$

$$\sum_{y\in V} \beta_{xy} = \sum_{y\in V} \beta_{yx} + S_x \ \forall x \in U_{SRC} \tag{8}$$

$$S_x + \sum_{y\in V} \beta_{xy} = \sum_{y\in V} \beta_{yx} \ \forall x \in U_{DST} \tag{9}$$

$$\sum_{y\in V} \beta_{xy} = \sum_{y\in V} \beta_{yx} \ \forall x \in V,\ N_x \neq N_{SRC} \tag{10}$$

$$E_{Rx} \sum_{z\in U} \sum_{y\in V} \beta_{xy} + \sum_{z\in U} \sum_{y\in V} E_{Tx} * \beta_{yx} \leq e_x \ \forall\, x \in V \tag{11}$$

Seeing that the objective is to minimize the energy dissipation of nodes for this model, our first problem is the minimization of the maximum energy consumption in the network by finding the βxy that satisfier the constraints. The equations belonging to the recommended first LP framework may be explained briefly as follows:

Eq. (4) shows that all currents flowing in the network are positive.

Eq. (5) shows currents that should and should not be present within the network. For example, a node cannot send data to itself. Similarly, a base station cannot send data to a node.

Eq. (6) shows that none of the nodes within the network can send data to the LT-SN nodes.

Eq. (7) shows that none of the LT-SN nodes can send data to the nodes within the network.

Eq. (8) shows that the data sent by nodes to other nodes is equal to the data produced by that node and the data obtained by other nodes.

Eq. (9) shows that the sum of data produced by one node and the data obtained by other nodes is equal to the data sent to other nodes by that node.

Eq. (10) shows that each node can act as a node in-between, except the base station, LT-SN and node operating as a source. Eq. (11) shows that the sum of total energy consumed for receiving the total energy by each node and the sum of the total energy consumed for the sent data is not greater than its battery energy, except for base station and LT-SN. Our purpose with the second LP model is the maximization of the network lifetime (Eq. (12). Equations of this model are given in the Eq. (13)-Eq. (19) interval. While single, double, triple and quintet data sources were used simultaneously in the first LP model which is minimizing the consumed energy, single and triple sources were used in the second LP model which maximizes the lifetimes.

The objective function of optimization problem is to maximize the L parameters as given below:

Maximize L (12)

Subject to the following constraints:

$$\beta_{xy} \geq 0 \ \forall (x, y) \in W \tag{13}$$

$$\beta_{xy} = 0, if\ \ N_x = N_y \forall (x, y) \in W \tag{14}$$

$$\beta_{xy} = 0, if\ \ N_y = N_{LT-SN} \forall y \in U_{LT-SN} \tag{15}$$

$$\beta_{xy} = 0, if\ \ N_x = N_{LT-SN} \text{ and } N_x = N_1 \tag{16}$$

$$\sum_{y\in V} \beta_{xy} + S_x L = \sum_{y\in V} \beta_{yx} \ \ \forall x \in U_{SRC} \tag{17}$$

$$\sum_{y\in V} \beta_{xy} = \sum_{y\in V} \beta_{yx} \ \ \forall x \in V, N_x \neq N_{SRC} \tag{18}$$

$$E_{Rx} \sum_{y\in V} \beta_{xy} + \sum_{y\in V} E_{Tx} * \beta_{yx} \leq e_x \ \forall\, x \in V \tag{19}$$

4. Analysis

In the first scenario where the effects of the LT-SN on the general lifetime of the network are investigated by using two different LP models, the utilized energy is minimized in the best way possible by a linear program coded in a General Algebraic Modeling System (GAMS) optimization and modeling software environment [22] while in the second scenario, the lifetime of the nodes was tried to be maximized [23,24].

While single, double, triple and quintet sources were used in the first LP model, single and triple sources were used in the second LP model. Initially, a R=100 radius, disc shaped area was observed by 100 sensor nodes. In this scenario, the data was initially produced by a single source as 1024 bit. The data producing source changes on each operation. In this regard, the produced data are sent to the exact center of the disc area and the N_1 collecting node present at the coordinates (0,0) via the most ideal algorithm together with energy minimization through linear programming. In this scenario, the nodes are operating normally and no LT-SN node is present. The average of the lowest energy consumption values of 1000 operations were obtained in this scenario and are kept for the later obtainment of single source normalized reference values. This is because the scenario in which all nodes are operating is a normal scenario. As time progresses, the number of LT-SN increases and the results obtained in each run are divided with normal values in order to obtain the normalized values. The state of the consumed energy or obtained network lifetime durations will be evaluated in accordance to the values obtained under normal conditions.

The initial scenario of 100 nodes protecting and observing the disc area with one source is afterwards repeated with double sources, triple sources and quintet sources. In the quintet operation, the data produced by any five sources distributed randomly within the disc area, with the exception of the collecting node, is transmitted to the collecting node via the remaining nodes.

In the following scenarios, single source, double source, triple source and quintet source operations are carried out with 50 nodes in the R=100 m radius disc shaped area. The same procedure is carried out for 25 nodes in single source, double source, triple source and quintet source as well. Each run is repeated 1000 times and the obtained mean values are saved for normalization. Initially, the locations of the sensor nodes scattered in the area did not change at all. As the LT-SN decrease after some time, the distance between the remaining nodes increases naturally.

New analysis was carried out under the assumption that the LT-SN nodes within the wireless sensor network are emerging as time progresses and that their numbers increase by 1%, 4%, 6%, 8%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80% and 90%. In the case of increase; the number of the nodes (25, 50 and 100) as well as the number of sources was considered. Analysis that had been carried out as single source initially were performed with multiple sources afterwards in respective order. During these studies, the LT-SN nodes were not allowed to operate in source, target or in-between node mode in any way. Nodes other than these were allowed to produce data as single, double, triple or quintet source nodes and the data produced by the sources was transmitted to the central node via the remaining nodes, except the LT-SN nodes.

The first LP model used in the study was mathematically minimizing the energy consumption. After the solution of the first model with a program coded in the GAMS environment, Figure 1, Figure 2, Figure 3, Figure 4 and Figure 5 were obtained following the analysis.

The second LP model on the other hand was maximizing the lifetime. Figure 6 and Figure 7 was obtained via the solution of the second model.

In Figure 1, the consumed normalized energy values, in the case where single, double, triple and quintet sources are used for N=100, are given as a function of the percentage increase of the LT-SN nodes. The LT-SN nodes increase in 1%, 4%, 6%, 8%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80% and 90% steps. As it can be observed in the graph, as the number of sources that are simultaneously producing data increases, the consumed energy increases as well. As the number of LT-SN nodes increases for each scenario shown in the graph, the remaining nodes receive a higher data transmission load and therefore the consumed energy increases as well. While the lowest energy consumption was observed in the single source scenario, the highest energy consumption was observed in the quintet scenario. As shown in Table 2, in an area with 100 nodes present, a LT-SN node increase of 10% corresponds to 0.9%, 1.0%, 9.0% and 11.1% utilized and normalized energy values for single, double, triple and quintet sources, respectively. In the scenario where N=100 nodes were used, the utilized and normalized energy values for single, double, triple and quintet sources in the case where the LT-SN nodes reached 20% was 5.6%, 7.7%, 18.4% and 19.4%, respectively.

Table 2. Percentage consumed power in case of using single and dual source node

Increase of the percentage consumed energy (for N = 25)				
$N_{LT\text{-}SN}$ (%)	N_S=1	N_S=2	N_S=3	N_S=5
10	9.1%	11.0%	14.1%	25.2%
20	18.4%	21.8%	23.0%	29.3%
30	19.7%	24.8%	25.8%	56.0%
Increase of the percentage consumed energy (for N = 50)				
$N_{LT\text{-}SN}$ (%)	N_S=1	N_S=2	N_S=3	N_S=5
10	5.8%	12.0%	13.9%	15.3%
20	9.5%	13.0%	15.5%	21.4%
30	12.9%	14.7%	16.3%	29.9%
Increase of the percentage consumed energy (for N = 100)				
$N_{LT\text{-}SN}$ (%)	N_S=1	N_S=2	N_S=3	N_S=5
10	0.9%	1.0%	9.0%	11.1%
20	5.6%	7.7%	18.4%	19.4%
30	11.7%	12.2%	19.8%	19.9%

In Figure 2, the consumed normalized energy values, in the case where single, double, triple and quintet sources are used for N=50, are given as a function of the percentage increase of the LT-SN nodes. As the number of LT-SN nodes increases for each scenario shown in the graph, the remaining nodes receive a higher data transmission load and therefore the consumed energy increases as well. While the lowest energy consumption was observed in the single source scenario, the highest energy consumption was observed in the quintet scenario. As shown in Table 2, in an area with 50 nodes present, a LT-SN node increase of 10% corresponds to 5.8%, 12.0%, 13.9% and 15.3% utilized and normalized energy values for single, double, triple and quintet sources, respectively. If the N=100 and N=50 node scenarios are evaluated for a LT-SN node increase of 10%, it can be inferred that the latter consumes more energy. This is because it is more advantageous to protect the present area with 100 nodes instead of 50 nodes.

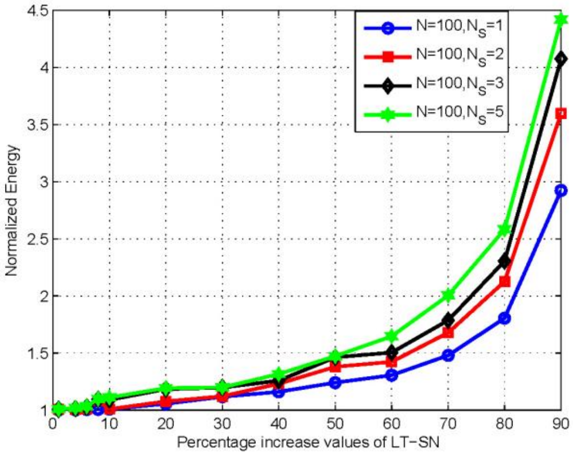

Figure 1. In the case where single, double, triple and quintet sources are used for N=100, the consumed normalized

energy value as a function of LT-SN nodes is.

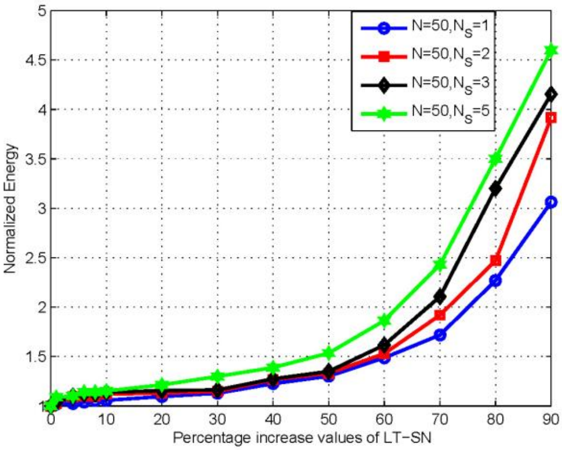

Figure 2. In the case where single, double, triple and quintet sources are used for N=50, the consumed normalized energy value as a function of LT-SN nodes is.

In Figure 3, the consumed normalized energy values, in the case where single, double, triple and quintet sources are used for N=25, are given as a function of the percentage increase of the LT-SN nodes. As the number of LT-SN nodes increases for each scenario shown in the graph, the remaining nodes receive a higher data transmission load and therefore the consumed energy increases as well. While the lowest energy consumption was observed in the single source scenario, the highest energy consumption was observed in the quintet scenario. As shown in Table 2, in an area with 25 nodes present, a LT-SN node increase of 10% corresponds to 9.1%, 11.0%, 14.1% and 25.2% utilized and normalized energy values for single, double, triple and quintet sources, respectively. If the N=50 and N=25 node scenarios are evaluated for a LT-SN node increase of 10%, it can be inferred that the latter consumes more energy. This is because it is more advantageous to protect the present area with 50 nodes instead of 25 nodes. The results obtained for the case where a single source was used for N=25, N=50 and N=100 nodes is graphically and collectively shown, in Figure 4. We can infer that all three curves are displaying a tendency for increase due to the increased number of LT-SN nodes. The energy consumption changes in relation with the number of nodes used in the network, as the number of nodes increases, the consumed energy decreases. While the highest energy consumption was observed in the N=25 node condition, the most ideal energy consumption was observed at N=100. The results obtained for the case where quintet sources were used for N=25, N=50 and N=100 nodes is graphically and collectively shown, in Figure 5. In the graph, we can observe that all three curves are displaying a tendency for increase due to the increased number of LT-SN nodes and that they display a higher increase than the single source. The energy consumption changes in relation with the number of nodes used in the network, as the number of nodes increases, the consumed energy decreases. While the highest energy consumption for quintet sources was observed in the N=25 node condition, the most ideal energy consumption for quintet sources was observed at N=100.

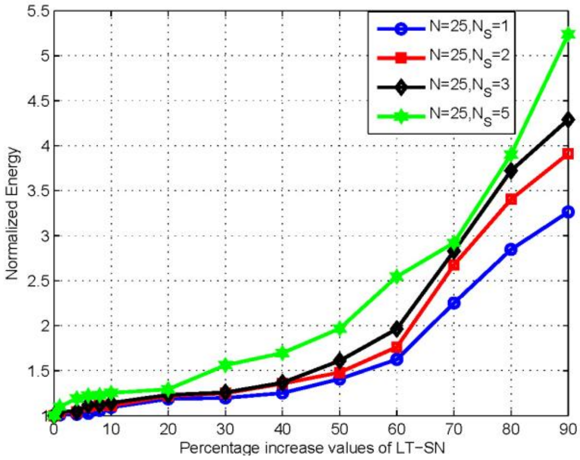

Figure 3. In the case where single, double, triple and quintet sources are used for N=25, the consumed normalized energy value as a function of LT-SN nodes is.

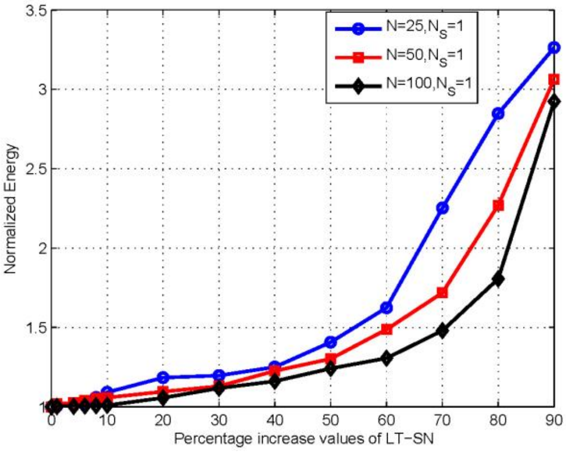

Figure 4. In the case where single sources are used for N=25, N=50 and N=100 the consumed normalized energy value as a function of LT-SN nodes is.

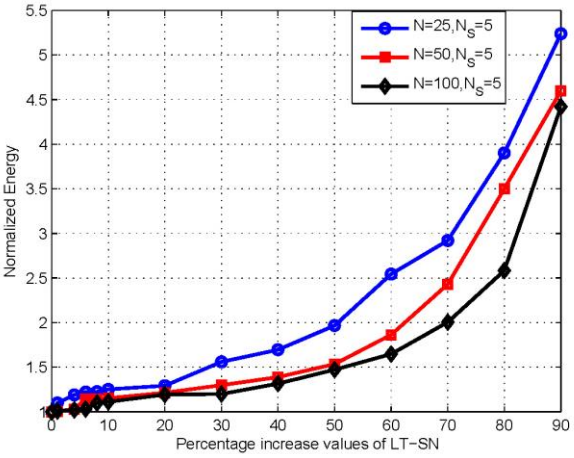

Figure 5. In the case where quintet sources are used for N=25, N=50 and N=100 the consumed normalized energy value as a function of LT-SN nodes is.

As it is shown in Figure 6, which was obtained via the solution of the second model, the normalized lifetime durations obtained for N=25, N=50 and N=100 nodes where a single source was used, are given as a function of the LT-SN nodes. While the highest lifetime durations are given with the curve where N=100 nodes were used, the lowest lifetime durations are given with the curve where N=25 nodes were used. The lifetime durations decreased due to the increased LT-SN nodes in all three curves. The lifetime durations decreased 13.0%, 4.0% and 1.9% for N=25, N=50 and N=100 nodes, respectively. As it is shown in Figure 7, which was obtained via the solution of the second model, the normalized lifetime durations obtained for N=25, N=50 and N=100 nodes where a triple source was used, are given as a function of the LT-SN nodes.

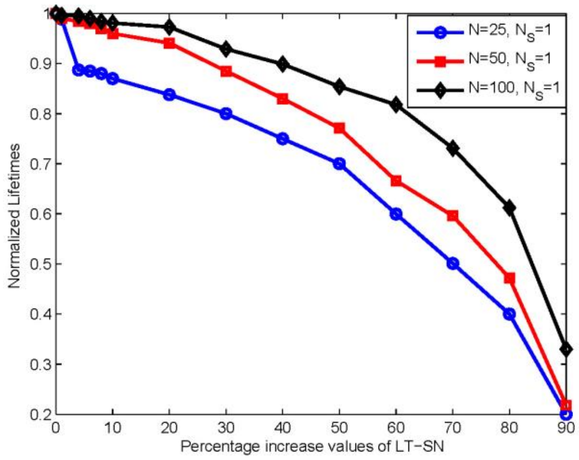

Figure 6. In the case where single sources are used for N=25, N=50 and N=100 the obtained normalized lifetime as a function of LT-SN nodes is.

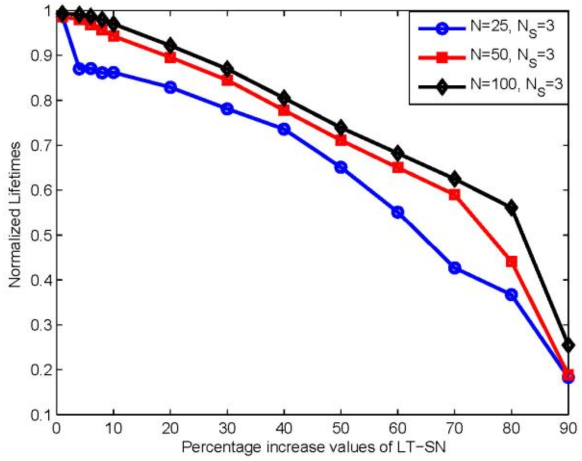

Figure 7. In the case where triple sources are used for N=25, N=50 and N=100 the obtained normalized lifetime as a function of LT-SN nodes is.

While the highest lifetime durations are given with the curve where N=100 nodes were used, the lowest lifetime durations are given with the curve where N=25 nodes were used. The lifetime in all three curves decreased due to the increased LT-SN nodes as well as the increasing number of sources. The lifetime durations for triple sources are 13.8%, 5.7% and 3.0% for N=25, N=50 and N=100 nodes, respectively.

5. Conclusion

In this study, we accepted the effects on the lifetime of the network and the consumed energy due to the energy spaces caused by LT-SN nodes, which are entering long term sleeping mode and are not waking up, thus are not participating in data transmission and are causing security issues, as a problem. We widely studied the effect of the LT-SN nodes on the network lifetime as well as the energy consumption. For this reason, we established two different linear programming models which minimize the energy consumption, extend the lifetime and carry out the most ideal data guidance.

The decreased number of the nodes placed randomly on the area was defined as LT-SN nodes in order to cover the present area in a complete manner with the remaining nodes after each run. Particularly the analysis results of our second LP model are similar with the results reported in [16]. Authors [16] found the effect of the most critical node as 2.0% in the topology where 100-sensor node was preferred by using discrete energy consumption model. In the present study, it was found that the network lifetime would fall down 1.9% when 10% nodes were out of service in case that same number of nodes, same topology and continuous energy model were used through LP.

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