



# A task-based model for minimizing energy consumption in WSNs

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## Abstract

Hardware viewed in current energy models, but no appropriate attention is given to the network environment and parameters. Components of the traditional design of the network are often viewed individually and separately in terms of power consumption. In this paper we, look at all possible sensor operations and generate a model for energy management in its integrated network. The work proposed divides these tasks into five energy consuming parts. The sensor's energy consumption is then modeled on its energy-consuming parts, parameters, and input operations. Thus, the energy consumption of the sensor can be decreased by effectively balancing and performing the chores of its constituents. The suggested strategy improves energy efficiency and can also be used as guide in setting wireless sensor networks (WSNs) parameters. Further more, It can help in designing an energy efficient WSNs. The serious energy limitations, however, pose special challenges for WSNs applications to establish and project scheduling which is usually has a strong influence on achieving energy efficiency and usage. This paper provides a framework for preparing the tasks, in which each node decides to do next according to the observed portion of the request. Within this Framework, we can exchange the application efficiency and the energy consumption provided by a weighted reward function and thus obtain better results in terms of energy/ performance. We can further improve this energy/performance trade off by exchanging data between neighboring nodes. The suggested approach analyzed in a target monitoring program. The simulation experiments show that cooperative approaches for this type of application are superior to non-cooperative approaches.

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## 1 Introduction

Applications like goal tracking, area control, or smart environments have been developed as an Attractive Platform for WSNs. Battery operated sensor nodes pose strong energy limitations where each sensor node has limited power supply, computation capacity and communication capability [1,2].

There are different activities to schedule on each sensor node in the standard WSN program. Nevertheless, the preparation of the different tasks usually has a significant impact on achievable energy consumption and efficiency. Under highly dynamic settings, the energized sensor nodes run. Therefore, there is a well-recognized need for adaptive and autonomous task planning in WSNs. Because tasks can not be scheduled a priori, it is important to schedule tasks both online and energy-aware [3,4].

The scheduler must take into consideration both the resource supply of the node and the energy demands and the impact of each available task on the performance of the request in order to determine its next task. The ultimate objective is to achieve a high quality in operation while maintaining low energy consumption.

The proposed strategy can be regarded as a sensor-centered strategy that takes into consideration the constituents of a sensor and the energy consumption tasks (duties) to perform its job in the WSNs and related application. The architecture therefore includes a modular framework but cross-cutting ideas. For the sensor resource, proposed model energy consumption is used to minimize overall energy use and to manage power. This paper demonstrates how a sensor controls the power consumption and extends the lifetime of the network [1]. We consider five components that utilize energy: individual, local, worldwide, environment, and sink. The individual sensor reflects all the sensor operations, which the sensor needs to survive and execute its sensing function, beginning with an individual sensor. The local component reflects all the sensor operations to create a connection with its neighbor [3].

All the sensor-operations required to develop feasible transport routes and to transmit information to the location (sink) are represented by the worldwide component. The sink component reflects all the sensor operations that the sink must execute. The final component, the environment, reflects the sensor's operations for the collection of environmental-friendly energy. Minimization of energy consumed by the elements includes identification, by selection of the element and by balancing the load and reduced energy utilization, of the workload of the sensors assigned to each element. The component power can generally be evaluated by monitoring each hardware resource for a component assignment and converting the resource utilization into power consumption using the resource energy model. No additional load or operating system inside the parts is required for this approach [3]. The component-based technique can of course be adapted to applications and even to configurations in hardware. Although past studies have suggested processes for developing network protocols or network layers for power efficiency, in the implementation, the total power consumption of a device is not optimized.

A sensor generally must manage and accomplish assigned duties while having sufficient energy. This is the foundation of our model, which includes all possible elements that consume energy. The battery's life depends on the way in which it distributes and exercises its functional tasks across its individual components, local, globally. To perform a task, a number of packets need to be swapped by the sensor. A packet flow ( $PF$ ) is a data and control packet sequence for the completion of a task. Sensors can handle their authority by assisting in setting task priorities with the assistance of internal energy consumption model. In addition, the designer can minimize energy consumption by assumption of optimum values to efficient parameters of network using an internal energy consumption model. In this paper, we focus on the internal energy consumption framework by shaping incoming activities so that a sensor can give priority to them, thus minimizing power consumption [5].

The main objective and scope of the paper as follows:

- Determine the impact of energy consumption components and their prevailing parameters on total energy consumption in WSNs.
- To obtain quantitative measurements and modeling on the basis of predominant criteria of total energy consumption.
- Propose a model applicable to all sensor applications in the network.
- Optimize total energy consumption through model optimization.
- The overall model will provide the best approach for reducing energy consumption through the incorporation of prevailing parameters

The rest of this paper is organized as follows. Section 2 discusses related work, and Sect. 3 describes proposed energy harvesting based on task and also explains our system generation model. In Sect. 4 presents criteria for the model and it explains the enhancement model. Section 5 discusses simulation setup and experimental results of enhancement model. Finally, the conclusion and future work are presented in Sects. 6 and 7 respectively.

## 2 Related work

### 2.1 Energy consumption

Network architectures are essentially functional models organized as layers where one layer offers services to the layer above. A network often evaluates the quality of its service parameters like time, power, accessibility, efficiency, and even safety. With respect to power consumption, however, the grid as a global model that takes energy consumption scarcely into account is often hard to evaluate and optimize. In general, the researchers concentrate on the traditional networking architecture and try to minimize a single-layer component in the hope that, regardless of other components or levels, the overall network EC will be reduced. It's not an ideal situation where the whole energy picture of a wireless sensor network cannot be seen as having one element. Most current models of energy minimization focus on the sending and receipt of the data [6,7]. The power usage model focused on the sending-receiving cost and reduced the maximum limit of the single-hop energy effectiveness [8,9]. This strategy

takes into account the node between source and destination to save energy. Other methods are evaluated using the power consumption model in wireless sensor networks [10].

The concept of a cross-cutting network for wireless networks was developed. The main concept in cross-layer design is to make the protocol stack's distinct layers of data shared more dependent [11,12]. It is asserted that by doing this, better results in wireless networking can be achieved, and the resulting protocols more suited than those in a purely layered approach to the use of wireless networks. Large cross-layering design examples include, for example, designing two or more layers together or passing parameters between layers over time. However, there are no criteria for the combination of which layers to reach the greatest overall EC result [13].

## 2.2 Energy harvesting

There are various technologies for energy extraction from the atmosphere like solar, thermal, cinematic and vibration energy, and power collection techniques can boost network life. The benefit of power collection schemes as the capacity to charge after depletion and track power usage, which may be needed to manage network algorithms, were described by Weddell et al. [14–16]. In applications which are anticipated to run for a long period of time, energy harvesting techniques play a significant role. Management of power harvests presents multiple difficulties. Kansal et al. [17] categorized power supplies into four categories of sources and their respective difficulties: uncontrolled/predictable, uncontrollable/unpredictable. They stressed that, because of the unpredictable power available in energy collection systems, energy management differs fundamentally from battery operated systems. It has been shown that the available energy differs in time and for various network nodes. This presents some node difficulty in taking decisions based on understanding of the network's residual energy. In addition, various nodes may have distinct harvesting possibilities. They suggested an analytical model for energy collection and efficiency to resolve these issues. In addition to this, Ref. [18] proposed that the energy and load of the node should be balanced. They explained the need for cooperation between power management applications where the source of harvest cannot maintain a load rate for nodes. Energy recovery for various wireless sensor applications is of important concern in order to enhance their sustainable lives, but a balanced need to ensure their efficiency and effectively use the available energy is required. The vast majority of wireless sensor research are based on the condition of the remaining battery, while estimating the available environmental energy at nodes remains an issue in harvesting schemes. Erickson et al. [19] suggested a method for energy management for environmental availability, but their method is based on a pre-visible resource of energy and cannot be used with an unforeseen resource.

Adu-Manu et al. [20] presented a full review of energy-harvesting WSNs for different environmental monitoring applications such as Air and Water Quality Monitoring. Most importantly, they addressed the challenges that must be considered to advance energy-harvesting-based WSNs.

Giannecchini et al. [21] proposed to assign dynamically the network resources between tasks of periodic WSN applications. The proposed approach called the Online Task Schematic Allocation (CoRAI). However, CoRAI doesn't mention energy consumption, or answer task mapping to sensor nodes.

Shah and Kumar [22] implemented a WSN task management program based on distributed independent reinforcement learning (DIRL). Despite of their claim about the efficiency of their approach, we think it has a complex structure compared to our simple and efficient approach. Furthermore, they did not take into account the neighborly cooperation or energy-performance compromise.

We believe that our approach is much more general and versatile, since we embrace WSN topologies, a more complex incentives feature to demonstrate the balance between energy consumption, efficiency, and community co-operation.

### 3 Proposed energy harvesting based on task

Present energy consumption models are defined for sensor network variables such as radio, information, and hop, but there are other important variables such as the number of packets that the node generates, handles, senses and transmits, and so on to be considered. Furthermore, wireless networks characteristics are somewhat different from wired device. The features of the wireless channel usually influence every OSI level. The regional handling of a layer directly affects the energy utilization of other layers in WSNs. Each level's individual optimization is designed to resolve the problem result in insufficient results. It has been asserted that using a traditional layered method, it is difficult to attain design objectives such as energy effectiveness.

The cross-layer strategy was therefore developed to improve system efficiency by jointly optimizing various layers of protocols. Changing one subsystem means modifications in other components as it all interconnects. Cross-layer designs are inexhaustible less flexible, interoperable and less durable without strong architectural rules. In addition, systems cannot be certain that it is difficult to predict the effect of modifications. Figure 1 demonstrates a fresh modular perspective with energy consuming companies. It proposes an approach that model the overall consumption of energy with regard to prevailing parameters and energy consumption. components. Energy consuming elements are considered based on their duties, as shown in Fig. 2. The individual element is defined as all vital and fundamental deployments or activities required for the sensor, i.e. to track situations in the environment, to operate the OS and to provide safety at operating system level. All communications with the direct vicinity of the node are established and maintained by the local organization.

Furthermore, the local entity may include monitoring, idle hearing, and collision. The component of the global project involves management of the entire network, the selection of an appropriate topology and energy-efficient routing strategy based on the application. Electricity waste due to congestions and packet errors could be included. The global topology control, package routing, packet loss and overhead protocol element are discussed as a function of energy utilization. The part of the sink involves the roles of WSN manage, control or load. The sink activities include directing, balancing, and minimizing the entire network's energy consumption, and

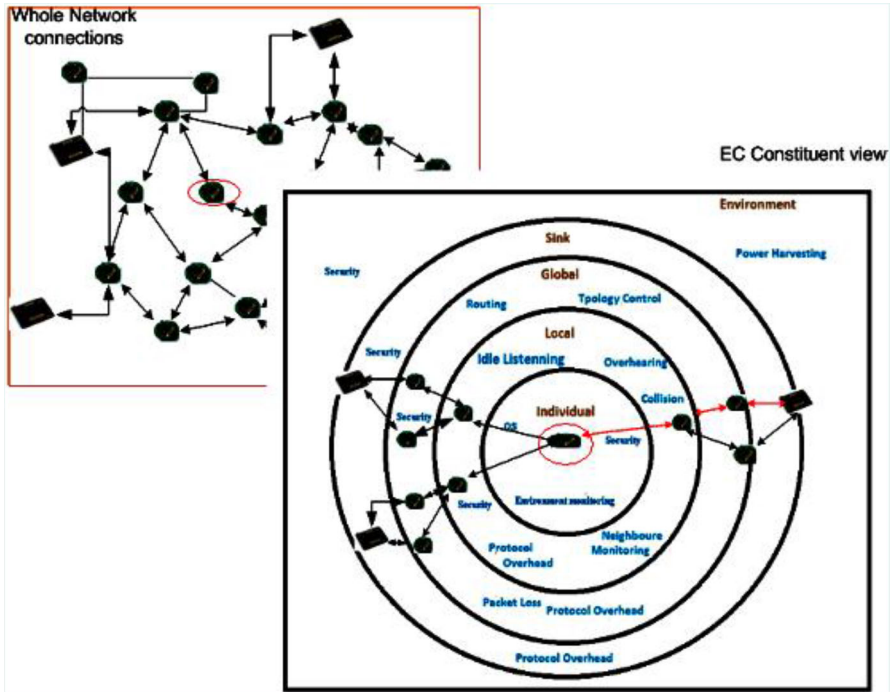


Fig. 1 Wireless network sensor-centered perspective

collecting produced information through the nodes of the network. Environmental functions are activities for energy harvesting, the nodes able to extract energy from the setting. Resources of Sensor, Central Processing Unit, radio, memory, and sensing units are required to perform these functions. The radius point of the sensor range ( $r$ ). Delay ( $g$ ), Number of packets ( $b_{sense}$ ), Stored memory number of pockets ( $b_{store}$ ), Operating System Instruction ( $b_{os}$ ) and individual level security ( $b_{sec}$ ) are taken into the simulation.

A relevant function can direct a sensor to perform tasks based on its residual energy and task significance. The equilibrium of the energy consumption of the components can also guide the sensor in its energy use minimization. Therefore, from the sensor point of perspective, the problem is that its energy consumption is efficiently selected and performed in significant ways. In addition, transferring tasks from high power consumption to low power consumption can minimize power use, i.e. data aggregation, which reduces global responsibilities and reduces individual responsibilities. In addition, a high energy consumption job can be divided into low-level activities for low-energy consumption elements. This enables sensors, based on a network energy consumption model, to intelligently manage job performance efficiently.

Usually, the energy is consumed in the Central Processing Unit (CPU), memory, radio or sensor units when a sensor performs a typical job:

$$e_t = e_{mem} + e_R + e_{cpu} + e_{sensor} \tag{1}$$

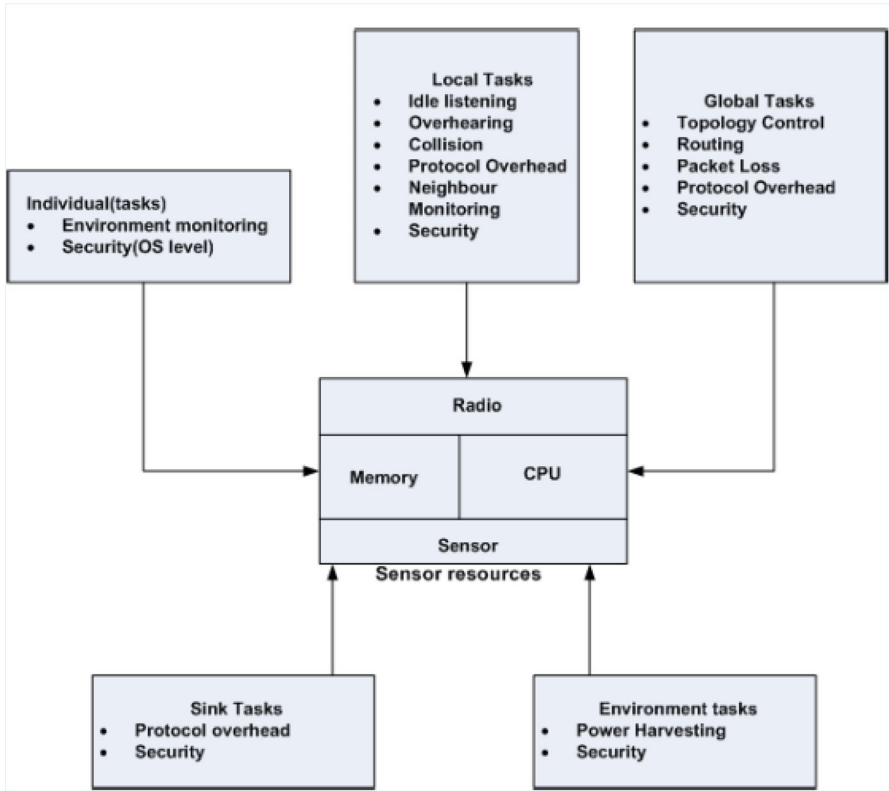


Fig. 2 System design for the tasks of the components

A sensor performs the fundamental activities for each assignment. We suppose that a sensor is a server for performing incoming functions. In order to model energy consumption, from hardware view, we use the suggested strategy:

$$\begin{aligned}
 e_{cpu} &= p_{cpu}b_{cpu} \\
 e_{mem} &= p_{mem}b_{mem} \\
 e_{Radio} &= e_{Tx} + e_{Rx} \\
 e_{Rx} &= P_{Rx}b_{Rx} \\
 e_{Tx} &= p_{Tx}b_{Tx} \\
 e_{sens} &= p_{ens}b_{sens}
 \end{aligned}
 \tag{2}$$

where  $b_{cpu}$ ,  $b_{mem}$ ,  $b_{Rx}$ ,  $b_{Tx}$ ,  $b_{sens}$  are the number of CPU packets that are saved in the memory, received, broadcast by radio, and sensed. Each function of a sensor is allocated to a component during its life. An additional power consumption of the individual, local, international, environmental and sink functions allows the general energy consumption of the typical device [23–25]:

**Table 1** Parameters in individual

Parameter	Description
$n$	Number of neighbors
$e_i (idle)$	Idle power consumption
$d_{ij}$	Distance to the neighbor
$b_{mon}$	Packet overhead for monitoring: depends on the application and its topology
$r_{Tx}$	Transmission radius
$b_{sec}$	Local security packet over head: depends on application
$b_{local}$	Packet overhead to avoid collision problem policy
$b_{reTx}$	Number of re-transmission packets: depends on probability of collision and number of neighbors

$$E_{overall} = E_{individual} + E_{local} + E_{Global} + E_{Environment} + E_{Sink} \tag{3}$$

Since several of tasks contribute to packet flow for each element, the energy consumption of a sensor is as follows:

$$\begin{aligned}
 E_{overall} = & \alpha_0 + \frac{\lambda_1 p_{cpu} + \lambda_2 p_{mem} + \lambda_3 p_{Rx} + \lambda_4 p_{Tx} + \lambda_5 p_{sens}}{\alpha_1} b_{Individual} \\
 & + \frac{\lambda_6 p_{cpu} + \lambda_7 p_{mem} + \lambda_8 p_{Rx} + \lambda_9 p_{Tx} + \lambda_{10} p_{sens}}{\alpha_2} b_{local} \\
 & + \frac{\lambda_{11} p_{cpu} + \lambda_{12} p_{mem} + \lambda_{13} p_{Rx} + \lambda_{14} p_{Tx} + \lambda_{15} p_{sens}}{\alpha_3} b_{global} \tag{4} \\
 & + \frac{\lambda_{16} p_{cpu} + \lambda_{17} p_{mem} + \lambda_{18} p_{Rx} + \lambda_{19} p_{Tx} + \lambda_{20} p_{sens}}{\alpha_4} b_{environment} \\
 & + \frac{\lambda_{21} p_{cpu} + \lambda_{22} p_{mem} + \lambda_{23} p_{Rx} + \lambda_{24} p_{Tx} + \lambda_{25} p_{sens}}{\alpha_5} b_{snk}
 \end{aligned}$$

or simplified as

$$E_{overall} = \alpha_0 + \alpha_1 b_{individual} + \alpha_2 b_{local} + \alpha_3 b_{Global} + \alpha_4 b_{Environment} + \alpha_5 b_{Sink} \tag{5}$$

We will clarify the prevailing parameters of the energy consumption sensor model of each element in the following segments.

● **Individual**

$b_{Individual}$  includes packet flow of the individual functions shown in Table 1, That is detection, OS execution, and application which installed, as well as individual



**Table 2** Parameters in local

Parameter	Description
$n$	Number of neighbors
$g_{Tx}$	Transmission interval
$net_{dens}$	Network density
$b_{ohear}$	Overhead packets
$a_i$	Number of sensors in covered area
$d_{iA}$	Distance between sensors and other sensors inside the covered area
$b_{topo}$	Packet overhead for topology
$N(t)$	Number of nodes in time t
$d_{iD}$	Distance between source and destination
$h_{iD}$	Number of hops
$b_{rout}$	Number of routing packets
$b_{global}$	Number of packets to avoid packet loss
$d_i$	Distance between node $i$ to nearest sink
$b_{pktls}$	Number of packet losses
$Snk$	Number of sinks
$b_{sec}$	Number of hops

**Table 3** Parameters of the environment

Parameter	Description
$H_i$	Harvested energy (Watt)
$b_{ph}$	Overhead produced due to harvesting power

sensor safety. The packet flow in each component is therefore as follows:

$$b_{individual} = b_{ens} + b_{os} + b_{sec} \tag{6}$$

The number of detected and produced packets relies on the detector region  $r_{sens}$  and detection delay  $g_{sens}$ ,

$$b_{sens} = P(Sense|r_{sens}, g_{sens})b_{individual} \tag{7}$$

from the above equations

$$b_{individual} = \frac{b_{os} + b_{sec}}{1 - P(Sense|r_{sens}, g_{sens})} \tag{8}$$

• **Local**

$b_{local}$  involves neighboring surveillance packet flow for the collection of information about accessible resources, for instance, their remaining power, space memory,

security management (to avoid malicious network connectivity and data tampering node malicious nodes), idle listening packs and re-transmission packets (Table 2). The packet flow of the local constituent can therefore be indicated as

$$b_{local} = b_{coll} + b_{idle} + b_{ohear} + b_{sec} + b_{mon} + b_{ohead} \quad (9)$$

where

$$\begin{aligned} b_{coll} &= p(coll|n, g_{Tx}, net_{dens})b_{local} \\ b_{ohear} &= p(ohear|n, net_{dens}, r_{Tx})b_{local} \\ b_{idle} &= p(idle|n)b_{local} \end{aligned} \quad (10)$$

### • Global

The global entity has several functions: routing, topology control, packet loss retransmission and packet loss prevention tasks.

$$b_{global} = b_{pktls} + b_{sec} + b_{topo} + b_{rout} + b_{ohead} \quad (11)$$

The packet loss depends on common network parameters like: node-destination distance, and  $net_{dens}$ , the number of network nodes (see Table 3):

$$b_{pktls} = b(pktls|D, net_{dens})b_{global} \quad (12)$$

$$b_{global} = \frac{b_{sec} + b_{topo} + b_{rout} + b_{ohead}}{1 - P(pktls|D, net_{dens})} \quad (13)$$

### • Environment

When the node is capable of harvesting environmental energy, the environment includes managing safety and energy recovery (see Table 4).

$$b_{environment} = b_{sec} + b_{ph} \quad (14)$$

### • Sink

$$b_{sink} = b_{sec} + b_{ohead} \quad (15)$$

The sink component provides safety for sink communication and provides sink instructions, if relevant for the application. We have defined up to now the component components and their relation to general energy consumption.

**Table 4** Parameters of the sink

Parameter	Description
$b_{ohead}$	Network management policy
$b_{sec}$	PF security in sink level

### 3.1 Model evaluation

The use of learning methods like linear regression to estimate model parameters enables for numerous observations of the observable quantities. Because of its closed-form calculations, we use linear regression to minimize the least square error between observations and predictions (i.e. L2-norm). The model is created in four steps: profiling, regression of the model, assessment criteria and model refinement. We have performed various experiments with loading sensors and have calculated energy consumption of the individual components with a packet flow set for their components. 4-10 minutes. Meanwhile, the network was identified as a general energy consumption. The values were collected in the  $\Delta t$ , periods and for several time frames each experiment was repeated, since the tasks in each component and thus energy consumption change in time. Repeating experiments and establishing a model based on different situations helps understand the component cost of responsibilities. A sensor can decide which activities are to be performed to be energy efficient. This model allows a sensor. Due to the change in the time, the overall energy consumed can be expected to differ slightly from several experiments, with the same packet flows for the constituents. The average of several experimental runs was therefore regarded to be the total energy consumption of the experiment.

### 3.2 Generation of model

This section describes how to map the connection between the prevailing parameters and the WSN's general energy use. The issue of linear regression modeling includes selecting appropriate modelling coefficients, so that the output of the model is closely related to the reaction of a true system. Consider the number of  $M$  tests for a WSN implementation with one degree of linear algebraic equations for 5 parameters.

$$\begin{bmatrix} E_1 \\ E_2 \\ \vdots \\ E_M \end{bmatrix} = \begin{bmatrix} 1 & b_{Ind}^{(1)} & b_{local}^{(1)} & b_{global}^{(1)} & b_{snk}^{(1)} & b_{env}^{(1)} \\ 1 & b_{Ind}^{(2)} & b_{local}^{(2)} & b_{global}^{(2)} & b_{snk}^{(2)} & b_{env}^{(2)} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & b_{Ind}^{(M)} & b_{local}^{(M)} & b_{global}^{(M)} & b_{snk}^{(M)} & b_{env}^{(M)} \end{bmatrix}$$

The above formulation converts the approximation problem to an assessment of the parameter values of model to optimize the cost from approximation to true energy consumption values. The request for a fresh invisible experiment is then anticipated to have approximate energy consumption ( $E$ ). The parameters of the model calculated mathematically by minimizing the lowest square mistake between approximate and

real value.

$$A = (B^T B)^{-1} B^T E \quad (16)$$

## 4 The criteria for evaluation

We assess the precision of the fitted model based on several measurements, produced by regression like Root Mean Squared Error, Mean Absolute Percentage Error Prediction precision as briefed in the following paragraphs.

Mean absolute percentage error

$$MAPE = \frac{\sum_{i=1}^M \frac{|E^{(i)} - \hat{E}^{(i)}|}{E^{(i)}}}{M} \quad (17)$$

$E^{(i)}$  yields the expected and  $M$  is observation number for that prediction in the dataset, if  $E^{(i)}$  is the real general consumption of energy in the network? Then a reduced value of MAPE means that the forecast model is better adapted.

Root mean squared error

$$RMSE = \sqrt{\frac{\sum_{i=1}^M (E^{(i)} - \hat{E}^{(i)})^2}{M}} \quad (18)$$

A lower RMSE shows that the forecast system is more efficient [26].

Accuracy of prediction

$$R^2 = 1 - \frac{\sum_{i=1}^M (E^{(i)} - \hat{E}^{(i)})^2}{\sum_{i=1}^M (\hat{E}^{(i)} - \sum_{i=1}^M \frac{E^{(r)}}{M})^2} \quad (19)$$

This measure is frequently used for linear models of regression. Actually, the accuracy of the  $R^2$  prediction determines how close the model matches the actual information points. The precision of a  $R^2$  prediction of 1.0 shows that the forecast model fits perfectly.

### 4.1 Enhancement of the model

The issue with the model, however, resides not necessarily in the linearity of the parts because they have no homogeneous packet flows. The packet flux ( $PF$ ) is a significant term for network protocol which directly influences the number of packets needed to perform the job. A sensor determines the  $PF$  of each assignment, based on the average number of packets sent or received during the first task implementation (both control and information packets). Moreover, each sensor has a distinct model because of functions of distinct components, such as sensors close sinks having more worldwide functions than sensors far away from sinks (Table 5).

**Table 5** Packet flow

Packet flow	Constituent
Packets having sensed data	Individual
Packet carrying information of current node and its neighbors	Local
Scheduling packets to avoid collision	Local
Packet carrying topology information	Global
Packets carrying routing information	Global
Received data packets	Global

## 5 Experiments and results

In this section will explain setup of the network that used to conduct the experiments. Also present values of all simulation parameters, then illustrate and discuss the obtained experimental results.

### 5.1 Network setup

We used 100 detectors to produce environmental information at random moments in a  $500 \times 500$ -pixel zone in our simulation. We have considered the sort of sensing application as the main concept not the sensory type, but the link between functions conducted by sensors and sensor networks and complete energy consumption. The sensors are generic information gathered through the setting. Sensing applications may also include temperature, contamination or other environmental factors. We considered the preceding power usage process, memory and radio unit parameters as continuous in the individual components of all sensors. The experiment length was also presumed to be 60 seconds continuous. Since the model is task oriented, 60 sec. of simulation time is sufficient to take into account every task performed by a sensor. The findings of our task-based model will not change longer simulation times. A sensor produces environment information. We take sensing costs as a constant and clearly boost and reduce complete energy consumptions in the sensing method due to the frequency of sensing, information quantity or sensing radius produced. The number of neighbors was changed in our application based on the variation in the rate of transmission. Depending on transmission radius and network density, the number of neighbors is different. Clearly, the largest average number of neighbors in the network is the maximum nodes are 200 and the maximum radius of transmission is 150 m. Table 6 summarizes all aforementioned simulation parameters assumptions.

Also in our experiments, the following general assumptions are used:

- Network environment with specified sensor number.
- The network setting was square.
- Sensors are distributed uniformly equally.
- Sensors are static.
- Sensors are aware of their locations.
- Initial sensor energy is defined.

**Table 6** Summary of simulation parameters assumptions

Number of nodes	100–200
Network size	500 × 500
Energy model	MicaZ
Battery model	Linear
Initial energy	1.2 J
Maximum transmission range	200 nodes
Transmission power	0 dbm
Routing protocol	0 AODV/Bellman
Simulation time	0 60 s

## 5.2 Experiments

To evaluate the energy consumption of components, we simulated a WSN request. The request gathers data on occurring occurrences. In its covered zone, sensors will detect an incident, generate a packet and send it to the closest sink. Sinks in a particular place are situated as a group. In general, in our WSN application simulator, we suppose three stages. During the initialization stage, sensors run their own software, connect them to neighboring nodes and collect data on the assets of the neighbor. The sensor then utilizes the information relay data of the neighbor during the collecting stage. It collects information, produces and sends data from the configuration, as well as processing and relaying incoming packets. They perform these tasks if they have sufficient power, or if they don't. During the maintenance stage, the sensor controls its vicinity to update their condition and performs additional worldwide duties, such as topology organization and routing tables, when needed. These stages can be repeated several times in the network life by a sensor. The results in Fig. 3 demonstrate how packet flow are allocated to the simulator components. Sensors are connected to all instant nodes in our implementation and these sensors select neighbors on the basis of its remaining energy. The sink has no application roles and sensors don't collect energy, so sink and environmental components in our modeling are ignored.

## 5.3 Results

The proposed model examined through simulation experiments, where different packet flow and energy consumption of each component at all stages inspected. The first stage comprises three times before a sensor begins to detect, monitor and transmit data packets.

The sensor uses (independently) energy to initiate, regulate and initialize packets of neighboring (local) connections. It also sends packets to set up global routing tables. In the second phase, the detector starts to record events and produces and sends information packets to the sink (individual tasks). Local operations in this phase involve surveillance of neighborhood resources by sending packets to neighbours. Furthermore, by inspecting your routing table and selecting the appropriate neighbor or route, the sensor will transfer income information packets to its place. The third

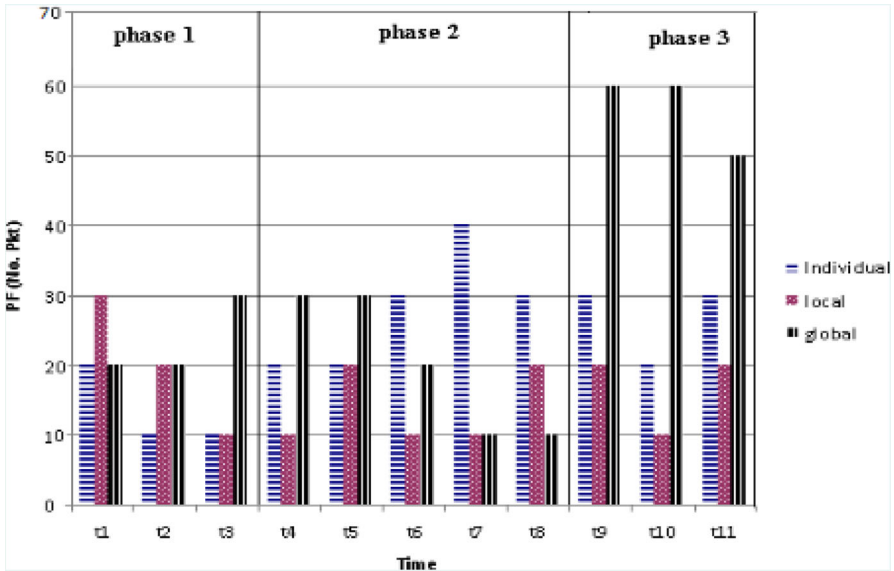


Fig. 3 Packet flow in different time interval

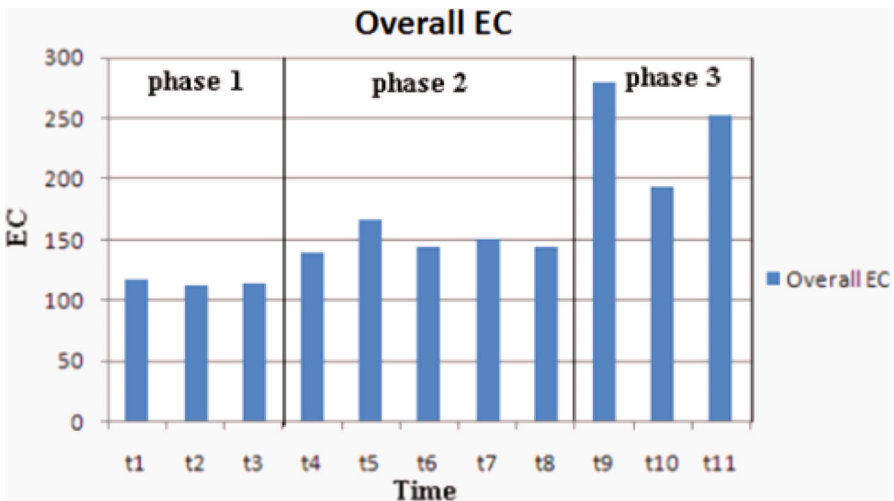


Fig. 4 Packet flow in different time interval

phase starts with the retrieval of a linked path. In relation to additional worldwide network maintenance duties, the sensor conducts functions in this stage during the second stage. These functions include the collection of path data and the updating of routing tables.

Figure 4 illustrates the packet flow and energy consumption of each of the typical sensor components at different stages of simulation experiments (initialization, collection of data and maintenance). The packet flow and energy usage (depending on present

sensor power) of components have been reported in each segment. As per the obtained results the general network energy consumption has grown dramatically during stage 3 of the worldwide component operations. As stated in stages 1 and 2, however, differences of duties in the individual and local components have no important effect on the general energy consumption level. The proposed research concluded that global (international) operations are therefore highly cost in terms of sensor lifetime, energy usage and there is an effect on the complete energy consumption of WSN.

## 6 Conclusion

We have suggested a generic model that includes multiple energy consumption elements and sensor elements in a wireless network. Although this model is independent of the fundamental architecture of the network, its contribution to a sensor's general energy consumption and its key components are identified. This capacity, combined with the interaction between sensors and the network, enables different approaches to be realized while respecting energy requirements of the individual sensors. The model can then be used by a sensor to prioritize the electrical component's duties in terms of energy and significance by employing a linear regression in model interactions between its detectors and the network total energy. The sensor can thus efficiently utilize energy and stay longer alive. The conclusion of this paper is that the global component has the largest effect on a WSN's general energy consumption.

Our findings of the precision problem in the extraction of common parameters call for further task in order to detect the non-linear correlation between parameters and the consumption of energy in worldwide components within WSNs using sophisticated statistical and machine training methods. Because of the large number of parameters, it is not a preferable choice for a parameter to plot the relation between energy consumption and then select an appropriate kernel to explain the relation. In addition to p-value, additional sophisticated assessment is needed to rank the parameters based on their statistical significance. It should be used to identify their common parameters by the same analytical instruments with other constituents. This provides a map of helpful parameters that affect the energy consumption throughout the WSNs scheme.

## 7 Future work

In future works will consider a real world motion model for the targets, also will implement data association as a task. Further more, will conduct a study to compare the proposed approach with other variants of reinforcement learning methods.

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## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.



## References

1. Akhtar, F., Rehmani, M.H.: Energy replenishment using renewable and traditional energy resources for sustainable wireless sensor networks: a review. *Renew. Sustain. Energy Rev.* **45**(C), 769–784 (2015)
2. Nayyar, A., Singh, R.: A Comprehensive review of simulation tools for wireless sensor networks (WSNs). *J. Wirel. Netw. Commun.* **5**(1), 19–47 (2015)
3. Ezhilarasi, M., Krishnaveni, V.: An evolutionary multipath energy-efficient routing protocol (EMEER) for network lifetime enhancement in wireless sensor networks. *Soft. Comput.* **23**(18), 8367–8377 (2019)
4. Sharma, N., Nayyar, A.: A comprehensive review of cluster based energy efficient routing protocols for wireless sensor networks. *Int. J. Appl. Innov. Eng. Manag. (IJAIEM)* **3**(1), 441–453 (2014)
5. Arafa, A., Ulukus, S.: Optimal policies for wireless networks with energy harvesting transmitters and receivers: effects of decoding costs. *IEEE J. Sel. Areas Commun.* **33**(12), 2611–2625 (2015)
6. Bergonzini, C., Brunelli, D., Benini, L.: Algorithms for harvested energy prediction in batteryless wireless sensor networks. In: 2009 3rd International Workshop on Advances in sensors and Interfaces, Trani, 2009, pp. 144–149
7. Davidson, J., Collins, M., Behrens, S.: Thermal energy harvesting between the air/water interface for powering wireless sensor nodes. In: Proceedings of SPIE—The International Society for Optical Engineering, pp. 728814 (2009)
8. Wang, Y., Saksena, M.: Scheduling fixed-priority tasks with preemption threshold. In: Proceedings Sixth International Conference on Real-Time Computing Systems and Applications. RTCSA'99 (Cat. No.PR00306), Hong Kong, China, pp. 328–335 (1999)
9. Lonare, S., Wahane, G.: A survey on energy efficient routing protocols in wireless sensor network. In: 2013 Fourth International Conference on Computing, Communications and Networking Technologies (ICCCNT), Tiruchengode, pp. 1–5 (2013)
10. Tripathi, A., adav, N., Dadhich, R.: Secure-SPIN with cluster for data centric wireless sensor networks. In: 2015 Fifth International Conference on Advanced Computing and Communication Technologies, Haryana, pp. 347–351 (2015)
11. Tahir, M., Javaid, N., Iqbal, A., Khan, Z., Alrajeh, N.: On adaptive energy-efficient transmission in WSNs. *Int. J. Distrib. Sens. Netw.* **9**(5), 923714–21 (2013)
12. Kim J., Chang, S., Kwon Y.: ODTPC: on-demand transmission power control for wireless sensor networks. In: 2008 International Conference on Information Networking, Busan, pp. 1–5. (2008)
13. Nagarajan, M., Karthikeyan, S.: A new approach to increase the life time and efficiency of wireless sensor network. In: International Conference on Pattern Recognition, Informatics and Medical Engineering (PRIME-2012), Salem, Tamilnadu, pp. 231–235 (2012)
14. Wen, Y., Zhu, X., Rodrigues, J.J.P.C., Chen, C.W.: Cloud mobile media: reflections and outlook. *IEEE Trans. Multimed.* **16**(4), 885–902 (2014)
15. Gao, Y., Guan, H., Qi, Z., Wang, B., Liu, L.: Quality of service aware power management for virtualized data centers. *J. Syst. Architect.* **59**(4–5), 245–259 (2013)
16. More, A., Raisinghani, V.: A survey on energy efficient coverage protocols in wireless sensor networks. *J. King Saud Univ. Comput. Inf. Sci.* **29**(4), 428–448 (2017)
17. Snow, S., Buys, L., Roe, P., Brereton, M.: Curiosity to cupboard: self reported disengagement with energy use feedback over time. In: Proceedings of the 25th Australian Computer–Human Interaction Conference: Augmentation, Application, Innovation, Collaboration (OzCHI '13), ACM, New York, NY, USA, pp. 245–254 (2013)
18. Nagarajan, M., Karthik, S.: Various node deployment strategies in wireless sensor network. *Int. J. Comput. Sci. (IJCS)* **5**(8), 38–44 (2017)
19. Erickson, T., Li, M., Kim, Y., Deshpande, A., Sahu, S., Chao, T., Sukaviriya, P., Naphade, M.: The Dubuque electricity portal: evaluation of a city-scale residential electricity consumption feedback system. In: Conference on Human Factors in Computing Systems - Proceedings. pp. 1203–1212 (2013)
20. Adu-Manu, K., Adam, N., Tapparello, C., Wendi, H.A.: Energy-harvesting wireless sensor networks (EH-WSNs): a review. *ACM Trans. Sens. Netw.* **14**, 1–50 (2018)
21. Giannecchini, S., Caccamo, M., Shih, Chi-Sheng: Collaborative resource allocation in wireless sensor networks. In: Proceedings. 16th Euromicro Conference on Real-Time Systems, ECRTS 2004, pp. 35–44 (2004)
22. Shah, K., Kumar, M.: Distributed independent reinforcement learning (DIRL) approach to resource management in wireless sensor networks. *IEEE Int. Conf. Mobile Adhoc Sens. Syst.* **2007**, 1–9 (2007)

23. York, D., Neubauer, M., Nowak, S., Molina, M.: Expanding the energy efficiency pie: serving more customers saving more energy through high program participation. *American Council for an Energy-Efficient Economy* (2015)
24. Sholiyi, A., Alzubi, J.A., Alzubi, O.A., Almomani, O., O'Farrell, T.: Near capacity irregular turbo code. *Indian J. Sci. Technol.* **8**(23), 1–10 (2016)
25. Alzubi, O.A.: An empirical study of irregular AG block turbo codes over fading channels. *Res. J. Appl. Sci. Eng. Technol.* **11**(12), 1329–1335 (2015)
26. Al-Najdawi, N., Tedmori, S., Alzubi, O., Dorgham, O., Alzubi, J.: A frequency based hierarchical fast search block matching algorithm for fast video communication. *Int. J. Adv. Comput. Sci. Appl.* **7**(4), 447–455 (2016)

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