A Novel Energy-Driven Architecture for Wireless Sensor Networks

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Abstract. This paper proposes a novel Energy-Driven Architecture (EDA) as a durable architecture and considers almost all principal energy constituents of wireless sensor networks applications. By creating a single overall model, a tolerable formulation is then offered to communicate the total energy use of a wireless sensor network application regarding the energy constituents. The formulation provides a tangible illustration for analyzing the performance of a wireless sensor network application, optimizing its constituent's operations, as well as creating more energy saving applications. The simulations are employed to show the feasibility of our model and also energy formulation.

1. Introduction

Energy consumption is probably one of the most basic and vital aspects concerning the deployment of sensors and wireless sensor networks (WSNs) as a consequence of numerous limitations , like the size of sensors, the unavailability of a power source, and inaccessibility of the location , which avoids additional managing of sensor devices when they are deployed. Endeavours have been created to reduce the energy consumption of wireless sensor networks and extend their helpful lifespan utilizing numerous methods at distinct stages [1-2]. Certain methods aim to reduce the energy consumption of the sensor itself at its operating stage [2-4], certain aim to reduce the energy invested in the input/output operations at the data transmission stage, while others target the formulation of sensor networks regarding their topology and relevant routing mechanisms [5-7]. The widespread aim this is to decrease the energy consumption of a few aspects of the application as often as possible by reducing the tasks which have to be performed by the sensors and the connected networks, but still accomplish the aim of the application [8-9]. Along with the minimisation effort, some methods have attempted to refill the energy capacity of the sensors by building into them parts and mechanisms for harvesting additional energy from available energy sources within their environments, for example solar, thermal, or wind power sources [10-12].

2. Principal Energy Constituents of WSN Applications

2.1. *Individual Constituent*

The overall energy consumption in individual constituents is expressed as follows:
$Eindividual$, k $(\Delta t) = \sum_{p=1}^{Mp} \sum_{q\in Q} \sum_{r\in R} \mathrm{I(ep, q, ep, r, tp, q)}$; where $\sum_{r\in R} \mathrm{ep, r} < \sum_{q\in Q} \mathrm{ep, q}$
where $e_{p,q}$ is the duration of the activity in each state. Since most energy minimisation methodologies use idle and sleep states to avoid wasting energy in idle states, the above constraint states that the total energy consumed for switching among states $e_{p,r}$ should be smaller than the total energy consumption of states $e_{p,q}$.

2.2. *Local Constituent*

The following equation shows the local energy consumption of a node in interval time Δt:
$Elocal$,k $(\Delta t) = \sum_{\mathrm{l\in neighbouri}} \mathrm{Z\{ekl\ [(mon), (sec), (idle), (local), (coll), (ohear)]\}}$
$subject\ to$: $neighbour$k≥1; ekl $local \leq e$kl ($idle$ +$coll$ +o$hear$)
The first constraint shows that the node has to have at least one neighbour to be able to relay data and survive in the network. The second constraint is the condition of having optimum energy consumption.

2.3. *Global Constituent*

The global constituent is defined as a function of energy consumption for topology management, packet routing, packet loss, and protocol overheads.
$Eglobal$,k (Δt) = Y [ek {$topo$, $rout$,$global$,$pktls$}]
$subject\ to$: ek ($rout$) ≥0; ek $rout$ > [ek {$topo$, „s}]
The first constraint shows that there is at least a path from node k to destination within the network so that it participates in the global communication. The next constraint shows that the energy consumed for control packets and the retransmitted packet should be smaller than the routed data packets from an effective energy consumption point of view, otherwise this constituent wastes the node's energy.

2.4. *Environment Constituent*

The environment constituent as a positive energy component can be formulated as follows:
$E_{battery,}$k $(\Delta t) = -$Xk(t); where Xk(t) is the amount of harvested energy at time t by node k.

2.5. *Sink Constituent*

Energy consumption of nodes from a sink constituent viewpoint can be formulated as:

$E_{qmv,\,k}\,\Delta t = V(e_k(qmV))$; where $ek(qmv)$ shows energy consumed by each node to communicate with the sink and perform the sink"s commands, as Ek (qmv) =E14 (osnk):-
The above equation means that the energy consumption of node k for a sink constituent depends on the number of received bits from the sink.

3. Simulation Results

This section describes a range of simulated experiments conducted to evaluate the residual energy in the network with respect to different constituents of the EDA. Because events in the network occur at millisecond intervals and the initial power of the sensors is limited, the network is usually one to two minutes. Therefore the residual energy of the wireless sensor application was evaluated within an interval of sixty seconds. In particular, we focused on the individual, the local, and the global constituents. To gain a better understanding of the energy consumption of these constituents and their main parameters, the focus at this stage was on several parameters that are believed to play significant roles in the overall energy consumption. For the individual constituent, the sensor's sensing radius was selected as it determines the coverage of the sensor field. For the local constituent, we selected the transmission radius of a sensor, as it concerns the number of neighbours. For the global constituent, the routing scheme was chosen as it affects data transport from sensors to sinks. We investigated the influence of these constituents by measuring the residual energy and energy consumption of the network. Sensor sensing radius, sensor transmission radius, and routing scheme were considered as variables in our simulated experiments, while all other parameters were fixed; then the variations in residual energy were compared for the different constituents' parameters to obtain the best result for an energy consuming component of a constituent.

In our simulation, 100 sensors were deployed in a 500*500 pixel area (Figure 2) that generates data from environmental events at random times and places in the area. In response to the type of sensing applications, we addressed generic data collected from environment as the central idea is not about the type of sensing but the relationship between the tasks to be performed by sensors and sensor networks and the total energy consumption. Sensing applications could measure environmental temperature, pollution, or other parameters. We considered the prevalent parameters of energy consumption of process, memory and radio units as constant in the individual constituent of all sensors. Also the duration of the experiments was set to 60 seconds. As the model is task-oriented, 60 seconds of simulation time is adequate to account for all the tasks that a sensor can perform. Longer simulation times will not to alter the results of our task based model. A sensor generates data from the environment.

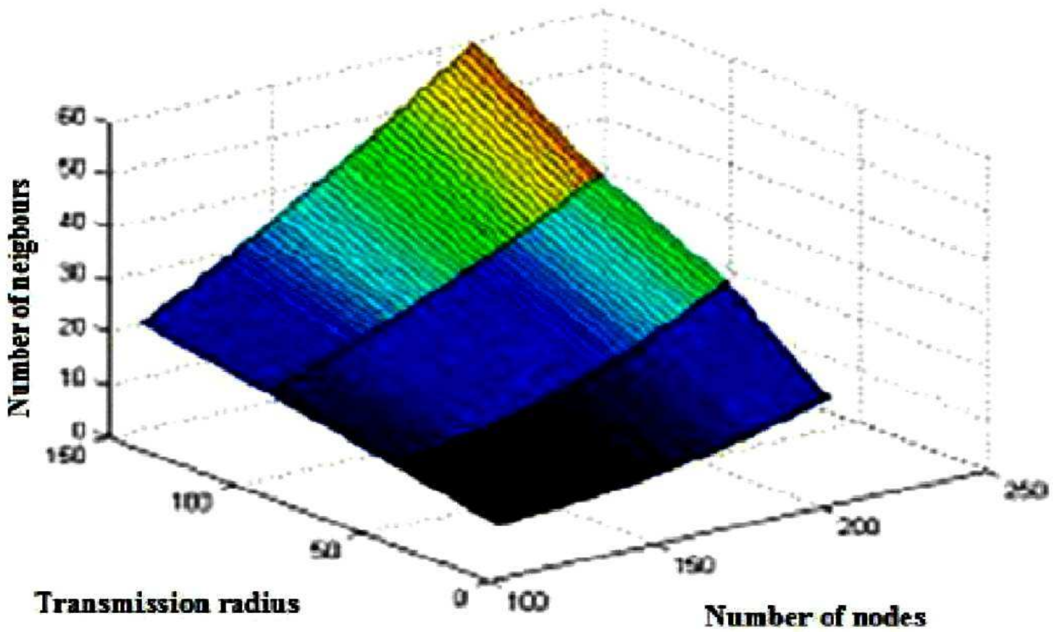

Figure 1. The average number of neighbours for the diverse transmission radius and the network size

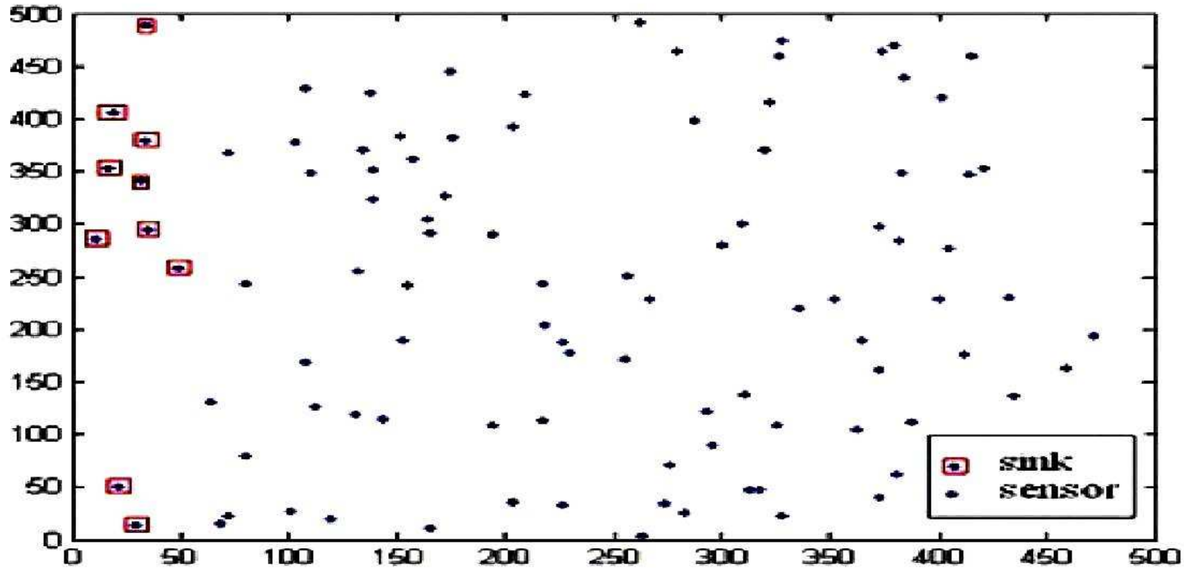

Figure 2. Randomly deployed sensors and sinks in Application

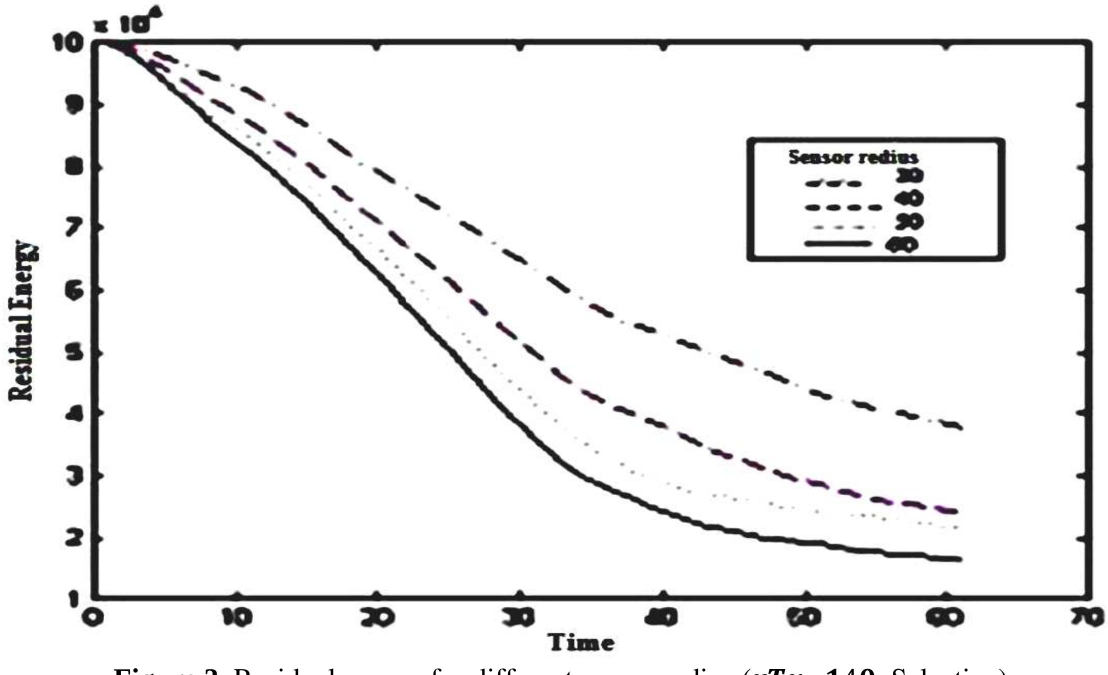

Figure 3. Residual energy for different sensor radius (rTx=140, Selective)

We consider cost of sensing as a constant and it is clear that the frequency of sensing, the amount of generated data or sensing radius will increase or decrease the total energy consumption for the sensing process. Relationships between the overall energy consumption and relevant tasks remain the same, except scaling factors.

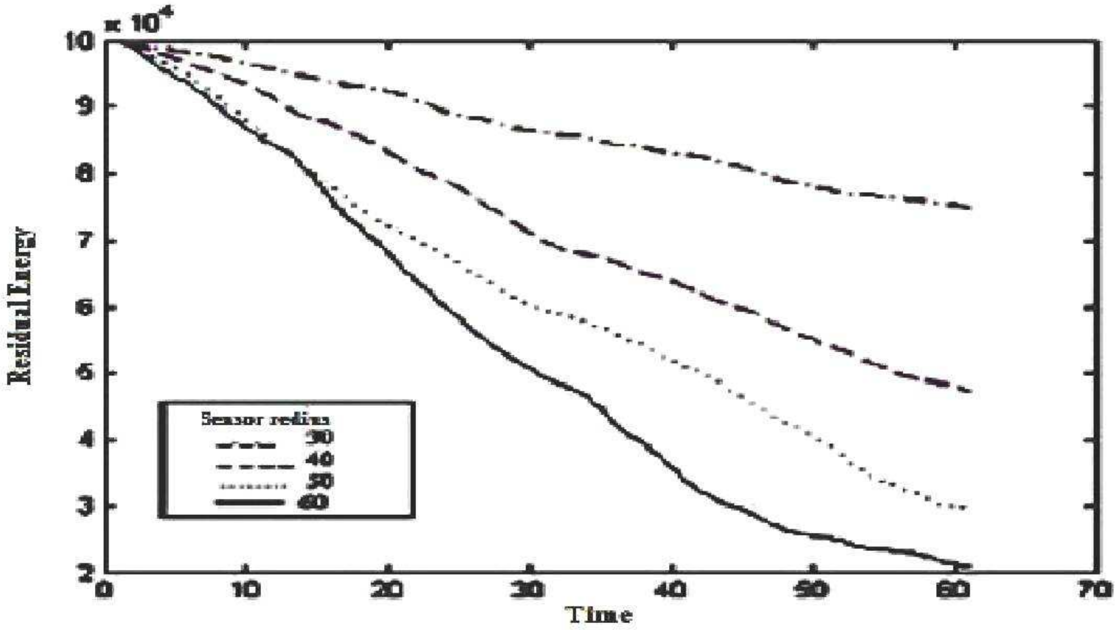

Figure 4. Residual energy for different sensor radius (r_{Tx}=**140**, Random)

For our experiments, sensor radius was considered as a prevalent parameter of the sensor unit; other parameters of the individual constituent such as the sensing rate and the costs for different states of various units were kept constant for selective study. The influence of different sensor radius was measured on the overall residual energy of the network. Also, the considered variation of sensor radius parameter was the same for all sensors in the network.

For the local constituent parameters, the number of energy-consuming bits required to maintain an individual sensor's local environment and network density was kept constant for the duration of the experiments, but sensor transmission radius was varied. Neighbour selection usually is application-dependent, and a node placed in the area covered by another node may be chosen as a neighbour of that node. In our application, the number of neighbours was changed based on the variation in transmission rate. Figure 3 shows how the number of neighbours varies according to the transmission radius and network density. Clearly, the maximum number of nodes (200) with the maximum value for transmission radius (150) results in the highest average number of neighbours in the network. In addition, to be realistic, the cost of distance was considered in transporting packets through to the network. For the global constituent, we considered the routing method as the variable of interest. As topology and routing are costly and consume a significant amount of energy of the global constituent, they play the main roles in determining the residual energy of the network. Increasing the transmission radius increases the number of possible connections of each node and decreases the number of hops from nodes to their sinks. Nodes can establish connections with all nodes located in the area reached by the node's transmission radius, and the type of connection among nodes is determined based on the geographic positions of nodes and sinks.

4. Conclusion

In this paper, we proposed a generic model incorporating various energy consumption constituents and components of sensors in a wireless network. In this model, while being independent from the underlying network architecture, helps identify essential energy consumption constituents and their contributions to the overall energy consumption of a sensor. Such capability, coupled with the interplay of the sensors with the network, facilitates the realisation of various strategies while fulfilling the individual sensors' constraints in terms of energy. Employing linear regression to model relationships between sensors' functionalities and the overall energy of the network, the model can then be utilised by the sensor to prioritise the constituents‟ tasks in term of energy level and importance in order to make an appropriate decision. As a result, the sensor can use the power in an effective way and remain alive longer. In this paper, it was concluded that the global constituent has the highest impact on the overall energy consumption of a WSN.

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