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MINIMIZE ENERGY CONSUMPTION AND MAXIMIZE PATH RELIABILTY IN WIRELESS SENSOR NETWORK USING MULTIOBJECTIVE GENETIC ALGORITHM

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Abstract

Wireless Sensor Networks (WSN's) is prominent and advanced technology in present day which allows assembling the embedded systems in small size. It contains of self- governing battery powered devices known as nodes which act as a transducer. The nodes are intelligent enough to sense, assess and transmit the data. As the nodes are battery powered equipment, so the crucial task of the sensor network is to regulate the use of energy. Several aspects which cause an energy deficiency in the network, hence the reliability of the sensors and their associated paths degraded. The transmission path should be such which drains minimal energy along with successful dispatching of data. The paper focuses on this perspective and proposes a nature inspired approach Genetic Algorithm of Multi-Objective to find a route using energy utilization and reliability as the cost functions or fitness functions as two different objectives for addressing data to the destination in order to diminish the energy consumption and ensure path reliability and the network lifetime. The simulation results carried out on MATLAB and conclude that the proposed technique consumes minimum energy with high path reliability.

Keywords: EHSN,BPSN,WSN and end-to-end path reliability.

1. INTRODUCTION

Wireless sensor networks (WSNs) are built with sensor nodes to monitor and control physical or environmental conditions. WSNs must not restrict to energy consumption, reliability, scalability, cost, and topology and operating environment [1, 2].

Wireless links can be highly unreliable in actual complex environments [3, 4]. When a source sensor node is not within transmission range of the sink node, subsequently other sensor nodes within the WSN must act as relay nodes and deliver sensed data from the source node to the sink node through one or multiple hop paths. Hence, to achieve reliable wireless communications within WSNs, it is important to have a reliable routing protocol. Comprehensive research has been carried to minimize energy consumption within WSNs or to maximize lifetime of battery powered sensor nodes (BPSNs) [5]. But, with BPSNs it is difficult or even impossible to optimize all performance parameters at the same time.

The simulation will be carried out in MATLAB and the results of the proposed technique are evaluated. Further, the paper is differentiated as follows: section 2 describes the concepts of Wireless Sensor Network. Section 3 presents the problem formulation by evaluating reliability and energy; section 4 gives detailed information of the proposed technique. Section 5 discusses the simulation results followed by a conclusion.

2. CONCEPTS OF WIRELESS SENSOR NETWORK

Fundamentally, sensor nodes contain 4 units and these are, refer Figure 1. Sensing unit additionally has two subunits i.e. sensors and analog to digital converters. Processing unit comprises microprocessor which controls the sensors and carries execution of communication protocols along with the signal processing algorithms on the gathered sensor data. Transceiver unit is responsible for generating a communication wirelessly with neighboring nodes and the outside world. Power unit consists of a battery that provides power to the whole sensor network.

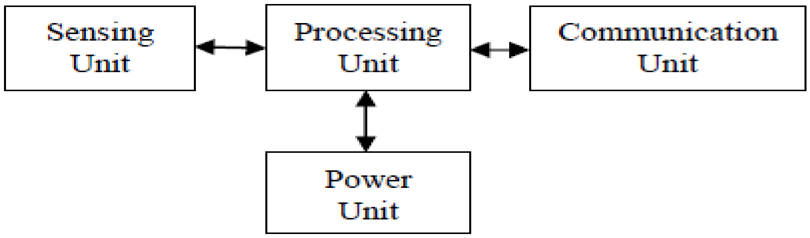


Figure 1 Block diagram of the Architecture of Sensor Node in WSN

One approach to maximize the network lifetime is through an energy-efficient reliable routing algorithm for data communications within WSNs, which can offer the best combination of total energy utilization, communication reliability and cost. As a result, a cost function (CF)-dependent routing protocol is required to deem all these significant factors. In [6], a CF-dependent energy-aware routing algorithm was propounded to deem end-to-end energy consumption and rest of the energy of nodes to balance energy utilization among nodes. In this paper, a new approach is presenting a more extensively a method to minimize cost function-dependent routing approach, which integrates end-to-end path reliability and residual energy (RE) in BPSNs Another contribution made in this paper is the significance of reliability - analysis-based method for finding optimal locations of BPSN with the aim of maximizing the average end-to-end path reliability. Several node selection protocols have been suggested for WSNs [7]. In this paper, an effective location selection protocol based on energy and reliability combined together as significant analysis is proposed for determining the optimal locations of BPSN, maximizing the average end-to-end path reliability with minimizing energy consumption.

3. RELIABILITY ANALYSIS

3.1 Sensor Nodes

Figure 3 depicts the main constituents of a BPSN. Depending on the flow of energy as depicted in Figure 3, reliability of BPSN under two different conditions (relay and full function) can be, respectively, calculated as

$$R_{relay}(t) = R_{EF}(t) \times R_{ra}(t) \times R_{mc}(t). \quad (1)$$

$$R_{fullfunction}(t) = R_{EF}(t) \times R_{ms}(t) \times R_{ra}(t) \times R_{mc}(t). \quad (2)$$

In equations (1) and (2), $R_{ra}(t)$, $R_{mc}(t)$ and $R_{ms}(t)$ show the reliability of radio components (ra), microcontroller (mc) and micro-electromechanical systems (MEMS) sensor (ms), correspondingly. REF (t) shows reliability of the energy flow (EF).

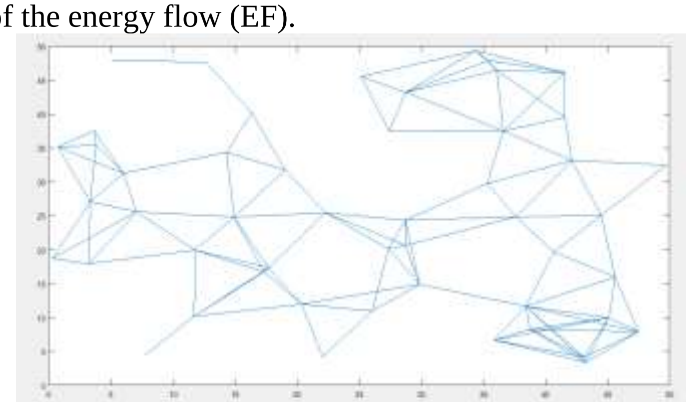


Figure 2 Connectivity of sensor nodes of uniformly distributed with 50 nodes

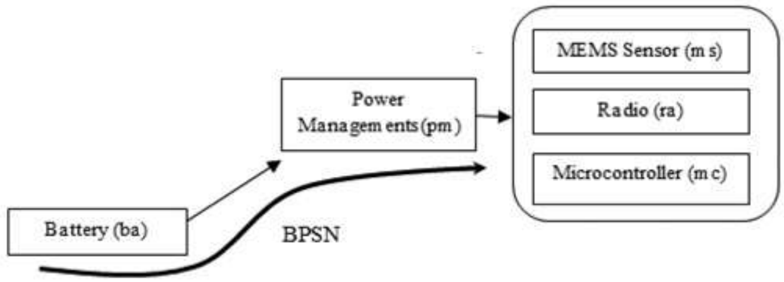


Figure 3 Energy flow in BPSN

For BPSNs, REF(t) = Rba(t) × Rpm(t), which involves reliability of battery (ba) and power management (pm) units.

3.2 Wireless link reliability

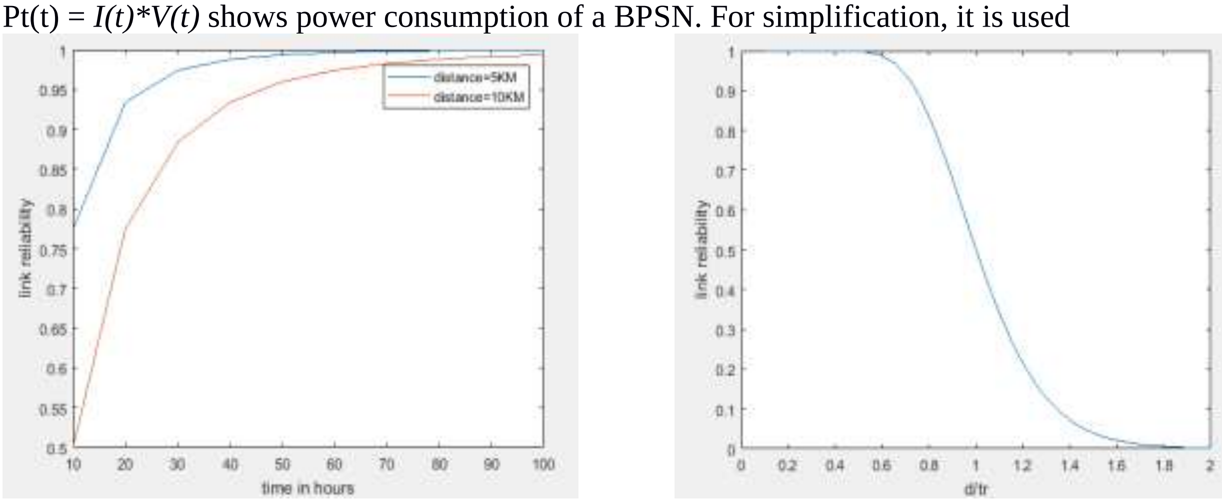
In WSNs, link failures can be produced by factors such as radio fading or interference, signal attenuation and background noise. Depending on details in [30], the probability of having a reliable link for BPSN can be stated as a function of distance between the transmitter and the receiver *d* as

$$p_{\mathrm{Link}}(P_r(d) > P_{\min}) = \frac{1}{2}\left[1 - \operatorname{erf}\left(\frac{10\log(d/\mathrm{tr})}{\sqrt{2}\log(10)\psi}\right)\right], \quad \psi = \frac{\sigma}{\eta}; \quad \text{if } \frac{d}{\mathrm{tr}} \le 1, \tag{3}$$

where *Pr(d)* is the received power, *Pmin* is the minimum power needed compare to the ratio of signal power to the noise power in the receiver, σ is standard deviation of shadowing, η is path loss exponent, and ψ= σ/η which can alter in the range from 0 (no shadowing effect) to 6 (strong shadowing effect). From equation (3), the probability that a link prevails between two sensors nodes having distance greater than t_r (i.e. $d/t_r > 1$) is just zero. Figure 3 depicts the relationship between the link reliability and the ratio d/t_r. In BPSNs, the link reliability can be identically calculated utilizing equation (3) except that the constant t_r is replaced using a time-dependent model [4] to find the maximum transmission range of a BPSN, denoted by $t_{rmax}(t)$. Equation (4) gives the formula of evaluating $t_{rmax}(t)$ using the Friis formula [8]

$$\mathrm{tr}_{\max}(t) = \frac{\lambda}{4\pi}\sqrt{\frac{P_t(t)G_tG_r}{P_r}}, \tag{4}$$

where λ is operating wavelength, Gt and Gr are gains of transmitting antenna and receiving antenna, and Pt(t) = *I(t)*V(t)* shows power consumption of a BPSN. For simplification, it is used



(a) (b)

Figure 4 BPSN link reliability (a) time dependent (b) time constant

an average consumed current in both sleep and active modes with a duty cycle of 35%. Thus

$$P_t(t) = I_{\text{average}} V(t). \quad (5)$$

V(t) in (5) is evaluated as

$$V(t) = \frac{A}{B+t} + \frac{C}{D+t} + Et + F \quad (6)$$

3.3. Energy Consumption

A first-order radio model [11] is used for considering energy dissipation in transmitting and receiving modes. The energy dissipated for transmitting a k-bit message over distance tr is

$$E_{\text{Tx}}(k, \text{tr}) = E_{\text{Tx-elec}}(k) + E_{\text{Tx-amp}}(k, \text{tr}) = E_{\text{elec}} \times k + e_{\text{amp}} \times k \times \text{tr}^2 \quad (7)$$

where $E_{Tx\text{-}elec}(k)$ is the energy dissipated in the transmitter circuitry for a k-bit message, and $E_{Tx\text{-}amp}(k, tr)$ is the energy dissipated for a k-bit message in transmit amplifier to achieve an acceptable Eb/N0 over the distance tr. E_{elec} and e_{amp} are energy consumption to run the transmitter/receiver circuitry and for the transmit amplifier per bit, respectively. The tr^2 energy loss is considered due to channel transmission condition. The energy consumption for receiving a k-bit message is

$$E_{\text{Rx}}(k) = E_{\text{Rx-elec}}(k) = E_{\text{elec}} \times k \quad (8)$$

where $E_{Rx\text{-}elec}(k)$ is the energy dissipated in the receiver circuitry for a k-bit message. The energy consumption by communication is a function of hop count and path length between a source node and the sink node.

3.4 Cost Function

In WSNs, a comprehensive routing protocol is needed to maximize the network lifetime while considering important factors such as energy consumption, implementation cost and reliability.

$$CF_\rho(t) = \alpha_R \times f_R(\rho, t) + \alpha_{NH^{BPSN}} \times f_{NH^{BPSN}}(\rho, t) + \alpha_{RE} \times f_{RE}(\rho, t)$$

$f_R(\rho,t)$ is the reliability function of path ρ evaluated using equation 7

$f_{NH^{BPSN}}(\rho,t)$ is the function of number of BPSN hops along path ρ reflecting the cost and/or communication energy consumption of a typical BPSN;

$f_{\mathfrak{R}}(\rho,t)$ is the function of minimum RE of BPSNs along path ρ. It is evaluated using the method

The weight of RE function can be as low as possible at the starting point of application. As time passes, the RE in BPSNs decreases, and consequently effects of RE on network performance become more significant thus its weight should be increased. The minimum and maximal values of the CF for a path are 0 and 1, respectively; a higher value of the CF implies better performance of the path.

4. PROPOSED TECHNIQUE

For the proposed technique the sensing area is divided into cells and in each cell the equal number of nodes is deployed and initial energy values are assigned to each node. Communication would occur from source to destination and it is mandatory that the route gets into each cell of the network and selects one node from each cell. First of all the initial population is generated which randomly gives the set of routes between source to destination. The total energy and reliability of each route are calculated and the minimum energy value and maximum reliability value obtained by any route are considered as a best fitness value. This is the initial solution. To obtain a route the iterations are carried out using Multi-

Objective Genetic Algorithm (MOGA) which helps to update the initial population with new offspring population.

4.1 Algorithm

The parameters included in the fitness function are aiming to form more balanced clusters and reduce the overall energy consumption in order to increase reliability too.

Total Energy Consumption for Single Data Collection Round: It is taken directly in calculating the fitness function of the chromosomes. Total energy consumption is the sum of intra-cluster and inter-cluster energy consumptions and the product of intra-cluster and inter-cluster reliability

Intracluster energy and reliability are

$$E_{\text{intra}} = \sum_{i=1}^{n} E(i, \text{CH}) + E_{\text{Rx}} + E_{\text{DA}} \tag{10}$$

$$R_{\text{intra}} = \Pi R_{SN_i}(t)\, R_{CH_i}(t)$$

Intercluster energy and reliability are

$$E_{\text{inter}} = \sum_{i=1}^{m} E(i, \text{BS}) \tag{11}$$

$$R_{\text{inter}} = \Pi R_{CH_i}(t)\, R_{BS}(t)$$

The total energy and reliability are

$$E_{\text{Total}} = E_{\text{intra}} + E_{\text{inter}} \tag{12}$$

$$R_{\text{Total}} = R_{\text{intra}} \times R_{\text{inter}}$$

E(i,CH) represents energy consumption from ith node to its corresponding CH node, $R_{SN_i}(t)$ is the sensor reliability at ith node and $R_{CH_i}(t)$is the cluster head reliability, ERx is the reception energy spent at CH, and EDA is the energy consumption due to data aggregation in CH in (10). (i, BS) is transmission energy and $R_{BS}(t)$ is path link reliability from ith CH to BS as in (11). "n" and "m" represents cluster member and cluster head, respectively, in (10) and (11). Equation (12) illustrates the total energy per communication round.

The fitness functions are represented

Minimizing Fitness function1= W1 × E_{Total}

Maximizing Fitness function2 = W2 × R_{Total}

4.2 Working of an Algorithm

It works by 2 phases

Cluster formation phase and data collection phase.

Cluster Formation Phase. As in other WSN clustering algorithms in cluster formation phase, this proposed algorithm runs in the centralized BS which is having all the location details of the nodes in the network. The genetic operators are applied over the random initial population till the termination condition.

At the end, the best fit chromosome in the population represents the new cluster architecture. The value "1" in the chromosome represents the CH designated nodes and "0" is the cluster member CM designated node. These newly selected CH and CM nodes will be intimated by the BS directly to them.

Data Collection Phase. In data collection phase, the CH nodes will be generating a TDMA schedule for its members. The member node has to report its data to corresponding CH only during its allotted time slot. In other time slots, it may enter sleep state, but the CH nodes will be always in wakeup state in order to receive the data from its members. The received data from the member nodes will be aggregated at the CH and sent to BS at the end of each communication round. The elitism is the genetic operator with single point crossover.

4.3 Performance

According to Tables 2, paths #2 [1 6 4 5 14] is the best path to satisfy CF. Hence, we evaluate the importance of sensor nodes #1, #2 and #7 involved in these two paths from sensor node #8 to the sink node #16. We then extend our approach to rank all sensor nodes by finding all paths from each sensor node to the sink node

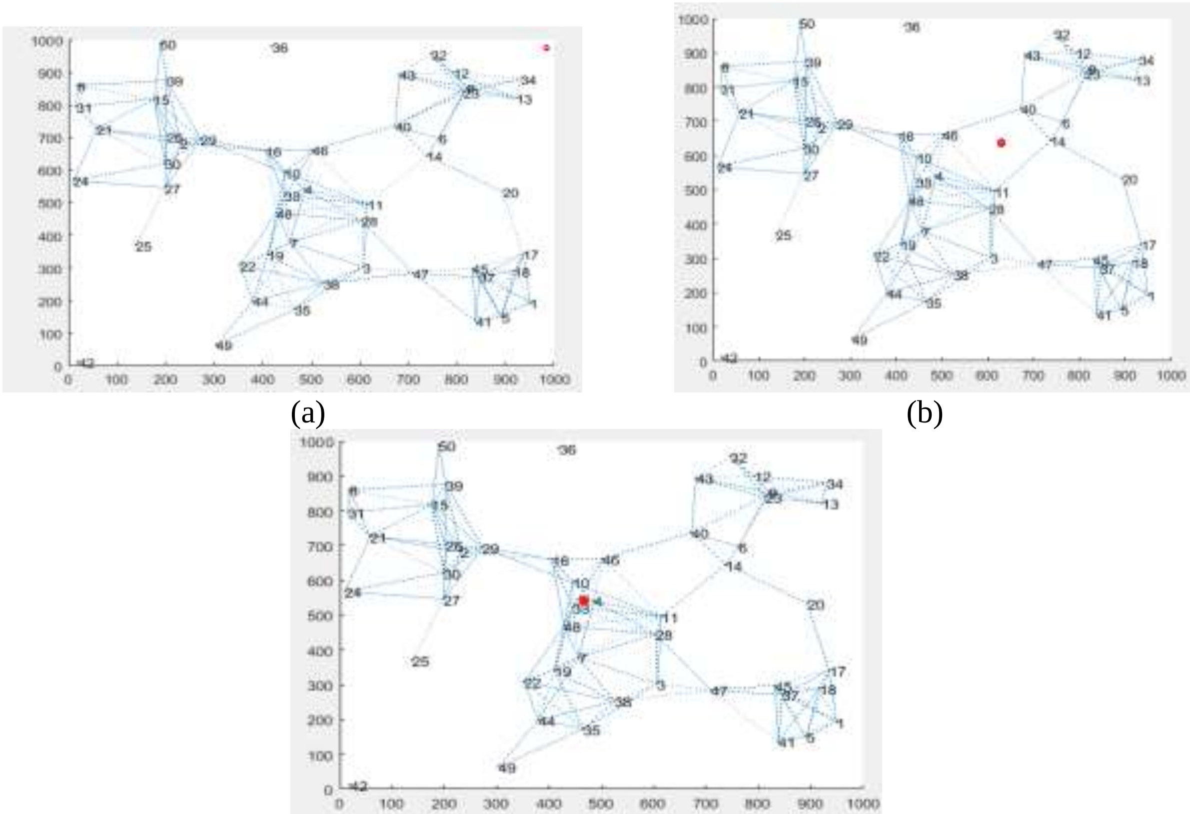
The Figure 6 (a) shows the final optimized route from source to destination which is highlighted with green color selecting one node from each cell as it is mandatory to select a node from each cell. Selected node from each cell is a cluster head for that cell, which performs the function of data aggregation and data transmission in order to send the data packets to the destination. The nodes are automatically selected for the route formation in order to have a data transmission from source to destination with minimum energy and maximum reliability. The data transmission is carried out through this route which is obtained by the optimization process. The selected node from each cell acts as a cluster head, all other sensor nodes send data to the cluster head and cluster head combines the data and sends to next cluster head so that the data reaches up to destination.

S.No	Parameter	Value
1	Ψ	3
2	Frequency	900 MHz
3	Transmitter power consumption (Pt(t))	10 to 2 dB
4	Receiver power consumption (Pr)	-40dB
5	Eelec or ERx or Erx	50 nJ/bit
6	Transmit amplifier (Eamp) 100 pJ/bit/m2	100 nJ/bit
7	Average current	34 mA
8	Duty cycle	35%
9	Gain of transmitter antenna (Gt)	1.2 dBi
10	Gain of receiver antenna (Gr)	1.2 dBi
11	A	36.11
12	B	68.112
13	C	202.854
14	D	-869.39
15	E	2.675× 10-3.5
16	F	1.2097

Table 1 Simulation Settings

Path	Path	Path length	Reliability	Energy Cost	CF
1	[1 9 5 12 14]	9..54	0.564	12	0.946542
2	[1 6 4 5 14]	9.85	0.665	11	0.991334
3	[1 8 4 10 14]	10.12	0.747	12	0.923145
4	[1 5 7 3 14]	9.63	0.631	9	0.958766
5	[1 8 4 2 14]	9.94	0.712	11	0.945387

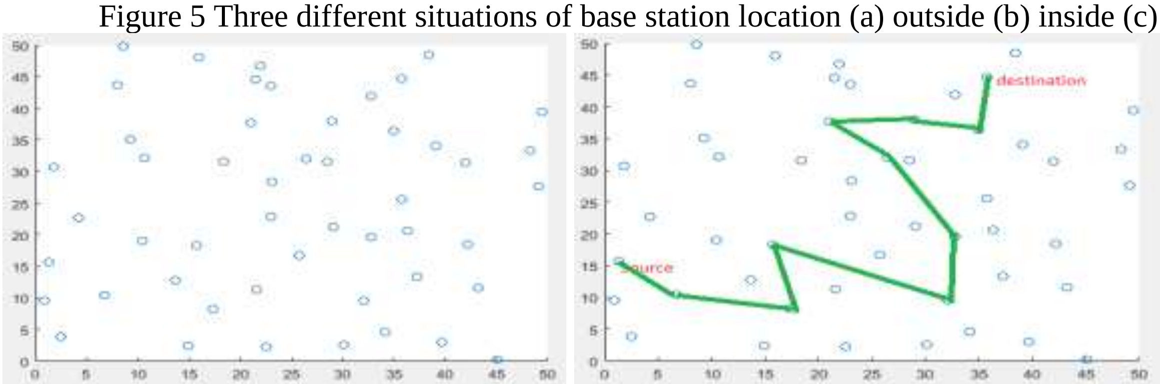
Table 2 Simulation results of various paths



(a) (b)

(c)

Figure 5 Three different situations of base station location (a) outside (b) inside (c) center



(a) (b)

Figure 6. (a) Initial system model (b) Optimized Route

5. CONCLUSIONS

In this paper, the proposed routing approach integrates energy and end-to-end path reliability, RE in BPSNs to applications running on the WSN. Efficiency of the proposed routing method was investigated via a case study with different requirements. The method can be used for WSNs with any given topology. The results show that the average end-to-end path reliability can increase significantly in comparison to random location selection for the same number of BPSNs. All the investigation was performed using the genetic algorithm to find the optimized locations for BPSNS, improving the end-to-end path reliability and reducing energy as well as the overall CF value.

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