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EMPIRICAL FACTORS FOR ROBUSTNESS OF SENSOR NODES ON ENERGY EFFICIENCY

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ABSTRACT

Sensors are the devices which are used to measure the temperature of their surroundings and inform it to the base station through central heads which forms large scale networks, have become more in number. These sensors can act individually by using small hardware devices and it can be embedded into the devices like mobile phones, laptops, iPods, or in combination of these in Mobile Ad-hoc Networks (MANETs) more battery power is needed for the measurement of temperature. Depending on the rate of battery power consumption, more research works are being focused on the influence of data processing and communication network as these sensors are tiny and they cannot withhold larger batteries. The problem arises when the sensors are treated as either tiny stand alone devices or particularly used when it is embedded with robust devices. It is necessary to make research work on embedded devices. Even though the literature shows the effectiveness of energy consumption by sensors, studies on the embedded devices robustness are seen rarely. It is being pointed out by architectural design of sensor networks which is different according to their applications and constraints. In order to address these issues, this paper try to arrive at certain coefficients called as factors that are empirically determined by involving series of experiments in the NS 2.0 environment. High, Medium, Low are the three scales of robustness which are suggested for the factor and also the three scales are immense to be used in the deployment of sensors in manets. Robustness on the consumption of energy of the sensor embedded devices in networks is indicated by the factors considered. The experimental work is delimited in its scope with energy consumption due to the computing process. The work is delimited to comparative studies on hierarchal and flat algorithms. Concluding remarks have been drawn out of these experimental studies.
Keywords: *Manets, Central Head, Wireless Sensors, Robustness, Routing*

1. INTRODUCTION AND BACKGROUND

Small-sized battery-operated sensors are capable of detecting energy sources such as temperature, sound etc. These sensors are generally embedded with communicating and computing devices. They are capable of sensing and measuring energy sources from their surrounding environment and transforming them into electric signals. Consequently they help in detecting some properties about objects located and/or events happening in the vicinity of the sensor. Therefore aggregating these capabilities of individual sensors in a large scale network can be operated unattended [1]. They can be deployed randomly in the area of interest by a relatively uncontrolled means, thereby to collectively form a network in an ad-hoc manner [2]. However, the short lifespan of the battery-operated sensors and the possibility of having damaged nodes during deployment or operation, the life span as well as the rate of consumption of battery power would play an important role. Designing and operating such network of sensors along with their equipments that carry them might require scalable architectural and management strategies [3]. In view of these issues, the paper attempts to study the role of certain chosen parameter of sensor embedded systems, such as mobile phones and/or computer systems in a network with respect to power consumption factor. As literature point out to unattended nature of sensor embedded systems, the experimental work reported in this paper considers non-mobility of the systems under network at particular instance of the study. However, the systems, called nodes in this paper might also be ad hoc. For the arrangement of experimental studies, unlike [2], is only with

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braided sensor nodes are considered for the experiments of this paper. This paper forms a part of a whole larger research. The need for the research, through the experimental studies, is to propose efficient schema of the braided sensor nodes and appropriate routing algorithmic procedures that consider three categories of varying transmitting powered sensor nodes. The varying transmitting power of the sensors would be grouped into the three categories (ranges) of robust (gradation of resilient) sensors.

Architectural designs of wireless sensor networks would be different according their constraints and applications. Such networks basically consist of sensor nodes, base-station and a monitor system [4]. Most of architecture of sensor networks assumes their nodes are stationary. In some architecture, the aggregated data are assigned to a Central Head that could as well be a powerful node. However in such cases these Central Heads are not over burdened, so as to facilitate them to provide accurate data efficiently [5]. An indication for parametric studies in such situations as it may be necessary to assign backup Central Heads for a cluster or it may be needed to rotate some nodes to act as the Central Head [6]. Sensor networks require low reporting rate in order to save energy [7]. Sensor nodes and their link qualities, and their capabilities around the nodes are important decisive parameters that would contribute to weights for data transmission and hence must be considered for study [9]. In the case of sensor networks having homogeneous nodes, all having equal capacity in terms of power and other attributes, then Central Head may be picked from the nodes [6] which have significantly more resources. In such case the selection is carefully tasked. Three important criteria that would drive the design of large-scale sensor networks are scalability, energy-efficiency and Robustness [11]. These networks require novel routing techniques for scalability and robust data dissemination. The paper accordingly attempts to demonstrate two selective algorithmic approaches for two situations. Literature on homogenous sensors in terms of resilience has been reported. But the present paper brings out research findings from heterogeneous nodes with the chosen three categories of resilient sensors (robustness). The ultimate objective of the paper is to bring out empirical factors that would help in identifying the optimum ratios of the chosen three categories of the robust sensors. The analyses in the overall larger research will be carried out in three different layers and correlated with combined three categories of resilient sensor layers. However this study is beyond the scope of this paper. The paper attempts to bring out only the empirical factor for the categories for efficient combinations.

2. EXPERIMENTAL STUDIES

The aim of the proposed experiments is to determine the influencing factors of robustness of sensor nodes in Networks for computing the energy consumed by the nodes in transmitting the data to a Central Head (CH). The contribution of CH in facilitating the transmission of data for receipt to it, from the sensor nodes is considered for the experiments. This class of experiment has not to be found in literature and thus justifies the novelty of our work.

2.1 Conditional Parameters for the Experiments

Residual energy of each hardware item of the sensor embedded node would be the primary parameter that should be considered for election of CH [4]. We have thus attempted to correlate the node's robustness with residual energy. In view of this, three categories in the form of types of nodes grouped in lots are considered for the proposed study. These three types of nodes mentioned below are subjected to the proposed parametric study to determine the behavior of the nodes under two different kinds of algorithm for receiving and transmitting the sensor data sent by the nodes to the CH. This CH is a special node acting as the recipient of data sent by the nodes in the experimental setup. The algorithm is deployed in this CH. The three categories or types of nodes considered are:

1. High Robust system: Tightly coupled; Single functioned and Rigid systems.
(Ex. Mobile phones, I_pads)
2. Low Robust system: Loosely constrained; Multi functioned and Flexible systems.
(Ex. Assembled clone systems)
3. Medium Robust system: Properties and components in-between the above two.
(Ex. Branded LAP TOP systems).

All the above three parameters are specified for the nodes which are embedded with sensors and considered in different lots for the

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experiments. The number of nodes considered in lots is increased from 100 to 1000 in increment of 100, thus amounting to 10 lots for 10 experiments, as generally, the network has a large number of sensor nodes [1]. The experiments are done for two categories of routing algorithm, as per the objective of the paper, as more resilient typically consume more energy [11]. They are: i. Hierarchical routing algorithm and ii. Flat routing technique. Literature points out to the fact in determining parameters that are to be infused in the algorithm for determining energy consumptions [10]. These parameters, such as power and hops, need to be used in mathematical forms for ultimately achieving minimal energy consumption [1]. Simulated experimental results show reduction of energy levels that used such parameters [10]. This will lead to a total of 20 cases for 20 experiments. NS 2.0 package has been adapted for the experiments.

2.2 Delimitations for the Experiments

For the purpose of the proposed experiments the following delimited principles and definitions have been assumed.

1. Preference for selection of node, when multiple nodes are received by the CH, depends on the robust parameter of the particular node.
2. Euler's geometry is not considered for exactly computing network characters and the CH is located at the central of the nodes.
3. As the experiments are meant for the study of behavior of nodes of three categories only, dynamic behavior of nodes of Networks is not considered for the experimental studies.
4. The data transmitted time on receiving from nodes by the CH is only the processing time by the CH and the network travel time and retention time in nodes are not considered. Because, no routing protocol could have the prior knowledge of the actual path of data traffic and how the pattern would be [8].
5. The battery power consumed by a node is proportional to the data transmission time consumed by the node. Other criteria like mobility of nodes are not considered by the study.
6. Fixed uniform packet sizes have been considered for transmitting from all the nodes at a time for the experiments.
7. Hierarchical routing philosophy refers to grouping of routers together by function into a hierarchical table. Flat routing technique refers to the fact that no efforts are made to organize the traffic or network routing preference; instead data transmitted first cum first basis.

3. RESULTS AND DISCUSSIONS

For the purpose of determining the contribution of hierarchical routing algorithm, which is based on grouping different types of nodes under the selected three robust types, the energy consumption of individual node is computed as under.

The battery power consumed after a time interval of 't' Secs. by a node: BP (t) --------(1)
It is delimited that the power consumption by battery is directly proportional to the data transmitting time taken by the node.

R_c = Category number of the node (1 to 3) ----(2)

T_j = Total number of nodes in corresponding category (j) -------------- (3)

Data transmitted time by each node = T_t (i, j) -------------(4)

Where i = 1 to R_c (Equ. (2)) of corresponding node category and j = 1 to T_j of equ. (3).
Virtual Time consumed by a node for battery power $V_t(i,j) = \alpha(i) * T_t(i,j)$ ------------- (5)

Where α (i) is an empirical factor determined by parametric study for each category and T_t (i,j) of equ. (4) for the 't' of equ. (1).

With the above equations from (1) to (5), it is evident, that empirical factors need to be arrived at experimentally for different conditions as explained above. Under these conditions our experiments using NS.2.0 consist of 6 categories of robust combinations for a set of multiples of 100s of sensor embedded nodes. The number of runs of the experiments reported in [11] and the number of sets in each run were adjusted to obtain acceptable confidence intervals [11]. In line with this the experimental set up are arranged in our case. The data for both the chosen routing methods are analyzed and results provided in Table 1.0.

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Table 1.0: Average Data Transmitted Time By Different Routing Techniques

Category	Hierarchical Routing Algorithm		Flat Routing	
	No. of Nodes	Average Data Transmitted time in Secs.	No. of Nodes having only one category of sensors	Average Data Transmitted time in Secs.
1)100% High robust	100	9.58	100	9.01
	200	21.02	200	20.12
	300	31.56	300	29.66
	400	43.33	400	41.13
	500	54.10	500	50.16
	600	65.00	600	63.23
	700	76.78	700	75.08
	800	88.06	800	86.86.
	900	97.98	900	96.68
	1000	105.45	1000	101.15
2) 50% High and 50% Medium robust	100	11.02	100	17.92
	200	24.04	200	20.09
	300	36.46	300	56.36
	400	47.34	400	49.54
	500	59.91	500	97.91
	600	72.71	600	76.71
	700	84.02	700	89.72
	800	97.98	800	97.18
	900	104.43	900	114.48
	1000	123.23	1000	129.43
3) 100% Medium robust	100	10.04	100	10.01
	200	21.00	200	21.00
	300	30.09	300	30.09
	400	42.21	400	41.27
	500	53.23	500	51.28
	600	64.02	600	63.09
	700	75.51	700	74.56
	800	85.98	800	85.98
	900	97.21	900	98.29
	1000	108.88	1000	104.08
4)50% High and 50% Low robust	100	11.32	100	14.34
	200	25.08	200	29.28
	300	38.64	300	44.44
	400	49.84	400	38.14
	500	61.61	500	66.69
	600	75.76	600	85.16
	700	88.92	700	88.12
	800	105.98	800	115.00
	900	110.63	900	115.63
	1000	128.43	1000	141.43
5) 50% Medium and 50% Low robust	100	17.23	100	12.13
	200	38.05	200	22.13
	300	52.46	300	42.46
	400	91.31	400	101.31
	500	111.17	500	117.12
	600	132.22	600	130.22
	700	156.72	700	158.12
	800	169.23	800	169.13
	900	185.34	900	189.33
	1000	199.63	1000	209.63
6)100% Low robust	100	10.24	100	13.24
	200	21.07	200	23.17
	300	31.29	300	32.29
	400	41.21	400	41.91
	500	53.23	500	55.27
	600	65.92	600	67.92
	700	75.54	700	79.04
	800	88.08	800	88.98
	900	98.21	900	101.26
	1000	108.89	1000	108.32

Experimental Design Variables and Definitions

In Equation (2), the R_c is taken as three different categories by the hierarchical algorithm where as it is unity for the flat routing algorithm. The T_j of Equation (3) is shown with corresponding values in column 1 of Table 1.0. The average data transmission time as defined in Equation (3) under T_t (i, j), are obtained from simulation package NS 2.0 are presented under columns (3) and (5) of Table 1.0 for heterogeneous nodes and homogeneous nodes respectively. These results will be subjected to normalization to determine empirical factors (denoted as so as α (i) in Equation 5). This procedure is presented in the subsequent sections. This α (i) is independent in the experiments demonstrated so far. As the experiments are limited and demonstrated for specific situations under controlled conditions, the factors are termed as 'Empirical'.

Graphical representation separately for Hierarchical routing algorithm and Flat method are displayed in Figures 1.0 and 2.0 respectively. The observations from both the graphs so as to arrive at inferences are also been provided.

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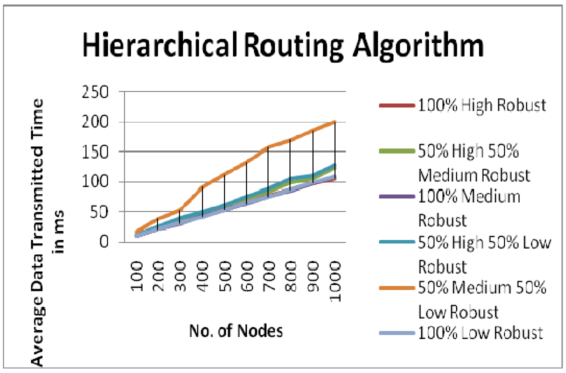

Figure 1.0 Distribution Of Data Transmission Time By Systems Of Different Nodes Under Hierarchical Routing Algorithm

Observation:

But for the 50% Medium and 50% Low robust systems, the rest are almost linearly distributed in consuming energy (Figure 1.0). As low and medium robust combined systems are highly un-defined in their behavior, the distribution shown is perhaps highly deviating from the rest. It is therefore inferred that the cluster is recommended to be mostly representative of uniform configuration.

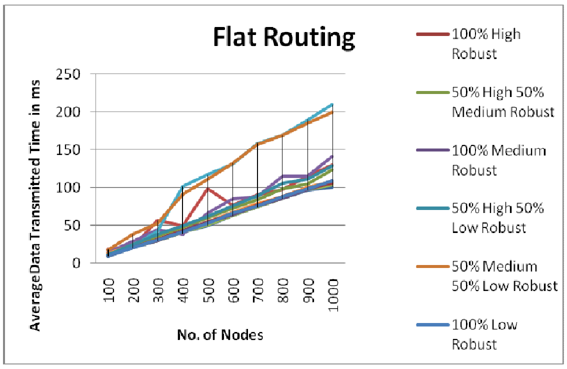

Figure 2.0 Distribution Of Data Transmission Time By Systems Of Different Nodes Under Flat Routing.

Observation:

For the purpose of comparison, the parameters are replicated with hierarchical (heterogeneous) situation, as 50%High 50% Medium etc. But in all the situations, corresponding sensors such as 'High'/'Medium'/'Low' robust sensors are considered as homogeneous for 'Flat' routing algorithm.

Compared with hierarchical routing algorithm, flat routing is erratic in the behavior, as seen from Figure 2.0. As there is no table that holds different types of systems, the routing is done first cum first basis.

3.1 Factor analysis

Table 1.0 presents average data transmitted time in Secs. by the two routing techniques for the two situations narrated in the experimental design below. The overall average transmitted time is computed as below for both the techniques.

Hierarchical Routing algorithm:

This routing algorithm is suggested for combined presence of the three categories of sensors (heterogeneous). The average transmission time in such situation is computed through the equations demonstrated below.

Complete experimental average transmission time by category (1) = (9.58 + 21.02/2 + 31.56/3 + 43.33/4 + 54.10/5 + 65.00/6 + 76.78/7 + 88.06/8 + 97.98/9 + 105.45/10) / 100 = 0.11774 Secs. = 117.74 ms.

Complete experimental average transmission time by category (2) = (11.02 + 24.04/2 + 36.46/3 + 47.34/4 + 59.91/5 + 72.71/6 + 84.02/7 + 97.98/8 + 104.43/9 + 123.23/10) / 100 = 0.136390 Secs. = 136.39 ms.

Complete experimental average transmission time by category (3) = (10.04 + 21.00/2 + 30.09/3 + 42.21/4 + 53.23/5 + 64.02/6 + 75.51/7 + 85.98/8 + 97.21/9 + 108.88/10) / 100 = 0.121051 Secs. = 121.05 ms.

Complete experimental average transmission time by category (4) = (11.32 + 25.08/2 + 38.64/3 + 49.84/4 + 61.61/5 + 75.76/6 + 88.92/7 + 105.98/8 + 110.63/9 + 128.43/10) /100 = 0.14240 Secs. = 142.40 ms.

Complete experimental average transmission time by category (5) = (17.23 + 38.05/2 + 52.46/3 + 91.31/4 + 111.17/5 + 132.22/6 + 156.72/7 + 169.23/8 + 185.34/9 + 199.63/10) / 100 = 0.22294 Secs. = 222.94 ms.

Complete experimental average transmission time by category (6) = (10.24 + 21.07/2 + 31.29/3 + 41.21/4 + 53.23/5 + 65.92/6 + 75.54/7 + 88.08/8 + 98.21/9 + 108.89/10) / 100 = 0.12120 Secs. = 121.20 ms.

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Flat Routing:

This routing algorithm is suggested for the presence of any one category of the sensors (homogeneous). The average transmission time in such situation is computed through the equations demonstrated below.

Complete experimental average transmission time by category (1) = (9.01 + 20.12/2 + 29.66/3 + 41.13/4 + 50.16/5 + 63.23/6 + 75.08/7 + 86.86/8 + 96.68/9 + 101.15/10) / 100 = 0.11327 Secs. = 113.27 ms.

Complete experimental average transmission time by category (2) = (17.92 + 20.09/2 + 56.36/3 + 49.54/4 + 97.91/5 + 76.71/6 + 89.72/7 + 97.18/8 + 114.48/9 + 129.43/10) / 100 = 0.14371 Secs. = 143.71 ms.

Complete experimental average transmission time by category (3) = (10.01 + 21.00/2 + 30.09/3 + 41.27/4 + 51.28/5 + 63.09/6 + 74.56/7 + 85.98/8 + 98.29/9 +104.08/10) / 100 = 0.11637 Secs. = 116.37 ms.

Complete experimental average transmission time by category (4) = (14.34 + 29.28/2 + 44.44/3 + 38.14/4 + 66.69/5 + 85.16/6 + 88.12/7 + 115.00/8 + 115.63/9 + 141.43/10) /100 = 0.15608 Secs. = 156.08 ms

Complete experimental average transmission time by category (5) = (12.13 + 22.13/2 + 42.46/3 + 101.31/4 + 117.12/5 + 130.22/6 + 158.12/7 + 169.13/8 + 189.33/9 + 209.63/10) / 100 = 0.23338 Secs. = 233.38 ms.

Complete experimental average transmission time by category (6) = (13.24 + 23.17/2 + 32.29/3 + 41.91/4 + 55.27/5 + 67.92/6 + 79.04/7 + 88.98/8 + 101.26/9 + 108.32/10) / 100 = 0.12099 Secs. = 120.99 ms.

3.2 Normalization of Factors

From normalization out of averaging with pairs of α (1) and α (2), α (1) and α (3) α (2) and α (3) using numerical methods, the empirical values for robust categories after normalization, are:

Hierarchical Routing algorithm:

α (1) = 127.74 ms; ratio with respect to α (1) = 1.00.
α (2) = 150.77 ms; ratio with respect to α (1) = 1.18.
α (3) = 152.40 ms; ratio with respect to α (1) = 1.19.

Flat Routing:

α (1) = 151.99 ms; ratio with respect to α (1) = 1.00.
α (2) = 192.97 ms; ratio with respect to α (1) = 1.27.
α (3) = 197.81 ms; ratio with respect to α (1) = 1.30.

Empirical factors are arrived with respect to the base, which is fully robust from the average value of both the routing techniques. The final empirical values thus arrived at are:

For robust nodes α (1) = 1.0.
For semi robust nodes α (2) = 1.23.
For non robust nodes α (3) = 1.25.

The virtual time of data transmission by nodes, is determined from Equ. 5, by applying respective α values. Equation 1 will provide the virtual energy efficiently consumed by the nodes.

4. CONCLUSION AND FUTURE SCOPE

The results will be of immense use to researchers in the field of optimizing braided resilient sensor network for energy saving. The two algorithms suggested by the research are to be applied (i) hierarchical routing algorithm for combined layer situation (heterogeneous resilient sensors) and (ii) flat routing algorithm for single layer situation (homogeneous resilient sensors). The three empirical factors indicate the optimum ratios of resilience features of the sensor categories along with suitable routing algorithms (for multi layer as well as single layer) for implanting in the braided sensor networks so as to achieve minimum energy consumptions of the overall network.

The experiments and the results show that suitable routing algorithm and robustness's of sensor nodes or sensor embedded nodes would be sensitive with respect to transmission time leading to energy consumption by the nodes, even though an established hierarchical algorithm compared with traditional flat technique. The experiments also prove that grouping of sensor nodes according to levels of robustness would organize large number of sensors in network for better managements.

It is clearly demonstrated that hierarchical routing algorithm through maintaining a table, in spite of its overhead caused to the system, is found to be slightly more reliable than flat routing technique. Hence an

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efficient algorithm specific for specific situations need to be incorporated that takes robustness into account. The overall power consumption by nodes increased from higher robustness to lower robust nodes in both the cases of 'Hierarchical routing algorithm' as well as 'Flat routing'.

The future work will be extended with computation of probability values of success/failure rates of sensor nodes in different braided situations. For the two situations namely homogeneous and heterogeneous resilient sensors, conditional probability with 'Naïve Bayes' theorem would be applied, as each category of robustness will be conditional in playing the corresponding power transmission rates in the network.

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