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Novel framework of retaining maximum data quality and energy efficiency in reconfigurable wireless sensor network

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Article Info	ABSTRACT
	There are various unseen and unpredictable networking states in Wireless Sensor Network (WSN) that adversely affect the aggregated data quality. After reviewing the existing approaches of data quality in WSN, it was found that the solutions are quite symptomatic and they are applicable only in a static environment; however their successful applicability on dynamic and upcoming reconfigurable network is still a big question. Moreover, data quality directly affects energy conservation among the nodes. Therefore, the proposed system introduces a simple and novel framework that jointly addresses the data quality and energy efficiency using probability-based design approach. Using a simplified analytical methodology, the proposed system offers solution in the form of selection transmission of an aggregated data on the basis of message priority in order to offer higher data utilization factor. The study outcome shows proposed system offers a good balance between data quality and energy efficiency in contrast to existing system.

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1. INTRODUCTION

The rapid development of digitalization has led organizations to focus on low-cost, low-power, multi-functional devices and distributed network environments. However, WSN emerged as a required network application platform that leverages cost-effective implementation services to facilitate a flexible network infrastructure and also adapts to, many changes based on application requirements. WSN incorporates with hundreds of resource constraints tiny sensor nodes which have ability to sense the environment after it collects data, processes data and perform communication via radio link channel among other sensor devices [1, 2]. The main purpose of designing WSN is to detect the events and transmit sensed data to relative user. WSN's are highly adapted to monitor services for various environments such as military-defense, weather forecasting, biological healthcare, surveillance & security and disaster-relief work [3]. The functioning of these applications is mainly based on the real-time information. Due to resource constraints nature of sensor devices WSN tends to be less reliable. The raw data collected by the sensor is affected by various factors such as structural changes, signal strength changes, multipath propagation, and interferences and also sometimes it provides redundant data, which does not guarantee end-to-end reliability [4]. Therefore, in the field of WSN research, energy efficiency with data reliability becomes a very challenging issue. The term 'data reliability' refers to a state that satisfies the quality requirements such as data is relevant, sufficient, valid and unaltered [5]. There are several approaches based on retransmission and redundancies are discovered by many researchers for providing reliable data transmission in WSN [6, 7]. However, the overhead and transmission load problems of these approaches results in a higher amount of

energy exhaustion. Hence there is a need of multi-objective approach which ensures both energy-efficiency and data reliability for real-time WSN applications. Moreover, it has been observed that many existing researches have carried towards in the domain of energy efficiency with ensuring reliable data processing [8-10]. Also, various and different existing works of data reliability for energy efficient WSN application are discussed in the review of literature section. The prime contribution of the proposed system is to address the problems associated with the data reliability as well as energy efficiency jointly so that this problem can be investigated for its effect over the network lifetime performance.

The proposed system also discusses about a message prioritization scheme that perform selection transmission of data packet on the basis of time factor and sensor node. The organization of the proposed paper is as follows: Section 1.1 discusses about the existing literature where different techniques are discussed for detection schemes used in power transmission lines followed by discussion of research problems in Section 1.2, the problem statement describes in section 1.2.1 and proposed solution in 1.3. Section 2 discusses about algorithm implementation followed by discussion of result analysis in Section 3. Finally, the conclusive remarks are provided in Section 4.

This section discusses about the existing research works that carried in the division of energy efficient data reliability in WSN. The work carried out by Alipio et al. [11] have concentrated on the issue related with reliable data transmission and proposed cache based traffic control protocol which utilizes information resource from the cache management program to recover the packet losses in WSN. The experimental outcomes of presented approach achieves good improvement compared to base line protocols and existing cache based transport protocols in terms of end-to-end delay and cache utilization. Alshaheen and Rizk [12] have considered energy problem and packet loss in body sensor network. The author have used linear network coding approach to improve data reliability by computing the probability of successful packet receiving at the sink node. The work of Duan et al. [13] have design an improved software defined network for addressing the issue of energy consumption and reliability in industrial WSN.

Elsafrawey et al. [14] have presented self-recovery shuffled distributed approach using proactive and reactive protocol to enhance the quality of data collected by unattended WSN. The study of He and Jiang [15] have applied approach of Quantum mechanics to evaluating and modelling the consistency of sensor reports. Jin et al. [16] have constructed novel optimization framework for Industrial WSN. The presented framework composed of channel management layer for improving reliability and flow-scheduling layer for resolving temporality factor in network. Kamezaki et al. [17] have presented detection scheme for measuring the reliability of data collected in Hydraulic Manipulators. The work of lei et al. [18] have examine the energy management policy and designed scheduling and allocation algorithm for reducing heavy packet loss for energy harvesting industrial WSN.

A robust ant-jamming routing protocol is adopted in the study of Liu et al. [19] in order to address the data transmission problem in high medium noise and electromagnetic interference environment. In the study of Long et al. [20] have developed a data collection scheme that ensures the required quality of service for optimizing the total energy consumption and improving data reliability. Another work carried out by Luo et al. [21] has presented a new approach for getting reliable data. The author has used fusion mechanism on redundant data with utilizing approximation algorithm for chain and tree topologies. In the study of Pielli et al. [22] have studied to combine energy-efficient factor with over all required QoS of network and used machine learning algorithm in order to make sensor node able to take self-decision for utilizing their energy for transmission. Sun et al. [23] have presented novel model for estimating reliability of end-to-end packet delivery and optimizing the transmission link quality for the industrial WSN. The outcome of presented model achieves good performances for reliable data transmission at network level.

Teng et al. [24] have formulated a novel optimization scheme based on broadcast technology for enhancing the reliability and minimizing the communication delay in the network. Wang et al. [25] have introduced novel analytical model using smart feeder for improving reliability factor of integrated cyber distributed systems. The work of Yan et al. [26] have, presented a closed loop based measurement model to enhance the accuracy of vibrant sensors. The outcomes of presented approach reveals that it achieve beneficial property for removing human factor error and is more suitable compared to open loop technique. A loss function based Inference technique is used in the work of Yand et al. [27] for enhancing data reliability for large distributed data from the WSN.

The study of Zhu et al. [28] have carried analysis for investigating the reliability problem in WSN of which topology switches between the possible available connection operated by Markovian chain. The findings of presented work suggested that the reliability factor dependents on three points that are network parameters and topology, and Markovian chain. In the same way another work carried out by Zhu et al. [29] have presented a novel technique based on the evidence theory for estimating the reliability constant of sensors established on training data. Therefore, there are various scheme implemented for

the purpose of data reliability but all these above scheme is associated with beneficial points as well as non-beneficial points. Samara et al. [30] have illustrated efficient power, price decreases, and QoS based routing method for WSNs. Chisab et al. [31] demonstarted a method for power saving in WSN unfder preservative white Gaussian noise way. The study focused to enhance IF-Algorithm for data aggregation methods in WSNs by Ingle et al. [32]. The next section discusses about identified research problem from existing literature.

The significant research problems are as follows:

a. Existing system does not offer much simple and computationally effective solution towards data reliability problems.
b. There is lack of any consideration of WSN to be integrated with pervasive networks or no discussion of reconfigurable network and the problems associated with it.
c. Exising system does not discuss about any possible linkage of message prioritization with the data reliability as well as energy efficiency.
d. There are very less discussion of solutions that offers a good balance between scheduling, precise data transmission, and energy efficiency considering heterogeneous network.

The problem statement of the proposed study can be stated as "Developing a mechanism to solve the data reliability problems with energy efficiency on reconfigurable networking state of WSN is a computationally challenging task". The next section discusses about proposed solution.

The proposed study is continuation of our prior research work [33-35] emphasizing towards data reliability in WSN. The prime aim of the proposed work is to develop a simple and novel model that is capable of performing integration of WSN with any pervasive network via gateway system with higher degree of energy efficiency as well as data reliability. The implemented architecture of proposed system is shown in Figure 1.
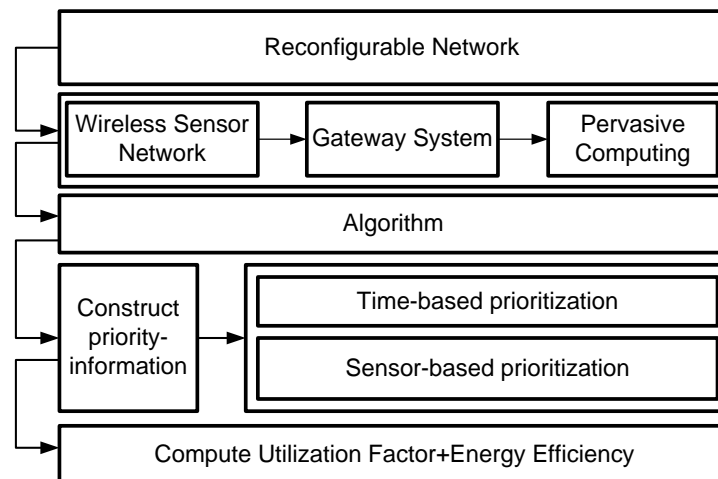

Figure 1. Proposed methodology

Figure 1 highlights the proposed methodology where a reconfigurable network is modeled in order to construct a communication bridge between WSN and pervasive computing (i.e., cloud, Internet-of-Things, Optical Network, etc.). This environment is intentionally constructed as it represents the real-world situation of heterogenous communication system that still suffers from data reliability problems. The proposed system introduces a simple construction of algorithm that uses time parameters as well as sensor node. An interesting fact introduced in the proposed system is that it offers a selection mechanism via the gateway system to choose the forwarding of the data packets on the basis of the selected WSN. Another interesting part of the proposed methodology is that it offers prioritization of the messages that are generated dynamically from the traffic of WSN. This will mean that proposed system constructs a many-to-one networking between WSN and pervasive network and implements its algorithm that has capability to perform selective transmission of the data packet on the basis of priorit with a sole motive of ensuring higher degree of data utilization and lower rate of depletion of the transmission energy. The applicability of the proposed algorithm is more on those areas that demands consistent monitoring activity and forwarding of the aggregated data packet in large scale. The next section discusses about the algorithm implementation followed by discussion of the outcome obtained from its implementation.

2.   ALGORITHM IMPLEMENTATION

The proposed algorithm is constructed retaining the utilization of WSN with pervasive computing in mind and hence a pervasive reconfigurable network is considered for modeling. The agenda of the design principle is to offer a good balance between an effective utilization of aggregated data as well as enhancing the data reliability with a terger of better energy conservation. The challenges of data quality is handled by introducing a mechanism where a particular set of data is selected for forwarding on the basis of time and urgency level. The discussions of the algorithm are as follows:

Algorithm for Constructing Priority Information
Input: N (number of networks), n (number of sensors), u (number of dynamic users), E_o (initialized energy)
Output: MAT (matrix to reposit priority information)
Start
1. init N, n, u, E_o
2. (x, y)→rand_dist(n)
3. **For** i=1:t
4.   **For** j=1: u
5. $\mu(i,j)$→f(rand(N))
6.   **End**
7. **End**
8. **For** i=t
9.   **For** j=1:u
10.   c.$\mu(i,j)$→ [c.$\mu(i,j)$+1]
11.   **End**
12.   c→c/$\sum$c
13.   MAT→c
14. **End**
End

The above algorithm is responsible for establishing a concrete foundation of data reliability considering a case study where WSN will be deployed in reconfigurable network for its upcoming technologies. The algorithm performs random distribution of the sensors (Line-2) as well as the complete network (Line-4) along with a placement of a gateway in order to assist in communication between WSN and pervasive network. The algorithm also introduces a mechanism to perform communication with respect to the dynamic user u (Line-5) as well as upon certain time period t (Line-3). An explicit function $f(x)$ is created that takes the input of random value of number of WSN in order to generate request and all the generated request are stored in an explicit matrix $\mu(x)$(Line-5). The proposed system also constructs an empty matrix MAT that considers the dimension of number of WSN and maximum value of time. The next part of the study is to compute the probability of each sensor for a given instance of time and the entire dynamic user (Line-8 and Line-9). The system than uses the same function μ and obtains its count c value that is a direct representation of probability of the entire service request (Line-10).

Finaly probability is computed by dividing the count with sum of all the count (Line-12). All the respect information of count c is now stored in matrix MAT. This algorithm on successful implementation assists in analyzing probability of data request with respect to the various time instances of a day, which is nearly equivalent to any real time sensory operation. It should be known that basedon the information of MAT, the proposed system allows the sensor to forward only particular set of information to the different network (pervasive) on the basis of priority and time for the dynamic user. This information is used for taking a decision of routing on the basis of the time factor and priority factor. From a different viewpoint, this algorithm could be also seen as a substitute of scheduling and clustering approach as well as this algorithm also offers a good extension to perform routing from WSN to different reconfigurable network using a gateway services. The information retained within MAT is consistently updated as depending on this updated information, the algorithm assist the other side of the network (i.e., pervasive network) to select the set of nodes (i.e., N) on the basis of their relative priority level.

Although, this algorithm does not directly involve any kind of energy modeling that is carried out in the next part of the algorithm, but its complete operation saves a significant amount of energy that is required for data aggregation. It is also successfully capable of processing highly scheduled data aggregation on the basis of data priority and time that directly increases the utilization and reliability level of the data.

The next algorithm is responsible for invoking an energy efficient modeling that initiates by loading the information retained with the MAT (Line-1) that yields computed energy as an output. The significant implementation steps of this algorithm are as follows:

Algorithm for Energy Efficiency
Input: MAT (matrix to reposit priority information)
Output: E (Energy)
Start
1. load MAT
2. **For** i=1:size(x)
3.   **For** j=1:length(t_x)
4.   AdjNodes→(n_{ix}= =j)
5.   **End**
6. **End**
7. **For** k=1:u
8.   c(t_{req}(k))=[c(t_{req}(k))+1]
9. **End**
10. MAT→100*c/∑c
11. **For** i=1:length(P_1)
12.   k=∑(Ei)≥0
13.   [v, ri]→sort(E(i))
14.   **For** j=1:lenth(tx)
15. N_i→(r_i= = N_{ix})
16.   **For** k=1:n1
17.   E(j, rix(k))→f(E(j, rix(k))
18.   **End**
19.   **End**
20. **End**
End

The algorithm constructs a loop where it reads all the value of positional information *x* of the nodes (Line-2) as well as all instantaneous time-based information t_x (Line-3). It then extracts all the adjacent nodes using Euclidean distance *d* approach followed by comparing the distance with range and extract information about the adjacent sensors (Line-4). This step is also followed by elimination of node identity that is finally stored in a matrix called as *AdjNodes* (Line-4). The algorithm than access information of priorityfrom the MAT and reperform the process of generation of the new demands for current time period followed by computation of probability of service request and updating the MAT matrix (Line-7 and Line-8). The proposed system also introduces logic in order to compute the degree of data utilization. For this purpose, the algorithm computes the demand by considering all the count c corresponding to total length of count *c* matrix.

It also accesses the corresponding readings of the sensors and computes the utilization degree bysubtracting demand from reading value. If the value of this utilization degree is positive then the empirical value of the utilization factor is computed from demand factor itself (which is nothing by corresponding counts). This process directly assists in computing the reliability of the data. The next step is to construct a matrix *k* which considers nodes with sufficient residual energy (Line-12). It is further followed up by searching total number of alive nodes followed by ranking the sensors on the basis of their residual energy (Line-13 to Line-16). This process also assists in obtaining percentile informationof the MAT matrix followed by extracting total number of communicating sensors.

The algorithm constructs a matrix r_{ix} in order to apply random permutation of the matrix of value equivalent to length of t_x. For all the communicating nodes (n_1 is in percentile), the proposed system applies a function *f*(x) that performs reduction of energy. The complete process of implementation assists in obtaining information related to residual energy, number of nodes that still have good residual energy left, and utilization degree. Therefore, the proposed system offes a comprehensive solution using simple approach for maintaining good balance between data reliability and energy efficiency. The proposed system also ensures that there is always a lesser extend of overhead factor as complete process of selection is carried out by the pervasive network or any other form of networks. However, the algorithm is required to be run not only among the sensors but also within the gateway node too. The next section outlines the outcomes that are obtained after implementing the above mentioned algorithm of the proposed system.

3.   RESULT ANALYSIS

This section discusses about the outcome obtained from the implementation of the proposed system. The study considers that there is only single pervasive unit and 10 users with 10 different number of sensor networks where the user resides. The analysis of the proposed study was carried out using 500-1000 sensor nodes with a presence of one singlegateway node that performs the heterogenous communication system. The simulation area of 1000x1200 m^2 is considered with 50 meter as the transmission range and 10 joules of initialized energy. Considering 1000 data packets and 10 bytes of packet length, the analysis is carried out considering four performance parameters that are discussed as below. The study is also compared with existing LEACH [36] and PEGASIS [37] for assessing their performance.

Figure 2 highlights the comparative analysis of the utilization degree that directly relates to the data reliability of transmitted data of the sensor node. The outcome shows that proposed system offers better data utilization factor as compared to exitsing LEACH and PEGASIS algorithm. The prime reason behind this is LEACH offers centralized data aggregation scheme which increases maximum events of the data redundancy as well as stale data whose utilization factor is very less. At the same time, PEGASIS uses chain-based data aggregation approach that does not caterup the dynamic demands of multiple data points to single heterogeneous network.
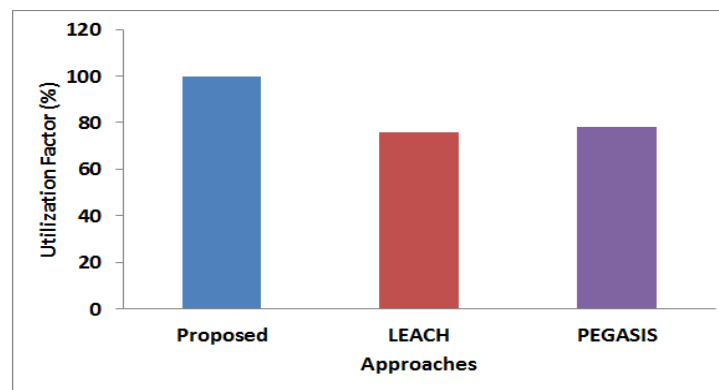

Figure 2. Comparative analysis of utilization factor

3.1.   Performance evaluation

The proposed system offers streamline capability to forward only reliable data that is selected by the pervasive network on the basis of time and sensor network. Figure 3 and Figure 4 offers the comparative performance analysis with respect to energy efficiency. A closer look into the graphical outcomes will show that proposed system offers significant level of energy saving by retaining maximum remaining energy and number of nodes in contrast to existing system. The prime reason behind this is majority of the task of forwarding the data packet is outsourced to the pervasive network via gateway node on the basis of the sensor network and specific prioritization level. This will mean that on the basis of data priority level as well as location of origination point of data, the proposed system performs the complete process of data aggregation. This operation offers significantly lesser amount of load on any node (member / clusterhead) causing saving of residual power (Figure 3) that directly ensures more number of alive nodes till the end of simulation (Figure 4). However, LEACH and PEGASIS offers highly iteratve steps along with no much ensurity of data reliability. This causes adverse effect on data utilization factor that significantly increase the process of data retransmission causing more depletion of energy in WSN.

The proposed system is also computationally cost effective as it offers significantly lesser computational resources as well as time to perform processing. The complete algorithm is less iterative in its modeling and it encourages more progressive operation that leads to potential reduction in processing time. Apart from this the algorithm does not need any extra gain on memory system in order to offer compiled-based outcome that are quite realistic in nature. Hence, the algorithm offers both time and space complexity reduction capability to show that it is cost effective solution to ensure a good balance between data reliability and energy efficiency. The proposed system has been developed in matlab under normal 32-bit windows platform.
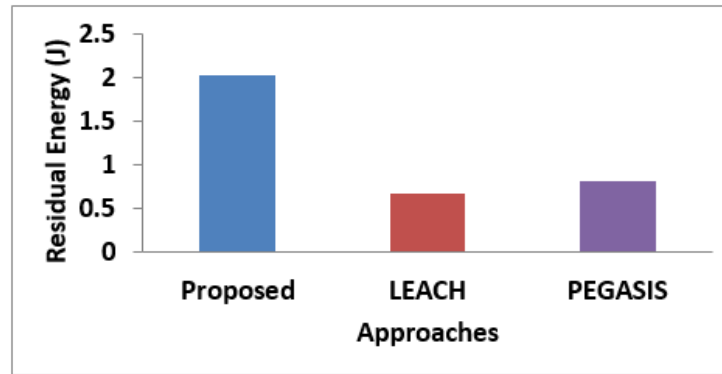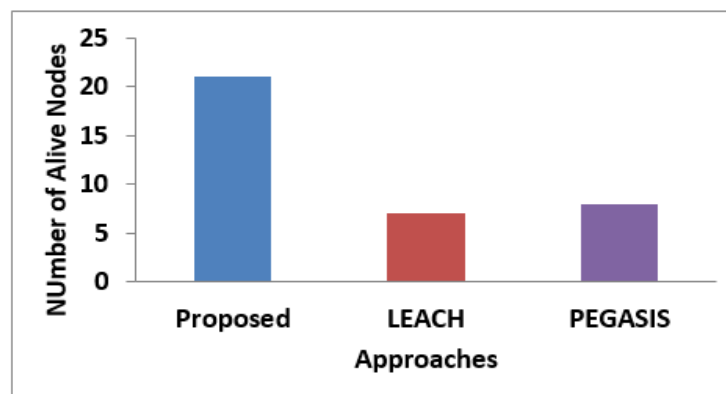
Figure 3. Comparative analysis of residual energy

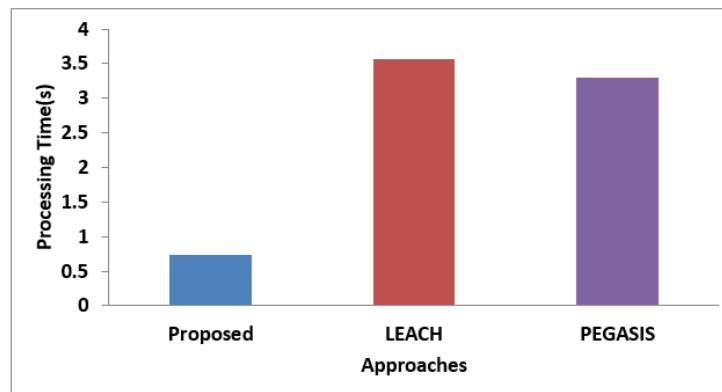

Figure 4. Comparative analysis of alive nodes

Figure 5. Comparative analysis of processing time

4. CONCLUSION

This paper introduced a method where a selective transmission is carried out using many to one direction. The complete network is divided into many forms of WSN which performs *many* communications with *one* pervasive network via gateway system. The significant contribution of the proposed systems are as follow i) the proposed system offers selective transmission scheme that is significantly beneficial for all the heterogenous network with emergency-sensory application, ii) the proposed system offers good saving of dissipation power among the sensors irrespective of its number of deployment, iii) the processing speed of the proposed system is significantly faster than any existing standard energy efficienct algorithms, and iv) the utilization degree offers direct usability of the aggregated data in the WSN.

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