Traffic and Energy Aware Routing for Heterogeneous Wireless Sensor Networks

1 P. Vijay Bhaskar Reddy 2 M. Padmavathi
1 Assistant Professor, Dept. of Master of Computer Applications, Narayana Engineering College, Gudur.
2 PG Scholar, Dept. of Master of Computer Applications, Narayana Engineering College, Gudur.

Abstract — The energy-efficiency of routing algorithm is crucial for improving the lifetime of battery constrained Wireless Sensor Networks (WSNs). The consideration of nodes heterogeneity in routing is essential for achieving optimal resource utilization. This letter considers sensor nodes with random initial energies and random disparities in data generation rate (traffic) to model a realistic clustering based WSN suited for heterogeneous sensing applications. The letter presents an energy model for the scenario and proposes a Traffic and Energy Aware Routing (TEAR) scheme to improve the stability period. The simulation results indicate that TEAR outperforms other clustering based routing algorithms under the scenario.

Index Terms— Wireless sensor networks, routing protocols, heterogeneity, clustering, stability period

I. INTRODUCTION

Internet of Things (IoT) envisions interoperability of heterogeneous devices to support diverse applications, and the Wireless Sensor Network (WSN) technology is an important building block of IoT sphere. Consideration of heterogeneity (e.g., energy, link and computational heterogeneities) [1] can improve the performance of WSN routing algorithms in terms of network lifetime, stability, reliability, network delay, etc. The energy heterogeneity in WSN routing is pursued widely; however, the link and computation heterogeneities, which are generally used along with the energy heterogeneity, are relatively less explored areas.

In the early work in WSN routing algorithms for energy heterogeneous scenarios, Stable Election Protocol (SEP) [2] considers two-level energy heterogeneity in Low-Energy Adaptive Clustering Hierarchy (LEACH) [3] like cluster-head (CH) role rotation environment. SEP proposes weighted election probabilities based on the initial energies of the nodes to give energy-rich nodes more chances of becoming CHs. The Distributed Energy-Efficient Clustering (DEEC) [4] considers multi-level energy heterogeneous WSN and prefers nodes with higher initial energy and residual energy for CH role.

The heterogeneity in terms of disparities in data generation rate (traffic) is considered under computation heterogeneity [5]. Sharma et al. [6] analyzed the effect of traffic heterogeneity in homogeneous WSN routing (LEACH) algorithm. Energy Dissipation Forecast and Clustering Management (EDFCM) [5] considers traffic heterogeneity along with energy heterogeneity in a very specific two-level WSN. Further, EDFCM considers additional nodes (management nodes) to control the number of clusters, which makes its natural distributed localized decision-making behavior questionable. The consideration of traffic heterogeneity along with energy heterogeneity is crucial for modeling realistic WSNs with application heterogeneity and event-driven scenarios.

This letter considers both, energy and traffic heterogeneities, with multiple random levels. An energy model is presented for the multi-heterogeneity scenario, where consideration of multi-level traffic heterogeneity is a novel concept. A novel routing algorithm named Traffic and Energy Aware Routing (TEAR) is presented, which considers node’s traffic requirements along with its energy levels while making CH selection. TEAR shows improvements in terms of stability period (reliable lifespan of the WSN before the death of its first node) over existing algorithms (LEACH, SEP and DEEC) under the scenario.

The rest of this letter is arranged as follows. Section II presents the system model, which includes the energy model for the multi-heterogeneous scenario. In Section III, the proposed routing algorithm is described. The simulation results have been discussed in Section IV. Finally, Section V concludes the letter.

II. SYSTEM MODEL

Considering the basic radio model [3], the transmitter (Tx) considers energy dissipation in the radio electronics and the power amplifier, and the receiver (Rx) considers the radio electronics dissipation. The energy spent in transmitting an mi-bits message over a distance d is given by $ETx(mi) = mi.Eele + mi.eff.s.d2 \text{ if } d < d0$ $mi.Eele + mi.emp.d4 \text{ if } d \geq d0$ (1) Where $Eele$ is the electronic circuit’s per bit energy dissipation of the transmitter or the receiver, and the per bit energy dissipation in transmitter amplifier is represented by $e f s.d2$ or $emp.d4$ depending on the free space or the multipath transmitter amplifier model respectively (based on $d0 \text{ = efs.emp}$). $efs$ and $emp$ are fixed radio parameter related to $Tx$ amplifier’s energy dissipation in free space and multipath scenarios respectively. The energy dissipated in receiving an mi-bits message is given by $Rx(mi) = mi.Eele$ (2) Consider ing the clustering based approach [2-6], with N heterogeneous nodes uniformly distributed (spatially) in a square region (RxR). The base-station/sink (BS) is located at the centre of the region [2, 4, 5] and all the nodes are within a range of distance d0 (free space model) from the BS. The nodes send their data to their respective CH, which aggregates the member nodes’ data and forwards the aggregated message to the BS. The initial energies of the nodes are

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randomly distributed over $[E0,(1+aehi)]$ to represent a realistic energy heterogeneous deployment, where $E0$ is the energy heterogeneity factor controlling the upper bound. The total initial energy of the WSN is given by

$$E_{Total} = \sum_{i=1}^{N} E01+aehi$$

(3) Where aehi is the energy heterogeneity factor for node $i$. Further, to support heterogeneous sensing/computing requirements in terms of data-generation/traffic (i.e. the number of bits in data-messages), the data-message length of the node $i$ with traffic heterogeneity factor athi is given by $m_i = m01+athi$, which is randomly distributed over $[m0,m0(1+athi)]$, where $m0$ is the lower bound and athi is the traffic heterogeneity factor controlling the upper bound. It is assumed that the system fulfills the bandwidth requirements to support such heterogeneity. Based on [2-4], for uniformly distributed nodes the average distance between the cluster member nodes and the CH (dtoCH), and the average distance between the CHs and the BS (dtoBS) are given by

Where $k$ represents the number of clusters. Based on [3], the total energy dissipated in one round is given

$$dtoCH=R/2nk$$
$$dtoBS=0.765 R/2$$

Where $k$ represents the number of clusters. Based on [3], the total energy dissipated in one round is given by

$$ERound=(ECH+N/k−1) EnonCH$$

$$k.ECH+N EnonCH$$

(6)

Where $ECH$ and $EnonCH$ are energies dissipated in a CH node and a non-CH node respectively. The energy dissipated in $N$ non-CH nodes in a round is given by

$$N EnonCH=\sum(m_i.Eele+ml_e.f.s.d2toCH)$$

(7)

Considering (4), (7) and $aTota=\sum athi N =1$

$$N EnonCH=m0(N+aTo)(Eele+ef.sR2 2nk)$$

(8)

The CH aggregated message which is sent from any CH to the BS is $m_{max}=m0(1+athi)$ bits long. The energy dissipated in the $k$ CH nodes in one round in receiving $N-k$ member nodes data, aggregating the information and transmitting $k$ CHs data to the BS is given by

$$k The Traffic and Energy Aware routing in sensors nodes have limited and non-replenishable energy supplies. Non-uniform traffic patterns are common, so particular nodes may burn out quickly if energy is not considered. Other routing techniques have major shortcomings is idealized multicast requires many control packets Full-network flooding is very wasteful. Packets are routed to a particular node (or set of nodes) based on a destination node id in the packet. Packets are routed to a target region instead of a particular Data-centric nature of sensor networks makes this appropriate. Estimated cost degenerates to greedy geographic forwarding when energy levels are equal. Once packet reaches target region, need to disseminate it to all nodes. Flooding in target region too energy expensive, since each node needs to broadcast and all of its neighbours need to listen. Instead packets are sent to recursively smaller sub-regions. Current node’s neighbours are all energy deleted. Packet is near the target region.

III. PROPOSED ROUTING ALGORITHM

This section first discusses in brief the effects of energy and traffic heterogeneities, which provides insight for an effective CH selection in multi-heterogeneity scenario. Then, the proposed routing protocol is presented, which considers nodes’ initial energy, residual energy and traffic load along with the average energy of the round during CH selection. A. Traffic and Energy Heterogeneities in WSN An increase in traffic heterogeneity, by increasing nodes’ packet lengths, increases the effective number of bits per round for communication. This increases the WSN energy consumption per round and reduces the WSN lifetime (and the stability period). The effect is discussed further in Section IV based on simulation results. The Traffic and Energy Aware routing in sensors nodes have limited and non-replenishable energy supplies. Non-uniform traffic patterns are common, so particular nodes may burn out quickly if energy is not considered. Other routing techniques have major shortcomings is idealized multicast requires many control packets Full-network flooding is very wasteful. Packets are routed to a particular node (or set of nodes) based on a destination node id in the packet. Packets are routed to a target region instead of a particular Data-centric nature of sensor networks makes this appropriate. Estimated cost degenerates to greedy geographic forwarding when energy levels are equal. Once packet reaches target region, need to disseminate it to all nodes. Flooding in target region too energy expensive, since each node needs to broadcast and all of its neighbours need to listen. Instead packets are sent to recursively smaller sub-regions. Current node’s neighbours are all energy deleted. Packet is near the target region. Packets delivered before network partition Connectivity after network partition. Now the energy efficiency of TEAR is evident, since far fewer pairs are disconnected per delivered packet also has much better connectivity after partition.
As the field of wireless sensor networks (WSN) is based on numerous other domains, it is recommended that students have taken courses such as networking and operating systems (or comparable courses) before they take a course on sensor networks. This chapter discusses definitions and background of WSN. While sensor networks share many similarities with other distributed systems, they are subject to a variety of unique challenges and constraints. These constraints impact the design of a WSN, leading to protocols and algorithms that differ from their counterparts in other distributed systems. The chapter describes the most important

Fig. 1. Energy consumption pattern of traffic heterogeneous nodes

The nodes residual energies are analyzed over the WSN lifetime for different traffic heterogeneous scenarios (i.e., for different ath with aeh=0). Fig. 1 shows the energy consumption pattern over the rounds of operation for a traffic heterogeneous scenario (ath=2; aeh=0) in DEEC environment. E(r) is the residual energy of node i for the round r. It shows that the nodes with higher traffic load (i.e., higher ath) lose their energies faster in comparison to the nodes with lower traffic loads over the rounds of operation. Under two-level energy heterogeneous WSN, SEP performs better than LEACH by preferring nodes with higher initial energy for CH role. DEEC performs better than LEACH and SEP under multi-level energy heterogeneous WSN by preferring nodes (for CH role) with higher initial and residual energies over the average energy of the round. B. Traffic and Energy Aware Routing (TEAR) The CH selection in TEAR is based on the CH role rotation approach [2-4], where the node i becomes a CH in the current round r, if the random number selected by the node i is less than the threshold T(i, r).

\[
T(i,r)=\begin{cases} \frac{pi(r)}{1-pi(r)} & \text{if node } i \in G(r) \\ 0 & \text{otherwise} \end{cases}
\]

Where round r. (r) is a set of eligible nodes for the round r, where the rotating epoch for node i to become eligible again is 1/pi(r). DEEC considers randomly distributed energy heterogeneity and prefers nodes with higher initial and residual energies for CH role, i.e., an energy-rich node has higher p(r) and higher chances of becoming CH. As the operations of a CH are energy intensive, preferring nodes with higher initial energies and higher residual energies improves the life of energy weaker nodes and hence it improves the WSN stability period. Section IIIA discusses that an increase in traffic loads increases the effective number of bits to be communicated to the BS and hence increases network energy consumption. In traffic heterogeneous scenario, the rate of energy consumption is higher for the nodes with higher traffic loads. So, it is logical that such nodes should be avoided for energy intensive operation, e.g., CH role. For a realistic WSN model, with the nodes having heterogeneous initial energies and data traffic requirements, the proposed algorithm (TEAR) prefers the nodes with higher energies (initial and residual) and avoids the nodes with higher traffic loads for CH role.

In TEAR, the probability of becoming CH for node i during round r is defined as

\[
p(i)=\text{popt} N (1+ath-aeh) Ei(r) / N + \sum aeh N \approx (1+N+ath-aTot) EAvg(r) \tag{15}
\]

Where \( EAvg(r) \) is average energy of the round and \( \text{popt} \) is optimal probability of a node to become CH, given by \( \text{p opt}= kopt / N \). The remaining functionality of TEAR is similar to DEEC. Further, in the absence of traffic heterogeneity, TEAR falls back to DEEC behaviour. Based on DEEC, the \( EAvg(r) \) is given by

\[
EAvg(r)=1/N \text{ETot}(1-r R); \text{ where } R = \text{ETot ERound}
\]

Where R is the estimated value of network lifetime in terms of the number of rounds based on uniform energy drainage in each round. In actual scenario, the network energy may not drain. In a uniform manner and few nodes remain alive for \( r>R \). Based on (16), when r approaches R, \( EAvg(r) \) becomes a very small quantity and for \( r>R \) it becomes a negative quantity. In DEEC, R is considered 1.5 times of the estimated value to avoid the situation where the last few remaining nodes stay alive and do not form clusters. Many approaches have been proposed in the literature to improve the accuracy of estimated energy per round, e.g., SEARCH [7] considers a semi-centralized approach, where BS keeps track of alive nodes and their residual energies to estimate the average residual energy of the network over the rounds of operation. This letter focuses on heterogeneity aspects and a simple approach is applied to handle the scenario. The \( EAvg(r) \) is considered as the value \( EAvg(0.9R) \) for the ensure active participation of remaining nodes in cluster formation for the remaining rounds. This is a better approach for distributed decision-making as nodes are aware of R and it can handle the scenarios, where r is much greater than R. The values of ETot and R are calculated and supplied (through BS broadcast message or node’s initial settings) to the nodes before the beginning of WSN operations.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of sensor nodes (N)</td>
<td>100</td>
</tr>
<tr>
<td>WSN Area (RxR)</td>
<td>100m x 100m</td>
</tr>
<tr>
<td>Initial energy lower bound (E0)</td>
<td>0.5J</td>
</tr>
<tr>
<td>Energy consumed in Tx/Rx electronics (εeεle)</td>
<td>50 nJ/bit</td>
</tr>
<tr>
<td>Energy consumed in Data Aggregation (EDA) 5 nJ/bit</td>
<td></td>
</tr>
<tr>
<td>Amplifier energy dissipation in free space (εmp)</td>
<td>10pJ</td>
</tr>
<tr>
<td>Tx Amplifier energy dissipation in Multipath scenario (εmp)</td>
<td>0.0013 pl/bit/m4</td>
</tr>
</tbody>
</table>

**IV. RESULTS AND DISCUSSION**

The simulation setup considers 100 nodes (N), with randomness in energy and traffic levels, deployed uniformly in a 100m x 100m (RxR) area with BS located at the centre of the region. The system model for the multi-heterogeneity approach is based on Section II. All the scenarios have been simulated in MATLAB and the
simulation parameters are detailed in TABLE I. LEACH and SEP have been modified to support multi-level energy heterogeneity based on [4]. Further, the algorithms are customized to support energy consumption in multi-level traffic heterogeneity, where nodes consider their specific traffic and the aggregated message sent from CH to BS is mmux bits long. To handle the traffic heterogeneity in DEEC, it has been extended based on the above sections (except the proposed probability function for TEAR). Fig. 2 shows the effect of multi-level traffic heterogeneity on LEACH, SEP and DEEC algorithms in the multi-level energy heterogeneous scenario. An increase in node packet size (from \( a_{th}=0 \) to \( a_{th}=2 \)), while maintaining the energy heterogeneity \( (a_{eh}=3) \), deteriorates the stable region of all the three algorithms.

The performance of proposed algorithm (TEAR) under multi-heterogeneity scenario is depicted in Fig. 3 for \( (a_{th}=4; a_{eh}=1) \), where the stability periods are 285, 280, 291 and 379 for LEACH, SEP, DEEC and TEAR respectively. Fig. 4 shows a similar scenario for \( (a_{th}=2; a_{eh}=1) \), where the stability periods are 521, 448, 567 and 614 for LEACH, SEP, DEEC and TEAR respectively. TEAR shows improvement in the stability period over LEACH, SEP and DEEC algorithms under the multi-heterogeneity scenario. The detailed results of TEAR under different heterogeneity parameter \((a_{th} \text{ and } a_{eh})\) are shown in TABLE II, where each instance (mean and standard deviation) is based on analyzing the algorithm on a set of ten random WSN deployments.

The number of messages transmitted to the base station is reduced by data aggregation and fusion, which reduces the overall energy consumption. Cluster-based routing is mainly implemented as a two-layer strategy. One layer is used to select cluster heads, and the other layer is used for routing. High-energy nodes can be used to process and send information, whereas lowenergy nodes can be used to perform sensing in close proximity to the target. The clustering algorithm is based on cluster selecting, which incurs an additional energy cost. The other type is centralized routing, which uses probabilistic forwarding or an optimization strategy, such as ant colony optimization, linear programming, or heuristic approaches, to find an energy-balanced route based on the global information on the network topology and energy consumption. However, most existing energy-aware routing algorithms assume that energy consumption in WSNs is evenly distributed or that a WSN is deployed as a specific scenario when analyzing the validity of its routing algorithm. primary objectives of the wireless sensor design are balancing network energy consumption and extending the entire network lifetime. The analyses the effectiveness of LEACH protocol in cluster-head selection, and proposes an improved clustering algorithm. This new algorithm takes nodes residual energy and location information into account, optimizes the selection method of the threshold for electing cluster-head, improves optimal cluster-head selection strategy that is normal nodes select the optimal cluster-head based on the cost.

Each of these network’s logical ingredients is interrelated and indispensable for a safe, secure, reliable, effective, and efficient communication between the interacting nodes of near or far distant networks. All of these logical ingredients are measured and finalized at the node and utilize its resources. Furthermore, wireless sensor network is a synergistic mating of wireless communication, sensor, and network technology. Apart from other inherent issue from the wireless and ad hoc network as mentioned in the previous section, induction of ideas in WSN is confined by its stringent constraint factors of computational power, memory, and bandwidth. Along with these, node energy is another limitation in the domain of WSN. The cause of this pervading issue is in-general battery operated and unattended deployment of WS nodes. Also, replenishment of battery is almost impossible due to inaccessible and far distant deployment of nodes in most of the applications. Since the node energy is the most participating factor in the completion of any task relating to the above issue, any of the presenting solutions in any aspect of WSN domain considers this very factor in its idea. Proposed Projects are beneficial only if they can be turned out into information system. That will meet the organizations operating requirements. Operational feasibility aspects of the project are to be taken as an important part of the project implementation. Some of the important issues raised are to test the operational feasibility of a project. The aspect of study is to check the level of acceptance of the system by the user. This includes the process of training the user to use the system efficiently. The user must not feel threatened by the system, instead must accept it as a necessity. The level of acceptance by the users solely depends on the methods that are employed to educate the user about the system and to make him familiar with it. His level of confidence must be raised so that he is also able to make some constructive criticism, which is welcomed, as he is the final user of the system. This system is targeted to be in accordance, the management issues and user requirements have been taken into consideration. So there is no questions of resistance from the users that can undermine the possible application benefits. The purpose of design phase is to plan a solution of the problem specified by the requirement document. This project is the first step in moving from the problem domain to solution domain. In other words, starting with what is needed for design takes us towards how to satisfy the needs. The design of a system is perhaps the most critical factor affecting the quality of the software. I has the major impact on the later particularly testing and
The flow of information through the system and the activities that process this information. Data-flow diagrams provide a graphical representation of the system that aims to be accessible to computer specialist and non-specialist users alike. The models enable software engineers, customers and users to work together effectively during the analysis and specification of requirements. Although this means that our customers are required to understand the modeling techniques and constructs, in data-flow modeling only a limited set of constructs are used, and the rules applied are designed to be simple and easy to follow. These same rules and constructs apply to all data-flow diagrams (i.e., for each of the different software process

The node that makes way for a node to communicate its packet to other nodes in a network or the base station is called forwarding node and the process of finding such node is referred to as forwarding node selection. According to a broadcast process, the source and a subset of nodes form a flooded tree such that any other node in the network is adjacent to a node in the tree. Nodes on the tree are called forward nodes and form a connected dominating set. Forwarding node is/must be in the footprint of the current node. Forwarding node selection is the key step in route discovery, reroute discovery, and void bridging. For these to complete, the efficiency of any routing protocol depends mostly on the selection of a node that may lead its data to the destination. In case of clustered network architecture, forwarding node for a cluster member node can be cluster head (CH) or other nodes and then the CH depending upon the communication scenario. The selection parameter can be energy, distance to destination (BS), nodal density (node degree), feasible position, time to reach to BS, hop count to BS, or the combination of these. So, a sensible decision for selecting a most suitable node for forwarding the message/data to the targeted destination node matters a lot in the success of any routing application. The selection parameters for forwarding node vary with the intended application, but in all cases, energy conservation is/should be considered, since energy is the stringent constraint factor in wireless sensor network. Moreover, a better trade off is also required among the competing selection parameters. For example, in realtime application energy, time and distance to destination (BS) are the competing factors. Which have contributed their rich article in the literature. This article targets the combined effect of broadcasting and forwarding node in designing the protocols for networks with scarce resources. The ad hoc and wireless sensor network can be the examples of such networks. The taxonomy of broadcast routing protocols and nature of algorithms is also given in the article. The constituent nodes that assist a packet to direct to the destination node(s) make the route, and those constituent nodes of those routing paths are called the route nodes.

![Graph showing Number of alive nodes vs Number of rounds for various algorithms](image)

**Fig. 4.** Stability period in Multi-heterogeneous WSN

These all have their strong impact not only on the efficient routing positively but also on its energy consumption aspect negatively. This severity becomes more intense in case of a large-scale network. Hence big routing table squeezes more network energy along with pessimistically affecting other network parameters. Since the cluster-based network is more organized than flat based sensor network, establishing and maintaining the updated routing table in the clustered network are comparatively less costly than in flat networks. Due to these very reasons, exchange of routing table is not appreciated to be included in routing algorithm unless direly needed in special case of routing which is affiliated to the requirements of routing algorithm or underlying application. Introducing the routing table is more common in the static wireless sensor network as compared to mobile wireless sensor network. Its management is a big challenging task and in some cases almost impossible as in the scenario with high mobility of nodes. Routing table designing strategies, its requirements, and its challenges.

The results show that the extended version of SEP (based on [4]) do not perform well under traffic heterogeneity scenarios. As SEP considers initial energies in CH selection, it does not perform well with increase in traffic loads. DEEC better handles (over SEP) the increase in traffic heterogeneity, as it also considers node’s residual energy. TEAR shows improved performance with increased traffic as it additionally considers the traffic loads while making CH decision. In the absence of traffic heterogeneity, TEAR performs like DEEC. However, TEAR performs better than all the three algorithms in the presence of traffic heterogeneity. The Distributed Energy-Efficient Clustering (DEEC) considers multi-level energy heterogeneous WSN and prefers nodes with higher initial energy and residual energy for CH role.
The heterogeneity in terms of disparities in data generation rate (traffic) is considered under computation heterogeneity. Sharma analyzed the effect of traffic heterogeneity in homogeneous WSN routing (LEACH) algorithm. Energy Dissipation Forecast and Clustering Management (EDFCM) considers traffic heterogeneity along with energy heterogeneity in a very specific two-level WSN. Further, EDFCM considers additional nodes (management nodes) to control the number of clusters, which makes its natural distributed localized decision-making behaviour questionable. The consideration of traffic heterogeneity along with energy heterogeneity is crucial for modeling realistic WSNs with application heterogeneity and event-driven scenarios. This letter considers both, energy and traffic heterogeneities, with multiple random levels. An energy model is presented for the multi-heterogeneity scenario, where consideration of multi-level traffic heterogeneity is a novel concept. A novel routing algorithm named Traffic and Energy Aware Routing (TEAR) is presented, which considers node’s traffic requirements along with its energy levels while making CH selection. TEAR shows improvements in terms of stability period (reliable lifespan of the WSN before the death of its first node) over existing algorithms (LEACH, SEP and DEEC) under the scenario. The rest of this letter is arranged as follows. Section II presents the system model, which includes the energy model for the multi-heterogeneous scenario. In Section III, the proposed routing algorithm is described. The simulation results have been discussed in Section IV. Finally, Section V concludes the letter. The Traffic and Energy Aware routing in sensors nodes have limited and non-replenishable energy supplies. Non-uniform traffic patterns are common, so particular nodes may burn out quickly if energy is not considered. Other routing techniques have major shortcomings is idealized multicast requires many control packets Full-network flooding is very wasteful. Packets are routed to a particular node (or set of nodes) based on a destination node id in the packet. Packets are routed to a target region instead of a particular Data-centric nature of sensor networks makes this appropriate. Estimated cost degenerates to greedy geographic forwarding when energy levels are equal. Once packet reaches target region, need to disseminate it to all nodes. Flooding in target region too energy expensive, since each node needs to broadcast and all of its neighbours need to listen. Instead packets are sent to recursively smaller sub-regions. Current node’s neighbours are all energy deleted. Packet is near the target region Packets. Current node’s neighbours are all energy deleted. Packet is near the target region Packets delivered before network partition Connectivity after network partition. Now the energy efficiency of TEAR is evident, since far fewer pairs are disconnected per delivered packet also has much better connectivity after partition. As the field of wireless sensor networks (WSN) is based on numerous other domains. The number of messages transmitted to the base station is reduced by data aggregation and fusion, which reduces the overall energy consumption. Cluster-based routing is mainly implemented as a two-layer strategy. One layer is used to select cluster heads, and the other layer is used for routing. High-energy nodes can be used to process and send information, whereas low-energy nodes can be used to perform sensing in close proximity to the target. The clustering algorithm is based on cluster selecting, which incurs an additional energy cost. The other type is centralized routing, which uses probabilistic. The feasibility of the project is analyzed in this phase and business proposal is put forth with a very general plan for the project and some cost estimates. During system analysis the feasibility study of the proposed system is to be carried out. This is to ensure that the proposed system is not a burden to the company. For feasibility analysis, some understanding of the major requirements for the system is essential. The main objective of the feasibility study is to test the Technical, Operational and Economical feasibility for adding new modules and debugging old running system. All system is feasible if they are unlimited resources and infinite time. There are aspects in the feasibility study portion of the preliminary A System can be developed technically and that will be used if installed must still be a good investment for the organization. In the economical feasibility, the development cost in creating system is evaluated against the ultimate benefit derive from the new systems. Financial benefits must equal or exceed the costs. The system economically feasible. It does not require any addition hardware or software. Since the interface for this system is developed using the existing resources and technologies available at NIC. There is nominal expenditure and economical. Implementation is the stage where the theoretical design is turned into working system. The most crucial stage is achieving a new successful system and in giving confidence on the new system for the users that it will work effectively. The system can be implemented only after through testing is done and if it found to work according to the specification. It involves careful planning, investigation of the current system and its constraints on implementation design of methods to achieve the change over and an evaluation of change over methods a part from planning. Two major tasks of preparing the implementation are training of the users and testing of the system. The more complex the system being implemented, the more involved will be the systems analysis and design effort required just for implementation. The implementation phase comprises of several activities. The required hardware and software acquisition is carried out. The system may require some hardware and software acquisition carried out. The system may require some software to be developed. For this, Programs are written and tested. The user then changes over to his new fully tested system and the old system is discontinued. Implementation is the process of having systems personnel check out and put new equipment in to use, train users, install the new application and construct any files of data needed to it. Depending on the size of the organization that will be involved in using the application and the risk associated with its use, system developers may choose to test the operation in only one area of the firm, say in one department or with only one or two persons. Sometimes they will run the new and old systems together to
compose the results. In still other situations, developers will stop using the old system one day and being using the new one the next. As we will see, each implementation strategy has its merits, depending on the business situation in which it is considered. The nodes residual energies are analysed over the WSN lifetime for different traffic heterogeneous scenarios. Under two-level heterogeneous WSN, SEP performs better than LEACH by preferring nodes with higher initial energy for CH role. DEEC performs better than LEACH and SEP under multi-level energy heterogeneous WSN by preferring nodes with higher initial and residual energies over the average energy of the round. The CH selection in TEAR is based on the CH role rotation approach, where the node I becomes a CH in the current round r, if the random number selected by the node I is less than the threshold T (I, r). Where \( p_i(r) \) is the CH selection probability for node I during round r. \( G (r) \) is a set of eligible nodes for the round r, where the rotating epoch for node I to become eligible again is \( 1/p_i(r) \). DEEC considers randomly distributed energy heterogeneity and prefers nodes with higher initial and residual energies for CH role; an energy-rich node has higher \( p_i(r) \) and higher chances of becoming CH. As the operations of a CH are energy intensive, preferring nodes with higher initial energies and higher residual energies improves the WSN stability period. Testing is a process used to help identify the correctness, completeness and quality of developed computer software. With that in mind, testing can never completely establish the correctness of computer software. There are many approaches to software testing from using ALM tools to automated testing, but effective testing of complex products is essentially a process of procedure. One definition of testing is "the process of questioning a product in order to evaluate it", where the "questions" are things the tester tries to do with the product, and the product answers with its behaviour in reaction to the probing of the tester. Although most of the intellectual processes of testing are nearly identical to that of review or inspection, the word testing is connoted to mean the dynamic analysis of the product—putting the product through its paces. The quality of the application can and normally does vary widely from system to system but some of the common quality attributes include reliability, stability, portability, maintainability and usability. Refer to the ISO standard ISO 9126 for a more complete list of attributes and criteria. Testing helps is verifying and Validating if the Software is working as it is intended to be working. Thins involves using Static and Dynamic methodologies to Test the application. Because of the fallibility of its human designers and its own abstract, complex nature, software development must be accompanied by quality assurance activities. It is not unusual for developers to spend 40% of the total project time on testing. For life-critical software (e.g. flight control, reactor monitoring), testing can cost 3 to 5 times as much as all other activities combined. The destructive nature of testing requires that the developer discard preconceived notions of the correctness of his/her developed software. Integration tests are designed to test integrated software components to determine if they actually run as one program. Testing is event driven and is more concerned with the basic outcome of screens or fields. Integration tests demonstrate that although the components were individually satisfaction, as shown by successfully unit testing, the combination of components is correct and consistent. Integration testing is specifically aimed at exposing the problem that arise from the combination of components. Software integration testing is the incremental integration testing of two or more integrated software components on a single platform to produce failures caused by interface defects. The task of the integration test is to check that components or software applications, e.g. components in a software system or − one step up − software applications at the company level interact without error. Functional test. Functional tests provide systematic demonstrations that functions The numeric field can contain only numbers from 0 to 9. An entry of any character flashes an error messages. The individual modules are checked for accuracy and what it has to perform. Each module is subjected to test run along with sample data. The individually tested modules are integrated into a single system. Testing involves executing the real data information is used in the program the existence of any program defect is inferred from the output. The testing should be planned so that all the requirements are individually tested. A successful test is one that gives out the defects for the inappropriate data and produces and output revealing the errors in the system. Taking various kinds of test data does the above testing. Preparation of test data plays a vital role in the system testing. After preparing the test data the system under study is tested using that test data. While testing the system by using test data errors are again uncovered and corrected by using above testing steps and corrections are also noted for future use. Live test data are those that are actually extracted from organization files. After system is partially constructed, programmers or analysts often ask users to key in a set of data from their normal activities. Then, the systems person uses this data as a way to partially test the system. In other instances, programmers or analysts extract a set of live data from the files and have them entered themselves. It is difficult to obtain live data in sufficient amounts to conduct extensive testing. And, although it is realistic data that will show how the system will perform for the typical processing requirement, assuming that the live data entered are in fact typical, such data generally will not test all combinations or formats that can enter the system. This bias toward typical values then does not provide a true systems test and in fact ignores the cases most likely. Artificial test data are created solely for test purposes, since they can be generated to test all combinations of formats and values. In other words, the artificial data, which can quickly be prepared by a data generating utility program in the information systems department, make possible the testing of all login and control paths through the program. The most effective test programs use artificial test data generated by persons other than those who wrote the programs. Often, an independent team of testers formulates a testing plan, using the systems specifications. The package “Virtual Private Network” has satisfied all the requirements.

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specified as per software requirement specification and was accepted. A strategy for system testing integrates system test cases and design techniques into a well planned series of steps that results in the successful construction of software. The testing strategy must co-operate test planning, test case design, test execution, and the resultant data collection and evaluation. A strategy for software testing must accommodate low-level tests that are necessary to verify that a small source code segment has been correctly implemented as well as high level tests that validate major system functions against user requirements. Software testing is a critical element of software quality assurance and represents the ultimate review of specification design and coding. Testing represents an interesting anomaly for the software. Thus, a series of testing are performed for the proposed system before the system is ready for user acceptance testing.

V. CONCLUSION

Consideration of multi-heterogeneity in WSN routing algorithms can help in achieving optimal resource utilization in realistic scenarios. This letter considers WSN nodes with random levels of energy and traffic heterogeneities. It devises a traffic and energy aware routing (TEAR) technique with an improved CH selection method, which considers node’s traffic along with its initial energy and residual energy. TEAR performs better, in terms of stability period, over legacy algorithms (LEACH, SEP and DEEC) in the multiheterogeneous scenario. Further, the multi-heterogeneity concept (especially the traffic heterogeneity consideration) could be helpful in developing more effective routing algorithms for realistic WSNs and Internet of Things applications with heterogeneous sensing requirements.

REFERENCES
