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An Unified Deployment Framework for Realization of Green Internet of Things (GIoT)

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Abstract: Objects with unique identification play an important role in acquiring data facts from environment. Internet of Things (IoT) establishes connecting platform between the computerized and the physical world. Since the networking of objects in IoT is expansible and intricate, the IoT cannot be directly injected into existing Wireless Sensor Network (WSN) schemes such as exact, adhoc. It introduces need for Unified Deployment Framework exclusive for IoT. Besides, energy efficient IoT i.e., Green Internet of Things (GIoT) is also exigency. The objective of paper focuses on increasing energy efficiency, extending network lifetime, reduction of number of relay nodes and reduction in system budget. The objective can be procured by implementing the four modules, namely 1) creation of hierarchical system framework and Placement of sensor/actuator nodes, relay nodes and base stations, 2) clustering the nodes, 3) creation of optimization model to realize GIoT and 4)calculation of minimal energy among the nodes. The Unified Deployment Framework proposed in this paper is pliable, energy-saving and cost-effective when compared with the existing WSNs deployment scheme. Hence it is well suited for the Green Internet of Things GIoT.

Key words: Sensors · Energy · Deployment framework · Green computing · Internet of Things (IoT)

INTRODUCTION

The Internet of Things is one of the booming domains, which completes task in a sophisticated manner. Generally, the IoT includes all the objects in the world with unique identification and it is connected to the Internet. Sensors, actuators, mobile phones and RFID tags are some of the objects in IoT domain which can perceive the environmental data and sends it to the destination point through internet. Sensors are the objects which is capable of sensing of acquiring the parameters of the environment. Sensors involved in the perception of data might be temperature sensor, motion sensor, light sensor and so on. When considering Actuator it is the matter of responding to the commands from remote monitors. Examples of actuators are relay, stepper motor and so on. Colossal number of sensors and actuators has to be deployed for covering large area. The Objects in IoT observes data from the environment and it is sent to the terminal point through wired and/or wireless communication. It has become the efficacious tool to understand environment's status through acquiring data from environment and act/react to the crucial and emergent events. The furtherance of IoT brings challenges in implementation. The IoT differs a lot from existing WSNs, in many ways such as scaling and intricate. This instigate barrier in injecting the most of the current WSNs deployment scheme directly into the IoT. In consequent, need for unified deployment framework is a challenging concept. To find a solution for the existing incompatibility, we have come with Hierarchical based Unified Deployment Framework, which can be injected directly in to the IoT. Even if the number of sensors, actuators, relays and base stations increases, the Unified Deployment Framework is still efficacious. In akin to compatibility of adapting WSNs deployment scheme, the green issues are taken into account. Although the sensors and actuators, given source of power to work, still there is an important constraint that sending the data from sensor to the destination, involves large

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consumption of energy which is not prevalent in IoT. When considering IoT, the power source for sensors and actuators is a concern. Having lots and lots of objects involved in IoT, the consumption of power by all the objects is to be considered. Involving green concepts in networking, results in reduced emission of heat, least amount of energy consumption by sensors, minimization of operational and implementation costs and finally the power consumption by the whole system. Even though the existing WSN scheme, allows us to work with sensors/actuators, there is a constraint of deploying sensor/actuator nodes in an environment leads to consumption of lump sum energy for working. This large amount of energy consumption has to be decreased. While considering the reduction of energy, the feasibility of encompassing green IoT in the unified deployment framework has to be considered. Our proposed scheme is incorporated with 4 modules, which is initiated with the creation of Hierarchical based unified deployment framework and the placement of sensor/actuator nodes, relay nodes [1] and base stations. After creating and placing all nodes in a hierarchical setup, the nodes are clustered based on the distance between the nodes [2]. The Euclidean distance measure is used for clustering sensor/actuator nodes. Based on the resulting centroid values the clustered [9] sensor/actuator nodes are matched with relay nodes and further clustered. The energy consumed by all the nodes to acquire/send data to and from the environment is calculated and optimized energy calculation is implemented. As a result, the minimized energy consumption and the network lifetime in the whole network have been found.

Related Work: The available existing WSN deployment schemes are exact, ad hoc, hierarchy [3] and hierarchy + ad hoc. Basically, the exact scheme is the simplest scheme where the sensors deployed in a distributed manner in the network, which acquires the environmental information, as well as the process of sending and receiving the data to and fro the source and destination. The sensors not only act as the information observers, but also act as the relay node for the other sensor nodes. Although the sensor nodes in exact scheme reaches the reliability and sustainability still, it endure the problem of sensor nodes close to the sink run out of power due to overload. This induces incompatibility of exact deployment scheme to be injected in to an expansible and intricate IoT. The ad hoc also results as that of the exact but the placement of the nodes differs based on practical scenario. Hierarchy scheme allows the nodes to be placed in separate layer such as s/a node in s/a layer, relay in relay layer and base station in base station layer. In this scheme the sensor layers are only meant for acquiring data from the environment and to send those data to the intermediate layer called relay layer. There will not be any sensor acts like a relay layer. The impulse of this system provides the cut off of the overload and drain out problem which was already faced by the existing WSN scheme. Another hybrid approach which establishes the advantage of the hierarchy but still the adhoc's drawback is influenced in the result.

Our proposed work differs from the existing hierarchical scheme for WSNs in many ways such as 1) The hierarchical structure of WSNs is usually formed by a particular clustering algorithm which needs high and strong computing and storage requisites. The proposed work does not require intricate routing function at s/a node because nodes are in static mode. This results in unravel of sensor deployment and reduction in network cost. The relay nodes are deployed beforehand, which allows us to neglect the election of sensing nodes in each cluster. Usually the need for LEACH protocol and computing, storage capabilities for the relay nodes are eradicated. The author in paper [4] implemented the hierarchical framework which allows relays to communicate between them. But they are connected in the tree structure which follows Breadth-First-Search (BFS). In our proposed system, the relay nodes are connected in mesh mode i.e., each and every relay node can communicate with all other relay nodes within its transmission range called communication radius.

Being IoT intricate and expansible, applying unlimited adjustments in transmitting power causes a large amount of overheads for topology and deployment scheme. The strategy of reducing energy introduces the new unified deployment scheme. It addresses new challenges involved in IoT and it is eradicated by following the steps: 1) Considers energy consumption of both transmitting and receiving data for communications among nodes. 2) Link balancing has been introduced to reduce the network load in a particular node. 3) The optimization model vitalizes the increase in network life time as well as reduction in energy consumption. Finally the system budget has been considered and reduced.

System Design: As per the Gartner's prediction it is stated that by 2020 each person will be surrounded with 50, 000 IoT objects [5]. With or without knowledge of the person their data will be viewed by others. This illustrates that the IoT is scalable hence there is a need for alternative solution for the existing WSN schemes. Our proposed system Unified Deployment Framework provides the prompt solution for handling the numerous sensors in WSN and utilizes the energy efficiently. The first module of the System involves creation and placement of nodes. Clustering the sensor/actuator (s/a) nodes, the second module is clustering the relay nodes with s/a nodes. The third module explains about the Optimization model which is created to verify the change in network lifetime and energy consumption. The fourth module delivers the reduction in energy consumption, extending network life time and system budget reduction.

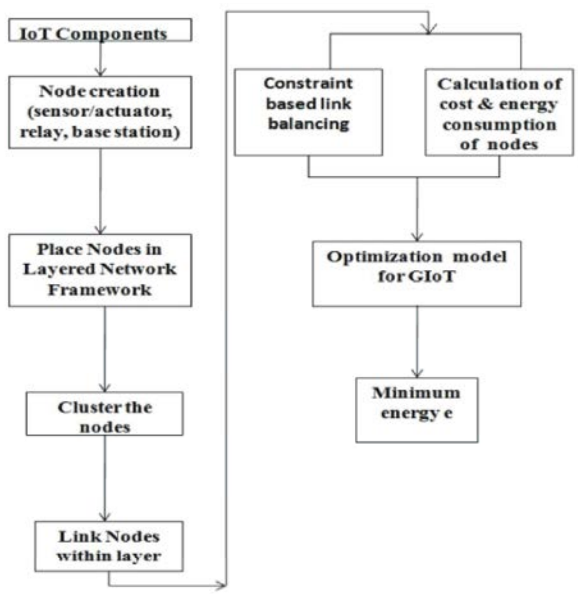


Fig. 1: Overall System Design

Our proposed system starts with the Node creation. It includes sensor/actuator node, relay node and base station node. In the second step the created nodes are placed in a hierarchical based unified deployment framework. Further the placed nodes are clustered using the K-means clustering method which is based on the Euclidean distance measure. The relay nodes are clustered with the s/a node based on the centroid value. For each each s/a node the edge is created from the relay node and linked with the s/a node and the base station. The created links are balanced so that no overload may occur in a particular relay node. Simultaneously the energy for working of the node and transmitting/receiving the data has been calculated and budget for the overall system is calculated. Having completed all the above mentioned tasks the realization of Green IoT is done through the Optimization of the energy consumption. Finally, the minimal energy consumed by the whole system is calculated and System process comes to an end.

Fig. 2: Example of an unified deployment of sensor/actuator nodes, relay nodes and base station in an city environment.

Creation and Placement of Nodes: Fig.2. Shows that example of a unified deployment of sensor/actuator nodes, relay nodes and base station in a city environment. The nodes deployed are 2 base stations, 11 relay nodes and about 40 sensor/actuator nodes. They are hierarchically placed. All s/a nodes sends and receives data to and fro only through the relay node which is above situated. The placement of nodes in a unified deployment environment involves some constraints such as its radius of coverage and its density. In our approach we are considering the static nodes. The nodes are to be placed in an effective location [4] so that the energy utilized can be controlled. The nodes in dynamic modes are not considered, because the dynamic nodes need the dynamic routing which observes more energy and results in less network lifetime.

Hierarchical Approach: There are several nodes present in the network which is statically deployed [6]. All the sensor/actuator nodes are placed in the lowest layer called sensor/actuator layer, upon that the relays are placed in the relay layer, in the top the base stations are deployed in the layer called base station layer. The sensor/actuator in a s/a layer can only have communication with the relay layer. When we consider the relay layer, it is the intermediate layer it can communicate to and from the base station and the s/a layer. The base stations will be communicating with only the relay layer. The sensor/actuator nodes used are temperature sensor, humidity sensors, ultrasonic sensors, Infrared sensors. Each sensor consumes different value of energy.

Communication Policy:

- To any $i \in SA, j \in SA$, i and j cannot be communicated with each other even $d(i, j) \leq sar$
- To any $i \in SA, j \in \text{Re}$ *if* $d(i, j) \leq sar$ i can send data to j.
- To any $I \in \text{Re}, j \in \text{Re} \cup Ba$, *if* $d(i, j) \leq$ Re i and j can reach each other.

where,

SA - Set of Sensor/Actuator nodes
A - Set of Actuator node
Re - Set of Relay nodes
Ba - Set of Base station nodes
sar >0 - Sensor/actuator node radius
rer > = sar - Relay node radius
bar (large) - Base station node adius
d (i, j) - Distance of node i from node j

Let x, y be the two points in Euclidean plane, d(x, y) be the distance between x and y. G(N, Ws) denotes the entire network of IoT. Fig. 3 shows the placement of all nodes in a hierarchical [7] based deployment framework and reveals about the policy which emphasizes that the radius we are fixing will induce a change in the relay node placement as well as the energy consumption.

Initial Setup of Node:

- All nodes in deployment are static.
- Nodes of similar type have same attribute such as initial energy, maximum energy and power consumption.
- Both s/a and relay node are energy constrained but base station is not.
- Each node in sensing layer send data to a base station in a multi hop manner.

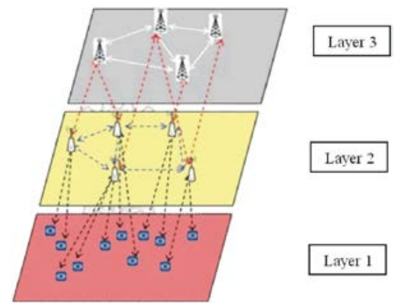
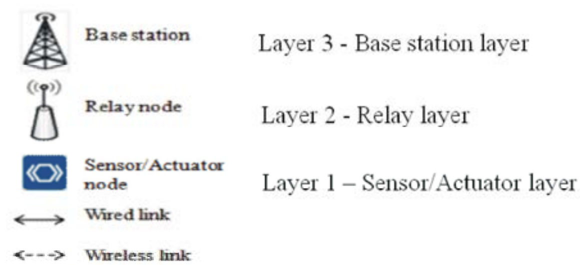


Fig. 3: Example of hierarchical based unified deployment framework for GIoT.

where,



Clustering of Nodes: All nodes in s/a are clustered using the K-Means clustering [3] algorithm. The Euclidean distance measure is used to find a set of clusters of s/a nodes and then the closest relay from each cluster is selected to form final cluster. The number of s/a are set to be 100, 300, 1000, 1500. Number of relay nodes will be 24, 72, 240, 370. Base stations count as 2, 3, 5, 8.

Model for Realization of GioT: Having completed the section IV and V our proposed system's, goal is to deploy a model for realizing the GIoT. The realization of GIoT focuses on determining the number and location of relay nodes which can satisfy the power-efficiency and budget constraints.

Our approach emphasizes on reduction in energy consumption to achieve GIoT. The Optimization model for GioT can be given as:

$$\min \left[\sum_{i \in SA} e_s + \sum_{j \in \text{Re}} e_r + \sum_{k \in Ba} e_b - \sum_{i \in A} e_a \right] \quad (1)$$

Graph Formation: There are clustered nodes available and the edges are created between them. The distance between the edges created nodes are set as the edge weight. G(N, Ws) is a directed and connected graph. The node i and j are called neighbors, if i and j are able to communicate between them. M being the adjacency matrix of G(N, Ws), then.

$$M = \begin{bmatrix} m11 & m12 & \dots & m1|N| \\ m21 & m22 & \dots & m2|N| \\ \dots & \dots & \dots & \dots \\ m|N|1 & m|N|2 & \dots & m|N||N| \end{bmatrix} \quad (2)$$

where, $mij = 1$ if $j \in N(i)$, otherwise $mij = 0$

To consider the green requirements the following constraints are considered.

Parameter Definition: Following are the notations of variables and parameters.

Etx	energy consumption at a node for data transmission
Erx	energy consumption at a node for data reception
Erel	energy consumption of radio electronics.
$\epsilon_0, \epsilon_1, \epsilon_2$	transmit amplifier of node, sensor node, relay node respectively.
L_d	data length
Dr_{ij}	data rate from node i to node j
Dr_{max}	maximum data rate of a link
Cs, $C_{R,}$	monetary cost of sensing node, relay node and base
C_B	station respectively.
a, b	cardinality of a SA, Re
T_0	Total System budget

Energy Constraint: In IoT, the energy consumption is a great concern. The energy consumed for acquiring data is very less than that for sending the data. Thus here we have considered the energy for radio electronics and sending data only.

According to the Friis free space model, we require;

$$E_{tx} = (E_{rel} + \epsilon_0 . d^2).L_d \quad (3)$$

energy for data transmission. For reception it is given as;

$$E_{rx} = E_{rel}, L_d \quad (4)$$

From the above equations, having data length L from node i and node j in a time unit will be equal to the data rate from i and j. The energy consumed by each node per unit time is calculated by;

$$e_s = \sum_{j \in \mathrm{Re}} m_{ij}.DR_{ij}.(E^{S}_{rel} + \epsilon_1 . d^2_{ij} - E^{A}_{rel}) \quad \forall_i \in SA \quad (5)$$

$$e_a = \sum_{j \in \mathrm{Re}} m_{ij}.DR_{ij}.(E^{A}_{rel}) \quad \forall_i \in A \quad (6)$$

$$e_r = \sum_{j \in SA \cup \mathrm{Re}} m_{ij}.DR_{ij}.E^{\mathrm{Re}}_{rel} + \sum_{j \in Ba \cup \mathrm{Re}} m_{ji}.DR_{ji}(E^{\mathrm{Re}}_{rel} + \epsilon_2 . d^2_{ji}) \forall_i \in \mathrm{Re} \quad (7)$$

$$e_b = \sum_{j \in \mathrm{Re}} m_{jk}.DR_{jk}.E^{Ba}_{rel} \quad \forall_k \in Ba \quad (8)$$

Eqns. 5-8 reveals the calculation of Energy for each node in the network.

Link Flow Constraint: When considering the relay and s/a node, the base stations have more bandwidth because they are interconnected with wired links. The relay nodes will communicate both with the s/a node and base station. Thereby the wireless link of relay should satisfy the following eqns.

$$m_{ij}.DR_{ij} + m_{ji}.DR_{ji} \le DR_{\max} \qquad \forall i, j \in \mathrm{Re} \quad (9)$$

whereas, the wireless links at s/a node and wired link base station should meet the following constraint:

$$m_{ij}.DR_{ij} \le DR_{\max} \forall i \in SA, j \in \mathrm{Re}\, or \forall i \in \mathrm{Re}, j \in Ba \quad (10)$$

Overall System Budget Constraint: The relay nodes and base stations are very expensive and the deployment of these nodes in IoT should be very cheap. To make it possible, being the base stations are fixed the IoT deployment should meet the overall system budget constraint as shown in eqn.11.

$$0 < C_S.a + C_R.b < T_0 \quad (11)$$

Based on the above constraints, the proposed system is ready to implement the optimization model for Green IoT (GIoT) deployment.

Reduced Energy Consumption Calculation Algorithm (RECCA): Our RECCA has been devised to achieve reduced energy consumption, so that the GIoT can be realized. RECCA step follows: Initially create all nodes and place the nodes based on the communication policy. Further (line 1) K-means clustering algorithm is used to select the relay and cluster with the s/a node. Then (line 2-8) constructs a graph to associate each edge a weight by mapping both the energies of the connected node pairs. Lastly in (line 9) RECCA incorporates a well-known Steiner tree algorithm to overcome the problem. Since, we are working in the static network there is no need for dynamic routing which in turn avoids the overhead problem and it is facilitated by RECCA.

Algorithm *RECCA*
Input:
  S, A, Re, Ba, $rer \geq sar \geq 0$
Output:
  Reduced Energy Consumption *rec*(e)

1 Apply K-means clustering algorithm to attain clustered s/a node set $Si / Ai \subseteq S / A$ and select relay $i \in$ Re to form clustered node set CR.
2 for $i \in$ Re, $j \in$ Re $\cup$ Ba, $i, j \notin A$do
3 calculate the distance d_{ij} between i and j;
4 if $dij \leq rer$ then
5 add the node i and j to a candidate set RN for node placement
  set $m_{ij} = 1$ in G;
6 end if
7 end for
8 Assign edge weight for G in terms of line 4, 5 and 6 on each edge;
9 Apply *Steiner Tree algorithm* on *Minimal Spanning Tree*
Output to calculate a Reduced Energy Consumption Steiner Tree G^T *of* $(SA \cup RN \cup Be, N)$spanning the Node set $Be \cup CR$.
10 for each edge in G^T do
11 sum the total weight on each edge, except weight of A, denoted as *rec*(e).
12 end for
13 return *rec*(e).

Experimental Results

Working Setup: In IoT, the energy consumption is a great concern. In this section, we implemented the working setup as the region nodes is distributed in 200 *200 m^2. We have considered s/a as 300, relay node as 72 and base station numbered as 3. The energy for radio electronics is set as E_{rel}=50nJ/bit, $E^{S}_{rel} = 4 E_{rel}$; $E^{Re}_{rel} = 4$; $E^{S}_{rel} = 2 E^{re}_{rel}$; $\epsilon_1 = \epsilon_2 = 100$ pJ/bit/m^2, DR_{ij} = 100 kbps for sensing nodes, DR_{ij} =200 kbps for relay nodes and DR_{max} = 400 kbps. We validate the energy consumption of IoT based on the number of nodes and communication radius variations.

RESULTS AND DISCUSSIONS

Fig. 4 illustrates the clustered output for 50 node setup. All the sensor nodes are clustered and it is matched with the relay nodes. For scaling up of nodes the number of cluster increases.

Fig. 5 shows that the number of relay nodes for each topology and the variation given in communication radius. For sensor nodes it is set as 15 and above and for relay node the communication radius is set as greater than the radius of sensor node.

The energy consumed by the nodes which are deployed in IoT (600) is shown in Fig. 7. As that of Fig.6. here also the communciation radii has been varied and the variation in energy consumed in recorded.

Fig. 6 depicts that the energy consumed by the nodes deployed in IoT (300). The communication radii is set as 15, 20, 30 and the number of relay nodes used.

Fig. 8. shows that the difference in number of relay nodes influences the energy consumption i.e. (1000) nodes has been used and energy for whole system is varied from the Fig. 6, 7.

Fig. 9 and Fig. 10 depicts that the network lifetime increase in Unified hierarchy when compared with the Hierarchical topology. The number of nodes used in Fig. 9. is lower than the nodes used in Fig.10. still there is no difference in network lifetime regardless of number of nodes used in the IoT. The system budget increases when there is an increase in number of relay and base stations in the deployment setup. The monetary cost for setting up a relay and base station is very high when compared with the deployment of sensor nodes. Hence concentration is brought towards the minimization of number of relay and base station nodes deployed. Thus by RECCA we can reduce the monetary cost of overall setup.

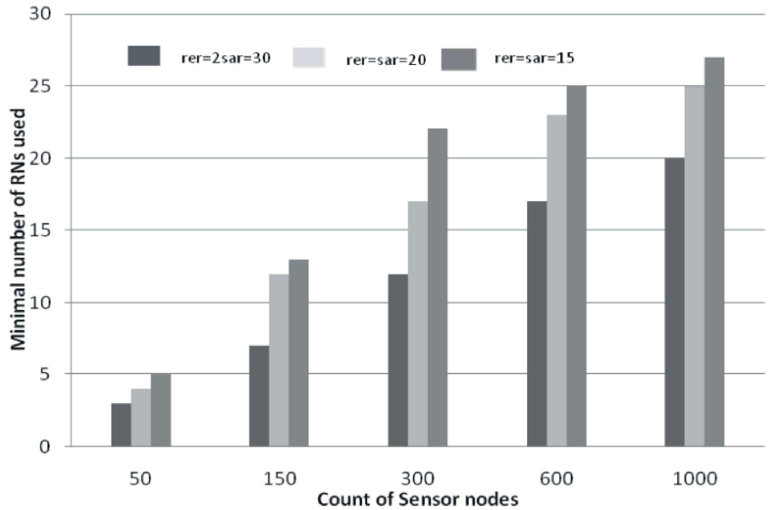


Fig. 5: Number of relay nodes used in different topologies and communication radii

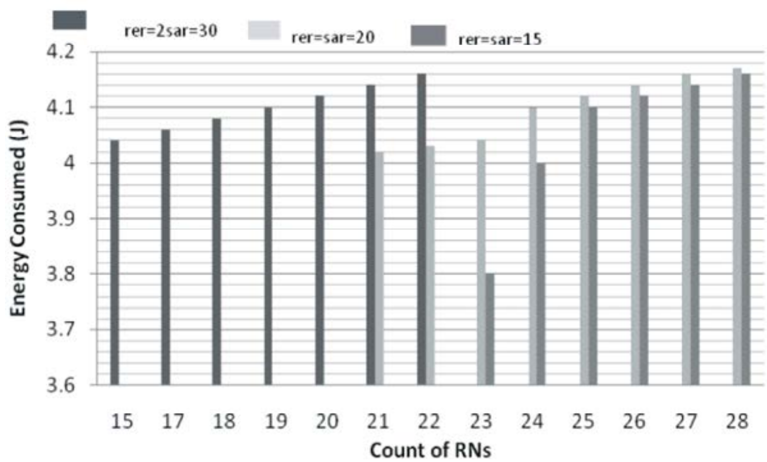


Fig. 6: Energy consumption of node in IoT (300) and the number of relay node with different communication radii

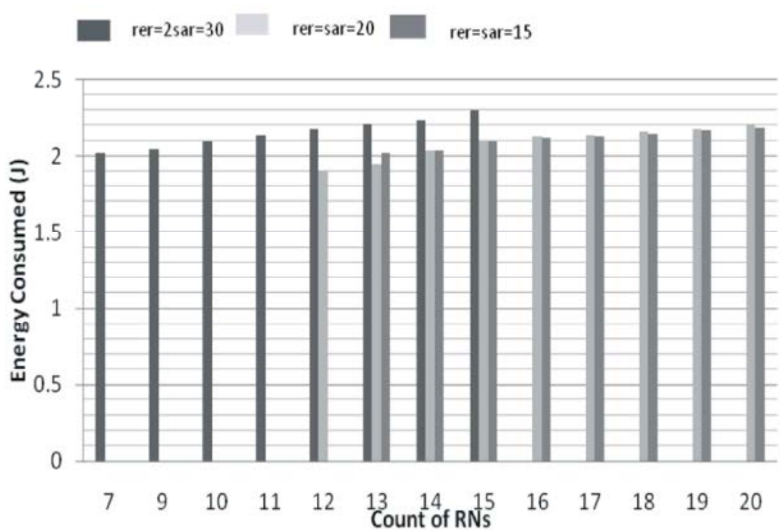


Fig. 7: Energy consumption of node in IoT (600) and the number of relay node with different communication radii

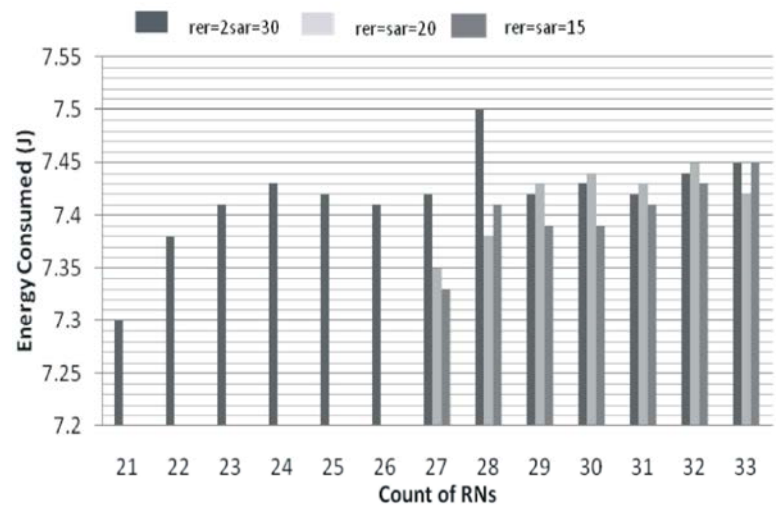


Fig. 8: Energy consumption of node in IoT (1000) and the number of relay node with different communication radii

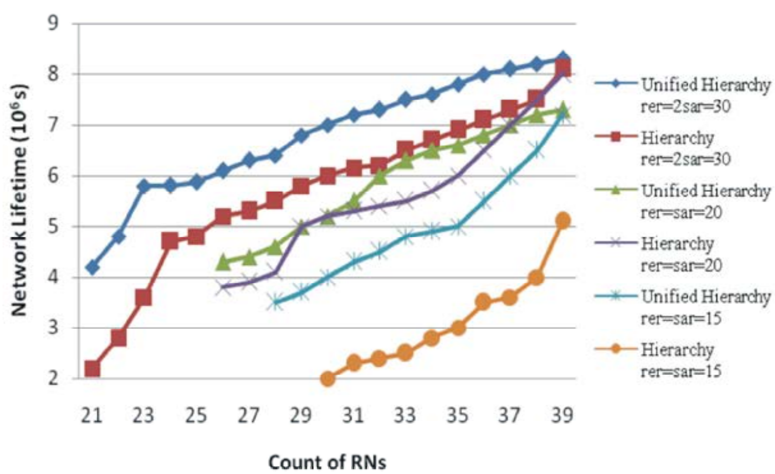


Fig. 9: Network Lifetime for two topologies of 600 nodes in different communication radii

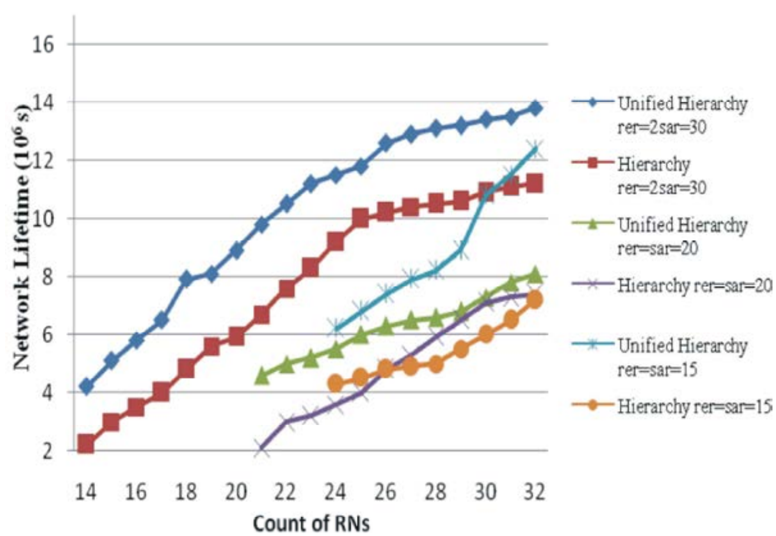


Fig. 10: Network Lifetime for two topologies of 1000 nodes in different communication radii

CONCLUSION

Our proposed system concentrates on extended network lifetime and reduction in energy consumption. In this paper we have investigated the realization of GIoT and evaluated the results of Unified Deployment Framework for realization of GIoT. This paper initially, starts with the placement of nodes in the network topology based on the Unified Hierarchical scheme. Secondly, the placed nodes are clustered and matched with relay nodes. Thirdly, the Realization of GIoT is implemented. Lastly, using the RECCA algorithm the reduced energy consumption and system budget is found.

The RECCA follows the Steiner tree algorithm for finding the intermediate nodes in the minimal spanning tree output. Further the distance of the nodes are given as the weight of the links that can be used as the energy consumption parameter. The network we have considered is static so, there is no need for dynamic routing which in turn reduces the overhead near in the sensor node. Also we have introduced actuators in the sensor layer, which does not need to transmit any data in the network therefore only the energy for radio electronics for actuator node is considered. By considering all these means the proposed system provides the well suited Unified Deployment Framework for existing scalable and intricate IoT. Further a research on compressing technique to be implemented in the proposed hierarchical framework and consideration of coverage and connectivity in the Iot will take proposed deployment framework into development path.

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