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Performance Analysis of Energy Efficient Grid based Wireless Body Area Network System

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Abstract- Wireless Body Area Network makes it possible to monitor patient's health under critical situations by integrating bio-sensors with a mobile phone. With this WBAN has now become a emerging technology to improve patient's quality of life by enabling health monitoring at home instead of at a hospital. WBAN reduces the workload of medical practitioners as well as healthcare costs which further results in higher efficiency. This paper presents the architecture of existing wireless health monitoring system (WBAN system). Due to limited battery capacity of sensor nodes there is need to have energy efficient design. This work explores the grid based data dissemination model for WBAN. The grid model divides the network area into cells. All the nodes will not participate in data transmission which conserves energy. Further we compare existing model with the grid model on the basis of energy consumed, throughput and delay.

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Performance Analysis of Energy Efficient Grid based Wireless Body Area Network System

Aashima Arya[α] & Naveen Bilandi[σ]

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I. Introduction

Advances in wireless sensor network technologies [1] leads to new opportunities to form WBAN for improving healthcare system and for remote sensing of biological parameters of human body. Hence became a cost effective solution in the field of health monitoring and fitness. WBAN use wireless communication technologies as well as biomedical signal processing in order to enable uninterrupted and long term monitoring of vital biological parameters under critical situations which can be either post operative care or old age homes. WBAN can be used to reduce mortality rate by early detection of the abnormalities and provide timely right treatment.

The strict requirement of WBAN [2] is reliable transmission due to limited battery resources of sensor nodes in order to collect information about the physiological parameters of the patient. These parameters such as Blood Pressure (BP), Electrocardiogram (ECG), and Electroencephalogram (EEG) etc are monitored and further collected on the base station. This collected data is then used or analyzed by various medical practitioners after being transmitted to the medical server. Fig1 illustrate the placement of sensor nodes on the body. Data from various nodes is transmitted to the sink node which is responsible for the data collection from various nodes. Sink node can be mobile phone o home personal computer. Sink node further transmits the data to the medical server.

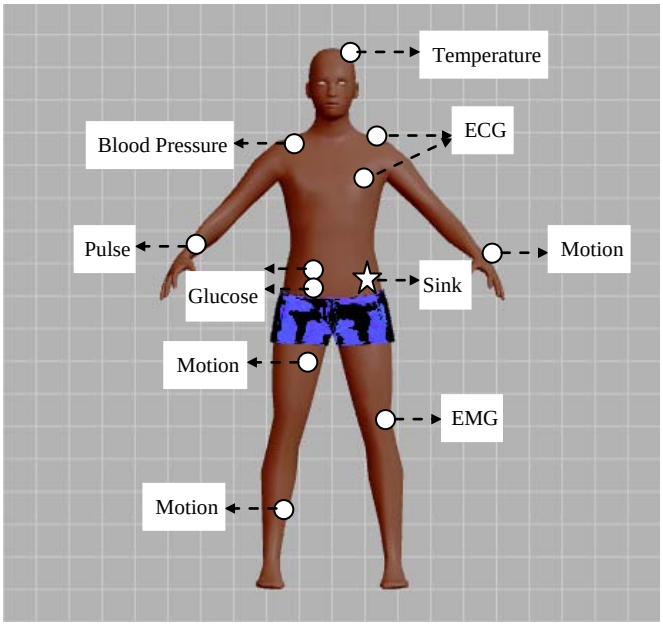

Fig. 1: Placement of WBAN nodes

The major requirements [3] for wireless medical sensors are:

1. Wearability - For effective WBAN, wireless sensors should be lightweight and small i.e. nodes should be easily wearable without restricting the mobility of patients in order to achieve non-invasive ambulatory health monitoring. The size and weight of batteries determines the size and weight of sensors.
2. Interoperability - Medical sensors should allow user to easily establish a WBAN depending on user's state of health by enabling health monitoring at home. Interoperability results in more affordable systems.
3. Reliable Communication - For the effective medical applications communication between the nodes must be reliable. To improve reliability, on sensor signal processing can be done. One example which leads to reliable communication is to extract some of the features on the sensors instead of transferring raw data and transfer only required information. This will reduce the load on communication channel

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which further save the energy and consequently increase the battery life of sensors.

4. Security - For the overall system security, wireless medical sensors must meet all the privacy requirements in order to guarantee data integrity. For this purpose key establishment, authentication etc can be done.

a) Existing Architecture of WBAN

Fig 2 describes the system architecture of wireless body area network [4] for remote healthcare monitoring system.

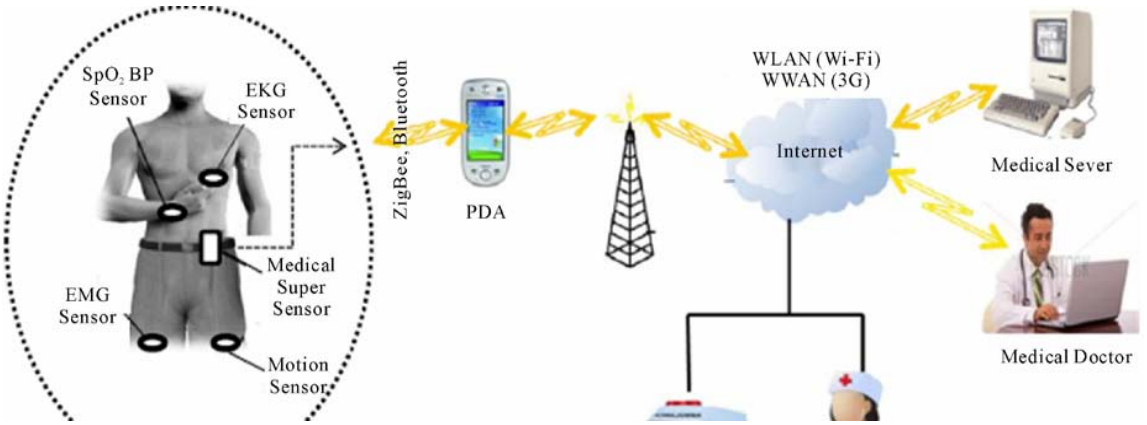


Fig. 2 : Existing WBAN system Architecture

The architecture is composed of three tiers:

First Tier (Wireless Body Area Network)

Patient is considered as the main part of this system. This tier includes integration of low power pervasive sensor nodes. These wireless medical sensor nodes combine to form a WBAN. These nodes have capability of sensing, processing and forwarding of one or more physiological signals of the human body. E.g. ECG sensor uses to monitor heart activity etc. These sensors are mainly consists of five main components: Sensor, Memory, Radio Transceiver, Microcontroller and Power Supply.

Second Tier (Personal Server)

This tier includes personal server (PS) application that can be run on PDA, cell phone or home personal computer. PDA has the capability to perform number of tasks. These tasks include providing interface to user, interface to wireless sensors and interface to medical server. The PS holds the authenticated patient information and IP address of medical server is stored in PDA in order to interface medical services. The various biological signals from WBAN are collected by PS, processes them and prioritization is done for the transmission of critical data with less delay when there is sudden change in current patient condition. Then PS establishes a connection with medical server and sends patient's report that can be combined with the patient's medical record. If link between PS and medical server is not available then PS will store the data locally and initiate the transmission when the connection is established.

Third Tier (Medical Server)

This tier encompasses a medical server for health monitoring that is accessed via internet. This is the backbone of the entire architecture as it analyzes the data received from PS and provides feedback accordingly. This tier may include various other servers that can be informal caregivers, emergency servers etc. the service provided by server can issue various recommendations and even issue alerts if any abnormal condition persists.

b) Grid Model for WBAN

Due to limited battery capacity of the nodes we need more energy efficient design of the WBAN model as energy consumption in WBAN includes the energy consumption by nodes and the overall lifetime of the network. It is not feasible to replace the power source for implanted bio-medical sensors and replacing batteries for wearable medical sensors might lead o discomfort of patients. If each sensor node transmits its information to the sink node directly, then it may exhaust its power and become out of service. This direct transmission scheme is preferred when the network is confined in a limited coverage. For this purpose we proposed a grid model for WBAN. In this model energy is utilized more efficiently as compared to existing model.

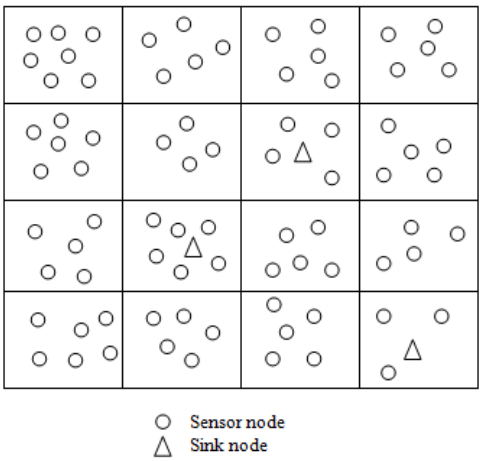


Fig. 3 : Grid based Data Dissemination

In fig 3, the network field [5] is divided into grids of square shape of certain length. All the energized sensor nodes are placed randomly in the network and sink node is kept fixed in the network.

After the grid based data dissemination one node per cell is selected as the cell head which is responsible for data transmission and local data collection. Other nodes of the cell considered as member nodes transmit their data to the cell head which further sends the data toward another cell head for onwards transmission towards the sink. Communication between the nodes can be done by selecting the path between cell heads on the basis of shortest path. The cell head remains active until it runs out of energy. The cell head is selected on the basis of node having highest energy in the cell. Other member nodes power down their radio power to save energy.

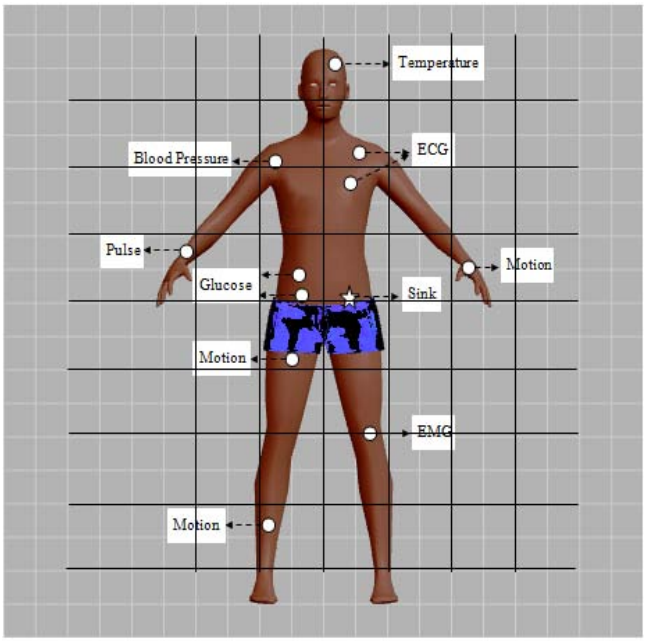


Fig. 4 : Grid based WBAN

Fig 4 illustrate the concept of grid based WBAN. In this body area is divided into cells. The data from nodes is transmitted to the sink node. In this model as only one node is responsible for data transmission; therefore energy consumed will be less. Nodes are selected as cell head on the basis of highest energy or the largest ID. Other members will sleep while cell head routes the packet. Since member nodes power down, the overall energy is conserved.

II. Related Work

The devices used in WBAN are battery operated therefore energy issue is present in almost every application of WBAN. The network consists of two types of nodes: wearable and implantable. In case of wearable sensors replacement of batteries is easier as compared to implantable sensors. So in order to make WBAN more energy efficient, energy of different nodes need to be utilized more efficiently.

From our literature survey we have observed that nodes in WBAN consume energy mainly for sensing/actuating, communication and data processing. Energy for these operations is mostly drawn from batteries. So there is need to have energy efficient design strategy. Therefore for this purpose, in this work we look into issue of energy consumption as sensor nodes have limited battery capacity and hence we design a grid based wireless body area network system. This system will minimize the energy consumed by the sensors. The basic idea of grid based system is to design an energy efficient network in which network is divided into a structure which provides reliable data collection.

In [6], mixed integer linear programming model is proposed, energy-aware wireless body area network design model which optimizes location and number of relays to be deployed, minimizing both energy consumed by wireless sensors and relays and network installation cost. Then proposed model is compared with other notable approaches.

The need for new energy efficient routing techniques is discussed in [7]. They study the effect of three different routing protocols on WBAN system in order to make the system more energy efficient. They study the failure and success of different routing protocol on the various parameters in body area network.

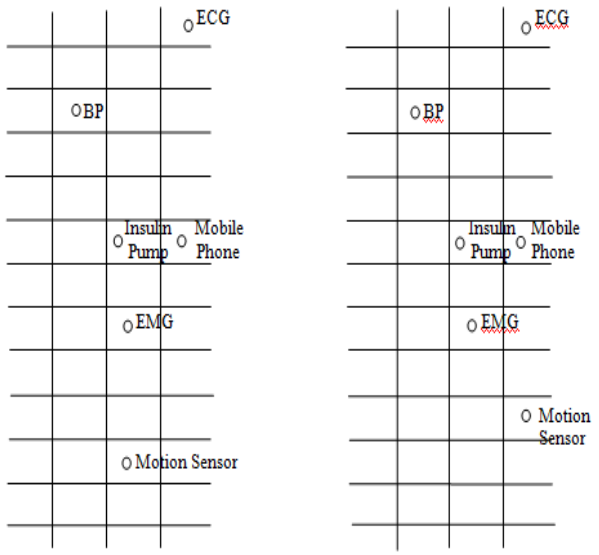
The two techniques for grid based network are proposed in [5] and author compared it with existing schemes using ns2. This is required due to limited battery capacity of wireless sensor nodes. They analyzed the efficiency of techniques in terms of data aggregation, network management and fault tolerance.
In [8], author explored the QoS of wireless sensor networks, the size of the grid area, and how the coordinator nodes are elected that will minimize the total

energy consumption and extend the lifetime of the network. The grid based coordinated routing is studied in wireless sensor networks and the energy available in the network is compared for different grid sizes.

III. Simulation Environment and Research Methodology

We have implemented grid model in ns2. Ns2 is a discrete event simulator written in C++ and OTcl. The primarily use of NS2 is to simulate local and wide area networks. To setup and run a simulation network, a user should write an OTcl script that initiates the simulation, sets up the network topology using the network objects and tells traffic sources when to start and stop transmitting packets through the event scheduler. When simulation is finished, NS produces one or more text-based output files that contain detailed simulation data, if specified to do so in the input Tcl script. The data can be used for simulation analysis or as an input to a graphical simulation display tool called Network Animator (NAM).

In our simulation, there are eleven sensor nodes, one sink node and one base station node. In Fig 5 dissemination of nodes in the grid in standing and sitting posture is presented.



(a) (b)

Fig. 5 : Data dissemination in grid (a) Standing (b) Sitting postures

The various sensor nodes used are ECG, EMG, BP, Insulin pump and motion sensors. Mobile phone is used as a sink node which collects data from all the sensor nodes. Data is further transmitted to the base station node. The complete set of the parameters that are used in the simulation are given in the table 4.1.

Table 4.1: Simulation Parameters

Parameter	Value
Topology Size	2400 × 1200
Number of sensors	13
Traffic type	Constant Bit Rate (CBR)
Simulation time	10.0
Channel	Wireless
MAC Protocol	802.11
CBR Data rate	0.5 Mb

Fig 6 illustrates the concept of grid model. Cell containing ECG node has other member nodes. These nodes will transmit the data to the cell head which further transmits the data to mobile phone. Rest of the sensor nodes in the other cells will also transmit the data in the same way. If the cell is farther from the mobile phone node then data from the cell head is transmitted to mobile phone by using multi hop technique. Fig 7 explains the concept of existing model of WBAN. All the sensor nodes are dispersed on the body. The data is transmitted from the sensor nodes to sink. Farther node transmits the data by using relay nodes.

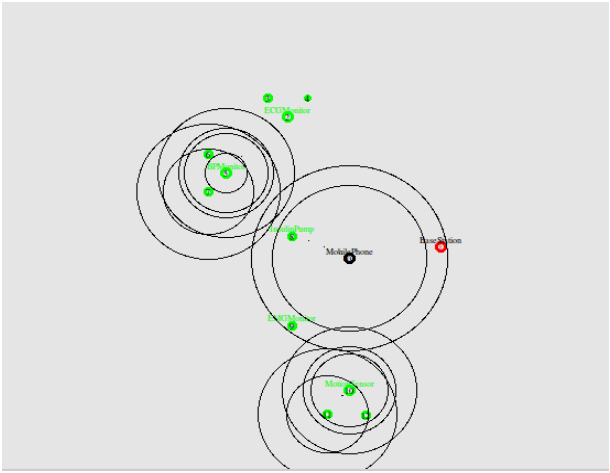


Fig. 6 : Grid model of WBAN in ns2

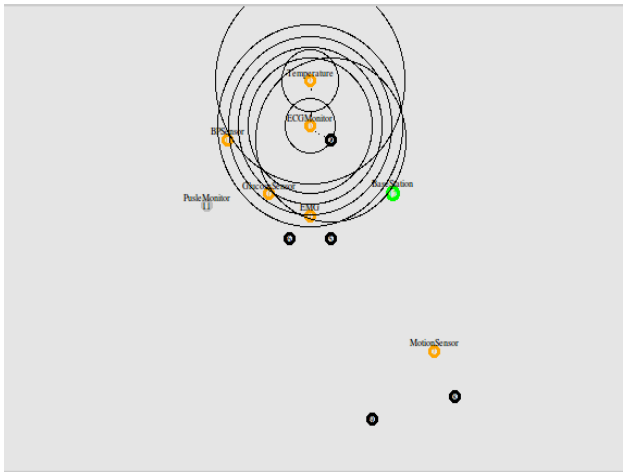


Fig. 7 : Existing model of WBAN in ns2

IV. Comparative Result Analysis

The results of the grid model are compared to the existing model of the WBAN on the basis of Energy consumed, throughput and delay.

a) Energy Consumed

In Fig 8 the energy decreases similarly as it decreased with time in the base model but the rate of decrease was steadier in the base model as compared to the grid body network. The rate with which the network looses energy is more in base model in comparison to grid body network. It is clearly seen in Fig 9 that energy of all sink nodes decrease almost constantly with time.

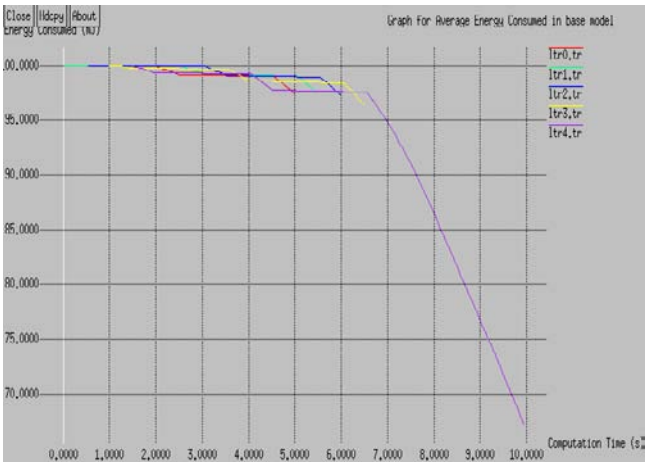


Fig. 8 : Energy consumed by grid model

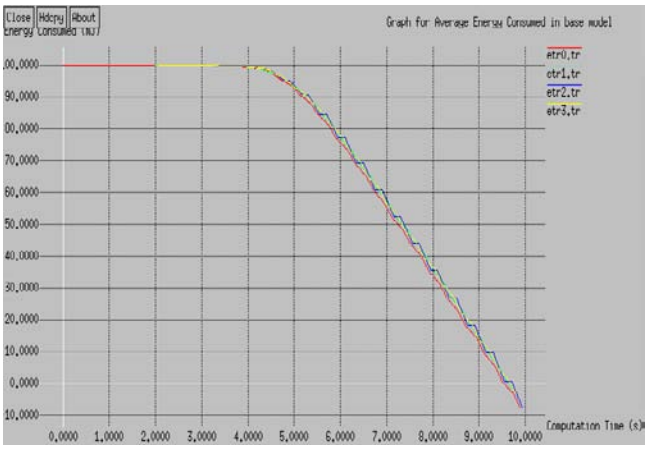


Fig. 9 : Energy consumed by existing model

b) Throughput

Fig 10 shows constant increase in the cumulative throughput of the mobile device with the body. But in Fig 11, ten different lines in the graph represent ten different links. We can at one time see only eight links in the simulation because the link which is paused when one of the receiver nodes gets overloaded is also plotted in the graph and also the new formed link with the new receiver node is plotted separately.

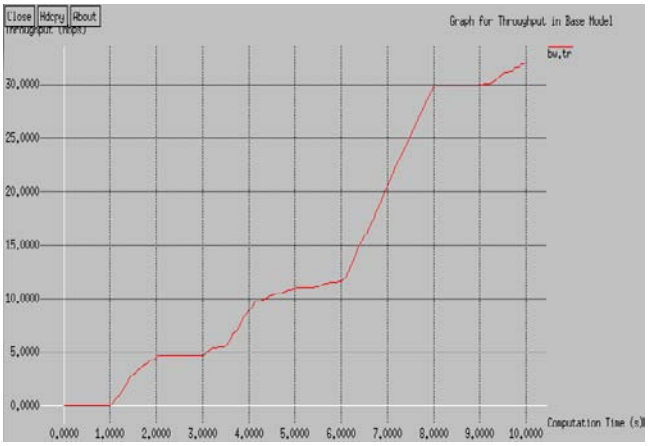


Fig. 10 : Throughput of grid model

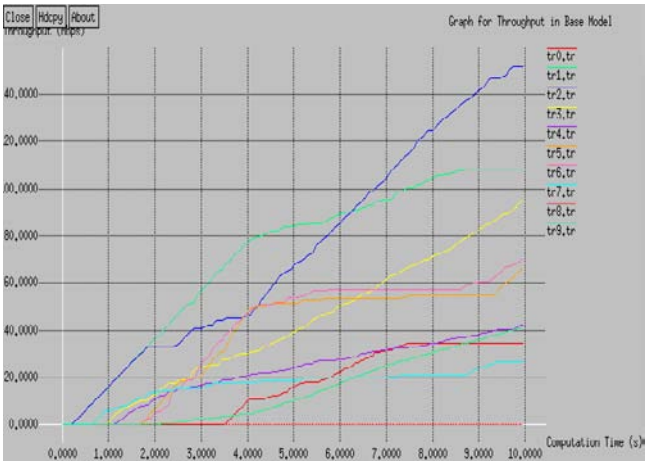


Fig 11 : Throughput of existing model

c) Delay

In Fig 12 the delay raises steeply then settles down to and around a particular flow depicting less fluctuation in the network which proves better performance. But in Fig 13 all the links are working fine without the queue length being full or any other problem that is why all the delay values are negligible. Only two receiver nodes which get overloaded causes delay which can be seen clearly in the graph.

Fig. 12 : Delay in grid model

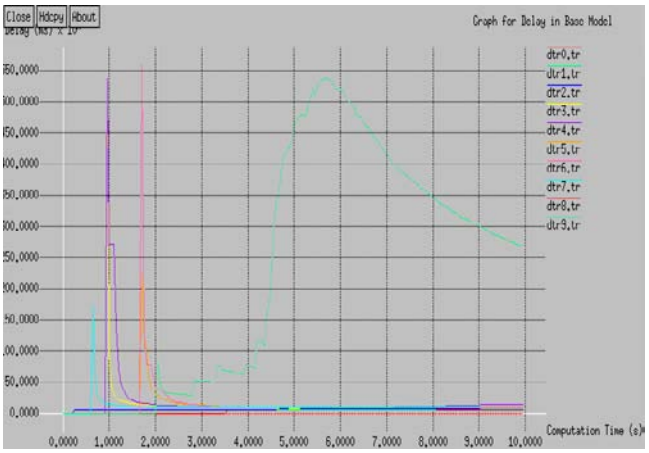


Fig. 13 : Delay in existing model

V. Conclusion

This paper completely deals with the need for energy efficient design for WBAN system by describing the grid based model for WBAN. For this we divide network into structure which provides reliable data collection. In this way energy of the nodes are better utilized to design energy efficient WBAN system. In this paper, details of our implementation of existing and grid model of WBAN based on ns2 as well as the simulation results are provided. The simulation result show the energy consumed, throughput and delay of the system. Further results of existing model and grid model are compared with each other. From the comparison we analyze that the energy consumed of grid model is less than that of existing model. There is need to use data routing techniques in grid model to make it more energy efficient.

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