

Energy Efficient Hierarchical Routing Protocols for IoT

Neha Rani, Pardeep Kumar



Abstract—IoT (Internet of Thing) is a wireless network in which smart objects communicate and interact with each other through internet, it also remotely control and monitor the objects within network. In IoT, data is sensed, gathered, processed and stored from real world environment. In this procedure a large amount of energy is consumed. Energy efficiency is the main concern for IoT. In this paper introduction to IoT its layered architecture, applications and various cluster based routing protocols has been introduced. The cluster based routing protocols used different schemes to make the nodes energy efficient. The major focus of this paper is on the LEACH, SEP, HEED and TEEN protocols.

Index Terms—IoT (Internet of Things), Sensor, Cluster Head, Routing Protocols

I. INTRODUCTION

The Internet of Things is an upcoming research area in recent days. Earlier the IoT was connecting PCs only but nowadays IoT has been changed from "internet of people" to "internet of things". Kelvin Ashton coined the IoT in 1999 and said "we need to empower computers with their own medium of information". RFID and sensors technology allow computers to detect, recognize and know the world without the control of human intervention. The innovation can be created by sharing the data among smart things. The concept of IoT is the existence of smart objects like laptops, tablets, smart phones equipped with sensors and actuator. These objects are smartly communicating with each other. It is expected that Internet of Things will encompass 26 billion units connected by 2020. Billions of devices are anticipated to connect to the internet in coming years that will demand a well defined mechanism where the objects work automatically.[1]

IoT is the interconnection among objects. In IoT data is transferred from one device to other device through internet. Routing is the selection of best path from source to destination. Data can be transferred from machine to machine (m2m), machine to human and human to machine. The basic concept of routing in IoT is that the sensed data is transferred in a continuous way from one node to another node. Large amount of energy is required for data transfer in IoT networks. This paper presents the different cluster based routing protocols to make the nodes energy efficient.

Routing protocols are classified into three types (1) Network Organization (2) Route Discovery and (3) Protocol Operation. Network organization is divided into three categories viz; flat based routing, hierarchical routing and location based routing. In this paper the focus is on hierarchical routing.

In this routing highest energy level nodes are used for the transmission and remaining nodes are used for sensing the data. This is also called cluster based routing because nodes are collected within different clusters for the fast delivery of data. Hierarchical routing used the protocols like LEACH, HEED, TEEN, SEP etc. [2]

II. ARCHITECTURE OF IOT

- **Perception Layer:** This layer is the lowest layer of IoT architecture. It collects data from environment such as (WSN, heterogeneous devices and real world object) of sensor type and transmits them in an automated setup.
- **Network Layer:** The function of this layer is to transmit the data between lower and upper layer. It accumulates data in digital format from the perception layer, arrange the framework and then transmit it to the application layer via Bluetooth and WiFi.

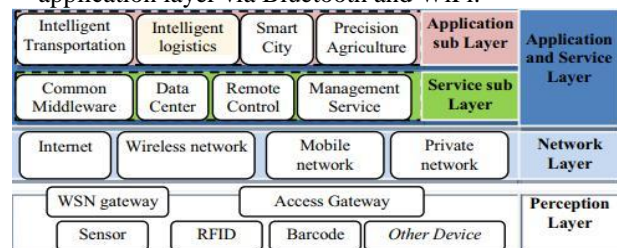


Fig. 1. Layered Architecture of IoT[3]

- **Service Layer:** This layer combine and store the data from network layer and send it to the upper layer. It provides different types of services like management services, data analysis and decision making.
- **Application Layer:** This is the top layer of IoT architecture. This layer provides the specific services to industries. These services are environment monitoring, smart healthcare, smart transportation, smart agriculture etc. [3]

III. APPLICATIONS OF IOT

- **Smart Cities:** IoT make the peoples life easy to provide the facilities in their city. These facilities are: remove the traffic congestion on the road, improve the infrastructure, provide the internet facilities for accessing the database of railways and airports etc.



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- **Smart Home:** By using IoT technology we can smartly operate our home devices like smart lights, automatically adjustment of room temperature, security of homes, water supply, power management. Users can remotely control their apparatuses with the help of IoT.
- **Smart Hospitals:** IoT is used for healthcare in hospitals. RFID sensor using with cell phones for monitoring different parameters such as temperature, blood pressure. IoT technology is used for the patients in hospitals who can't move from bed, sensors connected with IoT capture the health of patient and send the data to doctor.
- **Smart Agriculture:** Sensors are deployed in the place where required now they capture the soil moisture, water level, dryness, manure requirement and send the collected information to farmer so that farmer will prepare for it.[4].

IV. BACKGROUND ANALYSIS OF IOT

Shahid et al. [1] discussed the basic concept of IoT network where the information can be shared among smart objects. They provide the visions of IoT as (1) Things oriented

(2) Internet oriented and (3) Semantic oriented. A layered architecture of IoT shows that how layers work together to provide applications to users. The authors also presented the applications and research challenges for IoT.

Nisha et al.[5] provided the ESMR for IoT network to minimize the energy consumption of nodes by which network lifetime can be enhanced. In this approach there are two categories of nodes: network node and non-network node. The node along with maximum power will be elected as sink node. The non-network nodes forward message to sink node to invade into network. They use AVL tree structure to build the network. The altitude of the tree is upgrade in ESMR. They affix the network in the middle of data communication. After the simulation result it was found that ESMR is helpful to decrease the power consumption and also enhanced the existance of the network. They compared the ESMR with ADMR, DSDV and AODV.

Behera et al. [6] proposed a modified LEACH (Low Energy Adaptive Clustering Hierarchy) protocol for IoT applications. To overcome the cluster head (CH) election problem they set a threshold value in the existing routing protocol. A node

that has energy level above than threshold value, it can be the CH for the next round. After the results it was found that residual energy is utilized for the CH formation and the network lifetime will be prolonged.

Sadek[7] proposed a hybrid protocol for heterogeneous network in IoT. Author firstly discussed the three protocols named as SEP, LEACH, and Z-SEP. The CH selection process is different in all the protocols. A Hy-IoT protocol is proposed that uses the different weighted election probabilities for CH selection. The results show that proposed protocol is best and prolong the network life. This protocol used the LEACH and SEP with two regions;

regular region and superior region. The regular region has normal nodes with advance nodes and superior region has excellent nodes with high advance nodes. The author also discussed the CH selection process in both the regions.

Xin et al. [8] provided comparative analysis of different MANET routing protocols in perspective of IoT scenarios. The protocols which are used for analysis were AODV and DSR and the parameters are overhead ratio, delivery ratio and number of dropped packets.

Nasser et al.[9] proposed a multiple base station and packet priority scheme to extend the network lifetime and fast delivery of data. This scheme prioritizes the emergency data packets and sends to the BS so that nodes consume less energy. There are two base stations that receive the information from devices and than send to the internet which is stored to the web server.

Thuy[10] discussed architecture and characteristics of IoT networks after that they provides survey on different routing protocols of IoT with their various issues and challenges.

Mohamed et al. [11] proposed enhanced LEACH routing protocol and compared with existing LEACH protocol in terms of energy efficiency performance metrics like overhead ratio, average message delay and number of dead nodes.

Guo et al. [12] proposed hierarchal routing protocol for wireless IoT networks. in this proposed mechanism authors allow usage of resources based on neighbors of nodes usages but the drawbacks was that they didn't provides a way to distribution of resources in optimal way to increase efficiency of network.

Gherbi et al. [13] proposed distributed cluster based routing protocol in which cluster sizes are created based on the requirements and usages of nodes and cluster head is decided on the basis of election of nodes. The size and shapes of each cluster was same or mobility pattern was also same in network.

Poluru et al. [14] provided survey on different routing protocols of IoT. They compared different routing protocols in terms of parameters such as power usage, mobility pattern, overhead and so on. They also provides different pros and cons of different routing protocols of IoT.

Sajjanhar[15] proposed modified LEACH routing protocol with two additional parameters such as residual energy and spatio temporal variations to achieve energy efficiency during data transmissions in IoT network bit they increases lifetime only 50% in perspective of LEACH routing protocol.

V. CLUSTER BASED ROUTING PROTOCOLS

A. LEACH (*Low Energy Adaptive Clustering Hierarchy*):

LEACH is a hierarchical based routing protocol used for WSN to overcome the consumption of power in network. There are the thousand of nodes present within a network, this protocol distribute the nodes into clusters.

LEACH broadcast the information over short distance and decreases the transmission operations. One node is selected as a CH (Cluster Head) from the number of nodes within a cluster and randomization is used for the selection of CH. This CH aggregates the data from different nodes and sends to the base station. There are two stages of LEACH protocol:-(1) Setup stage (2) Steady stage. In the first stage clusters are created and a CH is elected from the different nodes and now the clusters can communicate with each other. All the nodes generate random number between 0 and 1. if the selected number is greater than the threshold value that node will become the CH. The CH uses the TDMA for the transmission time of data from one node to other node. In the second stage normal nodes sense the data and transmit it to the CH. CH aggregate the data and transfer it to base station. [6]

- Pros: (1) The CH collects the data from different nodes that lead to control the traffic generated in the network.
- (2) It is more energy efficient as compared to the other direct transmission approach.
- (3) It uses TDMA schedule to avoid clash among CHs.
- Cons: (1) The CHs are elected randomly in LEACH protocol so there is the chance of low energy node to be CH which will result low energy node may die first and no criteria for cluster head selection.
- (2) Cluster head directly communicate with BS which results that LEACH can not work properly for the large scale network.

B. SEP (Stable Election Protocol):

SEP is a heterogeneous protocol. It elects the CH by using the weighted probability of nodes. There are two levels of nodes namely advance nodes and normal nodes. Advance nodes have more chance to become cluster head because it has high energy level. It uses the fraction of energy to randomly select the cluster head. This protocol is scalable because there is no need for location of node sensing field. SEP use the extra energy of advance nodes and enhance the stability periode. In

order to extend the stable region, SEP try to keep the limitation of well balanced energy consumption. [7].

- Pros: (1) SEP works in heterogeneous networks.
- (2) In SEP it is not necessary to know the initial energy level of each node during election round.
- Cons: (1) The election procedure was not dynamic between two nodes as a result the nodes which are situated on cluster boundaries will die first.
- (2) Advanced nodes are died first due to reduction of residual energy level of advanced nodes.

C. HEED (Hybrid Energy-Efficient Distributed Clustering):

It upgrades the LEACH protocol by using remaining energy, node degree or thickness as an essential parameters for cluster improvement to fulfill control altering. HEED is distributed clustering protocol which groups the nodes into clusters and elects the CHs from them. There are two terms used for the clusters (1) Intra cluster and (2) Inter cluster. (1) When the

nodes communicate within the cluster and the CH aggregate the data from the other nodes is called intra cluster. (2) The second is Inter cluster in which different clusters communicate with other clusters. HEED uses residual energy for the selection of CH. [16]

- Pros: (1) HEED uses Inter cluster coordination which improves the network scalability.
- (2) Cluster head selection technique used in HEED improves the lifetime of network.
- Cons: (1) Energy consumption is more in HEED because more then one CHs present within single cluster at the different locations.
- (2) End to End delay will be more because all the nodes communicate through more than one node.

D. TEEN (Threshold Sensitive Energy Efficient Sensor Network Protocol):

TEEN is used in data centric method. In this protocol data transmission is based on Hard threshold (ST) and Soft threshold (HT).

Hard threshold (HT):- HT is the value of sensing field attribute. When a node sense value than it switches to the transmitter and communicate with the CH.

Soft threshold (ST):- ST is the small change in sensing value. When there is small change in sensing value it activates the node and sends the value to transmitter. So that by using the threshold value we can eliminate the small value changed transmission which saves the energy of nodes. [17].

- Pros: (1) In the TEEN protocol data sensing consumes less energy than data transmission.
- (2) Nodes transmit data only when it is required so TEEN protocol provides effective energy utilization.
- Cons: (1) The working of this protocol is based on the threshold value, if the threshold value is not reached than the nodes will never communicate and the user not gets information from the network.
- (2) Data flow in continuous mode is not possible.

TABLE 1 ASSESSMENT OF CLUSTER BASED PROTOCOLS

CLUSTER PROTOCOL	DATA FUSION	ENERGY AWARE	CH SELECTION	ROUTE SELECTION	BASE STATION
LEACH	YES	NO	RANDOMALY	PROACTIVE	STATIONARY
SEP	YES	YES	BASED ON ENERGY	REACTIVE	STATIONARY
HEED	YES	YES	BAESD ON ENERGY	HYBRID	STATIONARY
TEEN	YES	YES	RANDOMLY	REACTIVE	STATIONARY

VI. CONCLUSION

IoT is a network of interconnected devices that share messages through some intermediate nodes. In this paper an attempt has been made to discuss various cluster based routing protocols for IoT with their pros and cons. From the pros and cons of various cluster based routing protocols for IoT, it was identified that LEACH is a basic protocol for routing while the other three i.e. SEP, HEED and TEEN are enhancement of LEACH. Out of these three, SEP is a heterogeneous protocol and it increases the stability of network. Therefore the focus of research is on SEP.

In this protocol at the time of data transmission when normal node is near to dead stage (i.e. energy is very low), then advance node has more chance to become cluster head, due to this process advance nodes died fast which interrupt the data transmission. In future, one can try to use the super nodes to replace dead nodes and as result network has longer lifetime.

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