Multi Agent based Information Gathering Scheme in Internet of Things

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Abstract : Internet of Things (IoT) has become a fascinating word now a days and has sought the attention of the world entirely. IoT is a network of networks, containing physical objects(things) that are connected to the Internet and can be identified and globally queried. IoT can also be thought of as an advanced Wireless Sensor Network (WSN), where the networked sensor nodes sense the data and transmit continuously. So, it becomes an ultimate challenge to deal with the large amount of data that is being gathered. In this article, we have proposed an intelligent scheme for information gathering in IoT through agent based approach. The main contribution of our proposed research work is to design and develop an intelligent solution for information gathering in IoT. The proposed agent based information gathering scheme operational sequence is as follows: (1) Information sensing; (2) Information fetching from each (node) at device environment; (3) Information fetching from each (node) at user environment; (4) Storing the information into the Knowledge base(KB) avoiding redundant data. The proposed scheme validated by simulation. The scheme proposed performs better as compared to EDCMS (Efficient Data Collection using Mobile Sink) scheme in terms of information acquisition delay, gathering delay, packet delivery ratio, end-to-end delay and bandwidth utilization.

***Index Terms* - Internet of Things (IoT), Information Gathering, Multi-agents.**

I. INTRODUCTION

The concept of IoT is being revolutionalised because of the fact that it has huge distributed information, where any of the real-world physical object can participate in the network automatically, such that the physical 'thing' can be discovered and can be globally queried. The IoT surrounded with lat many types of technologies. It also has scope in research that targets on extending the present Internet to real-world physical things. It also has got open research issues to address with, that includes information gathering and its validation and aggregation, privacy and security issues, data analysis, heterogeneous architecture of the network, Quality of Service(QoS), energy efficiency, etc. The standard of living of the people and their life style has got transformed due to this IoT, which indicates the promotion of the advancement of science and technology that upgrades the social environment [1].

Any basic architecture of an IoT contains usually three layers: the sensing layer, the network layer, and the user application layer. The sensing layer contains sensor nodes, and discovers each of the physical things in the network. It also has RFID tags, cameras, GPS, etc. It is the physical layer which is responsible to identify each of the object or thing in IoT. This is accomplished with the help of sensor nodes and gathering of information about each object. The network layer, which is the most important layer of IoT and has the responsibility of interconnecting to other smart objects, network devices, and gateways and servers. And responsible for transmission of the gathered information by the sensing layer. The application layer converges IoT application services such as smart health, smart cities, smart homes, etc., to the user end[2].

When we compare IoT with other networks, IoT is a very complex network, as all of the physical objects may participate in the network. So ultimately the amount of data that gets generated is huge. So it is equally important to adapt some intelligent data collection schemes. The sensing node in an object may transmit the data it has observed or sensed, to its neighboring sensor nodes. Some times it may so happen that vicious nodes may send the false information that misleads the users. During these situations certain information validation techniques should be used before sending it to the further sensor nodes. These techniques would reduce overheads, improves the lifetime of nodes by eliminating redundant data transmission.

The basic architectures and technologies of IoT are proposed in [3] - [5]. The architectures describe the binding of sensor technology, RFID, logic for embedding the objects, ad-hoc network conditions, information infrastructure for Internet for the use of smart object framework. The intention is to make the reader understand the current status of the IoT, methodologies that assists, the applications, challenge and the developments through a complete analysis and categorizing the literature [6].

The rest of the paper is organized as follows. Related work is discussed in Section II, the proposed data gathering scheme is illustrated in Section III, simulation and result analysis are discussed in sections IV and V respectively, and conclusions are drawn in Section VI.

II. RELATED WORKS

The necessary technical issues of IoT like exchange of information within massive different and unrelated network components, proper combination and interaction adjustment of varying data and service adjustment in the dynamic environment are addressed in [7] [8]. The perspective, issues, possible usage situations and IoT technological building blocks are discussed in [9]. Particularly, the RFID and scientific improvements like Internet protocol stacks and web servers are concentrated for smart everyday objects. Societal and ethical issues which will commonly arise are presented in [10].

Conversion of sensed information in to radio signals like time and frequency to gather the statistical distribution of data and the location of sensor nodes by introducing a design policy that simultaneously gather the data from sensors nodes to a fusion center is proposed in[11]. The work mentioned in [12] compares data gathering methods considering the compromise between reliability and consumption of energy by taking care of networking and compression aspects.

The work in [13] proposes a novel data gathering technique for WSNs, where the sensing nodes are randomly distributed to sense the physical entity. The intention is to spread the information throughout the entire network so that the base station can gather the sensed information just by querying few nodes. A method to decrease the number of transmissions as well as reduction in the amount of data that will result in increased network lifetime is proposed in [14] where the nodes can support multiple sensors based on the relative change between the present and previously sensed values.

A model for information dissemination for vehicular ad-hoc networks that uses intelligent agents is presented in [15]. A model uses a concept of cognitive agent perceiving intelligent data dissemination. For analyzing the performance of the concept the bandwidth utilized, push latency and push/pull decision latency are considered. A model consisting of agents referred as heavy weight agents that are static and cognitive (BDI agents) and light-weight mobile agents is discussed in [16].

A novel real time data gathering scheme based on time and frequency mapping for WSN is proposed in [17], in which each of the sensing node will convert the data it has sensed into orthogonal frequency division multiplexed signal and the respective location into two time slots. Then, sensor nodes will send the tone signals accordingly. The sink node receives these tone signals sent by the sensor nodes and correct information is estimated from timing and frequency of the received signals by utilizing a spatial correlation of observed target or the position of sensor nodes. The research work presented in [18] is to manage data from IoT architecture point of view and why data management system should be different from the conventional one. Managing the data in IoT based system should support real time and off line data cycles to assist heterogeneous data and processing requirements of massive IoT users.

The main contribution of the research work given in [19] experimentally shows the coordination between various information agents that uses a plan based method, that decides which of the source and agents needs to be questioned so as to consolidate the information collected from the website. The work done in [20] deals with partitioning the neighbor nodes into one cluster that senses same target based on Information similarity concepts with suitable clustering algorithm. The research work in [21] provides literature on data collection methods that will enhance the capacity, protocols for routing for WSNs. All the schemes in this work tries to optimize the usage of energy at the node by finding the least cost energy route. A close review of secure knowledge aggregation conception in wireless sensor networks is provided in [22]. To offer the motivation behind secure knowledge aggregation, first, the protection necessities of wireless device networks are granted.

The work in [23] explains a technique to gather information efficiently from a huge set of physical objects that are attached with sensors, by using SRSS. Here the satellite will divide the sensor nodes into groups and bandwidth will be allocated based on divide and conquer rule and searches for the sensor terminals that have information to transmit. The work presented in [24] proposes an architecture for an IoT intelligent system to be able to gather and investigate the data from a large number of sensor nodes to perform the necessary task as per the domain specific application. An architecture is proposed in [25], that takes care of storage issues, processing the huge amount of information, analysis and scalability. In EDCMS scheme[26] , the two time-sensitive route planning schemes are presented to build a set of trajectories aims at minimizing the overall delay but the proposed system is designed to reduce information acquisition delay, gathering delay, packet delivery ratio, end-to-end delay and bandwidth utilization.

The limitations of existing information gathering in IoT are: lack of intelligence in information gathering, processing redundant data that reduces network life time, storing the duplicate data that will consume memory. So in this position paper we have proposed intelligent information gathering scheme that uses an agent based approach to overcome the above said limitations.

III. PROPOSED SCHEME

In this paper, we propose an agent based information gathering in IoT, that uses a set of Static Agent (SA) and Mobile Agents (MA). Static agent is an independent code consisting of set of instructions that performs on the host node. Mobile agent is a traveling agent loaded with predetermined set of instructions, which moves from one host node to another host node in a heterogeneous network and performs at a remote host node till it accomplishes a specific job. The MA travels through the network and fetches the queried information and shares the same to other MA in the network. The MA on its arrival compares the raw attribute value with the one in Knowledge Base (KB), if the newly arrived value deviates from the stored (mean) value, then the new value of attribute is stored in KB replacing the older. All Agents do need a platform that gives assistances like communication between agents, navigation, creation of agents, cooperation among agents, collaboration among others, etc.

This section discusses about network environment and agent based framework for information gathering.

III.I Network Environment

For the proposed scheme of information gathering, the network scenario shown in Fig.1 is considered, where the information message propagates through the network via intermediate nodes and reaches the cluster head through appropriate routing protocols. From which the message is routed through the gateway and reaches the destined sink node. The required sensed information is routed back to the source node. Each of the nodes have different sensors, GPS module, on-board circuitry for data processing, etc. This constitutes the node environment. The measured values (sensed information) from all the nodes for all the attributes are stored in the KB.

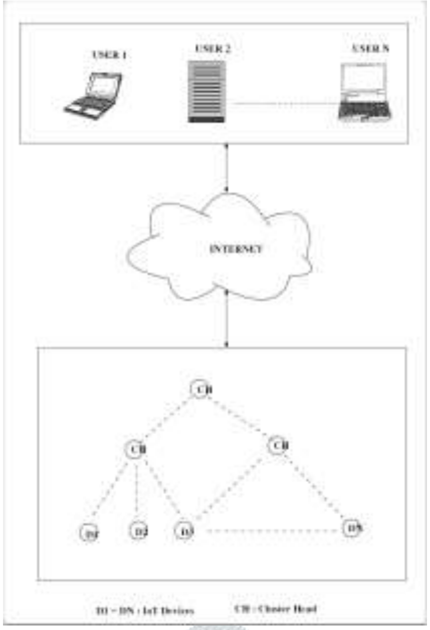

Fig.1 Network Environment

III.II Agent Based Information Gathering Scheme

The proposed agent based scheme for information gathering includes two agencies namely: Device Agency and User Agency.

III.II.I Device Agency

The Device Agency consists of knowledge base (containing gathered information), Device Manager Agent (DMA) and Information Collection Agent (ICA) and all these runs on devices (nodes). The device agency block is as shown in Fig.2.

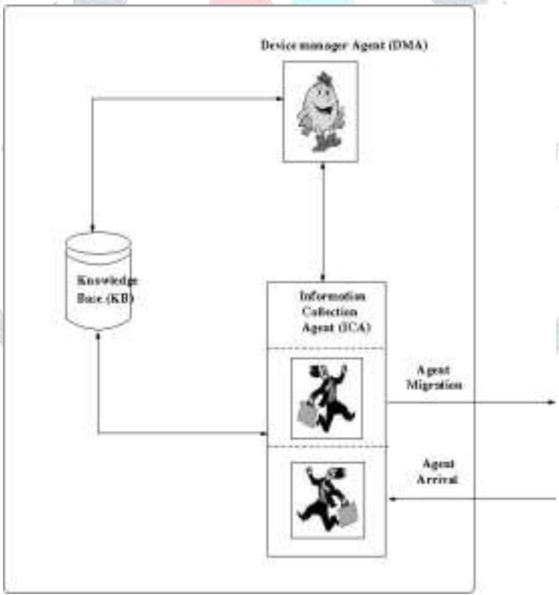

Fig.2 Device Agency

- **Knowledge Base (KB):** It consists of gathered information, information regarding the node IDs, list and IDs of neighbor nodes, bandwidth available for communication, status of nodes (alive or dead), etc. Both static agents and mobile agents utilize the knowledge base for information retrieval or updation.
- **Device Manager Agent (DMA):** DMA is a static agent that executes on a node(device). As and when DMA senses data, it creates or triggers Information Collection Agent (ICA).
- **Information Collection Agent (ICA):** The ICA is a mobile agent which can travel through the network and contain the information regarding the sensed parameters (attributes) from each node, in the form of a matrix.

III.II.II User Agency

The User Agency consists of knowledge base (containing gathered information), User Manager Agent (UMA) and Information Collection Agent (ICA). All of which are present at the user end. The user agency block is as shown in Fig.3.

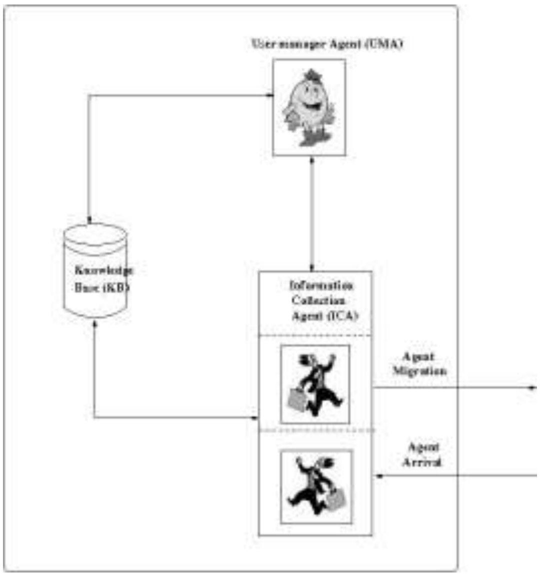

Fig.3 User Agency

- **Knowledge Base (KB):** It consists of gathered information, information regarding the user node IDs, list and IDs of neighbour user nodes, bandwidth available for communication, status of user nodes (alive or dead), etc. Both static agents and mobile agents utilize the knowledge base for information retrieval or updation.
- **User Manager Agent (UMA):** UMA is a static agent that executes on a user node(device). As and when UMA senses data, it creates or triggers Information Collection Agent (ICA) at the user end.
- **Information Collection Agent (ICA):** The ICA is a mobile agent which can travel through the network and contain the information regarding the sensed parameters (attributes) from each user node, in the form of a matrix.

The proposed agent based information gathering scheme operational sequence is as follows: (1) Information sensing; (2) Information fetching from each (node) at device environment; (3) Information fetching from each (node) at user environment; (4) Storing the information into the KB avoiding redundant data.

1) Since the network contains a huge number of sensing nodes (devices or things), each device can be thought of a node. Let the set of *'m'* sensing nodes (s) are represented as shown in Equation1.

$$S = \{s_1, s_2, s_3 \dots \dots s_m\} \tag{1}$$

and the set of *'n'* sensing parameters (a) (e.g. temperature, humidity, light etc.) for evaluation are represented as shown in Equation2.

$$A = \{a_1, a_2, a_3 \dots \dots a_n\} \tag{2}$$

2) Whenever there is a sensed data at the device end, the DMA triggers the ICA. The ICA will read and store the information in the form a matrix as shown in Equation3.

$$X = \begin{bmatrix} x_{11} & x_{12} & \dots. & x_{1n} \\ x_{21} & x_{22} & \dots. & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m1} & \dots. & x_{mn} \end{bmatrix} \tag{3}$$

where x_{ij} is the value of attribute *'j'* from node *' i'*.

3) The information can be fetched from user end also. If a node is unable to get the information at the device end, then it will search for the same in neighbouring nodes by communicating through its respective Cluster Head (CH).If the data is available at its CH then it updates KB, otherwise it will request other CHs of the network through its own CH. If it fails to get the required information then the request will be transmitted by DMA that triggers UMA on the user end over the gateway and Internet. If UMA manages to get the requested information from one of the users and the same can be sent through ICA from user end to device end by back tracing the requested path.
4) On the arrival of ICA, the DMA/UMA will create KB. To avoid storing of redundant(duplicate) information and to differentiate among the raw data of each sensed parameter, all measured values are normalized, which in turn reduces the computational overhead. This is achieved by using the standard expressions of mean and standard deviation as shown in Equation4 below.

$$P_{ij} = \frac{x_{ij} - \hat{x}_j}{\sigma_j} \tag{4}$$

where, $\hat{x}_j$ is the average (mean) value of the parameter *'j'*, given by Equation5.

$$\hat{x}_j = \left(\frac{1}{n}\right)\sum_{k=1}^{n} x_{kj} \qquad (5)$$

and σ_j is the standard deviation of the sensed value *'j'*, as shown in Equation6.

$$\sigma_j = \sqrt{\left(\frac{1}{n-1}\right)\sum_{k=1}^{n}\left(x_{kj} - \hat{x}_j\right)^2} \qquad (6)$$

Along with this, the matrix of $P = \left(P_{ij}\right)_{m\times n}$ can also be constructed.

III.III Algorithm

Algorithm.1 Proposed Information Gathering Algorithm

1 : *Nomenclature: sensor nodes - S_m, sensing parameters - a_n, data available - x_{ij} , mean value of data - $\hat{x}_j$, standard deviation - σ_j , normalized value of sensed data - P_{ij}, User Manager Agent (UMA), Device Manager Agent (DMA), Information Collection Agents (ICA).*
2 : Input : x_{ij}, σ_j, $\hat{x}_j$
3 : Output: Information gathered in KB avoiding redundant duplicate data.
4 : Begin
5 : *DMA triggers the ICA and ICA collects x_{ij}*
6 : ***if** (ICA has x_{ij}) **then***
7 :   *Determine P_{ij}*
8 :   ***while** (Pij > 0, OR Pij < 0) **do***
9 :   *Update the KB*
10 :   ***end while***
11 : ***else***
12 :   *ICA will search within device agency block among neighbouring nodes/CH. Go to step:6*
13 :   ***if** (ICA fails in getting x_{ij} within the device) **then***
14 :   *ICA on device agency will request UMA for the data availability in the user end via Internet. Repeat step:6*
15 :   ***end if***
16 : ***end if***

IV. SIMULATION

The recommended scheme for information gathering has been simulated using C++ programming platform as discrete event simulator. In this section, we discuss a simulation model, simulation inputs and performance metrics.

IV.I Simulation Model

Assumptions made for simulating the above scheme are as follows: We consider "N" number of IoT devices in a given area of length "X" mts and breadth "Y" mts. Communication link range for each IoT device is considered as distance "D" mts. Coverage area around each node has a bandwidth "BW" shared among neighboring nodes. The size of the control/data packets which is to be transmitted is in terms "PS" bytes.

IV.II Simulation Inputs

The simulation inputs to the proposed model are as follows: N = 5 to 25, X = 10000 mts, Y = 10000 mts, D = 100, 200, 300 mts, BW = 100 Mbps, PS = 8 bytes.

IV.III Performance Metrics

To analyze the performance of the proposed information gathering scheme, the following performance metrics are considered:

- Information acquisition delay: It is the time taken by the ICA to sense and collect the real time environmental parameters such as temperature, humidity and pressure etc. It is articulated in terms of milli seconds (ms).
- Information gathering delay: It is the time taken by DMA to gather the information sensed by the ICA. It is expressed in terms of milli seconds (ms).
- Computational delay: Computational delay is the time taken for the agencies for updating the knowledge base and is expressed in milli seconds (ms).
- Average time taken by user agency: It is defined as the time taken at the user agency for information gathering and is expressed in milli seconds (ms).
- Total packet loss: It is defined as the ratio of number of packets lost to the total number of packets transmitted. It is expressed in percentage(%).
- Packet delivery ratio: It is defined as the ratio of number of packets received to the total number of packets transmitted. It is expressed in percentage(%).
- Bandwidth utilization: It is expressed in percentage(%) and is defined as the bandwidth utilized off the total available bandwidth for information gathering.

- End to End Delay: It is the time taken by ICA and DMA to sense and gather the information of the IoT environment. It is expressed in terms of milli seconds (ms).

V. RESULT ANALYSIS

For the testing and performance analysis of the proposed scheme, here it is analyzed with above said performance metrics.

Information acquisition delay for varying number of devices is depicted in Fig. 4 and it is evident that, the amount of time required to sense the information increases as number of IoT devices increases. But the proposed scheme takes less time for the same than the EDCMS scheme.

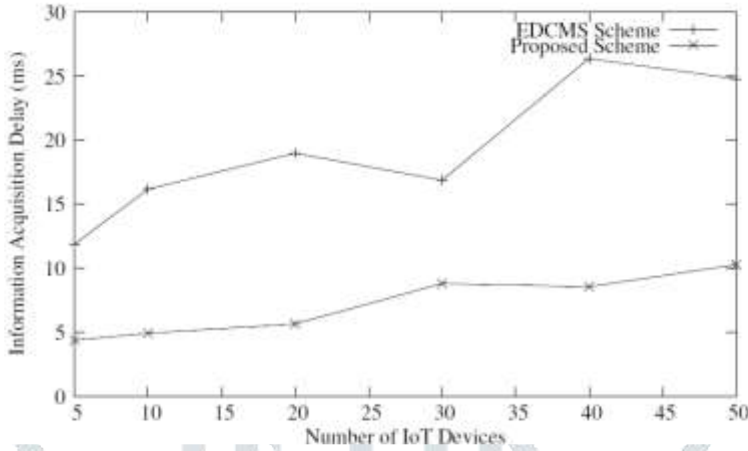

Fig.4 Sensing time Vs. Number of IoT Devices

Figure.5 shows that, as number of IoT nodes increases, the time taken to gather the information also increases and the proposed scheme performs better than EDCMS scheme.

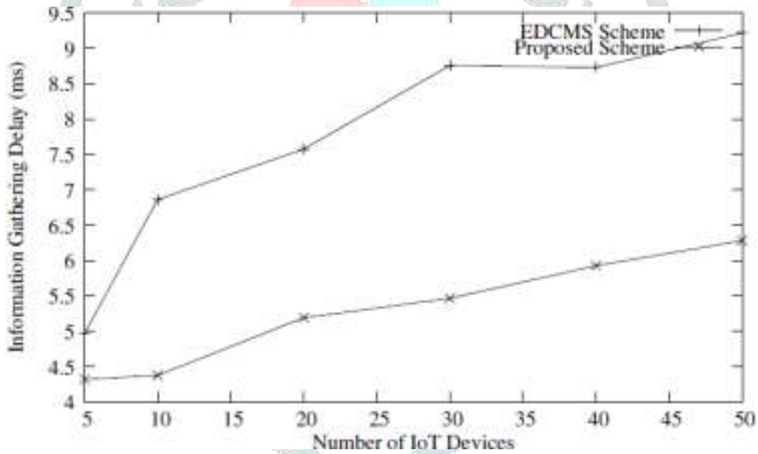

Fig.5 Gathering time Vs. Number of IoT Devices

It is clear from Fig. 6 that the time taken by the agencies to update the knowledge base increases with increase in number of IoT devices but the proposed scheme takes less time compared to EDCMS scheme.

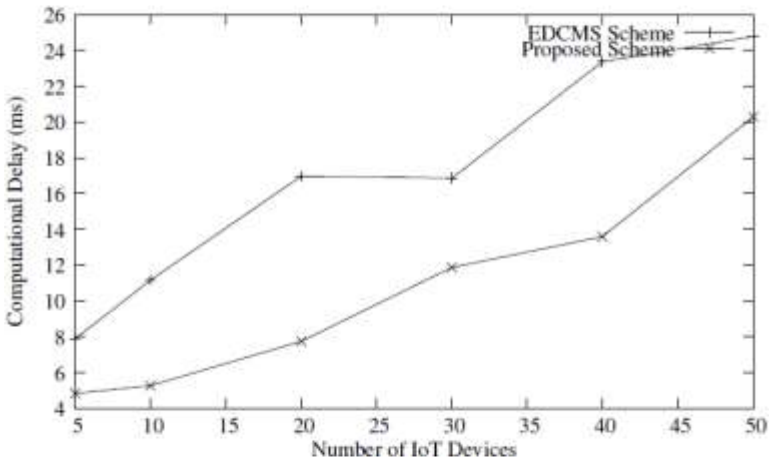

Fig.6 Computational delay Vs. Number of IoT Devices

Average time taken by user agency is depicted for different number of devices and from the Fig. 7, it can be seen that the proposed scheme takes less time for the same when compared to EDCMS scheme.

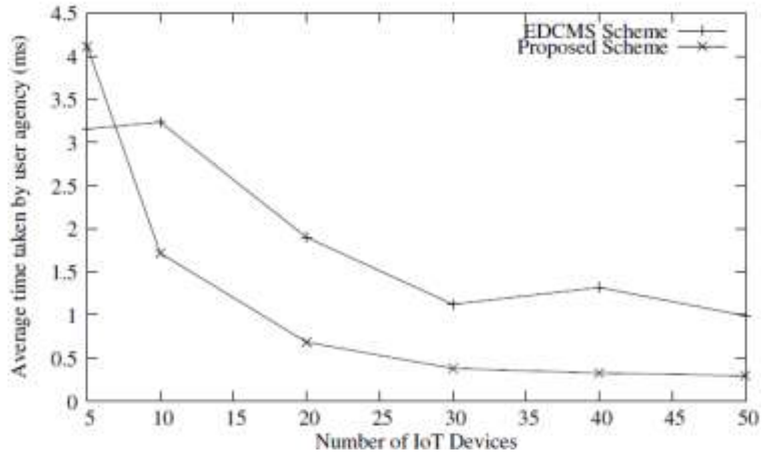

Fig.7 Average time taken by user agency Vs. Number of IoT Devices

The percentage of packet loss is more in EDCMS scheme than the proposed scheme, which is evident from Fig.8.

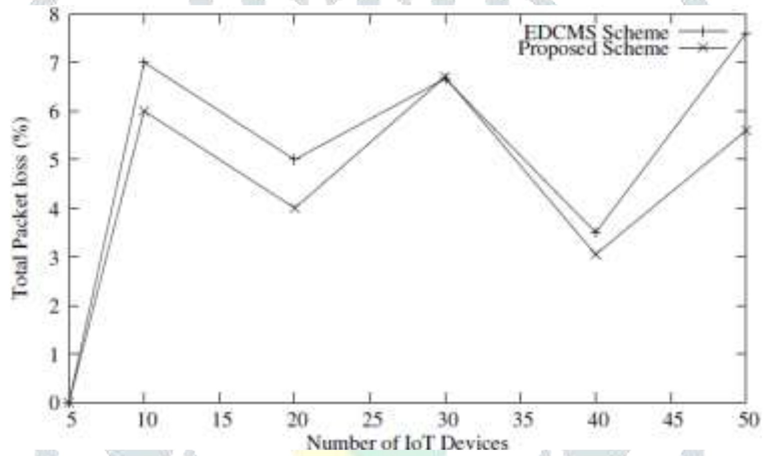

Fig.8 Packet loss Vs. Number of IoT Devices

The packet delivery ratio is plotted against varying number of IoT devices as shown in Fig.9 and the proposed scheme has higher PDR compared to the EDCMS scheme.

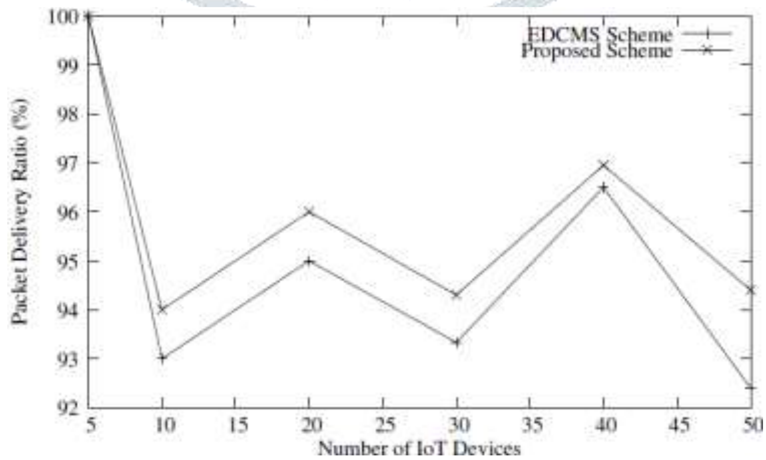

Fig.9 Packet delivery ratio Vs. Number of IoT Devices

The proposed scheme is designed in such a way that the amount of bandwidth utilized is lesser, which is shown in Fig.10 than MS scheme discussed above.

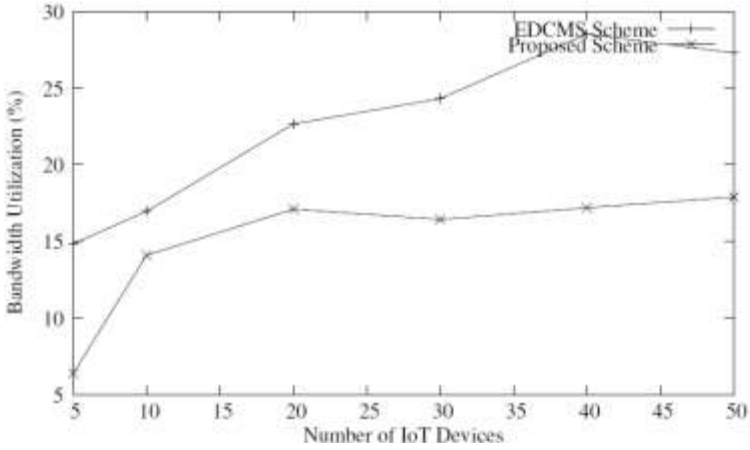

Fig.10 Bandwidth utilization Vs. Number of IoT Devices

It is evident from Fig. 11 that, the time taken by ICA and DMA to sense and gather the information of the IoT environment i.e. end-to-end delay for the proposed scheme is lesser when compared to the EDCMS scheme.

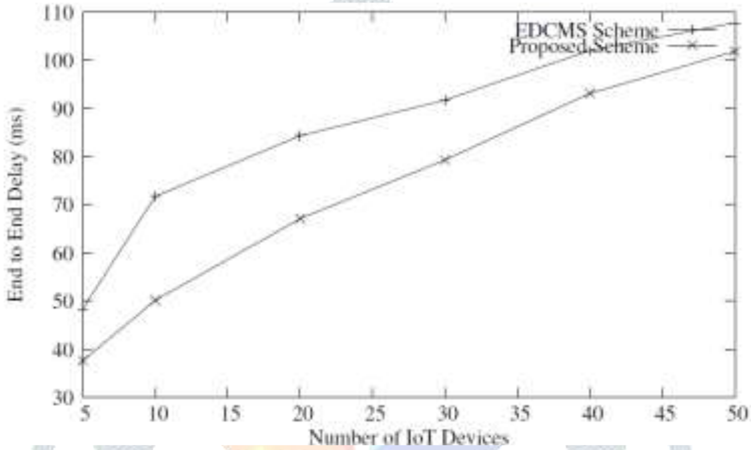

Fig.11 End to End Delay Vs. Number of IoT Devices

VI. Conclusion

Processing the enormous amount of IoT data will certainly increase the work load of sensor nodes, resulting into heavy network traffic, transmission cost, processing cost as well as storage cost. So it is necessary to adapt some intelligent data gathering schemes. In this paper, we have proposed an intelligent information gathering scheme in IoT using agent based approach. The proposed work is simulated for varying number IoT devices to validate the performance. From the simulation results it is observed that the proposed multi agent based scheme performs better as compared to EDCMS scheme in terms of information acquisition delay, gathering delay, packet delivery ratio, end-to-end delay and bandwidth utilization.

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