Design of IOT Based Water Supply Application using Zone Based Clustering

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Abstract— The Internet of Things is enabling smarter use of water at home. The water usage is monitored by deploying Automated Meter Reading (AMR), which helps in monitoring pressure, flow, usage of water. AMR based water supply applications, there is a loss of privacy and increased security risk from network or remote access. In this paper, Wireless Sensor Network (WSN) based nodes with Zigbee communication module are installed in each and every consumer's place instead of AMR to sense and store the parameters like pressure, flow, and usage of water. The geographical region is dived into Zone based clusters for managing the nodes in an efficient way. Zone Head (ZH) is selected using election algorithm. The data sensed by each node within the zone by the Zone Member (ZM) is forwarded to ZH. ZH sends data to the next upper level Zone Head directly or intermediate node, Duplication is eliminated by using Header based duplicate rejection algorithm. The aggregated data is sent to the sink node. Communication is established between sink node and the server for billing, troubleshooting, and analyzing.

Key words: Water Supply, IOT

I. INTRODUCTION

Internet of Things (IoT) refers to the networked interconnection of everyday objects, which are often equipped with ubiquitous intelligence. IoT will increase the ubiquity of the Internet by integrating every object for interaction via embedded systems, which leads to a highly distributed network of devices communicating with human beings as well as other devices. Smart homes, smart cities, manufacturing, healthcare, transports and logistics and smart grids are some examples of areas on which IoT is creating new business opportunities.

Nowadays smart water management is an emerging issue. Smart sensor or meters are used to transfer the sensed data from the water network to data centers for further analysis. Battery powered wireless sensor networks are a suitable solution for these large-scale smart water management systems. The main challenge of this approach is that sensor nodes require a lot of energy to transmit high precision data, sensor node has limited energy for which enhancement of network lifetime and aggregation is a major issue. Sensor nodes are equipped with a memory unit, a micro controller, a radio transceiver, and a set of transducers using which nodes can acquire and process data from the deployed regions.

ZigBee is based upon IEEE 802.15.4 standard. ZigBee is a set of high level protocols for low cost and low power wireless personal area networks. The aim of hierarchical routing is to reduce energy consumption and routing cost of sensor nodes by making them within a cluster in order to perform aggregation and reduce the number of messages transmitted to the sink node.

The rest of the paper is organized as follows: Section II explains related works. Section III deals with network deployment, Section IV explain about system overview, Data aggregation is given in section V and section VI elaborates about simulation result. Section VII concludes the paper.

II. RELATED WORK

In water supply, network utilizes Internet of Things (IoT) technologies to monitor and control the behavior of water network resources. Smart sensor, meters and actuator nodes are used to transmit information from the water network to the server for further analysis. Due to the underground position of water resources, many water companies tend to deploy battery driven nodes which last beyond the 10-year mark. This prohibits the use of high-sample rate sensing therefore limiting the knowledge we can obtain from the recorder data.

Sokratis Kartakis *et al* proposed compression technique for sensing the data. Two types of compression are lossless compression and lossy compression. Lossless compression technique compression is done without sacrificing original data. In lossy compression reconstruction error is possible.

Xianzhong Tian *et al* proposed Network Coding and Power Control based Routing (NCPCR) protocol. This protocol reduces the energy by encoding and decoding the packets. Although reducing transmit power can increase energy-saving, it may sustain bit error rate and packet loss rate, causing packet retransmissions.

Ruonan Zhang *et al* proposed node-density-based clustering and mobile collection (NDCMC), to combine Mobile Element (ME) data collection and hierarchical routing in WSNs. A number of cluster heads (CHs) collect information from cluster members and then an ME visits these CHs to collect data. The ME broadcasts beacon signals frequently when it is roaming through the sensing area and a node communicates with the ME when it listen the beacon signal. performance and energy efficiency should be improved.

Vipin Pal *et al* proposed balanced cluster size and this extends the life time of WSNs. The balanced cluster id formed by using threshold value. At the time of initial cluster formation threshold value has been set for number of nodes in clusters (Thcluster), whereas a distance threshold (Thdistance) has been set for unclustered nodes to join cluster. Unclustered nodes, after initial cluster formation, join cluster head (CH) according to Thdistance and Thcluster. Proposed solution has better balanced cluster formation depending upon these thresholds, resulting to prolong the life time of network.

Jin-Shyan Lee *et al* clustering approaches frequently use two methods: selecting cluster heads with more residual energy, and rotating cluster heads from time to

time, to distribute the energy consumption among nodes in each cluster and extend the network lifetime. Expected/Estimated Remaining Energy is used in Clusterhead (CH) Selection. Fuzzy inference systems (FIS) is used for the **chance** computation of each node. Two input variables are the residual energy and the expected residual energy and one output parameter is the probability of a node to be selected as a CH, named **chance**. The bigger chance means that the node has more chance to be a CH.

Rashmi Ranjan Rout *et al* proposed a system to enhance the lifetime of WSNs in bottle neck zone (sink) having heavy traffic-flow. The energy efficiency of bottleneck zone is improved by using duty cycle and network coding. In duty cycle Energy savings are done at the node level through switching between active and sleep states. Network coding mechanism uses intermediate nodes to encode data packets received from its neighboring nodes in the network.

Basavaraj S.*et al* proposed energy efficient data aggregation technique for WSN. In this paper, cluster is formed and the cluster head is selected based upon the cost value. The nodes in the cluster maintain a Neighbor Information Table (NIT) containing Node id, Distance and Cost. Each cluster selects a coordinator Node (CN) randomly in the network which is closer to the cluster and monitors the operations of the sensor nodes and commands them for specific operations. The cluster head aggregates the data and sends it to the CN. The CN calculates the loss ratio. Based upon the loss ratio, the cluster size can be modified. Once the cluster size is changed, the CN gathers the information again from the cluster head compresses it and sends it to the sink.

The previous works are dealing with energy minimization and enhancing the life time by efficient data collection, cluster head selection and data aggregation.

III. NETWORK DEPLOYMENT

Consider set of nodes and a sink deployed in a sensing area. Assume that the sensor network has the following properties.

1) Sensor network is to collect sensing data from sensor nodes to the sink, such that the destination of every sensing data is the sink.
2) The network is organized into hierarchical levels and each level is having one nor more zone based clusters. The ZM sends sensing data i.e, pressure, flow, usage of water to its ZH by intra cluster communication.
3) ZH forwards packets to the sink via multi-hop relays with the inter cluster communication.

IV. SYSTEM OVERVIEW

In this paper, sensor nodes are deployed in geographical area. The region is divided into Zone based Clusters for managing nodes very efficiently. Zone Head (ZH) is be selected using election algorithm. Zone Member (ZM) senses the data from each customer place and forwards it to Zone Head (ZH). Level 0 ZH sends information to level 1 ZH and level 1 ZH sends to Level 2 ZH and thereby aggregated information reaches the sink node.

Communication is established between sink node and the server for billing, troubleshooting, and analyzing. The following are the advantages of using zone based clustering and header based duplicate rejection algorithm:

1) Centralized control
2) Information from the sensor nodes can be obtained as when required
3) Life time of the network can be increased due to intra and inter cluster communication
4) Duplicate data will be eliminated.

A. Centralized Control:

Sink act as a coordinator node to control the overall network. Centralized control is maintained whenever it requires the sensed data; Sink will send the request message to all zone heads (ZHs) in level 1 zone clusters. This request message passes to within the zone members and next lower level 0 zone clusters (ZHs) and ZHs forward request message to Zone members (ZM), each zone have zone id (ZID), within the zone each member have node id (ZMID).

B. Zone Head Election:

Zone head is selected by each zone (Z_i) by using following zone head election algorithm

Algorithm 1: Zone Head Election

1) Let Z_i be the i^{th} level zone
2) ZMs in Z_i, send "HELLO" message to each other ZMs
3) Compare message arrival time with other message arrival time.
4) The hello message with earlier arrival time is wins the process. The id of the winning ZM will be ZH
5) Rest of the nodes are zone members and all ZM register ZH as the Zone Head.
6) Repeat the steps 2 to 4 if ZH fails
7) End

C. Data Collection-Level 0 zone members collect and send the sensed data to zone head. The data have the following parameters:

P1-Pressure
P2-Flow
P3-Usage

Intra zone cluster communication data packets have following format as shown in Fig 4.1.

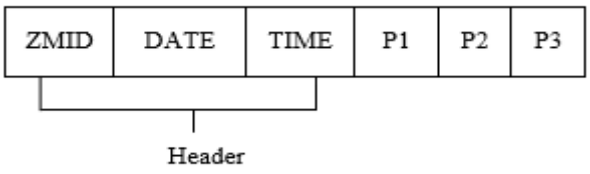

Fig. 4.1: Intra Zone Data Packet Format

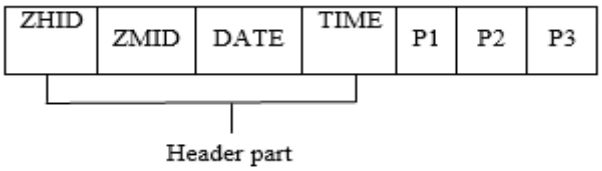

Fig. 4.2: Inter Zone Data Packet Format

Inter zone cluster communication packet have the following format as shown in Fig. 4.2.

Each node sends the collected data by establishing communication using send Clear-To-Send (CTS), Request-To-Send (RTS) and Acknowledgment message (ACK). Once RTS message is received by zone member ZM sends data to ZH. If ZH is busy with receiving data then CTS message will

be sent. After successfully sending data to ZH, it will reply the ACK message.

Algorithm 2: Zone based Clustering and data collection

1) Let N be the number of nodes in the network where N >0
2) Geographical region is divided into zones and let NOZ be the Number of Zones where NOZ > 0
3) Let Zi be the Zone and Zone Head (ZH) is in the i^{th} Zone where i= 1 to NOZ
4) Let Ni be the number of members available in i^{th} zone where i = 1 to NOZ

$$N = \sum_{1}^{NOZ} N_i$$

5) Let S be the Sink node (or) Coordinator
6) S send request message to Zone (Zi) and to the Zone Head (ZH)
7) ZH send the request message to the member of the that particular zone and also to the next level Zi
8) Repeat Step 7 till all the member of the network receives request message
9) ZH collects information such as pressure,flow,usage, member ID,date and time from ith Zone and send to Zi of next higher level.
10) Repeat Step 9 until the collected information reaches S
11) End

The overall architecture diagram is shown in Fig 4.3.

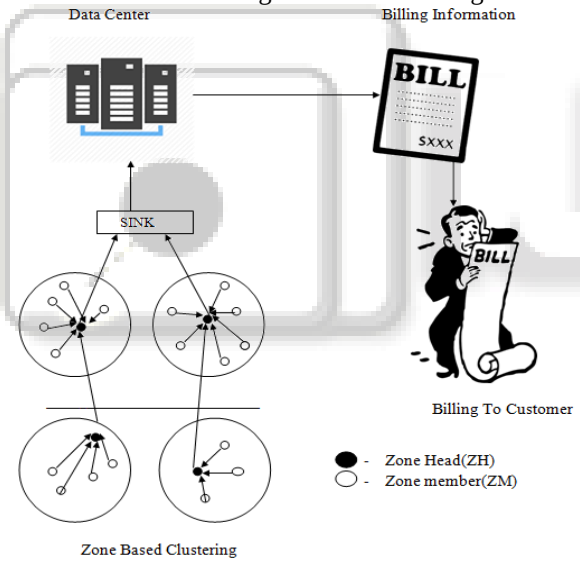

Fig. 4.3: Architecture Diagram

V. Data Aggregation

The main aim of data aggregation is to gather and aggregate data in an energy efficient way so that network life time is improved. Data aggregation or data fusion, which is the process of aggregating the data from multiple nodes to eliminate redundant transmission and provide fused data to the sink. Aggregation is a technique for WSNs to save energy. Data aggregation method is clustering data aggregation, in which each ZH aggregates the collected data and transmits the fused data to the sink node. Data aggregation is performed by each zone head ZH with the data received from the corresponding ZM. Level 0 zone head aggregates the data and it is send to level 1 zone head via inter cluster communication. Level 1 cluster head sends the aggregated data to the sink node. If ZH of a particular zone receives the same data from more than one ZHs of lower level cluster then there is chance of receiving duplicate message. This duplicate data is eliminated by using Header based duplicate rejection algorithm.

Algorithm 3: Header based duplicate rejection

1) Let ZHID be the ID of a Zone Head
2) Let ZMID be a ID of a member in a particular Zone
3) Let D be the date and T be the Time
4) Let a packet contains header part with ZHID, ZMID, D, T information and data part with P1, P2, and P3 where P1 is pressure, P2 is flow and P3 is usage
5) ZH of i^{th} level receives the packet from ZH of i-1 level
6) Compare the Header part of the packets received by ZH
7) If the header part of two packets match, keep one copy of the packet and discard the other packet
8) Else keep both packets for further processing
9) Repeat Steps from 5 to 7 until all the information reach S
10) End

VI. Simulation Result

In this section, experimental set up is done using NS2 simulator, taking 1000*1000 area for 50 sensors nodes deployment to evaluate following metrics:

1) Packet delivery ratio
2) Data latency

Throughput

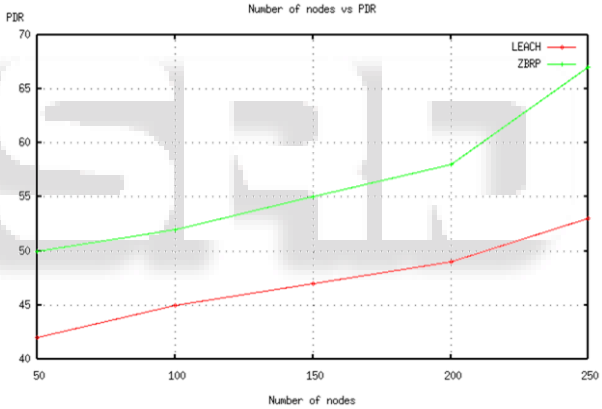

Fig. 6.1: Number of Nodes Vs Packet Delivery ratio

The graph between number of nodes and Packet delivery ratio (PDR) comparing the performance of LEACH and Zone Based Routing Protocol (ZBRP) is shown in Fig. 6.1. From the Fig. 6.1 it is understand that the packet delivery ratio is increased when number of nodes increase in both LEACH and ZBRP. As LEACH has limited data transmission time it stops sending packets after the time limit. Hence, packet delivery ratio is more in ZBRP compared to LEACH.

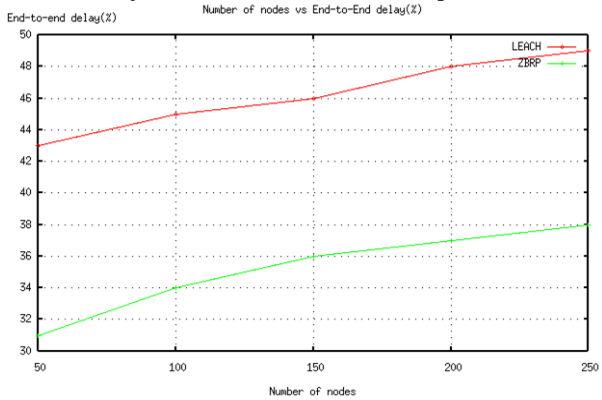

Fig. 6.2: Number of Nodes Vs End-to-End delay

The graph between the number of nodes and End-to-End delay comparing the performance of LEACH and ZBRP is shown in Fig. 6.2. From the Fig. 6.2 it is evident that the end-to-end delay is increased when number of nodes increases. In LEACH delay is caused by discovery of route and use of TDMA scheduling data packet transmission. Comparing the End-to-end delay of ZBRP, LEACH has high End-to-End delay. In ZBRP, shortest path from the node to sink is determined using neighbor information table.

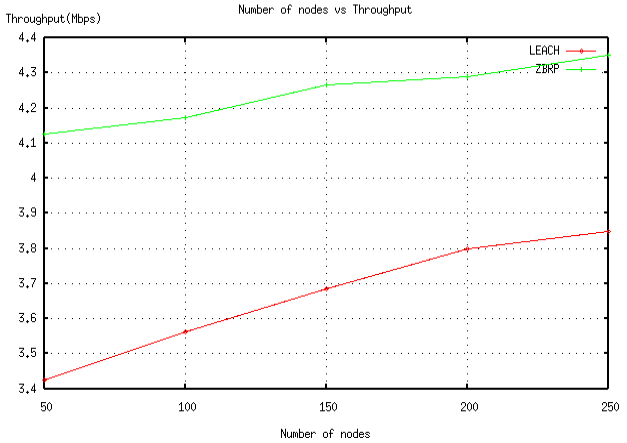

Fig. 6.3: Number of nodes Vs Throughput

The number of nodes versus throughput is shown in Fig. 6.3. From the above graph, it is clear that the throughput is increased when number of nodes increases. Data packets are successfully delivered to destination as ZBRP uses RTS-CTS-ACK mechanism. Also packet drop rate is decreased in ZBRP compared to LEACH and hence throughput is increase in ZBRP.

VII. Conclusion

The proposed water supply application network use zone based clustering and Zigbee based routing. The data collection and aggregation are used to achieve the greater performance of the network, less load, less energy consumption. From the simulation results it is revealed that the packet delivery ratio increased, packet drop rate is decreased maximizing network lifetime by eliminating redundant data. Also the throughput of ZBRP is better than LEACH protocol.

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