Sensor Data Aggregation using a Cross Layer Framework for Smart City Applications

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***Abstract**: Smart cities are developed with the help of many Internet of Things applications. WSN is made of few to hundreds and thousands of nodes and a node is connected to one or many sensors. Sensor nodes communicate with each other through wireless network and generates a vast amount of data. To transmit the sensed data, more energy is required. There is a need of a proper framework for the applications to search and use the data efficiently. In this paper, we have used a distributed protocol which uses query based data aggregation to extract the sensor data from different applications. The first application refers to garbage management which abstain from spreading some dangerous infections, by observing the status of the dustbin. The second application is the traffic alert to give traffic congestion data to the user. The cross-layer commit protocol analyzed in this project is based on cross layer designs of the application layer and network layer. Also, a middleware is designed to process the query request.*

Keywords: Smart Cities, EEPROM, Wireless Sensor, Data aggregation, Cross Layer.

1. INTRODUCTION

With emergence of Radio-frequency identification, the concept of IoT has started and has grown rapidly with the support of Wireless Sensor Networks. WSN has an important role to play in the growth of IoT as the hardware becomes low-priced, hefty and boost the battery life [1]. Sensor network provides a bridge between real and virtual world. However, the sensor nodes in wireless sensor network have limited battery and are resource constrained with respect to energy, computation and memory. A sensor node generates data and transmit sensed data packet to the sink through intermediate sensor nodes. Since more energy is required to transmit data over long distances, so to save energy and resources and to reduce the traffic, the data must be aggregated. Aggregator nodes collect data from multiple sensor nodes, uses some aggregation function to aggregate the data and sends the aggregated data to the sink node. Data aggregation reduces the energy consumption and get rid of unwanted data transmission. Smart cities are based on a lot of applications [2] which requires a billion of sensors which generates a vast amount of data. To make use of these data efficiently, the applications should analyze the data properly. For this, there should be a proper framework to search the required sensor. The distributed cross-layer commit protocol is implemented to reduce the consumption of sensor energy by introducing query based data aggregations. It uses the cross-layer communication between the network layer and application layer.

2. LITERATURE SURVEY

In this section, we have briefly explained the existing methods and protocols in data aggregation and cross layer designs. Data aggregation approaches has been extensively studied before [3]. Sensor networks are distributed event-based systems that differ from traditional communication networks in several ways: sensor networks have severe energy constraints, redundant low-rate data, and many-to-one flows. Data centric mechanisms that perform in-network aggregation of data are needed in this setting for energy-efficient information flow. Data-centric routing is modelled and its performance is compared with traditional end-to end routing schemes.

The impact of source destination placement and communication network density on the energy costs and delay associated with data aggregation is examined. Data-centric routing offers significant performance gains across a wide range of operational scenarios. The approach proposed is not efficient for query-based search data aggregation approaches that are used in many IoT applications. Data aggregation has been put forward as an essential paradigm for wireless routing in sensor networks. The idea is to combine the data coming from different sources enroute – eliminating redundancy, minimizing the number of transmissions and thus saving energy. This paradigm shifts the focus from the traditional address-centric approaches for networking (finding short routes between pairs of addressable end-nodes) to a more data-centric approach (finding routes from multiple sources to a single destination that allows in-network consolidation of redundant data).

In the existing cross-layer atomic commit protocol called CLCP uses multiple coordinators and makes use of acknowledgement messages to piggyback information [4]. Transaction processing in mobile ad-hoc networks must take network problems like node disconnection, message loss, and network partitioning into consideration. Special to the simulation environment is the use of the quasi-unit-disc model, which assumes a non-binary message reception probability that captures real-world behaviour much better than the classical unit-disc-model, often used in theory.

The cross-layer communication has been attempted in a few papers. Hardware for sensor nodes that combine physical sensors, actuators, embedded processors, and communication components has advanced significantly over the last decade, and made the large-scale deployment of such sensors a reality. Applications range from monitoring applications such as inventory maintenance over health care to military applications. In [5], query layer for sensor networks is designed. The query layer accepts queries in a declarative language that are optimized to generate efficient query execution plans with in-network processing which can significantly reduce resource requirements. The main architectural components of such a query layer, concentrating on in-network aggregation, interaction of in-network aggregation with the wireless routing protocol, and distributed query processing is examined. A database layer for sensor networks is proposed and evaluated; component of the system that is located on each sensor node is called as the query proxy. Architecturally, on the sensor node, the query proxy lies between the network layer and the application layer, and the query proxy provides higher level services through queries.

In [6] the authors concentrated in the problem of energy conservation and life expectancy of smart sensors; because, they are not refillable by micro-piles. To solve the problem of limitation of the network regarding energy resources, the approach is based on a combination between several existing mechanisms of energy saving by addressing more particularly on the data routing. The existing routing protocol ZRP cannot resist in large scale (because it isn't an adapted protocol for WSN). To overcome this limit, the approach consists in improving this protocol with the aim of having the best answers for the requirements of WSN by the introduction of hierarchical organization based on the crossing between different layers, to obtain the proposed protocol H-ZRP.

3. PROPOSED BLOCK DIAGRAM

The architecture of IoT is designed with four layers: application layer, middleware, network layer, sensing layer.

All the IoT applications will run in the application layer from where it can interact with the sensing layer. Through the middleware, applications will query the sensing layer to that data can be obtained which is required for the applications. An interface is provided by the service layer which is independent of the platform and device to extract the data from the sensors. The network layer is used to interconnect the sensors and is used to transfer data between the data store of middleware and sensors in the physical layer.

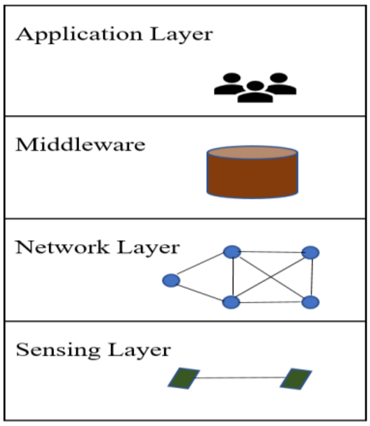

Fig. 1 Architecture implemented

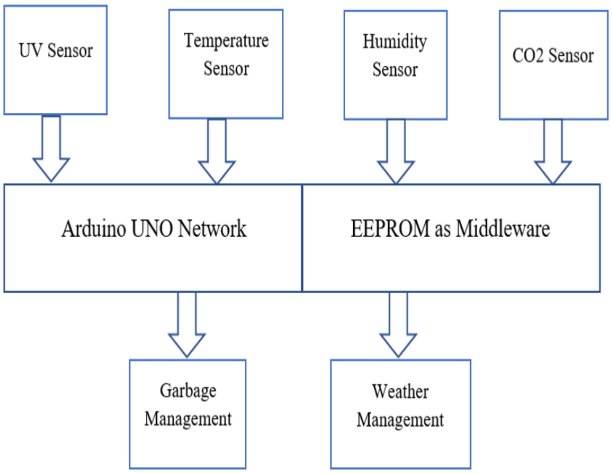

Fig. 2 Block Diagram

4. IMPLEMENTATION

The entire system will be used to monitor the following applications:

Garbage Management:

Smart dust bins are used here to abstain from spreading some dangerous infections, by observing the status of it which should be connected to the internet for the real-time information. Microcontrollers are integrated into the dustbins which contains Infrared Sensor and RF Transreceiver. The dust level is detected by the sensor and the data is sent to the microcontroller and then to the cloud.

Weather Management:

To screen and evaluate the conditions if there is a rise in the occurrence of surpassing the endorsed level of parameters, an efficient environmental monitoring system is required. Smart environment is achieved at the point when the items like condition furnished with sensor gadgets, microcontroller and different programming applications turns into a self-securing and self-checking condition.

Board Hardware Resources Features:

Ultrasonic Sensor:

It is used to detect any moving or stationary objects within the specified range which is pre-decided. The HCSR04 ultrasonic sensor uses sonar rays reflection and reception mechanism to calculate the distance from the object.

Temperature and Humidity Sensor:

AM2302 output calibrated digital signal. It applies exclusive digital-signal-collecting-technique and humidity sensing technology, assuring its reliability and stability. Its sensing elements are connected to 8-bit single-chip computer.

The cross-layer commit protocol implements data aggregation using both the network and application layer. The application layer initiates the query request and goes to the network layer. Whichever nodes will reply to the query will be considered as the members of the cluster. In this protocol, two parameters are considered to determine the cluster head: residual energy and average distance between cluster members. The nodes having higher value for both the parameters is selected as the cluster head.

There are two stages involved in this approach:

1. To find the cluster head:
   - Sensor nodes should take the routing decisions.
   - The data registry generates a query which is forwarded to the sink node.
   - The sink node then forwards the query to the sensor network.
   - The nodes which will be responsible to provide data for that particular query should reply to the root node by sending an acknowledgement message.
   - All the nodes which will the send the acknowledgement will form a cluster.
   - Based on the highest residual energy and the average distance of the cluster members, the cluster head will be selected.

2. To collect the data:
   - After receiving the acknowledgement, the sink nodes will a send a signal to the cluster members to send the data.
   - The cluster members will now send the data to the sink node via the cluster head.
   - Cluster head is responsible for data aggregation in the network layer.
   - As the query period expires, the cluster and cluster head identified will be removed and new cluster will be formed for new queries.

5. RESULTS

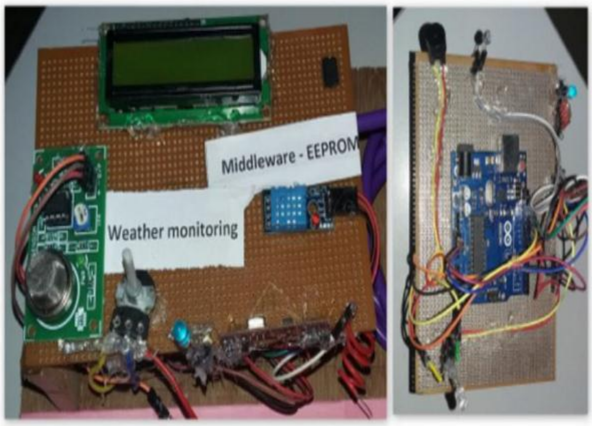

Fig. 3 Prototype module

Initially all sensors are in sleep mode. Sensors are initiated by Arduino and gross the data and passes it to middleware. Application layer consists of many designed applications like garbage management and weather management Application layer takes the data from middleware and performs the data aggregation.

6. CONCLUSION

A working prototype of the proposed system was successfully created and implemented. The cross-layer commit protocol method along with the query based data aggregation has better performance than the other approaches in reducing energy consumption. Different applications use different sensors according to their requirement. To search the appropriate sensor according to the application and retrieve the data from the right sensor, query based search is very useful. Performing data aggregation in a single node instead of using all the sensor nodes will improve the consumption of energy of the entire network.

The system can be improved by using caching mechanism to store the aggregated values for a long time which is not possible in the current system.

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