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Delay-aware heterogeneous cluster-based data acquisition in Internet of Things☆

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ABSTRACT

The environmental conditions of a wildlife habitat are monitored using many heterogeneous sensors, including temperature, humidity, pressure, and water-level sensors. Sensor data are collected from various regions for knowledge retrieval about the various parameters to analyse the wildlife habitat and take necessary actions. The Delay-Aware Heterogeneous Cluster-based Data Acquisition (DA-HCDA) technique is proposed, which ensures maximum coverage. A multifarious Sensor-based Cluster Formation Algorithm (MSCFA) is used to from the cluster and elect the controllers to handle the different types of sensors. A multi-tier aggregation function called Quartile Aggregation is proposed, which eliminates the redundancy of aggregated data at the controller. Thus, the proposed DA-HCDA and Quartile Aggregation mechanism improve the network lifetime and end-to-end delay across the wildlife habitat reserve.

1. Introduction

The Internet of Things (IoT) contains groups of interrelated devices that are able to exchange data. It brings the Internet into the physical world such that the objects can be tracked and managed remotely. A thing within the Internet of Things can be someone with a cardiac-monitoring implant, an automobile with inbuilt sensors that alert the driver when tire pressure is low or any other natural or man-made object that has been allotted an IP address. The primary aim of the IoT is to create a better world for people, where things around us communicate with one another and know what we like, what we want, and what we need and act accordingly without specific instructions.

We consider the three layers of IoT architecture [15,16,17,21], namely, the Application layer, Network layer and Physical layer, which are shown in Fig. 1. The edge devices, such as light sensors, humidity sensors, temperature sensors, and pressure sensors, are in the physical layer. Data collection, parameter tuning and the transmission of collected data are the main functions of the physical layer. Communication technologies such as WiFi, Bluetooth, and 3G are the facilities in the network layer, which helps in providing the communication facility. The application layer has, for instance, monitoring devices, smart watches, and tablets and is where data storage, data processing and decision-making are performed. As the sensors are energy-constrained devices, sensor data is periodically collected and stored in some database [13]. The application layer processes the collected data and provides services to the end users. The network layer consists of middleware devices, such as WiFi, WiMax, and ZigBee. Middleware devices act as bridges between applications and the underlying hardware. They are used to transfer information over a large area. The sensing layer (physical layer) consists of various sensing devices such as

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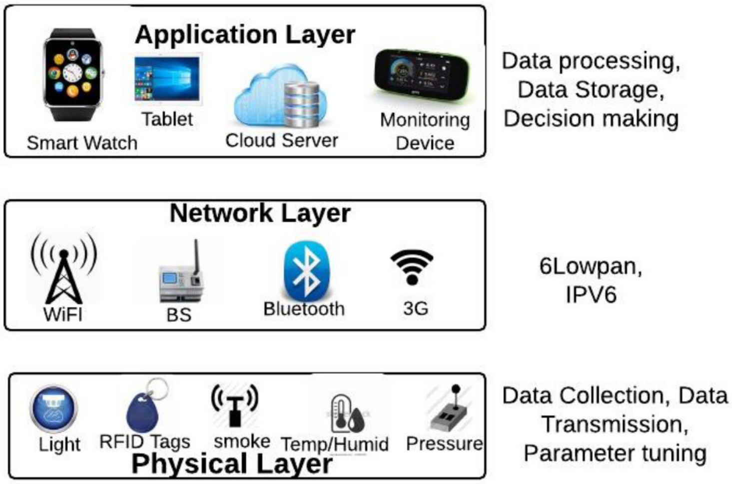

Fig 1. Architecture of IoT.

controllers, sensors (smoke, temperature, pressure, light, humidity), RFID tags, cameras, energy metres, and actuators, which monitor, collect and tune the measurements. They have limited energy, memory and processing power. These devices also communicate with one another and send the appropriate data back to the network layer using RFID, Bluetooth or other technologies. In the physical layer, data collection, transmission and parameter tuning are based on the places and events to be monitored. This collected information is transmitted to the BS with the help of Bluetooth, WiFi, WiMax, etc. A massive number of devices are used to monitor different types of events in the environment. 6LoWPAN is used to identify individual devices in a massive environment. The pre-processed information is stored in the BS to serve the devices based on their needs.

The IoT technology can be applied to the Wildlife Habitat Monitoring system, as the sensors can be used to continuously monitor the specific environmental conditions where the human intervention is not possible. Different types of sensors, such as temperature, pressure, humidity, heat (to determine the sunlight intensity), and water-level sensors, can be installed around each animal reserve and the data gathered by these sensors can be used for the betterment of the environment of wildlife. Water is mandatory for the survival of animals. The current drinking-water level can be found for each animal and the water reservoir can be refilled when necessary. The surrounding temperature and humidity should be adapted to the different types of animals. This can also be monitored using appropriate sensors. The animals require a minimal amount of sunlight to survive, which can be regulated using heat sensors.

The environmental monitoring system requires the deployment of a large number of sensor devices to sense the region and transfer the sensed data to the higher layers. Hence it is mandatory to have an efficient data-collection method for these applications to collect the information from these tiny devices and send those data to the BS. Since the sensing layer of IoT is similar to a Wireless Sensor Network (WSN), the methods used in WSN are also applicable to the IoT environment.

Data-acquisition methods for WSN are classified based on the mobile sensor nodes as static-link approaches and mobility-based approaches. The latter are further divided into single mobile sinks and multiple mobile sinks, where the mobile sinks will have higher energy. These sink nodes collect the data from the nearby nodes and the links between the mobile sinks and the nodes will change over time. The data-collection phase is divided into data discovery, data transfer and data routing phases. The data-gathering methods [11] differ based on the logical topology of the network and are classified as flat, chain, cluster, tree and cluster-tree based topologies.

The monitoring component of IoT is the Wireless Sensor Networks. The sensor networks are comprised of one or more sensor nodes of different types, which have sensing, computing and transmission capabilities. These nodes are deployed in specific areas depending on the data-collection needs. Direct communication between these nodes and the BS will result in loss of energy and delay in the delivery of data. Therefore, clustering of the sensor nodes is performed to provide an efficient data-collection process. Clustering is a method during which nodes in close proximity organize themselves as a group and elect a Cluster Head (CH), which acts as a representative of the group. The CH receives sensed data from its cluster members, aggregates the data and forwards it to the BS. The CH should be elected based on some predefined parameters, which helps in improving the performance of the network.

Usually, clustering is done in homogeneous networks, in which all sensor nodes have similar amounts of battery, computational and communication power. Additionally, every sensor is of the same type. They have the same lifetime since they have the same energy-consumption rate. However, in real-world scenarios, each node is different from the other nodes in some way. In a heterogeneous WSN, since each sensor is of a different type, the sensor nodes will have different capabilities such as communication capability, sensing range, storage and processing capacity. This provides more flexibility in deployment. There are three types of heterogeneity:

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