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Energy aware cluster and neuro-fuzzy based routing algorithm for wireless sensor networks in IoT

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Abstract

Wireless Sensor Networks (WSNs) are used in the design of Internet of Things (IoT) for sensing the environment, collecting the data and to send them to the base station and the locations used for analysis. In WSNs for IoT, intelligent routing is an important phenomena that is necessary to enhance the Quality of Service (QoS) in the network. Moreover, the energy required for communication in the IoT based sensor networks is an important challenge to avoid immense packet loss or packet drop, fast energy depletion and unfairness across the network leading to reduction in node performance and increase in delay with respect to packet delivery. Hence, there is an extreme need to check energy usage by the nodes in order to enhance the overall network performance through the application of intelligent machine learning techniques for making effective routing decisions. Many approaches are already available in the literature on energy efficient routing for

WSNs. However, they must be enhanced to suite the WSN in IoT environment. Therefore, a new Neuro-Fuzzy Rule Based Cluster Formation and Routing Protocol for performing efficient routing in IoT based WSNs. From the experiments conducted in this research work using the proposed model, it is proved that the proposed routing algorithm provided better network performance in terms of the metrics namely energy utilization, packet delivery ratio, delay and network lifetime.

Introduction

Internet of Things (IoT) [35] is a new computing facility which consists of the features from networks, devices and software and it helps to connect many devices for co-ordinated working. The design of IoT must take care of challenging issues with respect to interconnection and communication. The existing protocols designed for wired, wireless and sensor networks cannot be used directly for enhancing the performance of IoT based networks due to the presence of heterogeneous devices including tiny devices and larger house hold devices. There are many applications in day to day life in which we use mobile phones, laptops, sensors and house hold devices such as air conditioner, fridge, coffee maker, microwave oven and washing machines that are collected with IoT for performing many of our activities. Moreover, IoT can be used along with our vehicles using vehicular adhoc networks and they can be used for data collection routing and an amount of intelligence can be introduced in IoT for effective co-ordination and communication.

The intelligence can be introduced in IoT devices through the application of machine learning techniques and soft computing approaches. In such a scenario, the sensors present in the IoT can use the rules formed by deep learning algorithms for making effective decisions on actions to be performed. Moreover, mobility of devices is also allowed in IoT devices and hence the formation of rules for mobility management, energy optimization and intelligent routing are the important challenges into be addressed in the design of IoT based networks. In an IoT system, the human-usable objects namely air fresheners and smart vehicles can be made intelligent by writing rule based programming techniques so that such devices can respond flexibly based on the decision made by the decision manager. An inference engine can also be designed for effective decision making with respect to improvement in quality of service in IoT environment. However, it is different from Ubiquitous Computing environment [34]. Internet Protocol Version 6 (IPV6) provides some support for routing of data in the IoT environment. However, the data collection, data representation, data storage and communication must all together cooperate for effective working of the IoT application. This can be achieved by developing machine learning and rule based approach for making data collection and communication intelligently.

An intelligent device can be designed by making a sensor for efficiently sensing the environment, an actuator which can take actions based on deductive inference by firing rules and a decision making module which can provide intelligent decisions by the skilful applications of rules. Such a design can be made effective through the mathematical modelling of the behaviour and by developing an intelligent data communication mechanism. So, IoT can be given as an equation with the sum of three main components namely Physical object, Controller, Sensor and Actuator (CSA) and the Internet. The Internet Protocol version 6 (IPv6) is the lowest power network used to connect the sensors that are incorporated in the IoT. There are many factors that will affect the working of IoT such as design, configuration, language communication, data flow, setting up of a generalized framework, compatibility, energy consumption at data centres and user interface to interact with the objects [37]. In such a scenario, energy efficient intelligent routing is a major aspect to be considered during data transfer between sensors and sink node and then to the internet in the IoT environment. An eventual and drastic change in data communication is possible only via WSNs in IoT. So, IoT is considered null without the support of WSNs.

In IoT environment, Wireless Sensor Networks (WSNs) [36] is an important component that has attracted the overall networking and IoT communities, especially with the advancement of Micro Electro Mechanical Systems that supported the change of smart and intelligent sensors. These sensor nodes present in WSN is capable of sensing the environment and to measure the environmental conditions for accumulating the corresponding data to be sent to the user through base station. In such a scenario, battery life is the most important resource to be considered in the design of such nodes [1]. A sensor node carries limited and generally irreplaceable power sources. Therefore, it is necessary to design the nodes of the WSN with energy efficiency and to make the related protocols to focus on the improvement of overall quality of the network.

Clustering of nodes in the network is the successful topology design and control technique that can be adopted to diminish energy utilization in the nodes of the WSN. Clustering and performing the cluster based routing improves the network conditions namely energy efficiency, reduction in delay and increase in scalability [15]. The two imperative steps that are used in the cluster based routing include the selection of Cluster Head (CH) and routing through CHs [16], [17]. The energy can be conserved more by the CH by collecting the data from the nodes and forwarding them through the CHs to the sink node [2]. So, selecting the CH appropriately among the nodes can diminish the energy utilization and prolong the lifespan of the WSN. Moreover, most of the researchers focused on CH selection in clustering and cluster based routing. However, [2], [3] and [7], [8], [9] energy consumption is the most important factor on cluster formation and routing only a few researchers have concentrated on cluster arrangement for effective routing this past [10], [11], [12]. In Low Energy Adaptive Clustering Hierarchy (LEACH) [22], [23], clusters are formed for each round based on the space between the node and the CH, the nodes disregard the alternate components that impact the energy utilization and the system life span. In this protocol, energy is modelled and the node having the highest energy and the lowest distance from the member nodes are considered for the selection of CHs. Whenever the energy available in

the CH becomes less than any of the available cluster members in the network then, a new CH is elected using the same criteria. In [10], cluster is formed using fuzzy logic by considering 3 factors. One limitation of this work is that it does not consider the cluster size in the network, which is an important component for the uniform energy utilization by the nodes in the network. In [9], a new member joining method is proposed where upon receiving the willing to join message, the CH allows the sensor node to join the CH. But they did not clearly mention on what factor the member can join with the CH. Other related works in this area include [18], [19], [20], [21]. All these works attempted to reduce the energy consumption and provided techniques for optimal energy consumption. However, due to the uncertainty happening due to the movement of nodes, most of this works had the limitation in terms of energy optimization.

There are many works that are discussing about cluster based intelligent routing in WSN. Among them, the Fuzzy Logic based Cluster Formation Protocol (FLCFP) is considered in this work with extensions for performance improvement through the use of deep learning techniques by applying convolutional neural network (CNN) for predicting the energy requirements so that it is possible to make effective routing decisions. Comparing with FLCFP, the proposed model discussed in this paper enhances the network life time and reduces the energy consumption by the skilful application of fuzzy rules and the modification of knowledge base consisting of rules dynamically through the effective training of the neural network. In another work by Younis and Fahmy [3] called Hybrid Energy Efficient and Distributed (HEED) model for energy efficient cluster based routing, a probabilistic model is used to measure the network traffic and the probability values are used in the clustering and cluster based routing process. However, the probabilistic approach used in this work must be enhanced in order to improve the accuracy of decision making.

To overcome the issues in the previous cluster formation techniques, we propose a new protocol called neuro-fuzzy based cluster formation protocol (FBCFP), which performs learning of the network by considering four important components namely current energy level of the CH, distance of the CH from the sink node, change in area between the nodes present in the cluster and the CH due to mobility and the degree of the CH. For this purpose, the network is trained with convolutional neural network with fuzzy rules for weight adjustment. Moreover, we used fuzzy reasoning approach for powerful cluster formation and to perform cluster based routing. Once the CH has been selected, each of the non-CH nodes in the system apply these four factors for all CH in the proposed network using Mamdani Inference System and it uses the member join principle by considering the maximum value of energy for becoming the CH. In order to evaluate the proposed routing algorithm, its performance is contrasted with LEACH, FLCFP and HEED. The experimental results pertaining to this work has shown that the proposed technique namely FBCFP expands the system lifetime extensively than LEACH, FLCFP and HEED. In addition, it is shown that the proposed FLCFP reduces the energy utilization and enhances the QoS in IoT based sensor networks by keeping the cluster size uniform and the power utilization to become optimal by applying rules learnt from training of the system using machine learning algorithm and by applying the rules for making effective routing decisions. Through the simulations conducted in this research work, it has been proved that

the packet delivery ratio is enhanced and the other QoS parameters namely delay and energy consumption are reduced due to the use of convolutional neural networks for learning in the proposed work.

The rest of the paper has been organized as follows: in Section 2, the related work in the areas of cluster based routing has been explored. In Section 3, the proposed work along with the fuzzy based routing protocol developed in this work has been detailed. In Section 4, assessment of the proposed work is performed and the results are depicted with suitable comparative analysis. Finally, we concluded this paper in Section 5.

Section snippets

Literature survey

Energy efficient design of sensor networks based IoT system is complex due to the energy constraints present in the sensor nodes. In such a scenario, energy conservation during the data collection and routing process is an important design issue that is also used for evaluating the performance of IoTs using WSN. To accomplish the energy efficiency, numerous routing algorithms based on clustering have been proposed in the literature [2], [3], [4], [5], [6], [33]. LEACH [13] is an important...

Cluster formation protocol using neuro fuzzy rules

The most important goal of the proposed research work is to enhance the lifetime of the IoT based WSN. So, this work proposes a deep learning based approach integrated with Neuro-Fuzzy Inference System (NFIS) for the extension of network lifetime. NFIS is the method which is useful for decision making by taking multiple inputs to provide a single qualitative output. The proposed model works in many rounds starting with initial round, continuing with intermediate rounds and ending with the final ...

Results and discussions

The proposed cluster formation protocol was tested through simulations using the MATLAB software. Moreover, experiments have been conducted by varying the number of nodes starting from 100 nodes and tested upto 500 nodes. These nodes have been deployed over an area of (100×100) m^2. The parameters that have been used in this work for the simulation are presented in Table 2.

The proposed algorithm is tested broadly and the outcomes are presented. In our simulation, we conducted two set of...

Conclusion and future enhancement

In this paper, a new routing algorithm for IoT based sensor networks that uses neuro-fuzzy rule based clustering approach for performing cluster based routing in order to enhance the network performance. In this approach, the cluster formation in WSNs utilized the energy modelling for efficiently routing the packets through the application of machine learning using convolutional neural network with fuzzy rules for weight adjustment and hence the network lifetime is prolonged. Moreover, we...

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> ...Finally, the simulation outcome has revealed that the developed model has outperformed other conventional protocols with respect to hop count, probability of message delivery, count of dropped messages, the ratio of message overhead, and average buffer time. In 2019, Thangaramya et al. (Thangaramya et al., 2019)

> have stated that there has an immense requirement on checking the node's energy usage for enhancing the total performance of network by the intelligent machine learning models application to make efficient routing decisions. Already, there exist more models under the routing process....

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