Clustering Based Optimal Cluster Head Selection

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The goal of today's technological era is to make every item smart. Internet of Things (IoT) is a model shift that gives a whole new dimension to the common items and things. Wireless sensor networks, particularly Low-Power and Lossy Networks (LLNs), are essential components of IoT that has a significant influence on daily living. Routing Protocol for Low Power and Lossy Networks (RPL) has become the standard protocol for IoT and LLNs. It is not only used widely but also researched by various groups of people. The extensive use of RPL and its customization has led to demanding research and improvements. There are certain issues in the current RPL mechanism, such as an energy hole, which is a huge issue in the context of IoT.

RPL | fish swarm | bio-inspired approach | energy optimization | grid formation | convolution clustering | data transmission | cluster head | alive and dead node

1. Introduction

Every object should be smart in today's technological world. The Internet of Things (IoT) is a new paradigm that gives common objects and things a whole new dimension. Wireless sensor networks, particularly Low-Power and Lossy Networks (LLNs), are essential components of IoT. It has a high impact on usage in everyday life [1]. The usage at home, industry and institutions is growing exponentially every day. It is considered one of the most influential technologies of the modern era. The devices added to IoT are growing in leaps and bounds every day. Homes, classrooms and cities are becoming smart with IoT [2][3].

IoT is a new paradigm that connects computers, humans, devices and objects together for communication. There are many definitions given for IoT [4]. A popular definition is: IoT is a connection between the physical and digital worlds. Sensors and actuators are used to connect the digital and physical worlds. IoT is a concept in which computing and networking capabilities are incorporated virtually into any device. The capabilities are used to query the state of the object as well as change it, if possible. IoT is the networking of persons, things, objects and devices that communicate with each other to achieve a complex task, where a high degree of collective intelligence is required [5]. For computing and communications, IoT makes use of sensors, actuators, transceivers and processors. IoT cannot be considered as a single or standalone technology. It is a large collection of connected technology that works synchronously [6].

The network layer in IoT performs the major task of establishing connections among nodes and the server. It is the core layer that does the addressing, routing, formation and maintenance of the network. The network layer has protocols that perform the connectivity and networking tasks. The protocols of the network layer are: IPv4, IPv6, 6LoWPAN, 6TiSCH, 6Lo, IPv6 over Bluetooth Low Energy, IPv6 over G.9959, etc. [7]. IoT consists of LLNs that have low power, low energy and scarce computing resources. The conventional routing protocols for the networks may not be suitable for LLNs. The network layer protocols available for IoT are IPv6 Routing Protocol for Low Power and Lossy Networks (RPL) [8], Cognitive RPL (CORPL) [9], Channel Aware Routing Protocol (CARP) [10], Enhancement over CARP (E-CARP) [11] and others.

RPL has become a standard routing protocol suitable for LLNs due to the following characteristics in comparison with the rest: (i) RPL has a better packet reception ratio (PRR) and energy consumption; (ii) it has lesser churn and control traffic overhead; (iii) it had a shorter convergence time; (iv) it is independent of the link layer. Additionally, RPL has the following features: (i) self-healing; (ii) auto-configuration; (iii) Loop avoidance and detection; (iv) independence and transparency; (v) multiple edge routers [12].

Various features of RPL remain the main reason for preferring RPL over other protocols. In spite of its features, RPL also has a lot of room for improvement since the IoT is exponentially growing, and improved routing support is required [13]. Various enhancement methods have been devised for the RPL based on its function and application. Each enhancement method focuses on improving any one of the limitations of RPL or adding more effectiveness to the existing function of RPL [14].

2. The Standardization of RPL

Several reports have been published in 2009 and 2010 [15][16] to identify the routing requirements for the standardization of RPL based on its application in various routing environments. The widespread usage of RPL and its customisation has necessitated substantial study and development. The control packets in the network are necessary to establish a connection and maintain the network. The frequent change and resetting of the network in a mobile setup led to overhead in the link. An efficient way of detecting and controlling congestion is required [17]. LLNs are backbone networks of IoT. They are constrained by energy, memory and processing capacity. The traditional and popular network protocols are not suitable for LLNs due to these constraints. Among the existing routing protocols, RPL is more suitable for LLNs, due to its special features such as auto configuration, self-healing, loop avoidance, multiple edge routers and robustness [18]. RPL is also easily malleable to various environments of LLNs. This section presents an overview of RPL with the background, characteristics and various components.

The Internet Engineering Task Force (IETF) envisioned the standardization of IPv6RPL and started the Routing over Low-power and Lossy networks (ROLL) working group in 2008. The working group aimed at the standardization of RPL, which has the following implicit characteristics [19]: (i) LLNs are constituted by hundreds of nodes that are constrained by energy, size, processing power and memory. (ii) The constrained nodes of LLNs are connected to each other through lossy links, which have low data rates and are unstable. (iii) The traffic patterns of these LLNs may be point-to-multipoint, multipoint-to-point or, in some cases, point-to-point [20], such as urban settings [21], industrial settings, home automation and building automation [22].

Multi-hop WSN node restrictions are closer to BS's demand to infuse traffic from some other channel, enabling their energy to be spent quicker and possibly leading to very high remaining energy. As a consequence, Distributed Wedge Merging in Multi-Hop Access (DWMA) is presented here as a possible solution to the energy hole problem and routing. The major objective is to remove energy gaps while reducing the likelihood of them emerging in the future. To avoid energy holes from occurring, this DWMA method is combined with a nearby wedge [23].

In heterogeneous networks, violating the response and broadcast buffer specifications has resulted in uneven traffic loads, congestion and, as a result, packet loss in RPL, according to the author. This research discusses the CBR-RPL technique, which uses a unique drop-aware Objective Function (OF) to arrange nodes into route data. The newly defined OF takes into account both queue occupancy and node transceiver drop rates [24]. The Energy Hole problem, which is common in WSN, drastically affects the lifetime of any established network. The energy diffusion required for data packet forwarding between HN is reduced when a good Head Node (HN) selection technique is used [25].

PEGASIS (Power-Efficient Gathering in Sensor Information Systems) is an energy-saving protocol that tries to extend the network's lifespan by reducing energy consumption. This research proposes a modification of the PEGASIS approach. SNs are sorted into groups, clustering is carried out using the k-means method and every group is assigned the PEGASIS label. Rechargeable sensor nodes were also used in the suggested strategy. The sensor node's Euclidean distance from the base station and the sensor node's residual energy are utilised to determine the chain leader. Every CH's datum is instantly forwarded to the BS [26]. Various surveys on energy use, energy gaps and attacks on RPL and LLP systems can be found in [27][28][29][30]. The glowworm swarm-based approach cast-off energy-based transmission strategy has been presented to decrease energy consumption caused by control overhead [31]. A least-square support vector machine (LS-SVM) based on modified particle swarm optimization (MPSO) is developed. To begin, the MPSO's inertial weight is adjusted to accomplish faster iterations, and an LS-SVM-based MPSO's prediction model is constructed. Second, the predictive simulation was performed and confirmed using the MPSO's optimised parameters, and the MPSO and PSO predicted values were compared [32]. This work introduces a resilient clustering routing mechanism for WSNs. To estimate the number of cluster heads and identify the best cluster heads, the technique employs the Locust Search (LS-II) approach. After the cluster heads have been identified, other sensor elements are allocated to the cluster heads that are closest to them [33]. Based on the Optimal Low-Energy Adaptive Clustering Hierarchy (LEACH) protocol, a methodology for an energy-efficient clustering algorithm for gathering and transferring data is developed. The new optimised threshold function is used in the selection of CH. LEACH, on the other hand, is a hierarchy routing protocol that picks cluster head nodes at random in a loop, resulting in a higher cluster headcount but higher power consumption. In order to improve the energy per unit node and packet delivery ratio with less energy use, the Centralised Low-Energy Adaptive Clustering Hierarchy Protocol is the best [34]. WSNs are designed for specialised applications, such as monitoring or tracking, in both indoor and outdoor conditions, where battery capacity is a major issue. Several routing protocols are designed to solve this problem. A sub-cluster LEACH-derived approach is also proposed in order to improve performance. The Sub-LEACH with LMNN surpassed its competitors in terms of energy efficiency, according to simulation data [35].

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