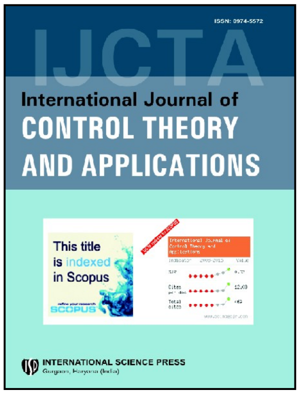


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# QoS Aware Adaptive Continuous Neighbor Discovery Protocol for Asynchronous WSN

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***Abstract:*** Wireless Sensor Network (WSN) is a dynamic network with highly mobile nodes. The nodes of the network can enter and exit the network at any instant of time. So, the neighboring nodes of each node keep changing from time to time. Also, any path developed through these mobile nodes is prone to damage. Hence, it is very critical for every node to update itself with information related to the changes in the network topology so as to ensure robust environment. In this paper, we propose to develop a continuous neighbor discovery protocol where the information about the discovered neighbors are recorded and updated. Then it is used as required during data transmission.

## 1. INTRODUCTION

### 1.1. Wireless Sensor Networks

Wireless Sensor Network (WSN) consists of several sensor nodes which are connected wirelessly and work cooperatively in an infrastructure less environment to monitor various environmental scenario such as environmental fire, pollution level detection, object body motion, etc. WSN is globally used in achieving the various application needs due to its minimized manufacturing expense and easy deployment methods. Intrusion detection is one among the several WSN applications which has been used widely due to its varied usages. For instance: when the wireless sensors are implemented in an ad hoc method, it can be used in military applications [1].

Wireless sensor networks (WSNs) are made up of several minute, low energy, less expensive, multifunctional sensor nodes. These sensor nodes are heavily deployed in the network in order to monitor or handle a process, track a system, etc. Personnel applications like home automation, business applications like sales tracking; industrial applications like architecture maintenance; and military applications like enemy target monitoring and tracking, etc are the various domains where WSN can be used. Internet of Things (IoT) is an emerging area in WSN where every entity of the human life will be deployed with sensors. This will make the day to day activities simpler due to the communication between the sensors deployed in all the entities. When IoT is implemented, the sensor nodes enter the network robustly and engage in the internet environment to cooperate with other nodes in performing the specific task [2].

### 1.2. Continuous Neighbor Discovery Protocol

In the multihop wireless networks, the neighbor discovery process is a critical task. Through the neighbor discovery process, every node in the network discovers a group of nodes that are its direct neighbors. Through these neighbors, the nodes can communicate with the different parts of the network which are not within the direct communication range of the node. Regular broadcasting of discovery messages is a conventional technique of discovering neighbors in both the wired as well as wireless networks. But, this kind of processes does not work well in networks with duty cycles. Also, since the sensor nodes have limited battery power, protocols have to be developed considering several features whenever used in environments with restricted access, rough conditions, critical infrastructures, etc. where there is scope to change the battery. Therefore, every protocol being designed for wireless network needs to be developed carefully considering all the critical factors related to the node energy level. Similarly, the neighbor discovery technique requires specific attention with respect to the energy consumption due to the extensively used routing process [3].

In this paper, we propose a QoS aware adaptive continuous neighbor discovery protocol for asynchronous sensor networks.

## 2. RELATED WORKS

Hamed Khanmirza *et al.* [3] have presented the neighborhood discovery protocols and their energy efficient integration with Low Power Listening (LPL) is studied. Neighbor discovery technique based on passive mechanisms are considered and its performance is featured through an analytical model.

Lizhao You *et al.* [4] have studied the problems faced during neighbor discovery in wireless sensor networks with lower duty cycle. An algorithm similar to ALOHA algorithm is considered and the relative time required to detect its (n-1) neighbor nodes is estimated.

Venkatraman Iyer *et al.* [5] have proposed NetDetect algorithm, a reliable and distributed method for solving the neighbor discovery problems in wireless networks. This algorithm is used on dynamic network with highly mobile nodes such as multihop mesh networks, etc. In this algorithm, the communication is performed based on the beaconing technique where the device beacon rate is adjusted according to the local density as determined by the neighboring nodes.

G Senthil Kumar *et al.* [6] have presented two methods to minimize time and maintain power consumption: Continuous Neighbor Discovery and Link Assessment Method. In the Continuous Neighbor Discovery technique, the neighboring nodes are detected and an immediate neighbor node view is maintained continuously. In the Link Assessment Method, collision free exchange of packets is performed and is ensured probabilistically. Every sensor node discovers the hidden nodes by utilizing the simpler techniques which also minimizes the power usage.

Guobao Sun *et al.* [8] have studied the ND issue in networks with lesser duty cycle and MPR. Initially, a protocol similar to the ALOHA protocol is considered and it is depicted that $O(n \log n \log\log n / k)$ time duration is required to detect (n-1) neighbor nodes when the scenario is generalized to the classic K Coupon Collector's Problem. Next, it is depicted that ND can be performed in $O(n\log\log n\, k)$ time duration if a feedback scheme is used to inform the nodes whether the data transmission performed by it was a success or not. Then, it is described that when there no knowledge of n results at a factor of two, then it effects by reducing the speed of other two protocols.

Reuven Cohen *et al.* [9] have presented a continuous neighbor discovery protocol. In this protocol, the neighbor discovered is differentiated into two types i.e., neighbor discovered during the network initialization stage and during the continuous neighbor discovery. The continuous neighbor discovery stage is considered as a combined task of every node in the linked segment. All the nodes use a simpler protocol to minimize the power usage along with not effecting the time needed for node discovery.

## 3. QOS AWARE ADAPTIVE CONTINUOUS NEIGHBOR DISCOVERY PROTOCOL

### 3.1. Overview

In this paper, we propose a QoS aware adaptive continuous neighbor discovery protocol for asynchronous sensor networks.

In this protocol, each node in the segment estimates its link quality and energy level and piggybacks the values in the periodical HELLO messages. Based on this information, the information about neighbors with bad link quality and low energy level will be passed on to the underlying routing protocol which will try to bypass those neighbors.

Apart from this, the duty-cycle period of nodes in the normal state is determined and updated adaptively, based on the obtained energy level of the nodes. (ie) nodes with less residual energy will have shorter period as compared to nodes with high residual energies.

The proposed protocol will be implemented in NS-2 and it will be shown that it outperforms [9] in terms of better throughput and lifetime in presence of bad channel conditions.

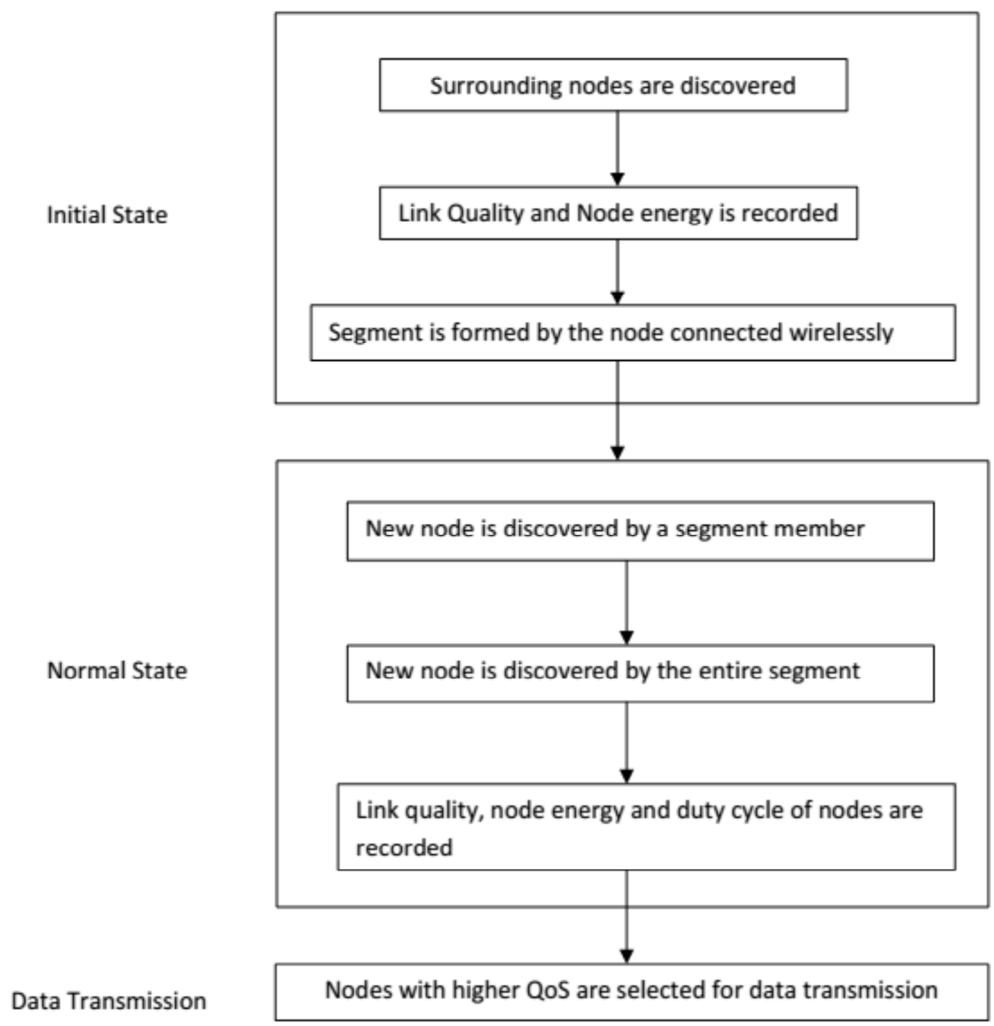


**Figure 1: Block Diagram**

## 3.2. Quality of Service (QoS) Estimation

QoS describes the performance of the wireless network. So in this protocol, the data forwarding is done to the nodes with higher QoS, thus ensuring effective data transmission. To determine the QoS of the segment, parameters such as link quality, energy level and duty cycle is used. These three parameters are estimated during the neighbors are being discovered. So, along with the neighbor node address; the link quality, energy level and duty cycle information is also recorded.

### 3.2.1. Estimation of Link Quality

The link quality is a very important parameter to ensure data transmission with any data loss. The link quality, $LQ$ is estimated according to equation (1) given below.

$$LQ = PRR \times normalized\ (RSSI_{mean}) \tag{1}$$

Where $RSS$ : Received Signal Strength

$$normalized\ (RSS_{mean}) = \frac{RSS_{mean}}{60} + \frac{100}{60}$$

$$RSS_{mean} \in [-100, -40] dbm$$

$$normalized\ (RSS_{mean}) \in [0,1]$$

$PRR$: Packet Reception Rate $\in [0, 1]$

### 3.2.2. Estimation of Energy Level

Node energy level is very critical during data transmission since the energy in wireless node is limited. So, if a node has higher energy, then it is more reliable; else the node becomes unreliable. Thus, energy level of each node is an important characteristic to be considered during data transmission. The node energy, is calculated based on equation (2) given below.

$$Energy_{node} = Energy_{total} - Energy_{consumed} \tag{2}$$

where $Energy_{total}$ : Initial Total energy at a node, it is predefined and is same for all nodes

$Energy_{consumed}$ : energy consumed while forwarding/ handling the data/message packet

$$Energy_{consumed} = x \times packet_{size} + y$$

where $x$ and $y$ are the energy consumption overhead related to packet transfer.

$packet_{size}$ is the size of the packet being handled

### 3.2.3. Estimation of the Duty Cycle

The duty cycle of the nodes is estimated during the normal state. The duty cycle, DC is measured on the basis of the energy level of each node in the segment.

If $Energy_{node}$ is high, then DC period will be longer.

If $Energy_{node}$ is low, then DC period will be shorter.

## 3.3. Neighbor Discovery Protocol

The arrival of any new nodes in the segment is discovered effectively by continuously detecting the new nodes. The new node discovery along with successful data transmission is performed in two stages: the initial state and the normal state. In the initial state, each node determines its neighbors, collects its QoS information and forms a wireless link with its neighbors; leading to the formation of a segment. The normal state is attained when the segment is already created and discovery of a new node by a member of a segment leads to the discovery of this new node by the entire segment.

HELLO message is used for neighbor discovery. The format of the HELLO message is given in figure 2.

| Sender Node Address | Intermediate Node address | LQ value | Node energy |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |

**Figure 2: Format of HELLO message**

The neighbor discovery protocol with the two states is described in algorithm 1.

## Algorithm 1

1. In the initial state, each node in the network discovers its neighbors by broadcasting a HELLO message with the sender node's address included in it.
2. When the HELLO message reaches a node, the link quality and energy level of the node is estimated based on equation (1) and (2).
3. The estimated values are piggybacked in the HELLO message and sent back to the sender node.
4. Thus a wireless link is formed between the communicating neighbor nodes and each node has information related to the QoS of these neighbor nodes which together forms a segment.
5. In the normal state, when a node in the segment discovers a new node, it issues a WAKE message to all the members of the segment.
6. When a segment member node receives the WAKE message, it wakes up.
7. Then the segment member nodes periodically broadcast the HELLO message at the same time interval.
8. When the HELLO message reaches a neighboring node, the link quality, energy level and duty cycle of the node is again estimated based on equation (1), (2) and (3) to record the latest information related to its QoS.
9. The estimated values are piggybacked in the HELLO message.
10. When the HELLO message reaches the new node, its information is collected according to equations (1), (2) and (3) and piggybacked.
11. Then a wireless link is formed between the new node and the segment members, thus making this new node as a member of the segment.

12. When a node has to transmit data, the node uses the collected information related to the QoS properties in the routing protocol.
13. The intermediate node selected to forward the data will be the neighboring node with high link quality, high energy level and, duty cycle.
14. During data transmission, the routing protocol selects nodes with high QoS and avoids using any node with lower QoS.

Thus, the nodes in neighborhood are continuously detected. The discovery of a new node by any one node in the segment lets the discovery of this new node by all the members of the segment. During the node discovery, all the required information of the node is collected and then it is considered in selecting the forwarding nodes efficiently by avoiding the nodes with lower QoS. This ensures effective data transmission with continuous node discovery.

## 4. SIMULATION RESULTS

### 4.1. Simulation Parameters

We use NS-2 [11] to simulate our proposed QoS Aware Adaptive Continuous Neighbor Discovery Protocol (QACNDP). We use the IEEE 802.11 for wireless Sensor Networks as the MAC layer protocol. It has the functionality to notify the network layer about link breakage. In our simulation, the number of nodes is varied as 50,100,150 and 200. The area size is 500 meter x 500 meter square region for 50 seconds simulation time. The simulated traffic is Constant Bit Rate (CBR). The simulation settings and parameters are summarized in table 1.

**Table 1**
**Simulation parameters**

| | |
|---|---|
| No. of Nodes | 50,100,150 and 200 |
| Area | 500 X 500 |
| MAC | 802.11 |
| Simulation Time | 50 sec |
| Traffic Source | CBR |
| Rate | 250Kb |
| Propagation | TwoRayGround |
| Antenna | OmniAntenna |
| Initial Energy | 10.3J |
| Transmission Power | 0.660 |
| Receiving Power | 0.395 |
| Range | 200,250,300 and 350m |
| Time | 25,50,75 and 100sec |

### 4.2. Performance Metrics

We evaluate performance of the new protocol mainly according to the following parameters. We compare the Continuous Neighbor Discovery [9] protocol (CNDP) with our proposed QACNDP.

**Average Packet Delivery Ratio**: It is the ratio of the number of packets received successfully and the total number of packets transmitted.

**Residual Energy:** It is the amount of energy remains in the nodes after the successful flow transmission.

**Packet Drop**: It is the number of packets dropped during the data transmission

## 4.3. Results & Analysis

The simulation results are presented in the next section.

### *(A) Based on Nodes*

In our first experiment we are varying the number of nodes as 50,100,150 and 200.

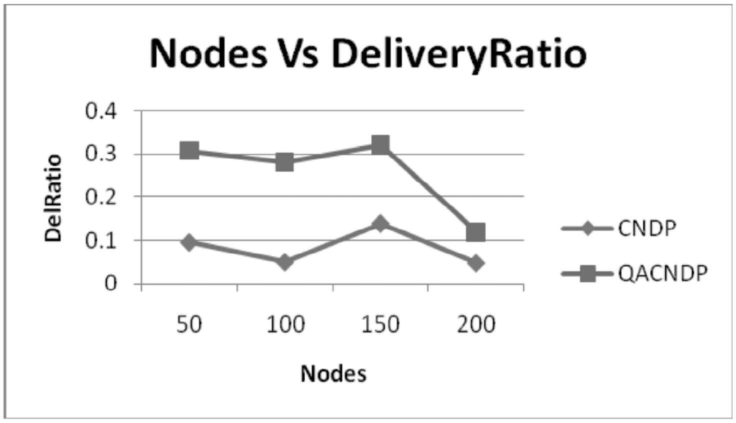


**Figure 3: Nodes Vs Delivery Ratio**

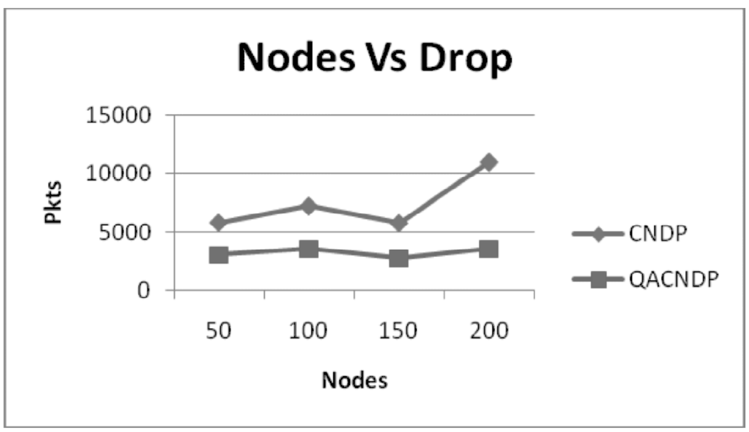


**Figure 4: Nodes Vs Drop**

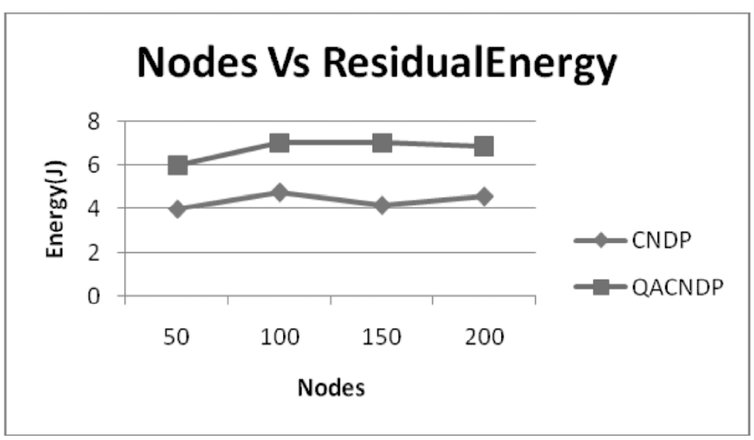


**Figure 5: Nodes Vs Residual Energy**

Figures 3 to 5 show the results of delivery ratio, packet drop and residual energy by varying the nodes from 50 to 200 for the CBR traffic in QACNDP and ADRC protocols. When comparing the performance of the two protocols, we infer that QACNDP outperforms CNDP by 67% in terms of delivery ratio, 55% in terms of packet drop and 35% in terms of residual energy.

## (B) Based on Range

In our second experiment we vary the transmission range as 50,100,150 and 200.

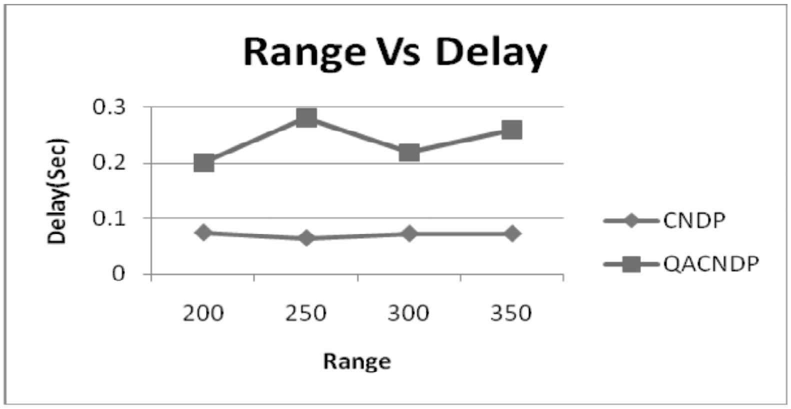


**Figure 6: Range Vs Delay**

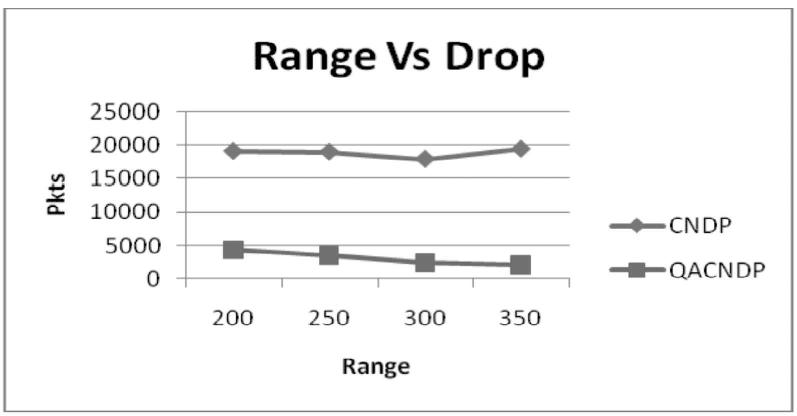


**Figure 7: Range Vs Drop**

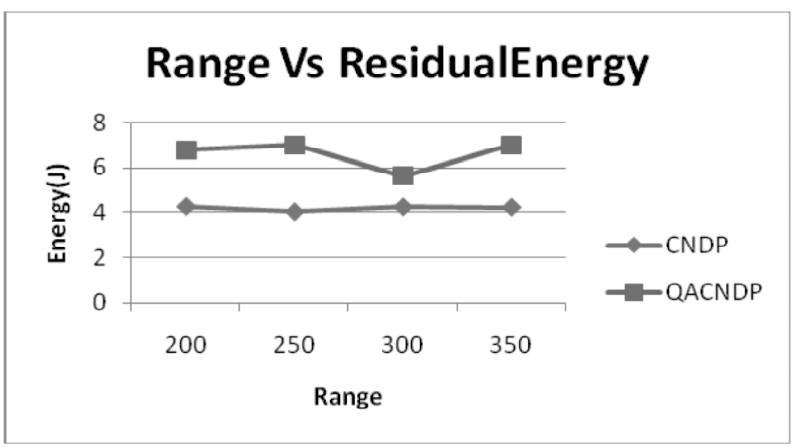


**Figure 8: Range Vs Residual Energy**

Figures 6 to 8 show the results of delivery ratio, packet drop and residual energy by varying the range from 200 to 350 for the CBR traffic in QACNDP and ADRC protocols. When comparing the performance of the two protocols, we infer that QACNDP outperforms CNDP by 70% in terms of delivery ratio, 83% in terms of packet drop and 36% in terms of residual energy.

### (C) Based on Time

In our third experiment we vary the simulation time as 25,50,75 and 100sec.

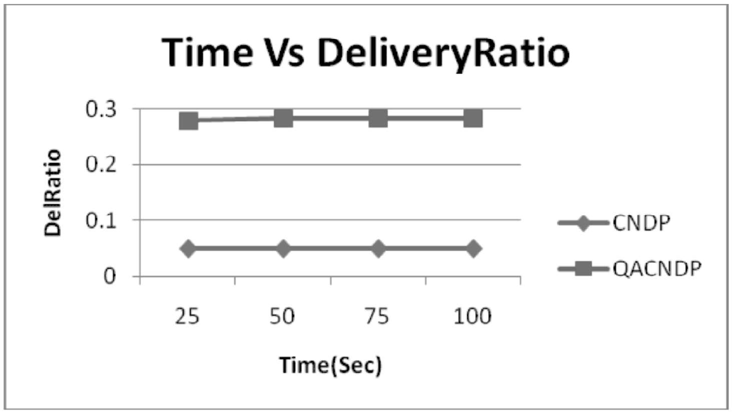


**Figure 9: Time Vs Delviery Ratio**

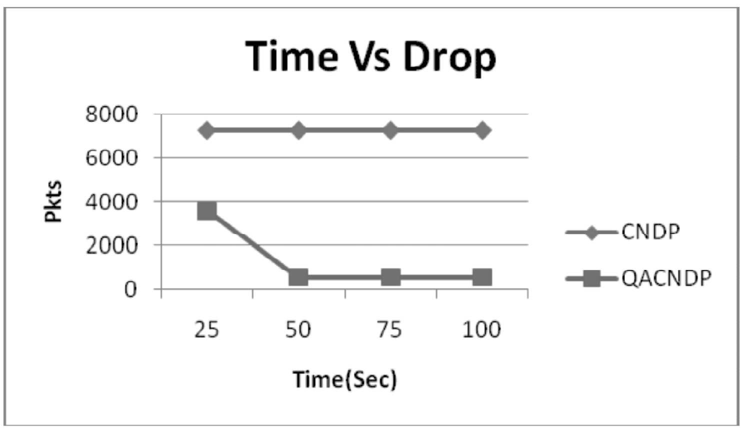


**Figure 10: Time Vs Drop**

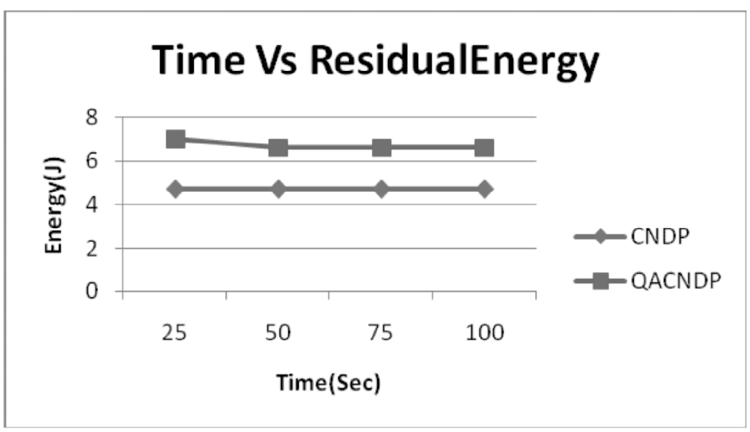


**Figure 11: Time Vs Residual Energy**

Figures 9 to 11 show the results of delivery ratio, packet drop and residual energy by varying the range from 200 to 350 for the CBR traffic in QACNDP and ADRC protocols. When comparing the performance of the two protocols, we infer that QACNDP outperforms CNDP by 82% in terms of delivery ratio, 82% in terms of packet drop and 30% in terms of residual energy.

## 5. CONCLUSION

In this paper, we have developed a QoS Aware Adaptive Continuous Neighbor Discovery Protocol for Asynchronous WSN. This protocol works in two states: initial state and normal state. In the initial state, each node determines the nodes in its surrounding using a HELLO message. Information about the neighbors such as neighbor address, link quality, and node energy is recorded. Thus a segment is formed by all the discovered nodes, as these nodes link to each other wirelessly. In the normal state, every node in the segment is connected to each other. If any one segment node discovers a new node, then it lets every member of the segment discover it by making them broadcast messages regularly. The new node information is recorded by all the nodes in the segment. When data has to be transmitted, the transmitting node offers all the recorded neighbor node information to the routing protocol. Based on this, the routing protocol uses the nodes with good QoS to forward the data and avoids using nodes with lower or bad QoS. Thus, ensuring reliable data transmission through efficient intermediate nodes.

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