International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 5s
DOI: https://doi.org/10.17762/ijritcc.v11i5s.7097
***Article Received**: 20 March 2023 **Revised**: 10 May 2023 **Accepted**: 30 May 2023*

EASND: Energy Adaptive Secure Neighbour Discovery Scheme for Wireless Sensor Networks

Sagar Mekala[1], Mallareddy A[2], Dr. D. Baswaraj[3], Jyothirmai Joshi[4], Raghava M[5]
[1]Associate Professor, Department of Computer Science Engineering
CVR College of Engineering
Hyderabad, Telangana, India
arjunnannahi5@hotmail.com
[2]Associate Professor, Department of Information Technology
CVR College of Engineering
Hyderabad, Telangana, India
mallareddyadudodla@gmail.com
[3]Professor, Department of Computer Science Engineering
Vasavi College of Engineering
Hyderabad, Telangana, India
braj.d@staff.vce.ac.in
[4]Assistant Professor
VNR Vignana Jyothi Institute of Engineering and Technology
Hyderabad, Telangana, India
jyothirmai_j@vnrvjiet.in
[5]Professor, Department of Computer Science Engineering
CVR College of Engineering
Hyderabad, Telangana, India
raghava.m@cvr.ac.in

Abstract — Wireless Sensor Network (WSN) is defined as a distributed system of networking, which is enabled with set of resource constrained sensors, thus attempt to providing a large set of capabilities and connectivity interferences. After deployment nodes in the network must automatically affected heterogeneity of framework and design framework steps, including obtaining knowledge of neighbor nodes for relaying information. The primary goal of the neighbor discovery process is reducing power consumption and enhancing the lifespan of sensor devices. The sensor devices incorporate with advanced multi-purpose protocols, and specifically communication models with the pre-eminent objective of WSN applications. This paper introduces the power and security aware neighbor discovery for WSNs in symmetric and asymmetric scenarios. We have used different of neighbor discovery protocols and security models to make the network as a realistic application dependent model. Finally, we conduct simulation to analyze the performance of the proposed EASND in terms of energy efficiency, collisions, and security. The node channel utilization is exceptionally elevated, and the energy consumption to the discovery of neighbor nodes will also be significantly minimized. Experimental results show that the proposed model has valid accomplishment.

Keywords- Energy Efficient; Neighbor Discovery; Security; Wireless Sensor Network.

I. INTRODUCTION

WSNs primarily involves in various types of applications that use both in the IoT and mobile computing devices, where hundreds and thousands of resource constrained nodes are deployed and interconnected using the wireless communication channels [1][25]. They are being deployed in numerous areas such as environmental monitoring (temperature, pressure, humidity, pollutants, etc.), tracking (animal, vehicle,), surveillance application, detection (mines, harmful animals, etc.), smart building applications, health monitoring, industrial applications, and so on [2][25]. In many WSNs applications, sensor nodes are deployed in inaccessible and inhuman areas. Therefore, good self-organized approaches are required for sensor node maintenance and service due to lack of fixed infrastructure support [17]. Hence, nodes in the network must adapt to changes in the environment, topology, configure themselves and cooperatively operate with other nodes. Every component of the sensor node and network alone has energy efficiency parameters. In the life of node neighbor discovery plays vital role in energy efficiency. Once sensor nodes deployed in an area of interest needed to operate until the purpose of node deployment or the battery can be depleted [4][5].

Resource constraints are always the obstruction that controls the design and development of IoT applications based on WSNs. However, suffer from synchronization, energy consumption, security, and collisions in dynamic environments. Due to the sensor node limited resources such as energy, processing capabilities, and communication range routing is a challenging in WSNs and these are basic constraints for many WSN applications [1] [2]. Since these aspects, the construction of neighbor discovery can lead to a maximum execution time of a node and provide efficient processing and communication. To manage communication, processing, and storage capabilities of a node in limited infrastructure wireless sensor network. In recent years, research in WSNs primarily focused on energy conservation to improve network performance and elevating its lifetime [2] [3]. Sensor devices are deployed according to application need, sometimes they are distributed in biting environment where these devices cannot be replaced and recharged [2]. The information relaying in WSNs implies route discovery they obtained information from source node to destination, leads to multi-hop wireless communication for network functionality [4]. Therefore, it is necessary to design a novel model to combine the benefits of the existing neighbor discovery process and make it available in extremely resource constrained sensor devices.

As a result of an extremely realistic application, where the processing of data, synchronization, and security among nodes are no longer energy efficient in WSNs. Neighbor discovery process is an emerging fundamental operation with respect to energy efficiency, and it can handle synchronization even if nodes deployed densely [8]. By careful design of neighbor discovery is also able to reduce the data traffic to the sink node. This makes it timely to investigate new models for neighbor discovery process and a realistic experimental study shows that in this area. On the other hand, without careful design techniques of security and privacy preserving mechanisms of a node, neighbor discovery process cannot be adopted despite its effectiveness. To cover sensor devices connectivity and communication proposed various neighbor discovery approaches in the existing literature that can applied on synchronous and asynchronous strategies [8][12]. The probabilistic algorithms can minimize energy consumption by exploiting synchronous based duty cycle. Neighbor discovery will suffer from the traditional security and privacy issues which are drawn from the wireless network and Ad-hoc networks. And neighbor discovery prolonged from unique threats because of the adoption of sensor devices such as man-in-the middle attacks [6]. In this paper, we provide insights in the field associated with WSNs and neighbor discovery schedule architecture, presenting the new emerging model, energy efficiency performance evaluated in various algorithms and improvements, and WSN application developments [25] [28].

There are various developments in neighbor discovery models that allow adaptive and energy efficient resource allocation and duty cycle or discovery scheduling and proposed models can secure the data and neighbor node information in WSNs [4] [5] and satisfy the network key parameter indicators such as minimize energy consumption, low discovery latency, channel utilization, maximize the throughput and routing of network based on the application request. The basic neighbor discovery algorithms for symmetric and asymmetric scenarios are analysed and energy efficient neighbor discovery power management and enhanced node lifespan are the primary issues in WSN field [30][32]. The goal of neighbor discovery is reducing the power consumption and enhancing the lifespan of the network. Therefore, the major contributions of this paper are as follows:

- Exploring the challenges for neighbor discovery and security in wireless sensor networks. Reducing the energy consumption by adapting the delay of an application and enhance the network lifespan.
- Design and developing EASND (Energy Adaptive Secure Neighbor Discovery Scheme) according to need of the application. Aggregate the node energy before constructing its duty cycle schedule to consume limited energy to discover neighbors.
- We study the security measures for neighbor discovery in sensor networks and minimizes the node failures. Design and developing an authenticated communication using EASND building block.

The remainder of the paper is organized as follows: Section 2 provides the related works in neighbor discovery; next Section 3 describes general overview of communication and neighbor discovery models. Implementation of our proposed architecture presented in Section 4. Then, in Section 5 discusses the simulations performed on the proposed scheme that we compared with existing works. Finally, Section 6 concludes.

II. RELATED WORK

The neighbor discovery process in WSNs is a major issue to which various solutions have been designed and implemented by many authors in literature. We proposed these implements into four categories according to their analysis and evaluations.

A. Initial Neighbor Discovery Process

Elyes et al [1], provided the impact of node radio interferences [28] on nearby node identification, the simulation results of proposed model show that the average number of nearby node knowledge can be discovered by a node based on the hybrid model and discussed the impact of mobility of a node in the neighbor discovery process.

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 5s
DOI: https://doi.org/10.17762/ijritcc.v11i5s.7097
Article Received: 20 March 2023 Revised: 10 May 2023 Accepted: 30 May 2023

Authors in [2][31], introduced and analyzed various neighbor discovery process algorithms according to optimization. Depending on the distance of the radio communication range, the battery power of a node exhausted after each transmits or reception of data packets.

B. Quorum-based Neighbor discovery protocols

According to Quorum-based protocols the authors [5], proposed two algorithms that are adaptive, distributive and energy efficient. The energy usage in idle listening is limited by simulation of the suggested adaptive asynchronous sleep scheduling.

Quorum-based protocol (QNDP) [7], asynchronous sleep scheduling protocols has been initially introduced by designing schedule with equal sized intervals, called slots. If at least two neighbouring nodes overlap their active slots, QNDP is required to use. In the proposed model each node has an active schedule that made by arbitrarily selecting a row and a column from a $n \times n$ matrix space [24][26].

C. Probabilistic and Deterministic Neighbor discovery

Example for Probabilistic protocol, Birthday protocol [12], allows various probabilistic to perform different modes which are transmitting, receiving, and listening in discrete slots. In [13], presents, Birthday paradox with respect to the average discovery latency, probabilistic approaches provide efficient performance in WSNs.

The major limitations of probabilistic approaches are well suited for immobility networks and uncontrolled worst-case discovery latency. Disco [14], U-Connect [15], Searchlight [16], Hedis and Tedis [18], Blind Date [21], Hedis and Todis [22], and WiFlock [17] few very important deterministic protocols, which are closely incorporated in our proposed implementation and these protocols have been implemented to address the common problem of duty cycle for efficient neighbor discovery.

D. Secure Neighbor discovery Process

Security is a challenging task in WSNs and require careful decisions and trade-off among security measures are defined in and provided the issues and models to obtain the secure communication in sensor networks [6] [7].

TABLE I. SUMMARY OF NEIGHBOUR DISCOVERY SCHEMES IN WSN

Neighbour Discovery Schemes	Implementation achievements	Limitations
OFDMA [39]	The strategy adapted using the sleep cycle and duty cycle to identify the neighbor nodes is arguable as the timely detection of the neighbor nodes are always questionable.	The proposed solution does not comply with the requirements for the lower delay cycles. The adaptation complexity is significantly higher.
SAQND [36] [24] [26]	Quorum based model. Collisions are reduced. Dynamically adjusting the schedule.	Symmetric duty cycle, and not for mobility
SD-WSN [33]	Software-defined Neighbor Discovery for Wireless Sensor Network (SD-WSN) architecture proposed to examine the implications for network performance when making the WSN reprogrammable. The proposed model consists of breaking down all key functions involved in the correct functioning of an SD-WSN, namely, neighbor discovery, neighbor advertisement, network configuration, and data collection.	The virtualization of the network and other infrastructure demands higher processing capacity to the nodes and the base stations, which makes this solution hard to adapt.
CREDND [35]	CREDND is a localized protocol. Security based Neighbor discovery Collaboration occurs during discovery process when a node shares with the sink its local knowledge of its own neighborhood. Worst case discovery delay is reduced.	Energy Consumption is high, Discovery design complexity is high. Symmetrical duty cycle mode.
U-Connect [15], Disco [14], SPND [38]	These are prime number assisted discovery schemes. Nodes can adopt Proactively wakeup model, additional active slots added if needed. And mobility of node also considered during neighbour discovery.	Unnecessary active wake-up consumes more energy.
GBND [40]	One-hop nodes form a group. Uniformly adjusting the distribution of the nodes' active slots in the group, the nodes outside the group can be found more quickly. The nodes in the group selectively share the sleep and wake times of their	Unnecessary active wake-up consumes more energy. Cannot limit the worst-case maximum discovery.

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 5s
DOI: https://doi.org/10.17762/ijritcc.v11i5s.7097
***Article Received**: 20 March 2023 **Revised**: 10 May 2023 **Accepted**: 30 May 2023*

	existing neighbors to the new discovered neighbor nodes in the group. Enhances the performance of average case discovery latency. Reduces the collisions.	
xBOND [37], Griassdi [34]	xBOND is proactively recommended potential neighbors to nearby nodes to reduce the discovery latency. xBOND achieve a better tradeoff between energy overhead and discovery latency. After a node wakes up to receive the beacon message of other nodes in the certain time slot. Achieves the synchronization among neighbor nodes, and Collisions are reduced.	Not for mobile scenarios, and Higher design complexity. Control message overhead for discovery is high. Therefore, energy consumption is very high.

The sensors can capture environmental information dynamically. This scenario has diversified applications associated with it. The nodes have features like mobility and sleeping with dynamic topologies. In such networks, there is difficulty in discovering neighbour nodes faster. There is no establishment of optimal distribution decisions of nodes maintained by the network. The problem with existing systems is that there is long-time waiting delay due to passive neighbour discovery approaches. Another problem identified in such networks is availability of efficient asynchronous wake-up schedules. Due to low duty cycles requirement in many real-world sensor applications, it is essential to design a protocol for continuous neighbour discovery with efficient asynchronous wake-up schedules.

III. THE BASICS OF SENSOR NETWORK MODEL AND PROBLEM FORMULATION

In WSN different applications, each node can perform various operations, such as sensing nearby object information, tracking, object monitoring, and transmitting data to sink node [2]. Hence, communication through single wireless channel more energy effective one [23]. Therefore, each sensor node xi in sensor network and can operate in two modes such as active and sleep. We assume these two modes [1, 0] in this article: where 0 indicates the node turns off by radio to save energy consumption, while 1 to represent the node turns on by radio for communication. Before communication in multi-hop communication each node needs to obtain the knowledge of neighbor nodes in the network. Communication between nodes can achieve after successful neighbor discovery.

A. Communication Scheme

There are n sensors nodes are deployed in an environment denoted as $\{x_1, x_2, x_3, \dots, x_n\}$ and all these devices are connected wirelessly in a multi-hop communication [7] for transmission of sensed data from the field of interest to base station. Nodes in WSNs are resource constraints such as low power, less communication range, interference [28] between nodes, and collisions reflects communication between any two neighbors in a network and different strange constraints of node leads to different design issues in WSNs. Some of the important constraints and challenges of WSN design are energy efficient, deployment, power management [1] [2] [5] [25], and security [6]. In these we try to analyse and provide secure and an energy efficient protocol to maximize the network existence. Energy constraint is an important issue in the WSNs, and it is regularly incorporated in the sensor network design, because of devices in the network have finite battery power. These devices should be restored with new batteries, replaced with new devices, and recharged when node drained energy, but in surveillance or battlefield, and wild environment applications neither choice are suitable, then nodes simply be avoided once their battery drained. As a result, basic design issues of all most of all limited infrastructure wireless sensor networks energy efficiency is a primary concern.

B. Neighbor Discovery Problem

In WSNs, after the deployment of nodes in a field, it is important to obtain knowledge about surrounding nodes in a multi-hop communication system. The process of obtaining knowledge about nearby nodes, If any two nodes are called the neighbors, their communication radio range within each other and that can be denoted by R_{tr} is called transmission or radio range of nodes.

Duty Cycle: the ratio of the amount of time a node in work mode by total time of a node spends on work and energy saving mode together. The duty cycle of the node denoted as follows:

$$\Delta_d = \frac{w}{t}$$

Where Δ_d is a duty cycle of node, w total duration of time a node spends in work mode (i.e., active mode or turning on by radio), and t total time including work and sleep periods of a node. Neighbor Discovery: Design procedure to get neighbor node information for efficient communication in resource constraint networks. In general, most of the WSN application's node can adapt two modes, active and sleep mode to save energy. If a node x_i in active mode, it's turning on the radio, otherwise turning off by radio and node x_i in sleep mode, then no communication established between nodes. To measure

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 5s
DOI: https://doi.org/10.17762/ijritcc.v11i5s.7097
***Article Received**: 20 March 2023 **Revised**: 10 May 2023 **Accepted**: 30 May 2023*

their discovery operation generally two metrics are considered such as duty cycle and discovery latency. Let x_i start at time t_i^{in} and turning on its radio in a particular time t_i and attempt to identify its nearby nodes. To extent node energy, each node in the network has some efficiency algorithm to construct a duty cycle schedule. The duty cycle of node defined as follows:

$$\omega_{x_i} = \{x_i(t) \mid t \geq t_i^{in}\}$$

Where ω_{x_i}: Duty cycle schedule of a node x_i. t: Length of schedule contains a sequence of on and off modes. t_i^{in}: Time slot of a node x_i, when it is active. If symmetric, for any two nodes, in fact for all nodes in the network duty cycle schedule must be same. Let us consider duty cycles of any two nodes are same, then it represented as follows:

$$\omega_{x_i} \equiv \omega_{x_j} = \{x_{ij}(t) \mid t \geq t_i^{in}\}$$

$$x_{ij}(t) = \begin{cases} 1 \ \mathit{if\ both\ turning\ on\ by\ radio\ at\ time\ slot\ t} \\ 0 \ \mathit{otherwise, turnning\ off\ radio\ at\ time\ slot\ t} \end{cases}$$

The process of neighbor discovery between any two nearby nodes, only if these nodes are active at the same time slot and they are within communication range of each other, then discovery achieved between these two nodes as follows:

$$x_i(t_i^{in}) = x_j(t_j^{in}) = 1$$

Where 1 indicates active mode of a node and can make communication. Another important metric of neighbor discovery process is discovery latency. The maximum amount of time needed to obtain knowledge about its nearby nodes once start their operation and turning on their radio together is referred as discovery latency.

$$L(x_i, x_j) = T - max\{t_i^{in}, t_j^{in}\}$$

IV. ENERGY ADAPTIVE SECURE NEIGHBOR DISCOVERY ARCHITECTURE

EASND contains five important self-contained building blocks: i) Energy Unit for efficient utilization of node energy in a single channel multi-hop communication system. ii) Application block used to construct required latency of various network applications. iii) Creation of duty cycle schedule by adapting existing discovery protocols is referred as Algorithm block, iv) Communication block is accountable for collision free communication with nearby nodes of a node in the network and finally, v) security block is responsible to adopt an efficient security protocol to prevent from intrusion and malicious attacks in sensor networks. Inputs for our proposed model are needed application latency, a residual energy of a node, and security parameter for neighbor discovery. Best available neighbor discovery algorithm can generate the duty cycle schedule and it is the input to the communication unit to produce energy efficient discovery latency and securely discovered neighbor nodes. Figure 1, illustrates that the organization of our proposed model.

A. Energy Block

In EASND, remaining energy of a node and application required latency parameters are input to block. Then it produces an application dependent duty cycle as output, which adopted by node. Energy unit can perform two important responsibilities such as evaluating the node lifespan and rearranging the duty cycle. Let assume a node x_i, which started at a particular time slot i.e., t_i and constructed schedule for node is $\omega_{x_i} = \{x_i(t) \mid t \geq t_i^{in}\}$ and drained out its battery power at t_i^d. We consider the following equation.

$$\int_{t_x^{in}}^{t_x^d} x_i(t).\lambda_n = N_{bc} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

N_{bc} : Defined as node battery maximum capacity and λ_n: consumed energy to turn on the radio in each slot. Therefore, lifespan of a node x_i described as follows.

$$LS_{x_i} = t_i^d - t_i^{in} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Each node in the network has a duty cycle contains a sequence of 0s and 1s, where 0 indicates turning off its radio and 1 represents node turns on the radio. These sequences of 0s and 1s indicate the state of a node either in work mode or energy saving mode. The constructed schedule $x_i = \{x_i(t)\}$ describes that node x_i status at time slot 't', more generally $x_i(t) = 1$ sensor node state is on mode, i.e., a node communication mode and if $x_i(t) = 0$ state of the node is off mode. As a result, the node is in energy-saving mode. We use two identification functions as follows:

$$s_{1t0} = 1 \ \exists \ x_i(t-1) = 1 \ and \ x_i(t) = 0 \ldots\ldots\ldots\ldots\ldots (3)$$

$$s_{0t1} = 1 \ \exists \ x_i(t-1) = 0 \ and \ x_i(t) = 1 \ldots\ldots\ldots\ldots\ldots (4)$$

Function in 3, describes that the node transforming from on to off state and other hand equation 4 represents that the node transforming from off to on state. By merging equations 4 and 5 to evaluate the energy consumption between states in the node duty cycle schedule as follows:

$$\int_{t_{x_i}^{in}}^{t_{x_i}^d} x_i(t).C_1 + (1 - x_i(t)).C_0 + s_{1t0}(t).C_{10} + s_{0t1}(t).C_{01} = N_{bc}$$

As we discussed energy conservation off state of a node is then $C_0 = C_{1t0} = C_{0t1} = 0$ then we reconstruct above equation as $\int_{t_{x_i}^{in}}^{t_{x_i}^d} x_i(t).C_1 = N_{bc}$. Due to the application requirement a node turn on in complete schedule, then above equation can be

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 5s
DOI: https://doi.org/10.17762/ijritcc.v11i5s.7097
***Article Received**: 20 March 2023 **Revised**: 10 May 2023 **Accepted**: 30 May 2023*

rearranged as $(t_{x_i}^{d} - t_{x_i}^{in}).C_1 = N_{bc}$ and the lifespan of node that the maximum value $LS_{x_i} = \frac{N_{bc}}{C_1}$. To maximize the lifespan of a node x_i, it should turn on the radio for less time duration. Then a node x_i chooses the duty cycle as a fixed value $\tau \in (0,1)$. If a node C_0 is 0 then lifespan of a node can organize as follows:

$(t_{x_i}^{d} - t_{x_i}^{in}).\tau.C_1 + (t_{x_i}^{d} - t_{x_i}^{in})(1-\tau).C_0 = N_{bc}$ and $LS_{x_i} = \frac{N_{bc}}{C_1 \tau}$ .... (5)

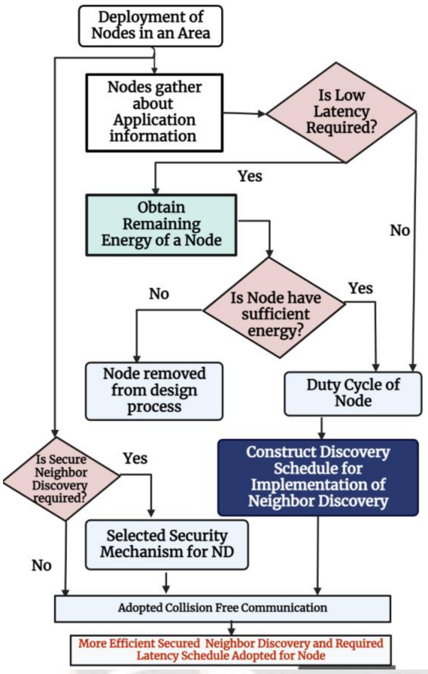


Figure 1, EASND Organization

Based on the application a node x_i, can arrange the duty cycle schedule time being. If a node initiated the duty cycle at $t_{x_i}^{in}$ and changed the schedule for the duty cycle $\tau_0 < \tau_1 < \tau_3 < \cdots < \tau_k$ where $t_{x_i}^{in} = \tau_0$ and $t_{x_i}^{d} = \tau_k$ then we the use equation as: $\sum_{m=0}^{k} \left(\int_{T_m}^{T_{k+1}} x_i(t).C_1 \right) = N_{bc}$ and $\sum_{m=0}^{k} (\tau_{m+1} - \tau_m).\tau_{x_i}(\tau_m, \tau_{m+1}).C_1 = N_{bc}$. Hence, $\tau_{x_i}(\tau_m, \tau_{m+1})$ and $\tau_{x_i}, x_i \in [0, m]$ are known then $t_{x_i}^{d} = \tau_{m+1}$ can be evaluated and we analyze the impact of the node lifespan of different approaches that adjust duty cycle discussed and also computed the lifespan of the node in Section 5.

B. Application block

A WSN consist of a set of resource constrained sensor nodes are deployed in an area to perform various operations such as sensing environmental conditions (i.e., temperature, humidity, and pressure), tracking moving objects (animals in wildlife, enemy tracking in battlefield surveillance, and vehicle tracking). In order to relay information about objects timely and nodes need to adopt low discovery latency, where node has to discovery its neighbors in less time, that is nodes in the network are turning on their radios more continuous to achieve require bounded latency of the application. Two important functions performed in application block are: 1) To relay latency requisite at a particular time t, that is discovery latency should be fixed within L_{x_i}, and 2) to construct a desire, duty cycle based on the discovery latency requisite at L_{x_i}.

C. Algorithm block

The main task of the algorithm block is to create an energy-efficient duty cycle plan that depends on the application. Energy block passes duty cycle requirements to algorithm block to construct a duty cycle schedule for maximizing the lifespan of a node. We use existing neighbor discovery protocols to design duty cycle schedule for asymmetric networks. Table 1 illustrates the relationship between discovery latency and duty cycle schedules in existing protocols in the literature of neighbor discovery in wireless sensor networks.

D. Communication block

Once nodes are deployed in an area, these devices must relay sensed information to a base station in a cooperative manner. Due to numerous network problems, a node can be known to use most of its energy during the communication phase. Nodes carry out the operations in accordance with the modified duty cycle schedule.

The efficient discovery schedule can play vital role in the single channel system, and communication block also responsible for secure neighbor discover when collision exists among multiple nodes must access channel at some instance of time. Communication block responsible for implementation of following functions: 1) construct lightweight security measures for neighbor discovery, 2) maintaining of discovering neighbor devices information such as node id, initial time, and duty cycle, 3) maintains the discovery latency of neighbor nodes.

If more than one neighbor node, wants to access channel, then communication collision often occurred. In this paper, we adopted two methods to minimize the collisions, and the existing models rewritten by methods to enhance performance of EASND.

E. Security block

In WSNs, security is also the important factor when they are deployed in an unattended environment. To provide secure, the communication and neighbor discovery in the WSNs. Generally, the cryptographic algorithm is incorporated, while adapting cryptographic algorithms there are number challenges and issues such as communication, storage overhead, and energy consumption. By keeping these limitations, we implemented a non-cryptographic algorithm for secure data

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 5s
DOI: https://doi.org/10.17762/ijritcc.v11i5s.7097
***Article Received**: 20 March 2023 **Revised**: 10 May 2023 **Accepted**: 30 May 2023*

communication []. To study the challenges and issues, we proposed two functionalities that 1) defining the secure neighbor route discovery approach that aims on optimality and 2) towards malicious attack vulnerability. We use following algorithm to obtain the secure neighbor discovery.

Algorithm - 1: Energy Aware Secure Neighbor Discovery Process

Input: N is collection of sensor nodes {x1, x2, x3, x4, ... xn} deployed in the field.

Output: N nodes in Network with list of secure neighbour nodes

1. x1, x2, x3, x4, ... xn sensor nodes in network
2. rk is communication range between nodes
3. mA : malicious node with true of false values
4. schedule contains 0s and 1s for specifying active and sleep modes of node
5. for each node in N do
6. if x1 == 1 and x2 ==1 #Nodes are active at same time
7. r_k :=commRange(x1, x2) #Used to find common communication range for every node in network
8. if x2 known neighbour of x1 then
9. nodes schedule is adjusted.
10. else
11. mA = verification(x2) #Used for valid neighbour in the network
12. if (false= = mA) then
13. x2 become neighbor of x1 #x2 appended to neighbour list of x1
14. nodes schedule is adjusted
15. else
16. node x2 suspicious node, then restrict to add into neighbor list.
17. inform to known neighbors.
18. end for.
19.
20. Procedure for Malicious Attack verification
21. mA: =conduct primary check with node and application compatible
22. if(mA) then
23. return true.
24. for i=1 to 3 do
25. Y: =getDetails(node)
26. t=testFit(Y)
27. end for
28. mA:=verify($t \geq TH$) #TH :Threshold value
29. if(!mA and test) then
30. return warning
31. return mA

V. POWER MANAGEMENT METHODS FOR ADOPTING DUTY CYCLE

Energy efficient algorithms in WSNs are aimed to reduce battery power consumption during communication. As we discussed a large amount of energy is consumed by the radio unit for transmit or reception of data. Power management methods are adjusting the duty cycle schedule by switching off by radio unit, whenever not needed. As per equation 5, node x_i lifespan is $LS_{x_i} = \frac{N_{bc}}{C_1.\tau}$, if node as same duty cycle (τ) in the lifespan. We can enhance node lifespan by adjusting the duty cycle of a node whenever remaining energy is draining. We use two strategies to adjust the duty cycle as per requirements and energy.

A. *Node-Wise Reducing (NWR)*

Each node can construct r a variety of energy levels and they have associated duty cycle levels well in advance they represented as $N_{bc} = \check{N}_1 > \check{N}_2 > \cdots > \check{N}_r > 0$ and $\omega_{x_i} = \acute{r}_1 > \acute{r}_2 > \cdots > \acute{r}_r$. If node x_i remaining energy reduces to $\check{N}_l$, the node adopts the duty cycle to $\acute{r}_l$. We use $\check{N}_{r+1} = 0$ and x_i choose a duty cycle at t as $\tau_{x_i}(t) = \acute{r}_1,\ if\ N_{x_i}(t) \in [\check{N}_{l+1}, \check{N}_l\,]$ then lifespan of a node x_i can be constructed as:

$$LS_{x_i} = \sum_{l=1}^{r} \frac{\check{N}_l - \check{N}_{l+1}}{C_1.\acute{r}_l} \ldots\ldots\ldots\ldots (6)$$

The proposed method can enhance the node lifespan as compared with the general duty cycle equated in equation (4).

B. *Continuous Energy Reducing (CER)*

After deployment of a node in an area of interest, node x_i has initial energy (N_{bc}: Node initial battery capacity) and selects an initial duty cycle $\acute{r}_1$ assign when it started. Each node in the network adopts the duty cycle in continuous time intervals based on the remaining energy of a node, and fixed constant time. Assuming that the energy level at a particular time t, the node duty cycle is minimized as:

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 5s
DOI: https://doi.org/10.17762/ijritcc.v11i5s.7097
***Article Received**: 20 March 2023 **Revised**: 10 May 2023 **Accepted**: 30 May 2023*

$$\frac{N_{x_i}(t)}{\tau_{x_i}(t)} = \frac{N_{bc}}{ŕ_0} \dots\dots\dots\dots (7)$$

When the residual energy is comparatively very minimum, i.e., $N_{x_i}(t) \leq N_{min}$ where N_{min} a fixed constant is and then node has to adopt a duty cycle as $ŕ_{min} = \frac{N_{min}}{N_{max}} \cdot ŕ_0$. In order to determine the lifespan, it is mandatory to determine how many numbers of times that specific node adjusted its duty cycle. Assume after some fixed (k) periods of length Ť, the residual energy is no longer than N_{min}. Then lifespan of node can be derived in following equations:

$$\begin{cases} Ň_0 = N_{bc}, & ŕ_0 = ŕ_0 \\ Ň_1 = Ň_0 - Ť \cdot ŕ_0 \cdot C_1, & ŕ_1 = \frac{Ň_1}{Ň_0} \cdot ŕ_0 \\ \vdots & \\ \vdots & \\ Ň_i = Ň_{i-1} - Ť \cdot ŕ_{i-1} C_1 & ŕ_i = \frac{Ň_i}{Ň_0} \cdot ŕ_0 \\ \vdots & \\ Ň_k = Ň_{k-1} - Ť \cdot ŕ_{k-1} \cdot C_1, & ŕ_k = \frac{N_{bc}}{Ň_0} \cdot ŕ_0 \end{cases} \dots 8$$

Then lifespan of a node x_i is denoted as follows:

$$LS_{x_i} = k \cdot T + \frac{Ň_k N_{max}}{N_{min} ŕ_0 C_1} \dots\dots\dots\dots\dots\dots\dots . (9)$$

C. Discovery Latency Constraints

In realistic WSN applications, node need to obtain nearby node information timely then the node must adopt or increase the duty cycle depends on the application required latency. Therefore, discovery latency between any two nearby nodes is computed by the selected algorithm and the duty cycles of neighbor nodes. In table 2, illustrates that the various symmetric and asymmetric algorithms represent the variety of discovery latencies. For example, in Disco discovery latency constraints $Ľ_{x_i}(t)$ at time t for node x_i and it verifies the availability of the obtained neighbors. Assume duty cycle of a neighbor node x_j is $ŕ_j$ and node x_i must maximize its duty cycle as: $ŕ_i \geq \frac{4}{ŕ_j Ľ_i(t)}$. In order to obtain all nearby nodes, where node x_i has to verify the minimum schedule and node can maximize the duty cycle $ŕ_i \geq \frac{4}{ŕ_j Ľ_i(t)}$. Then, according to the application needs and remaining energy node x_i has to adopt better duty cycle. Here, two important metrics are considered to adjust the duty cycle by merging the latency constraints and remaining energy. The function of the adaptive duty cycle of a node denoted as follows.

$$\tau_i(t) = f\left(N_i(t), Ľ_i(t)\right) \dots\dots\dots\dots\dots (10)$$

D. Procedure to Reduce Collisions

In single channel wireless communication avoiding collisions is a non-trivial task. In multi-hop realistic applications, any two nodes can communicate successfully only when they are not interfered by other nodes. Due to interference, communication collisions were discovered, and many network nodes were unable to find their neighbours. In order to detect and reduce collisions, we peruse the neighbor discovery probability and propose two procedures to minimize the collisions in single channel wireless communication system.

E. Probability of Neighbor Discovery

In view of two nodes x_i and x_j have set of neighbor nodes denoted as $|N_{x_i}|$ and $|N_{x_i}|$. Assume these nodes x_i and x_j turn on their radio at time (t), and nearby nodes of these x_i and x_j are may turn on their radio as $Ň_{x_i} \leq N_{x_i}, Ň_j \leq N_{x_j}$. Here, $x_j \in Ň_i$ *and* $x_i \in Ň_j$, x_i and x_j can discover and communicate each other only if:

$$|Ň_i| = 1, |Ň_j| = 1 \dots\dots\dots\dots (11)$$

The average duty cycle for a node x_k as τ_k. We assume the scenario where node x_k turns on its radio with a probability of τ_k. The two nodes x_i and x_j turn on the radio at time t, the probability of discovery of nodes determined as follows:

$$D_{pr}\left(|Ň_i| = 1, |Ň_j| = 1\right) \leq \min\left\{f_{pr}\left(|Ň_i| = 1\right), f_{pr}\left(|Ň_j| = 1\right)\right\}$$
$$= min\left\{\Pi_{x_k \in N_{x_i}, k \neq j (1-\tau_k)}, \Pi_{x_k \in N_{x_j}, k \neq i (1-\tau_k)}\right\}$$

We adopt the basic function of the probabilistic algorithm to minimize the communication collisions and we use two important procedures are considered as follows.

F. *True Probability Reducing Procedure*

The TPR procedure can implemented as follows for existing deterministic discovery algorithms constructs the discovery schedule for x_i as $\omega_{x_i} = \{\omega_{x_i}(t) | t \geq t_i^{in}\}$ at particular time slot t that $\omega_{x_i}(t) = 1$, node x_i turns on the radio with probability Pr_1 to construct a modified sequence as $Ŝ = \{\omega_i(t) | t \geq t_i^{in}\}$.

$$\begin{cases} if\ \omega_{x_i}(t) = 0, & Ŝ_{x_i}(t) = 0 \\ if\ \omega_{x_i}(t) = 1\ , & Ŝ_{x_i}(t) = 0 \end{cases}$$

If two neighbor nodes x_i and x_j turn on the radio at time t the expected probabilities of $|Ň_{x_i}| = 1$ and $|Ň_{x_j}| = 1$ are then

$$D_{pr}\left(|Ň_i| = 1\right) = \Pi_{x_k} \in N_i, k \neq i\ (1 - Pr_1, ŕ_k)$$
$$D_{pr}\left(|Ň_j| = 1\right) = \Pi_{x_k} \in N_i, k \neq i\ (1 - Pr_1, ŕ_k)$$

We evaluate the success of these procedures in subsequent sections of this paper. For example, $Pr_1 = 0.5$, and τ_k=1%, the discovery probability is less than $1/2$ where $max\left\{|N_{x_i}|, |N_{x_j}|\right\} \geq 139$.

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 5s
DOI: https://doi.org/10.17762/ijritcc.v11i5s.7097
***Article Received**: 20 March 2023 **Revised**: 10 May 2023 **Accepted**: 30 May 2023*

VI. IMPLEMENTATION OF PROPOSED METHODS

To evaluate EASND performance and quantify its efficiency, we borrowed deterministic neighbor discovery algorithms. We performed simulations of proposed model using the NS2 simulator. We used various approaches for implementation of proposed EASND. We deployed and borrowed existing protocols are incorporated with EASND to construct efficient schedules for static duty cycles. Table 2 describes the initial parameters of simulation. We consider three strategies for comparing of existing protocol in neighbor discover:

TABLE II. BASIC SIMULATION PARAMETERS

Number of Nodes Deployed	: 100
Target Area	: 1000 x1000
Location of Nodes	: Static and uniformly densely distributed
Transmission rate	: 20m, 50m
Node Initial Energy	: 2Joule
Simulation Duration	: 1200 Seconds
Communication range ($\boldsymbol{R_{tr}}$)	: 50m
Slot length ($\boldsymbol{t_0}$)	: 20ms
Number of Base Stations	: 01
Duty Cycle Ratio	: 0.1 – 0.7
Idle or Sleep Energy	: 0Joule
Energy consumed by a node to turn on node each slot (C_1)	: 0.1J
Neighbour Discovery Schemes used for Comparison	: Hedis, Hello, Searchlight, and U- Connect.

i) Discovery with respect to central node. Assume x_i has number of neighbors $|N_{x_i}|$ in the network. Node x_i duty cycle τ_{x_i} and its neighbors can choose the duty randomly between $[0.1, 0.7]$.

ii) Discovery with respect to 1000 nodes. Once node's deployed in an area can construct duty cycle randomly to make connectivity and coordination between nodes and each node can choose a duty cycle randomly between $[0.1, 0.7]$.

iii) Discovery within two nodes. Our proposed model significantly generates the best available schedule for fixed duty cycles.

A. Enhancing Discovery Rate

Average discovery latency, the discovery rate, and lifespan or percentage of discovery is determined under various arrangements, and we described in table 3 the common parameters for every arrangement.

Number of Neighbors: We assume a central node x_i has number of neighbors $|N_{x_i}|$ and choose duty cycle $\tau_{x_i} = 0.3$. Here, we choose Hedis as the example and set $m_1 = m_2 = 0.5$ for TPR and DPR. In Figure 4 that the discovery rate of x_i with a specified duty cycle time slot and number of neighbors are increasing from 1 to 100.

In Hedis unable to discover neighbor if $|N_{x_i}| \geq 7$ and it cannot obtain knowledge of even one nearby node when $|N_{x_i}| \geq 18$. The existing system incorporated with implemented, all nearby node information can be obtained when $|N_{x_i}| \leq 43$ and $|N_{x_i}| \leq 33$. We also determine the significance of TPR and DPR at $m_1 = 0.4$ *and* $m_2 = 0.2$ and proposed outer form the models when $m_1 = m_2 = 0.5$.

B. Prolonging Lifespan

In this paper, we study two important methods to reduce the discovery latency Node-Wise Reducing and Continuous Energy Reducing that can enhance node lifespan. We computed the performance of node x_i in WSNs with set of $|N_{x_i}|$ neighbors. In continuous energy reducing, duty cycle at the initial level at 0.3 and $N_{min} = 200$ and node can adopt the duty cycle every $\hat{I} = 100000$ time slots.

Lifespan: Figure 7, shows that the lifespan of a node compared x_i for various existing neighbor discovery algorithms, both NWR and CER methods node lifespan can expand significantly. Suppose the lifespan of NWR and CER are approximately 5 and 6 times higher than the Hedis.

C. Enhancing Discovery for Two Neighbor

Our proposed model enables the estimation of symmetric and asymmetric duty cycles for neighbor discovery in asynchronous WSNs.

Symmetric Scenario: Assume x_i, x_j are two neighbors have the identical duty cycle τ, randomly selected between $[0.1, 0.5]$. In the Figure, illustrates that the average discovery latency, if the discovery latency of all existing algorithm minimizes as the duty cycle of algorithm maximizes.

Asymmetric Scenarios: Assume duty cycle of node x_i is constant at 0.2 and other node x_j duty cycle τ_{x_j}, randomly selected between $[0.1, 0.5]$. In the Figure, illustrates that the average discovery latency, if the discovery latency of all existing algorithm minimizes as the duty cycle of algorithm maximizes.

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 5s
DOI: https://doi.org/10.17762/ijritcc.v11i5s.7097
***Article Received**: 20 March 2023 **Revised**: 10 May 2023 **Accepted**: 30 May 2023*

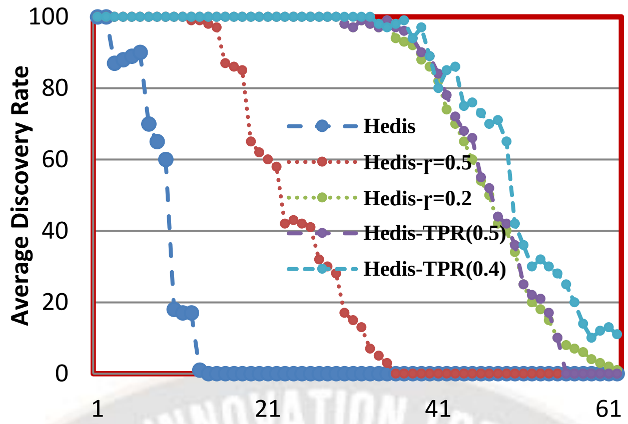
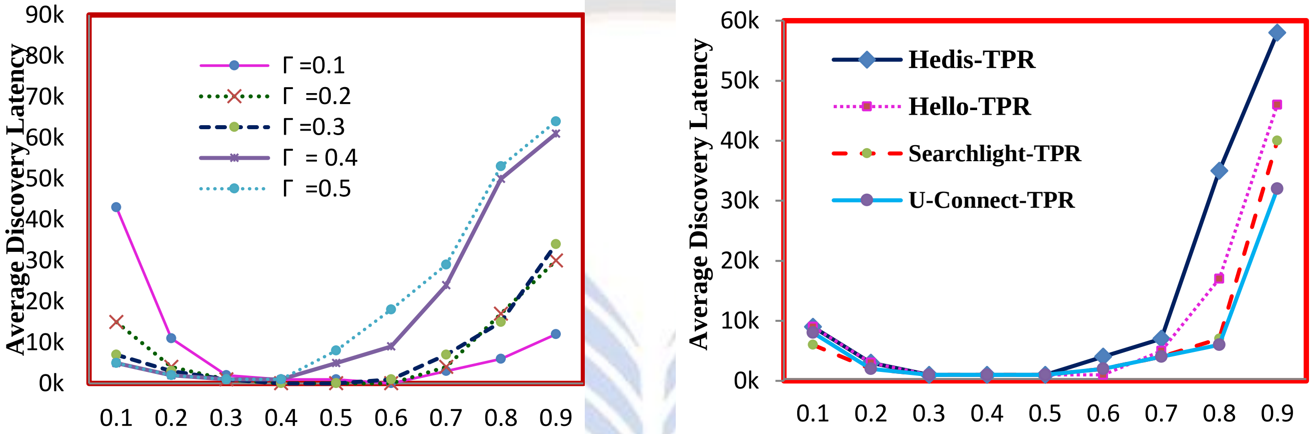
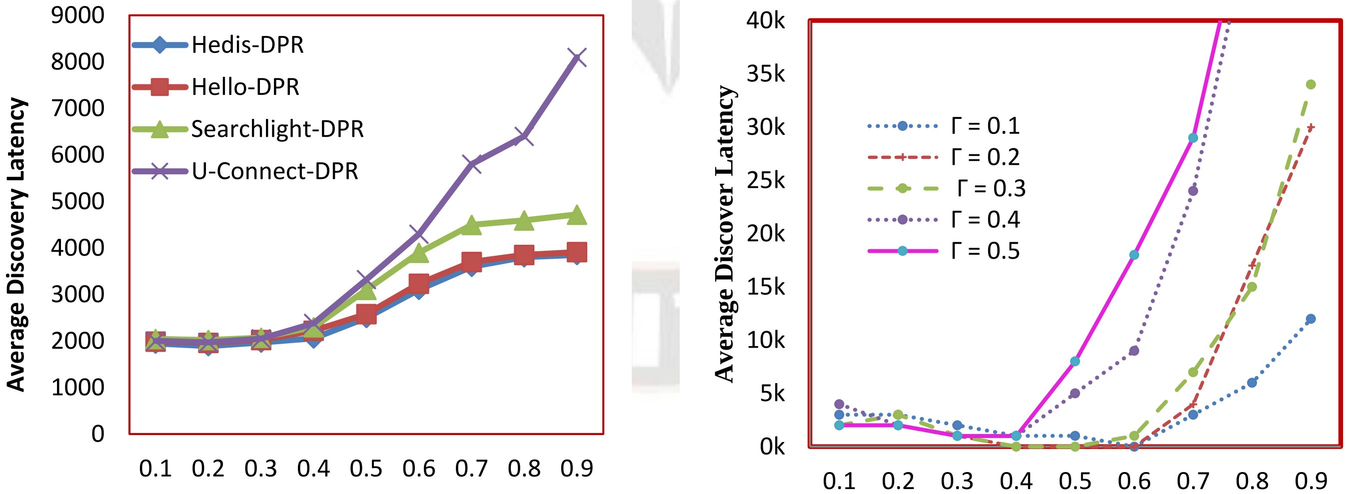


Figure 2. Neighbor Discovery rate by incorporating with TPR and DPR



(a) (b)

Figure 3. Responsiveness of Pr_i in the TPR procedure in (a) U-Connect TPR, (b) $\Gamma_{Xi} = 0.3$



(a) (b)

Figure 4. Responsiveness of Pr_i in the DPR procedure in (a) U-Connect DPR, (b) $\Gamma_{Xi} = 0.3$

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 5s
DOI: https://doi.org/10.17762/ijritcc.v11i5s.7097
***Article Received**: 20 March 2023 **Revised**: 10 May 2023 **Accepted**: 30 May 2023*

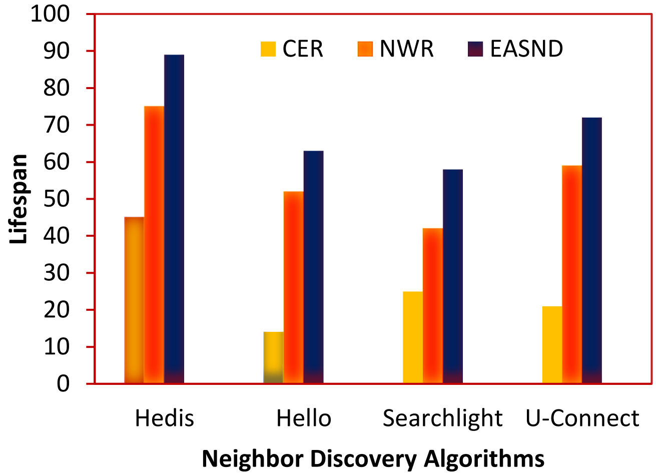
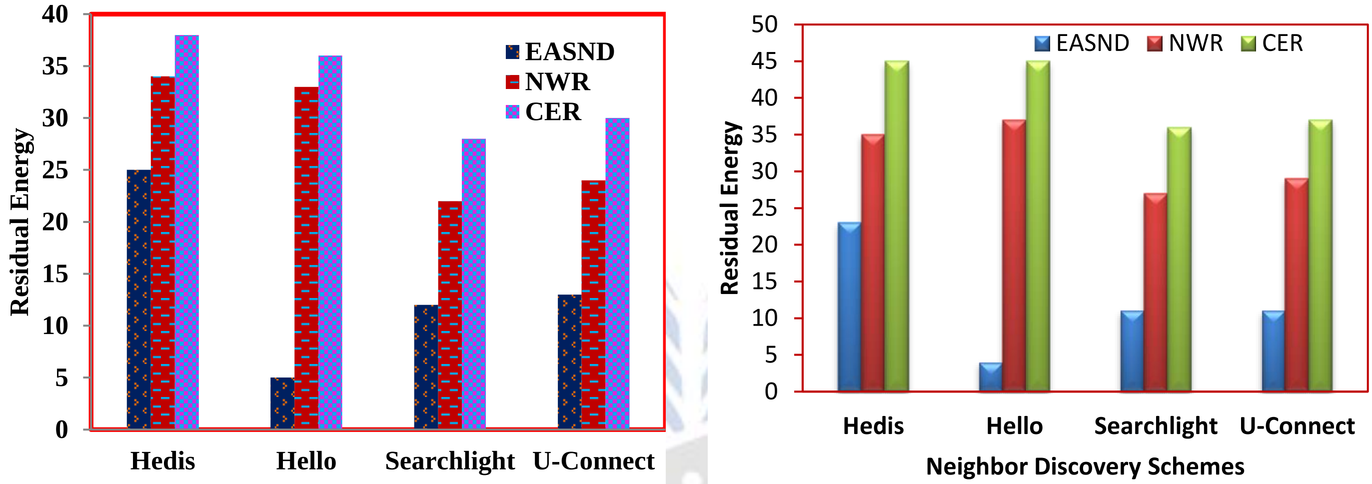
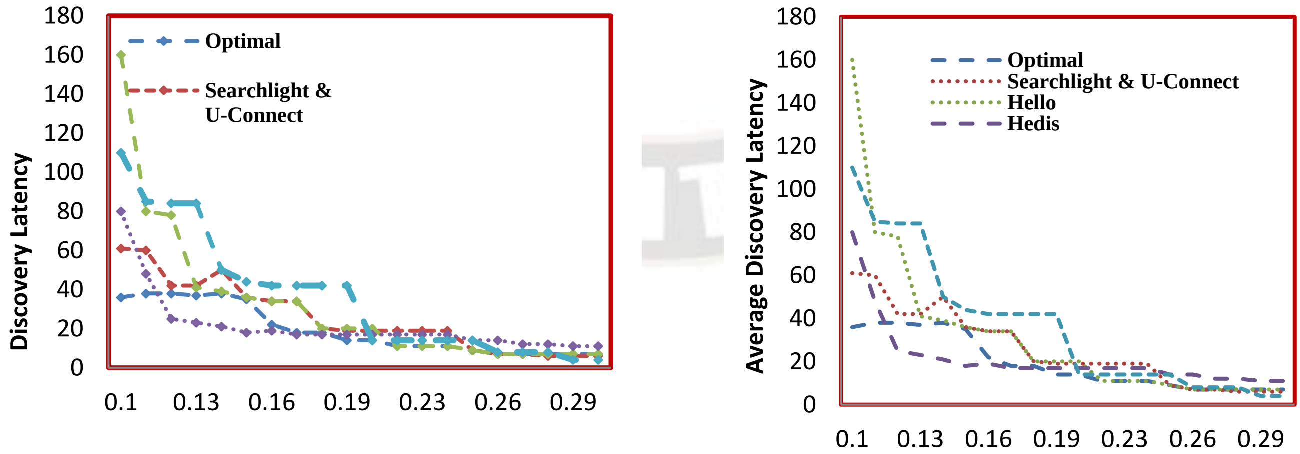


Figure 5. EASND enable with NWR and CER to enhance the lifespan of a Node



(a) (b)

Figure 6. EASND saves energy by adopting NWR and CER, (a) after 2T and (b) after 3T



(a) (b)

Figure 7. EASND can perform Neighbor Discovery in two scenarios such as: (a) Symmetric duty cycle, and (b) Asymmetric duty cycle

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 5s
DOI: https://doi.org/10.17762/ijritcc.v11i5s.7097
***Article Received**: 20 March 2023 **Revised**: 10 May 2023 **Accepted**: 30 May 2023*

VII. CONCLUSION

In this paper, we propose efficient adaptive secure neighbor discovery process. According to the application and remaining energy of a node, sensor devices in single channel wireless networks can adapt their duty cycle dynamically. We propose an extended general scheme to handle the secure neighbor discovery problem. After deployment of nodes arbitrarily in the monitoring area and then perform a neighbor discovery process to obtain knowledge about neighbor nodes. Initially node doesn't know about neighbors such as start time, active and sleep slots of a node. We borrowed various deterministic algorithms that can generate discovery of the nearby node according to the dependent discovery latency. In addition, we are proposing a non-cryptographic algorithm to provide secure neighbor discovery. From the simulation results, the proposed EASND has significantly better performance when sensor devices, select a duty cycle based on the application latency.

REFERENCES

[1] Elyes, Ben. Hamida.; and Guillaume, Chelius.; " Neighbor discovery Analysis in Wireless Sensor Networks", ACM, 2006.
[2] Daniele, Angelosante.; Ezio, Biglieni.; and Marco, Kops.; " Neighbor discovery for Wireless Networks", ISIT, 2007.
[3] I.F.Akyildiz.; W, Su*; Y. Sankarasubramaniam; E.Cayirci,; "Wireless Sensor Networks: a Survey"
[4] Beakcheol. Jang.; Jun Bum, Lim.; Mihail, L. Sichitiu.; "AS-MAC: An Asynchronous Scheduled MAC protocol for Wireless Sensor Network", IEEE,2008, 434-441.
[5] Bang Jun.Choi, and Xuemin.Shen, "Adaptive Asynchronous Sleep Scheduling Protocols for Delay Tolerant Networks", IEEE Transactions on Mobile Computing, 2011,10,1283-1295.
[6] Harish. R, Lei. P, James XZ, et al. "Practical overview of Security issuses in Wireless Sensor Network applications. IJCA, 2017.
[7] C.T Seng, C.S Hsu, and T.Y. Hsieh, " Power Saving Protocols for IEEE 802.11 Based Multi-hop Ad Hoc Networks", IEEE INFOCOM, 2002.
[8] Cohen, R.; Kapchits, B.; "Continuous Neighbor Discovery in Asynchronous Sensor Networks", In IEEE TON, 2011, 19, 69-79.
[9] Hussain Bukhari, S. N. . (2021). Data Mining in Product Cycle Prediction of Company Mergers . International Journal of New Practices in Management and Engineering, 10(03), 01–05. https://doi.org/10.17762/ijnpme.v10i03.127.
[10] Michnel.Segal, "Improving Lifetime of Wireless Sensor Networks", Network Protocols and Algorithms, 2009,1,48-60.
[11] J.Wiesellwer, G.Nguyen, and A.Ephrimides, "On Construction of Energy Efficient broadcast and multicast trees in Wireless Networks", INFOCOM, 2000.
[12] Singh, M. ., Angurala, D. M. ., & Bala, D. M. . (2020). Bone Tumour detection Using Feature Extraction with Classification by Deep Learning Techniques. Research Journal of Computer Systems and Engineering, 1(1), 23–27. Retrieved from https://technicaljournals.org/RJCSE/index.php/journal/article/view/21
[13] Elaine. Shi, Adrian.Perrig, "Designing Secure Sensor Networks",IEEE, 2004
[14] Borbash, S. A.; Ephremides, A.; McGlynn, M. J.; " An Asynchronous Neighbor Discovery Algorithm for Wireless Sensor Networks", Elsevier Ad Hoc Networks, 2007, 5, 998-1016.
[15] McGlynn, M.J.; Borbash, S.A.; "Birthday Protocols for Low Energy Deployment and Flexible Neighbor Discovery in Ad Hoc Wireless Networks." In the Proceedings of the 2nd ACM International Symposium on Mobile Ad Hoc Networking & Computing, USA, 2001.
[16] Dutta. P,; Cullar.D; "A Practical Asynchronous Neighbor Discovery and Rendezvous fo Mobile Sensing Applications." In Proceedings of the 6th ACM Conference Embedded Network Systems, Releigh, NC,USA, 2008, 71-84.
[17] Kandhalu, A.; Lakshmanan, K.; Rajkumar,R.R.; " U-Connect: A Lower Latency Energy Efficient Asynchronous Neighbor Discovery Protocol", In Proceedings of of the 9th IEEE Conference on Information Processing in Sensor Networks, Sweden, 2010, 12-16.
[18] Bakht, M.; Trower, M.; Kravets, R.H.; "Searchlight: Won't you be my neighbour?", In proceedings of the 18th Annual Internation Conference on Mobile Computing nad Networking, Turkey, 2012, 22-26.
[19] Aveek, Purohit.; Bodhi, Priyanath.; Jie, Liu.; "WiFlock: Collaborative group Discovery and Maintenance in Mobile Sensor Networks", In the Proceedings of the 10th International Confereence on Information Processing in Sensor Networks, USA, 2011.
[20] Chen, L.; Fan, R.; Bian, K.; Che, L.; Gerla, M.; Wang, T., Li, X.; " On Hetrogeneous Neighbor Discovery in Wireless Sensor Networks", In Proceedings of th IEEE Conference on Computer Communications (INFOCOM), China, 2015.
[21] Robert Roberts, Daniel Taylor, Juan Herrera, Juan Castro, Mette Christensen. Leveraging Machine Learning for Educational Data Mining. Kuwait Journal of Machine Learning, 2(1). Retrieved from http://kuwaitjournals.com/index.php/kjml/article/view/176.
[22] Nathanson, M.B.; "Elementary Methods in Number Theory", Springer, Germany, 2000, Vol, 195.
[23] Vasudevan, S.; Towsley, D.; Goeckel,D.; Khalili, R.; " Neighbor Discovery in Wireless Networks and the Coupon Collector's Problem", In Proceedings of the 15th Annual International Conference on Mobile Computing and Networking, China, 2009.
[24] Dhabliya, D. (2021). An Integrated Optimization Model for Plant Diseases Prediction with Machine Learning Model . Machine Learning Applications in Engineering Education and Management, 1(2), 21–26. Retrieved from http://yashikajournals.com/index.php/mlaeem/article/view/15.
[25] Wang,K.; Mao, X.; Liu, Y.; "BlindDate: A Neighbor Discovery Protocol", TPDS, 2015, 26, 949-959.
[26] Sun, W.; Yang, Z.; Zhang, X.; Liu, Y.; "Hello: A Generic Flexible Protocol for Neighbor Discovery", In Proceedings of the IEEE INFOCOM, Canada, 2014.
[27] Qiu, Y.; Li, S.; Xu, X.; Li, Z.; "Talk More Listen Less: Energy Efficient Neighbor Discovery in Wireless Sensor Networks", In Proceedings of the 35th IEEE INFOCOM, USA, 2016

[28] Wang Wei, Natural Language Processing Techniques for Sentiment Analysis in Social Media , Machine Learning Applications Conference Proceedings, Vol 1 2021.

[29] Lai, S.; Ravindran, B., Cho, H.; " Heterogeneous Quorum-based Wake-up Scheduling in Wireless Sensor Networks", IEEE Trans. Computing, 2010,59,1562-1575.

[30] Zikria, Y.B.; Afzal, M.K.; Ishmanov, F.; Kim, S.W.; Yu, H.; " A Survey on Routing Protocols supported by the Contiki Internet of Things Operating System", Future Gener. Comput.Syst, 2018, 88, 699-706.

[31] Jiang, J.R.; Tseng, Y.C.; Hsu, C.S.; Lai, T.H.; " Quorum-based Asynchonous Power-Saving Protocols for IEEE 802.11 Ad Hoc Networks. Mob. Netw. 2005,10,169-181.

[32] Margolies, R.; Grebla, G.; Chen, T.; Rubenstein, D.; Zussman, G.; "Panda: Neighbor Discovery on a Power Harvesting Budget", IEEE J.Sel, Areas Commun. 2016, 34, 3606-3619.

[33] Zanella, A.; Bazzi, A.; Pasolini, G.; Masini, B.M.; " On the Impact of Routing Strategies on the Interference of Adhoc Wireless Networks", IEEE Trnas. Commun, 2013,61, 4322-4333.

[34] Zheng, R.; Hou, J.C.; Sha, L.; "Asynchronous Wakeup for Ad Hoc Networks", In Proceedings of the 4th ACM International Symposium on Mobile Ad Hoc Networking & Computing, USA, 2003.

[35] Sagar Mekala, Chatrapati, K.S "Hybrid Approach to Neighbour Discovery in Wireless Sensor Networks" Intelligent Automation and Soft Computing, 35(1), pp. 581–593, 2022.

[36] Sagar Mekala, Chatrapati, K.S. "Present State-of-the-Art of Continuous Neighbor Discovery in Asynchronous Wireless Sensor Networks" EAI Endorsed Transactions on Energy Web, 8(33), pp. 1–7, 2021.

[37] Sagar Mekala, Chatrapati, K.S. "A continuous neighbour discovery protocol for asymmetric wireless sensor networks", Journal of Advanced Research in Dynamical and Control Systems, 2020, 12(7 Special Issue), pp. 633–645

[38] F. F. Jurado-Lasso, K. Clarke and A. Nirmalathas, "Performance Analysis of Software-Defined Multihop Wireless Sensor Networks," in IEEE Systems Journal, vol. 14, no. 4, pp. 4653-4662, Dec. 2020.

[39] Ruchika, & Chhilar, R. S. . (2023). Novel Approach for Improving Secure Scheduling in Fog Environment and in Context of Smart Homes. International Journal of Intelligent Systems and Applications in Engineering, 11(1s), 23–29. Retrieved from https://ijisae.org/index.php/IJISAE/article/view/2473

[40] P. H. Kindt, D. Yunge, G. Reinerth, et al, "Griassdi: Mutually assisted Slotless Neighbor Discovery," ACM/IEEE International Conference on Information Processing in Sensor Networks, pp. 93–104, 2017.

[41] X. Luo et al., "CREDND: A Novel Secure Neighbor Discovery Algorithm for Wormhole Attack," in IEEE Access, vol. 7, pp. 18194-18205, 2019.

[42] Hao Cai, and Tilman Wolf . Self-Adapting Quorum-Based Neighbor Discovery in Wireless Sensor Networks. In IEEE INFOCOM 2018 - IEEE Conference on Computer Communications

[43] Y. Wang, G. Sun, G. Yang and X. Ding, "XgBoosted Neighbor Referring in Low-Duty-Cycle Wireless Sensor Networks," in IEEE Internet of Things Journal, vol. 8, no. 5, pp. 3446-3461, 1 March1, 2021. (xBOND)

[44] O. A. Saraereh, I. Khan and B. M. Lee, "An Efficient Neighbor Discovery Scheme for Mobile WSN," in IEEE Access, vol. 7, pp. 4843-4855, 2019.

[45] M. Jamalabdollahi and S. A. R. Zekavat, "Joint Neighbor Discovery and Time of Arrival Estimation in Wireless Sensor Networks via OFDMA," in IEEE Sensors Journal, vol. 15, no. 10, Oct. 2015, pp. 5821 - 5833.

[46] L. Chen, Y. Shu, Y. Gu, et al, "Group-based neighbor discovery in low duty-cycle mobile sensor networks," IEEE Transactions on Mobile Computing, vol. 15, no. 8, pp. 1996–2009, 2016.