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CDS Based Lifetime Improving In Wireless Sensor Networks And Wireless Ad Hoc Networks

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Abstract: Energy consumption and extending the lifetime of the networks plays a vital role in wireless sensor networks and wireless ad hoc networks. The sensor network is formed by connecting large number of small sensor nodes which are randomly deployed. To maximize the lifetime of the network, a graph is constructed named Connected Dominant Sets (CDS) which forms a virtual backbone of the network. In the sensor networks using CDS, failure of a single node causes to network partitioning and leads to disconnection of the network. Replacing the faulty node takes many displacements and consumes more energy. There is no effective scope in for fault detection and replacement in wireless sensor networks. The lifetime of the networks depends on the connectivity between the nodes. In this paper, we concentrate on two important factors: one is extending the lifetime of the network and energy consumption, the other one is covering the maximum area with a minimum number of sensor nodes. Replacement of the faulty dominant node is replaced by the neighbor dominant node with high residual energy.
Keywords: Wireless sensor network, Fault tolerance, Energy consumption, Connected Dominant Sets (CDS).

I. INTRODUCTION

Wireless Sensor network is a self configuration network with a collection of numerous nodes (motes) which communicate with one another and is connected to main location through a gateway. The gateway commonly used in WSN is zigbee or a low power wifi. The node consists of sensors and actuators for sensing, monitoring and analyzing the environmental conditions. Sensors produce analog voltage with respect to the data which it senses. A radio transceiver is present in the nodes which have an antenna internally or an externally. The power supplies to the nodes are provided by battery or any other external electricity. The size of nodes may vary in different size and it is cheap in cost. WSN may follow any topology like star network or multi hop wireless mesh network. The sensor nodes communicate with one another to form a network. Each node of the sensor network consists of three subsystems: the sensor subsystem which senses the environment, the processing subsystem which performs the local computation of the sensed data, and the communication subsystem which is responsible for message exchange with neighboring sensor nodes.

Wireless sensor networks are composed of independent sensor nodes deployed in an area working collectively in order to monitor different environmental and physical conditions such as motion, temperature, pressure, vibration sound or pollutants. Different constraints such as size and cost results in constraints of energy, bandwidth, memory and computational speed of sensor nodes. WSNs have a wide variety of applications. The main reason in the advancement of wireless sensor network was military applications in battlefields in the beginning, but now the application area has extended to other fields, including industrial monitoring, controlling of traffic, health monitoring, environmental monitoring and tracking. The particular applications are tracking of object, monitoring of health, fire detection and control of nuclear reactors. Deployment of sensor nodes in an area for collection of data is a typical application of WSN. The events occurring in the environment are monitored by the sensor nodes deployed in the region. Monitoring of area involves detecting enemy intrusion by a large number of sensor nodes deployed over a battlefield. The detected events are then reported to a base station for some action. A large scale wireless sensor networks are deployed for environmental monitoring, including forest fire/flood detection, monitoring of the condition of soil and space exploration. WSN have a lot of applications concerning commercial are such as office/home smart environments, health applications, controlling of environment in buildings, monitoring of industrial plants. In tracking area, WSN applications include targeting in intelligent ammunition and tracing of doctors and patients inside a hospital. A search and rescue system is designed using connectionless sensor based tracking system using witness CenWits. Sensors with different radio frequencies and processing devices are used. This rescue system consists of mobile sensors, access points and GPS receivers. The search and rescue efforts are concentrated on an approximate small area with the help of CenWits. Automated Irrigation System (AIS) is the ability to handle

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variations in productivity within a field and maximize financial return, reduce waste and minimize impact of the environment using automated data collection, documentation and utilization of such information for strategic farm management decisions through sensing and communication technology. Several technologies were used in the AIS such as Remote Sensing (RS), Global Positioning System (GPS), and Geographic Information System (GIS). The most important step in AIS is the generation of maps of the soil with its characteristics. These included grid soil sampling, yield monitoring, and crop scouting.

A dominating set (DS) is a subset of all the nodes such that each node is either in the DS or adjacent to some node in the DS. A connected dominating set (CDS) is a subset of the nodes such that it forms a DS, and all the nodes in the DS are connected. CDS is used as a virtual backbone in wireless networks. The virtual backbone reduces the communication overhead and it is reliable. The nodes alone will relay the messages. It reduces the communication cost and redundant traffic. The virtual backbone is used in the computation of routing in WSN. In these applications minimum connected dominating sets are used as backbone for communication. The nodes that are not in the CDS will send messages through the neighbor nodes that present in the CDS.

II. LITERATURE SURVEY

In military applications, micro-sensors are used which has limited power source. Micro-sensor uses battery which is impossible to replace or recharge the battery of the sensor nodes which are deployed in the battlefield. To reduce the energy consumption and improve the performance of the network, some of the sensor nodes are moved to passive mode. The nodes in the active mode will take care of data transmission, routing process and network connectivity [1].

In [4] this paper gives solution to the above issues in clustering algorithms. The nodes are detected and their locations were also detected during initial deployment and also during the addition of nodes to the network. It is an essential function of wireless sensor networks. In large networks, some of the topology details will not be shared which are unimportant regarding the network in order to save the bandwidth and energy. The CDS construction depends on the construction maximal independent sets [5]. The main objective of the topology management techniques in wireless sensor networks is to improve fault tolerance, reduce loss of connectivity and limit the energy usage. It can be done by node deterministic node placement or through automatically after the nodes are randomly deployed with limited human intervention [6]. In [7,14] survey on fault tolerance in wireless sensor networks is done comparing various algorithms regarding fault tolerance. The wireless sensor networks which are deployed in critical zones in which human intervention is difficult in that region. In such regions the sensors will be deployed randomly, and these sensors form the networks by its own according to any one of the topology. This helps to extend the lifetime of the network and also saves energy. They avoid redundant data so that it reduces congestion [2,3,8,13]. DARA: In this approach the failure node detection does not need adjustment in the topology of the network, if the failure node doesn't partition the network. The failing node which is detected does not need any adjustments if the failure node does not disconnect the network. The coverage zone of the faulty node will remain without changing the coverage area if the faulty nodes never partition the network. It focuses on the connectivity maintenance [9].

The failure of a single node may lead to network partitioning and loss of connectivity. An algorithm C^3R (Coverage conscious connectivity restoration) is designed to overcome this situation. It recovers a single or multiple failed node from the failure. The neighbor to the failed node will replace temporarily for the failed node and complete the task [10]. In [11], a new fault management technique is used by extending the cellular approach for faulty node detection and recovery. A hierarchical structure is used to distribute the fault management tasks among the nodes. It is done by introducing 'self managing' function. In many fault tolerant mechanisms, the sensor nodes require either additional energy to detect the failure node and to recover it or else it requires additional software and hardware resources. Power efficient sleep schedule algorithm is developed to improve the lifetime of the node in sensor network. It combines the connected dominant sets (CDS) with a conjugative sleep schedule algorithm. The features of this combination include the process of forming the network should be as simple as possible, resultant dominant set should also get connected and minimum. In conjugative power efficient sleep scheduling scheme, conjugative sleep schedule operation and conjugative power efficient sleep scheduling algorithm are used. This scheme is used in CDS for sensing data aggregator in sensor networks to extend the lifetime network. The power efficient sleep schedule algorithm is constructed based on connected dominating sets [12]. Wireless adhoc networks are self-organizing, autonomous networks, which have multi-hop routing. Wireless local networks have predefined network facilities which include base station and router. But wireless ad hoc networks do not depend on any predefined network infrastructure, because the sensor nodes are distributed randomly [15]. In [16] a novel energy-aware fault tolerance mechanism is developed for wireless sensor networks and the algorithm is named as Informer Homed Routing (IHR). In

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IHR the non cluster head nodes will select few targets and helps in data transmission. This algorithm consumes less energy. The wireless sensor networks are implemented in the medical field, battlefield surveillance, military, monitoring and tracking system and biological detection systems. The sensors monitor the environmental conditions in soil, marine and atmospheric context. An algorithm is proposed to cover entire monitored region with minimum number of sensor nodes. The redundant nodes are found out and it is used to replace the fault node. The mobility assistance minimum connected sector cover (MCSC) consumes minimum amount of energy and it prolongs the lifetime of the network. It uses either direct movement or cascaded movement to replace the faulty node and it reduces the distance location. [17]. In [18], this paper discusses about different approaches in fault tolerance in Wireless sensor networks. As the sensor nodes are deployed randomly in a hostile environment, the fault tolerance and reliable dissemination are major issues in WSN. The wireless communication plays an important role in data processing networks. They do not need infrastructure and also it provides mobility. Due to the mobility of the users, they were under active deployment. The characteristics of the mobile environment include frequent disconnection, limited source of energy. Since the major number of nodes will have a low power battery for their power source and it can't be replaced as the sensor nodes are deployed in the battlefield, civil and military environment, etc. So energy should be utilized properly to extend the lifetime of the network. DFRN: Detection and replacement approach of a failing node helps in fault tolerance in wireless sensor networks using connected dominant sets CDS) gives solution to the fault tolerant issue. It works like as if a node fails, then the failure node have to be replaced by its neighbor node which has higher potential energy. The replaced node has to perform the functions of the failure node. Then the replaced node's position has to be replaced by some other node to ensure its functions. It has two algorithms, namely: detect-fail() for detecting the faulty node, repl-fail() for replacing the faulty node. This algorithm improves the lifetime of the network and also consumes less energy. The numbers of replacements were also minimum when compared to the C^3R algorithm. [19]. In [20] an algorithm is proposed for efficient faulty node detection and recovers the faulty node by replacing with other nodes with alternative routes. This algorithm includes combination 3 different algorithms namely bootstrapping algorithm, genetic algorithm and grade diffusion algorithm. In [21], the least-cost tree augmentation problem is NP-Complete for both single node failure and 2 adjacent node failures. Two approximation algorithms are proposed one for single node failure and the other for 2 adjacent node failures.

WSN when applied in inhospitable environment such as battlefield reconnaissance, large-scale damages which leads to failure of multiple sensor node failures and thus causes network partition. To restore the overall network connection is very crucial. An algorithm is proposed to overcome this problem. It is Connectivity Restoration with Assured Fault Tolerance (CRAFT) algorithm which forms a largest inner circle or a backbone polygon (BP) around the failure area in which no partition lies inside [22]. A Bridge Protection Algorithm (BPA) which is a combination of mechanisms that respond to a catastrophic event which change the behavior of the topology and at the same time it relieve the overwhelmed nodes. It prevents the partition of bridge nodes [23].

In[24] the study of fault management algorithm and recovery the faulty node is done using FNR algorithm. In network management, fault management is the most important one. The fault management algorithms are spliced into different types based on their functions: namely fault detection, fault diagnosis and fault recovery. The two approaches that the fault detection falls into is Centralized and Distributed approaches. The fault diagnosis process answers three questions that are: where the fault is occurs, what is the type of the fault and how does it occurs. Fault recovery algorithms include generic and diffusion algorithm. FNR algorithm uses minimum number of displacements, minimize the cost of replacing sensors and also it uses reused routing paths.

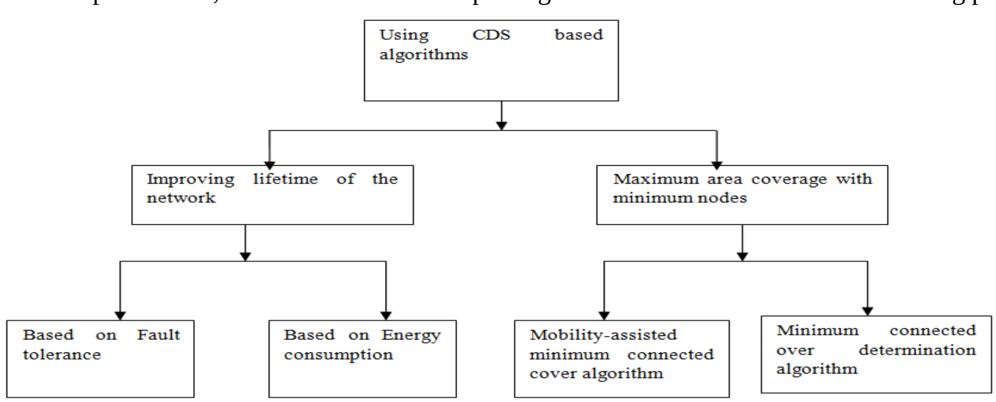

Figure 2.1 Using CDS based algorithms to improve the performance of the network

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In [25] an algorithm is proposed for fault detection and recovery. The node failure occurs due to the depletion of energy, environmental conditions, and failure occurs in either hardware or software. This algorithm depends on the ladder diffusion, which is combined with genetic algorithm. It extends the lifetime of the network by consuming less energy. In [26] an algorithm is proposed for fault node recovery, which enhances the lifetime of the sensor network. It shut down the nodes when they are not in use. So it consumes less energy, increases the number of active nodes, and reduced power consumption, number of hops. This algorithm works based on a fault node detection algorithm and fault node route recovery.

There is no effective strategy for replacing the faulty dominant node in the wireless sensor networks using CDS concept. In some cases, the system detects the faulty node but it fails to replace it using proper algorithm, or else it detects and doesn't replace as if the faulty node doesn't partition the network, or else the replacement consumes much energy.

III. ALGORITHM FOR IMPROVING THE PERFORMANCE OF THE NETWORK

In this paper, we proposed a multi-objective algorithm which improves the fault tolerance, prolongs the lifetime of the network and also energy consumption. In general, the Cluster Head (CH) are not the dominant nodes. A node is assigned as CH based upon three parameters namely high Packet size, high Data burst rate and minimum idle time. The multi-objective algorithm for the wireless sensor networks recovers the faulty dominant node from the failure. It includes of three phases namely: formation of minimum connected dominating sets, detection and replacement of the fault node and the last step is recovery.

A. *Minimum Connected dominating set Formation:*

Once the deployment of the sensor node gets over, each and every sensor node communicates with other sensor nodes and get the information of the neighbor nodes and forms a cluster. The cluster will cover the maximum coverage area with minimum nodes. Each cluster will have a Cluster Head which is a dominating node and cluster members. The cluster head is the node which has high residual energy or high potential to transmit more data or else which is close to the centre of the cluster so that it can cover maximum area in each cluster. It collects all the information from the cluster members, aggregate the information and send the aggregated information to the receiver base station. The cluster members are the nodes that sense the environment and send the data to their cluster head. The cluster head does not sense the environment but only collects the data from cluster members and transmits it to the base station. The minimum connected dominating sets are constructed by connecting all the dominant nodes or cluster heads. The MCDS cover of the clusters is constructed based upon the cluster member's information. Different clusters transmit data at different point of time. The entire cluster heads are connected by wireless connection. The minimum connected dominating sets are constructed based upon the Path Connection algorithm. The path connection algorithm helps to find how to cover the maximum coverage area with minimum number of nodes. The concentric circles during data transmission show the maximum area coverage.

B. *Detection and replacement algorithm for fault tolerance:*

In the existing system, in detect-fail() algorithm the Cluster head (CH) waits for the reply from sensor node by sending beacon signals. If it doesn't receive reply from the node it considers as the node failure. The repl-fail() algorithm will replace the fault node by the nearby neighbor with high energy and the functions of the faulty node [3]. In the proposed system it has 4 steps namely: Setup phase, Identification phase, Data transmission and Replacement phase.

1) *Setup phase:* The Cluster Heads(CH) are assigned as the Dominant Nodes(DN), based upon setting the three parameters (High packet size and data burst rate because the DN collects data from all of its cluster members , aggregate the information and it has to send it to the base station. So the size of the data packets should be high. Low idle time since the dominant keeps on transferring the data from the sensor nodes to base station through wireless communication). And also based upon CH which can able to connect with other nodes quickly.
2) *Data transmission phase:*The data transmission takes place via Dominant Node (DN). The topology in this system is implemented as such data transfers through DN which is nothing but the Cluster Head (CH). Our topology is designed based upon the energy model. During the data transmission in the energy model, the control packets are also transferred along with the data packets. The control packets will calculate the residual energy of the DN which is nothing but the remaining energy of the DN. The threshold for the energy has been set as 20%. The data transmission takes place in the DN until the residual energy falls down below its threshold level. The routing algorithm for data transmission uses AODV (Ad hoc On-demand Distance

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Vector) routing algorithm. A routing protocol for ad hoc mobile networks with large numbers of mobile nodes. The protocol's algorithm creates routes between nodes only when the routes are requested by the source nodes, giving the network the flexibility to allow nodes to enter and leave the network at will. The routes remain active only as long as data packets are traveling along the paths from the source to the destination. When the source stops sending packets, the path will time out and close.

3) *Identification Phase (Identification of a faulty node:* If the residual energy of the node reduces below 20%, then it is considered as the energy drain node. The data transmission at the node with 20% of the residual energy will automatically choose the neighbor node. The energy drain may be either due to physical damage or energy depletion. In both cases, the failed dominant node is identified. All the Dominant nodes are connected indirectly by synchronizing with receiver base station. During implementation, the duplex connections has been established between the Dominant nodes and the base station. The base station will have the residual energy information of all the dominant nodes. The Dominant node can identify its neighbors by communicating with the base station. A neighborhood algorithm has been designed to identify the neighbors of the dominant node. At the time of failure due to any means, the DN can contact the Base Station for another dominant node to control its sensor nodes or cluster members and ensure the faulty DN's functions. In the Setup phase the link gets established between DN and the sensor nodes. DN send beacon signals to neighbor node. The nodes which receive the signals reply to the DN with their IDs and thus form the cluster. Residual energy (RE) will be calculated for the DN. If the RE is less than the threshold value then nearest neighbors for the DN is determined. For all the neighbors, the one DN which has highest energy will take care of all the nodes of the faulty DN. The new DN will be reinitialized as the DN for the faulty DN's members. In the data transmission phase, the data is transmitted from the sensor nodes to DN and from the DN to Receiver Base station (BS). Data transmission phase takes place after the identification phase if re-initialization of DN takes place. Identification phase takes place before the date is transferred from DN to Base Station. Because the DN may also fail after receiving the data from the sensor nodes. At that time redundant server will had the backup of faulty DN and transmits the data to BS in the recovery phase.

a) *Algorithm for cds-replfa():*

{

i) Setup phase:

#Cluster Head send beacon signals.
#Sensor nodes reply with their IDs.
#Cluster Head forms the cluster.
#Link establishment between Cluster head and sensor node.
#Cluster is assigned as Dominant node base upon 3 paramters:

1. It should have high Packet size
2. It should have high data burst rate
3. It should have minimal idle time.

b) Data transmission Phase:

#Residual energy calculation
//threshold level 20%
Sensor node senses the data ;
#DN collects the data from sensor nodes;
#DN transmits the data to BS;
{
    If(DN's energy >Threshold energy)
    {
    Transmit the data;
    }

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```
        Else
        {
        //Energy drain may be due to energy depletion or Physical damage.
        Identification phase;
        }
}
```

c) Identification Phase:

```
{
        If( DN's energy <Threshold energy)
        {
        find out nearest neighbors for DN;

        //by using neighborhood algorithm DN finds out the nearest neighbor by synchronizing with BS;

        While(neighbor's energy>threshold energy)
        {
        Re-initialization of DN in the place of fault DN
        //Replace temporarily until it regains its energy
        }

        }
        Else
        {
        Data transmission phase;
        }
```

d) Recovery Phase:

```
If (sensor node gets failed)
{
        Nearest node will take care of the faulty nodes functions and send the information to DN;
        }
Else If( DN gets failed during data transmission between DN and sensor node)
        {
         Nearest DN with highest energy will take control over the whole cluster of the faulty DN;
        }
Else
        {
        DN gets failed during data transmission  between DN and BS;
         Redundant server will transmit the data to BS;
        }
```

---

4) *Recovery phase:* In this algorithm, if the cluster member gets failed then the other neighbor sensor node in that particular cluster will sense and send the data to the cluster head. If the Cluster head say Dominant node gets failed then the information will be send to nearby DN through wireless communication. The DN which is very close to the failed DN will take full control of all the cluster members of the failed DN temporarily until the failed DN regains the energy. The energy may be gained either through rechargeable batteries or from the base station as it is a wireless sensor networks.

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IV. SIMULATION AND EXPERIMENTAL RESULTS

The simulation for our approach is developed in NS2 simulator. The sensor nodes are placed in a 1000 x 1000 m^2 area and it forms wireless sensor networks. The network consists of 70 nodes, 7 cluster head, one Receiver Base station, one Gateway and one Router. The cds-replfail() algorithm is compared with existing detect fail algorithm using different QoS parameters, namely Packet data rate, Packet loss rate, Packet delay, Energy consumption, Throughput and number of active nodes.

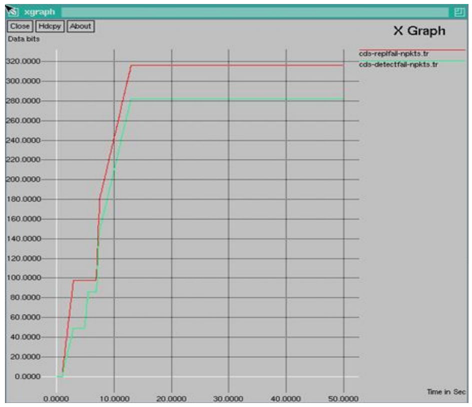

Figure 3.1 Comparison analysis of Packet data rate.

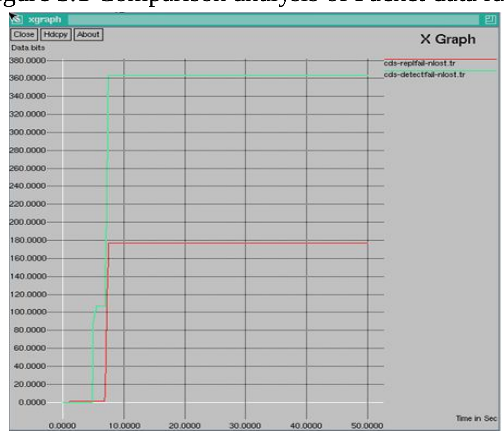

Figure 3.2 Comparison analysis of Packet loss rate.

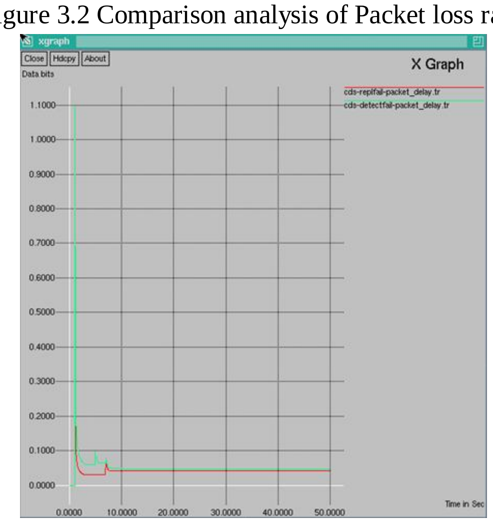

Figure 3.3 Comparison analysis of Packet delay.

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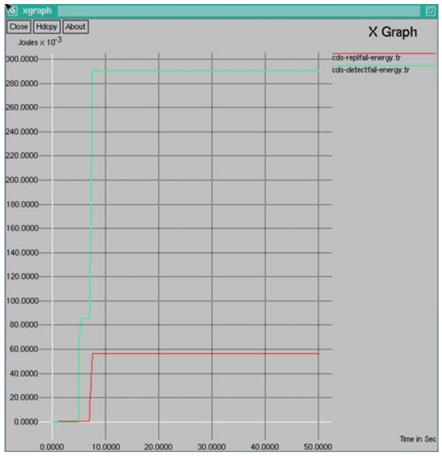

Figure 3.4 Comparison analysis of Energy consumption.

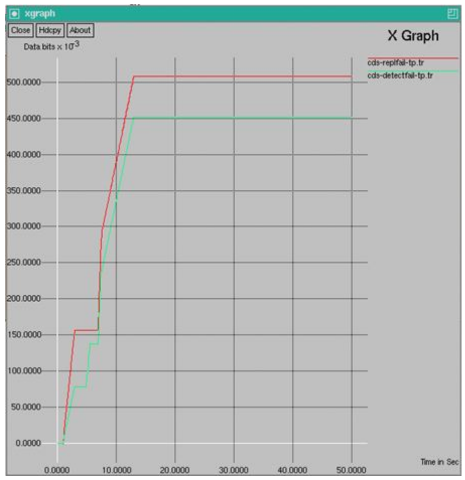

Figure 3.5 Comparison analysis of Throughput.

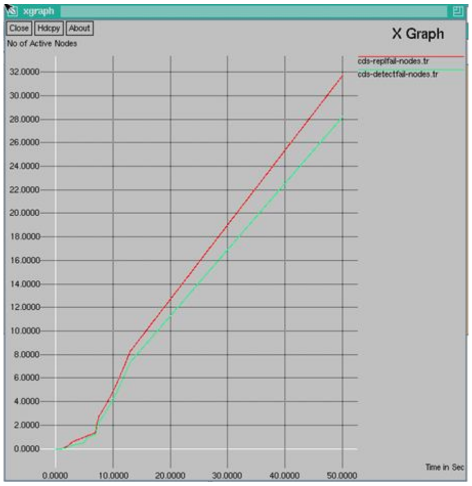

Figure 3.6 Comparison analysis of no. of Active nodes.

The packet data rate, throughput and the number of active nodes are higher in the proposed algorithm than the existing algorithm. For 5 seconds, the energy consumption is nearly 58 joules per m^{-3} in the proposed system and nearly 84 joules per m^{-3} in the existing system. From 10 seconds onwards the energy consumption is constantly 58 joules per m^{-3} in the proposed system whereas in the existing system, the energy consumption is above 280 joules per m^{-3}. In the meanwhile packet delay, packet loss rate and energy consumption are greatly less in the proposed algorithm than the existing algorithm.

V. CONCLUSION

In this paper, we proposed a fault tolerance algorithm using CDS for Wireless sensor networks. A solution is given for the fault tolerance in this algorithm by detecting the faulty node and replace with neighbor node that has the highest residual energy. The recovery is done by the nearest neighbor DN when the data is transmitted from sensor node to DN without loss. In case of DN failure during data transmission from DN to BS, then the redundant server which has the backup will transmit the data to BS. The proposed algorithm consumes less energy and the number of active nodes is higher than the existing system. This improves and prolongs the lifetime of the network and energy consumption. The energy drain due to malicious attacks and security mechanisms against malicious attacks are not covered as it is very rare in the wireless sensor networks. In future security algorithm like intrusion detection algorithm can be implemented and secure the DN from the malicious attacks.

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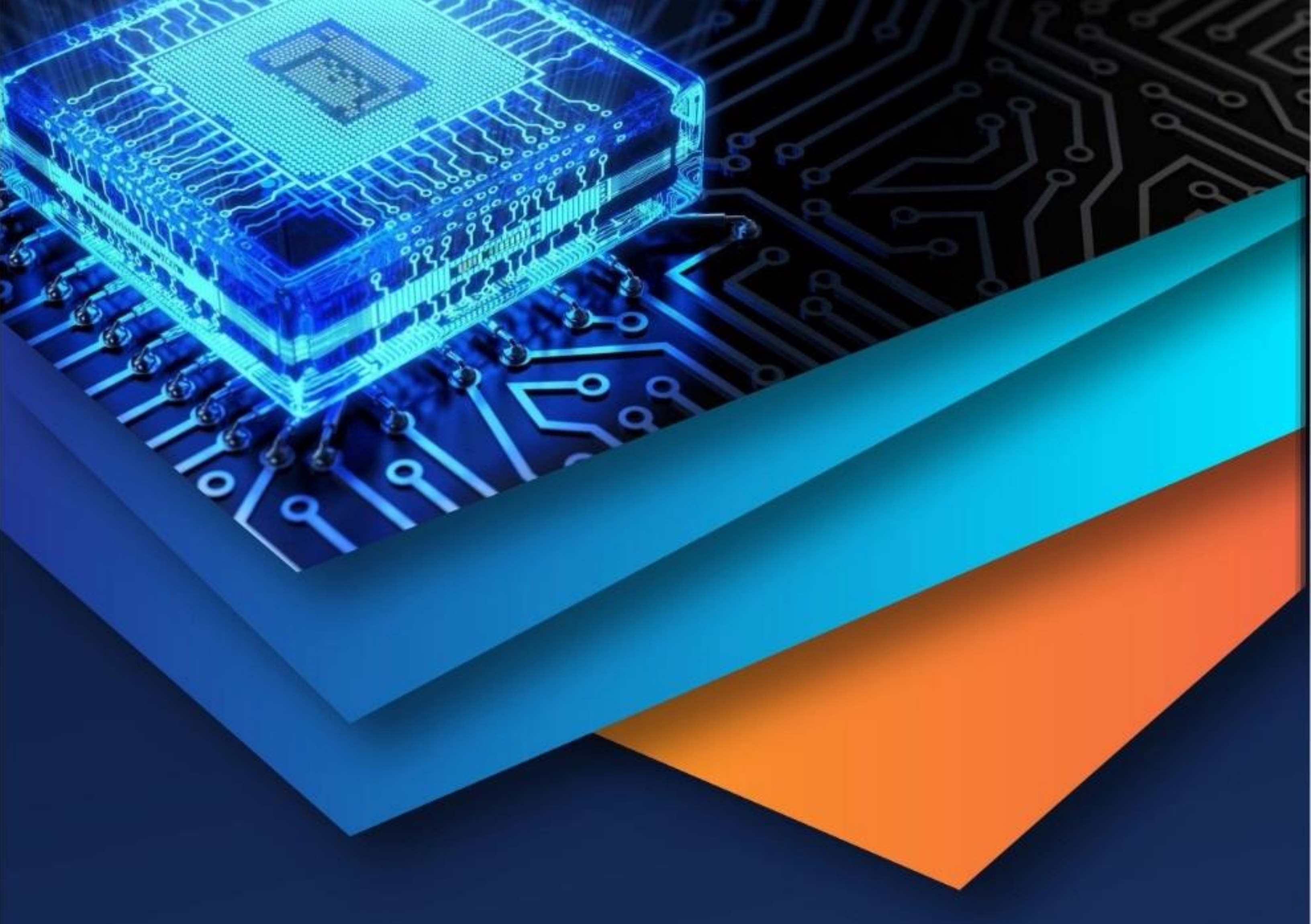

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