WDMRR: Watch Dog Monitored Ring Routing Protocol to Improve QoS in Wireless Sensor Networks

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***Abstract*: Wireless Sensor Networks (WSNs) consists of randomly deployed sensing nodes that cooperatively monitor the surrounding environment. The routed information is monitored using Watch Dog Monitored Ring Routing (WDMRR) protocol. The WDMRR protocol includes formation of ring structure and monitoring by making use of watchdog nodes. Simulation results showed that WDMRR protocol improves the throughput, minimizes the delay compared to the centred sink structure by adapting efficient routing path and mobile sink. The WDMRR protocol shows 13% improvement over Ring Routing with respect to Network Lifetime.**

***Index Terms*: Delay, Energy Efficient, QoS, Security, Throughput, Wireless Sensor Networks.**

I. INTRODUCTION

Sensor nodes are spatially distributed which can sense, process and forward the diverse kind of information to other nodes for further transmission. The operation of WSNs includes battery operated sensor nodes which is expected to lower its energy level during its transmission. Today's, WSNs applications demand delay sensitive uninterrupted communication. QoS (Quality of Service) in network is the measure of various capabilities of a system to deliver a guaranteed level of service without interruption to different applications [1]. Transmission of time-critical data can be transmitted using QoS-based energy-efficient routing protocols. In a given network, the network efficiency can be increased by prioritizing routing paths using QoS-based routing protocols. Network lifetime can be increased by using a mobile sink that helps in consuming same energy by the remaining nodes. This mobile sink achieves load balancing with respect to energy[2][3][4]. During transmission of information in WSNs should provide guaranteed QoS requirement and energy efficient service selection. Different mechanisms have to be developed that are capable of satisfying QoS requirements such that high energy is maintained at the same time [5].

Sensor Nodes in Wireless Sensor Networks are supervised by Watchdog node which can evaluate various parameters and avoids different attacks. These Watchdogs are responsible to detect when it finds malicious nodes in the network [6]. There are many sensor networks that are developed to detect and collect information related to activities of enemy, explosions and other activities [7].

A. Motivation

Energy conservation becomes important monitoring entity which requires efficient routing paths for transmission. Thus, efficient routing protocols like ring routing helps to stabilise the energy burden on the network. Using static sink node can drain networks energy especially nodes which lie close to sink node, so mobile sink nodes can be used in the network to save maximum energy.

B. Contribution

The real-time applications demand QoS based data transmission within the network. Using mobile sink, network parameters like network lifetime, throughput and delay can be improved to large extent. Watchdog nodes defined in our work avoids transmission to malicious nodes and provides secured data transmission.

C. Organisation

The paper is organized as follows: In Section II, the literature review on routing protocols is provided. In Section III Background of the work carried out is given. In Section IV Problem statement, Objectives and Assumptions are discussed. System setup, Mathematical model and illustration are shown in Section V. The Simulation results and performance evaluation of Watchdog Monitored Ring Routing and various QoS parameters are presented in Section VI. The paper is concluded in Section VII.

II. LITERATURE REVIEW

The raise in the requirement of WSNs in various applications requires reliable security mechanisms and energy efficiency. Also, it should not compromise with the QoS parameters of the network with the increase in the size of the network.

Ben et al., [8] addresses a new transportation method called LBDD (Line-Based Data Dissemination) in Wireless Sensor Networks with mobile sinks. This protocol compares and analyses various approaches for data dissemination in WSNs, by using realistic simulations and analyses, LBDD performance is greater than other many existing methods when considering both event and query-based situations. The working operation of LBDD consists of the following steps: (i) *Dissemination:* During generation of data by any of the regular sensors node, it forwards the data to the nearest inline node and (ii) *Collection:* In order to get back a specific data, a sink should send a query towards the line in a perpendicular path. First, the inline-node receives this query packet and it propagates along the line in both directions until it reaches the lined up -node storing the data. The data is transmitted directly to the sink and reaches the destination. Indicating the placement of mobile sink becomes a difficult task.

Xufei et al., [9] proposed Energy-Efficient Opportunistic Routing concept in WSNs considering both fixed transmission power and dynamically adjustable transmission power . In this routing, the nodes that can hear the transmission and which lie close to the sink node are allowed to participate in further transmission of packets. Priorities are set based on the node list generated by node forwarder. A node can discard the packet if the priority set is less compared to other higher priority node.

Dali et al., [10] proposed an energy-efficient clustering approach for Wireless Sensor Networks. Nodes that carry heavy traffic loads are expected to deplete their energy leads to disruption in network services. Cluster Heads (CH) which are created in the network have a heavy responsibility of gathering and transferring information. To balance this heavy traffic load in the network and the energy consumption a distributed clustering algorithm is proposed known as Energy-efficient Clustering (EC) which selects cluster sizes based on its distance to data sink without compromising in its node lifetime. Further, an energy-efficient protocol suitable for multihop data collection is proposed which evaluates the effectiveness of EC and calculates the end-to-end energy consumption.

Zhaoming et al., [11] proposed the dependency of the optimal hop distance (OHD) on the lifetime of a sensor node. The link quality of service (QoS) requirements plays a vital role. Here, OHD is calculated as the distance between the node and its next reachable nodes position to the sink. In this work, an algorithm is designed to improve Network Lifetime for energy-efficient path selection and link-rate allocation based on hop distance. The results obtained shows that the lifetime can be improved when hop distance value is comparatively less. The EERS-LRA-OHDS algorithm is also proposed in this work to further increase the NL.

Sangeeta et al., [12] described the analysis of equalized and double cluster head selection schemes in WSNs. Two hierarchical protocols namely ECHERP (Equalized Cluster Head Election Routing Protocol) and PDCH (PEGASIS with Double Cluster head) are proposed. The scheme of ECHERP and PDCH protocols is presented based on few of the QoS parameters like Delay, Throughput, Packet Drop Ratio and Energy consumption. Multiple cluster formation in this protocol becomes tedious while considering a large network.

Yun et al., [13] proposed a node self-localization scheme using a movable anchor nodes in underwater acoustic sensor networks [UASN] based on compressive sensing. The underwater monitoring area is divided into different units and the energy calculation is done for all the unknown nodes with respect to movable anchor nodes. The difficulty in moving path is studied and the mobile node path based on the Random Way Point and the layered scan representation is proposed. The analysis show that the proposed algorithm can be used to the node localization issues in UASNs. Transformation of UASNs anchor node localization issues into a dimensionality vector reformation problem is proposed.

Habib et al., [14] proposed Energy-Efficient scheme for Reliable Routing in WSNs. In current multipath routing techniques energy cost is more significant. Multi-hop data transmission of WSNs demands trustworthy links for end-to-end data delivery. To improve the performance of the network in terms of multi-constraints QoS parameter, a distributed learning automaton (DLA) based algorithm is proposed. The algorithm considers the benefit of DLA to find the best possible nodes to save the residual energies of other nodes in achieving the QoS metrics. While routing the information, end-to-end consistency and delay is taken into consideration for path selection. There is considerable amount of delay involved when we consider the network operation for short time.

Yuan et al., [15] proposed an algorithm that adapts overlapping clustering method for dynamic constant monitoring in the network. In this method, 2-logical-coverage overlapping grouping structure is proposed and nodes which lie together can be into single cluster for data combination. The cluster movement function can be operated without altering the overlapping formation among grouped nodes. Hybrid data reporting approach is addressed to reduce energy usage based on the QoS requirements. This method is suitable for dynamically monitoring application.

III. BACKGROUND WORK

Can et al., [16] proposed Ring Routing protocol adopting movable sink in the network. Here, a ring formation is done to get information of movable sink position. The ring structure sends the updated sink location to the normal nodes via the selected Anchor nodes along its path. When the Anchor nodes (AN) loses the contact with the sink, mobile sink selects new AN and communicates to the old AN. Sensor node updates its position using neighbor discovery protocol. The nodes in the ring consume more energy compared to the remaining nodes. To retain its life, ring nodes change their roles from time to time. Ring Routing is very reliable and efficiently delivers the protocol. This Ring Routing Protocol is used to overcome the hotspot problem. However, choosing AN becomes a tedious task and having a trustworthy ring node becomes a major issue when adopting a secured transmission.

IV. PROBLEM DEFINITION

A. Problem Statement

Given a Wireless Sensor Networks, the sensor nodes are deployed in different areas randomly that are capable of transferring information from every node to the sink. Due to the uneven distribution of nodes large amount of energy is consumed by the sink node during information exchange. The main concern of WSNs is to reduce energy usage for transferring collected information from source nodes to sink node since Wireless Sensor Networks are resource constrained.

B. Objectives

The main objectives of the work are:

- To design an algorithm to achieve Energy Efficiency and to increase the Network Lifetime
- To evaluate the QoS metric for efficient secured data transmission.

C. Assumptions

- WSNs are deployed with static sensor nodes and a movable sink.
- Ring nodes in WDMRR consume more energy than other regular nodes.
- Threshold monitoring energy level is set half of the initial energy considered.

V.SYSTEM AND MATHEMATICAL MODEL

The proposed WDMRR System consists of five Stages (A) Network Formation (B) Ring Construction and Routing (C) Event Generation (D) WDMRR (E) Data Transmission as shown in the Figure 1.

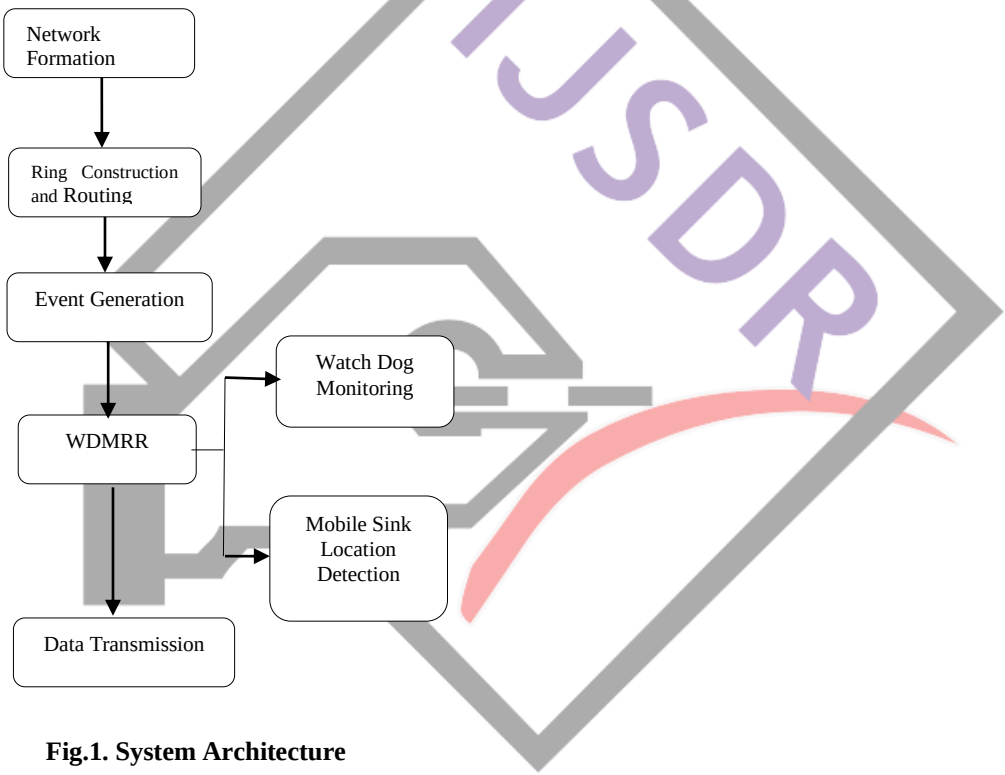

Fig.1. System Architecture

A. Network Formation:

Network formation of this sensor network consists of 50 to 300 nodes (n) in an area of 1000*1000 m^2. These nodes are independently deployed and network centre node (*C*) is chosen. Distance to all sensor nodes from *C* is calculated [17]. The performance of WDMRR is evaluated using NS2.34 network simulation platform. The sensor nodes are distributed randomly in a network. We have assumed that, each source node generates Constant Bit Rate or Transmission Control Protocol and flows at different speed depending on the size of the packets. The packet size may be 128 bytes, 256 bytes, or 512 bytes. The performance of WDMRR protocol is evaluated based on the following simulation parameters: Delay, Throughput, Network Lifetime, Number of Death Nodes.

B. Ring Construction and Routing

The high-tier nodes in the network are always subjected to hotspot problems and replacement of these nodes becomes very important task in WSNs operation. In this paper, we propose a hierarchical routing protocol called Watchdog Monitored Ring Routing Protocol for WSNs to monitor hotspot issues in the network. A mobile sink and randomly deployed stationary sensor nodes are considered. Ring Routing is adopted that uses virtual ring structure for communication from source node to sink node. This reduces the overhead in the network.

1)Ring Routing

Some key features of Ring routing are as follows:

- It is a routing protocol adapted for large-scale WSNs consisting of stationary sensor nodes and a mobile sink.
- A virtual ring structure is established with the nodes which accepts information from the source and in turn delivers the information to the mobile sink [16].
- The ring structure can be defined for various ring radius from the centre node and the normal nodes change their roles and reduces the energy constraint issues.
- The source node selects the watchdog node along its path and these watchdog node relays sensor data to the ring [10].
- In Ring routing there is minimal amount of broadcasting among the ring nodes and is used for sensor networks with low-power designed MAC protocol [16].
- Ring routing can be adopted for both event-driven and periodic data reporting applications.

2)Ring Construction

The ring with a particular radius is defined and the closed strips of nodes that fall in this region are called the ring nodes.

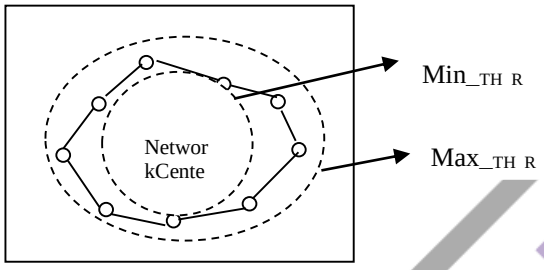

Fig. 2. When Sink is Outside the Ring

Figure 2 shows the ring construction that is done to define ring nodes. There is a pre-determined network centre from which the radius is defined known as ring radius. The shape of the ring might not be exact circle but a closed loop can be obtained. There is certain threshold ring radius that is set to determine ring node candidates. These ring nodes can be easily accessible by the normal nodes and each normal node should be aware of its location from the ring nodes.

- **Watchdog Monitored Ring Routing Model**

Let, number of nodes be,

$$N_i = \{n_1, n_2, n_3, n_4 \ldots n_i\} \quad (1)$$

where, *i* is the maximum number of sensor nodes considered.
C= Network center
R = Network radius
$\mathbf{R_R}$ = Ring Radius
$\mathbf{A_S}$ = Search area

$\mathbf{A_S}$ is defined with respect to minimum and maximum threshold radius as,

$$\mathbf{A_S = Area\ of\ Min_{TH\_R} - Area\ of\ Max_{TH\_R}} \quad (2)$$

where, $\mathbf{Min_{TH\_R} = R_R - Threshold\ Ring\ Radius}$
$\mathbf{Max_{TH\_R} = R_R + Threshold\ Ring\ Radius}$

Ring nodes are defined from the set of given nodes and which are present in the search area.

$$\mathbf{N_R \subseteq N_i}, \quad (3)$$

where, N_R = nodes which lie in the search area A_s and is defined as Ring Nodes.

The probability of ring formation is approximately 0.99[16],

$$\mathbf{P(R_F) = 0.99} \quad (4)$$

where, $P(R_F)$ = probability of Ring formation function.

Watchdog Monitoring Ring Routing node is defined from the remaining set of nodes other than the ring nodes and is defined as,

$$N_{WDMRR} \subset \{ N_i - N_R \} \quad (5)$$

VI.IMPLEMENTATION AND ALGORITHM

During implementation, 100 nodes are randomly deployed as defined in equation (1) over an area of size 1000m x 1000 m and the ring radius is set to 50m. The threshold value is set to different values, when the ring is not formed after m number of trials and the procedure is repeated with an area defined in equation (2) and equation (3). An example for ring construction is shown in the Figure 2. The probability of ring construction depends on equation (4). Initially, same type of nodes are used in the ring construction as in [16]. Watchdog nodes are also defined for efficient path computation using equation (5).

(i) Ring Node Selection

There are three types of sensor nodes: ring node, normal node, watchdog node. Ring nodes [16] are established virtually and the information is communicated through these nodes. Watchdog node is also defined in between the source and appropriate ring node that is capable of monitoring the QoS parameters like throughput, network lifetime, delay, security and energy [10]. The remaining nodes are called as normal nodes.

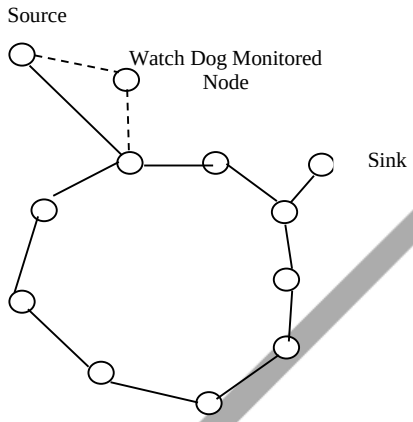

Fig 3. When Sink is Outside the Ring

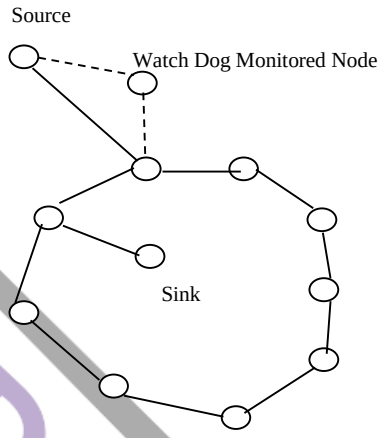

Fig 4. When Sink is inside the Ring

Sink is considered as mobile and can be placed either inside or outside the ring as shown in Figure 3 and Figure 4. The shortest distance between the mobile sink and the obtained ring structure is computed first. Then, one of the nodes is selected from that particular ring so as to establish the data transmission [19].

(ii) Event Generation

Whenever an event is generated, data is transmitted from source to sink. Before, data transmission to sink node, the nodes should be validated and secure transmission path should be provided [20]. Threshold energy set for the ring node and node ID are taken as criteria for validation when an event has occurred like fire detection, entry of intruder, etc.

(iii) Data Transmission

After validation of the few QoS parameters, efficient ring node is selected after validation [24][25][26]. Watchdog Monitoring Ring Routing Protocol improves the Network Efficiency and it validates by checking its energy level and node ID. Thus, providing secure transmission which can be achieved by using ring nodes as the intermediate nodes. Watchdog nodes are also defined which selects efficient ring node for data transmission. Selected ring node broadcasts its data to all its ring node candidates [21][22][23].This ring node broadcasts the information to all other ring nodes about the event generation. The ring node close to the sink is selected for further data transmission by computing shortest path from ring to the sink [27][28]. First the position of mobile sink from all ring node candidates must be established. To compute the path from ring node to mobile sink shortest path algorithm is adopted which effectively calculates the shortest distance from ring to the sink

Illustration

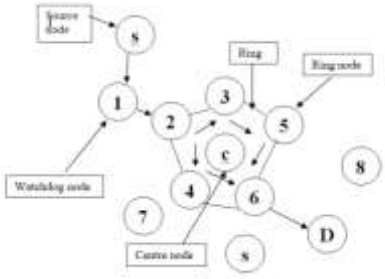

Fig 5. Example of WDMRR

Figure 5 shows the deployment of eleven sensor nodes in a random fashion. Node *C* is considered as the centre of the network. Here, source node *S* senses and transfers the information to the destination node *D*. Let us define ring radius as 50 m from network centre node *C*. All nodes which lie in this radius considering the threshold value (2.5J) are called as ring nodes. In the example nodes 3, 2, 4, 6, 5 are considered to be the ring nodes. In between the source and the ring node watchdog node is defined if its energy is greater than the threshold energy set. Node 1 is chosen as watchdog node. This node selects one of the ring node based on the shortest path and maximum available energy.

During transmission of information, source node *S* transfers its information to node 2 after verifying its energy level and its position from source node by watchdog node 1. After receiving the information node 2 in turn transfers the information to all other ring nodes and sink node *D* is considered mobile. Using shortest distance one of the ring node close to the destination is selected. In this example, node 6 is close sink node *D* and it transfers all information to node *D*. Thus, information from source *S* to sink *D* reaches via efficient routing path and is verified by its watchdog node.

(iv) WDMRR Algorithm

Watchdog Monitored Ring Routing Algorithm consists of selection of watchdog nodes along its path from source to ring which monitors the transmission from source to sink via the constructed ring structure. In this watchdog monitoring system, number of sensor nodes is selected as watchdogs based on the events generated to detect malicious nodes in a WSNs. Watchdog nodes are mainly dedicated for sensing operations and monitoring tasks. The watchdog nodes are selected based on the retained energy of the nodes and its position. It is one of the realistic methods since sensor nodes can easily communicate to sink making use of proposed ring structure and achieves quality of service.Maintaining quality of service is important during transmission. On successful transmission of data from the source to the ring nodes that are selected after validation of QoS parameters like residual energy, distance, security and the packets are successfully delivered by watchdog nodes. A watchdog node detects the trusted ring nodes based on the node ID. QoS parameters like maintaining maximum energy, nodes lifespan, Security can be improved effectively by using watchdog. The WDMRR Algorithm with steps involved is shown in Algorithm 1.

ALGORITHM 1: WDMRR Algorithm

Input: N – Number of sensor nodes in the network, j=0
Output: Data transmission via Secure Shortest Path between source and destination
Begin

Step 1: Node creation
```
for (i=0; i<n; i++) do
    set n[i] [new node]
End for
```
Step 2: Set centroid node
```
set xpos 500
set ypos 500
$n[i] set x_ xpos
$n[i] set y_ xpos
```
Step 3: Event Generation

Step 4: Ring_Node_Selection
```
for (i=0; i<n; i++) do
    if n[i]! =1 then
        dist[i]=sqrt((pow(x[n[i]]-x[n[1]]),2)+(pow(y[n[i]]-y[n[1]]),2)
    end if
end for
for (i=0; i<n; i++) do
    if dist[n[i]]>70 & dist[n[i]]<150 then
        ring_node[j]=n[i]
        j++
    end if
end for
```
Step 5: Watchdog_Node_Selection
```
for (i=0; i<n; i++) do
    if node lies between snode and near byring_node & energy[i] > max
        wd_node=i
        max = energy[i]
    end if
end for
```
Step 6: Path_Computation
```
for (i=0; i<n; i++) do
    for (j=0; j<n; j++) do
        if energy[ring_node[i]]  >ring_node[j] &dist[ring_node[i]] <dist[ring_node[j]]
        &wd_node_monitor is true then
        next_node=ring_node[i]
        end if
    end for
end for
for (i=0; i<n; i++) do
    for (j=0; j<n; j++) do
        if node[i] lies between ring node and mobile sink then
        intermediate_node =node[i]
        end if
     end for
end for
```
Step 7: Data Transmitted

VII.SIMULATION AND PERFORMANCE EVALUATION

*A.*Simulation Setup

WDMRR protocol is evaluated using NS2 simulator. The WDMRR protocol is compared with Ring Routing protocol. Our simulation is setup for different set of nodes in the range 50 to 300 nodes over the area 1000*1000m and simulation parameters are shown in Table 1.

Table 1: Simulation Parameters

Parameter	Value
Number of Nodes	Varing from 50 to 300.
Simulation Topology	1000*1000m
Traffic	CBR
Transmission Range	40m
Initial Energy	5J
Data Packet Size	64bits
Energy Consumption during Transmission	0.016J
Energy Consumption during Receive	0.018J
Energy Consumption during Idle	0.0005J
Simulation Time	20sec

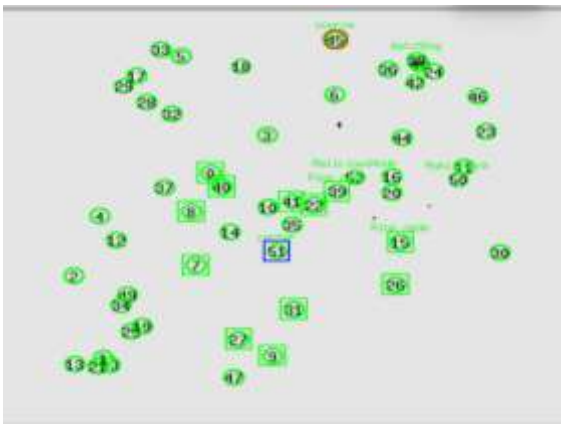

Fig 6: Randomly Deployed Sensor Nodes

B Performance Metric

- *Delay*: It is defined as the time taken by the network to deliver the packets from source to the given sink node.
- *Network Lifetime*: It is defined as the overall time period of the network which provides connectivity for data transmission.
- *Throughput*: It is the ratio of number of packets delivered to the total number of packets sent from the source.
- *Number of Node Death*: It is the number of nodes which die due to depletion of energy during network operation.

C. Performance Analysis

The performance analysis of various QoS parameters like Delay, Network Lifetime, Network Throughput, and Number of Dead Nodes is done in this section with respect to WDMRR and Ring Routing.

TABLE 2. DELAY

Number of Nodes	Delay(in msec)	
	WDMRR	Ring Routing
50	550	500
100	600	500
150	625	522
200	623	640
250	623	780
300	626	821

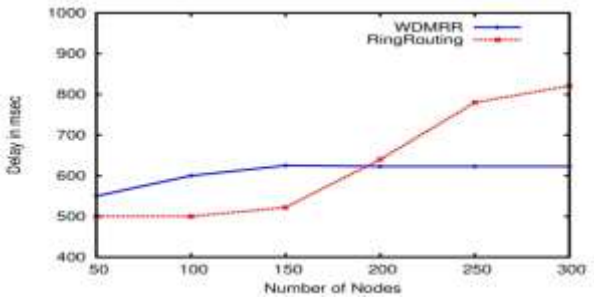

Fig. 7 Comparison of Delay in msec for varying number of nodes

TABLE 3. NETWORK LIFETIME

Simulation Time(ms)	Network Lifetime(in mJ)	
	WDMRR	Ring Routing
200	4980.718	4956.789
400	4492.016	4114.678
600	3811.647	3239.432
800	3795.602	2985.612
1000	3644.433	1811.223

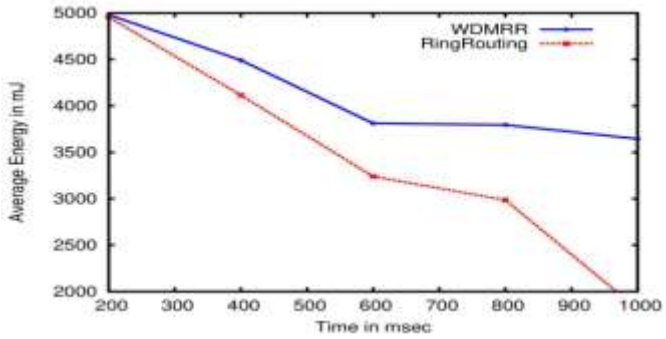

Fig.8 Comparative Performance of Network Lifetime

Figure 7 shows the graph of delay in the network for WDMRR which is compared with Ring Routing. Simulation Results shows that delay in the network is reduced for higher number of nodes by adopting WDMRR protocol. In Table 2 the delay involved for various simulation times is tabulated for both Ring Routing and WDMRR for different number of nodes. The delay aware applications show better performance by adopting WDMRR protocol when compared with Ring Routing. As the number of nodes increases, delay in WDMRR protocol decreases as compared with Ring Routing Protocols and is illustrated in Figure 7.
WDMRR protocol extends the Network Lifetime compared with Ring Routing. The movable sink addressed in the network collects the packets information and achieves load balancing in the network. Hence, the total quantity of node's energy required for packet communication between source to sink decreases. The overall improvement for the above simulation parameters shows 13% improvement over Ring Routing in terms of Network Lifetime. Graph of Average Energy in milli joules in the network for different run time is plotted as shown in the Figure 8.

TABLE 4. NETWORK THROUGHPUT

Number of Nodes	Network Throughput(in Kbps)	
	WDMRR	Ring Routing
50	91.32564	83.326
100	160.634	112.336
200	151.266	100.635

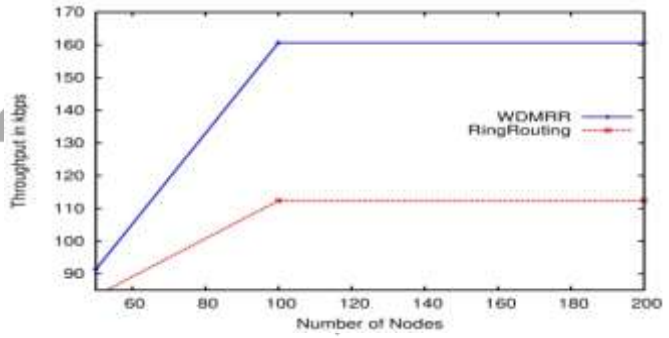

Fig.9 Comparison of Network Throughput

Network is scaled for 50, 100, 200, 300 nodes and network throughput is calculated for WDMRR and Ring Routing protocol. Network throughput is a vital parameter which is expected to provide better performance when congestion or delay in the network reduces and when malicious nodes are mitigated. In WDMRR, watch dog monitors the data transmission path and mitigates the data transmission to malicious node. Therefore, WDMRR increases throughput compared to Ring Routing shown in Figure 9. As the simulation process begins each of the sensor nodes starts depleting their energy when they start involving in routing of information. There are chances of sensor nodes to completely drain out their energy and these nodes are called as Dead nodes. Table 5 shows number of dead nodes for different simulation time and comparison is done for WDMRR and Ring Routing protocol.

TABLE 5 NUMBER OF DEATH NODES

Number of Nodes Death	Simulation Time(in msec)	
	WDMRR	Ring Routing
1	402.131	380.321
5	420.891	432.769
10	484.678	486.562
15	500.132	495.213
20	510.614	510.782
25	520.445	525.265
30	522.231	530.223
35	560.435	535.273
40	612.879	560.382
45	650.425	600.349
50	660.567	625.328

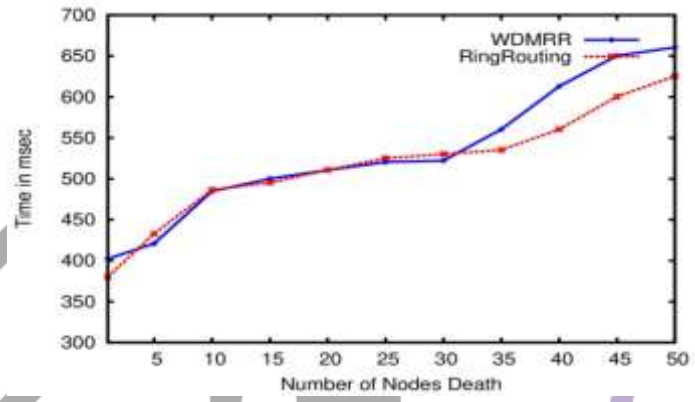

Fig.10.Number of Nodes Death

Figure 10 shows number of dead nodes with respect to time for both WDMRR and Ring Routing. Number of nodes death is calculated for different simulation time. Number of nodes death is less when compared with Ring Routing.

VIII. CONCLUSIONS

The challenging task in Wireless Sensor Networks is to improve Quality of Service (QoS). In order to improve the QoS, it is necessary to utilize uniform energy in the network, mitigate packet loss, congestion, latency, etc. The proposed algorithm focuses on efficient energy utilization in the network and improving network throughput thus minimizing packet loss. Mobile Sink in the WDMRR randomly moves to all locations and collects packet, the nodes resides in the search area, maintains the mobile sink location in their routing table. Watchdog monitors the entire network and it mitigates packet transmission to malicious nodes. Thus, it maximizes throughput, minimizes delay and shows 13% improvement over Ring Routing with respect to Network Lifetime.

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