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MPIGA – Multipath Selection Using Improved Genetic Algorithm

S K Satyanarayana[1], L Nirmala Devi[2], A Nageswar Rao[3]

[1]Assistant Professor, ECE Department, Sreenidhi Institute of Science and Technology, Hyderabad, India-501301, satyanarayanask129@gmail.com

[2]Professor, ECE Department, University College of Engineering, Osmania University, Hyderabad, India-500017

[3]Research scholar, ECE Department, UCE, Osmania University, Hyderabad, India-500017

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Abstract

The Wireless Multimedia Networks (WMNs) have developed due to the extensive applications of wireless devices and increasing availability of lower cost hardware. The WMNs are used to transmit the multimedia content like audio and video streaming and they can be deployed within a lower budget. These networks can also be used in real-time data applications that demand energy-efficient management and awareness of Quality of Service (QoS). The energy resources are limited in the wireless devices that lead to the significant threats on the QoS for WMNs. An energy-efficient routing technique is needed to handle the dynamic topology of WMN that includes a vital resource as energy. The energy-efficient routing method was proposed in this work for the purpose of data communication based on a cluster head selection from each cluster in addition to the multipath route selection to reduce the network overhead and energy consumption. The cluster heads for each cluster are selected based on Node Coverage & average residual energy parameters. In this work, the proposed energy efficient routing algorithm uses improved genetic algorithm (IGA)based on a cost function for dynamic selection of the best path. The proposed cost function uses link lifetime &average link delay parameters to estimate the link cost. The proposed algorithm's performance compared with other previous routing methods based on extensive simulation analysis. The results showed that the proposed method achieves better performance over three other routing techniques.

Keywords: Routing Overhead, Energy Consumption, Average Residual Energy, Genetic Algorithm, Multipath Routing, WMNs.

1. Introduction

The multimedia application needs are rapidly growing with the increased development of information technology that means the data sensing, exchanging, and processing are essential aspects. The WMN is a distributed network that includes a group of multimedia sensor nodes to communicate and compute the data [1]. Because of constrained real-time service and resource requirements, the challenges are posed for energy consumption and Quality of Service (QoS) in WMNs than the traditional wireless networks [2]. The research on various routing methods and their performances are more important as a routing protocol plays a key role in data delivery and communication.

Due to in-network communications like data transmission and reception, the higher percentage of energy up to 70% has been consumed while remaining 30% of energy consumes for in-node operations like local data processing in WMNs [3]. The clustering method is an efficient strategy for energy consumption of WMNs in data aggregation, where the network categorizes into 'n' number of clusters. The nodes' collaboration and network energy consumption should be simplified based on clustering that restricts the spatial redundant data transmission [4].

Based on a structure of network, protocol operation, and how routing data collect and maintain, the routing protocols can be made into classification in wireless networks. The multimedia applications include various QoS requirements, such as energy consumption, availability, jitter, throughput, and bounded latency or delay [5]. Many of these routing protocols don't provide great performance under QoS-constrained WMNs as the energy-efficiency is the main objective for routing protocols. The classification of routing techniques is performed for WMNs based on adopted algorithms, types of data delivery model, handled data types, and the used approach of hole-bypassing.

The optimization of one of the desired objectives is achieved in most of the routing methods, while others assume as constraints [6]. Several optimal solutions can be provided using a metaheuristic approach based on a multi-objective optimization algorithm in certain applications. Instead, the single design objective algorithms focus on a single solution or objective and ignore other related objectives. In the multi-objective algorithms, a set of optimal solutions could be produced, known as the Pareto solutions for a multi-objective problem based on the consideration of objectives simultaneously. In networks, finding of optimal routes is also known as a NP-complete problem for multiple objectives. In WMNs, the designing of a routing protocol is exacerbated further due to the requirements and characteristics of multimedia applications, including bounded delay and higher bandwidth demand [7]. It's a challenge to design a robust routing method for WMNs even though different approaches were proposed.

It's required to develop a routing technique that chooses an effective routing path between sensor nodes and SINK for addressing the above-mentioned issue and reduce the network overheads. The routing methods based on a single path approach are not able to provide higher data communication as they tend to sensitive towards the multi-hop path with a limited capacity and highly dynamic nature of wireless links for WMNs. The resources like bandwidth, memory, and computation energy are constrained in the sensor nodes that could be influenced the WMNs' performance levels profoundly in terms of network congestion. The routing protocols, such as multi-hop routing, multipath routing, and clustering are introduced with different approaches to enhance the network efficiency. Many routing methods are focused on maximized energy efficiency most often and they consider routing overhead issues and efficient selection of a routing path rarely. The performance of WMNs and their network lifetime can be affected without using efficient routing of multimedia data.

In this work, an energy-efficient routing technique was proposed to minimize the energy consumption and routing overhead of WMNs based on clusters' formation, reliable selection of a cluster head, and efficient multipath route to make data communication. The cost function is used to choose the best path dynamic by using a proposed energy-efficient routing method that uses improved genetic algorithm (IGA). The parameters of link lifetime and average link delay are used in the proposed cost function to determine the cost of a link. A clustering algorithm is utilized in a proposed approach to partition the nodes of a network into clusters dynamically. The cluster head is chosen from each cluster based on an efficient cluster head selection algorithm. To determine a path efficiently for data transmission, an inter-cluster multipath routing develops based on an IGA optimization technique. The best possible routing path can be selected as a proposed routing technique that utilized the GA-based meta-heuristic optimization that can handle the WMNs with dynamic topologies.

Our Contributions:

Our contributions are summarized as follows:

- The proposed CH selection algorithm uses node coverage (NC) & Average Residual energy (ARE) parameters that ensures the selected CHs have more neighbors in their coverage circle. It reduces the energy required for member nodes to reach the CH.
- The proposed relay node selection algorithm in IGA selects multiple paths based on Lifetime of the link & average delay parameters.
- The efficient routing path can be chosen using a proposed method as it can able to handle the dynamic network topologies of WMNs.

2. Literature Survey

Kapusta et al., [8] proposed an additively homomorphic encryption and fragmentation scheme (AHEF) for data aggregation process inside unattended WSNs. The evaluation parameters were considered as number of fragments, storage cost, number of rounds, and transmission cost. By comparing with state-of-the-art methods, the transmission cost and storage were very low. Additionally, the proposed technique resulted in the failure of designing and implementing IoT based architectures.

Durdi et al., [9] discussed a selective encryption method to achieve the secure data transmission over WSNs. In this approach, the performance metrics are used as compression rate and number of frames. The proposed approach shows a higher flexibility and robustness, but the computational complexity is also higher based on the experimental analyses.

Wang et al., [10] proposed an energy-efficient distributed adaptive cooperative routing method using the reinforcement for WMSNs. The improvement of QoS and reduced energy consumption are focused in the model. However, the better performance achieves using a designed model in terms of power consumption and QoS than the other existing routing protocols.

Aswale et al., [11] proposed a routing protocol using the algorithm of triangle link quality and minimum interpath interference-based geographic multipath routing (TIGMR) to minimize the energy consumption for data communication of multimedia files.

Ahmed [12] proposed a real-time method based on adaptive traffic shaping for data communication of multimedia files for WMSNs. The proposed technique shows the improved results in terms of reduced bit error rate, better QoS, minimized end-to-end delay, and smooth routing.

Magaia and Horta [13] designed a multi-objective routing method to enhance the improved performance based on QoS and end-to-end delay for WMSNs during the multimedia files' data communication among sensor nodes.

Cobo et al., [14] proposed an ant-based routing technique to achieve the data communication for multimedia files for WMSNs. A hierarchical network structure establishes using an AntSensNet protocol to perform the multimedia communication for improved QoS. The designed model is provide an improved convergence and QoS in WMSNs than the other existing models based on the analysis of analytical results.

Kandris et al., [15] proposed an energy-efficient and perceived QoS-aware video file routing technique for WMSNs. It was designed to carry out the energy-efficient hierarchical routing of video file and an intelligence method for video packet scheduling in a network. The least significant packets' transmission was denied using an algorithm that enhances the network lifetime.

S. Ambareesh and A. Neela Madheswari [16] outlined the minimization of four objectives, such as expected transmission cost, memory, delay, and packet loss to generate an optimal solution set. The simulation results were presented in two scenarios, including the optimization test functions and a network grid. The best optimal routing path achieves using a proposed approach of HDRSS than the other existing methods.

Soundarajan Ramesh et al., [17] proposed a novel protocol of optimized and compressed sensing routing protocol (OCSRP) to overcome the challenges like QoS and resource restrictions. Based on a quantitative analysis, the results were proved that the proposed method achieves higher QoS with high security level compared to the exiting LEACH algorithms.

3. System Model

3.1 Network Model

As shown in below Figure 1, WMNs consist of n multimedia wireless nodes that are powered with battery. A weighted undirected graph G = (V, L, W) is utilized for a network representation, where V is a vertex set and represented wireless nodes V = {v1, v2, v3,…vn} while W = {w1, w2, w3, ….wn} indicate a set of links' weights and L = {l1, l2, ….ln} represent a set of all bi-directional links. A power supply unit, a transceiver unit for data transmission and reception, and a processing unit for data processing are contained in each node $v_i \in V$. However, the random deployment of sensor nodes is performed over a network area.

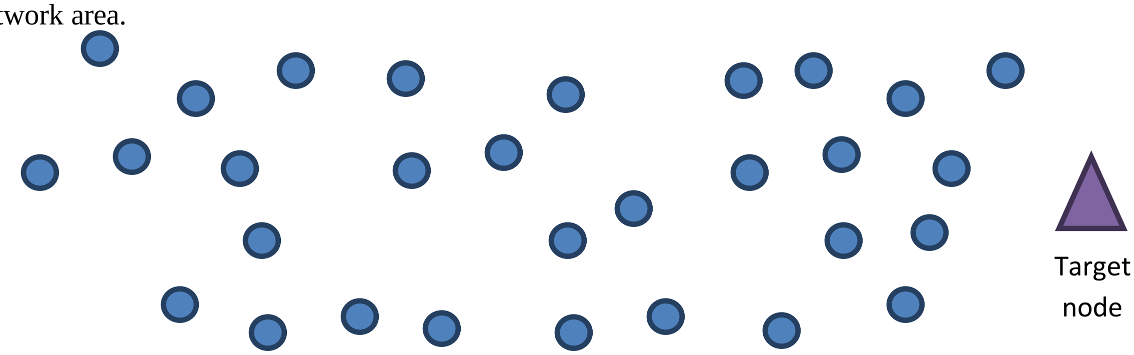

Figure 1. A Wireless Multimedia Networks

Every multimedia node includes a communication radius with R, a set of neighboring nodes, and a unique ID. The wireless nodes can able to determine the distance of their neighboring nodes even though they don't know their location. A bidirectional wireless links is existed, i.e., $l_{ij} \in$ L between two sensor nodes $v_i \in$ V and $v_j \in$ V. During the data transmission from sensor node v_i and v_j, the energy consumes for a weight W_{ij} and a given link $l_{ij} \in$ L.

3.2 Energy Model

In a radio energy dissipation model, the radio electronics and power amplifiers operated by the transmitting energy. The served energy by using receiver is the energy on radio electronics. If a distance between sender and receiver is'd', then the energy is consumed as 'd^2' in a single path fading model, whereas in multi-path fading model, it is 'd^4'. In case of k-bit packets transmission, the energy consumption is Es, which represented as follows:

$$E_s = \begin{cases} k * \left(E_{ec} + E_{frs} * d^2\right); & d \le d_0 \\ k * \left(E_{ec} + E_{mpf} * d^4\right); & d \ge d_0 \end{cases}$$

Where, Empf and Efrs are requisite energies to transmit the data bits through a multipath fading channel in the free space, Eec is the energy that requires for running an electronic circuit of SN; Empf*d^4 or Efrs*d^4 represent the distance between a sender and receiver for identification of multi-path fading or free space model's amplifier energy; d refers to the distance between a sender and receiver; and d_{thresh} refers to the threshold distance, which is given by:

$$d_{threh} = \sqrt{\frac{E_{frs}}{E_{mpf}}}$$

To receive k-bits of data packets, the energy consumed that is given using a below equation:

$$E_{rec} = k * E_{ec}$$

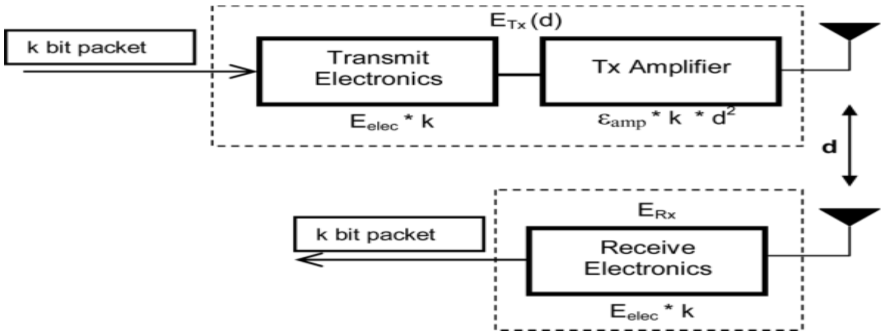

Figure 2. Energy Usage Model

3.3 Proposed Method

This section describes the proposed energy efficient routing algorithm, cluster-head selection and formation of a cluster in addition to the selection of multipath route for data communication. The cluster heads for each clusters are selected based on Node Coverage & average residual energy parameters. In this work, the proposed energy efficient routing algorithm uses improve genetic algorithm (IGA) to choose the path efficiently using a cost function. The proposed cost function uses link lifetime& average link delay parameters to estimate the link cost.

3.4 Clustering & CH Selection:

The wireless multimedia network categorizes into 'n' number of clusters for extending the network lifetime and enhancing the efficiency of data aggregation. The clusters are created dynamically according to the availability of sensor nodes in a specific area and a cluster head (CH) manages each cluster. In the clustering process, the nodes that having higher vicinity of event radius are being involving. Then, a cluster head is chosen after determining the cluster members. The two parameters: Node Coverage (NC) & average residual energy (ARE) parameters are used to choose the CHs.

Node coverage (NC): - It defines as the percentage of sensor nodes that having a distance of less than or equal to d_0 from respective neighbours. The nodes that are closer to their neighbours when a node coverage is higher. The lower energy consumes by normal nodes during transmission of data. The NC parameter evaluates using a proposed CH selection method for each node in the process of CH selection. The probability of becoming a CH is higher for sensor nodes that having a higher CH coverage than the others. However, the node coverage determines using a below equation:

$$NC = \frac{(Num_{nodes}(\mathrm{MIN_{Dist2CH}}) \leq d_0)}{n}$$

Where, n is a total number of sensor nodes, $Num_{nodes}(\mathrm{MIN_{Dist2CH}}) \leq d_0$ indicates a total number of sensor nodes with a minimum distance that is less than or equal to d0,d_0 is represented as $\sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}}$, where$\epsilon_{fs}$ & ϵ_{mp} represent the free-space and multi-path channel with values 0.0013 pJ/bit/m and 10 pJ/bit/m, respectively.

Average Residual energy (ARE):- It describes as the preference is given for nodes with a higher initial energy to choose a cluster head. By comparing with sensor nodes that having medium or lower energy levels, the higher energy nodes are sustained for a longer duration.

$$ARE = \frac{1}{N}\sum_{i=1}^{N} E_{(n)}$$

Where, N indicates a total number of sensor nodes in a network and En is the energy for nth node.

The weighted sum approach is used to overcome the trade-offs among objectives that formulates the CH selection. Finally, it could be represented as:

$$W_n(t) = \alpha * NC_n(t) + \beta * ARE_n(t)$$

Where, α and β represent weighted importance for each objective and Wn(t) is a final weight of sensor node 'n', such that $\alpha + \beta = 1$ and $0 < \alpha, \beta \leq 1$.

Finally, the node will be chosen as a CH when it has a higher weight value than the other nodes.

3.5 Energy Efficient Multipath Selection Using Improve Genetic Algorithm (IGA):

To determine the multiple data path over a wireless multimedia network, the proposed multipath routing method is used for data transmission. However, an IGA is used in a network for multipath searching. The parameters like average link delay, lifetime of a link, and cost function are chosen to choose the best path dynamically.

3.6 Overview of Genetic Algorithm

For producing solutions for optimization and search problems, the Genetic algorithm is used as an evolutionary algorithm. Based on natural selection, the method was improved and uses the techniques, such as mutation, selection, and crossover to get the optimized solutions. Figure 3 shows a flowchart for genetic algorithm. The random generation of initial population is involved in the primary step, in which the population size relies on the nature of a problem. In the second step, the survival of fittest and defined fitness function are used to choose the population from an initialized population. In next generation, the selected individuals are parents and utilized them for contributing the population generation. Based on a particular problem, a fitness function defines and varies according to the problem type. It uses for selection of individual solutions and computation of a quality of the solution. Two different genetic algorithm operators are existed, such as mutation and crossover operators. With the implementation of random changes to the parents individually, the new children formed using a mutation operator. By considering the features from both parents, new children generate with the combination of these two parents in a crossover operator. If a termination criterion reaches, the new population generation is stopped.

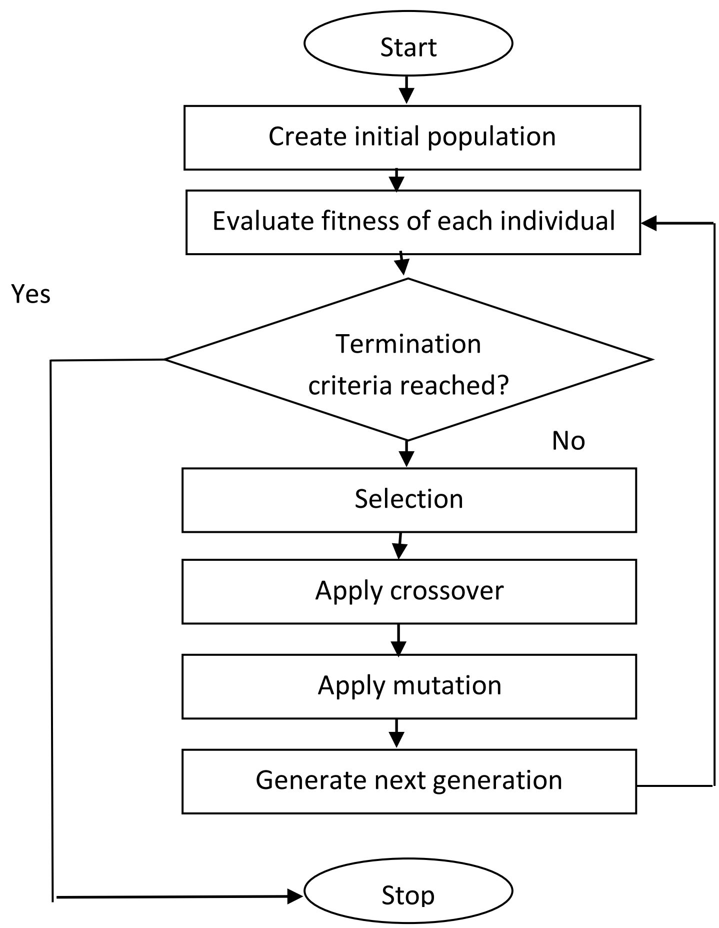

Figure 3. Flowchart Of Genetic Algorithm

4. Encoding of Chromosome

The encoding process of a routing path from nodes to the destination is involved in a chromosome, which encodes as a sequence of positive integers. It relates to the determined sensor node in a routing path from CH to the BS with length m that equals to the cluster size. The population is defined as a group of chromosome. The population with a cluster size is initialized in the initial phase. If two conditions, such as one of the possible next hops of a network included the gene value of a chromosome and any loop doesn't include for all possible multi-paths of a chromosome are satisfied, the chromosome's validity is assured.

5. Fitness Function

The energy-efficient path is determined using a fitness function. For a given problem, the quality and appropriateness of a solution should be evaluated based on its fitness value. The nodes' maximum fitness value is used for selection of a routing path. To estimate the energy-efficient path for a destination, the cost value is maximized based on a fitness function, which considers average link delay and link lifetime.

Link lifetime (LLT): - The link lifetime uses multiple parameters to predict the lifetime of the link. The bi-directional links are existed among sensor nodes in wireless networks. In an available path, the maximum duration for data transmission is provided for each link using a link lifetime. The network lifetime is larger if a link lifetime is higher. It is determined using a below equation:

$$LLT = \frac{2 * ((E_i + E_j))}{T + P_s + P_r + R + \left\| D_i - D_j \right\|}$$

Where, Pr is a receiving packet rate of ith sensor node, Ps is a sending rate of packet for ith node, Ei and Ej represent energy levels of sensor nodes i&j, T is a constant value, R is a transmission range, $\left\| D_i - D_j \right\|$ indicates a distance between sensor nodes i & j. The distance between two sensor nodes defines using a below equation for two nodes i&j that having a transmission range R and position coordinates (xi, yi) and (xj, yj):

$$\left\| D_i - D_j \right\| = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}$$

Average link Delay: - It is a measurement of a delay that experienced for data packets during the traversing of a link from a sensor node i to CH. The propagation delay P_d, queuing delay Q_D, and the transmission delay T_d are included in a link delay. It is formulated as follows:

$$ALD_{itoCH} = Q_D(i, CH) + T_D(i, CH) + P_D(i, CH)$$

$$Q_D(i, CH) = \frac{1}{\alpha - \beta_{CH}}$$

Where, α and β refer to the rate of entry for new data packets at a CH node.

$$T_D(i, CH) = \frac{l_i}{\gamma}$$

Where, γ is a link bandwidth (bps) and l_i indicates a packet size of a node i (bits).

$$P_D(i, CH) = \frac{\|i - CH\|}{S}$$

Where, S is a propagation speed (m/s) and $\|i - CH\|$ represents the length of a physical link from sensor node i to CH.

However, the fitness function is represented:

$$F(i) = LLT_i + ALD_i$$

When a routing path has a maximum fitness value among sensor nodes, the next hop chooses in a routing path. If an average delay is minimum and link lifetime is a maximum value, the maximum value of cost is obtained for a fitness function. The chromosome with a higher fitness value is selected for a next process, known as crossover. The best individuals are selected from a population based on Roulette Wheel selection in the evaluation of fitness function.

6. Crossover

The fitness value is used to choose the parent chromosomes in a crossover process. They will swap with their position of gene values and the generated child chromosomes are evaluated. The replacement of parent chromosomes with their offspring chromosome is performed and will discard when their fitness values are greater compared to the other parents or vice versa.

7. Mutation

From parent chromosomes, three random genes are selected in this phase. To determine a new position for a mutated gene, a random number, $\alpha \in (0,1)$ is selected. The fitness value evaluates for new mutated genes at the end of a mutation. It will incorporate into a current population when it is found to be a valid or fit. It will reach to the next phase finally. The new gene's position is determined as follows:

$$MI = G1 + \alpha * (G2 - G3)$$

Where, G1, G2 & G3 represent randomly chosen positions for parent gene within a range $0 \leq \alpha \leq 1$ and MI is a mutated individual in a chromosome.

7.1 Algorithm

INPUT: m: number of nodes in a cluster
##
Initialize network
Divide network into 'n' clusters
CH selection
For $i \leftarrow 1{:}m$
  Calculate NC_m, ARE_m
  Estimate W_m
End for
$While\ (delay\_time\ != 0)$
All nodes in the cluster receive CH request from other members;
  Assign the node with higher W to be CH
End while
CH sends an advertisement to non-CH nodes
Initialize population with equal to m
Calculate each node fitness value
Select parent chromosomes & perform crossover and mutation
Compute the fitness of each mutated individual
$If\ (fitness_{new} > fitness_{old})$
  Replace the parents with new value
End if
End

8. Results and Discussion

8.1 Simulation and Performance Evaluation

The performance of the proposed mechanism was evaluated by simulating a multimedia network environment in NS2 simulation tool. The nodes are randomly deployed in a network field spreading across 1000mX 600m. The wireless nodes are provided with initial energy of 100joules to perform network activities. The network size is varied from 25 to 100 nodes. The transmission agent is UDP agent & CBR (Constant Bit rate) is used as traffic source to generate traffic at constant rates. The video packets are fragmented as 1024bytes. The quality analysis and multimedia transmission are performed using a myEvalvid framework. The three-hundred frames of yuv video sequence was downloaded and coverted into the traces of mp4 video that sending over a network. Table 1 shows the experimental values and Figure 4 represents the snapshots of source video sequences. Table 2 represent the performance evaluation of metrics while comparing proposed with existing methods.

Table1. Simulation Parameters

Parameter	Value
Network area	1000 m x 600 m
Data traffic	CBR
Packet rate	1024
Initial energy	100 j
Network size	25 to 100
Routing protocol	AODV
Fragmentation size	1024
Source file format	Yuv
Frames	300
Codec	H.264

Figure 4. Snapshots of Source Video Sequences

Packet delivery ratio (PDR): It is demonstrated as a ratio of delivered data packets to the destination successfully. The PDR determines the network quality in data transmission. The parameter of link delay is considered by choosing efficient relay nodes, stable CHs, and efficient data aggregation that enhances the data packets' delivery ratio. The proposed method achieved maximum PDR of 0.9425% whereas the existing OCSRP &HRDSS methods were resulted the average PDR rates of 0.895 and 0.86, respectively. Figure 5 shows the outputs of packet delivery ratio.

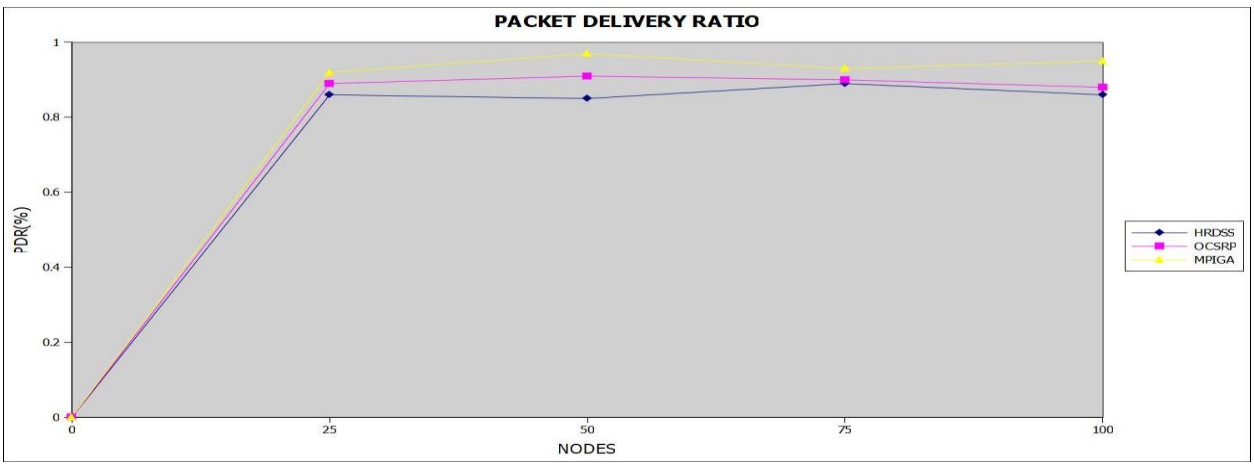

Figure 5. Packet Delivery Ratio

The proposed and existing techniques were evaluated using the simulation results of end-to-end delay. The data aggregation & efficient relay selection scheme using the modified fitness function in the proposed relay selection scheme ensures only quality nodes are selected for data communication. The paths selected by the proposed method have less interference than the other available paths in the network. In a proposed network, the end-to-end delay is minimized while the minimum average delay of a network was reported as 0.017ms. It was higher for existing methods within a range from 0.025 to 0.048 ms under all conditions. The delay performance showed in figure 6.

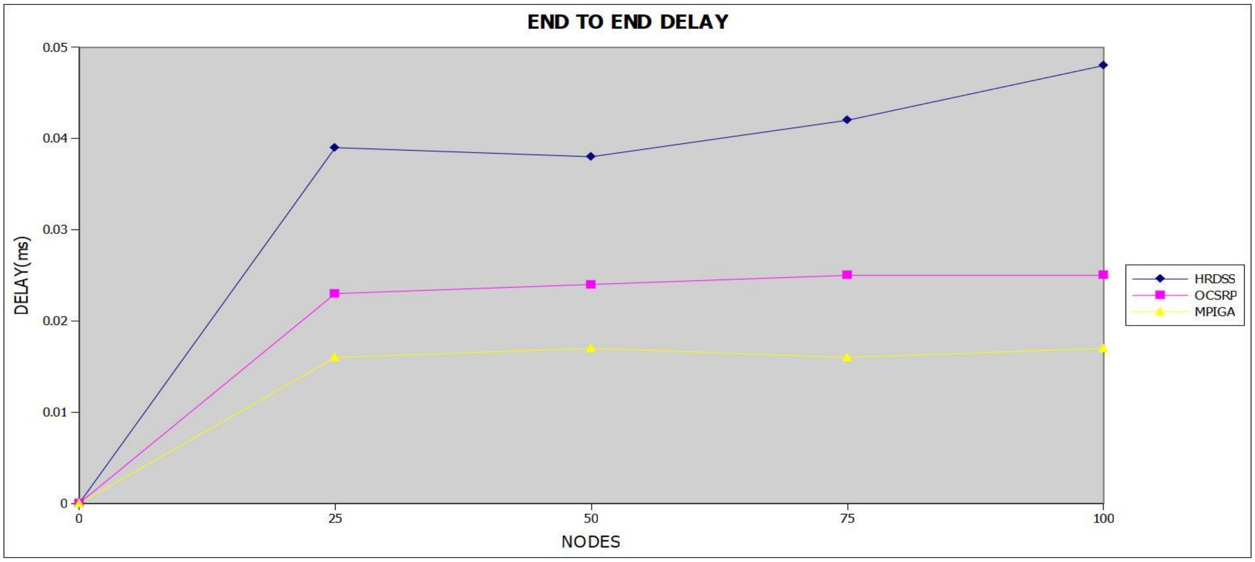

Figure 6. Performance Analysis of Delay

Energy consumption: All network activities consume energy. All sensor nodes equip with the energy of 100j to carry out all activities. Most of the energy is utilized during data transmission & efficient relay selection saves a considerable amount of energy to be wasted. The unwanted energy consumption is being controlled among sensor nodes based on efficient selection of relay and CH nodes in a proposed technique. The amount of energy saves considerably compared to the earlier methods by analyzing the simulation results. As shown in Figure 7, the network's energy consumption results were compared for both proposed and existing methods.

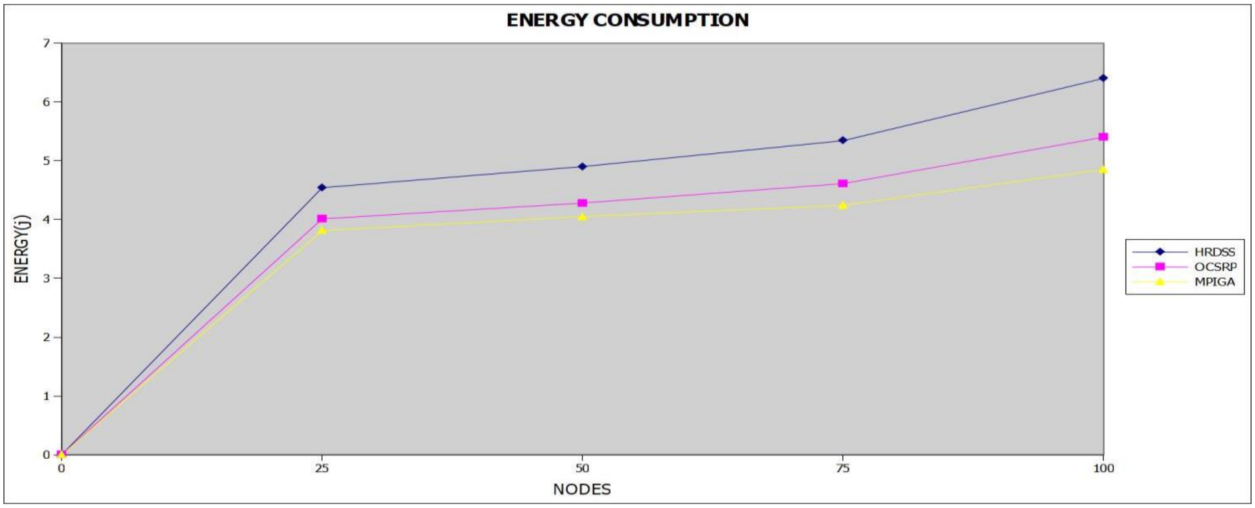

Figure 7 Energy Consumption

BER: It represents the percentage of data bits with errors that related to the total number of received data bits during the transmission. The BER evaluates how often the data units or packets have to be retransmitted due to the errors. It is one of the significant parameters to compute the performance. Based on improved fitness function, the data packets were chosen efficiently over a reliable routing path to ensure the data transmission with lower network overheads. The simulation results proves that the proposed method improves the BER and help the network to send data units successfully without any additional overheads. Figure 8 represent the overall bit error rate in network.

Figure 8. Bit Error Rate

Table 2. Performance with Frame or Data Retransmission

Parameters	HRDSS	OCSRP	MPIGA
PDR	0.865	0.895	0.9425
End to End Delay	0.04175	0.02425	0.0165
Energy consumption	5.295	4.575	4.2375
BER	0.2775	0.215	0.142

9. Conclusion

An energy-aware multipath routing method was proposed by using improved genetic algorithm (IGA) for selection of an efficient path based on a fitness function. The proposed cost function uses link lifetime & average link delay parameters to estimate the link cost. Also, for data aggregation efficiency, the network is divided into clusters and each cluster is represented by cluster head nodes. The cluster heads for each cluster are selected based on Node Coverage & average residual energy parameters. When compared to the earlier methods, the proposed technique shows improved performance in terms of higher network throughput, reliability, balanced energy consumption, and prolonged network lifetime.

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