International Journal of Computer Information Systems and Industrial Management Applications
ISSN 2150-7988 Volume 17 (2025) pp. 67–78

Article

Improving the Quality of Service by Enhancing the Network Lifetime in Wireless Multimedia Sensor Networks

K.S. Kannan [1], B. Swathi [2], Kartik Jayathirth Kulkarni [3], Ganesh Davanam [4,*], Madhu Munagala [5] and Puvirajan T. [6]

1 Department of CSE, Kalasalingam Academy of Research and Education, (Deemed to be University), Krishnankoil, Tamil Nadu, India; saikannan2012@gmail.com
2 Department of CSE, G Pulla Reddy Engineering College, Kurnool, AP, India; bswathi.cse@gprec.ac.in
3 Department of Computer Science, KLS VDIT Haliyal; Kulkarnikartik214@gmail.com
4 School of Computing, Mohan Babu University, (Erstwhile Sree Vidyanikethan Engineering College(Autonomous), Tirupati, Andhra Pradesh, India
5 Department of English, Koneru Lakshmaiah Education Foundation, A.P., India; dr.madhumunagala@gmail.com
6 ECE Department, New Horizon College of Engineering, Banglore; shanmusree17@gmail.com
* Correspondence author: dgani05@email.com

Received date: 15 June 2024; Accepted date: 18 August 2024; Published online: 6 January 2025

Abstract: Data has become paramount in the 21st century, from major contributors including social media, smartphones, individual health records, etc. Megabytes and gigabytes used to be the standard units of data storage, but nowadays Petta bytes and Zetta bytes of data are being produced at an exceptional rate and in a wide range of formats. Wireless sensor networks (WSN) are a type of WSN in which each node is equipped with sensing, processing, and communication capabilities. This network's ability to monitor and sense has led to its widespread use in fields as diverse as surveillance, military, medicine, and even the household. Networks that evolved from WSN to address problems peculiar to multimedia transmission are known as Wireless Multimedia Sensing Networks (WMSN). Video, audio, and visual content, as well as numerical data, can all be retrieved by the multimedia nodes. Every node in a WMSN has an energy limit. The network's lifespan is shortened because it's difficult to recharge or replace a dead battery. Transmission of video, music, images, and scalar data by wireless multimedia sensor nodes will increase their power consumption. In addition, the efficient operation of the network is contingent upon the following parameters being met during the transfer of multimedia data: a large bandwidth, high transmission of packets ratio, excellent throughput, acceptable end to end a delay, tolerable jitter, less frames loss rate, and low computation time. The sum of these measurements is the network's Quality of Service (QoS). A network's lifetime is defined as the amount of time it is able to function normally and carry out its designated function. To extend the useful life of multimedia networks, we devised a novel splitting of the underlying multidimensional functional structure and integrated it with Machine Learning techniques.

Keywords: multimedia transmissions; artificial intelligence; convolution neural networks; lifetime of networks

1. Introduction

Both the networking scientific community and the broader academic community are showing a great deal of interest in Wireless Sensor Networks (WSNs). Improvements in micro-mechanical systems (MEMS), low-power, fully integrated digital electronics, and wireless communications have led to WSNs becoming more practical, affordable, and multi-functional [1]. Large numbers of sophisticated batteryoperated sensor nodes equipped with sensing, processing, and wireless communication capabilities make up wireless sensor networks (WSNs) [2]. Simple ambient parameters, such as the surrounding environment's temperature, humidity, or light, are measured by the sensing circuitry and converted into an electrical signal. When such a signal is processed, it reveals characteristics of objects and/or events close to the sensor. Such information is transmitted from the sensor to the command center (sink) via radio transmitter, either directly or via many wireless hops [3]. WSNs can be used for a broad variety of purposes, including real-time object tracking, environmental monitoring, health infrastructure monitoring, and the development of a ubiquitous computer environment [4]. Figure 1 depicts the basic architecture of a WMSN.

All of these factors—fault acceptance, scalability, manufacturing costs, system architecture, operating atmosphere, hardware restrictions, power utilization—place significant limits on how WSNs can be built. In response to these obstacles, researchers have been focusing on ways in which sensors can work together to collect and analyze data. In most cases, there is no power or communication infrastructure in place where the program will be deployed. Therefore, the ability to function on a very little amount of power, typically provided by a battery, is a prerequisite for sensor nodes [5]. The network must remain online for a time period that ranges from a few months to a few years, depending on the nature of the service it provides.

However, the advent of cheap CMOS (Complementary The metal Oxide Semiconductor) microphones and cameras, along with advances in distributed processing of signals and multimedia coding from source techniques, allowed for the development of what are now known as wireless multimedia sensor networks. A Wireless Multimedia Sensor Network (WMSN) [6] is a system of interconnected sensor nodes that can capture and share audio and video, as well as still images and scalar data, through wireless communication and the use of multimedia devices such as microphones and cameras. There is a wide range of potential civilian and military uses for WMSNs, including surveillance networks, traffic control systems, improved medical care delivery, automated aid for the elderly through telemedicine, and the oversight of industrial operations.Multimedia integration has the ability to increase data collection quality, coverage area, and view resolution in these applications [7]. High bandwidth requirements, real-time shipment, acceptable end-to-end delay, and an appropriate jitter and frame loss rate are only some of the extra features and issues faced by WMSNs beyond those faced by WSNs due to the nature of real-time multimedia data.

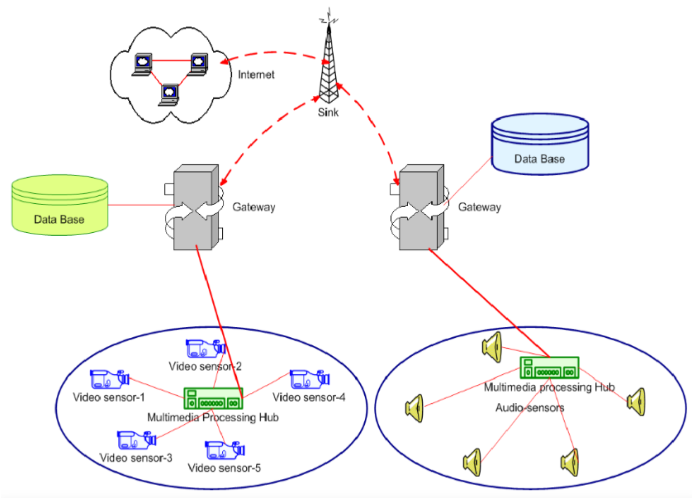

Figure 1. The Structure of Wireless Multimedia Sensor Systems [8].

The client-server model is widely used in multimedia processing technology today. According to the demand of multimedia in-formation processing technology, the server must switch to the experience mode of the server and provide feedback from the request analyzing and other aspects, such as receiving the request, processing it, returning an error message, and concluding processing of the report. In the end, the request finishes the object conversion, deletes the converted object, and frees up system resources. After completing the aforementioned procedures, a command request for the communication process can be sent. Startup, pause, reimbursement, and other aspects can be customized for media material that follows a time sequence based on factors such as the current play position, the play cycle time, and more. Depending on the use case, editing and analysis of still images may necessitate the non-time series output. In order to provide established data processing machinery of operating system administration equipment, software and hardware for the storage of multimedia content, and the administration of other information resources, multimedia data processing technology serves as a connecting principle and function among multimedia software for applications and its function.

Multimedia information has numerous forms, the most common of which are audio data, image/video data, and associated textual information. Information in a variety of popular formats is included in these multimedia communications. The format used to process data must match the format used for all multimedia files. In order to provide a multimedia application service, it is necessary to rely heavily on multimedia technology, which is used in two main ways: first, to process the request for information and return the outcome to the application (via the interface of multimedia in-formation technology). All of these multimedia formats are supported by the multimedia information processing technology. Figure 1 depicts the development of multi-media data processing technologies. Figure 1 analysis reveals that prior to initiating the converting function of multimedia information processing technology, the processing technology will generate and arrange the required processing sequence. Different data kinds will execute various processing modes, and the converting function of multimedia information processing technology can be broken down into four distinct phases. Next, we put a stop to the data's conversion, resulting in the expected multimedia data processing output. In order to prevent data confusion and the use of unnecessary storage space during the processing of multimedia data, the object data that has been processed & converted are destroyed automatically.

Here is how the rest of the paper is structured: In Section 2, we'll talk about related works and how social network analysis makes use of Wireless multimedia sensor networks. The Novel Separation of multidimensional functional framework approach presented in Section 3, evaluating the presented Systems in Section 4, and summarizing the work in Section 5, then the paper concludes.

2. Related Works

Due to its capacity to transmit both scalar sensor data (like traditional WSNs) and multimedia content (like smartphones), Wireless Multimedia Sensing Networks (WMSN) have been the subject of increased study in recent years. Due to the sending and receiving of multimedia content like picture, music, video, etc., Multimedia sensor networks can use more power and exhibit greater battery usage compared to their scalar WSNs. Therefore, suitable energy aware scheduling algorithms are very important in prolonging the network lifetime of WMSNs. Since the multimedia sensors have been installed in a wireless and distant environment, the network's lifespan of WMSNs should normally be quite high; otherwise, the deployment of WMSNs could become uneconomical due to the need for constant replacement. Therefore, a thorough and methodical examination is required before a structure for a WMSN with longer lifespan can be developed.

Media coding and communication systems are illustrated schematically in Figure 2, which provides a high-level perspective.Images [9] and videos [10] are the cornerstones of most other pictorial data formats, and they share the depicted building pieces. The goal of source coding is to get rid of any unnecessary information by eliminating redundant data. This is accomplished by, for instance, applying a DCT or DWT transformation on the visual data, which converts it to a sparser domain. When data is sparse, it can be compressed significantly. Another option is to apply the change to specific image portions. Visual data is quantized before being compressed. When images are quantized, just the data that is most useful to the human retina remains. Multimedia bit streams are compressed using entropy coding [11] by giving shorter representations to more frequent bit stream patterns and giving longer representations to less frequent patterns. Since video streams contain a succession of connected images, special techniques are required for video coding in order to take advantage of the temporal correlation.

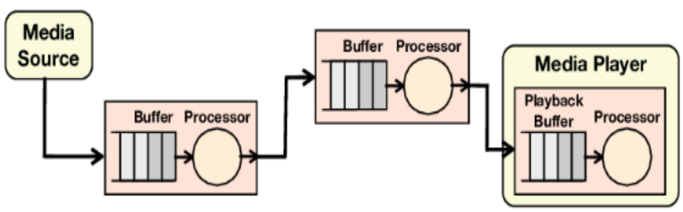

Figure 2. Technology for Simple Multimedia Conversation [9].

In the initial model of an OSN, emphasis is placed only on the users and their relationships with one another. Several methods have been proposed to make use of this paradigm for various purposes, such as lurker detection [12,13], influence analysis [14], & expert discovery [15]. These methods, however, ignore the value added by multimedia presentations. To this goal, increasingly sophisticated models for social data networks have been suggested, broadly falling into four classes.

One group models a social network as a graph with a diverse range of nodes. Qi et al. [16] used this kind of model to present an algorithm for multimedia data tagging that takes into account the material itself and the information environment of the network. In consequently, Jin et al. [17] proposed a novel idea of picture similarity using graph modeling and data on multimedia content. The social network is modeled using a bipartite structure in the second family. To study how information spreads over a social network, A bipartite graph representation of user-media interaction was created by Zhu et al. [18]. A potential embedding method for social recommendation generation was proposed by the authors of [19] for generic bipartite (user-item) graphs.

Tripartite graphs are used in the third class of methods, and their vertex sets often include users, tags, & resources. The primary innovations of the recommendation technique proposed by Zhang et al. [20] utilizing a user-image-tag model are the detection of user preferences based on user interactions with photos and the re-ranking of social images according to content. An attention-driven convolution neural network (CNN) is used to fine-tune the weights of the edges in an interaction triad graph made of heterogeneous vertex proposed in [21]. Liao, Zheng, & Cao [22] described a tripartite network for offering corona virus outbreak analysis via non-negative factorization of matrix and sentiment analysis; its collection of vertices is made of users, tweets, and themes. The final subgroup uses the term "hyper graph" to describe the OSN. The authors of [23] suggested a tensor decomposition method that ensures knowledge acquisition using a hyper graph with three uniform edges. In a friend-based location network, for activities involving friendship and location predicting, Yang et al. [24] created a heterogeneous hyper graph representation (LBSN2Vec++) to take into account complicated interactions between users, time, as well as Points of Interest (POIs). To better depict the complexity of social network connections when making product recommendations, Zheng et al. [25] created a hybrid factorization matrix approach that makes use of a hyper network data structure.

Several factors impact wireless signal propagation and contribute to declining network quality. As a result, wireless connections are not trustworthy and are prone to errors. In WMSN, link quality assessment has been a tricky problem since inaccurate estimates can negatively impact the efficiency of the networking protocols, leading to unanticipated packet loss. In addition, retransmission arrangements may cause additional increases in end-to-end delay and energy consumption, which shortens the lifespan of the system. Assuring a high packet delivery rate is a crucial part of any routing system, making connection quality measurement an essential part of the design process [26].

Disruption to the flow of information during wireless communications can have devastating effects on system performance. In order to achieve a decent packet delivery ratio, multimedia applications need power-efficient multimedia processing, effective routing and path selection, and audio/video rate adaption. Due to the massive volume of video or sound stream, WMSNs are more vulnerable to the effects of high-frequency fault occurrences than traditional WSNs. Only a few works have fully explored how impedance affects multipath routing. A critical requirement is evident for the development of routing protocols that sustain a high packet delivery ratio [27].

There is hope that Wireless Multimedia Sensing Networks (WMSNs) would improve audiovisual services, including live stream transmission. The rather high Quality of Service (QoS) demands of multimedia services, however, prevent the inclusion of all possible sensor nodes in the network. Therefore, admitting nodes into a WMSN is crucial for extending its lifespan [28]. Similarly, various studies have been conducted to extend the life of networks [29]. To achieve the desired picture quality, a fully decentralized approach is described here that optimizes both the encoding power & the source rate simultaneously.

3. Methodology

Here, a Splitting of multivariate functional structure (SMDFS) technique is used to improve both quality of service (QoS) and network lifetime. In the SMDFS approach, clusters are constructed using minimal computations, making it a graph partition method [30]. There are two main categories for graph partitioning techniques: local and global. The multilevel spectral partitioning scheme and the multilevel partitioning scheme are both examples of global partitioning approaches. Partitioning in a multilevel spectral scheme is done graphically using the estimated Eigen values and Eigenvectors of a graph's Laplacian matrix. The spectral approach has the primary drawback of having to recalculate Eigen values & Eigen vectors. It is common knowledge that the time needed to calculate Eigen values as part of spectral graphs partitioning algorithms is substantial. We employ the MSGP technique, which does not rely on iterative calculations of Eigen value as well as Eigen vectors, to address this problem.

- **System Model Assumptions**

The following are some of the presumptions made in the network model: We take into account N random heterogeneous nodes with identical starting energies. Cluster Heads (CHs) are responsible for relaying the data from these nodes to the final destination. We scatter the nodes around at random. In a short message sent to sink, each node communicates its current location. Every node is fixed, and it sends data to the sink at regular intervals. The sink uses this information to generate an Adjacency matrix, Degree matrix, and Laplacian matrix. Figure 3 shows the graph of a clustering example.

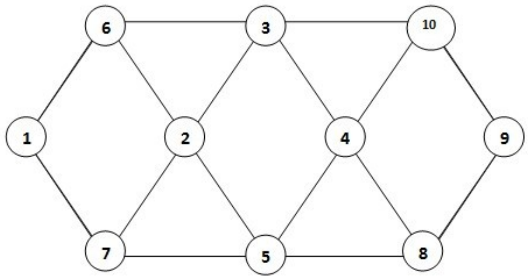

Figure 3. Sample Graph for clustering under SMDFS.

Let G (V, E) be a graph that is undirected where **V** is a set of vertices (sensor nodes) and **E** is a set of edges (connections between vertices). Each node in a network is given a unique index starting with **1** and going all the way up to **N,** where **N** is the total number of nodes. $\mathbf{e_{ij}}$ stands for the edge connecting nodes i and j. An adjacency matrix is a representation of the graph. Adjacency matrix **A** of N-node graph **G** is the **N2** matrix with non-diagonal entry $\mathbf{a_{ij}}$ = number of edges from **i** to **j** and diagonal entry $\mathbf{a_{ii}}$ = number of loops at **i**. Adjacency matrices, degrees, and Laplacian matrices will be computed according to established methods in the literature. The estimated Eigen values for the 10 node Laplacian Matrix are presented in Table 1.

Table 1. Nodes and the Eigen Values associated with them.

Node Numbers	Eigen Values (λ)
1	0.0189
2	1.0879
3	2.014
4	3.034
5	3.478
6	4.125
7	5.087
8	5.857
9	6.124
10	7.457

All Eigen values and their corresponding Eigen vectors are determined by reference works. The eigenvalues range from λ1, λ2, λ3, … λ10, as indicated. The associated Eigen vectors are denoted by the χ1, χ2, χ3, χ4,…..χ10. A graph's nodes are represented by the initial Eigen vector in SMDFS, while the following Eigen vector (Fiedler) cuts the graph in half to create two new graphs. When applied to the subgraphs created by the second Eigen vector, both of the subsequent Eigen vectors exhibit an exponential dividing ability.

- **SELECTION OF CLUSTER HEAD**

Having each cluster's leader elected is the next stage. A node with the lowest Eigen vector value is considered to have good connectivity to its neighbors in the cluster according to an SMDFS attribute. We select the node with the lowest Eigenvector as the cluster head by comparing their values. In order to reduce latency and balance the network's energy consumption, backup nodes are utilized in sensor networks. The cluster head keeps track of backup nodes, which will have the same amount of energy and computing power as the rest of the cluster. Assigning a node with the second-to-least Eigen vector value as the backup node and putting it to sleep until the current CH transfers control to it is part of the CH selection procedure.

- **NODE SELECTION FOR BACKUP**

When the cluster head node's residual energy drops below a certain level, the cluster head must rotate. To maintain a steady flow of energy throughout the cluster, we utilize standby nodes. In standby mode, we find the node with the second-lowest Eigenvector value and assign it. When the cluster head node's remaining energy drops below a certain threshold, the current cluster head immediately declares this information to all the other cluster members and awakens up the backup node, which has been in sleep mode. Following each transfer, the cluster leader will compare its current energy to a predetermined threshold. When the cluster head's remaining energy is above a certain level, the network will continue to transmit. If the primary node fails, the secondary one becomes the next CH. All members of the cluster and the sink will receive this data. The pseudo code of the Proposed SMDFS method for Network lifetime enhancement is as follows:

```
Imagine the network as a graph that is not directed.
Vertices (V) serving as nodes
Edges (E) represent the links among nodes.
Step 1
Determine the Adjacency A matrices.
If nodes i and j have a connection, then a_ij = 1.
Otherwise  a_ij = 0
stop
Discover D as a diagonal matrix of the degree matrix.
dii  = count of vertices with connected edges dij  = dji
= 0
The Laplacian matrix L should be determined.
Laplacian matrix L = Degree matrix D – Adjacency
matrix A
Determine the Eigen Values & Eigen Vector of a
Laplacian Matrix.
N = Vertices Count
N Eigen values count for L Matrix [λ1, λ2,
.......................................................................................
λN]
N Eigen Values of the L-Matrix
and the corresponding number
of Eigen Vectors
Eigen vectors for a
Eigen  value of λ1 are
[χ11,χ12,χ13,
......................................
χ1N]
All the nodes in a network are represented by
Eigen vectors whose first Eigen value is 1.
Clusters 1 and 2 are created by Eigen
vectors with an Eigen value of 2, and so
on.
if  λ2  Eigen vectors  value is positive
Include it in the first cluster.
otherwise
Include it in the second cluster
stop
The third Eigen value is represented by the vectors
labeled with χ3.
Considering the first  cluster
Cluster 1 '+' if the value of Eigen vector λ3 is
positive.
Include it in the third-cluster node
```

Otherwise
Include it in the Fourth-cluster node
stop
Clusters 1 and 2 were formed after then
Change n = 2 (after the first iteration, the total number of clusters)
if the quantity of nodes in the cluster M is higher than 2n-1 proceed to Method 1
otherwise
Keep the same terminal on the cluster.
Select the Cluster Head

Cluster Leader = Node with the Lowest Eigenvector Score

Selection of CH

Second-Least Node in Eigen-Vector Value (Backup CH)

Turning the cluster's heads

The network's average energy consumption might be used as the threshold value.

Network average energy = sum of all nodes' residual energies / by the overall amount of nodes

If the threshold is higher than the energy left over from the present CH

Modify the CH to be the backup CH.

otherwise

Never change the channel until the transmission is over.

The cluster's leader compiles information from each node in the cluster.

Data from the cluster heads are sent to the local CH or sink.

4. Results and Simulation

Multilevel Spectral graphs partitioning method (MLSGPM) & spectral graphs partitioning using neural networks (SGP-NN) [31,32] are compared to our new SMDFS technique in this section. The NS2 simulation is used in this approach. Table 2 displays the simulation results after we have discussed the simulation setup and determined the performance metrics.

Table 2. Simulations Parameters Description.

No.	Parameters	Description
1	Total Sensor Nodes	100
2	Transmission range	250 m
3	Number of cycle simulation	10
4	Square region	1,000 m * 1,000 m
5	Traffic type	Constant bit rate flow
6	Simulation time	100 sec
7	Size of data packet	256 bytes
8	Data packet generation	1 packet/sec
9	Transmitting energy	50 nJ/bit
10	Receiving energy	50 nJ/bit

11	Initial Energy	100 J
12	Compression	DWT
13	Constant bit rate	500 kbps

- **Computational Time**

The time required for computation is the amount of time necessary to complete a task. Clustering, recognizing the cluster head with backup node, and routine network activities of WMSN are all performed in SMDFS. All tasks done in the network are included in the computation time calculations. The entire computing time of SMDFS differs on the number of nodes, shown in Figure 4.

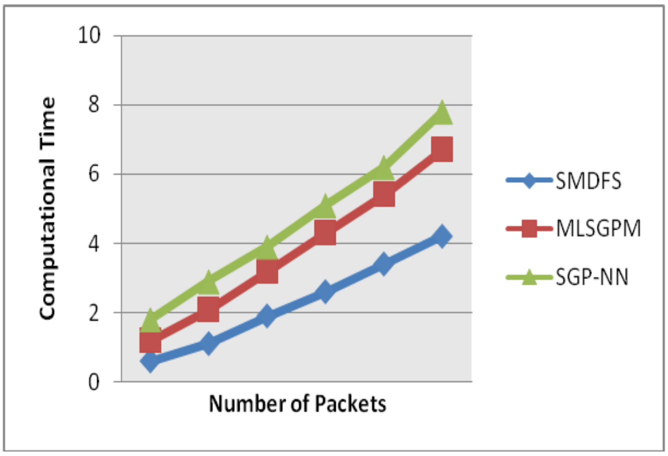

Figure 4. Computational Time Graph.

Time required to compute SMDFS, MLSGPM, and SGP-NN for different numbers of nodes is shown in Table 3 below. The SMDFS is a method for identifying the cluster head & backup node that requires minimal processing power. SMDFS also incorporates a CH duty rotation. When compared to other methods, SMDFS's main advantage is how quickly it can be computed. Clustering Eigen value calculations are performed in a single loop, drastically cutting down on processing time. The low energy usage of the nodes is due to a reduction in computation time. When running on 100 nodes, SMDFS requires 4.2 s, SGP-NN 7.8 s, and MLSGPM 6.7 s to complete calculations.

Table 3. Computational Time Results.

	Computational Time (ms)		
Number of Packets	**SMDFS**	**MLSGPM**	**SGP-NN**
10	0.6	1.2	1.8
20	1.1	2.1	2.9
40	1.9	3.2	3.9
60	2.6	4.3	5.1
80	3.4	5.4	6.2
100	4.2	6.7	7.8

- **End to End Delay**

The matter at hand holds significant importance and serves as a foundational concern within wireless sensor networks. The term "end-to-end delay" pertains to the overall duration required for a solitary packet to traverse a network, commencing from its point of origin and concluding at its intended destination.

$$\text{End-to-End Delay} = N*L/R \tag{1}$$

where Communicating distance (R), Packet Length (N), and number of links (L). The values of end-to-end delay represented in Table 4 and Figure 5.

Table 4. End-to-End Delay Results

	Delay (ms)		
Number of Packets	**SMDFS**	**MLSGPM**	**SGP-NN**
10	0.89	1.42	1.56
20	1.23	2.17	2.45
40	2.03	2.98	3.78
60	2.98	3.48	4.56
80	3.45	4.56	5.89
100	4.12	5.48	6.78

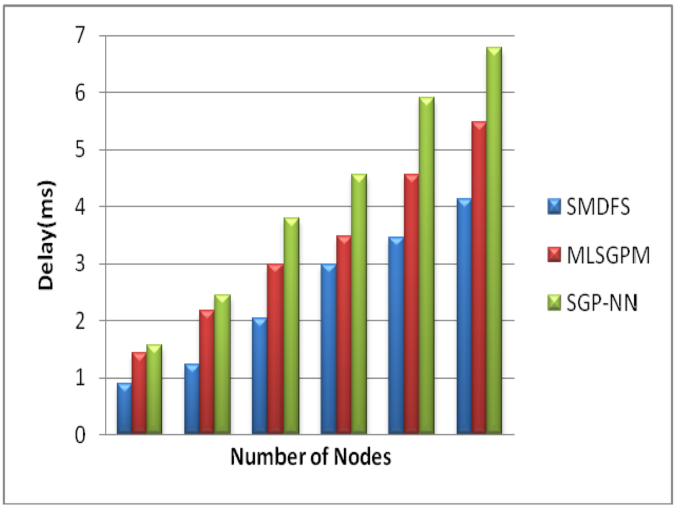

Figure 5. Delay Graph.

As can be seen in the preceding diagram, the minimal computation and strong connectivity among the nodes of the SMDFS technique contribute to a reduction in delay. There is less packet over head, and thus less delay, because there is no CH election process. Further, the delay in SGP-NN is affected by the relatively short computation time needed to calculate Eigen values compared to the MLSGPM. SGP-NN's recognized backup node shares the same high residual energy and excellent connectivity between nodes as the CH, allowing it to maintain and decrease delay in the same manner. As a result, SMDFS has been shown to be less delayed than both MLSGPM and SGP-NN. With 60 nodes, SMDFS has a delay of 2.9 s, SGP-NN 5.8 s, and MLSGPM 3.4 s. Therefore, it can be stated that SMDFS has a significantly lower delay than the other methods.

- **Throughput**

Network throughput refers to the amount of information that may be effectively transmitted from one location to yet another in a given amount of time. The percentage (%) is the standard unit of measurement for network throughput and its values represented in Table 5.

Table 5. Throughput Results.

	Throughput (%)		
Number of Packets	**SMDFS**	**MLSGPM**	**SGP-NN**
10	98	96	93
20	96	93	90
40	94	90	89
60	93	88	86
80	91	87	84
100	90	86	83

Figure 6 shows the simulation outcome for throughput versus the number of nodes. Transmitting the multimedia packets used in WMSN necessitates a large bandwidth, often greater than 256 kbps. Table 2 shows the bandwidth allocation for our proposed method, which is 500 kbps. While SMDFS's throughput is quite high compared to other methods, it drops off precipitously as the amount of nodes grows.

SMDFS's throughput improves because of its decreased latency and improved packet delivery. Due to the high bandwidth requirements of the multimedia packet in WMSN, a Consistent Bit Rate (CBR) of 500 kbps has been used for the simulation. Throughput in SGP-NN can be improved with the help of the CH's power control. As a result of SMDFS's low computing time, latency is reduced, and throughput is improved.

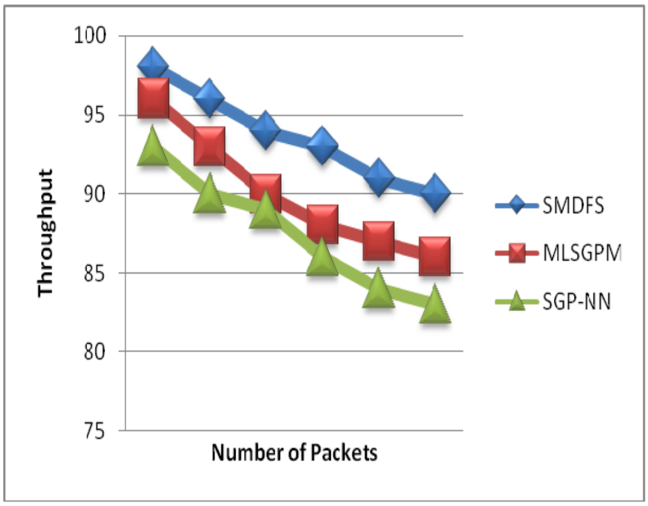

Figure 6. Throughput Graph.

5. Conclusions

The volume of multimedia data has grown steadily alongside the advent of the Internet, the widespread use of multimedia in modern society, and databases. In this paper, we present a new strategy for increasing the lifespan of networks by separating their multidimensional functional structures into clusters. Simulation results have been compared against MLSGPM & SGP-NN methods to see how well the proposed system selects cluster heads and backup nodes. We compare the MLSGPM & SGP-NN methods against the various QoS criteria, and draw some conclusions. We also examine and contrast the MLSGPM and SGP-NN methods for improving the lifespan of networks. The simulation findings show that the SMDFS strategy improves both the Network life time and quality of service of the WMSN network.

Author Contributions
All authors contributed equally, and all authors read and approved the final version of the paper.

Funding
No funding received from any organization.

Conflict of Interest Statement
Authors declare no conflict of interest.

Data Availability Statement
In this section, please provide details regarding where data supporting reported results can be found, including links to publicly archived datasets analyzed or generated during the study. Where no new data were created, or where data is unavailable due to privacy or ethical restrictions, a statement is still required.

Acknowledgment
The authors extend their gratitude for providing research facilities in their organization.

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