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Mobility aware multi-objective routing in wireless multimedia sensor network

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Abstract
The Quality of Service (QoS) and energy efficiency are the key issues for Future Internet. Targeting multiple objectives for efficient routing is a critical and demanding task in recent applications. Due to increase in mobility applications consideration of mobility parameters for dynamic routing is necessary. The objective of this research paper is to propose the multi-objective approach for dynamic routing in Wireless Multimedia Sensor Network. Extending the adaptive routing for mobility will definitely enhance the capabilities of routing protocols for Wireless Multimedia Sensor Network. In this paper, we propose the adaptive routing protocol which is considering mobility parameter during route establishment. We are using various parameters such as Remaining Energy, Hop count, Link Quality Index and Mobility Factor for path formation. The experimentation results show that mobility parameter extension improves network performance. The technique used in this paper will enrich applications for Internet of things (IoT).

Keywords Wireless multimedia sensor network · Wireless sensor network · IoT-internet of things · Multi-objective routing · Mobility aware routing · Energy aware routing

1 Introduction

Wireless Multimedia Sensor Network (WMSN) is combination of scalar node, multimedia node with and without mobility [4]. Very low cost multimedia devices are available in future internet applications are demanding dynamic protocols for various applications. The ubiquitous nature of applications in Internet of Things (IoT) required to make effective changes in the traditional routing protocols available for Wireless Sensor Network (WSN).

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The type of data transmitted through network makes big impact on efficiency of network - in terms of various parameters such as energy, lifetime, delay, packet loss and throughput. In recent years, very efficient routing protocols are available for addressing issues in WSN. The traditional routing protocols in WSN need some alterations to apply it to WMSN. The routing protocols in Wireless Sensor Network (WSN) are classified based on network structure and protocol operations [2]. Protocol operations are application specific e.g. multipath based, query based, QoS based, negotiation routing, etc.

WMSN contains of large multimedia information in form of image, audio and video. The multimedia information is heavy as compared to scalar data in sensor network. Large information, bandwidth demands and Quality of Service (QoS) requirements motivates the researcher to propose improved protocols for WMSN. WMSN has different types of information and mobility which differs it from WSN. Issues that affect the protocol designs of various WMSN applications are [1]:

- Energy consumption, Multimedia coverage
- Multimedia data processing capability
- Quality of Service requirements
- Bulky bandwidth requirement
- Multimedia information source coding techniques
- Integration with Internet architecture
- Integration with other wireless technologies

WMSN is useful for various modern applications such as Multimedia surveillance, Health care systems, Environmental monitoring, Intruder tracking services

and Industrial process control [1]. Adding an image or the video to the application will definitely improve the accuracy of information and also, reduce false alarms. The visual and audio information about the environment can be effectively used for surveillance and tracking applications. Disaster Management applications are commendably using camera node to give detailed information about the disaster events.

The single path transmission transmits through a single path from source to destination. For enhancing the Quality of Service and various other parameters routing through multiple paths is a suitable solution. Multiple paths routing scheme examines for multiple paths from source to destination. These multiple routes can be disjointing routes which outcomes in load balancing in the WMSN. Shifting the task of routing to multiple paths will distribute the workload of routing among multiple nodes. The advantages of finding multiple routes from source to destination are reduction in end to end delay, load balancing, reliability, application specific quality of service (QoS), improving the fault tolerance, etc. [12].

In WMSN data generated is in the form of audio, video and images. Sensor nodes are limited in terms of battery power, processing capability and storage capacity. For forwarding data towards destination in-network information processing is needed [7]. In [7] authors proposed data fusion for reducing the quantity of data for routing. In query based information routing instead of forwarding whole data only the selected information for the query is transmitted. Major difference between WSN and WMSN is the nature and volume of data transmitted over network. Hence it is very essential to develop energy efficient protocols.

This paper proposes multi-objective routing as a dynamic routing protocol. The main aim of paper is to propose generalized routing scheme, which will be well-suited for multiple modern applications. The proposed methodology is targeting to save energy to promote green communication for IoT (Internet of Things) applications with mobility awareness.

The rest of the paper is planned as follows. Section 2 discusses current literature related to routing in WSN and WMSN. Section 3 explores design objective and challenges. In section 4 we propose a novel method of routing for future internet. Section 5 describes the results achieved for single path and multipath routing. Section 6 defines conclusions and future work.

2 Literature analysis

To reduce the energy consumption in the network various techniques are proposed by the authors. These techniques ensure the data accuracy while collecting information in the network for variety of WSN applications [9]. Dynamic changes in WSN need support of multimedia aided services and mobility support [22]. Adding mobility to the nodes enhances the capability of WMSN for Internet of Things (IoT) applications.

The health monitoring services uses multimedia aided services to support the future network applications [22]. Volume of traffic generated is more and QoS requirements of WMSN are high, it is necessary to improve protocol performance for future applications. The protocols in current literature support multipath routing, but consideration of multiple parameters is important for dynamic environments.

Multipath non-interfering routing algorithm for balancing energy in the network is proposed in [14]. The proposed methodology separates the vicinity into multiple districts and a separate path is established from source to destination per district. The geographically node/link disjoint paths are formed. For information forwarding the greedy algorithm is used. It follows the dynamic decision making for path formation instead of the static fixed path. The implementation of GEAM (Geographical Energy-Aware non-interfering Multipath routing) gives improved results for real time environment. It also distributes load of the network equally and balances the energy consumption. For implementation the geographical awareness is necessary.

In the applications such as disaster management the quality of transmitted information plays an important role in communication. To transmit the information reliably the trust value is calculated by reading parameter values from neighboring nodes. The trust based model for neighbor selection for data transmission leads reliable data transmission. The cellular topology for formation of the cluster is used in EEQAR [15]. The quality of service assured routing is suitable for recent applications. The social network based analysis is used to calculate the trust value. It also uses data fusion to avoid redundant data transmissions to the neighbors in the network. The EEQAR is efficient in terms of improving lifetime of the WMSN.

Sensor nodes at remote locations have limited battery life. The energy issue is always of greatest interest for the researchers. Balancing the load of the network along all nodes will balance the energy utilization and also improves the lifespan of the network. In [17] authors proposed a model based on nodes remaining energy and routing load of the network. This protocol uses reactive approach for event based systems for multimedia routing. The routing scheme uses request and reply messages for communication. The destination sends the reply message towards source with selected path. The path establishment is done using remaining energy and active routes.

The implementation results shows improvement in throughput for multimedia information in LEAR approach.

The ant colony optimization is another efficient way to save the energy in the WMSN [8]. The audio and video information is critical in major future network applications. The AntSensNet [8] approach is extended version of ant colony optimization. It builds the hierarchical structure before path establishment. The hierarchy makes it easy to maintain QoS effective. To reduce video distortion packet scheduling scheme is implemented with multipath routing. to support multiple types of services the AntSensNet is more suitable.

Video Streaming based applications needs specific implementations as the QoS requirement for every application is different. Many routing protocols in WMSN give emphasis on video streaming methods for energy saving, as the video transmission is a major source of energy consumption in WMSN applications. In [16] authors proposed Geographic Energy-Aware Multipath Stream-based (GEAMS) protocol for reducing energy consumption using load balancing. Using two-fold policy it performs load balancing – 1) Smart greedy forwarding and, 2) Walking back forwarding. It also guarantees quality of service for multimedia data. This protocol requires Global Knowledge of the network and, the position awareness for implementation. The energy consideration is taken care for streaming data specifically. The history about packet forwarding is also taken care while routing the data towards neighboring node. The implementation shows that GEAMS results in improved lifetime of WMSN with QoS for video stream transmission.

Another type of geographical routing algorithm is TPGF [20] Two-Phase geographic Greedy Forwarding. During repeated executions it searches for shortest path for every run. It generates disjoint paths for transmission. It also performs hole bypassing in the network. Dynamic energy holes are created when nodes in specific area depletes their energy due to high energy consumption. Using multiple disjoint paths eliminates energy holes in the network.

In [10] Multi-objective routing algorithm is proposed. This algorithm takes into account the delay and the Expected Transmission count (ETX). The ETX metric is an estimation of expected total no of transmissions including retransmissions required to deliver the packet to the destination node successfully. This algorithm results in high throughput path. Satisfying multiple objectives enhances protocol efficiency for multiple applications.

In [10] authors proposed MEVI protocol to form the clusters and generates the cross layer routing scheme for network layer. The multiple paths are form from cluster head to the base station of the large scale network for reducing the energy consumption. The protocol performs efficiently for fire detection application. For large scale network the multi-hop communication is always efficient as compare to single-hop communication.

In WMSN the nodes can be static or mobile. The recent applications support mobile nodes along with mobile cluster head and base station. It also consists of mobile/static scalar nodes for recording environmental features [21]. Mobile Sensor Platforms (MSP) supports multimodal information forwarding along with mobility support. This comprises mobile multimedia sensor nodes.

As per demand of the applications in recent days, the role of the nodes changes in the Mobile Sensor Network [18]. The stationary nodes in the WMSN, controls the action or working mode of mobile embedded sensor nodes. The mobile nodes restricted vicinity mobile space for movement and capable of moving using self-mobility patterns. The other way is to collect information from all stationary nodes using the data mules. Data mules are the moving node for collecting data in vicinity. In sparse networks mobile nodes helps to maintain the coverage of the nodes for effective communication by adjusting their positions as per dynamic requirements.

Data gathering using mobile agents is an effective technic for modern applications [11]. The mobile agent's movement is schedules by the sink node to collect data from all static sensor nodes. The agent node moves from one sensing point to another and collects sensed data and forwards it to the sink node. To improve the energy utilization efficiency and video transmission quality opportunistic routing with multiple sink is one of the advanced approach [19]. By taking advantage of multiple sinks, the forwarding list candidate nodes that meet delay requirement can be selected.

In [13] authors discussed the various ways of saving energy while using static vs. mobile sink in WSN. Use of mobile sink will improve data gathering efficiency. The study shows that considering both maximum energy dissipation of a single node (Emax) and average energy dissipation over all nodes (Ebar) in energy analysis is important. It has also been observed adopting the mobile sink and reducing duty cycle does not essentially reduce the energy consumption. Careful selection of duty cycle value and the radius of the mobile sink is needed for effective energy saving.

The cluster based mobile sinks are often used in WSN. The clustering algorithms are proven energy efficient for modern applications. In [23] authors propose cluster based dynamic route adjustment using mobile sink. The particle swarm optimization based clustering [24, 25] also helps to improve performance in WSN in mobile environment.

As listed by many authors the future internet demands efficient transmission of high-quality multimedia information with maximum utilization of the network. Reducing energy consumption and delay for real time application is a key factor. To achieve this goal the dynamic multipath routing protocol for energy saving is required.

3 Design objective and challenges

As shown in fig. 1 the problem formulation and implementation include four important aspects:

a) Node mobility

Fig. 1 Implementation parameters for adaptive routing

Some nodes in the network are static and some are mobile. Mobile nodes are associated with values such as pause time and speed.

b) Hop count

No of nodes visited during path formation is an important measure for counting delay required to travel from source node to the destination.

c) Link Quality Index

In sensor network RSSI (Received Signal Strength Indicator) is used to decide the link quality. Higher the link quality value reduced the packet loss and improves the quality of transmission.

d) Remaining Energy of node

During data transmission if data is not emergency data then energy saving can be applied to the routing path discovery. Remaining energy of every node is sent to the source node to calculate the path value.

3.1 Problem formulation

The objective of our routing protocol is to implement the mobility aware multi-objective routing algorithm with achieving efficiency in terms of energy saving. In other words, we are implementing dynamic routing algorithm which aims to satisfy multiple objectives at run time.

3.2 Challenges

Occurrence of events and environmental changes make dynamic changes in the network. These dynamic changes create challenges in the pure static networks. Few of them are listed as [18]:

- Full coverage cannot be achieved through Initial deployment.
- For detecting and tracking objects more no of node are needed.
- The randomly deployed networks may get divided into small non connected networks. This may degrade the performance of the application.
- As sensor nodes are battery operated, these may deplete their energy after some time and energy holes may be created in the network. This will result in unconnected sensor field.

Adding mobility to the network expands the WMSN for IoT applications. If numbers of nodes in the network are less, then the available node can be relocated to cover the complete region. It will also help to remove the dynamic holes from the network. Addition of mobility has many benefits but it also adds some challenges to the protocol design.

The aim of this research paper is to suggest mobility aware adaptive routing for WMSN. Some of the design challenges for routing protocols in WMSN are [3]:

- Weakening of signal which results in increases packet loss. It also increases retransmissions in the network and reduces QoS.
- Frequent location updation results in change of path.

- Delay in Packet delivery increases with frequent route changes.
- Before actual communication the collection of information from neighboring node is needed. Neighbor discovery process introduces additional delay in communication of information.

4 Proposed methodology

This section outlines Mobility Aware Multi-objective Routing protocol for WMSN. This protocol works in two phases 1) Path Discovery Phase and 2) Packet Classification Phase.

4.1 Network architecture

As shown in fig. 2, it is assumed that the network consists of mobile and static nodes. It is a combination of multimedia and scalar sensor nodes. The static and mobile sink collects data from sensor nodes and forwards it to the network. Flat network architecture is assumed for implementation.

Various types of mobility can be applied to the network. Some of the mobility schemes are:

- Base Station Mobility
- Sink Node Mobility
- Sensor Node Mobility

Mobility models are applied to the individual node or to the group of nodes. Basic types of mobility models are [16]:

1) Entity / individual mobility models

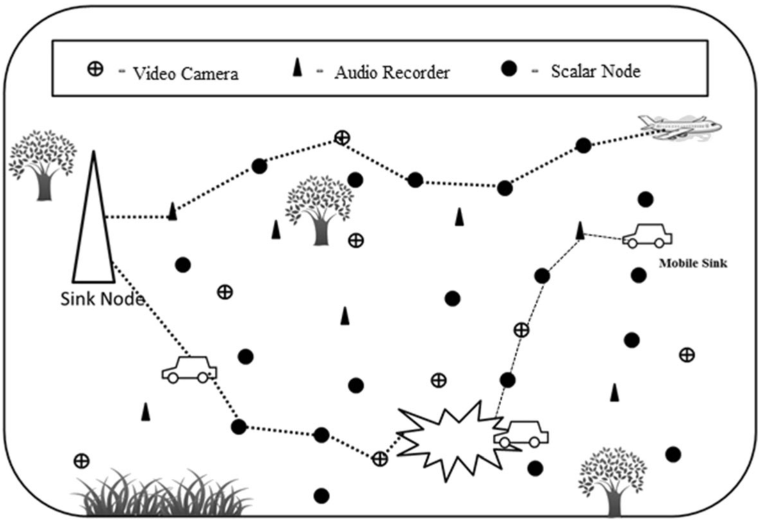

Fig. 2 Network architecture

- Random Waypoint
- Random Walk
- Random Direction

2) Group mobility models

- Geographic based
- Temporal based model

Reference point group mobility Figure 2 shows the network environment with video camera, audio recorder and scalar sensor nodes. These nodes are communicating to achieve specific task such as disaster handling, detection of fire in city/forest/building, battlefield monitoring, multimedia surveillance system. All these applications support event detection and monitoring, collection of periodic (hourly or daily) information and query-based communications.

For implementation, the Random Mobility Model is assumed for scalar sensor node and Sink node is assumed to be static.

In case of event detection, the information is forwarded to the sink in fast mode. Other information such as regular monitoring data values and query based information can be sent via energy efficient and quality paths respectively.

4.2 Path discovery phase

As shown in Fig. 3, the first step is random deployment of the nodes. As few nodes are having mobility, the network topology changes with the deployment. Using

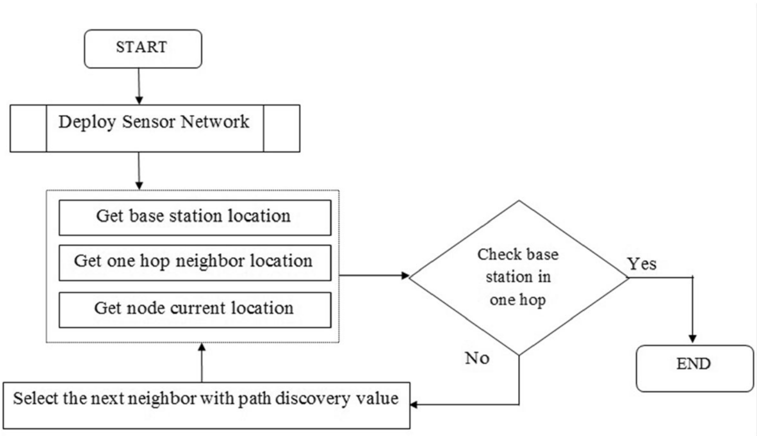

Fig. 3 Phase 1- Path discovery

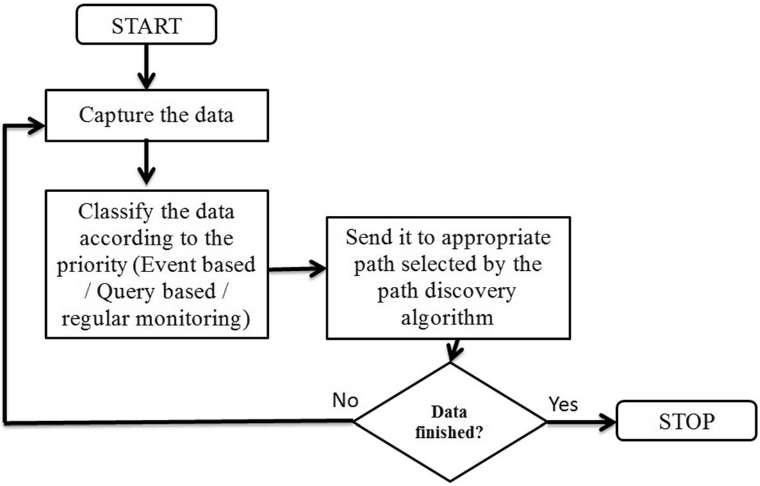

Fig. 4 Phase 2: Packet classification

history for path formation may have some drawbacks. A dynamic protocol for route formation is needed. Each node collecting the information from the environment initiates the path discovery process after collecting information from neighboring nodes:

a) Base station location information
b) Neighbor discovery
c) Nodes current location

Once data collection from neighboring node is carried out then the parameter values such as LQI, remaining energy and number of nodes travelled are collected from the nearby nodes.

It is also checked whether the destination node is reached or not. If not reached up to destination node then path discovery process is executed.

Using the parameters and path discovery scheme the three routes are established as:

1. Route with reduced Energy Consumption
2. Route with reduced delay
3. Route with high packet delivery ratio

Above mentioned paths extends the applications of WMSN and enables us to implement traffic aware routing scheme. For emergency services the fastest route is selected. For regular monitoring purpose the route with reduced energy consumption is used. For query based information applications the route with high QoS is used for communication. This allows us to explore path as per application requirement.

Algorithm: *Path Discovery Scheme*

Input: *Neighboring node information*

- *Er – Remaining energy,*
- *Hop_cnt – no of nodes unvisited,*
- *LQI- Link Quality Index,*
- *PT- Pause Time*

Outcome: *Prioritized paths*

Step 1: *Start*

Step 2: *Get base station location, one hop neighbor parameters, nodes current location.*

Step 3:

a) *Assign values to the probability factors – α, β, γ as per required priorities to the parameters of neighboring node.*

b) *Calculate $Node_{val}$ using probability distribution and neighboring node parameters using following equation:*

$$Node_{val} = \left(\alpha * \frac{Er}{Ei}\right) + \left(\beta * \frac{curLQ}{maxLQ}\right) + \left(\gamma * \frac{totHC - curHC}{totHC}\right)$$

c) *M_f is calculated as ratio of remaining pause time and total pause time as:*

$$\frac{PTr}{totPT}$$

d) *Path Discovery Value calculation:*

$$PD_{val} = Node\_val * Mf$$

e) *Packets in traffic are classification using traffic classification scheme.*

f) *Initiates information forwarding to the nominated adjacent nodes.*

Step 4: *Repeat step 3 until data reaches to the destination.*

Step 5: *Stop.*

Once the data is forwarded to the next node same procedure is repeated until it reaches to the destination. This facilitates the dynamic plan for routing. If we compare this methodology with static routing dynamic routing gives better results in recent application and it is more suitable for IoT applications.

4.3 Packet classification phase

As shown in Fig. 4 once paths are available for transmission the traffic towards the path is classified.

In [5] authors proposed the traffic classification scheme for future internet. The dynamic requirement of application and the network is taken into consideration during the classification process. The classes of traffic considered for the proposed scheme are:

a) Traffic generated by occurance of event.

b) Traffic generated by query from the sink node.

c) Traffic generated due to scheduled monitoring of sensitive area.

As per discussion in previos phase, the path discovery scheme produces three different routes. The three different routes are used by three different types of packets:

1. The traffic generated by occurance of event uses the path with reduced delay for fastest processing.
2. The traffic generated by query from the sink node follows the path with high packet delivery ratio.
3. The traffic generated due to scheduled monitoring of sensitive area follows path with reduced energy consumption and leads to improved lifetime.

Algorithm: *Traffic Classification Scheme*
Input: *Sensed information*
Outcome: *Classified packets*

Step 1: *Start*
Step 2: *Sense the information from environment and mark the code of the packet for its identification.*
Step 3: *Classify the packets using the contents as below:*

If information generated for Regular Monitoring traffic.
Packet Code = 1.
If information generated for Event based traffic.
Packet Code = 2.
If information generated for Query based traffic.
Packet Code = 3.

Step 4: *Apply path discovery scheme and calculatet Nodeval.*
Step 5: *Forward the information as per Packet code assigned to the respective path.*
Step 6: *If more data go to Step 2.*
Step7: *Stop.*

As shown in Fig. 5 the node which generates the data / receives data for transmission first performs path discovery and then packets are classified by the classifier. The scheduler directs the traffic to the appropriate paths and then the information is forwarded. Uses of multiple paths improve speed of communication and balance the energy consumption. Every path satisfies one objective for data transmission.

4.4 Mathematical problem formulation

4.4.1 Assumption and notations

The notation and terminology used is borrowed from [26]. A Wireless Multimedia Sensor Network (WMSN) can be represented by a connected graph ***G (V, E)*** where ***V*** is the set of vertices representing scalar node / multimedia node and **E** is the set of edges representing connecting bidirectional links between the nodes.

Each edge $e = u \rightarrow v$ is associated with k independent weights.

Where, $\omega_l(e) > 0$; $\omega_l(e) \in$ **E and** $1 \leq l \leq k$.

For each path $p = v1 \rightarrow v2 \rightarrow v3 \ldots\ldots v_n$,

$$\omega l(e) = \sum_{i=0}^{n} \omega_l (v_{i-1} \rightarrow v_i) \tag{1}$$

Path constraints (considered for proposed methodology) can be listed as:

- **Energy:** Low energy consumption path is expected for periodic monitoring of environment using WMSN.
- **Delay:** For faster response in event based communication / disaster management, path with minimum delay is required.
- **Link Quality:** Reducing the packet loss is needed for query based communication in WMSN. High link quality leads to the lower packet loss.

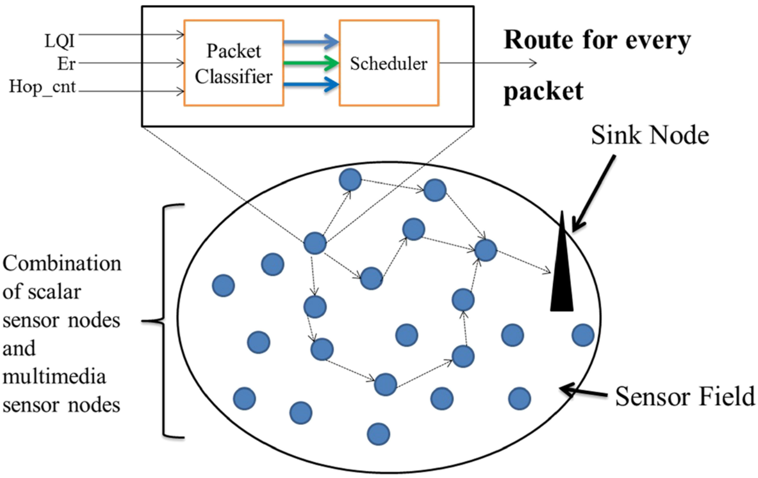

Fig. 5 Dynamic routing environment

4.4.2 Objective functions

The aim of the implementation is to calculate Path Discovery value (*PDval*) and minimize the following metrics: Energy Consumption, Delay, Packet loss.

Path discovery value calculation The Path Discovery value is calculated using eq. 2 using remaining energy value, link quality index value and the count of number of nodes travelled by the packet value. The probability distribution is used for deciding values of parameters α, β and γ. The values for probability parameters are based on investigation done in [6].

$$\boldsymbol{Node_{val}} = \boldsymbol{F1} + \boldsymbol{F2} + \boldsymbol{F3} \tag{2}$$

Where,

$$0 \le Node_{val} \le 1 \qquad and \quad \alpha + \beta + \gamma = 1$$

$$F1 = \alpha^* \frac{Er}{Ei}$$

$$F2 = \beta^* \frac{curLQ}{maxLQ}$$

$$F3 = \gamma^* \ \frac{totHC - curHC}{totHC}$$

Ei	*initial Energy of node*
Er	*Residual Energy of node*
curLQ	*current Link Quality of node*
maxLQ	*maximum Link Quality of node*
totHC	*total hop count*
curHC	*current hope count of node*

The probability factors α, β and γ are assigned values based upon the requirement of application and the nature of the protocol [6, 10].

The α is used for assigning priority to energy saving. The β is used for assigning priority to the quality of service of data transmission. The γ is used for improving speed of transmission. The dynamic approach of the protocol is set by the values assigned to the probability factors. Equation (2) is dynamically is used to calculate the node value. Same equation with different probability values can be used for numerous scenarios and applications. The eq. (3) adds the mobility factor to the node value which increases the reliability of the data transmission and makes it compatible for mobile node applications.

Mobility factor Node moves in vicinity for data collection and communication. The performance of the network changes due to mobility. Parameters which affects the mobility of the node for routing protocols are:

- Present position of node
- Motion speed.
- Pause time of the node.
- Range of the node.

- Link Quality Index.
- Remaining Energy of node.
- Mobility model used.

In our methodology the Mobility Parameter "Pause time of the node" is taken into consideration. The pause time is the time during which the node position is fixed for *totPT* duration. The mobility factor is useful for finding the probability value for node presence at a fixed location. This value can be used for finding the next neighbor based on its mobility value. The remaining pause time value will help to make decision about whether to start the data transmission or some other node is more suitable for transmission. If remaining pause time value is greater than the required transmission duration, then data transmission will not result in data loss and retransmissions. If remaining pause time is less than required transmission time, then it is not suitable to start the transmission as retransmission may take place after data loss. The mobility factor is calculated as ration of remaining pause time to the total pause time. This value is merged to the node value during path discovery process.

$$\textbf{\textit{Mobility factor}}\ (\textbf{\textit{Mf}}) = \frac{\textbf{\textit{PTr}}}{\textbf{\textit{totPT}}} \tag{3}$$

Where,

Mf	*Mobility Factor.*
PTr	*Remaining Pause time.*
totPT	*Total Pause Time.*

$$\textbf{\textit{Path Discovery value}}\ (\textbf{\textit{PDval}}) = \textbf{\textit{Node}}_{\textbf{\textit{val}}} * \textbf{\textit{Mf}} \tag{4}$$

As given in eq. 4, the product of node value and mobility factor selects the neighboring node which has longest pause time for communication. This selection leads to the selecting the node with highest stable from list of neighbors in terms of mobility.

Energy consumption calculation Ubiquitous computing demands high energy devices in future internet for modern applications. To establish the energy efficient path the remaining energy of every node is considered for calculation of path value.

The average energy (ENR_{Avg}) consumption can be given as:

$$\textbf{\textit{ENR}}_{\textbf{\textit{Avg}}} = \sum_{j=0}^{m} \left(\textbf{\textit{ENR\_con}}_{\textbf{\textit{j}}}\right) \tag{5}$$

Where,

ENR_{Avg}	*Average energy consumption of the network.*
ENR_con_j	*Energy consumption at node j.*
m	*Number of nodes in the network.*

Delay Reducing delay for interactive applications is very important. In WMSN for real time applications the delay plays an important role. Delay is calculated as addition of various types of delays in the network. In networks several types of delays are present such as transmission delay, processing delay, queuing delay and propagation delay.

In our implementation we have calculated delay based on no of nodes visited by the path.

$$d_{total} = \sum_{j=0}^{k} \left(delay_j \right) \tag{6}$$

Where,

k	Total no of nodes in established path.
$Delay_j$	delay at node j.
d_{total}	total amount of delay at established route.

Packet loss There are many applications in WMSN which need information based on query. Here the loss of packets is not tolerated due to importance of information. To reduce the packet loss rate the LQI is used. The value of LQI ranges from 0 to 255. The packet header contains information about the LQI through RSSI (Received Signal Strength Indicator). The node intended to transmit data calculate the LQI value as given in eq. (2).

5 Simulation and results

Experimentation is carried out in NS-2 to understand the effect of single-path routing and multipath routing. The experimentation includes heterogeneous nodes in the network. The networks represent Wireless Multimedia sensor network by including multimedia nodes along with scalar nodes. Table 1 illustrates the details of simulation parameters used for simulation environment.

Following cases are evaluated during implementation.

Case 1: Implementation of routing algorithm without including the mobility factor (using eq. (2)) for calculating the path value.

Case 2: Implementation of routing algorithm without including the mobility factor (using eq. (4)) for calculating the path value.

Packet delivery ratio (PDR) It is a ratio of the received no of packets vs. packets generated at source. Typically PDR is measured in packets per second. This parameter is used to evaluate the performance in terms of packets received vs. packets sent during the simulation periode. The values shown in the graph are calculated in percentage (%).

Table 1 Simulation parameters

Name of Parameter	Value
Type of data traffic	*Constant Bit Rate*
Packet generation rate	*5 packets per second*
Size of simulation area	*500 m × 500 m*
MAC protocol	*802.11*
Initial energy	*100 J*
Data rate	*10 Mbps*
number of nodes in the network	*100,110,120,130,140*

We have done experimentation to check the effect of mobility factor for packet delivery ratio (PDR). The results in Fig. 6 shows that methodology with considering mobility factor gives better result as compare to methodology without considering mobility factor in terms of packet delivery ratio (PDR). When selected neighbor is stable during complete data transmission, it reduces possibility of dropping the packets due to mobility. Figure 6 illustrates the 20% improvement in percentage of packets delivered during the simulation period when mobility factor is considered for routing scheme.

Delay Delay is calculated as summation of processing delay, propagation delay and processing delay. It is calculated in milliseconds (ms).

If we are not considering movement of a node while routing, this is definitely going to affect the delay of the network. If we are forwarding the data to a particular node and that node is immediately changing the position will increase the risk of delay and retransmissions in the network.

Figure 7 shows the delay is increasing in case we are not considering the mobility factor. The main reason of delay reduction in proposed routing algorithm is reduction in duration of retransmissions and location discovery process. We have achieved.

Remaining energy The remaining energy is the amount of energy balance at the node (Joules per second). The initial energy is assigned as 100 joules. When communication is initiated the energy is reduced as per work done by the node in the network for receipt and transmission of information.

As per results in Fig. 8 the remaining energy of the system is more in case 2, we are considering the mobility factor (pause time). If we know in advance what is a duration for which the node will be at fixed position and then forwarding data to the destination then complexity of implementation is reduced. Increase in complexity of algorithm will increase energy consumption. Lesser the complexity of algorithm less

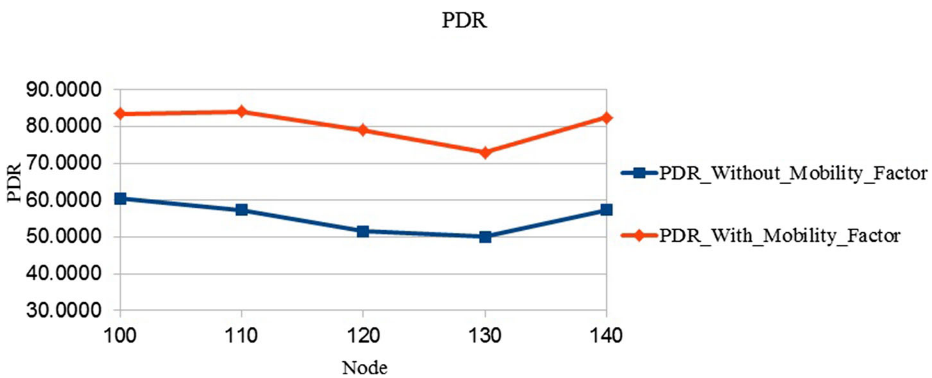

Fig. 6 Packet delivery ratio (%) for Case1 and Case2

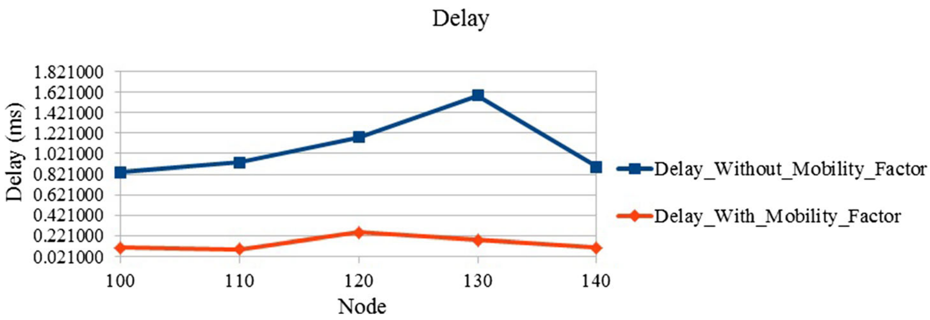

Fig. 7 Delay for case1 and case2

energy will consume. Reduction in energy consumption will increase the lifetime of network.

6 Conclusion and future work

Mobility awareness is a crucial issue for any routing algorithm for future internet applications. We have proposed the Mobility Aware Multi-objective Routing for WMSN. In WMSN the heavy traffic of multimodal data need to be transfer during routing. Selecting the node which will be at fixed position for longest duration is a key idea for implementation. Along with the mobility parameter hop count, remaining energy and link quality is also considered. Results shows that consideration of the pause time as mobility parameter is increasing the network performance in terms of packet loss, delay and average remaining energy. Retaining maximum energy during routing will leads to increase in lifetime of the network. Considering mobility factor for routing protocol will extent the applications of Wireless Multimedia Sensor Networks for the Internet of Things (IoT) environments.

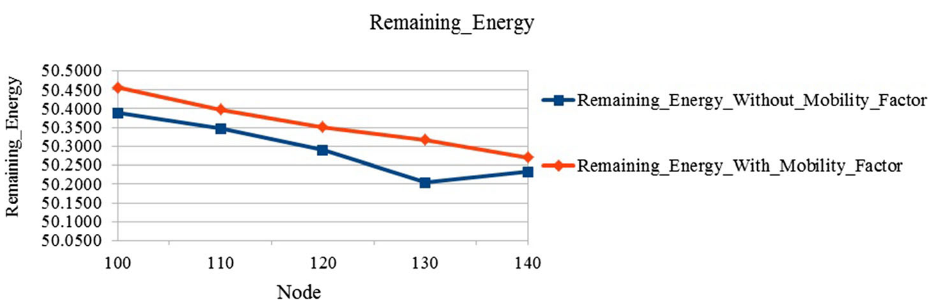

Fig. 8 Remaining energy for case 1 and case 2

In future the experimentation can be done for multimedia enabled smart vehicles. This methodology is suitable for applications such as vehicular technology, disaster management and many more. For applications such as battlefield monitoring and control adaptive sleep scheduling can also be added to save energy of camera nodes.

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