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A Secured Multipath Routing Technique for Wireless Multimedia Sensor Networks

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Abstract
Wireless Multimedia Sensor Networks becomes quite popular for transmitting and accepting image, audio and video files between the communicating devices. The Wireless Multimedia Sensor devices send the multimedia information in a unified path which creates high latency that lowers the performance of the communication network. Latency in data transmission and reception between the communicating devices in the Wireless Multimedia Sensor Networks could be reduced by exhibiting multipath routing mechanism. This work incorporates a security enhanced multipath routing protocol which exhibits improvement in Quality of Service with a reduced latency and high level of security in Wireless Multimedia Sensor Networks communication. The security of the proposed multi path routing process is secured by Location Secured Algorithm (LSA) using Secured Hash Algorithm (SHA-256). The analysis of our proposed method is compared with the existing multipath algorithms and proves that our technique exhibits a reduction of traffic delay by 6% than the existing algorithms and provides rigid security against malicious attacks.

Key words: wireless multimedia sensor network, multipath routing, quality of service, security, Triangular Quality Metric Multipath Routing Protocol (TQM2RP), traffic delay.

I. Introduction

The development of electronic sensors and its interconnectivity over wireless medium had facilitated varieties of applications in the domain of telecommunication engineering. The evolution of Wireless Sensor Networks (WSN) [1] [2] had facilitates the process of measuring and monitoring the critical activities with the deployment of electronic sensors in the concentrated areas. The developments in WSN facilitates the transfer of multimedia files like digital image, video and audio files from one place to another, specifically from the measurement cluster area to the base station that brings about Wireless Multimedia Sensor Networks (WMSN) [3]. The communication of Multimedia files from one location to another finds broad range of usecases in surveillance that could be extended to multiple applications like patient health care observation system, land monitoring remote sensing process, monitoring of land hazards etc. The electronic sensors employed in the Wireless Multimedia Sensor Networks (WMSN) experiences various concerns which were classified into sensor concern and routing concern. The sensor concerns of the WMSN deals with the energy conservation [4] of the sensor in the course of multimedia information transfer, leading to dead sensors due to drain of sensor energy. Apart from the sensor concern, the routing in WMSN is the major challenge that the sensor is related to the routing efficiency and security aspect [5]. The data forwarding in WMSN may be performed in dual methods namely uni-path routing and multipath routing [6] mechanism. The unipath routing of multimedia data through the neighboring sensors towards the Cluster Head involves critical tasks of identifying shortest path to achieve a high level of routing efficiency and poor traffic oad balancing. The unipath routing consumes huge power of the routing sensors which thwart the energy level of the routing sensors. To prevent these pitfalls in the unipath routing mechanism, this research paper proposes a multi path routing protocol for forwarding

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multimedia files from sender node to the Cluster Head [7] via multiple path with an aim to achieve the following objectives. The proposed method aims to achieve better traffic load management in WMSN by transferring multimedia data packets through multiple paths. The data packets transferred via multipath routing mechanism possess reduced overhead as it incorporates only the sender and receiver address along with packet number, thus the proposed method targetss to reduce the end to end transfer delay. The multipath routing mechanism also intents to improve routing efficiency and better energy consumption [8] among the neighbor sensor nodes. The multipath routing mechanism plans to provide greater level of security [9] [10] to the multimedia information transferred like data is transferred as multiple modules. The diagrammatic representation of the multipath routing mechanism in WMSN is presented in Figure 1.

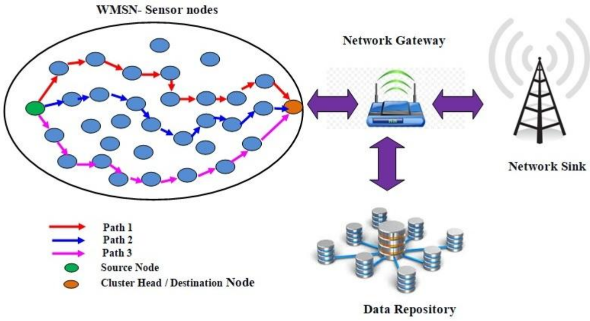

Figure 1: Architecture of WMSN with Multipath Routing

Figure 1 illustrates the multimedia data transmission in WMSN using multipath routing protocol. The multimedia data is partitioned into multiple packets and is transferred into multiple paths such that to provide the aforementioned objective of providing efficient traffic load balancing and security [11] such that a better Quality of Service (QoS) [12] will be achieved. The QoS efficient Wireless Multimedia Sensor Networks can be designed by performing secured multipath routing mechanism. The multipath routing mechanism reduces the packet delivery overhead hence leads to reduction in delay and provides high level security [13] as the intermediate malicious node may gain access only to a part of the data which will be secured by implementing hash functions. This research work concentrates on providing efficient QoS in the routing process of multimedia data in WMSN. Our research work is aimed to design an QoS efficient multipath routing protocol, Triangular Quality Metric Multipath Routing Protocol (TQM2RP) to perform efficient traffic load balancing, and reduced delay. The proposed work provides enhanced security level for transmitting multimedia data packets using Location Security Algorithm (LSA) using SHA-256 algorithm.

This research article is preceded by illustrating the Literature Review in Section 2 and a detailed illustration of proposed methodology in Section 3. The experimental results and the analysis are presented in Section 4 and Section 5 presents the concluding remarks.

2. Literature Review

The contribution of researchers is more in the evolution of the WSN and had introduced various efficient algorithms in improving the Quality of Service (QoS). The existing algorithms were highly concentrating on the unipath routing protocols which fails to provide a proper balancing of traffic data in the sensor nodes. The routing of entire packets through a common path creates multiple concerns like poor balancing of traffic loads, high consumption of energy which leads to the drain of energy thus creating more dead nodes. The dead nodes are irresponsive, leading to a situation of identifying alternate path for transferring the rest of the multimedia files. In this section, a brief narration of previous research results were introduced and the motivation of the proposed research work is defined.

Liu et al. (2015) had proposed an enhanced method to improve the energy conservation of Wireless Sensor nodes using Straight Line Routing [14] methodology. The Straight line Routing is a routing method with two hop information without any necessity for geographic information of the placement of sensor nodes. The performance analysis yields better results than the existing methodologies in terms of energy conservation. Wang et al. (2014) had designed a pair wise directional geographical routing scheme (PWDGR) [15] to perform effective routing in WMSN. The proposed method addresses the bottleneck concern that rises in the routing mechanism of WMSN. The author designed the PWDGR protocol in such a way that the pair wise nodes are identified equally in a 360° scope near cluster head or sink node in WMSN. The analysis of the proposed method yields 70% prolonged life time for the sensors when compared to the existing protocols. Liu et al. (2019) had presented an energy efficient and traffic load balancing framework [16] for WSN. The author proposed the method in such way to charge the sensor nodes with a preferable charging path to balance the total power of the sensor nodes. The experimental results of the proposed framework with the existing methods prove that the proposed framework exhibits better energy conservations. Amjad et al. (2017) discussed a QoS aware and heterogeneously cluster routing protocol [17] to obtain an efficient QoS in WMSN. The proposed QHCR protocol preserves the battery usage of sensor nodes and has effective bandwidth utilization.

Hasan et al. (2017) had proposed a mathematical modeling [18] for introducing a novel enhancing QoS in WSN. The proposed method satisfied the requirement of QoS and is applied for many usecases that leads real time sensitive routing process. The analysis of the proposed method exhibits better packet delivery ratio with moderate end to latency. Atto et al. (2020) had proposed a novel method to improve the effectiveness of the AODV protocol [19] by mitigating the bottleneck concern in WSN. The AODV protocol improvises the quality of the multimedia image transferred from one node to another and reduces the end to end delay and the network overhead. Shah et al. (2012) had proposed a framework [20] to improve the capacity of the Wireless Sensor Networks with an objective to enhance the video sources with QoS constraints. The author implemented Qyner Ziv lossy distributed source coding to perform the multipath routing process. The simulation result proves that the framework permits large quantity of the video sources in a distortion constraint. Deepak et al (2020) had designed a hybrid secured routing and monitoring system in the IoT based WSN. The author employed Two Fish (TF) systematic key approach and the Authentication Encryption Model (ATE) and Eligibility Weight Function (EWF) [21] to form a hybrid protocol for monitoring the sensor nodes. The proposed method is tested against multiple types of adversaries and proved to be rigid against all sorts of attacks.

Deepa et al (2020) had proposed an optimized QoS based clustering mechanism to perform multipath routing mechanism in WSN. The author designed Optimized QoS based clustering with Multipath Routing Protocol (OQoS-CMRP) [22] to reduce the consumption of energy by the sensor nodes in WSN. The sink coverage was increased by employing the Modified Particle Swarm Optimization (MPSO) to perform clustering of sensor nodes. From the literature, it is understood that most of the existing methodologies concentrates on unipath routing methodology as it involves simple routing mechanism and does not involve packet assembling process at the cluster head and also at destination node. The unipath routing mechanism increases the traffic load on the individual node, thus consumes more energy leading to increased quantity of dead sensor nodes. The unipath routing exhibits reduced level of Quality of Service in terms of increased end to end delay and reduction of throughput. The security aspect in the unipath routing mechanism is highly vulnerable due to existence of malicious nodes, which tends to acquire the entire multimedia file pretending to be a genuine node in the routing path.

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3. Proposed Methodology

The proposed methodology of enhanced QoS multipath routing protocol with enhanced security is two folded. The first fold relates to the introduction of novel multipath protocol named Triangular Quality Metric Multipath Routing Protocol (TQM2RP) for performing energy efficient and improvised QoS multipath routing protocol which is preceded by the second fold of adding security feature to the multiple data packets using Location Security Algorithm (LSA) using Secured Hash Algorithm (SHA-256).

3.1 QoS efficient Triangular Quality Metric Multipath Routing Protocol (TQM2RP):

The proposed Triangular Quality Metric Multipath Routing Protocol (TQM2RP) is the protocol that relies on the basic metrics of Signal to Noise Ratio (SNR), Link Quality Indicator (LQI), Packet Perception Ratio (PPR), and estimation of Wireless Link Quality (WLQ). SNR is the metric used to compute the quality of the received signal which is generally expressed in decibel difference among the strength of the received signal to the noisy content in it. LQI is a measure of quality of received multimedia signal in the destination node. The high values of LQI indicate a good quality of multimedia image and the low value of LQI denotes the poor quality of the received multimedia file. PPR is a metric to indicate the ratio of received multimedia packets to the total no. of packets transmitted by source node. The final characteristic of the Triangular Quality Metric Multipath Routing Protocol is the estimation of Wireless Link Quality. The wireless link quality measures the energy consumed and the aforementioned parameters of SNR, LQI, and PRR.

The proposed TQM2RP integrates all the aforementioned quantities of WSN. The illustration of triangular quality metric is measured by determining the SNR and the LQI for the received "n" multimedia packet. The SNR and the LQI can be mathematically expressed as in equation 1 and 2 respectively.

$$SNR = \frac{\sum_{n=1}^{m} SNR_n}{N} \quad (1)$$

$$LQI = \frac{\sum_{n=1}^{m} LQI_n}{N} \quad (2)$$

The routing weightage function is employed in WSN to find out the optimal path to transfer multimedia data. Considering any two neighboring nodes at a distance "d" between any two nodes with the coordinate systems (x_i, y_i) and (x_j, y_j) can be determined using the equation 3.

$$d_{i,j} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \quad (3)$$

The weightage of the link connecting any two neighbor nodes is estimated by the weightage estimation equation as represented in equation 4.

$$Weightage\ (W_{i,j}) = (d_{j,sink})^{\alpha} \times (TQM_{i\to j})^{\beta} \times (RE_j)^{\gamma} \quad (4)$$

Where,

- $W_{i,j}$ is the weightage between any two neighboring nodes
- $d_{j,sink}$ is the distance between the destination node and the sink node determined using equation 3.
- $TQM_{i\to j}$ is the Triangular Quality Metric between the source node and destination node.
- RE_j is the Residual energy left at the node "j" after the multimedia data transmission.
- α, β and ϒ are the constants for which the values are randomly chosen to satisfy the equation 5. Such that α = 0.4; β = 0.3; and ϒ = 0.3 respectively.

$$\alpha(0.4) + \beta(0.3) + \gamma(0.3) = k(1) \quad (5)$$

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The deployed sensor nodes in WMSN possess similar characteristics except the sink node, which will be deployed with energy back up facility. The sink node would attain no energy restrictions because of continuous energy supplied. The source node communicates the multimedia files to the sink node through neighboring nodes by performing single hop from one node to another node. The node specifications are illustrated in Table 1.

Table 1: Parameters considered in WMSN

WMSN parameters	Specifications
Total Coverage Area	250m X 250m
Total Nodes	200
Source Node	1
Sink Node	1
Transmitting Antenna	Omni-Directional
Traffic Mode	CBR
Payload size	100 bytes
Initial Energy of Nodes	100J
Simulation Duration	1000 seconds
RE_T	65mW
Power Consumption	61.03mW

The nodes deployed in the WMSN will move to active states once it is deployed and find itself to be in any of the following states namely, "FREE" state which indicates that the node is free to transmit the multimedia file and to form a propagating path for transmission. The "OCCUPIED" state mentions that the node is busy in data transmission and cannot be included in the propagation path temporarily. The "DEAD" state indicates that the node has drain all its energy and is considered to be the dead node. The process flow of the proposed multipath routing protocol is pictorially represented in Figure 2.

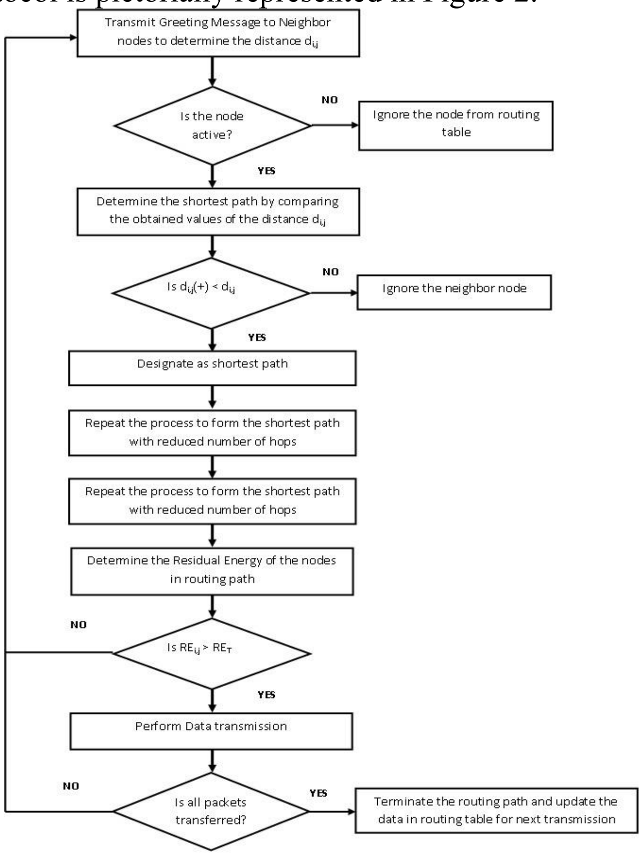

Figure 2: Process flow diagram of proposed Multipath Routing Protocol

The TQM2RP is composed of three phases namely:

- Neighbor Node Identification Phase
- Route Recovery Phase
- Route Maintenance Phase

3.1.1 Neighbor Node Identification Phase:

The neighbor node identification phase is the process of identifying the surrounding nodes of the source node which are located in the coverage range from source node. The neighbor node must be able to reach at a single hop from the source node [n(i)] and the immediate neighbor node is designated as [n(i+1)]. The identification of neighbor node is performed by sending "Hello" message to determine the number of hops from the source node and to determine the residual energy of the neighbor nodes. The source node determines SNR and LQI by transmitting the hello message and collecting the "RESPONSE" information from the neighbor node. The fitness value of each node is determined such that the node is capable of transmitting the multimedia files and to determine the residual energy of the node. The fitness value of the node is determined using equation 6.

$$Fitness: f(n) = \begin{cases} \frac{1}{1+f(n)}; f(x) > 0 \\ 1 + |f(n)|; f(x) < 0 \end{cases} \quad (6)$$

The procedure involved in identifying the neighbor node is expressed in Table 2.

Table 2: Neighbor node determination

Algorithm 1- Pseudocode to determine Neighbor node

Transmit HELLO message to all nodes with ID_i, RE_i, coordinates $i(x_i, y_i)$ $\sum_{i=1}^{N} n_i$
    If the previous observation duration T(i-1)<T(i)
    Then
Relay Hello packet
Set Time out duration
    end if
end
Receive Response message ($node_{i+1}$, $Hello_i$)
    If the present observation time T(i)>T(i+1)
Extract the parameters [ID_{i+1}, RE_{i+1}, $SNR_{i,\ i+1}$, $LQI_{i,\ i+1}$
Update the Routing Table [Ref.Table 3]
    end if
  end
Determine the Triangular Quality Metric for the node ID_{i+1} and designate as $TQM_{i,i+1}$
end phase process

3.1.2 Route Discovery Phase:

The route discovery phase is the preceding phase of the neighbor node identification phase, in which the state of the node is discovered and is classified under any of the three states namely free state, occupied state and dead state. The node active status is determined by computing the residual energy of the neighbor node. When the residual energy of the neighbor node is less the threshold value of residual energy, then the node will be designated as the "DEAD" node and will not get included in the routing table even though it possess the shortest path from source node. The routing path is discovered by forwarding a Path Request (PREQ) message from the source node to the immediate neighbor node. The PREQ message is responded by the neighbor node with a Path Response (PRES) message as depicted in Figure 3.

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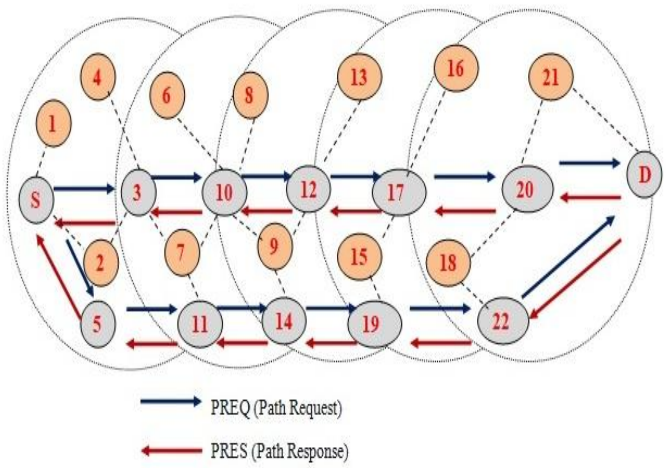

Figure 3: Formation of Multipath in Wireless Multimedia Sensor Networks

From the Figure 3, the source node (S) sends the PREQ message to the node 3 and the path extends in the sequence of (S-3-10-12-17-20-D) while the other path extends in the sequence of (S-5-11-14-19-22-D). The other nodes highlighted in red color are neighbor nodes with longest path or may not have sufficient residual energy (RE) to transfer the multimedia files. The initial path is discovered by determining the optimized and shortest path along with the computation of residual energy of the sensor nodes. The routing table for the sample multipath wireless multimedia sensor network is depicted in Table 3.

Table 3: TQM2RP Routing Table

Source Node Routing Table			
Source Node	**Neighbor Node**	**Hops to reach Sink node**	**Path ID**
S	3	7	1
S	5	6	2
Intermediate Routing Database			
Inter Node	**Neighbor Node**	**Hops to reach Sink node**	**Path ID**
3	10	5	1
10	12	4	1
12	17	3	1
17	20	2	1
20	D	1	1
5	11	5	2
11	14	4	2
14	19	3	2
19	22	2	2
22	D	1	2

The formation of first routing path is followed by the formation of subsequent routing path by identifying the node which is at Free State and with the second shortest path compared to the previous one. The path request and path response procedures are illustrated in Table 4 and Table 5 sequentially.

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Table 4: Pseudocode to path request (PREQ) procedure

Algorithm 2- Pseudocode to path request (PREQ) procedure
Process Path Request (Node$_i$, Node$_s$, PREQ)
if hop count to reach N_S from N_i = 1, then
Update sink node N_S as single hop neighbor
Set node N_S as the OCCUPIED state.
else
Determine the link weightage between N_i and N_S using equation 4.
Send PREQ message to the lowest weightage node
Set Node N_{i+1} as the OCCUPIED state.
else
Send PREQ message to sink node N_S
Set Source node N_i as the OCCUPIED state.
end if
end process

Table 5: Pseudocode to path response (PRES) procedure

Algorithm 3- Pseudocode to path response (PRES) procedure
Process Path Response (N_S, N_i, PRES)
if hop count to reach N_S from N_i = 1, then
Update path exists
Set node N_i as the OCCUPIED state.
end if
if (N_S = = 1 hop && path weightage <1), then
Set sink node N_S=1
end if
if ($N_S \neq$ 1 hop && path weightage >1), then
Send PRES message to neighbor node N_{i+1}
Send PRES message from N_{i+1} to source node N_i
end if
end process

Once the path request message is responded with the path response message from sink node (N_S), the source node (N_i) establishes multiple paths for sending the multimedia data packets.

3.1.3 Route Maintenance Phase:

The final phase of TQM2RP is the route maintenance phase, in which the multimedia data is sent by source node to the sink node through multiple routing path based on the established routing table. During the transmission of multimedia data through multiple paths, a node may exhaust its entire residual energy and may migrate its state from occupied node to dead node thus leading to the breaking of routing path. The source node is acquainted with the link break and it tends to forward its successive data packets through the broken link which proportionately reduces the throughput of the system. To mitigate this pitfall, the proposed TQM2RP protocol sends an alert message to source node regarding the link breakage and the alert message is termed as BALERT (Break Alert) message. The BALERT is the backward message which will be transferred from the dead node to the source node. To understand this scenario, let us assume the path 1 from the Figure 3 which flows in a sequential order of (S-3-10-12-17-20-D). In this path, consider the node 17 (N_{17}) had drained up shortly, hence the node 17 (N_{17}) sends a break alert (BALERT) message in the backward direction. That is from node 17 to node 12, then node 12 to node 10, followed by node 10 to node 3 and finally node

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3 to source node (N_i). The intermediate nodes will not forward any multimedia files in the forward direction during this BALERT propagating process thus the loss of data can be preserved. On receiving the BALERT message, the source node (N_i) erases the content in the routing table thus repeats the neighbor node identification phase, route discovery phase and route maintenance phase once again. During this period, the entire multimedia data packets are transferred through the alternate path of (S-5-11-14-19-22-D) until the new routing path is established. This process is considered to be more vital in the proposed multipath routing protocol and exhibits the following advantages. The loss of data is prevented by sending BALERT message by the dead node to source node. The source node sends the remaining multimedia data packet through the alternate path without waiting for forming another route, thus reduces the end to end delay and maintains the throughput level from deterioration. The algorithm for the route maintenance phase is presented in Table 6.

Table 6: Pseudocode to route maintenance phase

Algorithm 4- Pseudocode for route maintenance phase
Process Monitoring Residual Energy ( )
if RE ( ) $<$ Threshold Residual energy RE_T, then
Generate BALERT message
end if
end Process
Process Receive BALERT message (BALERT packet)
if node (N_{i+1}) = = N_i, then
Dead-next-node = single hop from N_{i+1}
Delete entry in routing table
if alternate active path exists (Source Node N_i, Sink node N_S), then
Forward data packet on active existing path
else / and
Determine new active path (Source Node N_i, Sink node N_S)
Update routing table with new active path (Source Node N_i, Sink node N_S),
end if
end
else
Discard BALERT packet
end
end process

The proposed Triangular Quality Metric Multipath Routing Protocol (TQM2RP) thus maintains a better traffic load balancing to support the achievement of better throughput, reduced end to end delay during the multimedia data transmission process. The probability of the dead nodes are determines after performing specific set of data transmission rounds. The probability is computed using equation 7.

$$P(N_D) = (\{RE_1 > RE_T\}\&\{RE_2 > RE_T\}\ \& \ldots\ldots\{RE_N > RE_T\} \quad (7)$$

The multipath routing mechanism possess a better level of security when compared to the unipath routing mechanism as the multimedia files are transferred in the form of multiple packets through various active routing paths. A malicious node pretending to be genuine one if enrolled in the active path tends to receive only a part of the multimedia file which is secured using Location Security Algorithm powered by Secured Hash Algorithm-256. Hence

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the malicious node cannot able to interpret the multimedia data thus provides greater security level for data packets.

3.1.4 Location Security Algorithm using SHA-256:

The second fold of the proposed model is to enhance the security level of WMSN against various attacks like spoofing [23], Sybil attack, wormhole attack, flooding, selective forwarding performed by the adversary nodes or malicious nodes. The parameter metrics to be measured for the analysis of the proposed methodology are end to end delay, and path length which were mathematically represented in equation 8 and 9.

$$Delay\ (D_{ete}) = C * (D_{hoping} + D_{supporting\ factors})$$
(8)

Where, C is the number of hops performed to transfer the data by the source node to sink node, while D_{hoping} and $D_{supporting\ factors}$ are the delay created during the hoping process and supporting factors created due to BALERT message. The number of hops can be determined using equation 9.

$$P_L = C\ (Number\ of\ hops\ in\ a\ single\ path) \quad (9)$$

The proposed Location Security Algorithm is composed of three phases namely setting up a network, identifying secured nodes, transmission through secured nodes. Among the aforementioned three phases, the initial phase of setting up the networks is performed in the first fold and later two phases will be illustrated in this sub-section. The algorithm for LSA is constructed by acquiring the identity of all the sensor nodes in WMSN. The acquired identities are accumulated before performing SHA-256 as represented in equation 10.

$$ID = \sum_{i=1}^{N} ID_i = [ID_1, ID_2, ID_3, \ldots \ldots \ldots ID_N] \quad (10)$$

The hash function is performed by executing ex-or operation among the successive bits of the identity of the sensor node. Let us consider the identity of a node is a_n which is of 16 bits. The 16 bit data is undergone ex-or operation as represented in equation 11.

$$H(N_i) = a_n \oplus a_{n+1} \oplus a_{n+2} \oplus a_{n+3} \oplus \ldots \ldots \ldots a_{n+15} \oplus a_{n+16}$$
(11)

The process flow of LSA is presented in Figure 4 in which the hash function is performed among the identity and the location specific coordinate system as represented in equation 12.

$$H(N_i) = (a_n \oplus x_a) \oplus (a_{n+1} \oplus y_a) \oplus (a_{n+2} \oplus x_a) \oplus (a_{n+3} \oplus y_a) \oplus \ldots \ldots \ldots (a_{n+15} \oplus x_a) \oplus (a_{n+16} \oplus y_a)$$
(12)

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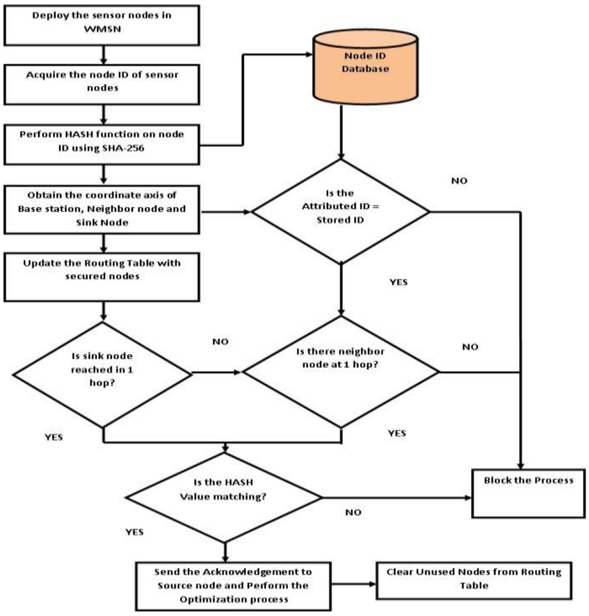

Figure 4: Process flow diagram for Location Security Algorithm using SHA-256

Table 7: Pseudocode for Location Security Algorithm

Algorithm 5- Pseudocode for Location Security Algorithm
Process The coordinates mentioning the location of the nodes are represented (x, y)
for (i=1; i<n; i++)
Obtain the identity value of the node (ID_i)
Determine the Hash value of the node ID using equation 11 employing SHA-256.
Perform the Hash value among the node ID and node location using equation 12.
end process
Process broadcast HELLO packet (ID_i, $H(ID_i)$)
Neighbor nodes: Compute Hash value of node ID_i and compares $ID_i = ID_{i+1}$
Hash Response packet ID_{i+1} to ID_i: (ID_{i+1}, $H(ID_{i+1})$)
if ($ID_i = ID_i'$) && ($ID_{i+1} = ID_{i+1}'$), then
Update the neighbor secured node in routing table
end if
if (ID_S = = 1 hop && path weightage <1), then
Update neighbor node = = ID_S
end if
Compute Hash value of node ID_i and ID_{i+1}
if ($H(ID_i)= H(ID_i')$) && ($H(ID_{i+1})= H(ID_{i+1}')$), then
Optimize the routing path in routing table
else if ($H(ID_i)\neq H(ID_i')$) && ($H(ID_{i+1}) \neq H(ID_{i+1}')$), then
else if ($H(ID_i)= H(ID_i')$) && ($H(ID_{i+1}) \neq H(ID_{i+1}')$), then
else if ($H(ID_i)\neq H(ID_i')$) && ($H(ID_{i+1}) = H(ID_{i+1}')$), then
Block the process and abort the procedure
Repeat the process from **Step 1**
end if
end if
end if
end if
end
end process

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The LSA procedure is described in Table 7. The routing table will be cleared and the routing process will be blocked in case of non equal hash values have been obtained as mentioned in steps 19 to 21 in the Table 7. Thus the Location Security Algorithm provides location based security [24] to the multipath routing process in WMSN.

4. Results and Discussion

The proposed system of performing multipath routing mechanism in WMSN with TQM2RP and incorporating security using LSA were executed on MATLAB platform and C# respectively. The analysis of the proposed system is performed and is presented in this section. The performance parameters to analyze the multipath routing algorithm are as follows.

- Packet Delivery Ratio (PDR)
- End to End delay
- Jitter
- Energy Consumption
- Network lifetime

The aforementioned parameters are compared with the unipath routing protocol (ASAR) and the Two Phase Geographic Greedy Forwarding (TPGF) protocol which is a multipath routing protocol.

4.1 Packet Delivery Ratio (PDR)

The packet delivery ratio (PDR) deals with the ratio of successfully delivered multimedia packets to the sink node. It can be computed using the mathematical equation 13.

$$PDR = \frac{\sum P_{ST}}{\sum P_T} = \frac{Total\ Packet\ successfully\ delivered\ to\ sink\ node}{Total\ packets\ transmitted} \tag{13}$$

The observed values for the proposed protocol is presented in Figure 5.

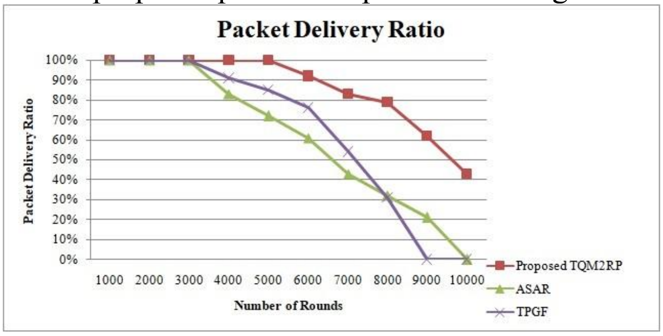

Figure 5: PDR vs No. of rounds

Figure 5 proves that TQM2RP yields better PDR than the benchmarking protocol. The proposed TQM2PR protocol exhibits 95% better PDR when compared to the existing protocols.

4.2 End to End Delay

The end to end delay in WMSN is the measure of time duration consumed by a multimedia frame or a packet to end up at sink node from the source node through multiple routers in the network. The end to end delay is the metric that directly depends on PDR. The proposed method exhibits better performance in terms of PDR and hence it reduces the end to end delay. The mathematical expression to determine the end to end delay is represented in equation 14.

$$D_{ete} = \frac{1}{N}\sum_{i=1}^{N}(T_{ri} - T_{Si}) * 1000\ (milli\ seconds) \qquad (14)$$

The comparison graph is represented in Figure 6.

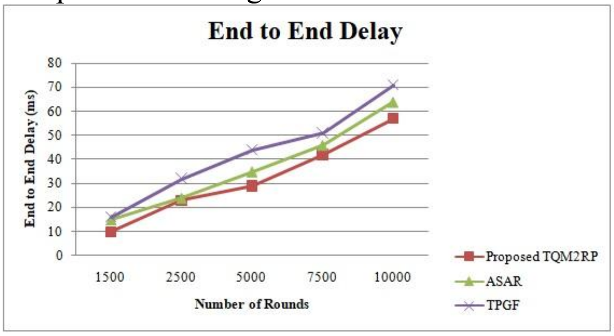

Figure 6: End to End Delay vs No. of rounds

Figure 6 illustrates that the proposed TQM2RP protocol possess a reduced end to end delay when compared to the benchmarking protocols. The end to end delay for the proposed protocol is reduced by 21% which is considered to be best end to end delay than any other protocols.

4.3Jitter

The jitter is the metric to determine the variation occurring in the end to end delay of the transmitted packets to reach to sink nodes. The jitter is the quantity will not attract the researchers during the normal data transmission while it is a crucial factor for multimedia data transmission. The graphical comparison is depicted in Figure 7.

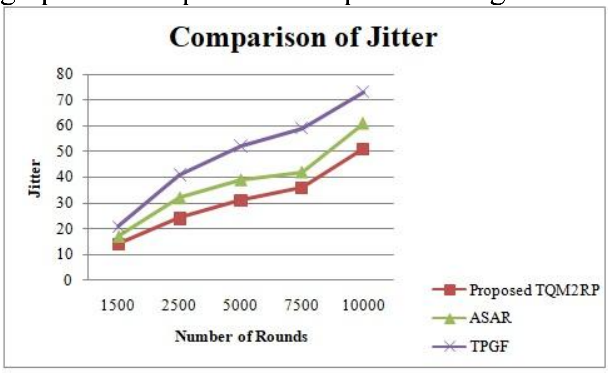

Figure 7: Jitter vs No. of rounds

Figure 7 proves that the proposed method exhibits reduced jitter value when compared to the benchmarking protocols.

4.4Energy Consumption

The energy consumption is the vital parameter to be considered in WMSN as the transfer of multimedia files consumed huge quantity of power (in Joules) which migrates the active nodes to dead nodes. The increase in quantity of dead nodes decreases the PDR and increases the end to end delay. The measured Residual energy values is depicted in Figure 8.

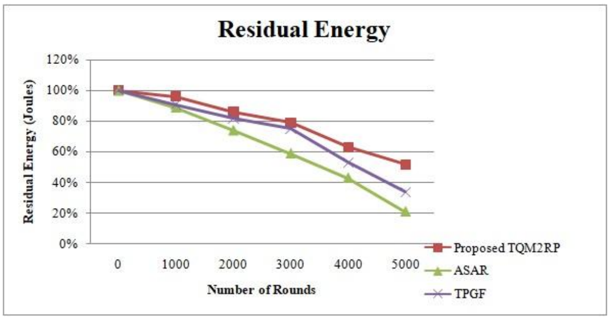

Figure 8: Residual Energy vs No. of rounds

The Residual energy of the proposed protocol is more when compared to the other benchmarking protocols of ASAR and TPGF protocols. The proposed protocol exhibits 20% better residual energy than the existing protocols.

4.5Network Lifetime

The network lifetime is one of the vital parameter to be considered in WMSN and is a measure of time duration until which the nodes will be active enough to transfer the multimedia files from one node to the sink node. The network lifetime is measured by performing multiple rounds of multimedia data transmission from source node to sink node and the comparative analysis is presented in Figure 9.

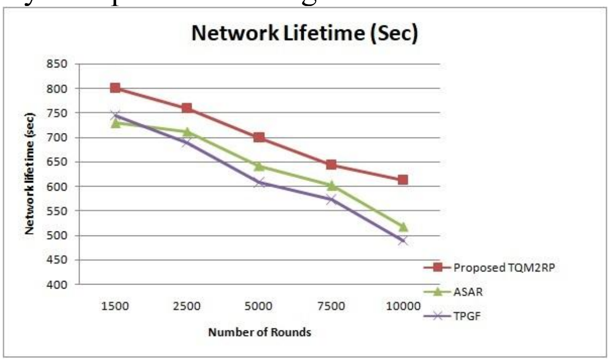

Figure 9: Network Lifetime vs No. of rounds

Figure 9 proves that the proposed protocol supports maximum network lifetime and it exhibits 150 seconds more lifetime than the benchmarking protocols.

4.6Security Analysis

The security factor of the proposed Location Security Algorithm (LSA) employs Secure Hash Algorithm which performs ex-or operation among the location coordinates of the nodes and the node identity values. The hash values cannot be duplicated and the comparative analysis of the proposed algorithm with the benchmarking algorithms [25] of SecuTPGF and GSR are illustrated in Table 8.

Table 8. Comparison of Security Parameters

Parameters	Proposed LSA	SecuTPGF	GSR
Network Model	WMSN	WMSN	WMSN
Computational cost	Low	High	High
Security level	High due to usage of Hash function	Limited due to User defined authentication	Better due to usage of SHA-2
Scalability	High	Moderate	Moderate
End to End Delay	Very low	High	Low

Spoofing	Yes	Yes	Yes
Sybil Attack	Yes	Yes	Yes
Computation attack	Yes	No	Yes
Flooding	Yes	No	No

The performance analysis [26] of the proposed method proves that it possess better scores in the vital aforementioned parameter and exhibits a highly rigid security against the adversary attacks [27] [28].

5 Conclusion

The multimedia file transfer using secured multipath routing in WMSN is the emerging technology which anticipated many developments with regard to routing efficiency and attaining better QoS. The existing methodologies perform unipath routing mechanism which fall short in providing better traffic load management. With an objective to address this concern, this novel method was proposed to provide better traffic load management and to transfer the multimedia data in a multiple path with high level of security. The quantitative analysis of the proposed Triangular Quality Metric Multipath Routing Protocol (TQM2RP) possesses a better Packet Delivery Ratio of 95% and 21% reduced end to end delay. Along with these excellent performances, the proposed model continues its efficiency by exhibiting 20% better residual energy leading to increased lifetime of sensor by 150seconds which is higher than any other existing protocols. The proposed scheme could be readily applicable for multimedia file transfer usecases in WMSN.

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