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QoS Constrained Network Coding Technique to Data Transmission Using IoT

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Abstract: The research work presents, constrained network coding technique to ensure the successful data transmission based composite channel cmos technology using dielectric properties. The charge fragmentation and charge splitting are two components of the filtered switch domino (FSD) technique. Further behavior of selected switching is achieved using generator called conditional pulse generator which is employed in Multi Dynamic Node Domino (MDND) technique. Both FSD and MDND technique need wide area compared to existing single node-keeper domino technique. The aim of this research is to minimize dissipation of power and to achieve less consumption of power. The proposed research, works by introducing the method namely Interference and throughput aware Optimized Multicast Routing Protocol (IT-OMRP). The main goal of this proposed research method is to introduce the system which can forward the data packets towards the destination securely and successfully. To achieve the bandwidth and throughput in optimized data transmission, proposed multicast tree is selected by Particle Swarm Optimization which will select the most optimal host node as the branches of multi cast tree. Here node selection is done by considering the objectives residual energy, residual bandwidth and throughput. After node selection multi cast routing is done with the concern of interference to ensure the reliable and successful data transmission. In case of transmission range size is higher than the coverage sense range, successful routing is ensured by selecting secondary host forwarders as a backup which will act as intermediate relay forwarders. The NS2 simulator is used to evaluate research outcome from which it is proved that the proposed technique tends to have increased packet delivery ratio than the existing work.

Keywords: Multicast routing; optimal node selection; secondary relay nodes; probability of interference; residual energy; bandwidth; throughput

1 Introduction

Environmental monitoring system in home based applications, wearable devices like sensors are integrated with applications which interact and accessed remotely to the people [1]. A recent developmental application like smart city, smart medical system, smart transports etc uses IoT for its deployment [2]. IoT is used in high end sensing applications like information sensing, data transmission, cloud distributed system for storage and process [3]. Other applications are E-healthcare, Internet of medical things, digital security, smart watch so on. These major applications are interconnected using 4G and 5G architectures [4].

IoT data are generated based on core network of IoT. Various data is sensed by smart device and transmitted to the network via IoT devices [5]. The loss of data packets and fake data interferences in IoT are due wireless communication of IoT [6]. Finally invention of software defined networks becomes very useful to improve IoT communication system [7].

The QoS improving techniques in ad hoc networks are well studied, where the main goal is to develop the parameters used in QoS [8]. However, security system needs are not paid attention and main problem id enhancing QoS in ad hoc networks [9]. A application widely depend on QoS for security provision, such as network security from Denial of Service attacks and fabrication based attacks [10]. The patient health monitoring system requires data integrity and timely computation of data in network. So QoS is considered as significant task for reducing delay and high throughput problems. QoS provides fined tuned channels for data communication [11].

The dynamic IoT networks can be easily run and execute in a wireless system [12]. The intruders can be captured easily and it manipulate illegally of any information transfer via wireless communication. Therefore, in same time multiple identities used to transmit same data by an adversary, which is called as Sybil attack. A Sybil attack leads to impersonation , Denial of Service, and other similar attacks [13]. Thus finally degrading happens in the QoS provisioning, apart from issues like Link and MAC layer in ad hoc networks.

The main aim of this research work is to introduce the techniques that can perform optimal and reliable data communication in the IoT network that consists of millions of small devices. This is done by adapting the network coding and the multicast routing to ensure the optimal and reliable data transmission. To achieve this various optimization algorithms and the network coding techniques have been adapted.

The overall structure of the research work is given as follows: In this section detailed introduction about the IoT devices and the need of data communication has been given. In Section 2, discussion about the various related research technologies has been given. In Section 3, detailed overview of the proposed research techniques in terms of their working procedure along with suitable examples and explanation is given. In Section 4, discussion of the simulation outcome of the proposed techniques and their comparison evaluation with the existing techniques are given. Finally in Section 5, overall conclusion of the research work based on simulation outcome is given.

2 Related Work

Zhao et al. [14] proposed model for flow of data. It tends to capture the every data transmission among IoT device. The process works from starting stage (creating redundancy using original data) to the various stage of repair with fewer devices.

Zhao et al. [15], the offloading technique is proposed smartly via deep reinforcement learning technique. In this procedure, automatic learning is done using deep Q network. The decision of offloading helps to optimize the performance of system and trained neural network helps to predict action in offloading. The environmental system helps to generate the trained data.

Pustišek et al. [16] discusses about Distributed Low-Bandwidth Applications architecture—an gateway with application awareness among Internet of things (IoT) communication devices. A backend of cloud servers connected to modular technologies and messaging formats are managed. The native API application logic meets the communication conditions of limited resources of end devices.

Ma et al. [17] implemented two techniques for bandwidth optimization and flows allocation: the method network utility maximization (NUM) and asymptotic examination method. The NUM technique gives general optimization solution for the problem, but certain computational complexity is required. The analysis using asymptotic techniques examines inherent network property and solution are explicitly expressed in terms parameters in protocol and traffic requirements.

Gravalos et al. [18] implemented Integer Linear Programming (ILP) to decrease networks total cost with respect to the deployed devices. Here it focus to achieve QoS requirements. The solution for random topology reveals effectiveness in less networking cost and high efficiency.

Peng et al. [19] proposed healthcare design to monitor the reliable data communication mechanism with requirements of using many-to-one streaming technique. This Fault-tolerant in coding Mechanism of network proposes a greedy algorithm based on grouping. It divides network topology into small logical units; it generates coding for linear network using spanning tree randomly. Further it also helps to generate independent linear coding in linear combination.

Gravalos et al. [20] brings great planning for the problem known as integer linear program (ILP). This formula reduces the device cost which is deployed in the network and also achieves QoS needs. Authors suggest heuristic techniques with less complexity which was experimental to present solutions near optimal outcome. The result evaluation exhibits the performance and effectiveness of the proposed techniques in parameters using cost of network and network efficiency.

Hasan et al. [21] proposed formulation using analytics for the error rate and a decisive path-loss structure is defined using specified level. There is also trust among nodes that are most frequently used. Additionally, irregular in the degree is addressed using parameters. The geographical transmission across distributed networks switches based on two schemes: 1. hop-by-hop retransmission scheme and 2. end-to-end retransmission scheme.

Cao et al. [22] implements technique for saving energy across mobile network. IoT devices are battery powered applications which tends to perform real-time approximate computation under the quality-of-service (QoS) constraint. Li et al. [23] promotes hybrid technique for automation using average CSI being available at the transmitter. It improves system performance at high level.

3 Interference and Throughput Aware Multicast Routing

The main aim of this proposed research method is to introduce the system which can forward the data packets towards the destination securely and successfully. The proposed research method introduces the following research methods to achieve the bandwidth and throughput optimized data transmission. Multicast tree is selected by introducing the optimization approach namely Particle Swarm Optimization which will select the most optimal host node as the branches of multi cast tree. Here node selection is done by considering the objectives residual energy, residual bandwidth and throughput. After node selection multi cast routing is done with the concern of interference to ensure the reliable and successful data transmission. In case of transmission range size is higher than the coverage sense range, successful routing is ensured by selecting secondary host forwarders as a backup which will act as intermediate relay forwarders. The processing flow of the proposed research method is shown in the following Fig. 1.
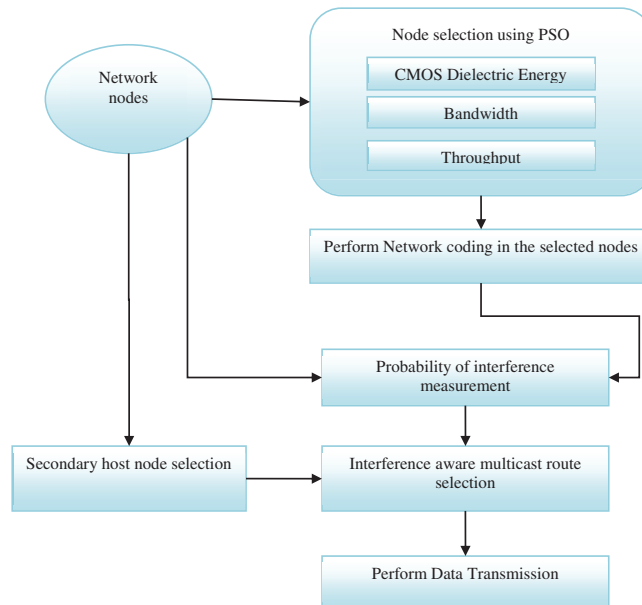
Figure 1: Processing flow of the proposed research work

3.1 Optimized Multicast Tree Construtction Using PSO

The PSO is a stochastic population-based evolutionary computational algorithm for problem solving. A multicast routing problem is given and a fitness function is used to evaluate a proposed optimal route. The communication structure, which assigns a neighbour for each individual to interact with it, is also defined. The fitness evaluation function iteratively evaluates the fitness of the population of multicast routes and remembers the location where they had their best success. The best optimal route of an individual is called the local best. Each set of nodes that forms a route makes this information available to its neighbour nodes. Here node selection is done by considering the objectives residual energy, residual bandwidth and throughput. The On-Demand Multicast Routing Protocol (ODMRP) is a mesh based multicast routing protocol, which uses a mesh over which packets are forwarded through the use of scoped flooding. It is proved that, reducing the forwarding nodes is equivalent to finding the solution at less cost multicast tree. Finally less cost tree is acquired with multicasting mesh. The proposed approach considers to minimize the data overhead and supervised to bring greater performance than traditional ODMRP at a less cost, in terms of forwarding efficiency. The algorithm 1 is computed using the following steps:

Algorithm 1: Optimized Multicast Tree Construction Using PSO

Step 1. Transform the mesh network into equal spanning tree.

Step 2. Randomly initialize the population of multicast routes.

Step 3. Initialize the local best route and global best routes randomly.

Step 4. Calculate the total cost of each route.

Step 5. Update the local best route and global best route.

Step 6. Update the routing table with the new optimum route.

Step 7. Repeat Step (4) until one of the following termination conditions is satisfied. a. The maximum number of iterations is exceeded. b. The best optimum route is converged.

Step 8. Build a forwarding mesh upon the minimum cost multicast tree obtained in step 7.

3.2 Perform Network Coding in Nodes

The data transmitted across IoT network may be huge size compared to single packet. For example, in air smart devices are updated using new firm ware. So first the data is divided into small fragments, and then transmits one data fragment in one packet at time among multiple packets. The packets must be transmitted linearly to get the original data. A data present in the source code is fragmented in to equal length. Finally coding group is formed using 'n' data packets to compute in network as liner coding randomly. In coding section 'h_i' in each packet, encodes using vector $\Delta_i = [\delta_{i,1}, \delta_{i,2}, \ldots, \delta_{i,n}]$ ($\delta_{i,j} \in$ GF(2^m), $1 \leq i, j \leq n$). This vector is appended to identify the packet used in encoding of h_i. GF(2^m) specify the finite elements of 2^m where $m \in \{8, 16, 32, 64,..\}$, which determines the size of symbol. For uncoded packet h_i, the all vector elements will become zero except $\delta_{i,j} = 1$. The source node request Algorithm 2 to transfer the encoded packet $g_i (1 \leq i \leq \lceil rn \rceil)$, where code rate is 'r' determined using the controller SWDN and $\lceil rdn \rceil$ is the maximum procedure to obtain smallest integer which is greater or equal to rn.

Algorithm 2: The network coding code rate r is determined/updated by the SWDN controller

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for i = 1 → $\lceil rdn \rceil$ compute

if i ≤ n **then Repeat**

   create a encoding vector $\Delta_i = [\delta_{i,1}, \delta_{i,2},.., \delta_{i,n}]$ randomly

until Δ_i is linear and independent uisng all the Δ_j, $1 \leq j < i$ (except for i = 1)

else

Construct a vector Encoded as $\Delta_i = [\delta_{i,1}, \delta_{i,2}, \ldots, \delta_{i,n}]$ in random

end if

Data packets h_j is multiplied by $\delta_{i,j}$

$$g_i \Leftarrow \sum_{j=1}^{n} \delta_{i,j} h_j$$

Send or transmit out $|\Delta_i||g_i|$ // where "||" is called as the concatenation operation

end for

sent out packets are reported using SWDN controller

In Algorithm 2, generates a source program $\lceil rdn \rceil$ using n-dimensional vectors Δ_i for encoding (vectors at first 'n' is linearly independent) and vector elements $\delta_{i,1}, \delta_{i,2}, \ldots, \delta_{i,n}$ used as coefficients to produce and send out encoded packets from the uncoded packets $h_1,\ldots,h_n$.

For every coding group, the receiving memory opens at intermediate node for storing the fresh incoming packets from designated nodes of SDWN controller for data encoding. Further encoded vectors are recorded for incoming packets at intermediate nodes. Fresh packet is created by encoding vector which is linearly independent by already received packets. The trade off between the diversity of packet and delay in communication is received by encoding new packets by intermediate node. The new packets are getting during preset τ interval. This interval is measured using timer then removes the buffer received at the time and it waits for new incoming fresh packets to restart all timer and buffering. For better understanding, packets are split as each of the n_τ fresh packets at receiving side buffer into the vector encoding Δ_i and data g_i ($1 \leq i \leq n_\tau$). n_τ Represents total number of fresh packets available in receiving side of buffer. Algorithm 3 is used by intermediate node to send out $\lceil rn \rceil$ the packets after encoding, where SWDN controller determines r as code rate. Finally reports are generated using SWDN controller with intermediate node. This node obtains details about packets received and sends.

Algorithm 3: The network coding code rate r is determined/updated by the SWDN controller

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for $i = 1 \rightarrow \lceil rdn_\tau \rceil$ **compute**

if $i \leq n_\tau$ **then**

repeatly Initiate a random vector $R_i = [r_{i,1}, r_{i,2}, \ldots, r_{i,nt}]$

until independent Ri as linear R_j; $1 \leq j < i$ (except for $i = 1$)

else

Create vector randomly $R_i = [r_{i,1}, r_{i,2}, \ldots, r_{i,nt}]$

end if

Multiply all symbols in g_j by $r_{i,j}$ $\Delta_t' \Leftarrow \sum_{j=1}^{h_r} r_{i,j}\Delta_j$

Multiply all symbols in g_j by $r_{i,j}$ $g_i' \Leftarrow \sum_{j=1}^{n_\tau} r_{i,j}g_j$

Transmit out $|\Delta_i' || g_i'|$, where $||$ is the concatenation operation

end for

Finally the packets received and encoded are reported.

The dimension of vector R_i is generated as $\lceil rdn_\tau \rceil n_\tau$ intermediate node by using algorithm 3, (first n_τ vectors are linearly independent) and coefficients $r_{i,1}, r_{i,2}, \ldots, r_{i,nt}$ elements of vector used to generate. Finally all recoded packets are send out a received packets $g_1, \ldots, g_{nt}$. Further processing of corresponding encoding vectors are similarly executed.

Once the linearly n independent packets received at sink nodes, the Eq. (1) can be solved and original data packets can be decoded as $h_1, h_2, \ldots, h_n$.

$$\begin{bmatrix} \Delta_1 \\ \Delta_2 \\ \cdots \\ \Delta_n \end{bmatrix} \begin{bmatrix} h_1 \\ h_2 \\ \cdots \\ h_n \end{bmatrix} = \begin{bmatrix} g_1 \\ g_2 \\ \cdots \\ g_n \end{bmatrix} \tag{1}$$

Then concatenation of $h_1, h_2, \ldots, h_n$ can be restored for original data. The sink node reports periodically for receiving packets status in SWDN controller.

Since the SWDN controller gets the status of packets sending/receiving from each node in the IoT core network periodically. The network coding rate can be adjusted based on the nodes. Let packets transmitted by node i is ηt_i, succeeding node N_i is set that receives node i from the packets and $\eta_j^{(i)}$ is the received packet at the node $j \in N_i$. The code rate for node 'i' is 'ra_i' calculated using Eq. (2)

$$ra_i = \frac{\eta t_i}{\max_{j \in N_i}(\eta t_j^{(i)})} \tag{2}$$

where max() represents selection operation of maximum element. The SDWN controller contains information regarding topology for all nodes i. The succeeding relay nodes is specified to receive packets from node i.


Algorithm 4: Updating nodes

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    for each source or intermediate node i **compute**

    ra$_i$ Calculated using the status of packet regarding sending/receiving of node i, N$_i$

    Transfer ra$_i$ for code updation rate of node i via the control path

    end for

3.3 Probability of Interference Measurement

Specifically, all neighbor nodes of nodes within range of interference are potential sources. We define consequently the node interference to be set of nodes cardinality covered using disks which are induced by range of interference. The neighbor nodes at interference range are also defined as interference node. However, there will be various interference levels at neighbor nodes to have the different nodes accordingly to Euclidean distances from node: if the distance is far between neighbor nodes, the interference will be small; if distance is small, their interferences is large. This condition helps to represent weights for various interference levels. Simply, 3 interference parts are divided (Fig. 2), and different weights are assigned to each and every part. In this article, the interference range is assumed as $\sqrt{3}$ times of range of transmission.
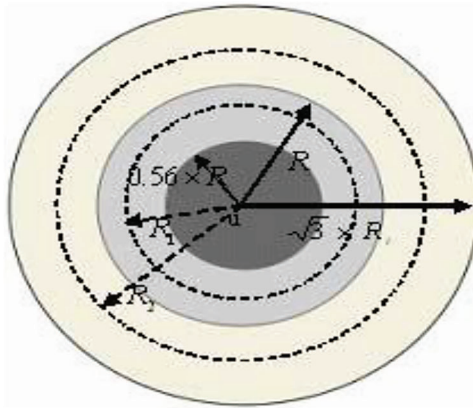
Figure 2: Interference in computation is illustrated

In Fig. 2 the circle is full of interference area with radius of $\sqrt{3} \times R_t$. The interference is higher, then area is dark shaded. Then weight is 1. The smaller interference area is compared to darker area. Then weight is α. The sandal section denotes the lowest interference as weight β. Thus, Eq. (3) is obtained by node-interference;

$$I(U) = N_1 + \alpha N_2 + \beta N_3 \tag{3}$$

In Eq. (3), dark area is represented as N_1, shaded area is represented as N$_2$, and yellow area nodes represented as N$_3$. N$_2$ weight is α and N$_3$ weight is β (less than 1) respectively, β is minimum than α. Equation [4] defines path loss TWO RAY GROUND model, the P$_r$ is receiving power signal from a sender which is d meters far away as Eq. (4).

$$P_r = P_t G_t G_r \frac{h_t^2 h_r^2}{d^k} \tag{4}$$

In Eq. (4), G_t and G_r are considers as gains of antenna transmitter and receiver, respectively. P_t is the sender node power transmission. h_t and h_r are antenna height respectively. Here, we assume that the homogeneous MANET, the each node is identical for radio parameters. In dark shaded section, the strong interference is generated by node and the interference difference at source node among nodes is imperceptible. We minimum power (d = 0.56R_t) is received to represent this area. However, other two areas and interference difference at source node and among nodes cannot be ignored. To be simple, mean range is chosen to represent the area, such as $R_1 \left(R_1 = \frac{0.56R_t + R_t}{2} \right)$ and $R_2 \left(R_2 = \frac{R_t + \sqrt{3} \times R_t}{2} \right)$ to represent shaded and yellow areas. Considering the weight 1 for dark area, we get Eqs. (5) and (6).

$$\alpha = \frac{P_t G_t G_r h_t h_r / R_1^k}{P_t G_t G_r h_t h_r / (0.56 \times R_t)^k} = \frac{0.56^k}{\left(\frac{1 + 0.56}{2} \right)^k}, \quad k \in [2, 4] \tag{5}$$

$$\beta = \frac{P_t G_t G_r h_t h_r / R_2^k}{P_t G_t G_r h_t h_r / (0.56 \times R_t)^k} = \frac{0.56^k}{\left(\frac{1 + \sqrt{3}}{2} \right)^k}, \quad k \in [2, 4] \tag{6}$$

We have kas 2. The final node-interference is

$$I(U) = N_1 + 0.52N_2 + 0.17N_3 \tag{7}$$

Based on interference node, interference link is estimated-as below:

$$I(e) = \frac{I(u) + I(v)}{2} \tag{8}$$

Here, link e = (u, v), I (u) and I (v) are the interference of node u and v respectively. For a path $P(u_0, u_n)$: $u_0 e_1 u_1 e_2 u_2 \ldots \ldots u_{n-1} e_n u_n$ the interference is computed as Eq. (9).

$$I(P) = I(e_1) + I(e_2) + \ldots + I(e_n) \tag{9}$$

$$= \frac{I(u_0) + I(u_1)}{2} + \frac{I(u_1) + I(u_2)}{2} + \ldots + \frac{I(u_{n-1}) + I(u_n)}{2} \tag{10}$$

$$= \frac{I(u_0)}{2} + I(u_1) + I(u_2) + \ldots + I(u_{n-1}) + \frac{I(u_n)}{2} \tag{11}$$

Single problem is interference path is directly related to path length. A low interference link with long path where all places than new path with large interference link. Therefore all path divides using Eq. (12)

$$Metric \; (p) = I(p)/n \tag{12}$$

Here, *n* is the path link, represents path length. Since considering average estimation length, link-interference paths (Metric) might balance Traffic to reduce path interference.

3.4 Interference Aware Multicast Routing

We execute ODMRP protocol called interference routing. These routing techniques are used by two protocols, which seen as two parts: discovery and maintenance of routing. The value of interference at each node is recorded using CLALIE protocol for every node presents in the network. It computes interference value using related links. Finally packets at route request is attains destination node. The whole path has interference which is figured easily and average value is computed finally for all paths. All Reply packet are induced by request packets of route. The possible path for routing is represented

using request route packets. From destination node reply packets are transmitted to source nodes. The information regarding average interference is recorded by source node with path details using routing table.

The routing table is constructed locally with nodes and link which consists of candidate routing paths. Then the source node transmits data packet in path with less average link-interference among all paths which is possible between the source and destination.

The CLALIE protocol implemented by adding new sector in common pocket header such as metric in article [8]. All the node must know nodes number within 0.56 times range of transmission and range of interference respectively (1 *N*, 2 *N* and 3 *N*) before implementing the value of interference for itself.

Algorithm 5: Source node sending data by searching best path

If (routes = suitable)

      then {

             Select the minimum Metric path (average link-interference);

             This path chosen to send data

       ;}

Else

{

      Initialize Route-Request metric as half of the value in interference source node;

      Route Request packets are Broadcasted, begins route discovery

;}

When packet is requested by route to node *i u*, then it works as follows:

If (it is not our packet)

    then

      metric = metric + $I(u_i)$;

else

{

   Metric = metric + $I(u_n)/2$;

   Metric = metric/n;

   Metric sector in Route Reply packet = Metric;

   Send : Route Reply packet back to source node

;}

In the route, intermediate nodes are updated as their routing tables based on the information given by the Replay packet of Route. Once the Route-Reply packet send to source node, then it records path information and corresponding Metric value to its local table of routing for future use. The minimum metric path is selected by source node to transmit data to destination. Due to topological variation drastically, path data at tables will be invalid. For every 10s once our protocol reads routing table and updates about new information regarding routing. This protocol works similarly as DSR routing mechanism.

4 Result and Discussion

In this section, the performance measurement of entire research work is done in the NS2 simulation environment along with the performance metrics for the proposed Interference and Throughput aware Optimized Multicast Routing Protocol (IT-OMRP). The comparison evaluation is done with the existing method namely secure multicast routing protocol (SMRP). The experimental setup is designed in Cadence–Virtuoso analog tools in 180 nm CMOS technology. This is resolved by proposed techniques and results are evaluated as follows.

4.1 Packet Delivery Rate

Nowadays, Routing protocols are used to delivery packets. The rate of packet delivery is measured as number of packets received to sender and is calculated as follows:

$$\text{PDR} = \frac{\sum_0^n \text{Packets Received}}{\sum_0^n \text{Packet Sent}} \tag{13}$$

The PDR of the methodology namely SMRP and IT-OMRP are compared together. Based on this the result IT-OMRP shows the improved performance than the existing methodology according to the Fig. 3. IT-OMRP shows 17% increased PDR than SMRP.
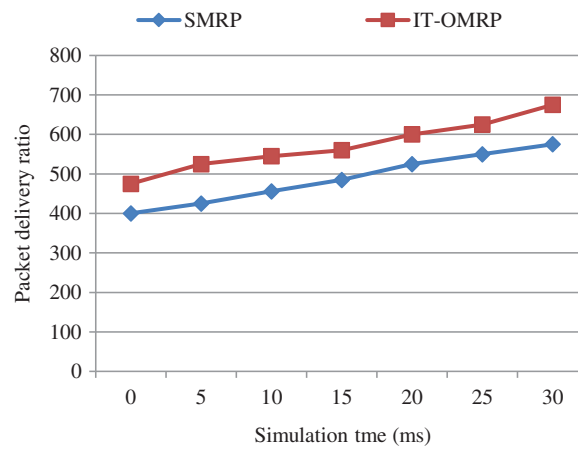

Figure 3: Packet delivery rate

4.2 Packet Loss Rate

The Packet Loss Rate (PLR) is a metric calculated in a protocol. PLR is estimated as follows,

$$\text{PLR} = \frac{\sum_0^n \text{Packets Dropped}}{\sum_0^n \text{Packet Sent}} \tag{14}$$

The PLR of the methodology namely SMRP and IT-OMRP are compared together. Based on this the result IT-OMRP shows the 11.14% improved performance than the other existing methodology according to the Fig. 4.
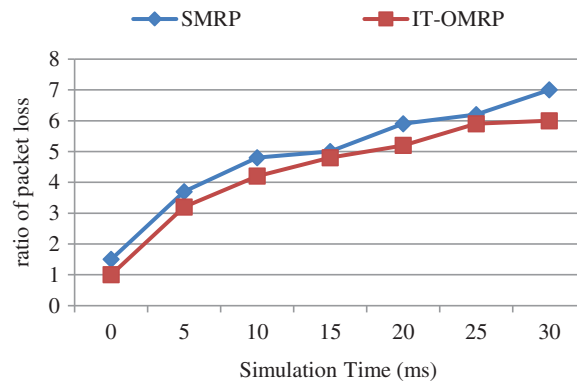
Figure 4: Packet loss rate

4.3 Average Delay

The difference in time between the current incoming packet and the last packet received bound is called as the average delay at node. It is measured using following equation.

$$AverageDelay = \frac{\sum_0^n PktReceivedTime - PktSentTime}{n} \qquad (15)$$

The average delay of the methodology namely SMRP and IT-OMRP are compared together. Based on this the result IT-OMRP shows the 18.67% improved performance than the existing methodology according to the Fig. 5.
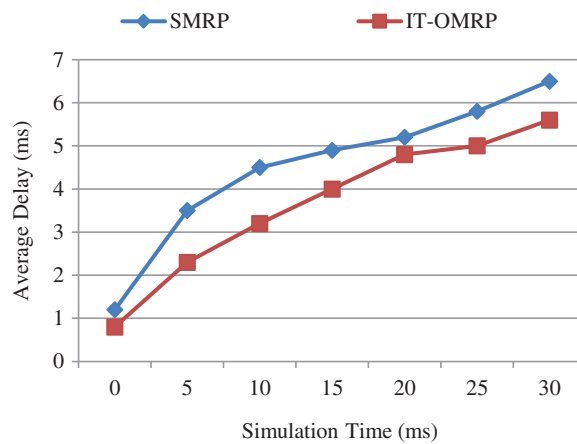

Figure 5: Average delay

4.4 Throughput

The stability of the network in selecting the destination at beginning of simulation i.e., calculation of correct delivering of packets to destination. This is shown in Fig. 6.

The throughput of various methodologies in simulation environment from the source to each destination node is shown in Fig. 6. As a result it concludes that the IT-OMRP will produce the 16.27% better results compared to the existing SMRP.
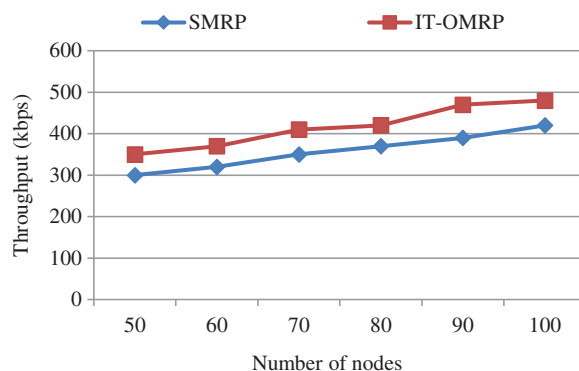
Figure 6: Throughput

4.5 End-to-End Delay

The end-to-end delay is time interval between generation time of data packet and last bit arrival time at the destination.

The end to end delay of various methodologies in simulation environment from the source to each destination node is shown in Fig. 7. As a result it concludes that the IT-OMRP will produce the 9.06% better results compared to the existing SMRP.
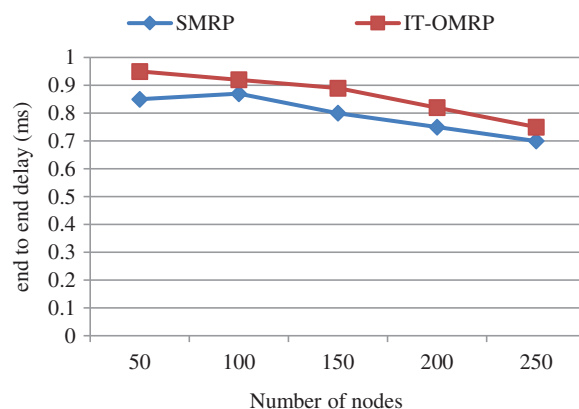

Figure 7: End to end delay

5 Conclusions

In this research work, multicast tree is selected by introducing the optimization approach namely Particle Swarm Optimization which will select the most optimal host node as the branches of multi cast tree. Here node selection is done by considering the objectives residual energy, residual bandwidth and throughput. After node selection multi cast routing is done with the concern of interference to ensure the reliable and successful data transmission. In case of transmission range size is higher than the coverage sense range, successful routing is ensured by selecting secondary host forwarders as a backup which will act as intermediate relay forwarders. The overall analysis of the research work is done in the NS2 simulation environment from which it is proved that the proposed technique tends to have increased packet delivery ratio than the existing work. In future swarm intelligence based various optimization algorithm can be used to check the performance of the route optimization.

Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.

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