

T-SRP: TREE BASED STRENUOUS ROUTING PROTOCOL FOR CONGESTION AVOIDANCE IN IoT MEDICAL APPLICATION

K.PRAGHASH^{1*}, R.RAVI²

¹Research Scholar, Anna University Recognized Research Centre, Francis Xavier Engineering College, Tirunelveli, Tamil Nadu 627003, India. Ph.: +914622502283

²Professor, Francis Xavier Engineering College, Tirunelveli, Tamil Nadu, India.

*Corresponding author: praghashk16@hotmail.com

Abstract— Now a days, the Internet of Things (IoT) plays the vital role of transferring the data through network without any human interaction. The creation of an effective IoT exploits the Wireless Sensor Networks (WSN) in the communication process. Basically, the WSN comprises of many independent sensors which acquire the data on the basis of different conditions. Meanwhile, transmitting a huge number of data through the gateway will leads to the congestion avoidance this creates a time delay and transmission loss problems. Moreover, the lifetime of the network depends on power consumption of sensors deployed in WSN. The construction of an energy efficient WSN in accordance with the dynamic operating conditions is the focus with the automatic configuration and reconfiguration abilities. This paper proposes an efficient Tree based strenuous Routing protocol (T-SRP) for selecting an optimal gateway. Initially, the inclusion of graph theory-based routing tree model collects the neighbor information to compute the optimal path in order to reach the Base Station (BS). The hierarchical tree structure on the basis of dynamicity in cluster formation predicts the optimal path that reduces the number of connections effectively. The reduction in a number of connections decreases the amount of power spent on the system. The tree based algorithm performs the clustering of sensor nodes (SNs) from the graph modeling and the node lies in centroid position is regarded as the Cluster Head (CH). The employment of Congestion Avoidance-Path (CA-P) algorithm selects the necessary gateway for the lossless transmission. The comparison between the proposed T-SRP with the existing protocols regarding the average residual energy, Packet delivery ratio (PDR), throughput and end-to-end delay assures the effectiveness of T-SRP in IoT applications.

Index Terms— Wireless Sensor Network (WSN), Internet of Things (IoT), Congestion Avoidance-Path (CA-P) algorithm, Tree based strenuous Routing protocol (T-SRP), Weighted Steiner tree algorithm, Cluster Head (CH).

I. INTRODUCTION

A wireless sensor network contains several sensors and composed of a set of tiny autonomous nodes with wireless communication capabilities. The effective communication

on the basis of the diverse protocols are the major constraints in Internet of Things (IoT). To achieve the reliability in communication, the interaction among the physical to digital world is necessary in any time. The massive amount of data generation from the sensors requires the suitable intelligent processing that transforms the data from one form to other (1-3). The sensing, processing and communication are the major tasks to achieve the integration between the physical and digital world. The WSN is the promising tool to govern the processes listed above. The BS can be static or movable node has the capacity of connecting all sensor nodes. Anyhow the sensor networks are constrain with the bandwidth and power supply. But the rising techniques will reduce energy efficiency will affect the network lifetime. One of the access point network called Zigbee 802.15.4 is proposed for enabling the energy efficient communication between WSN and IoT environment. The typical structure of the proposed zigbee 802.15.4 access point network is represented in Fig.1. The suggested network contains both the wireless and wired architecture. The connection between the gateway and IoT middleware is wired whereas the connection between the gateway and the sensor nodes is wireless.

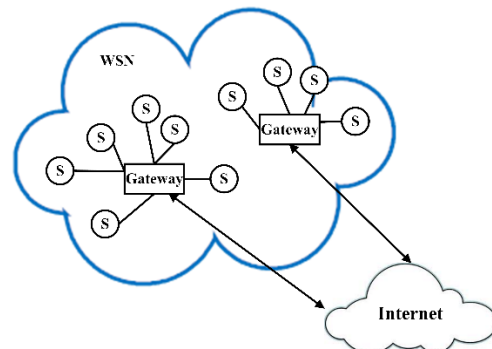


Fig.1. Structure of dense 802.15.4 access point network

Mostly the IoT applications are mostly based on the medical applications, smart homes and industries. Majorly

the in medical application the wireless body area networks (WBANs) are developed. In that different sensors are placed on the cloth or even in body or may be implanted under the skin. This helps to analyses the health condition and monitor the quality of life. In the efficient routing is necessary for transmitting the data without any congestion problem. In the existing systems, the WSN exploits the static environment with base station for storing and maintaining the data. Whereas, the proposed system considers the gateway as a repeater and protocol translator. Further, the sensor nodes uses the resource of the heterogeneous devices for enhancing the quality of the service management. The MAC layer version 802.15.4 architecture is exploited for establishing the neighbor link between the sensor nodes. During the route discovery process, the sensor node broadcasts the HELLO messages. Based on the obtained information from neighbors, a graph structure is created for every node. To provide an energy efficient routing, the sensor nodes in the WSN are clustered using the Tree based algorithm. The suggested algorithm selects an optimal link between the source sensor nodes and the gateway. An optimal communication link is estimated by the CA-P algorithm. Once the link between the sensor nodes and the gateway is established, the TCP/FTP application agents initiate the communication. As the gateway is chosen based on bandwidth, the packet drop is prevented.

A. Scientific Contributions

The scientific contributions of proposed work are listed below:

- Graph-theory-based information collection from the sensors such as energy and mobility factor, which decides the optimal path for minimum energy consumption
- The hierarchical tree structure on the basis of dynamicity in cluster formation predicts the optimal path that reduces the number of connections effectively.
- The employment of Congestion Avoidance-Path (CA-P) algorithm selects the necessary gateway for the lossless transmission.

The following sections contains, In Section II illustrates the existing routing techniques used in WSN for energy efficient routing, IoT integrated WSN and IoT integrated with WSN and gateway. Section III describes the overall steps involved in the proposed CA-P based T-SR Protocol. Section IV illustrates the results and discussions obtained for the proposed protocol and in section V presents the conclusion of the research.

II. RELATED WORK

This section provides a detailed description on the existing approaches used for energy efficient routing (EER) in WSN, WSN with IoT and WSN with IoT and gateway.

A. Energy efficient routing in WSN

Juan, et al (4) suggested an Energy Saving via Opportunistic Routing (ENS_OR) algorithm for minimizing the power cost at the time of data relay. When compared to traditional routing algorithms, the suggested algorithm saved the energy and network partition. But, the performance of the suggested algorithm was not validated in the sleep mode. *Hoang, et al* (5) suggested a clustering based Harmony Search Algorithm (HSA) protocol for maximizing the energy efficiency of WSN. When compared to the existing Low Energy Adaptive Clustering Hierarchy-Centralized (LEACH-C) protocol and Fuzzy C-Means (FCM) clustering algorithms, the suggested protocol maximized the lifetime of WSN. *Zhang, et al* (6) presented a Forward-Aware Factor based Energy-Balanced Routing Method (FAF-EBRM) for balancing the energy consumption in WSN. When compared to the traditional algorithms such as LEACH and EEUC, the proposed FAF-EBRM balanced the energy consumption, increased the lifetime and increased the Quality of Service (QoS) of WSN. Further, it enhanced the node degree, edge weight and strength. Thus, provided robustness, fault tolerance, minimal probability for successive node breakdown and increased synchronization of WSN. *Ren, et al* (7) suggested an Energy-Balanced Routing Protocol (EBRP) for protecting the nodes with minimal residual energy. The analysis results proved that when compared to the traditional EER algorithm, the proposed algorithm enhanced the energy balance, network lifetime, throughput and coverage ratio. *Mao, et al* (8) suggested an Energy Efficient Opportunistic Routing (EEOR) strategy for reducing the energy consumption of nodes in WSN. When compared to the existing ExOR protocol, the suggested EEOR protocol produced optimal output. But, accurate computation of the expected cost was complex. *Chen, et al* (9) suggested a Tunable Time Resolution (TTR) for minimizing the energy consumption of Micro Controller Unit (MCU) in WSN. Based on the dynamic adjustment and switching of the time resolution, the energy efficiency was increased. The deployment of TTR in Tmote-sky platform reduced the power model for the Wireless Body Area Network (WBAN). When compared to the existing baseline schemes and offline schemes, the proposed battery-aware approach produced 71.05% and 60.81% energy savings. Thus, it was clear that the proposed model was optimal for enhancing the energy performance of the WBAN. *Lili, et al* (10) proposed an energy consumption model with the transmission rate and distance. When compared to the baseline schemes, the transmission rate was minimum. Further, the exploitation of optimized scheme saved the energy by 59.77%. *Yu, et al* (11) suggested a data correlation based sensor scheduling algorithm for increasing the indoor power efficiency in WSN. The proposed adaptive DK-means algorithm enhanced the data

reliability. Further, it saved the energy consumption by 58% and minimized the average relative error of the group by 73.6%. *Alwakeel, et al* (12) suggested an efficient energy-saving routing scheme for the mobile WSN. The suggested algorithm increased the throughput by 10%, reduced the message duplicates 8 times, prevented the congestion and maximized the life time of nodes. Experimental results proved that the suggested algorithm was suitable for the dense sensor networks

B. Routing for WSN with IoT

Luo, et al (13) analyzed the data relay and power consumption model to develop an optimal data transmission. The lifetime of the complete network was increased using the optimal energy strategy. This method minimize the energy consumption without affecting the quality of the communication. *Santos, et al* (14) suggested an efficient mobile gateway based on IoT for the mobile health (m-Health) scenarios. The collected information were sent to the Intelligent Personal Assistants (IPAs) for managing the alarms and set of actions. The detection of the patient location, possible fall detection and heart rate were automatic. *Duan, et al* (15) proposed an effective game theoretic approach based energy-aware trust derivation scheme for handling the overhead in WSN. Experimental analysis proved that the suggested approach increased the security and efficiency of the WSN based IoT networks. *Shahzad and Shelhami* (16) analyzed various Medium Access Layer (MAC) schemes for WSN. The utilization of Energy Harvesting-based WSNs (EHWSNs) was enhanced by a novel scheme. The information from various regional IoT systems were processed by the resources of cloud services. *Anusha* (17) suggested a Redundancy based Weighted Election Protocol (R-WEP) for improving the stability period of WSN. The case monitoring weighted sensor network was developed. The application of the proposed R-WEP for the IoT minimized the power consumption. *Lazarescu* (18) deployed the WSN platform for performing long-term environmental monitoring of IoT applications. The design and deployment of WSN platform and components considered the application requirements such as faster deployment, longer lifetime, lower maintenance and higher quality of service.

C. Routing for WSN with IoT and gateway

Zhu, et al (19) suggested the Zigbee and GPRS protocols based IoT gateway system for enabling the transmission between WSN. The prototyping system was deployed and the system was validated. *Lazarescu* (20) analyzed the approaches for integrating the WSN with Internet. With respect to the characteristics, three integration approaches were evaluated. The existing solutions for the issues such as security, QoS and configuration management were found to be non-optimal

for the limited sensor node resources. Hence, to address these issues, optimal modifications were provided for the resource-constrained platforms. *Al-Fuqaha, et al* (21) suggested a rule-based intelligent gateway for bridging the gap between available IoT protocols and horizontal IoT services. Hence, to address this issue, a generic IoT protocol was proposed. The baseline MQTT protocol was enhanced by supporting the QoS features. The enhanced MQTT protocol produced optimal delay performance.

From the analysis of the existing WSN routing protocols it is clear that the existing protocols do not provide simple cost computation, optimal QoS performance and satisfactory non-satisfactory packet delivery ratio and throughput. Thus, to address these issues an efficient CA-P based T-SR protocol is proposed.

III. PROPOSED METHOD

This section explains about the proposed Tree based strenuous Routing protocol (T-SRP) in detail. The overall flow of the proposed T-SR protocol is represented in Fig.2. Steps involved in the proposed protocol are,

- Generation of IoT architecture
- Clustering the sensor nodes
- Selection of optimal gateway

A. Generation of IoT architecture

The structure of the suggested IoT architecture is represented in Fig.3. The key components involved in the proposed IoT architecture are as follows,

- IoT middleware
- Gateway establishment
- Sensor deployment

The generation of the IoT architecture is initiated with the deployment of the SNs. The sensor nodes collect the information related to the medical application such as measuring of body temperature, heartbeat, and electrocardiogram (ECG) etc...

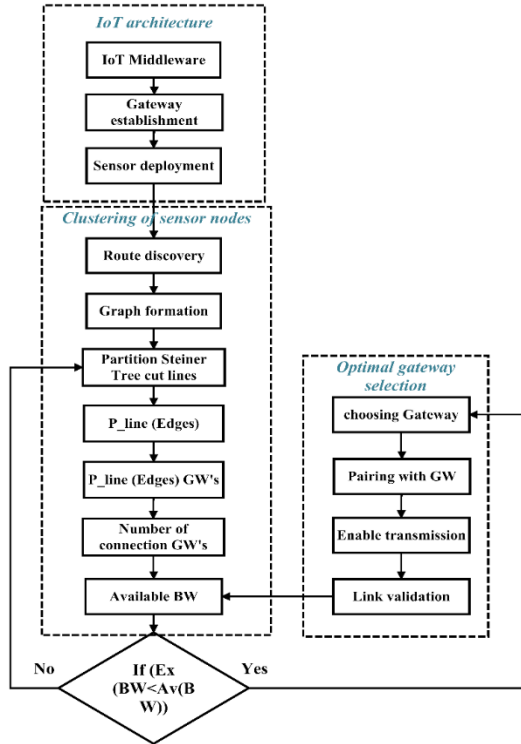


Fig.2. Overall flow of the proposed T-SRP protocol

The collected information are forwarded to the gateway through the CH. The optimal gateway is based on the Congestion Avoidance-Path (CA-P) algorithm. On receiving the information from SN, the gateway saves a copy of it in its local database and forwards it to the internet for initiating the necessary actions based on the application.

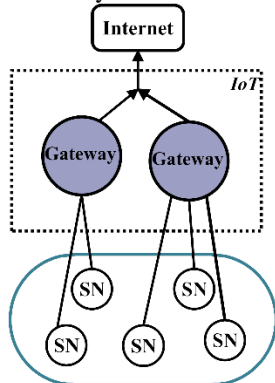


Fig.3. IoT architecture

B. Clustering the sensor nodes

To enhance the energy efficiency and network life time, the WSN is split into several clusters. Among the sensor nodes, the node present in the centroid position is chosen as the CH and selection of the cluster members. With a neighbor information, a graph is constructed with vertices such as v_1, v_2, \dots, v_n and Edges of $e_1, e_2, e_3, \dots, e_m$ as input, then α is a sequence parameter to connect the edge nodes with

corresponding vertices. The total number of vertices and edges is described as V, E . From the constructed graph, an edge weighted sub graph is constructed with vertex set, edge set and terminal set. By Construct a long- drawn-out graph $G' = (V', E')$, this helps to reach destination and ensure the limits of counts. Then calculating minimum spanning tree T' of G' by removing t to the particular tree structure of the node T' . Based on the tree structure the sub graphs will be constructed. The path which doesn't end the designation will be removed, the path remonstration process will be carried out to reduce the complexity of the network. Then computing a cluster head or centroid for communication, in two conditions as $Count(C) < k$ and $(C) > k$. The process will be computed until the condition $C=k$. The steps involved in the cluster member generation are illustrated below,

Algorithm 1: Algorithm for cluster formation

Input:

$Set\{G(V, E), \alpha\}; V: \{v_1, v_2, v_3, \dots, v_n\}; E\{e_1, e_2, e_3, \dots, e_m\}$

Output: Clustered nodes: $Set\{Tree\}$

Procedure ()

\forall nodes $getS\{v \in V\}, getS\{e \in E\}$

Connected to edge nodes with vertices

$calWeight\{v(e_i, e_j)\}$

Let $G'(V', E')$ be the long-drawn-out graph after generating edge t to V

Calculate MS-Tree T' of $G' \rightarrow$ remove t from T'

Construct sub-graph tree $g \leftarrow t..(T')$

while g' is empty from G'

$Set_p = \{v_0, v_1 \dots v_{len(g')} \in G', v_i \in V' \leftarrow G', G(v_j)\}$

Remove.path{notEndDst($G'\{\forall(v, e) \rightarrow empty\}$)}

for ($i = 0; i + + i < N$)

$Path_Reconstruct \leftarrow \max\{g'(v_i, v_j)\}$

Set ($low(\alpha) \rightarrow$ possibly to load $\rightarrow g'$)

Set number of cluster $C \leftarrow$

$len(g').longest_edges.Path_{Reconstructed}(g')$

if $Count(C) < k$

While $Count(C) \neq K$

Remove.CurrentLongestEdge($g'(C)$)

$C \leftarrow C + 1$

Compute centroid C of each $G'(t_i \in T')$

Return k clusters

if $Count(C) > k$

Compute centroid of C of each $T' \in G'$

Find the representative $c_i \in T'(t_i)$

Compute cluster until $Count(C) = k$

Return C clusters

After the generation of the clusters with cluster members and cluster heads, the information is routed to the internet through an optimal gateway.

C. Optimal gateway selection

A gateway is a router or PC that transfers the packets from the sensor nodes to the internet. The selection of an optimal gateway is mandatory for minimizing the congestion. Hence, an efficient Algorithm II: Congestion Avoidance-Path (CA-P) algorithm is proposed for selecting the optimal gateway. The steps involved in the suggested algorithm is illustrated below,

Algorithm II: Congestion Avoidance-Path (CA-P) algorithm

Input: Cluster Tree set G_c , set $\{gateways: GW\}$, Packet service rate(S_t), Average Queuing time (Q_t)
 $W^c(t)_i \rightarrow$ Queue waiting time is the amount of time that all packets

$C_i \rightarrow$ Transmission cost for all packets destined for node i in before time t

Output: congestion free route optimal path set

Procedure Update Current Status ()

\forall leaf(G_c) each D tree set

 If D of Cluster with single hop

 Route Status set True

 Else

 Route Status set false

 For each member in (G_c)

 Calculate the $Q_t = \sum_i^{len(c)} W^c(t)_i +$

$S_t + C_i(t - 1)$

 Calculate queue waiting time

$W(t) \rightarrow \sum$ each(pkt).jitter(i)+cost spend

For each vertex $v \in V$

$W(t) [v] \leftarrow +\infty$

End For

$W(t) [u] \leftarrow -\infty$

$S \leftarrow \Phi$

$Q \leftarrow V$

While $Q \neq \Phi$

$u \leftarrow$ Extract the minum value of Q

$S_t \leftarrow S_{1..n} \{u\}$

 For each vertex V such that $(u, v) \in E$

 If $Q_t [v] > \text{Max}(Q_t [u], Q_t (u, v))$ then

$Q_t [v] \leftarrow \text{Max}(Q_t [u], Q_t (u, v))$

 Return true

else

 Return false

Initially the congestion algorithm consider Cluster Tree set G_c , set $\{gateways: GW\}$, Packet service rate(S_t), Average Queuing time (Q_t) as input. The main motive is to avoid congestion problem by finding the average queuing time. The cluster is handling in single hop, by the use of each members in the clustering tree the average

queuing time will be calculated. Based on the cost for all packets destined, the queuing waiting time will be calculated. By comparing the weight of various paths, an optimal gateway is chosen. After the selection of the gateway it is paired with the CH for enabling the transmission.

D. Link validation

Increase in the congestion of a gateway would result in packet dropping. Hence, to prevent the packet dropping, the link validation step checks the available bandwidths. If the existing bandwidth is lesser than the available bandwidths, the corresponding gateway is chosen as the optimal gateway for enabling the transmission, else a different gateway is chosen for the transmission.

IV. PERFORMANCE ANALYSIS

This section illustrates the experimental results of the proposed T-SR protocol for the energy efficient routing. The T-SR protocol, is compared with the existing routing protocols such as Transmission Energy (MTE), Geographic Random Forwarding (GeRaF) and Energy Saving via Opportunistic Routing (ENS_OR) (4). Further, the throughput and end-to-end delay of the suggested protocol is compared with the existing communication protocols such as Ad hoc On-demand Distance Routing (AODV), Dynamic Source Routing (DSR) and Optimal Link State Routing Protocol (OLSR).

Table I Simulation parameters

Parameters	Values
Physical layer	IEEE 802.15.4
Network Size	50 × 50 m
CN location	25 m
Number of nodes	100
Simulation Period	100 secs
Listen Interval	5 ms
Buffer size	32
Energy Model	Energy Model-True
Initial Energy	5 Joules
Sample rate	10 samples / secs
Bandwidth	20 MHz
Data rate	250 kbps
Base Station	1
Packet Size	64-248 kbps
Packet Rate	Random packets/sec
Traffic/Application Type	UDP/CBR
Routing Protocol	WBAN-AODV

These algorithms are implemented in Network simulation 2 tool and their results are compared for the following metrics,

- Average residual energy

- Packet delivery ratio
- Throughput Vs existing protocols
- Throughput Vs communication protocols
- End-to-End delay Vs Number of nodes
- End-to-End Vs Simulation time

A. Average Residual Energy (ARE)

ARE denotes the estimation of relay nodes that have higher residual energy. The relay nodes with higher ARE can be alive for a longer time thus increasing the network lifetime. The comparison of ARE for the existing MTE, GeRAF, ENS_OR protocols and the proposed T-SR protocol is represented in Fig. 4. From the figure, it is clear that the suggested protocol has higher residual energy than the existing protocols.

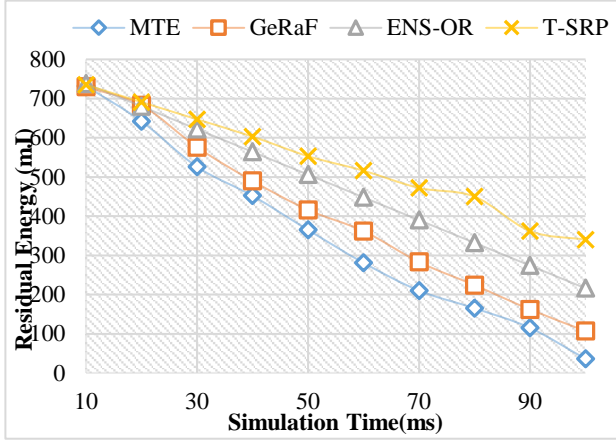


Fig.4. Comparison of residual energy for the existing and proposed routing protocols

In existing methods, the average residual energy values are high for ENS-OR method for minimum and maximum simulation period such as 738 and 216 mJ respectively. But, the prior clustering and the routing-based on the Steiner tree in proposed T-SRP improves the values to 735 and 340 mJ respectively. The comparative analysis between the proposed T-SRP with the ENS-OR shows that the proposed T-SRP offers 0.4 and 36.47 % improvement respectively.

B. Packet Delivery Ratio (PDR)

The estimation of PDR is based on the following equation,

$$\frac{\sum \text{Number of packets received}}{\sum \text{Number of packets sent}} \quad (1)$$

The comparison of PDR for the existing MTE, GeRAF, ENS-OR protocols and the proposed T-SR protocol is represented in Fig.5. From the figure it shows that the suggested protocol provides higher PDR than the existing protocols for the increasing number of parallel connections.

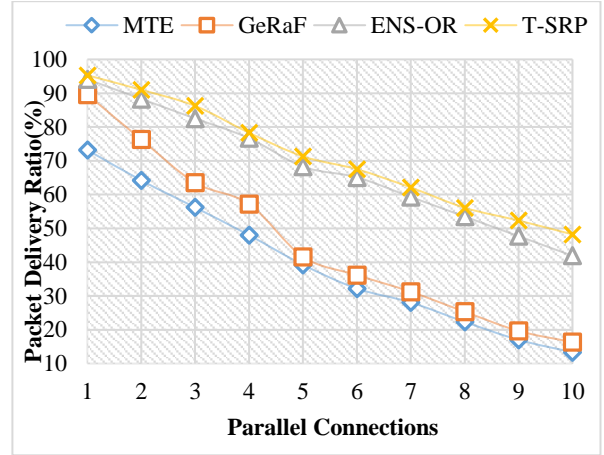


Fig. 5. Comparison of PDR for the existing and the proposed routing protocols

In existing methods, the PDR values are high for ENS-OR method for minimum and maximum simulation period such as 94.1 and 41.9 % respectively. But, the prior clustering and the routing-based on the Steiner tree in proposed T-SRP improves the values to 95.3 and 48.23 % respectively. The comparative analysis between the proposed T-SRP with the ENS-OR shows that the proposed T-SRP offers 1.26 and 13.12 % improvement respectively.

C. Throughput Vs existing protocols

This is estimated using the following equation,

$$\frac{P1}{P2} * 100\% \quad (2)$$

Where,

P1 is the number of packets received by the sink

P2 is the number of packets sent by the source

The comparison of throughput for the existing Minimum Transmission Energy (MTE), Geographic Random Forwarding (GeRAF), ENS_OR protocols and the proposed T-SR protocol is represented in Fig.6. It is analyzed that the proposed T-SR protocol provides higher throughput than the existing routing protocols.

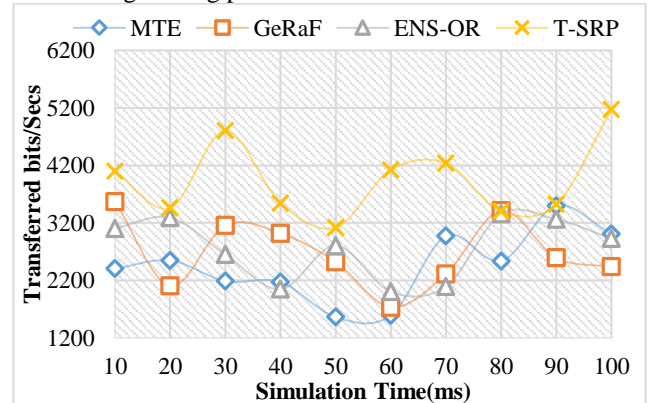


Fig.6. Comparison of throughput for the existing and proposed routing protocols.

In existing methods, the transferred bits are high for GeRaF MTE methods for minimum and maximum simulation period such as 3571 and 3007 respectively. But, the prior clustering and the routing-based on the Steiner tree in proposed T-SRP improves the values to 4098 and 5170 bits respectively. The comparative analysis between the proposed T-SRP with the ENS-OR shows that the proposed T-SRP offers 12.86 and 41.84 % improvement respectively.

D. Throughput Vs communication protocols

To validate the throughput of the proposed T-SR protocol, it is compared with the existing communication protocols such as DSR, OLSR, and AODV. The comparison of throughput with respect to the communication protocols is represented in Fig. 7. From the figure, it is analyzed that the proposed T-SR protocol provides higher throughput than the existing protocols.

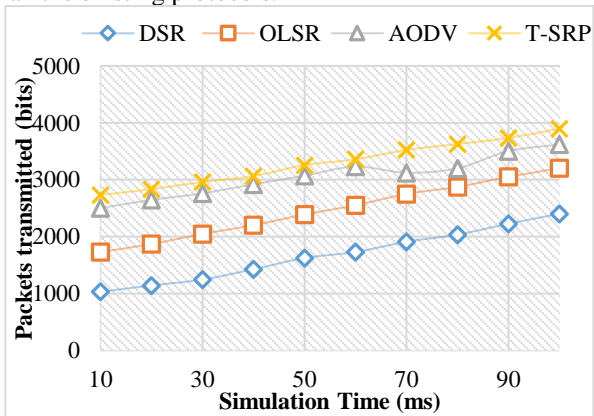


Fig. 7. Comparison of throughput for the existing and proposed communication protocols

In existing methods, the throughput values are high for AODV for minimum and maximum simulation period such as 2503 and 3621 bits/sec respectively. But, the prior clustering and the routing-based on the Steiner tree in proposed T-SRP improves the values to 2734 and 3895 bits/sec respectively. The comparative analysis between the proposed T-SRP with the ENS-OR shows that the proposed T-SRP offers 8.4 and 7 % improvement respectively

E. End-to-End delay Vs Number of nodes

The estimation of the end-to-end delay is based on the following equation,

$$\text{End-to-End delay} = \sum(S_i - S_{i-1}) / D \quad (3)$$

Where,

S_i denotes the time that the data packet arrives the destination, S_{i-1} represents the time that the first packet is transmitted by the source and D represents the number of packets transmitted.

The analysis of the end-to-end delay with respect to the number of nodes is depicted in Fig. 8. From the figure, it is

analyzed that the proposed T-SR protocol provides minimal delay than the existing protocols.

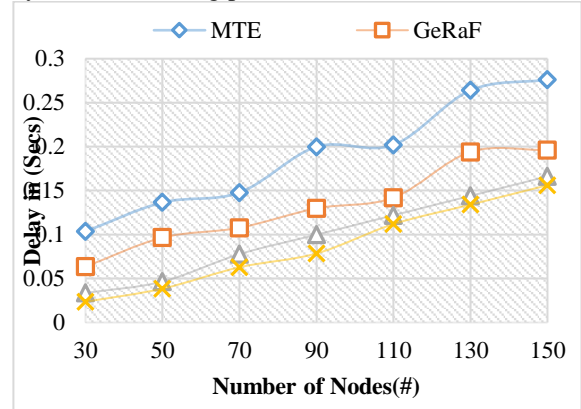


Fig. 8. Analysis of end-to-end delay Vs. Number of nodes

In existing methods, the delay values are less in ENS-OR methods for minimum and maximum simulation period such as 0.0335 and 0.1661 ms respectively. But, the prior clustering and the routing-based on the Steiner tree in proposed T-SRP decreases the values to 0.0235 and 0.1561 ms respectively. The comparative analysis between the proposed T-SRP with the ENS-OR shows that the proposed T-SRP offers 29.85 and 6.02 % improvement respectively.

F. End-to-End delay Vs. Simulation time

The analysis of the end-to-end delay with respect to the simulation time is represented in Fig.9. The proposed T-SR protocol provides minimal end-to-end delay for the increasing simulation time.

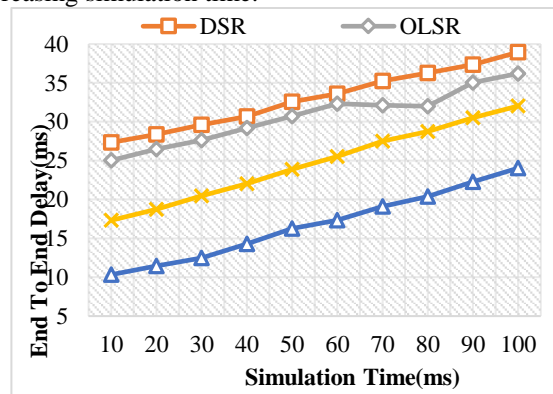


Fig. 9. Analysis of end-to-end delay Vs. Simulation time

In existing methods, the delay values are less in AODV methods for minimum and maximum simulation period such as 17.32 and 32.03 ms respectively. But, the prior clustering and the routing-based on the Steiner tree in proposed T-SRP decreases the values to 10.33 and 24.04 ms respectively. The comparative analysis between the proposed T-SRP with the ENS-OR shows that the proposed T-SRP offers 40.36 and 24.94 % improvement respectively.

V. CONCLUSION AND FUTURE WORK

The issues in achieving the high-network lifetime, lossless power transmission and minimum power consumption are discussed. The energy efficient WSN environment to govern the IoT-based applications faced the major challenges of dynamic operating conditions and the automatic configuration abilities. This paper proposed an efficient T-SR protocol to alleviate the issues in existing methods. Initially, the inclusion of graph theory-based routing tree model collected the neighbor information such as energy and mobility factors to compute the optimal path in order to reach the BS. The optimal path is predicted by using the hierarchical tree structure on the basis of dynamicity in cluster formation that reduced the number of connections effectively which in turn minimum power consumption. The tree based algorithm performed the clustering of sensor nodes from the graph modeling and the node lies in centroid position is regarded as the CH. The employment of CA-P selected the necessary gateway for the lossless transmission. The comparison between the proposed T-SRP with the existing protocols regarding the average residual energy, PDR, throughput and end-to-end delay assured the effectiveness of T-SRP in IoT applications. But, the follow-up of hierarchical levels during the tree formation affect the robustness and reliability in real-time system under resource-constrained policies.

In future, the robustness and reliability of the device organization for the IoT system can be enhanced. Further, real-time management can be considered for the resource constrained sensor networks.

REFERENCES

1. Alqassem I, Svetinovic D, editors. A taxonomy of security and privacy requirements for the Internet of Things (IoT). 2014 IEEE International Conference on Industrial Engineering and Engineering Management; 2014 9-12 Dec. 2014.
2. Collotta M, Pau G. Bluetooth for Internet of Things: A fuzzy approach to improve power management in smart homes. *Computers & Electrical Engineering*. 2015;44:137-52.
3. Pandya HB, Champaneria TA, editors. Internet of things: Survey and case studies. 2015 international conference on electrical, electronics, signals, communication and optimization (EESCO); 2015.
4. Juan Luo J, Di Wu, Renfa Li. Opportunistic Routing Algorithm for Relay Node Selection in Wireless Sensor Networks. *IEEE Transactions on Industrial Informatics*. 2015;11(1):112-21.
5. Hoang DC, Yadav P, Kumar R, Panda SK. Real-Time Implementation of a Harmony Search Algorithm-Based Clustering Protocol for Energy-Efficient Wireless Sensor Networks. *IEEE Transactions on Industrial Informatics*. 2014;10(1):774-83.
6. Zhang D, Li G, Zheng K, Ming X, Pan Z-H. An energy-balanced routing method based on forward-aware factor for wireless sensor networks. *IEEE Transactions on Industrial Informatics*. 2014;10(1):766-73.
7. Ren F, Zhang J, He T, Lin C, Ren SK. EBRP: energy-balanced routing protocol for data gathering in wireless sensor networks. *IEEE Transactions on Parallel and Distributed Systems*. 2011;22(12):2108-25.
8. Mao X, Tang S, Xu X, Li X-Y, Ma H. Energy-efficient opportunistic routing in wireless sensor networks. *IEEE Transactions on Parallel and Distributed Systems*. 2011;22(11):1934-42.
9. Chen Y, Yi W, Sun H, Xing Y. Tunable Time Resolution: An Energy Saving Mechanism for Wireless Sensor Networks. *IEEE Communications Letters*. 2015;19(7):1201-4.
10. Lili W, Peikang W, Chenfu Y, Ye L, editors. Energy consumption optimization based on transmission distance for wireless on-body communication. *International Conference on Wireless Communications & Signal Processing (WCSP)*; 2013 24-26 Oct. 2013.
11. Yu T, Akhtar AM, Shami A, Wang X, editors. Energy-Efficient Scheduling Mechanism for Indoor Wireless Sensor Networks. *IEEE 81st Vehicular Technology Conference (VTC Spring)*; 2015: IEEE.
12. Alwakeel S, Prasetyo A, Alnabhan N, editors. An adaptive energy-saving routing algorithm for mobile wireless sensor networks. *International Conference on Electrical and Information Technologies (ICEIT)*; 2015: IEEE.
13. Luo J, Wu D, Pan C, Zha J. Optimal Energy Strategy for Node Selection and Data Relay in WSN-based IoT. *Mobile Networks and Applications*. 2015;20(2):169-80.
14. Santos J, Rodrigues JJPC, Silva BMC, Casal J, Saleem K, Denisov V. An IoT-based mobile gateway for intelligent personal assistants on mobile health environments. *Journal of Network and Computer Applications*.
15. Duan J, Gao D, Yang D, Foh CH, Chen HH. An Energy-Aware Trust Derivation Scheme With Game Theoretic Approach in Wireless Sensor Networks for IoT Applications. *IEEE Internet of Things Journal*. 2014;1(1):58-69.
16. Shahzad F, Sheltami TR, editors. An efficient MAC scheme in wireless sensor network with energy harvesting (EHWSN) for cloud based applications. *IEEE 40th Local Computer Networks Conference Workshops (LCN Workshops)*; 2015 26-29 Oct. 2015.
17. Anusha K, editor Redundancy based WEP routing technology (IoT-WSN). *International Conference on Signal Processing And Communication Engineering Systems (SPACES)*; 2015 2-3 Jan. 2015.

18. Lazarescu MT. Design of a WSN Platform for Long-Term Environmental Monitoring for IoT Applications. *IEEE Journal on Emerging and Selected Topics in Circuits and Systems*. 2013;3(1):45-54.
19. Zhu Q, Wang R, Chen Q, Liu Y, Qin W, editors. IOT Gateway: Bridging Wireless Sensor Networks into Internet of Things. 8th International Conference on Embedded and Ubiquitous Computing (EUC); 2010 11-13 Dec. 2010.
20. Lazarescu MT. Design of a WSN platform for long-term environmental monitoring for IoT applications. *IEEE Journal on Emerging and Selected Topics in Circuits and Systems*. 2013;3(1):45-54.
21. Al-Fuqaha A, Khreishah A, Guizani M, Rayes A, Mohammadi M. Toward better horizontal integration among IoT services. *IEEE Communications Magazine*. 2015;53(9):72-9.