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Energy Efficient Routing in IoT Based on Chronological Atom Search Optimization

S. Srinivasa Rao, V. Subba Ramaiah, K. Raghu

Abstract: ***Internet of Things (IoT) is a developing technology used for enhancing the communication and providing flexibility to humans. The data packets are transmitted through better routing path using the IoT nodes in the network. This research presents an effective optimization algorithm for selecting the effective routing path for the transmission of the speech signal to the destination effectively. The optimization algorithm namely, chronological atom search optimization (chronological ASO) algorithm is developed for selecting the routing path. The chronological ASO algorithm is developed by integrating the chronological concept in ASO algorithm. After the initialization of the network, the effective routing path is selected using the fitness parameters, such as energy, delay and distance. Then, the speech signal is transmitted from the source node to the destination node by selecting the routing path having maximum fitness function. The performance analysis of the proposed chronological ASO algorithm is done based on the metrics, such as energy, throughput, and PDR. When compared to the existing methods, the proposed method provided a maximal energy of 0.2375, maximal PDR of 46.1538, and maximal throughput of 0.0792 for 50 nodes and obtained a maximal energy of 0.1381, maximal PDR of 32.0988, and maximal throughput of 0.0395, respectively.***

Keywords: ***Routing path, speech signal, network, optimization, communication.***

I. INTRODUCTION

Internet of Things (IoT) is an emerging technology that is used to enhance the flexibility and the communication for human [9]. IoT connects the things like mobile devices, Internet objects, and data analytics in the common network using the IoT platform. The data packets are transmitted through the better route in the network using IoT nodes. One of the most difficult tasks is routing the data as the protocols used by the traditional networks are similar to the wireless networks. During routing, the data is send to the right route by selecting the best routes between the nodes. In the traditional routing, the nature of the medium is not considered and the data is sending automatically for the wireless networks.

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***** Correspondence Author
Dr. S. Srinivasa Rao*, ECE, Mahatma Gandhi Institute of Technology, JNTUH, Hyderabad, India. Email: ssrinivasarao_ece@mgit.ac.in
Dr. V. Subba Ramaiah, CSE, Mahatma Gandhi Institute of Technology, JNTUH, Hyderabad, India. Email: vsubbaramaiah_cse@mgit.ac.in
K. Raghu, ECE, Mahatma Gandhi Institute of Technology, JNTUH, Hyderabad, India. Email: raghukasula@mgit.ac.in

IoT constitutes of smart things like, industry machinery, light switches, home equipment that can be embedded in IoT for various applications. The IoT is the new paradigm in the Wireless Sensor Networks (WSN) which is used for the interaction of the objects, such as actuators, sensors, and mobile phones, etc. The objects with unique addressing schemes are linked to each other and their associate neighbour in IoT for attaining common objective. The data collected from the IoT nodes are communication with the corresponding nodes which is the IoT routing [1].

Secure and efficient routing protocols are developed for routing the data effectively. An efficient routing protocol should require the following resources like dealing with lossy links, enabling fast convergence, saving energy and avoiding routing loops. The major issues in the wireless sensor network are the routing problem. Various routing protocols are developed for overcoming the issues. The routing protocols include the Rumor Routing, Gradient-Based Routing, Energy-Aware Routing, etc. and these protocols are known as data-centered oriented protocols [8]. In order to cope up with large scale WSN routing issue, the hierarchy routing protocol like PEGASIS, LEACH, etc are developed. The geographically related characteristics of WSN are considered in the Location-based Protocols, like Geographic Aware Routing, Minimum Energy Communication network and Energy Aware Routing. The prerequisites of security and QoS are met by the protocols like, energy awarded security protocol, Network flow protocol, Intrude torrent routing protocols, QoS Routing Protocol, QoS aware, and Energy-aware protocol [5].

The main aim of the research is the selection of an efficient routing path based on the optimization algorithm. Initially, the network is simulated and the necessity for the network is to communicate the recorded speech signals to the destination through the routing path. Here, the routing path is selected through the optimization algorithm, known as chronological ASO for the effective transmission of speech signals from the source node to the destination node.

II. LITERATURE REVIEW

Krishnaraj N. and Smys S. et al. [1] developed a Multipath Distance Vector routing algorithm based on Ant Colony Optimization algorithm for determining the efficient routing path. This method provided effective routing path in terms of delay and energy consumption for multi-homing networks. However, it failed to detect the presence of the node with high power in the network.

Sobral J. V. V. et al. [2] designed a Lightweight On-demand Ad hoc Distance-vector Routing Protocol-Next Generation (LOADng) for effective routing. Although this method provided better overhead efficiency, latency, packet delivery ratio and power, it failed to reduce the usage of the memory and assess in the real test beds.

Mick T. et al. [3] modeled a secure on boarding and routing framework for NDN-based IoT networks. This method provided acceptable on boarding convergence times and minimum network overhead. However, this method was not implemented in live test bed deployment. Hatzivasilis G. et al. [4] developed a trust-based system, SCOTRES for secure routing in the network. Although this method provided efficient load and energy balancing behavior, the efficiency was low for real application deployments.

A. Challenges

- The data transmission between the nodes is challengeable as the protocol that enhanced the speed may mitigate the delay and reduce the energy consumption of the node [7].
- The networks are time varying, highly unreliable, and prone to multi-hop inferences with constraints in power, memory and battery. Hence, the routing of the packets in the network is another significant challenge [6].
- In [2], the method provided better latency, packet delivery ratio, overhead efficiency and power. The main challenge lies in the reduction of usage of the memory and the assessment of the real test beds.
- The Multipath Distance Vector routing algorithm based on Ant Colony Optimization algorithm provided effective routing path in terms of delay and energy consumption for multi homing networks. However, the main challenge lies in the detection of nodes having high power in the network.

III. SYSTEM MODEL OF IOT

The WSN based IoT network has a sink node (base station), which is represented as B_D, f number of IoT nodes and cluster heads G_A. The maximum communication range in the IoT node is distributed uniformly between the dimension of O_τ and P_τ. The IoT nodes are clustered to form a network with a unique ID. The optimal location of the sink node is given as $[0.5O_\tau, 0.5P_\tau]$. The data symbols are received from the IoT nodes through the base station in the network. Every location of the IoT nodes are represented by the coordinate value of O_i and P_i. The cluster head mechanism is used for transferring the data packets to the base station in the IoT nodes. The cluster head node in the cluster represents the IoT nodes that are represented as G_A^f. The IoT network is divided into clusters in which the normal node is equal to $f - G_A$. After the cluster formation, the data packets are transmitted to the cluster head B_A from the normal node B_R. Finally, the cluster head gathers the data packets and transmits it to the sink node. The distance between the sink node to the jth cluster head and the distance between the jth cluster head to the ith normal nodes that are located at fixed location is given as B_D and $d_{i,j}$.

A. Energy model of IoT

The initial energy, L_0 in the IoT node cannot be recharged. The energy loss occurs while transmitting the packets from the ith normal node to the jth cluster head. The energy loss follows the free space and multipath fading model. For estimating the energy dissipation in every IoT node, the hardware of receiver and transmitter is employed [5]. At the transmitter, the power amplifier and radio electronics is used for measuring the energy dissipation, whereas in the receiver, radio electronics is used for measuring the energy dissipation. While transmitting the data from U_c, the dissipation of the energy at the normal node is represented as,

$$L_p(B_R^u) = \begin{cases} L_q \times U_c + L_k \times U_c \times \left\| B_R^u - B_A^j \right\|^4 ; \ if \ \left\| B_R^u - B_A^j \right\| \geq b_0 \\ L_q \times U_c + L_g \times U_c \times \left\| B_R^u - B_A^j \right\|^4 ; \ if \ \left\| B_R^u - B_A^j \right\| < b_0 \end{cases} \quad (1)$$

$$b_0 = \sqrt{\frac{L_g}{L_k}} \quad (2)$$

Where the energy of the multipath fading and the free space model is represented as, L_g and L_k, the electronic energy L_q generated using the various factors like, filtering modulation, spreading, digital coding, and amplifier. The electronic energy, L_q is represented as,

$$L_q = L_h + L_r \quad (3)$$

Where, L_p and L_h are the data aggregation energy and transmitter energy. The distance from the cluster head to the normal node is denoted as, $\left\| B_R^u - B_A^j \right\|$. The packet is transmitted to the corresponding cluster by the cluster head after receiving the packet from the IoT node. Then, the packets from the cluster heads are transmitted to the base station. Thus, the energy value is updated after receiving data from cluster head node. The energy dissipated at the cluster head node while receiving U_c data bytes from the IoT node is represented as,

$$L_p(B_A^u) = L_q \times U_c \quad (4)$$

are located after sending or receiving the data byte U_c, the energy value of the IoT node is updated. When the data is transmitted to the cluster head from the normal node, the energy value is updated as, $L_{d+1}(B_R^u)$. Similarly, the energy in the cluster head is updated as, $L_{d+1}(B_A^u)$.

$$L_{d+1}(B_R^u) = L_d(B_R^u) - L_p(B_R^u) \quad (5)$$

$$L_{d+1}(B_A^u) = L_d(B_A^u) - L_p(B_A^u) \quad (6)$$

The data is transmitted until each node becomes a dead node. The dead node is the node with energy less than zero. As explained in this section, the data is collected and transmitted to the destination via a secured routing path, where the problem is regarding the selection of the effective route.

IV. EFFECTIVE ROUTING MECHANISM IN IOT USING THE PROPOSED CHRONOLOGICAL ASO ALGORITHM

In this research, chronological ASO is used for choosing the routing path in IoT. Figure 1 shows the block diagram of the proposed routing based on chronological ASO algorithm. Initially, the networks are simulated for transmitting the speech signals to the destination through the effective routing path. The effective routing path is determined using the chronological ASO algorithm, which is developed by integrating the chronological concept in the ASO algorithm [11]. The routing path with the best fitness value is selected for the transmission of the speech signals. The fitness measures, like energy, delay and distance are used for the evaluation.

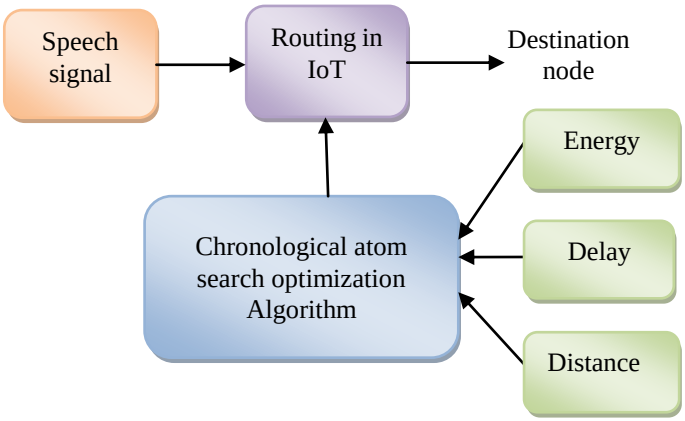

Fig. 1. Block diagram of proposed routing based on chronological ASO algorithm

A. Solution encoding

The solution vector comprises of the routing path that is selected by the proposed chronological ASO algorithm based on the fitness function and hence, the dimension of the solution varies as per the length of the path.

B. Fitness function

The fitness function assures the selection of the routes in IoT. The minimum fitness measure is computed by the below equation,

$$Q_{\min} = \sum_{i=1}^{n} E_i + F_i + w_i \quad (7)$$

The routing where E_i is the energy consumption of the mth node, F_i is the Euclidean distance between m^{th} and n^{th} node and w_i is the delay.

A. Proposed chronological-Atom search algorithm

In the routing, the proposed chronological-Atom search algorithm is used for the optimal selection of the routes for the transmission of speech signals. The chronological-Atom search algorithm is the integration of the chronological concept in Atom search algorithm. The optimization problems are solved using the Atom Search Optimization (ASO) algorithm. The ASO algorithm follows the atomic motion model in which the atoms are combined through the interaction forces resulting from the constraint and Lennard-Jones potential forces. Initially, the velocity v and set of atoms X_i are randomly initialized and atoms with best fitness value are considered as Q_{best}. For each of the randomly selected atom, the fitness value Q is computed as in equation-(16). If the fitness value in current iteration is higher than the fitness function of the previous iteration Q_{best} then, the fitness value of the current iteration is updated as the best fitness solution X_{best}. After the computation of the fitness solution, the next set of atom is selected and the acceleration, velocity is calculated until the end of the iteration and the fitness measures are updated. The acceleration of the atom related to its mass J_m is defined as,

$$a_m = \frac{H_m + W_m}{J_m} \quad (8)$$

where a_m is the acceleration of the atom, H_m and W_m is the interaction and the constraint force, $J_m(\tau)$ is the mass of the atom. In the eth dimension at the time instant τ, the interaction force acting on the mth atom from the nth atom is written as,

$$H_{mn}(\tau) = -\gamma(\tau)\left[2(y_{mn}(\tau))^{13} - (y_{mn}(\tau))^{7}\right] \quad (9)$$

where the repulsion region adjusted by the depth function is given as, $\gamma(\tau)$. The upper limits and lower limits of y is given as,

$$\begin{cases} y_{\min} = z_o + z(\tau) \\ y_{\max} = o \end{cases} \quad (10)$$

Where $y_{\max}$ and $y_{\min}$ are the upper and lower limits of y respectively. The drift factor is used for drifting the algorithm to the exploitation from exploration. The drift factor z is given as,

$$z(\tau) = 0.1 \times \sin\frac{\Pi}{2} \times \frac{\tau}{T} \quad (11)$$

The constraint force of the mth atom is given as,

$$W_m(\tau) = -2\beta(\tau)(x_m^e(\tau) - x_{best}^e(\tau)) \quad (12)$$

where $\beta(\tau)$ is the Lagrangian multiplier and $x_{best}^e(\tau)$ is the best atom's position at τ^{th} iteration.

Thus, substituting equation (9) and (12) in (8), we get

$$a_m(\tau) = \frac{H_m(\tau)}{J_m(\tau)} + \frac{W_m(\tau)}{J_m(\tau)}$$

$$a_m(\tau) = -\lambda(1 - \frac{\tau - 1}{T})^3 e^{\frac{-20\tau}{T}} \sum_{n \in S_{best}} \frac{rand_n \left[2(y_{mn}(\tau))^{13} - (y_{mn}(\tau))^7\right]}{J_m(\tau)} \frac{(x_m(\tau) - x_m(\tau))}{\|x_m(\tau), x_n(\tau)\|} + \alpha e^{\frac{-20\tau}{T}} \frac{x_{best}(\tau) - x_m(\tau)}{J_m(\tau)} \quad (13)$$

where $a_m(\tau)$ is the acceleration of the atom. The mass of the mth atom is calculated as,

$$J_m(\tau)=\frac{Z_m(\tau)}{\sum_{n=1}^{S} Z_m(\tau)} \tag{14}$$

where $Z_m(\tau)=e^{\frac{Q(\tau)-Q_{best}(\tau)}{Q_{worst}(\tau)-Q_{best}(\tau)}}$, Q_{best} is the fitness measure of the current iteration. The velocity and the position of the mth atom at $(\tau+1)^{th}$ iteration is given as,

$$v_m(\tau+1)=rand_m\, v_m(\tau)+a_m(\tau) \tag{15}$$

$$X_m(\tau+1)=X_m(\tau)+v_m(\tau+1) \tag{16}$$

where, $X_m(\tau)$ is the position of the atom and $v_m(\tau)$ is the velocity of the atom. Substituting the velocity equation in (16), we get,

$$X_m(\tau+1)=X_m(\tau)+rand_m\, v_m(\tau)+a_m(t) \tag{17}$$

The position of the atom at iteration τ becomes,

$$X_m(\tau)=X_m(\tau-1)+rand_m\, v_m(\tau-1)+a_m(\tau-1) \tag{18}$$

Substituting equation (18) in equation (17), we get

$$X_m(\tau+1)=X_m(\tau-1)+rand_m\, v_m(\tau-1)+a_m(\tau-1)+rand_m v_m(\tau)+a_m(\tau)`$$

$$X_m(\tau+1)=X_m(\tau-1)+rand_m\,(v_m(\tau-1)+v_m(\tau))+a_m(\tau-1)+a_m(\tau) \tag{19}$$

$$X_m(\tau+1)=\frac{X_m(\tau+1)+X_m(\tau+1)}{2} \tag{20}$$

Substituting equation (19) in equation (20), we get,

$$X_m(\tau)=\frac{X_m(\tau)+rand_m\, v_m(\tau)+a_m(\tau)+X_m(\tau-1)+rand_m\,(v_m(\tau-1)+v_m(\tau))+a_m(\tau-1)+a_m(\tau)}{2}$$

$$X_m(\tau)=\frac{1}{2}\left[X_m(\tau)+rand_m\,(2v_m(\tau))+v_m(\tau-1))+2a_m(\tau)+a_m(\tau-1)\right]$$

where, $a_m(\tau)$ is the acceleration of the atom and the value of $rand_m$ is the random number in $[0,1]$. Thus, the position of the atoms is determined and the best fitness measures are updated until the end of the iteration.

V. RESULT AND DISCUSSION

The result and discussion of the proposed chronological ASO algorithm, where the comparative analysis of the proposed chronological ASO algorithm is performed with the other existing methods.

A. Experimental setup

The proposed method is implemented in MATLAB software that runs in PC with Windows-8 OS and the data used for the analysis of the proposed chronological ASO algorithm is taken from ELSDSR corpus (ELSDSR database) [12].

B. Performance metrics

The performance analysis of the proposed chronological ASO algorithm method is done based on the metrics, such as energy, throughput, and PDR.

C. Comparative methods

The proposed chronological ASO algorithm is compared with the existing methods, like FGSA [5], ASO [11], Lightweight anonymous geometric routing [10], LASeR [3].

D. Comparative analysis

The comparative analysis of the proposed chronological ASO algorithm is done based on the performance metrics, like energy, throughput, and PDR for 50 nodes and 100 nodes by varying the number of rounds.

E. Analysis using 50 nodes

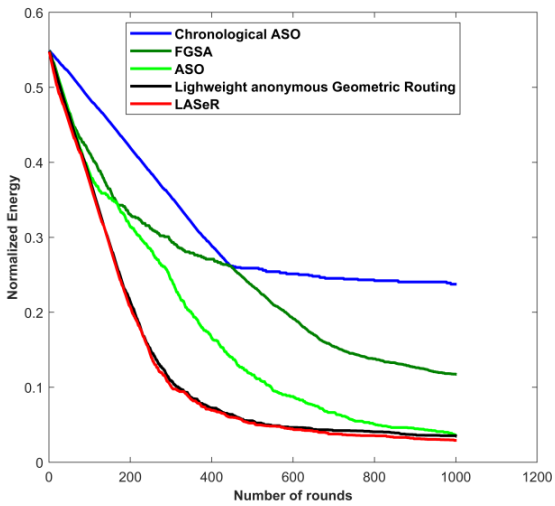

Fig 2.Comparative Analysis using 50 nodes a) energy

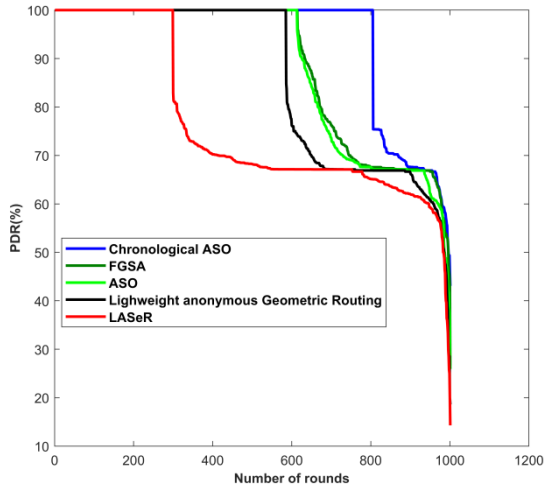

Fig. 2.Comparative Analysis using 50 nodes b) PDR

Figure 2 shows the comparative analysis of the proposed chronological ASO algorithm with the existing methods for 50 nodes by varying the number of rounds. Figure 2 a) shows the comparative analysis of the proposed chronological ASO algorithm with respect to the energy for varying number of rounds. At round 1000, the normalized energy obtained by the proposed chronological ASO algorithm and the existing methods, like FGSA, ASO, Lightweight anonymous geometric routing and LASeR are 0.2375, 0.1176, 0.0359, 0.0354 and 0.0292 respectively.

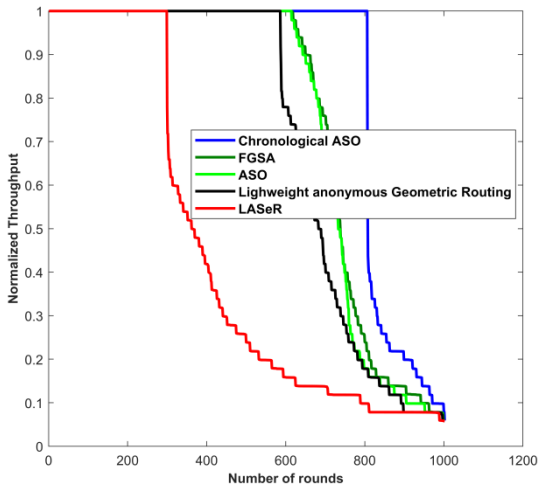

Fig. 2.Comparative Analysis using 50 nodes c) Throughput

Figure 2b) shows the comparative analysis of the proposed chronological ASO algorithm with respect to the PDR for varying number of rounds. The PDR obtained by the proposed chronological ASO algorithm and the existing methods, like FGSA, ASO, Lightweight anonymous geometric routing and LASeR, at round 1000 is 46.1538, 43.4211, 30.7692, 20 and 20 respectively.

Figure 2 c) shows the comparative analysis of the proposed chronological ASO algorithm with respect to the normalized throughput for varying number of rounds. At round 1000, the normalized throughput obtained by the proposed chronological ASO algorithm and the existing methods, like FGSA, ASO, Lightweight anonymous geometric routing and LASeR are 0.0792, 0.0590, 0.0588, 0.0581 and 0.0580 respectively.

F. Analysis using 100 nodes

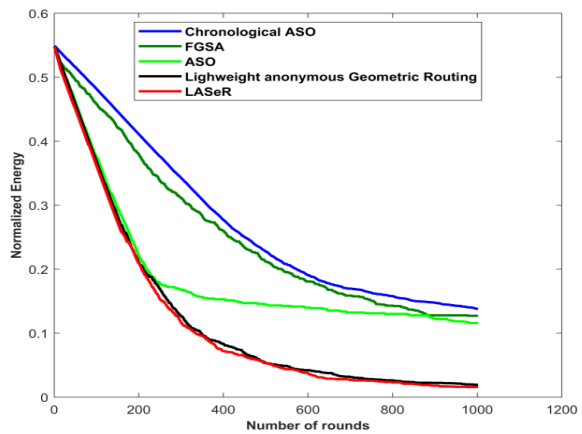

Fig. 3. Comparative Analysis using 100 nodes a) Energy

Figure 3 shows the comparative analysis of the proposed chronological ASO algorithm with the existing methods for 100 nodes by varying the number of rounds. Figure 3 a) shows the comparative analysis of the proposed chronological ASO algorithm with respect to the energy for varying number of rounds. At round 1000, the normalized energy obtained by the proposed chronological ASO algorithm and the existing methods, like FGSA, ASO, Lightweight anonymous geometric routing and LASeR are 0.1381, 0.1272, 0.1159, 0.0194 and 0.0159 respectively.

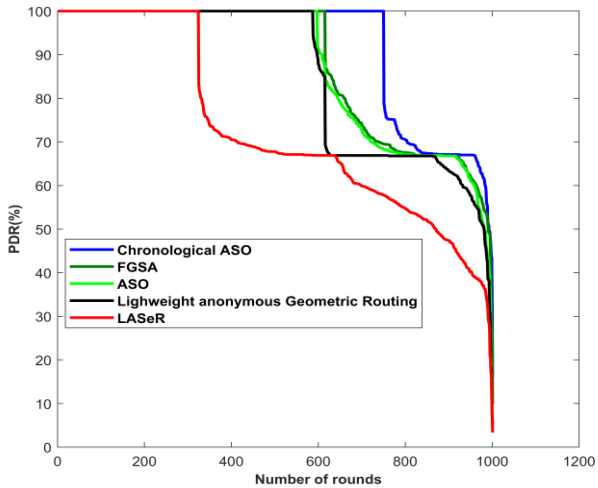

Fig. 3. Comparative Analysis using 100 nodes b) PDR

Figure 3 b) shows the comparative analysis of the proposed chronological ASO algorithm with respect to the PDR for varying number of rounds. The PDR obtained by the proposed chronological ASO algorithm and the existing methods, like FGSA, ASO, Lightweight anonymous geometric routing and LASeR, at round 1000 is 32.0988, 25.0000, 9.0909, 7.4074 and 6.6667 respectively.

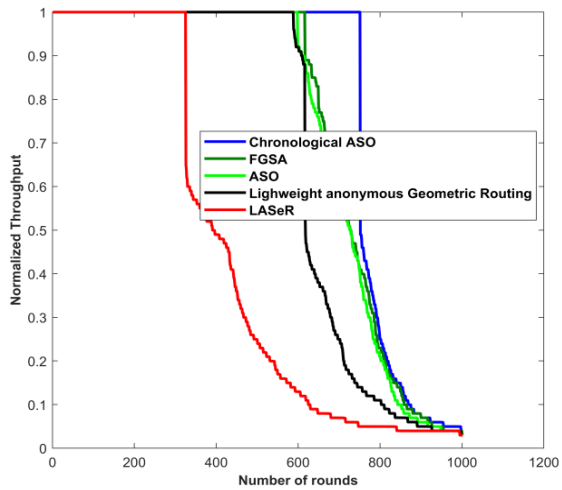

Fig. 3. Comparative Analysis using 100 nodes c) Throughput

Figure 3 c) shows the comparative analysis of the proposed chronological ASO algorithm with respect to the normalized throughput for varying number of rounds. At round 1000, the normalized throughput obtained by the proposed chronological ASO algorithm and the existing methods, like FGSA, ASO, Lightweight anonymous geometric routing and LASeR are 0.0395, 0.0388, 0.0298, 0.0297 and 0.0296 respectively.

VI. CONCLUSION

In this research, an effective optimization algorithm is developed for determining effective routing path thus, enabling effective communication of the speech signals to the appropriate destination. The optimization algorithm namely, chronological ASO algorithm is

developed for selecting the routing path. Initially, the network is simulated and the effective routing path is selected using the fitness parameters, like energy, delay and distance. The routing path with maximum fitness function is selected for the transmission of speech signal from the source to the destination node. The performance analysis of the proposed chronological ASO algorithm method is done based on the metrics, such as energy, throughput, and PDR. When compared to the existing methods, the proposed method provided a maximal energy of 0.2375, maximal PDR of 46.1538 and maximal throughput of 0.0792 for 50 nodes and obtained a maximal energy of 0.1381, maximal PDR of 32.0988 and maximal throughput of 0.0395 respectively. The future enhancement can be done using different optimization algorithms and moreover, hybrid optimizations would benefit better in selecting the best routing path in such a way that the communication performance will be enhanced.

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AUTHORS PROFILE

Dr. S. Srinivasa Rao is working as Associate Professor, Department of ECE, MGIT, JNTUH, Hyderabad, India. He received his Ph.D. (Electronics and Communication Engineering) degree from ANU, Guntur, Andhra Pradesh, India. He has 18 years teaching experience and has published 8 research papers in International journals, conferences. His research interest areas include Embedded Systems, Signal Processing, Wireless Networks, and IoT.

Dr. V. Subba Ramaiah is working as Assistant Professor, Department of CSE, MGIT, JNTUH, Hyderabad, India. He received his Ph.D. (Computer Science & Engineering) degree from JNTUH, India. He has 16 years teaching experience and has published 15 research papers in International journals, conferences. His research interest areas include Speaker Recognition, Image Processing, Wireless Networks, and IoT.

K.Raghu, M.Tech working as Assistant Professor, Department of ECE, MGIT, JNTUH, Hyderabad, India. He received his M.Tech. ((Electronics and Communication Engineering) degree from JNTUH, India. He has 16 years teaching experience and has published 5 research papers in International journals, conferences. His research interest areas include, Communications, Signal Processing, and Wireless Networks.