Indonesian Journal of Electrical Engineering and Computer Science
Vol. 32, No. 3, December 2023, pp. 1630~1638
ISSN: 2502-4752, DOI: 10.11591/ijeecs.v32.i3.pp1630-1638

Adaptive traffic aware clustering and routing model for wireless sensor networks

Rudramurthy Veeregowdanadoddi Chandraiah[1], Aparna Ramalingappa[2]
[1]Department of Computer Science and Engineering, Global Academy of Technology, Affiliated to Visvesvaraya Technological University, Belagavi, India
[2]Department of Information Science and Engineering, Siddaganga Institute of Technology, Affiliated to Visvesvaraya Technological University, Belagavi, India

Article Info

Article history:

Received May 5, 2023
Revised Aug 7, 2023
Accepted Sep 15, 2023

Keywords:

Hot-spot problem
Load-balancing
Network lifetime
Routing
Traffic aware clustering
Wireless sensor networks

ABSTRACT

Designing effective clustering algorithms plays a very important role in improving network lifetime target coverage (NLTC) in heterogeneous wireless sensor networks (HWSNs). However, the current clustering mechanism failed to address hotspot problem resulting in poor coverage and network lifetime performance. Recently, unequal clustering has been used for addressing hotspot problem in HWSNs. However, when performing inter-cluster routing, load balancing is not efficient and the energy degradation is high, which affects the overall network performance. This work introduces an effective model namely adaptive traffic aware clustering and routing (ATACR) model to address hotspot and load balancing issues. The ATACR introduces a novel unequal clustering and ideal distribution of load in different cluster levels. The ATACR model improves network lifetime, reduces control channel overhead, and attains better throughput in comparison with existing routing models.

Corresponding Author:

Rudramurthy Veeregowdanadoddi Chandraiah
Department of Computer Science and Engineering, Global Academy of Technology
Affiliated to Visvesvaraya Technological University
Belagavi, India
Email: rudramurthy.vc@gmail.com

1. INTRODUCTION

In order to support a variety of uses, including emergency planning, environmental monitoring, precision farming, and more, the next generation of wireless sensor networks (WSNs) must be integrated inside an internet-of-things (IoT) environment [1]. The WSNs are made up of a variety of small, self-organized sensing devices that are typically deployed in dangerous areas to perform tasks including detecting, information gathering [2], and data transfer in order to accomplish smart decision processing. As a result of their useful properties [3], such as low consumption of energy, high reliability, as well as simple deployment, WSNs are being used in a variety of applications, including medical and monitoring equipment. WSNs have a shorter lifespan as a result of constraints such as constrained connectivity, memory, processing capabilities, and compute capability [4]. Due to the fact that many sensor devices run on batteries, it is crucial to find ways to conserve electricity. In addition, current applications' demands for reliability necessitate a well-thought-out optimal routing design [5], [6].

Clustering methods, like low-energy adaptive-clustering-hierarchy (LEACH), have been highlighted for their ability to extend the network's life span [7], [8]. Under LEACH, the WSNs are divided into small groups called clusters, as well as the sensor devices only with highest available energy are selected as cluster-heads (CHs), while the remaining nodes act as members. Consequently, nodes share their information with one another via intra-cluster communication (i.e., CHs), which then aggregates the information to remove duplicates [9], [10] before sending it using a multi-hop or single-hop manner to the base-station (BS) (inter-cluster-communication). Cluster heads far away from the BS consume less energy than CHs near to the BS in multi-hop-based-clustering-models [11], [12], leading to a high chance of energy-hole issue. In other words, the node closest towards the BS is likely to die earlier [13] compared to CHs which are quite far away from BS. Nodes which are closer towards its BS use more energy than nodes which are farther away from the BS; this is because the sensor-device is typically positioned randomly in WSNs. Because of these factors, the nodes that are physically near the BS have a greater propensity to die off more quickly, which creates an energy-hole problem. A novel approach is presented in [14] to deal with the energy-hole issue; this approach is certainly an uneven clustering approach in which individual clusters are not all the same size; the cluster far-away to the BS will have a bigger cluster-size, while the clusters closest to the BS will have a lower cluster-size. A small amount of energy from relay-nodes (RNs) can be conserved through the use of an uneven clustering technique while communicating inside a cluster. In sensor-networks, RNs are a subset of nodes that are only responsible for relaying the information generated through other sensor-nodes and not performing any environmental sensing themselves. Nevertheless, none of the previous efforts have addressed routing and selection of cluster head while taking quality of service (QoS) constraints into account inside an uneven clustering environment. In addition, the formation of relay paths in the current method is accomplished at random, as well as is contingent on availability; however, QoS constrictions are not taken into interpretation. As a result, the method fails to meet the reliability requirements necessary for providing applications that have a data-intensive workload. This motivated the idea for the proposed effort to create an adaptive traffic aware cluster and routing (ATACR) for heterogeneous WSNs. The ATACR model's goal is to create an effective CH selection strategy that enhances network coverage and lessens hot-spot issues while taking into account an uneven clustering environment. The ATACR model's goal is to identify an adaptive traffic-aware routing route for sending data to the base station.

The paper is structured as follows. In section 2, the literature survey is discussed. In section 3 proposed methodology of adaptive traffic aware clustering and routing technique is presented. Section 4 discusses how using ATACR compares to the current routing method in terms of performance. Future study directions are provided as a conclusion in the last section of the paper.

2. LITERATURE SURVEY

This section investigates recent routing schemes that have been proposed for WSNs [15], [16]. With 5G networking, the IoTs, as well as other next-generation communication environments under consideration, the researchers provided a transmitting data clustering approach optimized for maximizing network lifespan as well as energy consumption. Han *et al.* [17] employ a k-mean clustering algorithm to organize nodes into groups, as well as a multi-hop technique to determine how packets would be routed between nodes. Here, packets are directed in a multi-hop manner by building a link, and cluster-based routing was performed until two-third of sensing devices die inside the network. The most significant drawback of the work, however, is that it results in increased overhead to CH that is located nearer towards the base station. With the use of a fog computing environment, Abidoye and Kabaso [18] proposed a hierarchical-based data transfer method for WSNs. In order to optimize WSNs energy consumption to meet the needs of IoT-based systems, researchers switched to fog-computing. An ant-colony-optimization (ACO) methodology is used to determine the best course of action. Convergence costs restricts the method's ability to pinpoint the optimal path. Maheshwari *et al.* [19] developed a butterfly-optimization method as a means of choosing the optimal CH from among the clusters of sensing devices. Connection, neighbor density, proximity to the access point, proximity to neighbors, as well as residual energy are amongst the many factors taken into account for optimizing the CH selection. The best route is then chosen using the ACO methodology, which takes into account a number of different criteria, including connection, proximity, as well as residual energy. Its main drawback is that it is affected by a hotspot issue, and that CH selection causes non-polynomial deterministic issues.

Zhu and Wei [20] describe a strategy for energy-efficient routing that takes advantage of uneven clustering to solve the hotspot issue. Even more so, twin cluster heads are chosen to lessen the energy burden of CHs. To achieve this equilibrium between cluster members as well as CHs, a rotating approach based on events and energy is used to choose CHs. Hotspot mitigation is ignored and it is only applicable to a localized network. In order to solve the issue of hotspots, Wang *et al.* [21] proposed a number of data gathering strategies that were built on mobile sinks. Therefore, single-hop communications is used between all nodes to send data to a mobile node. The researchers proposed a successful mobile sink migrating trajectory by combining a modified-particle-swarm and genetic-algorithm-optimization methodology, where particle swarm optimization (PSO) is used to locate a sink having a rate of high coverage as well as the genetic-algorithm (GA) is used to define a movable route of various sinks. Buffer-concurrency as well as transmission overhead make this approach prohibitively expensive to implement, though. Many existing approaches have underlined the utilization of the type-1 fuzzy-rule to overcome the challenges posed by the uncertainty in defining node location as well as power requirements of sensing devices [22]. Thirupathaiah [23] CHs were chosen using a soft-computing approach by way of type-2 fuzzy rules. The second goal of this approach is to distribute work evenly across CHs, but it was built assuming a constant number of nodes per cluster and does not account for things like packet-loss or link-quality while communicating between the nodes. Yuste-Delgado *et al.* [24] suggest a type-2 fuzzy regulations and emphasize a new routing architecture to increase longevity and strengthen security for WSNs in order to solve the hotspot issue. Type-2 fuzzy regulations deal with uncertainties better than type-1 fuzzy regulations because of the interval they introduced for constructing membership functions [25]. Nonetheless, CH is chosen using a mono-objective technique, which leads to inefficient load balancing and increased energy costs. Tao *et al.* [14] proposed efficient and scalable cluster routing (ESCR) employing uneven clustering methodology by applying type-2 fuzzy-logic-theory with intervals. In order to improve network lifespan, the ESCR solves the hotspot issue using minimal computing complexity (considering factors like node density, proximity towards the base-station, as well as residual energy). Furthermore, fuzzy rule [26]–[28] is employed for multi-objective-optimization of metrics including sensor densities, average energy, as well as proximity towards the sink; the result is used for optimizing number of clusters and choosing a CH. Nevertheless, QoS is not a requirement in ESCR's choice of CH or RNs. The RNs function as hop-nodes, shortening the path from the far-flung sensing device to the hub/sinks.

Jagan and Jayarin [29] present a novel fully-connected-energy-efficient-clustering (FCEEC) mechanism based on the electrostatic discharge algorithm to build a fully connected network with shortest path routing from sensor nodes (SNs) to the CH in a multi-hop environment. Alharbi *et al.* [30] showed it is impossible to develop methods that minimized both energy consumption and network lifetime. They discuss the interconnected problems of clustering and routing in a wide-area IoT-based WSN, and suggest a new technique to address both of them simultaneously. Area-based clustering, depending on the nodes' respective transmission ranges, enhances both the clustering and routing processes. Cluster-heads are chosen in a way that ensures reliable routing even if one node fails. Finding the path with the fewest possible hops requires considering all possible routes. Han *et al.* [31] showed in spite of the fact that energy harvesting (EH) technology can extend the lifetime of WSNs, an energy-efficient routing protocol must be designed for EH-WSNs because nodes are unreachable during the energy harvesting phase. If a significant fraction of the nodes in a WSN were to go down, the network's ability to keep an eye on the surrounding area would suffer. In order to ensure continuous coverage of the designated area, they presented an adaptive hierarchical-clustering energy-harvesting unequal-clustering (HCEH-UC) based routing protocol [32]. The HCEH-UC protocol may ensure continuous target coverage utilizing energy-harvesting technology for much longer lifetimes than the current routing strategy. Lenka *et al.* [33] showed that clustering and multipath techniques work together to reduce network congestion. To reduce the amount of duplicate data in cluster-based routing protocol with static hub (CRPSH), clustering was used. Furthermore, the multipath approach has the potential to increase the reliability of the proposed protocol. The purpose of CRPSH is to lengthen the life of the network by decreasing the amount of time spent on control packets. Kaur *et al.* [34], authors detail a hybrid congestion control technique for IoT-enabled WSNs that is energy efficient. Using an unequal clustering method helps conserve energy for sensor nodes with short battery life and addresses issues with energy holes. In addition, they create a novel congestion avoidance technique that uses a two-tiered priority structure to significantly cut down on communication delay with enhanced throughput, improved network lifetime, and better packet delivery performance for disaster control in applications for smart cities.

3. PROPOSED METHOD

This section presents adaptive traffic aware clustering and routing scheme for WSNs. In this work, first the system energy and channel model are described. Then, the CH selection method used in [35] is defined. Then, how the network is clustered into different levels is described, i.e., where the cluster closer to base station will have smaller cluster size and the cluster far away from base station will have higher cluster size. Finally, the work computes the energy required to route packet at different levels and routing optimization is done considering shortest path with minimal energy consumption that maximizes the network lifetime target coverage.

3.1. Channel and energy model

In this work, the rayleigh fading model is used for describing the channel between cluster leaders and between the base station and the cluster head. The channel gain experienced between two communicating devices separated by distance y is expressed through in (1);

$$i(y) = M(e_0)\left(\frac{y}{e_0}\right)^{-o}\beta \quad (1)$$

where $M(e_0)$ defines the path loss component considering distance e_0 and is measured as (2).

$$M(e_0) = \frac{H_u H_s m^2}{16\pi^2 e_0^2} \quad (2)$$

H_u defines sender antenna gain, H_s defines receiver antenna gain, m defines carrier frequency wavelength, β defines normalized randomness of fading parameter which is exponentially distributed and o defines the path loss component. In order to get ideal communication, a probabilistic model is considered (i.e., $P\{f_s \geq \delta\} \geq \gamma_m$), where f_s represents received signal strength, δ represents preconfigured signal strength threshold, and γ_m defines channel reliability characteristic.

3.2. Cluster head selection model

Tao *et al.* [14] and Kaur *et al.* [34] showed benefit of using unequal clustering in addressing hot-spot problem; however, the unequal clustering model (the clusters size varies at different level j i.e., the node closer to base station has lower cluster size in comparison with cluster far away from bas station) presented in [35] addressed both hotspot and coverage problem. Let the senor deployed in random manner with density δ and same communication range S. In this work, the factor r is adjusted by considering normalized overlapping section of sensor device d during cluster head selection process as described in (3);

$$r(d) = \propto \times\ \omega(d), \quad (3)$$

where $\propto$ denotes the typical size of cluster and ω pronounces sensor device normalized overlapping area. The threshold model $T(d)$ used for cluster head selection of node$d$ is computed as (4);

$$T(d) = \begin{cases} \frac{r(d)}{1-r(d)\times[\varphi mod(1/r(d))]}, & if\ d \in \bar{S}; \\ 0 & Otherwise. \end{cases} \quad (4)$$

where $\bar{S}$ defines member node which has not been selected as CH yet for corresponding gathering period, d symbolizes the CH for round $1/r(d)$; thus, different devices will have a dissimilar probability of being CH [20], [34]. the existing model [14], [35] failed to address the load optimization in inter-cluster routing which is addressed below in more adaptive manner with respect to varying traffic with minimal energy consumption.

3.3. Adaptive load optimization of different cluster

In this work, the packet is routed in hop-by-hop manner through intermediate cluster head with shortest distance towards base station; thus, the cluster head present in the j^{th}level communicates the packet generated to its nearby cluster head in the $(j-1)^{th}$ level. The distance between any two communicating cluster heads be presented by parameter y_j and the anticipated communication energy is expressed as (5);

$$Q_{U_j} = f_{uj}(\alpha_{pj} + \alpha_{qj}) \quad (5)$$

where f_{uj} defines energy consumption of CH for transmitting per bit of data. Using the proposed energy dissipation model, the anticipated energy consumption of any cluster head in the level j is obtained as (6);

$$Q_j = (f_{sy} + f_{uy} + f_{uj})(\alpha_{pj} + \alpha_{qj}) \quad (6)$$

the receiving energy f_{sj} considering respective f_{uj} is obtained as (7);

$$f_{sj} = f_{uj} M(e_0)\left(\frac{y_j}{e_0}\right)^{-n}\beta \quad (7)$$

the adaptive communication path i.e., most reliable path is obtained through in (8).

$$\mu_m = \mathcal{P}\{f_{sj} \geq \varphi\} = \mathcal{P}\left\{\beta \geq \frac{\varphi}{f_{uj}M(e_0)}\left(\frac{y_j}{e_0}\right)^{o}\right\} \quad (8)$$

The maximum path considering shortest-path routing is L; thus, to assure constraint μ_q in establishing reliable path, the following condition should be satisfied;

$$\mu_q = \mu_q^{\frac{1}{L}} \quad (9)$$

the tradeoff in minimizing energy to meet path reliability requirement is obtained by equating (8) and (9) as (10);

$$f_{uj} = \frac{L\varphi y_j^o}{M(e_0)e_0^o \log \mu_q} \quad (10)$$

the parameter y_j in (10) can be replaced with lower limits $y_{j_{min}}$ for upper limiting the anticipated lifetime improvement as given in (11);

$$y_{j_{min}} = \begin{cases} \frac{s_1+s_0}{2}, & for\ j = 1 \\ \frac{s_j-s_{j-2}}{2}, & for\ j = 2, \dots, K \end{cases} \quad (11)$$

the lower limits define the total radius of cluster in j^{th} level and radius of closest cluster within $(j-1)^{th}$ level. Thus, the space among the cluster heads of two next to clusters is minimum $y_{j_{min}}$. The total aggregated load considering certain bit rate that comes from clusters within level j through L is obtained through in (12).

$$\alpha_{totalj} = \pi\left(S^2 - s_{j-1}^2\right)\sigma\alpha\frac{\phi}{2\pi}, \ \ j = 1, \dots, L \quad (12)$$

In this work, the packet load experienced by cluster heads in j^{th} level is identical to overall data generated from all the clusters in level j to L due to adoption of hop-based communication; thus, the load is distributed evenly across different cluster heads in that level. The size of cluster heads in the j^{th} level is approximated through in (13);

$$O_j \approx \frac{2\pi s_j}{s_j - s_{j-1}}\frac{\phi}{2\pi} \quad (13)$$

thus, the average load experienced at the different cluster head in the level j is obtained through in (14);

$$\alpha_{pj} + \alpha_{sj} = \frac{\alpha_{totalj}}{O_j} \approx \frac{\left(S^2 - s_{j-1}^2\right)\left(s_j - s_{j-1}\right)}{2s_j}\sigma\alpha \quad (14)$$

using (10), (11) and (14) in (6), the anticipated energy dissipation of cluster head in j^{th} level is given in the (15);

$$Q_1 = \left[f_{sj} + f_{us} + \frac{L\varphi}{M(e_0)e_0^o \log \mu_q}\left(\frac{s_1+s_0}{2}\right)^o\right] \times \frac{(S^2 - s_0^2)(s_1 - s_0)}{2s_1}\sigma\alpha \quad (15)$$

and,

$$Q_j = \left[f_{sj} + f_{us} + \frac{L\varphi}{M(e_0)e_0^o \log \mu_q}\left(\frac{s_j+s_{j-2}}{2}\right)^o\right] \times \frac{\left(S^2 - s_{j-1}^2\right)\left(s_j - s_{j-2}\right)}{2}\sigma\alpha, \ for\ j = 2, \dots, K \quad (16)$$

the objective of this work is to compute s that reduces the average maximum energy dissipation between entire cluster heads using following optimization function;

$$\begin{cases} \min_{\{s_1,\dots,s_L\}} \{max\{Q_1, \dots, Q_L\}\} \\ \quad \text{subject to} \\ s_0 < s_1 < \dots < s_L = S \end{cases} \quad (17)$$

where Q_j, $j = 1, \dots, L$, are obtained using (15) and (16). The optimization problem of (17) is changed by introducing additional constraint $u \geq Q_j$ for $1 \leq j \leq L$ and is expressed as (18);

$$\begin{cases} \min_{\{s,u\}} u \\ \text{subject to} \\ u^{-1}Q_j < 1,\ j = 1, \dots, L \\ s_{j-1}s_j^{-1} < 1,\ j = 1, \dots, L \\ s_L = E. \end{cases} \quad (18)$$

using (18) for routing aided in reducing energy of CHs in more efficient way with enhanced network lifetime target coverage.

4. RESULTS AND DISCUSSION

In this section, the results have been discussed by comparing the LEACH, ATACR and ESCR method [14]. The experimentation has been done in the sensoria simulator [36] which is used widely for evaluation of various routing methods. The methods have been evaluated using the C# programming language. Comparison of the results with the previous methods have been done in terms of the lifetime of the node, communication-delay as well as the control-channel communication-overhead. The simulation parameter is defined as follows: network area is set to 100×100 m. one base station is considered and placed outside sensing area. The sensor devices are varied from low (500), medium (1,000), high (1,500), xhigh (2,000) with sensing and transmission range is set to 5 m and 10 m, respectively. The initial energy varies between 0.1-0.3 j. Th idle energy consumption (Eelec), radio unit energy consumption, and amplification energy (Emp) is set to 50 nj/bit, 50 nj/bit, and 100 pJ/bit/m^2. The control packet size, data packet size, transmission speed, and sensing time is set to 512 bits, 5,000 bits, 256 bits/s and 0.1s, respectively.

4.1. Lifetime

The lifetime performance of the proposed routing technique ATACR as well as the existing routing techniques, LEACH and ESCR have been evaluated by considering the sensor devices in this section. In Figure 1, low to extra high-density devices have been varied and the lifetime of the sensor nodes has been evaluated and compared with the existing routing techniques, LEACH and ESCR. It can be seen that in Figure 1, the performance of the lifetime of the sensor nodes for the ATACR technique has been increased by 61.36%, 60.621%, 63.63%, and 64.54% when compared with the existing routing technique, ESCR for low density, medium density, high density, and extra-high (xhigh) density, respectively. Further, it can be seen that in Figure 1, the performance of the lifetime of the sensor nodes for the ATACR technique has been increased by 75.51%, 77.33%, 85.78%, and 89.82% when compared with the existing routing technique, LEACH for low density, medium density, high density, and extra-high density, respectively. The proposed ATACR technique increases the performance of lifetime by 82.11% for LEACH and 62.53% for ESCR routing techniques. The results show that the proposed ATACR technique provides better results for the low and extra high density WSN environment as they adopt an enhanced method for the cluster head selection and automatic cluster head selection inside the unbalanced cluster environment.

4.2. Communication delay

The communication delay is the time taken for the sensor devices to communicate the information to the cluster head. The communication delay of the proposed routing technique, ATACR, as well as the existing routing techniques, LEACH and ESCR have been in this section. In Figure 2, low to extra high-density devices have been varied and the delay for communication of the sensor nodes has been evaluated and compared with the existing routing techniques, LEACH and ESCR. It can be seen that in Figure 2, the delay for communication for the sensor nodes to the cluster head for the ATACR technique has been decreased by 55.29%, 49.32%, 46.04% and 53.83% when compared with the existing routing technique, ESCR for low density, medium density, high density, and extra-high density, respectively. Further, it can be seen that in Figure 2, the delay for communication for the sensor nodes to the cluster head for the ATACR technique has been reduced by 58.28%, 55.52%, 54.82%, and 61.23% when compared with the existing routing technique, LEACH for low density, medium density, high density, and extra-high density, respectively. The proposed ATACR technique decreases the delay for communication by 57.46% for LEACH and 51.12% for ESCR routing techniques. Adopting multipath-based routing selection for transmission of packets in accordance with QoS criteria has resulted in a notable decrease in delay. The fact that ATACR was able to achieve this outcome is due to its widespread use, which demonstrates that it is capable of meeting the QoS requirements of contemporary applications.

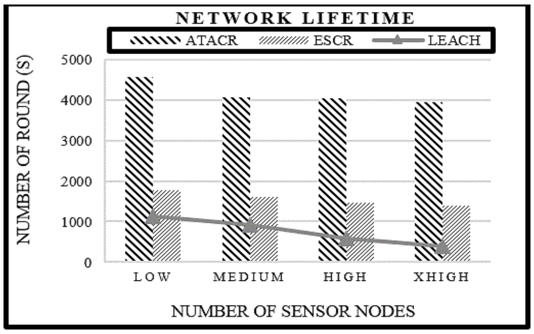

Figure 1. Network lifetime under varied density

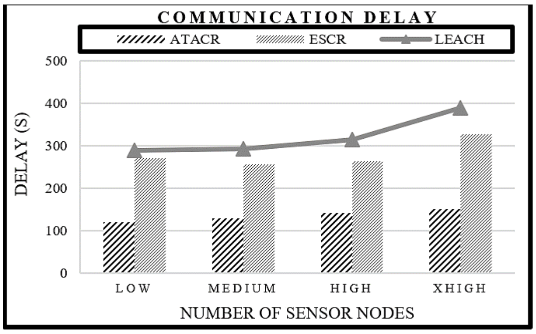

Figure 2. Communication delay under varied density

4.3. Control channel communication overhead

The control channel communication overhead of the proposed routing technique, ATACR, as well as the existing routing techniques, LEACH and ESCR have been evaluated in this section. In Figure 3, low to extra high-density devices have been varied and the control channel communication overhead for the sensor nodes has been evaluated and compared with the existing routing techniques, LEACH and ESCR. It can be seen that in Figure 3, the control channel communication overhead for the sensor nodes for the ATACR technique has been decreased by 11.92%, 17.27%, 31.27%, and 32.73% when compared with the existing routing technique, ESCR for low density, medium density, high density, and extra-high density, respectively. Further, it can be seen that in Figure 3, the control channel communication overhead for the sensor nodes for the ATACR technique has been reduced by 6.54%, 7.98%, 32.33%, and 44.54% when compared with the existing routing technique, LEACH for low density, medium density, high density, and extra-high density, respectively. The proposed ATACR technique decreases the control channel communication overhead by 22.84% for LEACH and 23.29% for ESCR routing techniques. All routing techniques provide the same results up to a limited number of nodes, however when the network grows larger than this threshold, the CCH cost for both LEACH as well as ESCR routing techniques becomes much more noticeable. However, the ATACR technique causes a minor increase in overhead by choosing an ACH that minimizes re-clustering overhead.

4.4. Throughput

The throughput of the proposed routing technique, ATACR, as well as the existing routing techniques, LEACH and ESCR have been evaluated in this section. In Figure 4, low to extra high-density devices have been varied and the throughput for the sensor nodes has been evaluated and compared with the existing routing techniques, LEACH and ESCR. It can be seen that in Figure 4, the throughput for the sensor nodes for the ATACR technique has been increased by 50.98%, 57.06%, 57.93%, and 53.23% when compared with the existing routing technique, ESCR for x low density, medium density, high density, and extra-high density, respectively. Further, it can be seen that in Figure 4, the throughput for the sensor nodes for the ATACR technique has been increased by 62.85%, 62.93%, 66.8%, and 59.74% when compared with the existing routing technique, LEACH for low density, medium density, high density, and extra-high density, respectively. The proposed ATACR technique increases the throughput by 63.08% compared to LEACH and 54.79% compared to ESCR routing techniques. When compared to LEACH as well as ESCR routing techniques, the substantial outcome was accomplished by switching to a cluster head selection method that places more emphasis on enhancing coverage, which in turn extends the network's lifetime and causes it to communicate more packets.

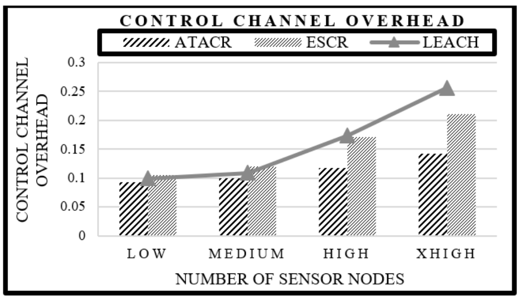

Figure 3. Control channel overhead under varied density

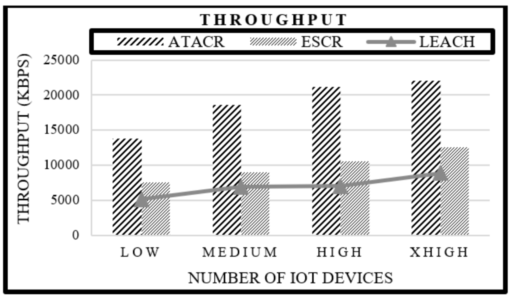

Figure 4. Throughput under varied density

5. CONCLUSION

One of the primary goals of WSNs should be to reduce the power requirements of individual sensor nodes and eliminate the hotspot issue. Recent years have seen the introduction of a number of strategies for reducing energy consumption. In the future, big data and IoTs applications that make use of sensor nodes will demand decreased access to real-time information. Not only are conventional approaches unsuitable for such uses, but researchers have also paid comparatively little attention to unequal clustering networks. In order to reduce power consumption, delay, and packet loss, the ATACR model is presented in this study. The efficiency of ATACR is compared to that of currently used routing protocols like LEACH and ESCR through a series of simulations and experiments. When compared to LEACH as well as ESCR routing approaches, the suggested ATACR technique improves WSNs' lifespan by decreasing control channel overhead and communication delay. It is clear from the outcome that the ATACR model can be applied to networks of varying densities of varying size. The future work would study model considering different simulation parameters.

REFERENCES

[1] F. Karray, M. W. Jmal, A. Garcia-Ortiz, M. Abid, and A. M. Obeid, "A comprehensive survey on wireless sensor node hardware platforms," *Computer Networks*, vol. 144, pp. 89–110, Oct. 2018, doi: 10.1016/j.comnet.2018.05.010.

[2] K. N. Kumar and A. Bharathi, "Real time energy efficient data aggregation and scheduling scheme for WSN using ATL," *Computer Communications*, vol. 151, pp. 202–207, Feb. 2020, doi: 10.1016/j.comcom.2019.12.027.

[3] I. S. Al-Mejibli and N. R. Alharbe, "A multi-hop routing protocol for an energy-efficient in wireless sensor network," *International Journal of Electrical and Computer Engineering*, vol. 13, no. 3, pp. 2953–2961, Jun. 2023, doi: 10.11591/ijece.v13i3.pp2953-2961.

[4] B. A. Begum and S. V. Nandury, "Data aggregation protocols for WSN and IoT applications-a comprehensive survey," *Journal of King Saud University - Computer and Information Sciences*, vol. 35, no. 2, pp. 651–681, Feb. 2023, doi: 10.1016/j.jksuci.2023.01.008.

[5] S. Savitha, S. C. Lingareddy, and S. Chitnis, "Energy efficient clustering and routing optimization model for maximizing lifetime of wireless sensor network," *International Journal of Electrical and Computer Engineering*, vol. 10, no. 5, pp. 4798–4808, Oct. 2020, doi: 10.11591/ijece.v10i5.pp4798-4808.

[6] R. V. Chandraiah and A. Ramalingappa, "Secure authentication and data aggregation scheme for routing packets in wireless sensor network," *International Journal of Electrical and Computer Engineering*, vol. 13, no. 3, pp. 3217–3226, Jun. 2023, doi: 10.11591/ijece.v13i3.pp3217-3226.

[7] H. El-Alami and A. Najid, "ECH: an enhanced clustering hierarchy approach to maximize lifetime of wireless sensor networks," *IEEE Access*, vol. 7, pp. 107142–107153, 2019, doi: 10.1109/ACCESS.2019.2933052.

[8] F. A. Khan, M. Khan, M. Asif, A. Khalid, and I. U. Haq, "Hybrid and multi-hop advanced zonal-stable election protocol for wireless sensor networks," *IEEE Access*, vol. 7, pp. 25334–25346, 2019, doi: 10.1109/ACCESS.2019.2899752.

[9] Q. Wang, D. Lin, P. Yang, and Z. Zhang, "An energy-efficient compressive sensing-based clustering routing protocol for WSNs," *IEEE Sensors Journal*, vol. 19, no. 10, pp. 3950–3960, May 2019, doi: 10.1109/JSEN.2019.2893912.

[10] T. Salam, W. U. Rehman, and X. Tao, "Data aggregation in massive machine type communication: challenges and solutions," *IEEE Access*, vol. 7, pp. 41921–41946, 2019, doi: 10.1109/ACCESS.2019.2906880.

[11] D. S. Nayagi, G. G. Sivasankari, V. Ravi, K. R. Venugopal, and S. Sennan, "REERS: reliable and energy-efficient route selection algorithm for heterogeneous Internet of things applications," *International Journal of Communication Systems*, vol. 34, no. 13, Sep. 2021, doi: 10.1002/dac.4900.

[12] O. P. Asqui, L. A. Marrone, and E. E. Chaw, "Multihop deterministic energy efficient routing protocol for wireless sensor networks MDR," *International Journal of Communications, Network and System Sciences*, vol. 14, no. 03, pp. 31–45, 2021, doi: 10.4236/ijcns.2021.143003.

[13] M. Y. Arafat, S. Pan, and E. Bak, "Distributed energy-efficient clustering and routing for wearable IoT enabled wireless body area networks," *IEEE Access*, vol. 11, pp. 5047–5061, 2023, doi: 10.1109/ACCESS.2023.3236403.

[14] Y. Tao, J. Zhang, and L. Yang, "An unequal clustering algorithm for wireless sensor networks based on interval type-2 tsk fuzzy logic theory," *IEEE Access*, vol. 8, pp. 197173–197183, 2020, doi: 10.1109/ACCESS.2020.3034607.

[15] M. K. Khan *et al.*, "Hierarchical routing protocols for wireless sensor networks: functional and performance analysis," *Journal of Sensors*, vol. 2021, pp. 1–18, May 2021, doi: 10.1155/2021/7459368.

[16] R. Zagrouba and A. Kardi, "Comparative study of energy efficient routing techniques in wireless sensor networks," *Information (Switzerland)*, vol. 12, no. 1, pp. 1–28, Jan. 2021, doi: 10.3390/info12010042.

[17] S. Han, X. M. Liu, H. Y. Huang, F. Wang, and Y. H. Zhong, "Research on energy-efficient routing algorithm based on SWIPT in multi-hop clustered WSN for 5G system," *Eurasip Journal on Wireless Communications and Networking*, vol. 2021, no. 1, p. 49, Dec. 2021, doi: 10.1186/s13638-021-01931-5.

[18] A. P. Abidoye and B. Kabaso, "Energy-efficient hierarchical routing in wireless sensor networks based on fog computing," *Eurasip Journal on Wireless Communications and Networking*, vol. 2021, no. 1, p. 8, Dec. 2021, doi: 10.1186/s13638-020-01835-w.

[19] P. Maheshwari, A. K. Sharma, and K. Verma, "Energy efficient cluster based routing protocol for WSN using butterfly optimization algorithm and ant colony optimization," *Ad Hoc Networks*, vol. 110, p. 102317, Jan. 2021, doi: 10.1016/j.adhoc.2020.102317.

[20] F. Zhu and J. Wei, "An energy-efficient unequal clustering routing protocol for wireless sensor networks," *International Journal of Distributed Sensor Networks*, vol. 15, no. 9, p. 9, 2019, doi: 10.1177/1550147719879384.

[21] J. Wang, Y. Gao, C. Zhou, R. S. Sherratt, and L. Wang, "Optimal coverage multi-path scheduling scheme with multiple mobile sinks for WSNs," *Computers, Materials and Continua*, vol. 62, no. 2, pp. 695–711, 2020, doi: 10.32604/cmc.2020.08674.

[22] A. Kousar, N. Mittal, and P. Singh, "An improved hierarchical clustering method for mobile wireless sensor network using type-2 fuzzy logic," in *Lecture Notes in Electrical Engineering*, vol. 605, 2020, pp. 128–140.

[23] A. Thirupathaiah, "Energy efficient clustering in multi-hop wireless sensor networks using minimum distance and maximum energy group search," *International Journal of Applied Engineering Research*, vol. 13, no. 9, pp. 7178–7183, 2018.

[24] A. J. Yuste-Delgado, J. C. Cuevas-Martinez, and A. Triviño-Cabrera, "A distributed clustering algorithm guided by the base station to extend the lifetime of wireless sensor networks," *Sensors (Switzerland)*, vol. 20, no. 8, p. 2312, Apr. 2020, doi: 10.3390/s20082312.

[25] A. M. Rahmani *et al.*, "An area coverage scheme based on fuzzy logic and shuffled frog-leaping algorithm (Sfla) in heterogeneous wireless sensor networks," *Mathematics*, vol. 9, no. 18, p. 2251, Sep. 2021, doi: 10.3390/math9182251.
[26] P. K. H. Kulkarni and P. Malathi, "Pfuzzyaco: fuzzy-based optimization approach for energy-aware cluster head selection in WSN," *Journal of Internet Technology*, vol. 20, no. 6, pp. 1787–1800, 2019, doi: 10.3966/160792642019102006010.
[27] M. Mishra, G. S. Gupta, and X. Gui, "Network lifetime improvement through energy-efficient hybrid routing protocol for IoT applications," *Sensors*, vol. 21, no. 22, p. 7439, Nov. 2021, doi: 10.3390/s21227439.
[28] S. K. Mothku and R. R. Rout, "Adaptive fuzzy-based energy and delay-aware routing protocol for a heterogeneous sensor network," *Journal of Computer Networks and Communications*, vol. 2019, pp. 1–11, Jan. 2019, doi: 10.1155/2019/3237623.
[29] G. C. Jagan and P. J. Jayarin, "Wireless sensor network cluster head selection and short routing using energy efficient electrostatic discharge algorithm," *Journal of Engineering (United Kingdom)*, vol. 2022, pp. 1–10, Feb. 2022, doi: 10.1155/2022/8429285.
[30] M. A. Alharbi, M. Kolberg, and M. Zeeshan, "Towards improved clustering and routing protocol for wireless sensor networks," *Eurasip Journal on Wireless Communications and Networking*, vol. 2021, no. 1, p. 46, 2021, doi: 10.1186/s13638-021-01911-9.
[31] B. Han, F. Ran, J. Li, L. Yan, H. Shen, and A. Li, "A novel adaptive cluster based routing protocol for energy-harvesting wireless sensor networks," *Sensors*, vol. 22, no. 4, p. 1564, Feb. 2022, doi: 10.3390/s22041564.
[32] F. Zhu and W. Wang, "A distributed unequal clustering routing protocol based on the improved sine cosine algorithm for WSN," *Journal of Sensors*, vol. 2022, pp. 1–13, Feb. 2022, doi: 10.1155/2022/7382098.
[33] R. K. Lenka, M. Kolhar, H. Mohapatra, F. Al-Turjman, and C. Altrjman, "Cluster-based routing protocol with static hub (CRPSH) for WSN-assisted IoT networks," *Sustainability (Switzerland)*, vol. 14, no. 12, p. 7304, Jun. 2022, doi: 10.3390/su14127304.
[34] G. Kaur, P. Chanak, and M. Bhattacharya, "A green hybrid congestion management scheme for IoT-enabled WSNs," *IEEE Transactions on Green Communications and Networking*, vol. 6, no. 4, pp. 2144–2155, Dec. 2022, doi: 10.1109/TGCN.2022.3179388.
[35] V C. Rudramurthy and R. Aparna, "Reliable and efficient routing model for unequal clustering-based wireless sensor networks," *International Journal of Computer Networks and Applications*, vol. 9, no. 1, p. 1, Feb. 2022, doi: 10.22247/ijcna/2022/211593.
[36] J. N. Al-Karaki and G. A. Al-Mashaqbeh, "SENSORIA: a new simulation platform for wireless sensor networks," in *2007 International Conference on Sensor Technologies and Applications, SENSORCOMM 2007, Proceedings*, Oct. 2007, pp. 424–429, doi: 10.1109/SENSORCOMM.2007.4394958.

BIOGRAPHIES OF AUTHORS

Rudramurthy Veeregowdanadoddi Chandraiah received the B.E. degree in Information Science and Engineering and M.Tech. degree in Computer Science and Engineering from Visvesvaraya Technological University, Belagavi, Karnataka, India in 2004 and 2008 respectively. Currently, he is working as Assistant Professor at the Department of Computer Science and Engineering, Global Academy of Technology, Bengaluru. His research interests include wireless sensor networks and security. He can be contacted at email: rudramurthy.vc@gmail.com.

Aparna Ramalingappa holds a Ph.D. from Visvesvaraya Technological University, Belagavi, Karnataka, India. Dr. R. Aparna is currently working as Professor in Department of Information Science and Engineering, Siddaganga Institute of Technology, Tumakuru, Karnataka, India. Her research areas are cryptography and network security, security in wireless sensor networks, and routing issues in Ad Hoc wireless networks. She has published more than 60 articles in various journals and conferences. She is having 3 book chapters. She can be contacted at email: raparna@sit.ac.in.