Automatika

Journal for Control, Measurement, Electronics, Computing and Communications

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/taut20

Energy efficient optimal hop transmission using minimum power least cost algorithm in cooperative routing for wireless sensor network

Immanuvel Arokia James K., Manjula P., Guga Priya G. & Karthikeyan A.

To cite this article: Immanuvel Arokia James K., Manjula P., Guga Priya G. & Karthikeyan A. (2023) Energy efficient optimal hop transmission using minimum power least cost algorithm in cooperative routing for wireless sensor network, Automatika, 64:4, 1054-1066, DOI: 10.1080/00051144.2023.2246242

To link to this article: https://doi.org/10.1080/00051144.2023.2246242

AUTOMATIKA
2023, VOL. 64, NO. 4, 1054–1066
https://doi.org/10.1080/00051144.2023.2246242

Taylor & Francis
Taylor & Francis Group

Energy efficient optimal hop transmission using minimum power least cost algorithm in cooperative routing for wireless sensor network

K. Immanuvel Arokia James[a], P. Manjula[b], G. Guga Priya[c] and A. Karthikeyan [d]

[a]Department of Information Technology, Vel Tech Multi Tech Dr Rangarajan Dr Sakunthala Engineering College, Chennai, Tamilnadu, India; [b]Department of Applied Machine Learning, Saveetha School of Engineering, Saveetha Institute of Technical and Medical Sciences (SIMATS), Chennai, Tamilnadu, India; [c]School of Electronics Engineering, Vellore Institute of Technology, Chennai, Tamilnadu, India; [d]Department of Electronics and Communication Engineering, Vel Tech Multi Tech Dr Rangarajan Dr Sakunthala Engineering College, Chennai, Tamilnadu, India

ABSTRACT
Cooperative communication has gained a lot of popularity recently. Through a variety of shortest path methods, this article's paradigm may efficiently reduce the amount of power consumed and hop transmission. In this research, we construct the Minimum Power Least Cost Routing (MPLCR) algorithm and evaluate its performance. The design of the proposed algorithm took into account link computation, sequential scanning algorithm approach, and balance (residual) energy. To prevent connection failures and lessen network traffic, the link calculation is used to choose the best route (relay node). In order to reduce network power consumption, a sequential scanning technique was used to find the shortest path with the fewest hops. And also discuss relay nodes and their characteristics in order to improve the transmission stream's quality of service. An ideal path is one that ensures end-to-end transmission while using the least amount of transmitted power. The minimum power least cost routing algorithm uses cooperative communications to help build the smallest power route. When compared to the current algorithms, the proposed approach uses less energy by more than 30%.

ARTICLE HISTORY
Received 14 February 2023
Accepted 3 August 2023

KEYWORDS
Cooperative routing; optimal route transmission; energy balancing; hop transmission; QoS

1. Introduction

Of late, researchers have been keen on the utilisation of agreeable transmission in routing. There has been a growing interest in the design and evaluation of cooperative routing protocols. The routing algorithm clearly explains about the various perspectives of the transmission of the nodes and the different views of the cooperative communication through the use of protocols [1]. This research paper presents an extensive survey of the various algorithms along with the highlights of the protocols. Networks have continued to grow rapidly in order to accommodate the increase in data traffic brought about by the Internet as well as enterprise applications. Due to the increasing growth in size and capacity of optical networks, survivability has become crucial since a breakdown could lead to the loss of data. A recent study explains how different multiple failure steps utilising various algorithms work. Generally, all the algorithms can be used according to the failure status. Failures may be in a single stream (from source to destination), a multiple layer stream (more than one node to destination), etc. The comparative study of a few algorithms helps to build a constructive broadcasting tower in order to transmit the nodes from source to destination in an alternative path. That helps to avoid link failures and the traffic between node-to-node communications [2]. The different way transmission transmits the node in the nature of administration The hand-off choice is accomplished through an opposition procedure among the neighbouring nodes and the source node itself. This is done within a period referred to as "relay contention". Data is usually transmitted from the source and relay nodes to the destination node. This is normally done in two continuous stages. This includes different energies. The mixing of signals is then done at the beneficiary. Estimations of transmission energies are traversed through an arrangement of linear programming problems. A broadcasting tree is typically a traversing tree that is established at one source node with a specific end goal to reach the greater part of alternate nodes. In order to comprehend the actual circumstances of the incitement correlation result, the suggested MPLCR method and Participation along the Briefest Non-Cooperative Path (CASNCP) algorithm will be compared in this work. Typically, the CASNCP algorithm calls for comparable transmission control. This is a result of how they both create comparative courses [3] and [4].

The exhibit includes an overview of cooperative diversity-enabled MAC conventions for wireless LANs

CONTACT A. Karthikeyan a.karthik1982@gmail.com Department of Electronics and Communication Engineering, Vel Tech Multi Tech Dr Rangarajan Dr Sakunthala Engineering College, Chennai, Tamilnadu, India

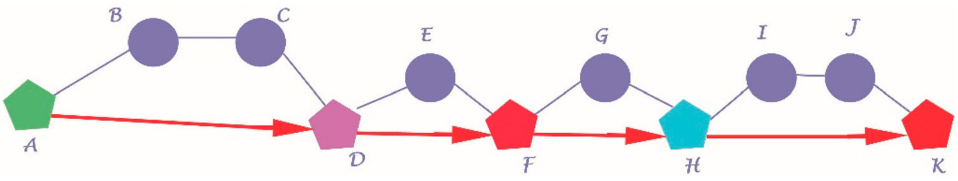

Figure 1. Cooperative Routing path.

and wireless sensor networks. In helpful decent variety conventions, neighbouring nodes go about as virtual multiple input and multiple output frameworks, where they coordinate with the transmitter-recipient combination to convey different duplicates of a bundle to the beneficiary by means of autonomous blurring channels. These various duplicates of a similar data packet will be consolidated at the recipient to recuperate the original data packet, enhancing dependability by misusing spatial diversity in the channel. Cooperative Medium Access Control (MAC) conventions can also gather channel state information between neighbouring nodes and deliver this data to the directing layer, where it can be misused for accomplice choice. Cooperative Medium Access Control, which is employed in the physical layer to promote cooperative transmission, has also gotten a lot of attention [4]. Consider Figure 1, in which the data must be transmitted from the source node A to the destination node K. The connection from A to K (A to B to C to E to F to G to I to J to K) is the non-cooperative node. Currently, node A transmits data to node B as part of a cooperative routing arrangement. Nodes A and B then send data to C, which is very beneficial. This should be followed until the data arrives at target node K. Taking a different approach to agreeable steering the broadcast range is increased by beneficial correspondence in various spatial configurations. In this manner, Node A has the ability to send data to node D, then to node H, and finally to node K. This method of participation is quicker than the non-cooperative method. As a result, it is safer to assume that this strategy will achieve high throughput while decreasing delays.

This paper includes the following sections:

- Literature survey, which includes cooperative routing, installing the broadcasting towers, and related works
- The proposed routing algorithm includes link computation, alternate path selection, balancing (residual) energy for optimum relay node selection, sequential scanning algorithm technique for shortest path selection, energy balancing in cooperative routing, and implementation.
- Result and discussions, which include confidence intervals, comparisons of metrics with the proposed MPLCR, conclusions, and future work.

2. Literature survey

2.1. Background

Cooperative communication (CC) has emerged as a promising method for reducing remote staining and improving the unwavering quality of remote systems by allowing nodes to interact with one another; nodes in agreeable correspondence assist one another with data transmission by abusing the concept of wireless correspondence transmission. The next node or neighbouring node will operate as a relay node, communicating between the transmitter and receiver, which then distribute multiple copies of a pack to the receiver node separately [5].

The ability of an acceptable variety to reduce multichannel staining without the use of several receiving wires has attracted a lot of interest. Recent years have seen scientists increase their passion for the description and evaluation of acceptable path norms and keep helpful transmission in mind when making decisions. The co-operative route algorithm is the routing method that takes into account the possibility of cooperative transmission to the physical layer [3].

In recent years, huge advances have been made in the outline and improvement of cooperative route protocols. These multi-layer routing protocols are distinctive parts of agreeable correspondence. Cooperative routing is a capable way to deal with enhancing energy productivity and QoS; this way decreases misfortune and spares energy from a blend of a few duplicates of a similar packet on the received node. Low transmit power causes a shorter link to have less route loss, which lowers impedance. Additionally, efficient power circulation between the transmitter and hand-off nodes helps cut down on energy use.

WSNs are made up of a collection of sensor nodes with minimal battery capacity that operate together to complete a task. Sensor networks are made up of a self-contained system of nodes linked by remote connections. There is no permanent framework, and the topology of the system can alter dramatically. As a result, it is expected that the battery will not last for an extended period of time after installation. Wireless systems make up the majority of unstructured and dynamic systems with circulating origins and destinations. They experience overpowering darkness and widespread information loss as a result of the mediation condition of distributed, varied clamour. The SN (signal-to-noise) ratio of the signals at the receiver side is frequently increased to combat blurring effects by using decent variation, which is an inherent component of the telecom idea of remote stations.

Assorted variety is accomplished utilising a few plans, for example, recurrence, time, polarisation, space, multi-client, and helpful, decent variety. Additional thickness during the time spent system steering and wasteful ability of nodes expands the waste of assets and data transfer capacity, and extra expenses may happen, and the requirement for numerous reception apparatuses for spatial variety is seriously felt; thus we go to the outline of the MIMO (Multiple Input and Multiple Output) strategy.

2.2. Cooperative routing

Cooperative communication includes a strategy that fuses another physical layer technique. This technique enhances the connection limit through misuse of the communication nature and, in addition, the spatial variety of the remote channel. A change in the customary meaning of connection and the dispute relationship among members is normally realised by the presentation of cooperative communication in wireless networks.

Cooperative communication improves link capacity by exploiting the broadcast nature as well as the spatial diversity of wireless channels. Sharing of antennas by single antenna nodes is usually brought about by cooperative communication. They also generate a virtual multiple-antenna transmitter. By transmitting cooperatively, the transmitter allows the antenna nodes to achieve user and spatial diversity. Cooperative communication significantly improves link capacity but does not improve the overall performance of the network. This all depends on the design of the upper-layer protocol. The upper layer can then exploit the spatial diversity introduced by CC. In order to increase reliability and reduce energy consumption, cluster-based multipath routing protocols utilise clustering and multipath techniques. There have been significant studies regarding the use of multi-path routing in wired networks.

In wired networks, multi-path routing ordinarily expands end-to-end throughput and, in addition, provides a burden adjustment group-based multi-path routing algorithm for multi-jump wireless networks. A straight-forward approach for a cooperation-based routing algorithm is executed by finding the most limited path route [6]. A cooperative route is then fabricated in the briefest way possible. Such algorithms don't abuse the benefits of agreeable calculation since helpful routing algorithms are entirely unexpected from different algorithms. The vast majority of the helpful nodes have worldwide data about every one of the nodes in the system. In some cases, such a node may be impractical in many systems. We will likely influence the utilisation of the transmission to side assorted varieties and, in addition, the wireless broadcast property [7]. This is done through cooperation to diminish the end-to-end vitality utilisation in routing the data between two nodes.

When designing multi-hop ad hoc networks, energy consumption is one of the major factors that should be seriously looked into. This is due to the fact that batteries are used to power the wireless nodes. In the past decade, there have been extensive studies involving energy-aware routing protocols. These energy-aware routing protocols typically take new energy-related parameters into account. In place of traditional route measurements like hop count or delay, these metrics consider the energy needed to communicate via a link, the nodes' remaining lifetime, or both. Sharing of physical layer resources usually occurs at the physical layer of cooperative communication. The physical layer also helps in forwarding each node's packet to its destination node [8]. At the physical layer, cooperative communication involves relaying and cooperative decision-making techniques. These relaying and cooperative protocols cover processes like amplify-and-forward, decode-and-forward, and coded cooperation, as well as the distribution of transmission power across nodes to meet Quality of Service (QoS) standards for the network [3].

In the previous decade, there have been broad investigations, including energy-aware routing conventions. These energy-aware routing conventions, for the most part, consider new energy-related metrics. These metrics incorporate the capacity of the energy required to convey over a connection or the nodes' residual lifetime, or both, rather than a great course metric, for example, a jump tally or deferral. Sharing of physical layer resources normally happens at the physical layer of cooperative communication. The physical layer additionally helps in sending every node's bundle to its goal node. Helpful correspondence at the physical layer includes basic leadership that includes agreeable and handing-off plans. These agreeable and handing-off plans incorporate exercises, for example, open up and forward, unravel and forward, and coded cooperation, the transmission power portion for every node to fulfil the Quality of Service (QoS) prerequisites of the system, and the transfer determination plans of the system [3].

As a rule, a couple of difficulties exist when creating directing conventions in WSNs. This is due to the shorter range of short-distance transmission. The standard distance for communication is often between a few and many metres. The sending power, which grows exponentially with increasing separation, plays the largest role in the transmission of energy in wireless nodes. The 802.15.4 convention is additionally defined as a low-power understanding. The sending power in

802.15.4 is by and large prescribed between −3 dbm and −10 dbm. In a domain with a complicated network, it is often difficult to ensure the nature of the transfer due to low power transmission.

2.3. Installing the broadcasting towers

Radio receivers and transmitters, as a rule, require antennas, keeping in mind the end goal of coupling electrical association with the electromagnetic field. Radio waves are generally electromagnetic waves that help motions through space or air at the speed of light with practically no transmission misfortune. Radio transmitters and receivers are utilised to pass on signals in broadcast (audio) radio, TV, portable Wi-Fi (WLAN) data networks, and remote control gadgets, among numerous others. Reception apparatuses are typically omnidirectional. They generally emanate energy similarly every which way, or directionally, where energy transmits more along one bearing than others. It's physically difficult to get a totally uniform omnidirectional antenna. Reception apparatuses, as a rule, send little energy upward or downward; however, they for the most part have a uniform radiation design in the horizontal plane [7].

A "directional" antenna is normally intended to boost its coupling to the electromagnetic field towards the other station. We accept that with a specific end goal to control the transmission range, every node can powerfully control the power that is transmitted. It is additionally expected that a few nodes that participate in sending data to a collector may correctly keep down their transmitted flag so as to accomplish consummate stage synchronisation at the recipient. Data is typically steered from the source nodes to the goal node in an arrangement of transmission openings. Every transmission opening is then entrusted with relating to one utilisation of the remote medium. A node might be chosen to communicate the data to a gathering of nodes in every transmission opening stage, or subsets of nodes that have officially gotten the data might collaborate to transmit that data to another gathering of nodes. Exploration of the antenna on another node in the network may further contribute to achieving spatial diversity. For most non-broadcast stations, effective radiated power (ERP) is usually used when calculating station coverage. Achieving the desired signal strength without antenna gain usually results in enormous electric utility bills for the transmitter and a prohibitively expensive transmitter.

2.4. Related work

The sensor networks that work in a domain where a system is autonomous of any structure are discussed. The component of self-organising decreases the cost and weight of their arrangements and support. Due to the node's low transmit energy in the majority of usages, they have a restricted quantity of correspondence, in addition to other issues. Resource sharing between cooperative communication nodes is conceivable and essential for these systems. The method has to do with lessening the total strain. Weaker connections ought to be replaced by shorter ones. Joins that are more firmly anchored can link the sink to the node. In order to strengthen defences against multi-way blurring and shadowing, new strategies for organising and steering elective courses between the node and base station are presented. In the space of WSNs, the control of mindfulness is an essential concern.

The energy-based cooperative communication protocols are composed in such a way that they finish information broadcasting with the least energy intake. Macintosh layer conventions function to maintain a strategic distance from clashes and duplication of information transmission, lessening energy utilisation in this manner by controlling the opening and hibernation conditions of the sending node and cooperative node.

2.5. Minimum-power cooperative routing (MPCR)

Energy saving is one of the main objectives of routing algorithms for different wireless networks, such as mobile ad hoc networks. The MPCR algorithm helps construct the minimum power route through cooperative communications. The power formula helps to construct the direct transmission power route. It can be implemented by the Bellman-Ford algorithm. In the conventional Bellman-Ford algorithm, each node denotes the set of neighbouring nodes that represents the estimated minimum path from the source to the destination. Each node calculates the costs (required powers) of its outgoing links and then applies the shortest-path Bellman-Ford algorithm using these newly calculated costs. The required transmission power between two nodes can be found by searching over all the possible nodes in the neighbourhood. If there is no available relay in the neighbourhood, a direct transmission mode will be considered. Moreover, the Bellman-Ford shortest-path routing algorithm is implemented at each node.

The MPCR and CASNCP algorithms require the same transmission power, as they both construct the same routes. Even though two algorithms are taken into consideration for our proposed MPLCR concepts. The MPLCR is proposed and compared with the above-mentioned algorithms to get a better result. CASNCP is supposed to compare the energy balancing variation and power savings with MPCR to understand the quality of service. Moreover, our algorithmic technique defines the optimal cooperative route with hop consideration in the below section.

3. Proposed routing algorithm

The proposed Minimum Power Least Cost Routing (MPLCR) is an algorithm developed for improving the network's lifetime. This algorithm is designed by calculating link computation, a sequential scanning algorithm, and balancing the energy shared by the neighbouring nodes [9]. The following objectives are considered to achieve energy consumption: minimising the number of relays, increasing the packet delivery rate, and reducing the end-to-end delay between the source and destination [10]. To design and analyse energy-efficient and optimal hop transmission using the minimum power, least cost routing algorithm, the following methods are considered:

- Link computation
- Alternate path selection
- Balance (residual) energy: optimal relay node selection
- Sequential Scanning Algorithm (SSA) Technique: Shortest Path Selection

3.1. Link computation

Traversing the signal from node to node has four possible ways. The basic principles of transmitting cooperative signal from source to destination have explained below. P_N denotes the starting point, and P_M denotes the ending point.

- **P_N – P_M Connection (1–1 Node)**

$P_N \rightarrow$ P_M, **P_N** denotes the starting Point and **P_M** denotes the ending point of the link. One node can transmit from **$P_N \rightarrow$ P_M** within a slot to a single target node and has shown in Figure 2.

In the above case, the link formulation can be denoted as $P_i = \{\ P1\}$ & $S_i = \{S1\}$. The parameters denoted as α and μ. The signal received by the receiver is expressed as $S(t) = \alpha K \mu^{j\beta} \lambda\ (t) + \eta(t)$. The total transmitted power denoted as $P_{ti} = |\chi_{\Phi}|^2$. The SNR ratio at the receivers is at $\frac{\alpha 2|\chi\Phi|2}{P\eta}$. To accurately decode the signal, the SNR ratio at the receiver must not be less than SNR_β [11]. The minimum power required is P_{ti} and the P_N – P_M Connection link cost shown in Equation (1).

$$LC\ (P_i, S_i) = LC(P1, S1) = \frac{P\eta SNR1}{\alpha 2} \tag{1}$$

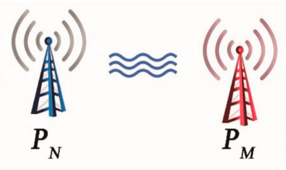

Figure 2. P_N – P_M Connection (1–1 Node).

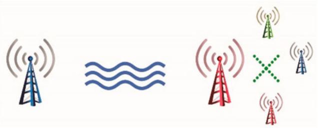

Figure 3. P_N – $P_{M \geq 1}$ Connections (1 to Many).

- P_N – $P_{M \geq 1}$ Connections (1 to Many): Broadcasting Route

$P_N \rightarrow$ $P_{M \geq 1}$, **P_N** denotes the Starting Point and **$P_{M \geq 1}$** denotes the node n greater than one (More than One: Multiple Nodes), therefore the value of N will be 0ne and M will be greater than one N = 1 & M **≥ 1** and is shown in Figure 3.

In the broadcasting mode, $P_i = \{\ P_1\}$ & $S_i = \{S_1, S_2 \ldots ..S_m\}$ where **$P_{M \geq 1}$**, where **$P_{M \geq 1}$** simultaneous SNR constraints must be satisfied at the receiver. Therefore, the cost of power needed for transmitting P_i to S_i the cost of reaching a set of node is the maximum over the costs for reaching each of the nodes in the destination set. LC is given by $LC\ (P_{i,}\ S_i) = LC(P_1, S_1) = \max\ \{LC(P_1, S_1),\ LC(P_1, S_2), \ldots ..,\ LC(P_1, S_m)\ \}$, where the value of $i = 1, 2, \ldots ., m$ [11].

- **$P_{N \geq 1}$ – P_M Connections (Many to 1): Cooperative Routing**

$P_{N \geq 1} \rightarrow P_M$, **$P_{N \geq 1}$** denotes the starting point of a node and **P_M** is the destination point. **$P_{N \geq 1}$** may be a different location, but the destination point (**P_M**) are the same location. **P_M** receives different levels of signals from various locations, as shown in Figure 4.

- **$P_{N \geq 1}$ - $P_{M \geq 1}$ Connections (Many to Many)**

$P_{N \geq 1} \rightarrow$ $P_{M \geq 1}$, **$P_{N \geq 1}$** denotes the starting point of a node and the signal process from various location to multiple destination nodes. This option may not consider under our assumptions, and so we are not considering this possibility in Figure 5.

3.1.1. Alternate path selection

Constructing the broadcasting towers helps to transmit the nodes from source to destination in an alternative path. That helps to avoid the link failures and the traffic between a node to node communications. The multiple-path transmission helps to transmit the node

Figure 4. $P_{N \geq 1}$ – P_M Connections (Many to 1).

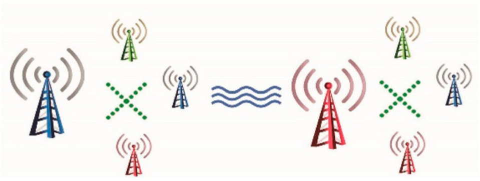

Figure 5. $P_{N \geq 1} - P_{M \geq 1}$ Connection (Many to Many).

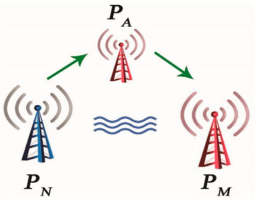

Figure 6. Alternative path transmission.

in a QoS. The towers many in number leads to transmission delay. Hence a single broadcasting tower can be used between the source and destination node. According to the time constraint process, transmission speed is usually slow in such cases. Even though the transmission speed is slow, the QoS be much better than the other transmission process. Few algorithmic steps can be used in the transmission process to achieve quality results. Multiple numbers of towers can be used in the large scale of transmission to avoid the link failures and traffic congestion. The signal can be transmitted from P_N to P_M via P_A (i.e.) $P_N \rightarrow P_A \rightarrow P_M$ is the alternate path in Figure 6, and the P_A is the relay node.

The relay channels usually do Amplify and Forward (AF) or Decode and Forward (DF) user cooperation [12]. By relay channel, consider that in addition to the source to relay and to the destination ($P_N \rightarrow P_A \rightarrow P_M$) there may be a direct communication ($P_N \rightarrow P_M$) from source to the destination node. In such cases, the transmission between the end to the endpoint, and the transmission in a single description. According to the distortion theorem and the steps of decoding, encoding protocol given in Equation (2).

$$C_h = 2\rho\lambda_r/\rho + \lambda_r \tag{2}$$

$\lambda_r = H_r$, where H_r is the number of channels used between the $P_N \rightarrow P_M$. and C_h represents the channel. It may be a single relay or multiple relay distortion according to the distortion algorithm.

An ideal route generally is depicted as a route that needs the base transmitted power while ensuring an end to end transmission. Inferring the cooperative based connection represents the base transmitted power. The Optimal cooperative route can calculate from the sender node S_i to the receiver node d_j. The initial point of the system S_i denoted as {S}, and the termination state denoted as d_j. The process from S_i to d_j will be calculated by the associative rule $S_{k+1} = Si\ U\ d_j$, where $S_i = \{s1, s2, \ldots sn\}$ and $d_j = \{d1, d2 \ldots .dn\}$. (point to point transmission). If the transmission takes an alternate path of a single tower, then the formulation can be denoted as in Equations (3) and (4) [13].

$$\begin{aligned} S_{k+1} &= (SiU\ h_i)\ U\ d_j = (SiU\ (h_iU\ d_j)) \\ &= S_iU\ h_iU\ d_j \end{aligned} \tag{3}$$

$$\sum_{\mathrm{Si}}^{\mathrm{di}} \mathrm{Sk} + 1 = S_iU\ h_iU\ d_j \tag{4}$$

3.2. Implementation of proposed method

MPLCR is considered for the construction of the minimum power route through cooperative nodes. Also, Johnson's briefest path algorithm helps in finding the briefest way between all sets of vertices. And it permits negative values yet not negative cycles, and it works along with Bellman-Ford briefest path routing. Execution is completed by using Johnson's briefest path algorithm. In the Bellman-Ford calculation, each node has a place the incentive from 1 to n esteems (i.e.) x ε (1, … , n). Assume that "x" as the source and "y" as the receiver.

The cycle will be dx(y) = min{c(x, v) + dv(y)}, where dx(y) = cost of least way from x to y. The base is assumed to control over all neighbours v of x. dx(y) = gauge of minimum cost from x to y, node x knows cost to each neighbour v: c(x, v), node x keeps up remove vector dx = [dx(y): yεN]. Node x additionally keeps up its neighbours' separation vectors for each neighbour v, x looks after dv = [dv(y): yεN]. For minimizing energy, there have been studies of cooperative multi-hop routing under more complex fading models [14–16]. The sole purpose of these methods involves reducing the total energy consumed in routing the packet from the source node to the destination node. Nonetheless, irregular energy distribution among nodes is experienced while using the minimum cost path. The irregular energy distribution can negatively affect the life-time of the network [8].

The MPLCR algorithm is compared with CASNCP and other algorithms to analyse the performances. CASNCP is supposed to compare the energy balancing variation and power saving with MPLCR to understand the QoS.

In different wireless networks such as MANETs, saving energy is one of the fundamental objectives. The proposed algorithm helps in the design of the minimum power and least-cost route through cooperative communications. The power formula helps in constructing the direct transmission power route. The execution might be done using the Bellman-Ford calculation. In the Bellman-Ford calculation, every node j∈ {1,… ..,N} executes the cycle Mi = min K∈N(j) (dj, kα + DK), where N(j) meant the arrangement of neighbouring nodes of node j, dj, kα indicates the separation between the node j and k, and D_k speaks to the assessed least way from k to the goal. Every node computes the

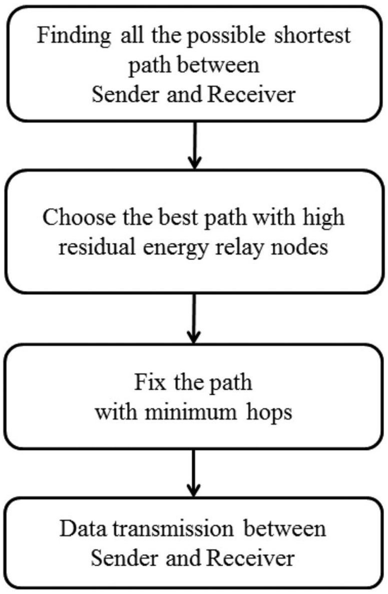

Figure 7. Flow of the proposed algorithm.

costs (required forces) of its active connections, and afterwards applies the most limited way Bellman-Ford algorithm utilizing these recently ascertained expenses. The following Figure 7 shows the flow of the proposed algorithm MPLCR.

Transmission power required between two nodes can find via seeking over all the conceivable nodes in the area. An immediate transmission mode might require on the off chance that there is no easy hand-off in the area. Additionally, the Bellman-Ford least cost algorithm actualized at every node. Every node refreshes its cost toward the receiver as Pi = min K $\in$ n(i) (Pj, k + Pk), where Pi signifies the required transmission control from node j to the goal and Pj, k means the base transmission control between node j and node k (Figure 8). Pj, k is equivalent to P_0 [6]. The steps in the algorithm are as follows [17]:

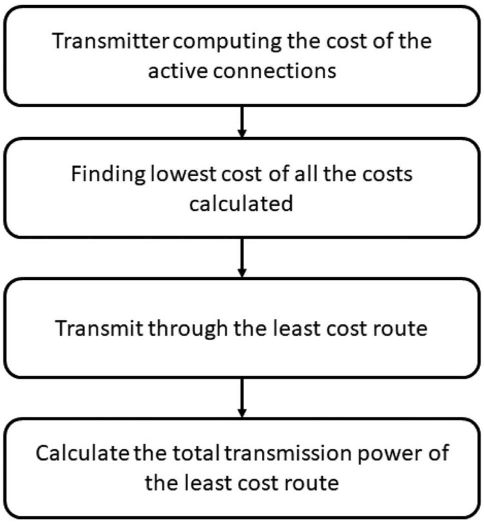

Figure 8. Flow of the Algorithm-1.

Algorithm: 1

```
Step 1: Every node $x \in \{1, \dots, N\}$ goes about as a transmitter that computes
    the cost of the active connection (x, z).
Where $z \in N(x)$ is the collector.
For every node, $y \in N(x)$, $y \neq z$, node x computes the cost of the helpful
transmission where y acts as a relay node.
Step 2: The cost of the $(x, z)^{th}$ connection is considered to be the lowest
cost of all the costs calculated in the step 1.
Step 3: In case the least cost agrees to a specific relay $y_*$, node x uses this
relay to transmit through that hop.
Step 4: By applying the distributed Bellman-Ford briefest-path algorithm
the costs of cooperation based link can be measured.
Every node $j \in \{1, \dots, N\}$ performs the steps by calculating Pi = min K∈n(i)
(Pj,k + Pk),
Where N(j) – represents the set of adjacent nodes of node j,
Pk – denotes the latest measure of the shortest path from node k to the
receiver and Pj, andk is the least possible communication power from node
j to node k [14].
```

One of the main outcomes is that among all the routing algorithms, the proposed algorithm requires the least amount of transmission power. This result is achieved about since this algorithm constructs the minimal power route by applying the cooperation based link cost formula. CASNCP algorithm's character is related to the heuristic algorithms. It is taken into consideration for comparing the energy level with MPLCR and the hop transmission cycle in the simulation result.

3.3. *Sequential scanning algorithm*

SSA finds the ideal cooperative route in an arbitrary network. It finds the briefest way in the comparing participation diagram. The pseudo-code for the SSA algorithm is given below.

Algorithm: 2

```
Step 1: Start S, while S is the starting node;
Step 2: Initialize the variable J to J-1;
Step 3: Constructing the shortest path by hop techniques;
Step 4: Increment the Counter until the shortest path occurs.
Step 5: While the shortest path is up to $J^{th}$ layer;
Step 6: Stop the link at D, when $J = n + 1$
```

The Figure 9 shows two-hop co-operation and Figure 10 shows three-hop cooperation. In an arbitrary network, the SSA considerably limits the multifaceted nature of finding the ideal cooperative route.

In any case, its many-sided quality is as yet exponential in the number of nodes in the wireless network. Table 1 shows the iterative results of the different hop cooperation network.

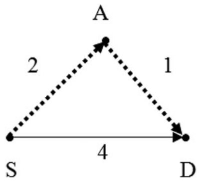

Figure 9. Two Hop co-operation.

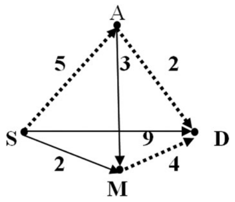

Figure 10. Three Hop co-operation.

Table 1. Hop comparison.

Path	Iterations	1st hop	2nd hop	3rd hop	Total Value
S→D	It:1	9	-	-	9
S→M→D	It:2	2	4	-	6
S→A→D	It:3	5	2	-	7
S→A→M→D	It:4	5	3	4	12

3.4. Energy-balancing in cooperative routing

In this Section, we first discussed how our purposed cooperative routing can balance the energy using the proposed MPLCR technique through single path from source to destination. Balancing energy in the single path is generated by a non-cooperative routing. Consider the path is $\lambda = \alpha_{0,}\ \alpha_{1,}\alpha_{2,\ldots.}\alpha_{\mathrm{h}}$, where $V_{\mathrm{s}} = \alpha_0$ and $V_{\mathrm{d}} = \alpha_{\mathrm{h}}$. Our aim is to perform CC for each hop $\alpha_{0+}\alpha_1$ along the path to maximize αi's remaining lifetime. Each node transmits the remaining energy, approximate energy consumed, and the location of its neighbours. Here we are using helper set for current node α_i which will sends the same packet again and again to α_{0+1} [8].

We first define a potential cooperative helper set $\mathrm{M}(\alpha_{\mathrm{i}}) \subset N(\alpha i)$ where M denotes helper set. Sending the packet directly saves more energy efficient. In wireless sensor networks [18], energy efficiency is one of the core performance measures to be considered. The introduction of diversity through cooperative communications techniques is one of the promising strategies that can be used to reduce the consumption of energy in such networks. Given that it offers a practical, affordable option for wireless network capacity and coverage expansion, multi-hop relay transmission is crucial in addressing this problem. It is important to establish a new transmission system that picks relay sensors optimally and allots power for their transmission in order to conserve energy and reach an energy-balanced level. In different wireless networks, energy is usually a scarce resource which in time limits the lifetime of nodes [19].

Multi-hop relay transmission has a critical influence in managing this issue since it speaks to a powerful minimal effort answer for scope augmentation and limit improvement of wireless network. To save energy to achieve an energy adjusted level, it is important to present another transmission plot that ideally chooses transfer sensors and relegates energy to their transmission. In various wireless networks, energy is normally a rare asset which in time restricts the lifetime of nodes.

4. Result and discussions

In this section, the results obtained and compared with the three mechanisms are presented. The performance of network, including the average SNR, buffer size and number of relays are analysed [20]. Analysing all the parameters using NS3 simulator, helps us to find the best technique through network simulations. The proposed Minimum Power Least Cost Routing (MPLCR) method is compared with the existing Buffer-Threshold based Relay Selection (BTRS), Max-Link Relay Selection (MLRS), Max-Weight Relay Selection (MWRS) scheme for the outage probability, average end-to-end queuing delay and the average throughput [21–23].

Balancing energy in the single path is generated by a non-cooperative routing. Consider the path is $\lambda = \alpha_{0,}\ \alpha_{1,}\alpha_{2,\ldots.}\alpha_{\mathrm{h}}$, where $V_{\mathrm{s}} = \alpha_0$ and $V_{\mathrm{d}} = \alpha_{\mathrm{h}}$. The aim is to perform CC for each hop $\alpha_{0+}\alpha_1$ along the path to maximize αi's remaining lifetime. Each node transmits the following information such as remaining energy, approximate energy consumed and the location of its neighbours. Helper set used for current node α_i, which send the same packet again and again to $\alpha_{0+1.}$

A potential cooperative helper set $\mathrm{M}(\alpha_{\mathrm{i}}) \subset N(\alpha i)$ is first defined where M denotes helper set. When we send the packet directly, it saves energy more efficiently. In WSN, energy efficiency is one of the core performance measures to be considered. The introduction of diversity through cooperative communications techniques is one of the promising strategies that can be used to reduce the consumption of energy in such networks. Multi-hop relay transmission plays an essential part in dealing with this problem since it signifies an effective, low-cost solution for the extension of coverage and capacity development of wireless networks. To attain the required energy balance level, introducing a new transmission scheme is necessary in which the scheme optimally selects relay sensors and assigns power to their transmission. In different wireless networks, energy is usually a rare resource which due course minimizes the lifetime of nodes in the network.

Multi-hop relay transmission has a critical influence in managing this issue since it speaks of a great minimal effort answer for scope augmentation and limit improvement of the wireless network. To achieve an energy-adjusted level, it is essential to present another transmission plot that ideally chooses transfer sensors and relegates energy to their transmission. In various wireless networks, energy usually is a rare asset which in time restricts the lifetime of nodes.

Moreover, the computer simulations illustrate the mode of energy balancing, saving of power and the function of negative values through the proposed technique in the network area. 600 m X 600 m random square area is considered where n nodes uniformly distributed. These concepts are applied in the network area randomly from source to destination to find out the corresponding required route. Numerous algorithms, which apply the Bellman-Ford briefest path algorithms, require the most transmission control per course.

Be that as it may, the proposed MPLCR calculation, which applies with briefest path algorithm and Johnson's calculation for negative cycle requires the transmission power at minimal rate. Number of hops in the network is one of the most critical factors in WSN is compared with the existing algorithms such as CASNCP and other algorithms in the simulation. Comparison result helps to know about the clear picture of the power saving methodology.

Moreover, the multiple numbers of hop transmission have better performance is analysed in the simulation results. Sometimes hop can travel with negative values in the network area. The multiple hop transmission with negative values inside the 600 m X 600 m can deal with Johnson's algorithm with the base of the shortest path algorithm.

In Figure 11, x-axis describes the network size as N, and the y-axis explains the average number of hops per route. The hop transmission route mentioned in a random area network in 600 m X 600 m square per route. The average number of hops per route can be mentioned to know about the MPLCR transmission route signal and the CASNCP route signal. In the proposed MPLCR algorithm, the route transmission signal can be useful when compared to the CASNCP and the other algorithms [24].

In Figure 12, twenty node linear networks taken for consideration. In 20 nodes linear network, the transmitted power of the proposed algorithm can be verified and compared with CASNCP and other existing algorithms. The transmission power can be comparatively better in the proposed algorithm. Also, the CASNCP algorithmic flow varied in a few nodes, and the flow of the diagram is not in a continuous stream that shows the irregularity of the stream flow. The proposed MPLCR algorithm travels in a constant stream, and it transmitted power in a better way.

The Figure 13 shows the negative values through Johnson's algorithm. This will check the values in path calculation and this converts with required equivalent values.

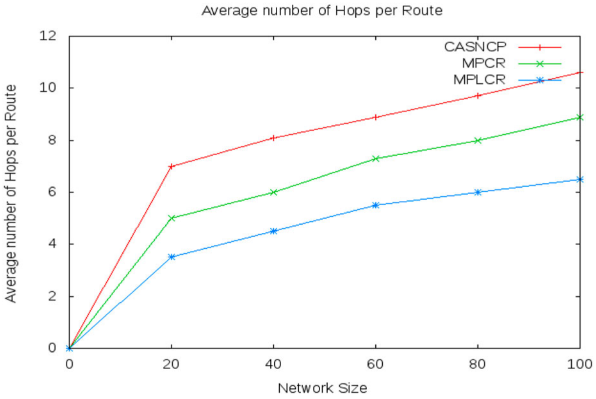

Figure 11. Average number of hops per route.

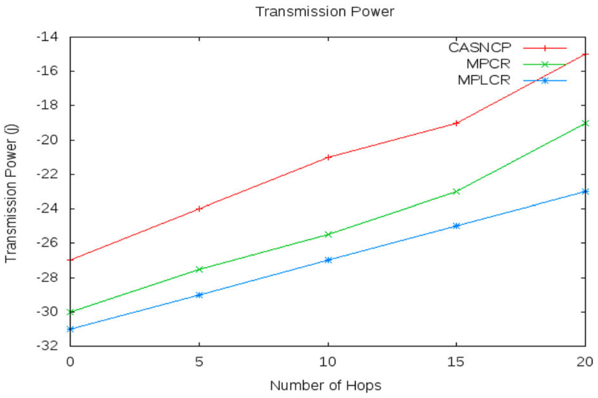

Figure 12. Transmission power.

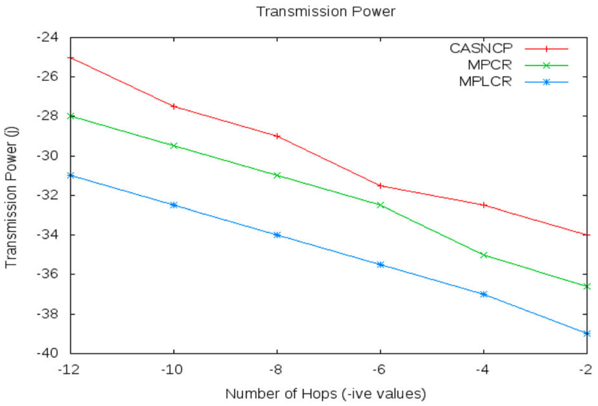

Figure 13. Using negative values through Johnson's algorithm.

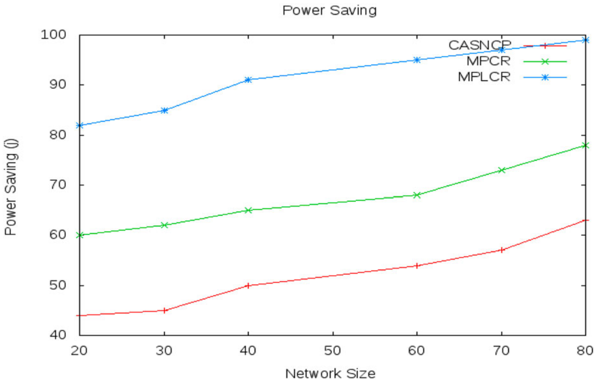

Figure 14. Power saving.

In Figure 14, the power-saving described in 600 m X 600 m network area. The energy flow of both comparisons explains the clear picture of the power-saving techniques. Sometimes the hop value travels in the network with the negative values with the help of Johnson's algorithm. More than 30% of the power saved through the MPLCR algorithm.

Table 2. Confidence interval sample calculation.

Average SNR	Outage Probability
0	0.0001
5	0.000064
10	0.000035
15	0.000024
20	0.000009
25	0.0000001

Table 3. Sample vales.

Descriptions	Values
Significance level (95%)	0.05
Mean	0.000039
Standard Deviation	0.000034
Sample Size	6
Confidence Value	0.000027
Confidence Interval	0.000039 ± 0.000027 (Min: 0.000011 and Max: 0.000066)

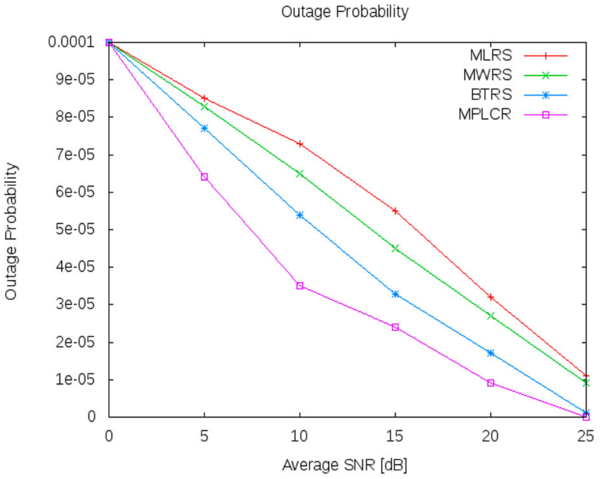

Figure 15. Average SNR vs outage probability.

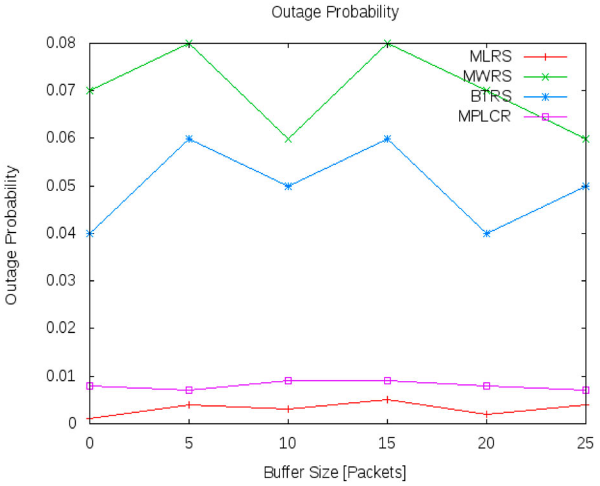

Figure 16. Buffer size vs outage probability.

4.1. *Confidence interval*

A sort of estimation known as a confidence interval (CI) will be calculated using the statistics of the observed data. The percentage of confidence intervals over numerous separate experiments that accurately reflect the true value of the unknown parameter is represented by the confidence level. In other words, if the selected confidence level is 90%, then in the hypothetical case where a very large number of independent tests were carried out, the percentage of the confidence intervals that contain the real parameter will gravitate towards 90% as the number of experiments increases. Most commonly, a 95% confidence level is used. Here the confidence interval of the main QoS metrics of the sensor network is verified by using the given formula 5.

$$\mathit{Confidence\ Interval} = \bar{x} \pm z\,(s/\sqrt{n}) \tag{5}$$

where,

Ci = Confidence interval
$\bar{x}$ = Mean
z = Confidence Level value
S = Standard Deviation
$\sqrt{}$n = Size

For each simulation, Confidence interval is calculated and furnished in the following sections. Confidence Interval Sample Calculation (for Figure 17) is shown in below Tables 2 and 3.

4.2. *Comparisons of metrics with proposed MPLCR*

Using NS3 simulator, since sending data across a network is a protocol's primary goal, evaluation of a protocol is mostly based on its routing metrics. Therefore, outage likelihood using MPLCR is used to measure the main metrics average SNR, buffer size, and number of relays.

Figure 15 shows the graph for outage probability vs. average SNR for the existing and proposed mechanisms. As the SNR value increases, the proposed mechanism MPLCR has better outage probability compared to the existing scenarios MLRS, MWRS and BTRS. Confidence Interval is 0.000039 ± 0.000027 (Min: 0.000011, Max: 0.000066). Figure 18 shows the graph for outage probability vs. buffer size of the existing and proposed mechanisms. The buffer size is measured in terms of packets.

The Figure 16 demonstrates, and compares the performance of the existing and proposed mechanism. Confidence Interval is 0.008000 ± 0.000653 (Min: 0.00735, Max: 0.00865).

Figure 17 shows the graph for outage probability vs. number of relays of the existing and proposed mechanisms. As the relay increases, the outage probability tends to decrease and it is demonstrated in the figure. Moreover, the outage probability in proposed MPLCR method is higher when compared to other schemes like BTRS, MWRS and MLRS. Confidence Interval is 0.0000462 ± 0.0000371 (Min: 0.00000910, Max: 0.0000833). This increase in the likelihood of an outage causes the coding gain to drop, which is

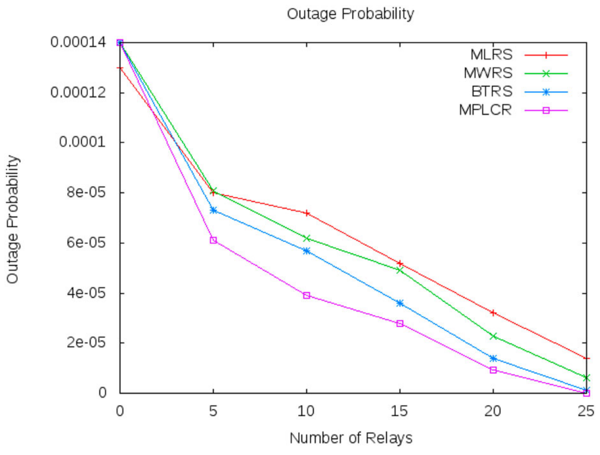

Figure 17. Number of relays vs outage probability.

exchanged for an improvement in the system's average end-to-end queuing delay or average throughput [3]. Also the same parameters average SNR, buffer size and number of relays are compared with the same existing methods of MLRS, MWRS and BTRS. And the proposed mechanism MPLCR is derived in terms of average end to end delay [9,21].

Figure 18 shows the graph of average SNR vs average end to end delay. As the SNR increases, the delay in the delivery of packets is reduced compared to the existing mechanisms. Confidence Interval is 68.17 ± 12.49 (Min: 55.67, Max: 80.66).

The graph for buffer size vs average end to end delay is shown in Figure 19. The average delay is measured in terms of milliseconds [25]. There is enormous amount of decrease in delay in the proposed MPLCR when compared to the existing mechanisms. Confidence Interval is 27.00 ± 7.64 (Min: 19.36, Max: 34.64).

Figure 20 shows the graph for number of relays vs average end to end delay. When the relay count is increased from 1 to 5, there is a huge decrease in delay from 55 to 15 in the proposed mechanism. Confidence Interval is 13.6 ± 4.85 (Min: 8.75, Max: 18.45).

Figure 21 shows the performances of the existing and proposed mechanisms in terms of average SNR vs average throughput. Confidence Interval is 29.6 ± 8.34 (Min: 21.26, Max: 37.94). MPLCR has improved throughput when compared to other existing schemes.

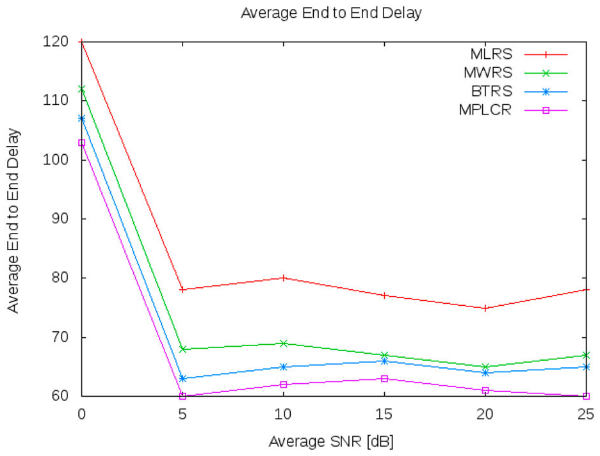

Figure 18. Average SNR vs average end to end delay.

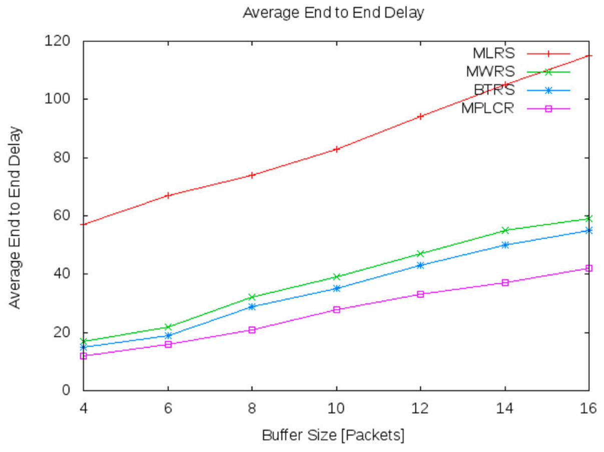

Figure 19. Buffer size vs average end to end delay.

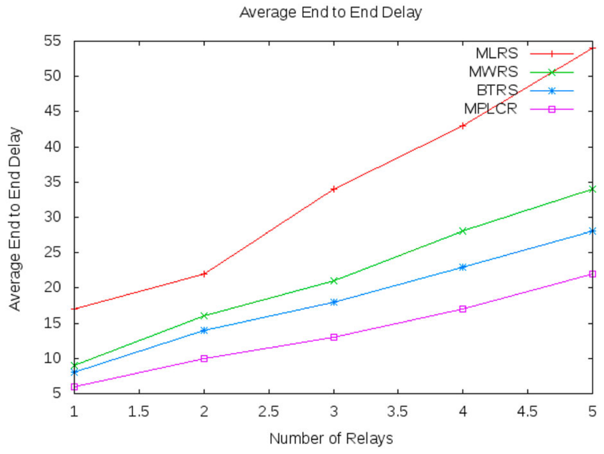

Figure 20. Number of relays vs average end to end delay.

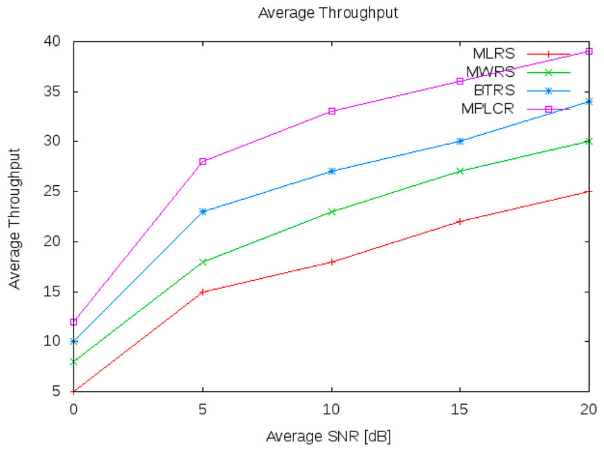

Figure 21. Average SNR vs average throughput.

The buffer size vs average throughput measurement is given in Figure 22. Confidence Interval is 0.44 ± 0.01 (Min: 0.43, Max: 0.45). MPLCR has improved throughput, compared to other existing schemes in terms of increasing buffer size.

Figure 23 shows the performances of the existing and proposed mechanisms in terms of number of relays vs

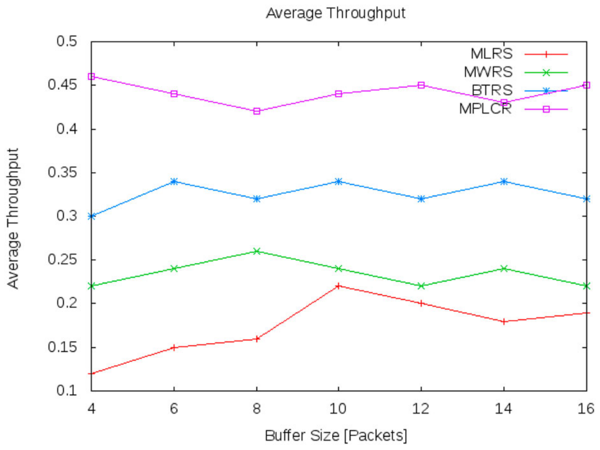

Figure 22. Buffer size vs average throughput.

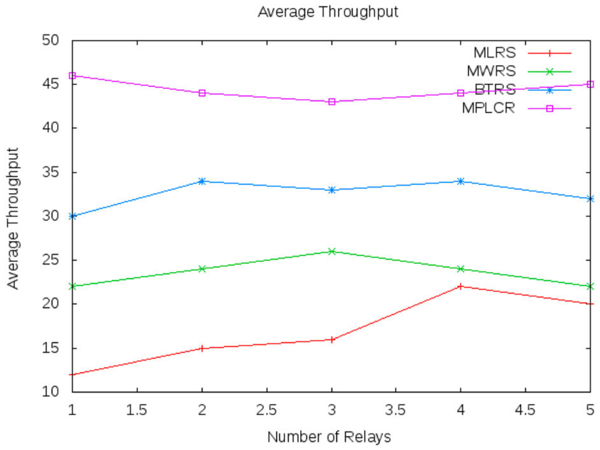

Figure 23. Number of relays vs average throughput.

average throughput. As the number of relay increases, there is better throughput for the proposed mechanism. Confidence Interval is 44.4 ± 0.89 (Min: 43.51, Max: 45.29).

As a result, for this scenario, the proposed MPLCR scheme's average end-to-end queuing delay is noticeably lower than that of the BTRS, MWRS, and MLRS systems. When compared to the queuing delays in the BTRS, MWRS, and MLRS systems, the average end-to-end packet queuing time in this situation is larger [20,6].

Along with evaluating the average throughput, the buffer size is increased. Regardless of whether the relay selection is based on the link quality or the buffer occupancy, an increase in the buffer size often results in the minute gains in the average throughput of the buffer-equipped relaying system.

5. Conclusion and future work

The main goal of this work is to apply the MPLCR algorithm using multiple techniques and allocate the minimum power among the nodes. In order to implement the MPLCR approach, link computation, the sequential scanning algorithm, and Johnson's algorithm are used. Additionally, the relay node is chosen by calculating the balance of energy shared by the nodes in its immediate vicinity. Johnson's algorithm also deals with negative numbers to obtain energy efficiency in a small way. The steady stream of signals is necessary for better signal transmission between the vertices. Therefore, sequential scanning is used at multiple hop levels to produce a better and more likely transmission path in the simulation output. To gain a better understanding of energy balancing and power saving, the MPLCR algorithm is compared with the CASNCP method and other existing algorithms. Through cooperative energy-balanced routing stages, energy efficiency is also tracked and calculated in order to maintain energy balance throughout the stream. Through the suggested methodology, energy-balanced cooperative routing transmits the remaining energy, the consumed energy, and an approximation of the position of its adjacent nodes.

It is reasonable to consider that future standards, such as the fifth generation of mobile communications, will have embedded support for cooperative communications. In the future, the MPLCR algorithm can be extended to cooperative cluster communication as an energy-balanced cooperative cluster-based routing technique. It can be carried out and compared with some existing protocols. This architecture can be designed by integrating intra-clustering with inter-clustering hierarchy [6,26]. The stable election protocol, energy-efficient multi-hop LEACH, and intra-balanced LEACH functionalities are also considered for cluster head selection based on residual energy, and the MPLCR algorithm is used for finding the best route selection. Based on those algorithms, the proposed architecture of the energy model utilises single-hop and multi-hop communication processes. The opportunistic routing concept may provide a successful answer for forwarding the packets to the surface sink. The stable election protocol can be taken into consideration for saving residual energy in the clustering architecture for CH selection, and the functions of MPLCR are utilised for finding all possible shortest routes in the intra-cluster and inter-cluster hierarchy.

Disclosure statement

No potential conflict of interest was reported by the author(s).

ORCID

A. Karthikeyan http://orcid.org/0000-0001-6290-6770

References

[1] Immanuvel Arokia James K, Prabakaran R, Karthikeyan A, et al. Co-operative beam forming selection with energy balanced operation for wireless sensor network. Wireless Netw. 2022;28(8):3653–3663. doi:10.1007/s11276-022-03067-w

[2] James KIA, Prabakaran R. Intracluster cooperative communication in smart home scenario through stable election protocol. Concurr Comput: Practice Exp. 2019.

[3] Mansourkiaie F, Ahmed MH. Cooperative routing in wireless networks: A comprehensive survey. IEEE Commun Surv Tutorials. 2015.

[4] Shirmohammadi Z, Farmani M, Mohseni M, et al. A cluster-based energy-aware routing algorithm for wireless sensor networks. Ad Hoc Sensors Wireless Netw; 53(3-4):303–315.

[5] Alrajeh NA, Khan S, Lloret J, et al. Secure routing protocol using cross-layer design and energy harvesting in wireless sensor networks. Int J Distributed Sensor Netw. 2013;9(1):374796), doi:10.1155/2013/374796

[6] Srinivas Rao N, Rama Rao KVSN. An energy-efficient routing scheme in wireless sensor networks for life time maximization using fuzzy based decision. Ad Hoc Sensors Wireless Netw; 51(1-3):23–39.

[7] Baddari I, Riahla MA, Mezghiche M. "A new AOMDV lifetime prolonging routing algorithm for Ad-Hoc networks", Int J Interdisciplinary Telecommun Netw, 2019.

[8] Chen S, Huang M, Li Y, et al. Energy-balanced cooperative routing in multihop wireless ad hoc networks. 2012 IEEE International Conference on Communications (ICC). 2012.

[9] Nasir H, Javaid N, Raza W, et al. Virtual-link relay selection scheme for buffer-aided IoT based cooperative relay networks. IEEE Access. 2018.

[10] Srirutchataboon G, Kochi J, Sugiura S. "Performance analysis of hybrid buffer-aided cooperative protocol based on half-duplex and virtual full-duplex relay selections", IEEE Open J Commun Soc, 2021.

[11] Han B, Li J, Su J, et al. Self-supported cooperative networking for emergency services in multi-hop wireless networks. IEEE J Sel Areas Commun. 2012.

[12] Kumar Singh S, Kumar P, Singh JP. A survey on successors of LEACH protocol", IEEE Access, 2017.

[13] Keleadile Ketshabetswe L, Murtala Zungeru A, Mangwala M, et al. "Communication protocols for wireless sensor networks: A survey and comparison", Heliyon, 2019.

[14] Ibrahim A. Distributed energy-efficient cooperative routing in wireless networks. IEEE Trans Wireless Commun. 10/2008.

[15] Habibi J, Ghrayeb A, Aghdam AG. Energy-Efficient cooperative routing in wireless sensor networks: A mixed-integer optimization framework and explicit solution. IEEE Trans Commun. 2013.

[16] Sanjeev Prakash RBVK. Intelligent mobility management model for heterogeneous wireless networks. Int J Adv Comput Sci Appl. 2015.

[17] Mansourkiaie F, Ahmed M. Optimal and near-optimal cooperative routing and power allocation for collision minimization in wireless sensor networks. IEEE Sens J. 2015.

[18] Jamil S, Jamil S, Ahmed S, et al. Cope: cooperative power and energy efficient routing protocol for wireless sensor networks. 2015 IEEE/ACIS 14th International Conference on Computer and Information Science (ICIS). 2015.

[19] Angeline Rachel Sharon R, Victor Jaya N. Efficient Cluster Head Selection and Fault Tolerant Routing Method for Mobile Wireless Sensor Networks. Ad Hoc Sensors Wireless Netw; 51(1-3):189–204.

[20] Raza W, Javaid N, Nasir H, et al. "Btrs: buffer-threshold based relay selection scheme for cooperative wireless networks", IEEE Access, 2019.

[21] Raza W, Javaid N, Nasir H, et al. Buffer occupancy based link prioritization for cooperative wireless networks. 2018 14th International Wireless Communications & Mobile Computing Conference (IWCMC). 2018.

[22] Ahmed E, Gharavi H. Cooperative vehicular networking: a survey. IEEE Transactions on Intelligent Transportation Systems. 2018.

[23] Raza W, Javaid N, Nasir H, et al. Buffer occupancy based link prioritization for cooperative wireless networks. 2018 14th International Wireless Communications & Mobile Computing Conference (IWCMC). 2018.

[24] Zhao Y, Yu H, Zhu Z, et al. A distributed energy-efficient cooperative routing algorithm based on optimal power allocation. IECON 2017 – 43rd Annual Conference of the IEEE Industrial Electronics Society. 2017.

[25] Zhang Y, Wang K, Shu L, et al. An Energy-Balanced Multi-Hop Relay Transmission Scheme Based on RVNS in DTMSN", 2015 IEEE Global Communications Conference (GLOBECOM). 2015.

[26] Mehmood A, Lv Z, Lloret J, et al. ELDC: an artificial neural network based energy-efficient and robust routing scheme for pollution monitoring in WSNs. IEEE Trans Emerg Top Comput. 2020;8(1):106–114. doi:10.1109/TETC.2017.2671847