International Journal of Computer Science
Scholarly Peer Reviewed Research Journal - PRESS - OPEN ACCESS
ISSN: 2348-6600
Since 2012

http://www.ijcsjournal.com
Reference ID: IJCS-480
Volume 11, Issue 1, No 5, 2023.
ISSN: 2348-6600
PAGE NO: 3246-3264

E2CFTR: ENERGY-EFFICIENT CLUSTERED FAULT-TOLERANT ROUTING ALGORITHM IN INTERNET OF THINGS

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Abstract:

The Internet of things which connects anything from tiny devices to large devices using Internet with the sensing equipment, in order to transfer information between devices. During this transmission, the link in IoT between devices and Base Station may fail due to temporary link breakage which is mainly due to the to the insufficient energy in the neighboring receiver IoT device and out of signal transmission range with respect to sender IoT device. As a result, the packet cannot reach its target. Devices used in hostile environments are more susceptible to faults associated with harsh environments, power outages, or hardware failure. Although it is quite evident that a non-CH faulty device will degrade the network performance, a faulty CH device can be much more problematic, as it will hamper the data dissemination process of this cluster and will make normal working devices useless. To overcome the massive energy consumption and cluster head failure issues, the proposed Energy Efficient Clustered Fault Tolerant routing algorithm schedules the sleep and awakening for all IoT devices and clusters the entire IoT network based on signal transmission range using the Cosine Distance. Hence a maximized Network lifetime with high throughput, less energy, and provides a less end-to-end delay while routing IoT data.

Keywords: Fault Tolerant, E2CFTR Analysis, Routing, Energy Saving

1. INTRODUCTION

The IoT is a new paradigm that has transformed a regular lifestyle into a high-tech lifestyle [1]. An IoT system is composed of several functional blocks that enable various applications of the system, including sensing, identification, actuation, communication, and management. An IoT system is based on devices that present sensing, actuation, control and monitoring functions. IoT devices can collect data from the environment, exchange data with other connected devices and send that data to a base station for processing.

Each IoT device is a tiny device made up of three basic components: a processing unit with a finite amount of memory and processing power, a sensing unit for gathering data from the surroundings, and a communication unit, typically a radio transceiver, for sending data to a centralized collection point, also known as a sink device or base station. In general, IoT devices are powered by small batteries that cannot usually be replaced or recharged [2].

Due to the extremely limited energy resources and large distances between IoT devices and sink, communication between IoT devices and sink does not occur directly, but instead, because of the high device density, via a multi-hop routing model, in which each device sends the readings it has collected to its neighbors, who in turn send them to their neighbors, and so on. The lifetime of a wireless IoT device is related to battery usage. Routing protocols can make informed decisions that extend the lifespan of the IoT network by being capable to assess the energy consumption of the IoT devices. The reduction of energy usage is a crucial study area for the deployment of IoT. Since most IoT devices run on batteries, how long they last depend on how much power they use. Consequently, energy-saving strategies (especially clustering-based routing) are needed to reduce energy consumption [3].

As one of the design strategies for effectively managing network energy usage, clustering is a useful method for reducing the number of devices involved in remote base station communication and for distributing energy usage evenly among devices in the network. Clustering classifies devices into distinct groups. Cluster-based routing's primary objective is to effectively lower device energy consumption.

In existing, IoT energy consumption was decreased using the Less Energy Consumption Routing (LECR) algorithm. But when two devices located far away try to communicate with each other, they consume more energy due to signal transmission range limitations [4]. Therefore, to overcome this problem, a clustering-based less energy consumption routing (CB-LECR) algorithm was used [5]. By clustering IoT devices, it is feasible to effectively lower an IoT network's energy consumption. Cluster heads (CHs), cluster members (non-CHs), and cluster gateways are discovered once devices are grouped into clusters. In IoT networks, CB-LECR has effectively contributed to energy reduction and network lifetime improvement.

However, IoT devices are often small electronic devices with limited battery life. IoT devices won't work if the battery runs out. In case of a failure in one CH, all members connecting with the faulty CH cannot broadcast their sensed data to the base station through the faulty CH. Due to this CH failure, all cluster members will be forced to send the packet directly to the base station. This results in high energy loss for all cluster members. Therefore, this chapter proposed an energy-efficient clustered fault-tolerant routing (ECFR) algorithm to overcome this problem. Because this algorithm discovers fault tolerant routes for all devices using primary and secondary cluster heads. If the primary cluster head (PCH) fails, it chooses the routes via the secondary cluster head (SCH) for data transmission. By using the ECFR algorithm, energy consumption and end-to-end delay can be reduced, and the throughput and network lifetime can be effectively increased.

II Related Works:

Bounceur et al, [6] has presented it starts from local leaders which will start the process of flooding to determine a spanning tree. During this process their value will be routed. If two spanning trees meet each other than the tree routing the best value will continue its process while the other tree will stop it. The remaining tree is the dominating one and its root will be the leader. This is turns out to be low energy consuming with reduction rates that can exceed.

S.Suguna Devi et al, [7] has proposed Trilateral Location based Maximum Weighted Directive Spanning Tree for Optimal Routing in IoV. The proposed TLIMWDST technique consists of two major phases, namely location identification and optimal path identification to improve the reliability of data transmission from source vehicle to destination vehicle. In the first phase, the location of the neighboring vehicles is identified by applying a trilateration technique. The author identified after the location identification, an optimal route path between the source and destination is identified using Maximum Weighted Directive Spanning Tree (MWDST) through the intermediate nodes.

Rashid et al., [8] has proposed the input port utilizes a bypass path, virtual channel (VC) queuing, and VC closing strategies. Moreover, the routing computation stage utilizes spatial redundancy and double routing strategies, and the VC allocation stage utilizes spatial redundancy. The switch allocation stage utilizes run-time arbiter selection. The crossbar stage utilizes a triple bypass bus. The proposed router is highly fault-tolerant compared with the existing state-of-the-art fault-tolerant routers.

A Load-balanced data gathering in Internet of Things proposed by Sadeghi et al., [9] they applied cuckoo-search algorithm makes the CH role to rotate between different sensors round by round. The results show efficiency of the number of transmissions, remaining energy, energy consumption variance, and network lifetime.

Milani et al., [10] to evade any overload or under-load on resources, load balancing, as a mechanism, spread the workload onto different resources. Load balancing, which distributes the load among different resources, is implemented either in physical equipment or software.

Xu, W. Tian et al., [11] The load balancing has some goals, including throughput maximization, response time minimization, and traffic optimization. Consumption optimization in the server-side resources, request processing time minimization, and scalability improvement in the distributed environment are some other purposes of the technique of load balancing.

S. Suguna Devi et al., [12] has presented a Quantile Regressive Fish Swarm Optimized Deep Convolutional Neural Learning for Reliable Data Transmission in IoV. The author introduced reliable data transmission with minimum end to end delay in IoV. The Deep Convolutional Neural Learning uses multiple layers such as one input layer, three hidden layers, and one output layer for vehicle location identification and optimal route path discovery. The different node characteristics of vehicle nodes are analyzed in the hidden layers using the quantile regression function. Depends on the regression analysis, the neighboring node is identified with minimal time. To improve the throughput and reduce the packet loss rate, the artificial fish swarm optimization technique is applied to choose the best route among the population based on the fitness function.

Adil et al., [13] presented a Dynamic hop selection static routing protocol (DHSSRP) to solve the load balancing problem of IoT networks in congestion-free and priority-based contact infrastructure. The DHSSRP routing protocol priority the critical/sensitive data of sensors devices with static routing and divert the neighbor's sensor communication by an alternating hop is chosen route, which handles the network traffic in obstruction-free surroundings. The traffic handling of the DHSSRP routing protocol using priority-based data balances the power expenditure by balanced traffic surroundings, enhancing the lifetime of the deployed IoT devices at the network. The authors conclude their system was compared by the field-proven system, which demonstrated an important development for the measurements, such as PLR, throughput, traffic obstruction, computational cost, communication cost, and network life span.

Chithaluru et al., [14] present an energy-efficient opportunistic routing protocol based on the fuzzy ARFOR-adaptive ranking for standard IoT applications. This protocol contains the parent node (PN), which acts as a head node in a cluster that integrates the packets with the DODAG root and the volunteer node (VN) acts as a forwarder to convert packets to PN with threshold power limits to raise network life during the transmission cycle. This VN selection uses fuzzy parameters, such as residual power, Canberra distance, and threshold.

RBrendhaet l., [15] presented Geographic Multiattribute Monarch Butterfly Optimization Based Traffic Aware Routing in VANET. The source node finds the nearest intersection point's closest to the destination node. Then the source node starts to find the optimal neighboring node to forward the data packets. In this technique, optimal neighboring node searching process is performed using Multiattribute Monarch Butterfly Optimization. The multiattributes used for the selection of neighboring node is received signal strength, distance, the battery power of the node, reliability pair factor and node cooperativeness. Initially, the fitness of each vehicle node is computed based on the multiple attributes with their threshold ranges to find the optimal neighboring node. Due to the mobility, the position of the nodes gets updated and finds the optimal neighbor node is found based on butterfly migration operator and butterfly adjusting operator. Finally, the author findsthe route path from the source node to the destination is established using route request (REQ) and route reply (REP) distribution. K. Akila, et al., [16] has proposed Secured IoT-WSN Architecture for Monitoring Environmental Pollution. A spanking new functional module is initiated in their work to constitute (SIAEM) which is indented to overcome some impuissance of applying generalized wireless sensor network architecture in the field of environmental pollution monitoring. The fresh functional module introduced in the work is Dynamic Security Scheme Manager (DSSM). The author finally identify it has projected Secured IoT-WSN architecture is to increase the Security.

P.Tamilselvi, etal,[17] has proposed Proximity Based Hierarchical Clustering with Neighbor aware Stable Link Communication for Mobile Ad Hoc Network. Identifying the stable route in a complex topology segment was also a major challenged. By combining the agglomerative clustering technique with proximity computation, to establishes the network structure. The link connectivity is monitored using Neighborhood Discovery Protocol (NHDP) to improve the stability. That algorithm allows for secure contact between clusters and within clusters. The currently disconnected connections are being tracked and reported towards the next neighbor. The number of clusters formed and the connection delay for inter-cluster communication are used in the simulation (PHC-NSL) of this technique.

The Internet of Things (IoT), a wireless sensor network (WSN) is used to gather sensing data from an application field. The sensor nodes in the IoT are generally multifaceted. Energy saving and fault tolerance are two important problems in IoT. In particular, energy saving is essential for IoT sensor networks since IoT sensor nodes are powered with their limited battery. The link breakage occurs due to the insufficient energy in the neighboring receiver IoT device and out of signal transmission range with respect to sender IoT device. Due to this link failure, the packet cannot reach its target. The proposed a novel Energy-Efficient Clustered Fault-Tolerant Routing (E2CFTR) algorithm reduces energy consumption, end-to-end delay, and also enhance throughput and Network Lifetime efficiently than the other existing algorithms.

III NEED FOR FAULT-TOLERANT ROUTING

IoTs are prone to fault as they are utilized in a harsh environment. Faults occur in devices frequently, which leads to data loss or retransmission that critically maximize the average transmission delay. It reduces transmission stability, which becomes major challenge to existing network technology. The constancy of data transmission is significant to assess the effectiveness of IoT. The establishment of the stable network topology comprehends the efficient and dependable data transmission required for the balance of energy utilization, low transmission delay, etc. Therefore, it is important to construct the clustering of IoT devices with stable data transmission, less power utilization, and less transmission delay. Clustering has been demonstrated to be one of the most efficient techniques for decreasing the energy utilization of the IoT. Also, the stable transmission of the network could be managed along with the fault-tolerant routing method when the device has a failure or loss of link. Links in IoTs between the sender IoT device and the receiver IoT device often fail due to the following important reasons. Energy depletion occurs in the IoT network due to energy starvation in the IoT devices and out of signal transmission range between sender IoT and receiver IoT.

3.1 Energy Efficient Cluster Fault Tolerant Routing Algorithm E2CFTR

Initially, the IBS creates the IoT network formation and cluster IoT devices for routing. IoT network includes IoT devices that utilizes the battery power to transmit a message from a sender to receiver IoT device. Due to the limitation of the Signal Transmission Range and maximum energy consumptions, the devices cannot communicate with each other directly when two devices are located for away. Hence cluster splitting and merging is applied. [JUL, 20B]. E2CFTR comprises of four phases. They are

- Cluster formation
- Determination of Primary Cluster Head and Secondary Cluster Head
- Route Discovery
- Fault tolerant

3.2 Cluster Formation

Clustering & Routing techniques are needed for energy saving. For clustering, the proposed E2CFTR algorithm uses two essential techniques called Cluster Splitting (splitting cluster into sub-clusters) and Clusters Merging (merging two sub-clusters into one)[JUL 21].

3.3 Determination of the rank-based selection in Primary cluster head and Secondary cluster head

The rank- based selection is based on in the following parameters

1. Residual energy level is calculated by using the formula

$$\mathbf{Node_{REL} = Node_{EL} - Node_{TDP} - Node_{RDP}}$$

2. Compute the minimum distance rank
3. Count the neighboring nodes based on the highest number of neighboring nodes rank
4. Find the average of three ranks from this average selected high

The rank- based selection is based on the Eq (5.4).

$$AR_i = \frac{(RE_i + D_i + N_i)}{3} \qquad (5.4)$$

AR_i is the Average rank of device i

RE_i is the Residual Energy Rank of device i

D_i is the Distance from the IBS Rank of device i

N_i is the Number of Neighbors Rank of device i

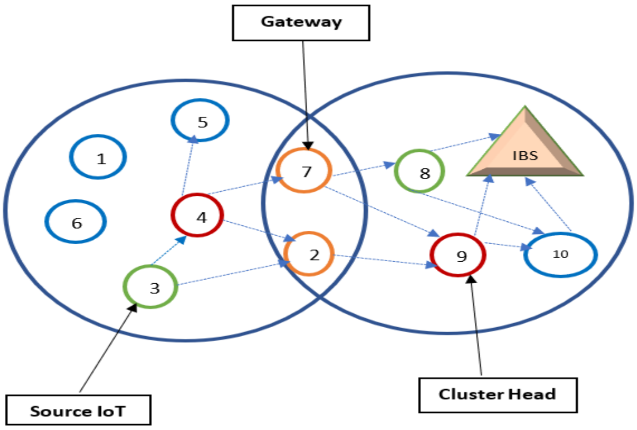

Fig 5.1 Simplified IoT network cluster

Table 5.1 for Residual, Distance and Number of Neighbors of each IoT device

Device Id	Residual Energy (J)	Distance from the IBS (in meters)	Number of Neighbors
1	20	22	3
2	50	15	3
3	70	25	3
4	90	17	7

5	30	10	3
6	20	12	3
7	80	15	3
8	60	20	3

Table 5.2 for Rank- based selection

Device Id	Residual Energy (in J)	Rank of Residual Energy	Distance from the IBS (in meters)	Rank of Distance from the IBS	Number of Neighbors	Rank of number of neighbors	Average Rank	Final Rank
1	20	7	22	6	3	2	5	7
2	50	5	15	3	3	2	3.33	4
3	70	3	25	7	3	2	4	6
4	90	1	17	4	7	1	2	1
5	30	6	10	1	3	2	3	3
6	20	7	12	2	3	2	3.66	5
7	80	2	15	3	3	2	2.33	2
8	60	4	20	5	3	2	3.66	5

The computation of rank- based selection of IoT devices in cluster is represented in table 5.1. The IoT device with id 4 has the maximum residual energy 90J, minimum distance to the IBS and maximum number of neighbors. Hence, the IoT device with ID 4 is considered to be the PCH. The next highest energy IoT device is ID7 which contains residual energy of 80J is considered to the SCH.

3.4 Route Discovery

The rank-based selection finds all routes including PCH and SCH for each IoT device to the base station.

Then it sorts all discovered routes from shortest route to longest route using cosine distance for energy-efficient routing because shortest routes consume less energy than longest routes. Cosine distance is one of the metrics used to measure the distance between two points. The term cosine distance is commonly used for the complement of cosine similarity in positive space. The cosine distance formula is shown in Eq. (5.1).

$$(X,Y) = 1 - (Cosine\_Similarity(X,Y))$$

Let the geo-location value of X is (x1, y1) and the geo-location value of Y is (x2, y2). To compute the cosine similarity between a device - X to the device - Y, the cosine similarity formula is shown in Eq. (5.2).

$$Cosine\_Similarity(X,Y) = \frac{(x1*x2)+(y1*y2)}{\left(\sqrt{(x1)^2+(y1)^2}\right)*\left(\sqrt{(x2)^2+(y2)^2}\right)} \qquad (5.2)$$

The cosine similarity value is used to find the cosine distance Eq. (5.1) between device - X to the device - Y. For example, to calculate the distance of a route (X-Y-BS), the distance of (X-Y) and the distance of (Y-BS) to be computed.

3.5 Fault Tolerance

The fault-tolerance property is defined by the ability of the network to maintain its functionality without interruption caused by IoT device failure. In IoT network, IoT devices are prone to failures due to various causes: energy depletion, damage due to weather conditions. The proposed algorithm detects the fault in the IoT device before the transmission of data packets through the cluster heads.

3.5.1 Energy Starvation

As most of the IoT devices are designed as small wireless portable consumer electronics, they are expected to be energy by on-device power supply, which is currently realized by various types and sizes of emerges depending on the application requirements. Unfortunately, for large scale IoT deployments, the dissipation of energy by the batteries is one of the drawbacks. Because batteries store a finite amount of energy, they either need to be recharged or replaced, which is not only inconvenient and costly, but also not possible in certain deployments [TRU,19]. The dumping of billions of toxic batteries is not environment friendly. Due to these reasons, powering a massive number of sensors is now recognized as one of the main challenges of the IoT revolution.

Before transmitting a packet to next node, energy level of the neighbor is checked by sending a control packet message. If the energy of the neighboring IoT device greater than the Threshold value, the packet will be transmitted. The node energy level can be calculated as follows.

$$\mathbf{Node_{REL} = Node_{EL} - Node_{TDP} - Node_{RDP}} \quad (5.3)$$

Node $_{REL}$ indicates Node Residual Energy level, Node $_{EL}$ represents measured Energy Level, Node $_{TDP}$ indicates energy to Transmit the Data packet and Node$_{RDP}$ represents the energy to Receive the Data packet. The residual energy is compared with threshold residual energy then PCH transmit the data to next available cluster head otherwise the data is transmitted through the SCH.

3.5.2 Signal Transmission Range

The distance between any two nodes such that the signal emanating from one node could directly reach the other node with strength significant enough to correctly extract the determined information. If the distance between the node and the base station is greater than the signal transmission range then the node is considered as out of transmission range. The link is considered as failed link.

Transmission range calculation is

$$\mathbf{STR = 20\log_{10}(d) + 20\log_{10}(f) + 20\log_{10}(4\pi/c) - G_t - G_r} \quad (5.4)$$

From (5.4) STR indicate signal Transmission Range, D Represent for Distance, F denotes Frequency, G_T represent Transmitter Gain (db) decibel, G_R denotes Receiver Gain (db) decibel, c represents velocity of light $3x10^8$ m/s

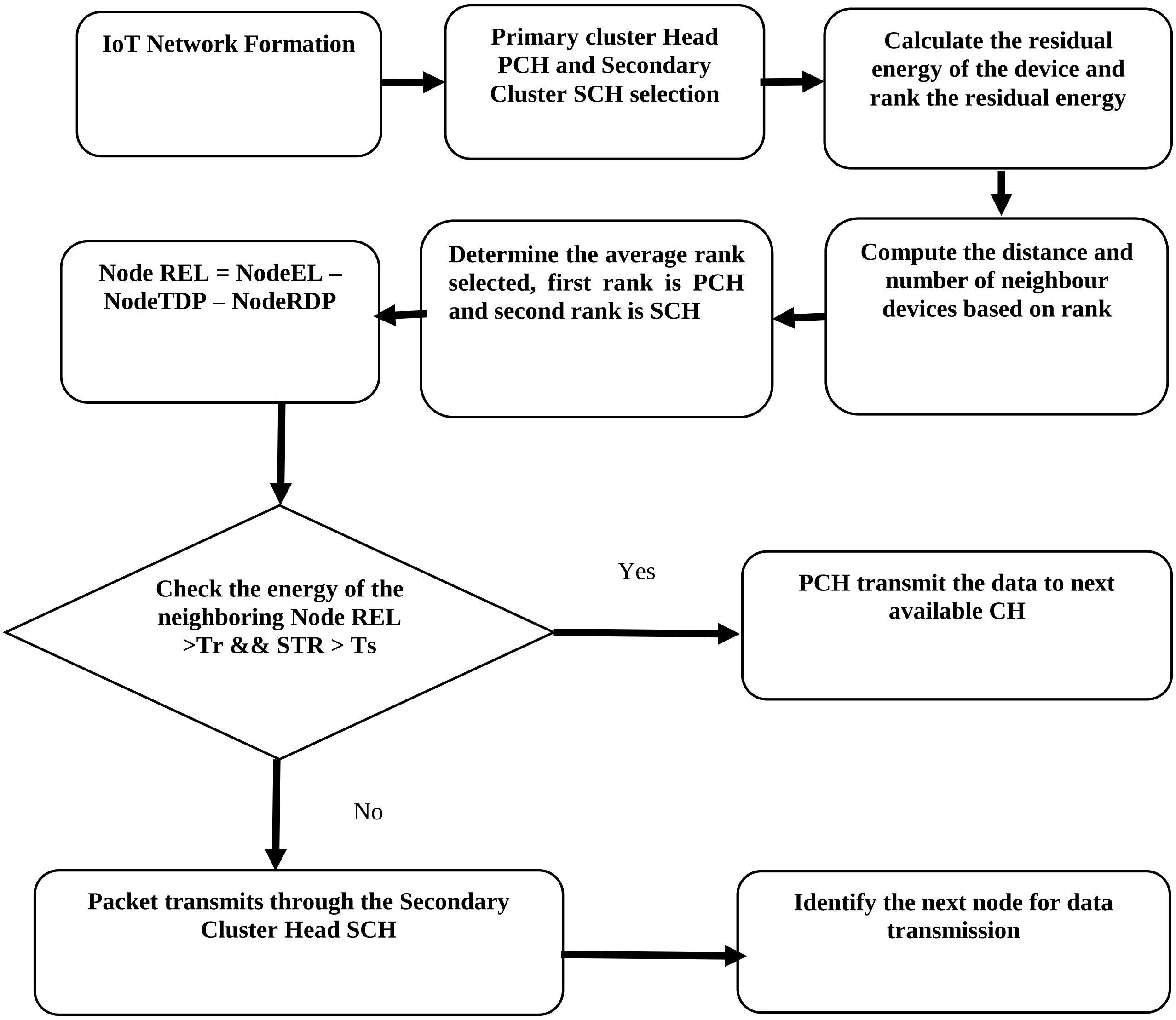

Figure 5.2 Flow diagram of E2CFTR algorithm

Algorithm 1: Energy efficient clustered fault tolerant routing E2CFTR algorithm

```
Input   : IoT Base station, IoT Devices (IoTs) with initial energy
Output  : Su   Successful packet Transmission and Reduce Energy Consumption
                // Cluster Formation
Step 1  :       Forms the IoT Network with IBS and IoT devices
Step 2  : Clusters IoT Network based on Splitting and merging technique
                // PCH and SCH Selection
Step 3  : Calculate the residual energy of the device and rank the residual energy
                $Node_{REL} = Node_{EL} - Node_{TDP} - Node_{RDP}$
Step 4    Compute the distance from the device to the IBS using Cosine distance andrank it
          $Cosine\_Distance(X,Y) = 1 - (Cosine\_Similarity(X,Y))$
          $Cosine\_Similarity(X,Y) = \frac{(x1 * x2) + (y1 * y2)}{\left(\sqrt{(x1)^2 + (y1)^2}\right) * (\sqrt{(x2)^2 + (y2)^2})}$
Step 5  : Count the number of neighbor devices between source and the IBS and rank it
Step 6  : De   Determine the average rank using
          $AR_i = \frac{(RE_i + D_i + N_i)}{3}$
                $AR_i$ is the Average rank of device i
                $RE_i$ is the Residual Energy Rank of device i
                $D_i$ is the Distance from the IBS Rank of device i
                $N_i$ is the Number of Neighbors Rank of device i
Step 7  : Select the device which has the first rank is considered as Primary Cluster Head (PCH)
Step 8  : Next Rank holding device is considered as Secondary Cluster Head (SCH)
                // Route Discovery
Step 9  : over the route from source device to the IBS with the help of Primary Cluster Header using the multiple parameters such as minimum distance and maximum number of neighbors holding route. Select that route for transmission
                // Fault Tolerant
Step 10 : Before the transmission check the residual energy and the signal transmission range of each PCH on the route
Step 11 : If the PCH's residual energy is > threshold residual energy && signal transmission range is > threshold signal transmission range. Transmit the data through the PCH. Else
```

Select the SCH for transmission.

Step 13: End If

Step 14: End

IV RESULT AND DISCUSSION

The simulation result analysis of the proposed E2CFTR with other existing routing algorithms, namely, SHM, MEA-DSR, EEPMM, LECR and the CB-LECR are discussed in this section. There are four different performance metrics such as energy consumption, Network Lifetime, throughput, and End to End Delay are considered for evaluating the performance of E2CFTR with help of tables and graphical representation.

1. Performance analysis of Energy Consumption

The energy usage of each device for receiving and transmitting is computed. In sleep mode, a device consumes far too little energy. Transmission and receiving powers are fixed at 0.6 J and 0.4 J, respectively. When a device transmits Packet (P) to the next device, the device's energy levelis computed using equation 5.5.

$$EC = Er + (Dist * PS * Et) \quad (5.5)$$

EC is the Energy Consumption of a device in J; Dist is the distance between a device to next device in meters, PS is the Packet Size in Kb. Er is the Energy to receive, Et is the Energy for transmission.

Table 1 Tabulation for Energy Consumption

Number of Device	Energy Consumption (J)					
	SHM	MEA-DSR	EEPMM	LECR	CB-LECR	E2CFTR
10	60	52	30	21	19	16
20	70	65	40	26	21	18
30	76	67	45	32	26	21
40	80	70	45	33	28	23
50	81	71	46	35	29	26
60	84	73	48	36	31	29
70	87	77	49	39	34	31
80	88	80	51	42	36	34
90	90	81	52	46	39	36
100	92	86	54	49	42	39

The performance results of the energy consumption versus the number of devices are described in table 1. The observed results indicate that the energy consumption is significantly minimized using E2CFTR. Similarly, the ten various results are shown in figure 5.3.

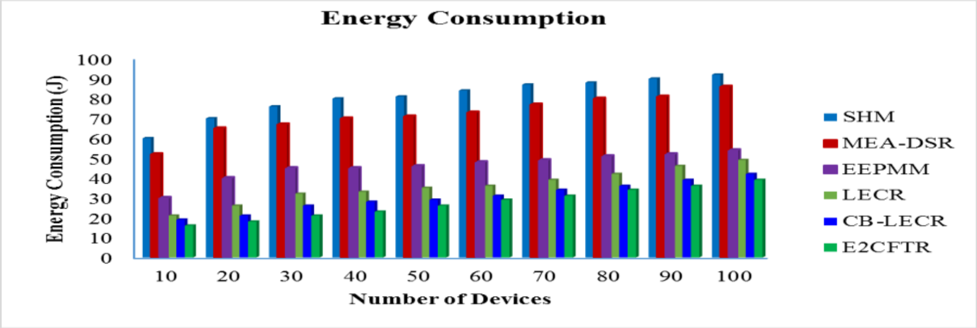

Figure 1Measurement of Energy Consumption

The performance analysis of the energy consumption based on the number of devices is shown in Figure 1 The above graph shows that the number of devices on the horizontal axis and the vertical axis represents the energy consumption. As shown in graph 5.4 there are three different colors of lines such as orange, blue and green that are represented by the three methods LECR [JUL 20A], CB-LECR [JUL 20B]. The observed results show that the E2CFTR minimizes the energy than the existing SHM, MEA-DSR, EEPMM. This improvement is achieved through the Energy efficient fault tolerant routing algorithm. The proposed E2CFTR efficiently performs the route selection in minimum distance and maximum number of neighbors and signal transmission range in order to achieve less energy consumption. The performance result of the propoed E2CFTR technique is compared to the existing results. The comparison of ten results confirms that the energy consumption of E2CFTR is considerably minimized when compared to CB-LECR [JUL 21B].

2 Performance analysis ofNetwork Lifetime

Network Lifetime is one of the essential performance measurements defined as the time from the beginning to the first node failure due to battery power exhaustion. Therefore, the overall Network Lifetime is calculated as given below

$$NL = FI - NS \qquad (5.6)$$

NL indicates inNetwork Lifetime, FI represent the time when the first IoT device died due to lack of energy and, NS is time when the network started

Table 2 Tabulation for Network Lifetime

Number of Device	Network Lifetime (Sec)					
	SHM	MEA-DSR	EEPMM	LECR	CB-LECR	E2CFTR
10	350	370	390	430	445	450
20	360	380	420	450	470	480
30	380	390	410	440	450	470
40	390	410	490	540	560	570
50	400	425	500	530	540	560
60	490	500	540	550	570	580
70	500	510	540	560	580	600
80	510	540	550	590	600	610
90	520	550	590	600	620	640
100	580	590	600	620	630	660

Table 2 displays the performance results of the Network Lifetime with respect to the number of devices taken in the counts from 10 to 100. As revealed in the table, different Network Lifetimes are obtained for various methods. The observed results state that the number of devices of the proposed E2CFTR is increased than the existing methods. The observed results are illustrated in figure 3

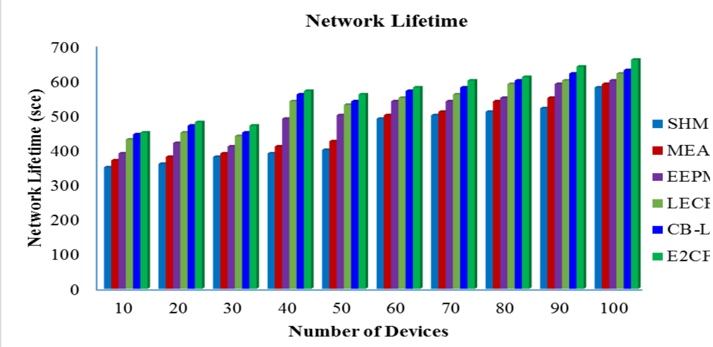

Figure 5.5Measurement of Network Lifetime

Figure 3 portrays the performance outcomes of the Network Lifetime of different methods. The graphical plot demonstrates that our proposed E2CFTR technique enhance Network Lifetime during the transmission. This is due to finding the grater residual energy in the next receiver and packet transmit through the primary cluster head selection or secondary cluster head selection. Due to the selection of best receiving devices energy level from sender to next receiving devices is established and performs efficient data transmission. This help to increase energy consumption and reduce the Network Lifetime by selecting the fine path with better connectivity when compared to existing SHM [21], MEA-DSR [22], EEPMM [23], LECR [JUL 20A] and CB-LECR [JUL 21B] respectively.

3 Performance analysis of Throughput:

Throughput is a measurement of how many data units can transmit in a given amount of time, shown in Eq. (5.7). The unit of throughput is kilobits/seconds.

Throughput = Number of a data packet transmitted / unit time (5.7)

Table 3Tabulation for Throughput

Number of Device	Throughput (Kbps)					
	SHM	ME-DSR	EEPMM	LECR	CB-LECR	E2CFTR
10	3630	3490	3490	3520	3550	3650
20	3340	3380	3310	3340	3400	3480
30	2740	2910	2910	2920	3000	3100
40	2290	2430	2510	2870	2960	2990
50	1910	2080	2170	2430	2670	2700
60	1970	1980	2110	2220	2400	2510
70	1500	1910	1970	2100	2130	2250
80	1490	1500	1620	1790	2020	2080
90	1300	1440	1570	1730	1980	2010
100	1280	1390	1390	1430	1820	1890

Table 3describes the simulation results of throughput using different techniques with various sizes of the number of devices in the ranges from 10 to 100 devices. From the table, it is clear that the throughput using the proposed E2CFTR technique is higher when compared to existing methods. The observed results of throughput of E2CFTR technique are compared the conventional and proposed methods. The average of ten comparison results indicates that the E2CFTR technique increases the throughput when compared to existing methods respectively.

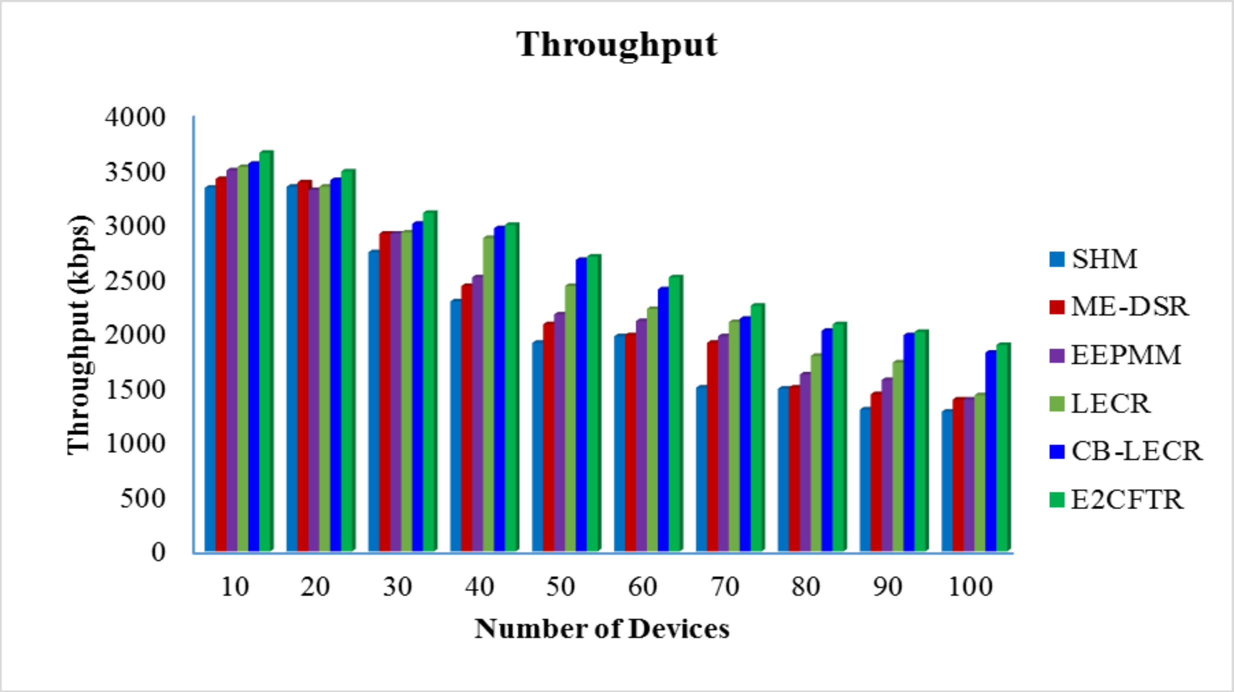

Figure 3 Measurement of Throughput

Figure 3 indicates the simulation results of throughput with respect to various sizes of the number of devices. The above graphical plot indicates that the throughput is found to be increased using the E2CFTR technique than the other methods. The reason for this improvement is to before the transmission check the residual energy and the signal transmission range of each cluster head. While transmitting the data packets from the source node, an energy efficient neighboring node continuously transmits the data packets from one node to another. This helps to improve the data packet transmission between source and destination.

4 Performance analysis of End-To-End Delay:

End to End Delay is calculated based on the time difference between the data packet arrival and sending time. The formula for calculating the overall End to End Delay is expressed as follows,

$$\boldsymbol{Tm} = \boldsymbol{T_d} + \boldsymbol{P_d} (5.8)$$

Where $T_d = \frac{number\ of\ packets}{transmission\ rate}$

and $P_d = \frac{distance\ between\ device}{propagation\ speed}$

T_d – *Transmission Delay* P_d – *Propagation Delay*

Table 4Tabulation for End to End Delay

Number of Device	End to End Delay (ms)					
	SHM	ME-DSR	EEPMM	LECR	CB-LECR	E2CFTR
10	12	19	20	10	8	6
20	54	48	49	43	41	37
30	106	79	84	78	64	60
40	156	102	120	95	88	83
50	188	121	154	111	103	99
60	189	154	168	121	119	112
70	221	173	194	149	127	121
80	267	213	231	209	175	154
90	276	233	259	213	192	187
100	301	259	282	257	230	221

The simulation results of End to End Delay based on the number of devices are reported in table 4. By applying the number of devices, the delay for data delivery using the E2CFTR algorithm found to be 221ms, and delay of SHM [21], MEA-DSR [22], EEPMM [23], LECR [JUL 20A] and CB-LECR [JUL 21B] found to be 301ms, 259ms, 282ms, 257ms and 230ms respectively. The comparison results indicate that the End to End Delay of the E2CFTR technique is considerably minimized than the existing algorithm. The above statistical analysis indicates that the E2CFTR technique outperforms well than the other methods. The comparison results of the five techniques are shown in the graph.

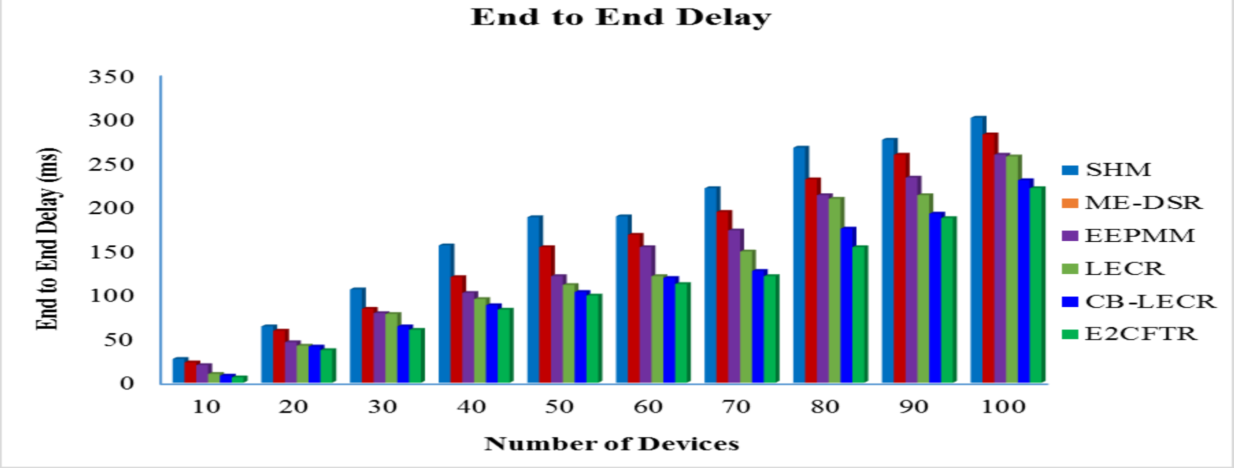

Figure 4 Measurement of End to End Delay

Figure 4 portrays the performance of End to End Delay with respect to a number of data packets using different routing methods. As revealed in the above graphical results, the proposed E2CFTR technique offers a lesser End to End Delay than the existing methods. The reason is to apply the Energy efficient clustered fault tolerant algorithm. The E2CFTR function finds the energy efficient and residual energy neighboring node for reliable data transmission. Moreover, the E2CFTR algorithm also finds route path with the shortest distance based on residual energy. Then the source node transmits the data packet to the destination through the shortest routes and higher availability, increases the data packet and minimize the delay.

V CONCLUSION

An Energy Efficient Clustered Fault Tolerant Routing called E2CFTR is developed to minimize energy consumption in IoT. To address the massive energy consumption and cluster head failure issues, the E2CFTR algorithm identify the PCH and SCH using the rank- based selection of IoT devices. The inter cluster head transmission of data packet leads to minimum the energy consumption, decreased End to End Delay and improve the Network Lifetime and throughput. The rank-based selection in IoT devices also helps to prevent fault by identifying the link breakage between senders to receiver IoTs devices.

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Acknowledge: The grant obtained under the Scheme of Seed Money for research projects from Cauvery College for Women (Autonomous), Tiruchirappalli-18.

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