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Cooperative Residual Battery (CORB) Resource Optimization in AODV Routing Protocol

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Abstract*: *In Ad-hoc network minimizing the energy utilization is one of the core issues in transmission of data with entail quality of service. Cooperative communication networks have been recently being studied as an alternative to MIMO wireless networks where cooperation between source destination and relay are considered. In this paper, Cooperative Residual Battery (CORB) Resource Optimization routing protocol is proposed in which the route formation in cooperative network from source to destination is established by selecting the minimum battery consuming node as relay. Packet reception ratio is considered for efficiently switching between the direct communication and cooperative communication depending on the type of scenario's that occur in real time. The proposed work is based on the modification done on AODV protocol. The relay selection in cooperative communication is established based on least hop count and residual battery life of a node. The protocol is mainly based on selecting a helper node from a list of intermediate nodes that are consuming less energy to forward the data on to the destination. Considerable modification in Route request and Route reply packet is done in order to carry the Residual battery information of nodes that are handling the Control packets (RREQ & RREP), along with the control packets, routing table is modified for managing the routing information. Simulation is carried out to assess the essence of the protocol proposed.

Keywords: Co-operative Communication, Residual Battery energy, Throughput, Wireless Network, NAV, Quality of Service, Bit Error Rate.

I. INTRODUCTION

Due to the development of micro electronic devices and signal processing technique, Wireless Ad-hoc Network are used in majority of modern world application in the field such as Telecom industry, military, environmental sensing devices. The wireless Ad-hoc network is an interconnection of low power nodes which contains small amount of buffer and central processing unit for computational work without a centralized controlling access point [1]. These low power nodes are responsible for sensing the arrival of the data and forwarding of data from source to destination by selecting the best intermediate node as the helper node.

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In wireless Ad-hoc network, the process of selecting the intermediate node and forwarding it should be energy efficient as energy is a constraint. The main objective of a good protocol is to discover the path, identify the destination and transfer encrypted packets between the source and destination [2].

Here cooperative communication can be an enhancement for Adhoc network scenario where in excessive channel fading and signal fading are observed. Also optimizing throughput, network lifetime with the required Quality of service. Hence Co-operative communication is a scheme in the wireless communication that performs well and maintains high quality of service (QoS). Better power management and collision avoidance in wireless sensor network is a key feature of routing protocol [8]. Routing deals with route discovery between the source and destination [6-10].

Relay selection is a decisive role taken in accomplishing better cooperation in cooperative networks. In order to exploit the benefits of cooperation the network layer should be appropriately designed for efficient relay selection. The Intermediate node selection for multi hop communication in wireless network plays a crucial role. There are different techniques involved in relay selection. such as fixed relaying scheme (FRS) and adaptive relaying scheme (ARS) [13]. ARS is demand oriented relay selection scheme which is based on Bit error rate (BER), signal to noise ratio (SNR) and cyclic redundancy check (CRC). In co-operative communication due to the cooperative nature of all the nodes, data is transmitted to the sink node along different intermediate nodes (multi-hop) [27]. since more nodes are involved in the process, energy consumption should be minimal. Hence node that consuming less energy and having more residual battery must be selected as the relay (helper node). In addition, in co-operative scheme, a node should be aware of when to, whom to and how to cooperate.

In this paper, Cooperative Residual Battery (CORB) protocol is proposed to achieve the required quality of service. The routing protocol is based on the AODV protocol, which accounts for constructing the route with minimum hop count from source node to the destination node considering residual battery energy. The data is transferred using direct communication or multi hop co-operative communication by enabling co-operative activation bit in the Route request or Route reply packet of route formation. The mode selection is also based on the packet reception rate. A cooperative routing table is maintained with the IP address of each node and their corresponding residual battery life. During the helper node selection, the source node selects the node with highest residual battery energy for data forwarding.

After selecting the helper node all other intermediate node, will be sent a co-operative notification in order to set the Network allocation vector (NAV).

The paper is systemized as follow: section-II deals with the related work performed on the cooperative network routing protocol, in section-III network model and the assumptions made in the simulation of the proposed work. Section-IV deals with the working of the proposed routing protocol. Section-V provides the evaluation of the performance parameter of proposed protocol, Section 6 gives the final conclusion of the paper and possible future work.

II. RELATED WORK

In wireless network energy resources and hardware are the major constraints. Various works have been published on improving network lifetime and efficient utilization of the resources.

In CMAODV [2], Co-operative mobile Ad-hoc on-demand distance vector routing uses adaptive co-operative routing in which the relay is selected based on the nodes that contains the highest sequence number. Here highest sequence number indicates that the node has involved in many previous transmissions hence its more reliable. The modification is done in the RREQ and RREP packet by removing the reserved bit and adding an extra field in the packet that contains information of the sequence number. End-End delay, packet loss and network load are reduced by using this protocol for the data communication. Simulation and network performance with large number of nodes forming real world scenario is kept as a future work.

In CRCPR [3], Constructive relay based co-operative routing, authors have proposed a reactive routing with proactive enhanced protocol. In this protocol the entire network topology is known and maintained in a co-operative table in advance. Along with the Co-operative table, Relay table is used to select the relay based on the least energy drain rate and high energy restoration capability. As the entire network topology is known route formation and data forwarding is very easy and delay in transmission of data is very less. Since the entire topology is predefined the network load and energy utilized by node are very high.

In EBLCR [1], energy balanced load aware relay selection in co-operative routing, the authors have proposed a threshold-based relay selection, In Ad-hoc network minimizing the energy utilization is the key issues in transmission of data with required quality of service. In this paper, Battery aware relay selection in co-operative routing protocol is proposed which is based on the minimum battery utilization and high throughput rate. The best path from source node to destination node is formed based on the node which require less energy to forward the data on to the destination. Considerable simulation is carried out in network simulator tool in order to assess the essence of the proposed protocol. Energy utilization threshold limit is set manually. Nodes that satisfy the threshold limit condition will be selected as relaying node. RREQ packet is modified by adding a new field to store the threshold limit. EBLCR table is maintained to keep track of nodes that satisfy the threshold condition which may be used as helper in future.

In DELP [4], Delay and energy proficient locality-based routing protocol, authors have proposed a novel method of selecting the intermediate nodes as helper node based on the locality information that is in cartesian format. The cartesian information gives the geographical location of each individual node in the network. This cartesian based information is placed in the RREQ packet and based on this information, node which is nearby to the source node is selected as the helper. This protocol improves the network lifetime, delay in the packet transmission and reliability.

III. PROPOSED NETWORK MODEL

AODV is a reactive protocol which obtains route to the destination based on hop count. This is a fair approach however, for energy constrained devices it would be beneficial if route selection happens on least energy consumption path also. To gain this advantage, in our work we have tuned the AODV frame work.

The major contrast of our Cooperative Residual Battery (CORB)protocol with the conventional AODV are

- Establishing of route from source node to sink node by choosing the helper node with highest residual battery life.
- Modification in the route RREQ and RREP control packet by including new field known as Remaining battery of the current node handling the packet.
- Route formation based on the shortest path as well as node with highest battery.

Modified RREQ message format in CORB

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |J|R|G|ResidualBattery|C|Reserved|   Hop Count   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Broadcast-ID                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                   IP Address of Destination                   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  Destination Sequence Number                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     IP Address of Source                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Source Sequence Number                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Fig.1. Message format-RREQ packet

Out of 13 reserved bits, one byte is used to include residual energy and one bit (bit-C) is used for enabling or disabling the Cooperative mode.

Modified RREP message format in CORB

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |R|A|Residualbattery|C|Prefix Sz|   Hop Count   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Destination IP address                    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  Destination Sequence Number                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    IP address of Source                       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            Lifetime                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Fig.2. Message format of RREP packet

one byte of the reserved bits is used to include residual energy information of nodes. Similar to RREQ packet C-bit is used for activation of Cooperative mode.

Table 1: Fields of CORB routing table

IP Address of Destination node
Sequence Number of Destination node
Hop-Count
Interface
Lifetime
Next-Hop
Routing Flags
Last Hop-Count
List of Precursors
Residual battery life

A new field, Residual battery life is included in the CORB table to maintain the information of the residual energy of nodes. As mentioned in the formats, modifications to the RREP, RREQ are made to include residual battery life of nodes which are participating in route formation. The source tabulates the routing table which includes the residual energy of all the nodes which come under route discovery process. The source selects the path which has the least hop count also considering the nodes with the highest residual energy.

Qualnet 7.1 is used as the network simulator tool. In our scenario wireless Ad-hoc network is established by placing nodes randomly on a terrain of size 400x400. The source and destination are far apart, such that direct communication is difficult. There are many intermediate nodes that are placed in between the source and destination node which may help in forwarding the data packets. In co-operative communication same type of data may arrive at the destination in different direction so omnidirectional antenna is chosen for both transmission and reception of data. As result efficient data transmission and increased network performance is observed.

CBR is used for transmitting data from the source node to the destination node along the intermediate helper node. Representation of co-operative scenario is shown in the Fig.3.

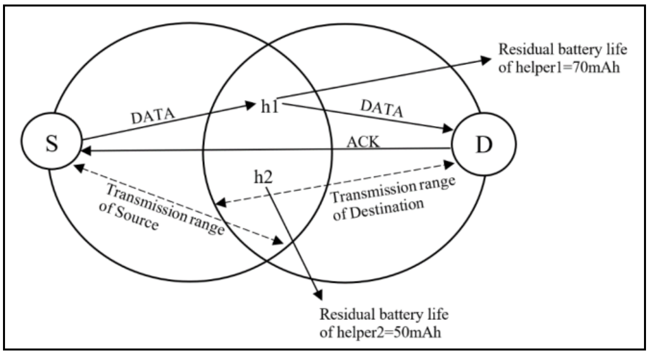

Fig.3. Cooperative scenerio

IV. METHODOLOGY

Data forwarding mechanism takes place in two Stages. Initially path is formed from source node to the sink node and then actual data is transferred in the route established. In CORB efficient relay selection algorithm is used to select the helper node based on the remaining battery charge. The source node broadcasts the modified RREQ message. Upon reception of RREQ by potential helpers, they reply using their modified RREP. The source selects the best relay based on the received RREPs. The modification incorporates the residual battery of the source node and helper nodes.

A. Route formation

The process of path formation from source to destination along the intermediate helper nodes in Cooperative Residual Battery (CORB) protocol is shown in Fig.5. The path establishment in Cooperative Residual Battery (CORB) protocol is similar to the Ad-hoc on-demand distance vector routing apart from the fact that the residual battery energy is considered. In Cooperative Residual Battery (CORB) protocol, unlike in EBLCR [1] the threshold level is not set manually, rather the Residual Battery Life information of all the nodes which are neighbors to the source node will be gathered in the co-operative routing table. Finally based on the information in the coop-table, the node with highest Residual Battery Life is chosen for routing.

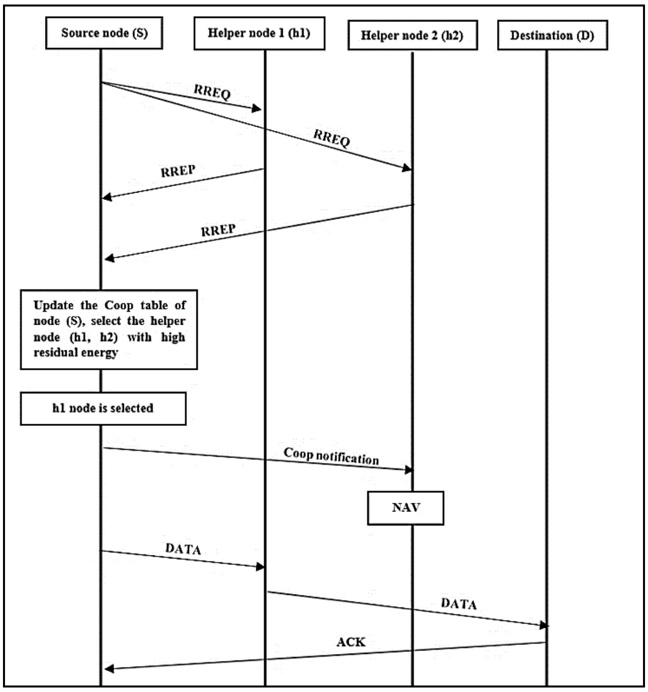

Fig.4. Flow diagram of CORB protocol

The RREQ packet in Cooperative Residual Battery (CORB) protocol is similar to conventional AODV with some modification such as the reserved field are used to store the remaining battery life information of a node. Since the residual battery life may vary at runtime, and that variation is handled easily in CORB there is no periodic checking of node's battery with the manual threshold value. This modification reduces the network overhead and energy utilization in a node.

Similar modification is done in the RREP packet to get better performance in terms of bidirectional communication. When the RREQ packet is broadcasted the packet is received at the destination side from multiple direction via different helper nodes. The destination node or the node which is currently handling the RREQ packet, replies with modified Route reply (RREP) packet in order to avoid the variation of battery during the transmission of packet from destination to source side.

After successful completion of the Route formation the source node sends the data packet along the selected intermediate helper nodes. At each hop the node checks the battery life of nearest neighbours and select the one with highest Battery life and with minimum energy utilization.
Because the modification is done in AODV protocol the data is forwarded based on two parameter one is minimum hop count and other with nodes minimum Battery utilization. When a node completely drains its energy, it will be treated as a dead node and it is added to the dead node list (precursor list). Further the dead node is not considered for the routing process. When we compare the CORB protocol with conventional AODV protocol, throughput and Network lifetime is increased progressively.

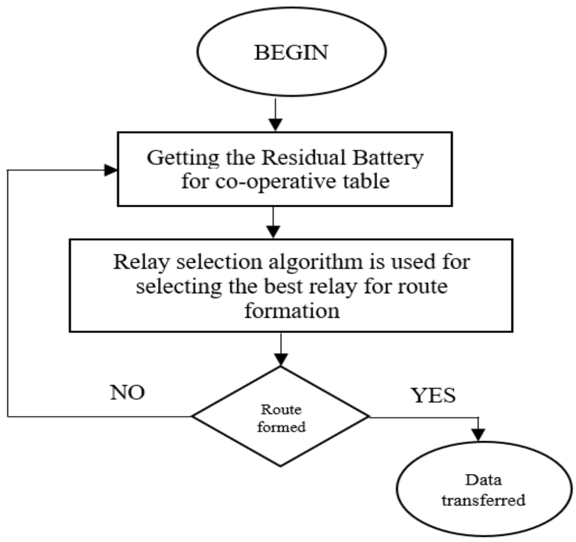

Fig.5. Action of Cooperative Residual Battery (CORB) protocol

B. Helper node selection

Deciding the helper node from a set of relay node is a crucial and most difficult process in the co-operative communication. Once the co-operative table is formed, any node can be selected depending on the residual battery. Once the route formation is completed, each selected node will work as a helper node. Based on the channel fading condition the residual battery life is calculated. The residual battery life ensures the reliability of the Cooperative Residual Battery (CORB) protocol which indicates that how effectively the packet is received at the next node. The working flow of the helper node is shown in Fig.6. initially the relay node will be in Idle mode, the route request packet is broadcasted and once the RREQ packet is received by a node it updates the co-operative table of that node using the information obtained in RREQ packet. Next the current node prepares the RREP packet by adding its Residual Battery life information in the route reply packet and unicast the packet back to the source node. Similarly, multiple route reply packets will be sent to the source node from different node that are participating for helper node selection process. After the reception of all the RREP packet the source node update the coop table and runs the relay selecting algorithm.

Relay selection algorithm

1. Initialization: Collecting the information of residual battery from the nearest neighbouring node.
2. Evaluating different residual energy information to get the highest residual energy node.
3. If Node selected

   Forward the data to the selected node
4. Else

   Search for the best relay node again
5. Endif

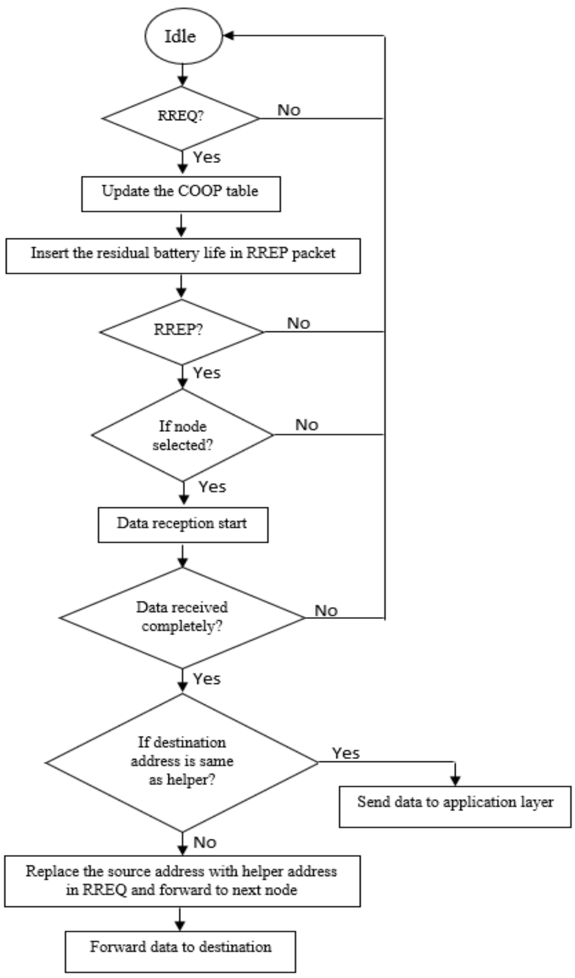

Fig.6. Flowchart of action performed at helper node

C. Co-operative mode selection

Selecting the Data transmission is governed by three condition first it checks if the Packet Reception Ratio is less than the threshold value (δ), secondly if direct communication is not possible as there is no record in the routing table and due to the network constraint, thirdly if there is NACK to source node from the destination node, in all the above three case co-operative mode will be enabled. The equation to find the packet reception ratio is given in equation (1)

$$PRR = \frac{Nr}{Nt} \; --- (1)$$

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Where, Nr is the overall packets received

Nt is the overall packets transmitted

Algorithm for mode selection

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1. Initialization: calculate the packet reception ratio
2. If PRR < δ select Co-operative communication
3. Else select Direct Communication.

Formula to calculate the throughput, delay and jitter

1. When session is finished

   $\text{Throughput} = (B_{\text{total data bytes received}} * 8) / (TL_{\text{time of last packet received}} - TF_{\text{time of first packet received}})$

   When session is not finished,

   $\text{Throughput} = (B_{\text{total data bytes received}} * 8) / (S_{\text{simulation time}} - TF_{\text{time of first packet received}})$

2. $\text{Average delay} = (D_{\text{total transmitting delay of all the packet received}}) / (P_{\text{total number of packets}})$

   $\text{Packets transmission delay} = TSR_{\text{time at which server receives the packet}} - TCT_{\text{time at which client transmits the packet}}$.

3. $\text{Average Jitter} = (JPR_{\text{jitter of all packet received}}) / (PR_{\text{total number of packets received}} - 1)$

   Jitter of a packet = Current packets transmission delay – previous packets transmission delay

   Unit of time are all in seconds.

D. Actions performed by Source node

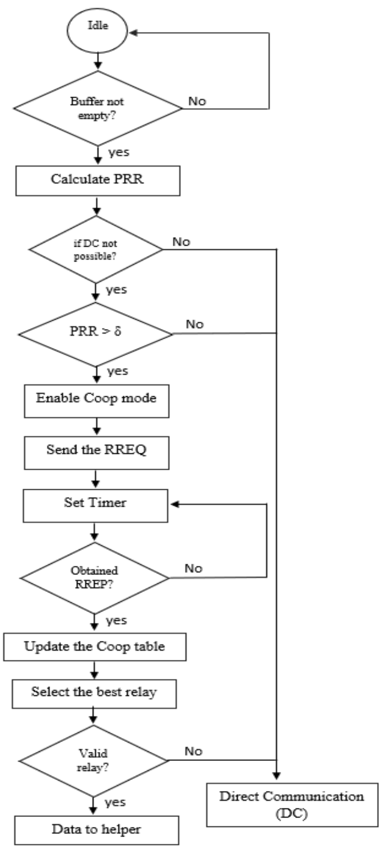


Fig.7. Flowchart of Action performed at sender node

Initially the source node will be idle until the buffer is full with the data that is to be transmitted to the destination. Once the buffer is full, node calculates its packet reception ratio in order to find the reliability of the node, also checks if direct communication is possible followed by if there is any negative acknowledgement from the destination side then the cooperative mode will be activated. Next the sender broadcast the RREQ packet by keeping the residual battery information in the control packet and waits for the unicast RREP from different destination. Based on the information obtained from RREP the coop table is updated and the node with highest residual battery is selected as the helper node and data is forwarded to helper node. In case if the entry is present in the routing table then direct communication is opted and if there is any NACK then again coop mode is activated for data communication. The working process of source node is shown in Fig.7.

E. Actions performed by sink node

The receiver node will be in idle condition until it receive a RREQ packet from any of the intermediate node or from the source node. Once the information obtained the coop table is updated and then check for the condition whether the current node is the destination node. If yes, the current node address is kept as the destination address in the RREP packet and forwarded to requesting node. Next data is transferred from the source node, if the data is received completely then positive acknowledgement is sent to the source else NACK is forwarded to the source node. Fig.8 shows the block view of working of receiver node.

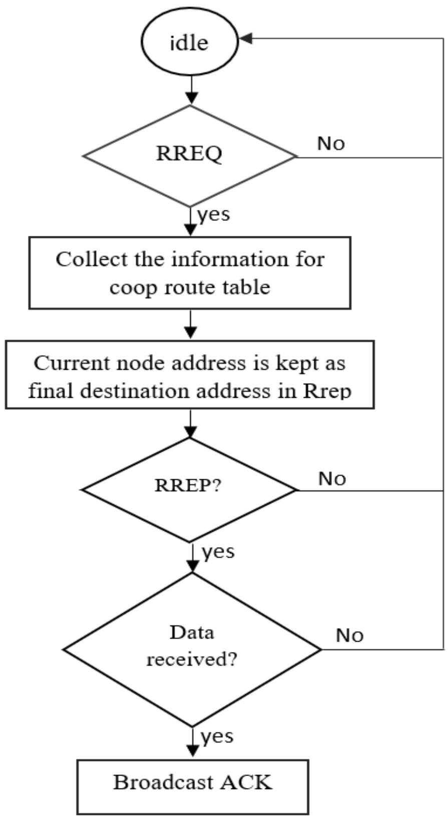


Fig.8. Flowchart of Action performed at receiver node

V. SIMULATION SCENERIO AND PARMETERS

The nodes are separated spatially hence the fading attribute is independent of each other nodes. Channel fading is also considered in the simulation purpose, the network scenario is shown in Fig.9. and Table.2. indicates the parameter that are considered for the simulation.

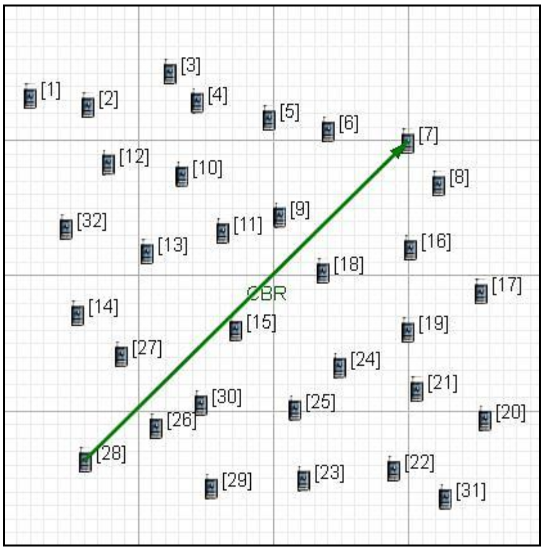


Fig.9. Co-operative network scenario in qualnet 7.1 simulator

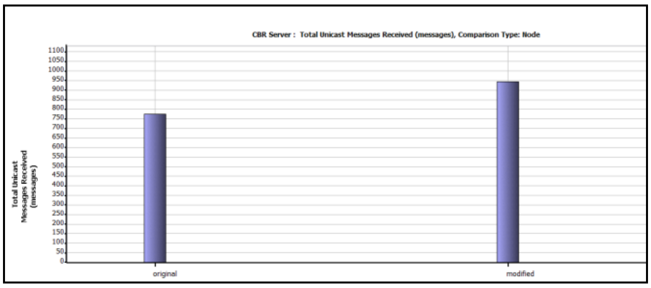
Table 2: simulation parameters

Parameters	Value
Number of nodes	32
Simulation time (seconds)	100
Simulation area (meter sq.)	400x400
Mac protocol (wireless)	802.11
Traffic types	CBR
Total packet sent	1000
Each packet size	2046
PRR threshold	0.6
Battery model	Duracell aa
Mobility	Random Waypoint

VI. RESULT AND DISCUSSION

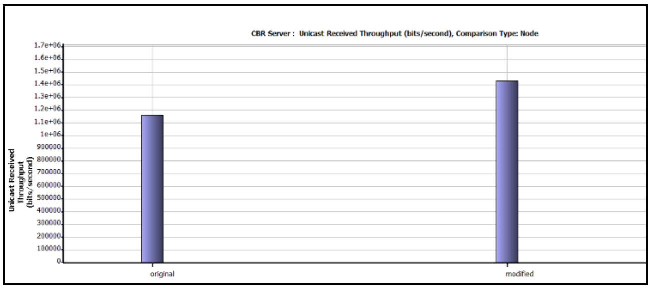
In this section, simulation results of the Cooperative Residual Battery (CORB) along with conventional AODV is evaluated using qualnet. CORB establishes the path based on least hop count and residual battery energy. The network simulation parameter is shown in table 2. 32 nodes are placed randomly in a 400x400 m^2 terrain. The source node generates 1000 packets each of size 2048 bytes which are transmitted at a rate of 10packet/s. The simulation last for 100sec. Random mobility model is enabled for all the nodes. We measure the Total number of packets received, throughput received, average unicast end to end delay and unicast variation in the delay (jitter). Table.3. gives an accurate deep understanding of the simulation results of AODV and CORB protocol.

Fig.10. shows the dissimilarity of different quality of service parameters, original indicates the results of conventional AODV protocol and modified indicates the proposed CORB protocol.



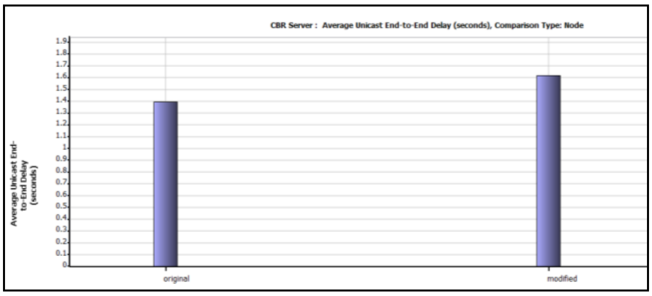
(a) number of packets received in AODV vs Cooperative Residual Battery (CORB) protocol

The result shown in Fig.10(a). indicates that there are less packet loss and good utilization of highest residual energy node in CORB protocol.



(b) Throughput of AODV vs Cooperative Residual Battery (CORB) protocol

Fig.10(b). shows that when Cooperative Residual Battery (CORB) protocol is used, the throughput in bits/sec is more as the data is transmitted intelligently due to switching nature of data transmission modes direct communication and cooperative communication. The packet received in Cooperative Residual Battery (CORB) protocol consists of 16% more data when compared with the AODV protocol. Due to the successful transmission of the data packet and the availability of node's for long duration in CORB protocol the network lifetime is more.



(c) Delay of AODV vs Cooperative Residual Battery (CORB) protocol

Fig. 10(c). specify the variation in end to end delay. CORB is a reactive protocol, packets has to wait until the route formation, computation of best route depends on both linkcost and residual battery energy, as a result delay is more in CORB.

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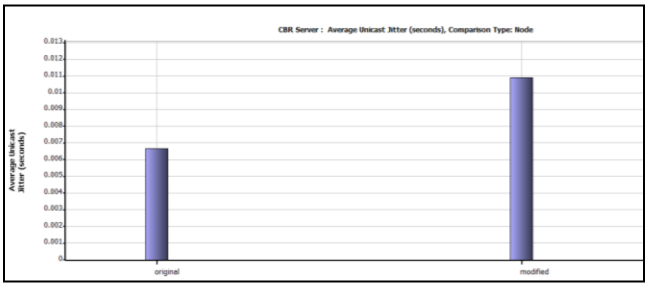
The route formation in AODV depends only on single parameter that is linkcost, so computation is faster and delay is less.



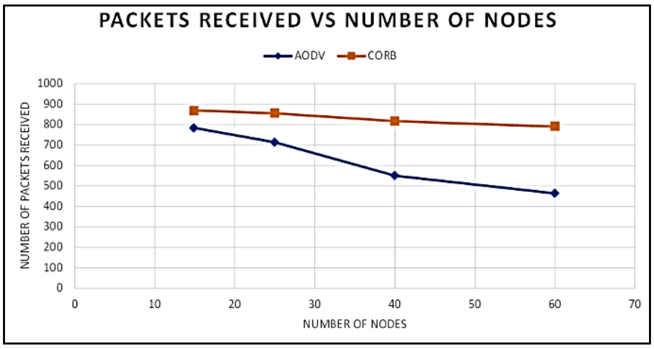
(d) Jitter of AODV vs Cooperative Residual Battery (CORB) protocol

Fig.10. Variation in quality of services (AODV vs CORB)

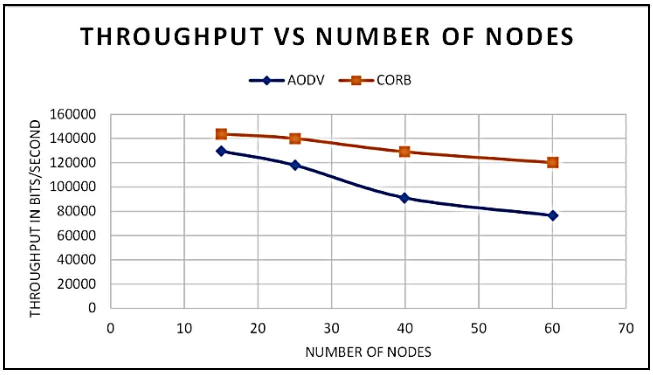
Fig. 10(d). indiactes the jitter for AODV and CORB protocol, variation in delay is more in case of CORB due to two transmission mode where as it is less in AODV with multi hop single transmission mode.

Table.3. Results comparision of AODV and CORB protocol

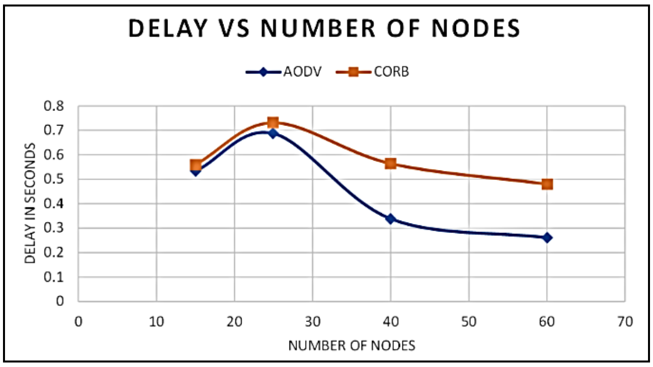
PROTOCOL	Throughput (bits/sec)	Packets Received	Delay (seconds)	Jitter (seconds)
AODV	$1.15e^{06}$	790	1.4	0.007
CORB	$1.46e^{06}$	950	1.62	0.011



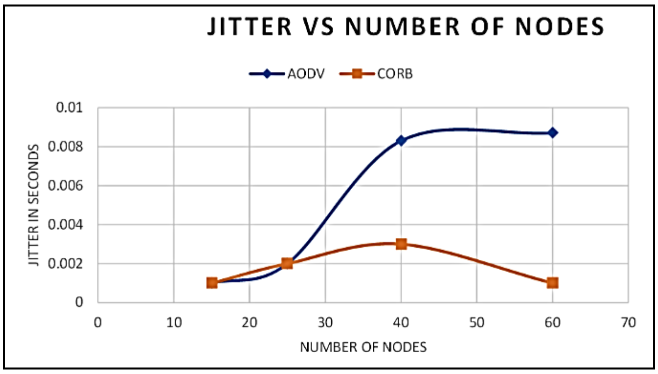
(a) Variation in packets received



(b) Variation in Throughput



(c) Variation in delay



(d) variation in Jitter

Fig.11. Variation in quality of services vs Variation in number of nodes

The source generates 1000 packets to transmit to destination with all the necessary channel condition and simulation parameter mention in table 2. The simulation is perfomed for different number of nodes. Fig.11. shows the divergance in parameter(QoS) when the number of nodes varied. Fig.11(a). shows the packets received for with respect to different number of nodes. Our CORB outperforms AODV upto 16% in transmission of data. The refinement is attributed by including the residual battery energy as one of the key parameter for route establishment.As the source node is aware of neighbour with highest redsidual energy during runtime the node performance is improved steadily. Fig.11(b) shows the comparision of throughput performance for different number of nodes. Throughput of CORB is more as the data forwarding can takes place in two ways, either by multi hop direct transmission or using cooperative transmission depending on the value of packet reception ratio. CORB outperforms AODV but a little inferior in terms of delay. AODV and CORB protocols are reactive thus route establishment occurs on demand. Fig.10(c). shows the increase in end to end incase of CORB. In AODV the node election process is based on only least hop count whereas in CORB the node election process happens on two parameter one is least hop count and the other is residual battery energy so, the packet experiences longer delay and has to wait until the formation of route. Fig.11(d). shows the variation in jitter in AODV and CORB protocol. Due to the switching nature of transmission mode in CORB the jitter drops substantially for different number of nodes. whereas in AODV it increases gradually and maintains a constant variation.

VII. CONCLUSION

The paper proposes Cooperative Residual Battery (CORB) protocol to improve the lifetime of the network, throughput and performance of the wireless network. The proposed protocol reduces the energy utilization in a node and intelligently select the node with highest residual battery life for data communication. The Cooperative Residual Battery (CORB) protocol precisely select the mode of data transmission based on the packet reception ratio. The performance of Cooperative Residual Battery (CORB) protocol is verified through considerable simulations and results indicates that the network performance is improved. Including different channel fading model and improving the delay parameter is kept as a future work.

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