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Energy-efficient QoS routing algorithm for mobile AD-HOC networks

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Abstract

Recently Mobile Ad-hoc Networks(MANETs) are deployed extensively in many areas. To obtain the important information in difficult terrain the feature of the mobility of nodes is used. The effectiveness of information collected by these nodes may be improved by setting up communication among nodes. It is very much important to consider energy conservation among nodes since these mobile nodes operate on limited battery power. The reactive routing protocols are mostly used over proactive routing protocols due to the nodes mobility and limited energy. The reactive routing protocols update routing information based on demand but proactive routing protocols update routing information when there is a variation in the network. The reactive routing protocols collect a huge amount of data and to route these huge data, energy may drain out easily. So it is very much important for the QoS mechanism to be made more energy-efficient. In this paper, an energy-efficient routing mechanism is proposed to achieve this goal. The proposed mechanism achieves by selecting a suitable neighbour node in its routing path to route the information load with efficient energy conservation.

Keywords: Reactive routing, QoS, Energy efficiency, Application prioritization

1. Introduction

In Mobile Ad-hoc Networks the nodes are arranged by themselves and can communicate directly among themselves if the nodes are in the range. MANET comprises a set of nodes in mobility and interact with each other through a shared wireless channel. The nodes will know about neighbour information through broadcast messages. The nodes which reply for the broadcast message are

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considered to be relatively neighbour nodes which can be used in the future as a relay node for routing data packets.

The extensive use of MANETs is found in disaster recovery applications and military applications. In recent days even in civilian life the MANETs are getting popular and have many applications. The QoS plays an important role in MANET's due to its critical nature of many applications. The data collection is more important in certain time-bound applications especially in disaster recovery applications. The data may be not important if it's not collected on a specified time interval. This leads to an action becoming inappropriate or less significant at that instance of time.

The QoS is defined as "the collective effect of service performance which determines the degree of satisfaction of a user of the service" by the United Nations Consultative Committee for International Telephony and Telegraphy. The implementation of Quality of Service in wired networks is easy when compared to wireless networks. In the wired network we can increase the number of resources in demand, the application specific QoS requirements can be reserved. The traffic can also be differentiated related to QoS and others in the wired network.

In wireless networks there are so many issues to implement the above mentions QoS requirements. Few of the drawbacks are listed as follows:

- Due to mobility and resource limitation, the MANETs bandwidth is very poor
- The dynamic topology nature of MANETs leads to frequent disconnection of nodes.
- Complex data processing may not be possible due to limited resources and computational capacities.
- Due to limited computational features in MANET nodes, it is difficult to maintain the status of updated network information
- The signalling of packets is a mandatory step for most of QoS mechanisms. This leads to a contest for network resources along with data packets.
- The Effectiveness of QoS may be reduced due to the lack of observing and supervision of admission control in MANETs.

In recent years for MANETs lightweight QoS mechanism was proposed which is easy to compute [22]. The lightweight QoS mechanism has addressed only minimum bandwidth and maximum delay parameters. The initial QoS parameter addressed will provide the minimum guaranteed bandwidth required for every node in the routing path selected. The later QoS parameter was addressed based on the maximum delay between source and a destination node in which a data packet can experience during its transmission. The DSR protocol is used for finding a proper route between source and destination. In [22], the important QoS parameter called Network Lifetime was not addressed and it is considered to be one of the major disadvantages. For example, assume that the route selected by the proposed scheme in [22] is QoS compliance and satisfied all the QoS parameters and transmitted packets. After some considerable amount of time the energy of the nodes among the routing path is measured and found that draining of energy happens among nodes which leads to disconnection of the network. Hence, it is very much important to enhance the QoS mechanism in [22] to provide a better lifetime of network and performance.

In this paper the following significant contributions are made to improve the network lifetime:

- The QoS mechanism for data transmission between source and destination is extended in [22] by selecting multiple feasible routes instead of a single route. This will reduce the load on a single route and also the data transmission is shared among multiple routes by maintaining QoS requirements.

- Different applications are categorized and prioritized. The highest priority applications or most critical applications are given first preference with the best available resources and routes with almost satisfaction of specified QoS constraints. The lower priority applications or non-critical applications are provided routes having almost satisfied QoS constraints.

- The nodes involved in the routing path will maintain a list of its neighbour nodes which meet the QoS requirements of one or more applications. The route path between source and destination must satisfy application-specific QoS requirements. The solution for achieving this is to define two-node energy thresholds. Firstly, a node will stop the data services provided to low priority applications if it reaches the first threshold and dedicates its services only to critical or higher priority applications. The old nodes in the routing path will get replaced by the neighbour node which will provide an alternate new path for routing the data. Secondly, the node will intimate to source and destination saying that it will no longer provide the existing routing path and informed to find a new route discovery for higher priority applications when it reaches a second threshold.

- The proposed scheme is implemented in NS3, and the same is compared with the traditional QoS scheme proposed in [22]. The results obtained on the network lifetime clearly demonstrate that our proposed routing mechanism is better than [22].

2. Literature review

In MANET one of the important goals to be considered during design is node energy conservation. The routing protocols in MANETS need to be designed keeping in view that energy supplied to MANET is limited [23, 16, 21, 6, 24, 18, 1, 8, 9, 7, 13, 3, 19, 12, 4]. The researchers have developed many protocols on node energy conservation and are presented [11, 17, 5, 20, 2, 10].

Kravets et al [11] have designed an energy aware routing protocol for MANET at the transport layer. The nodes are kept idle for a lengthier duration of time to save energy. The nodes will switch from idle state to active state only if it has a data packet for routing. It also addresses the trade-off between reducing power consumption and reducing delays for incoming data.

Suresh et al [17] have shown that the node energy conservation can be achieved to a greater extent using shortest path routing. The shortest routing protocol is designed which includes the cost of the path as a metric for energy consumption for achieving the goal. The results showed that in the shortest-cost routing there is a substantial reduction in cost when compared to shortest-hop routing.

Chang et al [5] the authors have realized that if more number of neighbour nodes are present the consumption of energy is also more. The authors have designed a technique that has the freedom to choose the number of neighbour nodes essential for routing, thus reducing energy consumption.

Woo et al [20] proposed the Local Energy Aware Routing (LEAR) protocol based on a balanced reduced network lifetime. The protocol has achieved an advantage over a short delay and node energy consumption. The protocol when compared with DSR protocol has proved to achieve good energy conservation.

Agarwal et al [2] proposed conserving energy based on the power control loop technique which was used in CDMA networks. The same technique was applied to Wireless Ad-hoc networks and the outcome on energy was demonstrated. The MANETs contains heterogeneous networks with different types of structures and responsibilities. In this types of network nodes, energy conservation is a big challenge.

Kawadia et al [10] have proposed Clustering based routing algorithm to conserve the energy of node in MANETs. The RREQ packets are flooded by AODV and DSR reactive routing protocols for finding the route in the network. A lot of overhead is created by flooding in the network and in turn causes the energy drain of a node.

Bin et al [21] have proposed a cooperative technique to detect DoS attacks and filter these attacks.

Biswas et al [3] proposed to secure wireless networks from a large amount of energy drainage may be caused due to the Denial of Service (DoS) attack.

Lim et al [14] proposed an efficient solution for a route discovery that was presented, which uses selective broadcasting instead of flooding which reduces the significant amount of overhead. The route request packet will be forwarded to some randomly chosen neighbours by every node for finding the route. The results are tabulated and proved to be efficient in terms of energy conserving of the proposed selective broadcast scheme.

Peter et al [15] proposed to improve the QoS performance of the network by modifying the "Stateless Wireless Ad hoc Networks model (SWAN)" algorithm. It provides stable delays under different traffic and mobility conditions.

Based on the above survey, the QoS mechanism needs to be extended to priority applications to achieve better energy efficiency. The QoS Routing mechanism is introduced to achieve this goal. This mechanism utilizes the suitable neighbour nodes around the routing path to share the routing load, and achieve energy conservation.

3. QOS in mobile AD-HOC networks

3.1. QoS mechanism

In MANETs the QoS mechanisms were developed and deployed. The applications are designed in such a way that it guarantees to provide minimum bandwidth and maximum delay by the nodes in the routing path along with the number of nodes. The QoS is integrated within the DSR algorithm in [22] the initial route discovery phase. The paths are established using the flooding of messages in the network. The proposed QoS scheme will ensure QoS compliance for the path it has selected. Figure 1 shows the route discovery process with QoS constraints for Maximum delay.

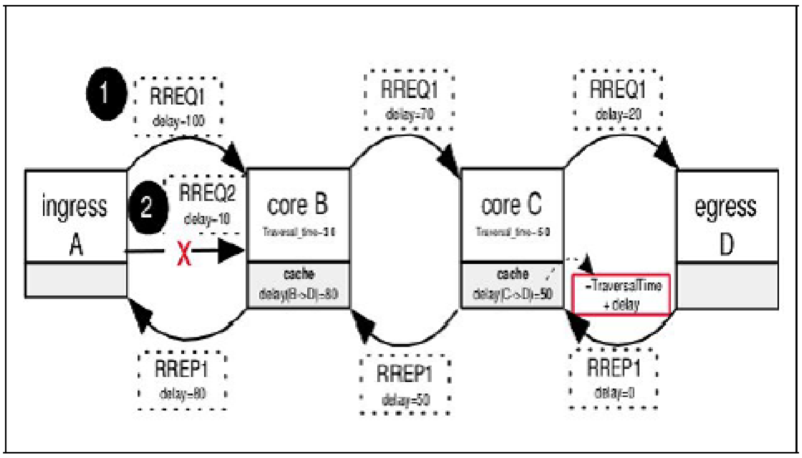

Figure 1: QoS constraint-maximum delay

The Route Request Packet (RREQ) is added with maximum delay constraint and broadcasted by the source node. If an RREQ packet is received by an intermediate node, it will update the new QoS constraint value in the RREQ packet after subtracting its delay value from maximum delay value. The updated value will be checked, if the new value is found to be negative then the RREQ packet will be dropped.

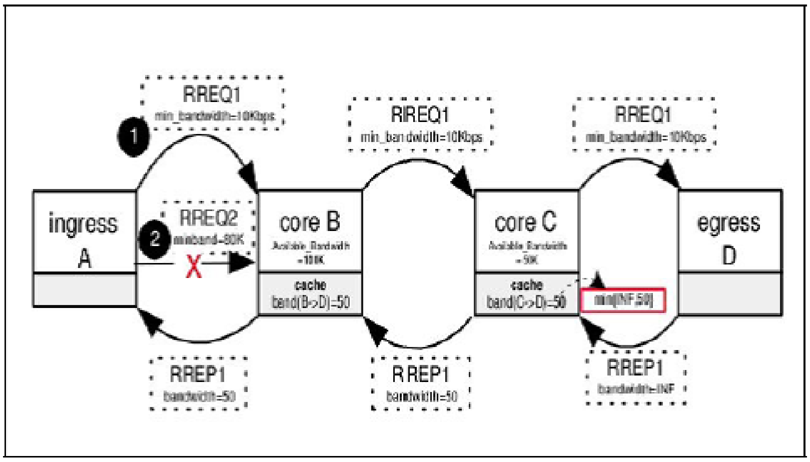

Figure 2: QoS constraint-minimum bandwidth

Figure 2 shows that the route discovery process for another QoS constraint for minimum bandwidth. The source node will add the minimum bandwidth information also along with maximum delay into the RREQ packet before broadcasting to the network. The QoS constraint information will be checked by the intermediate node. If it is not met with the minimum bandwidth requirement, then the packet will be dropped otherwise, the RREQ packet will be rebroadcasted. The main goal of the route discovery process is to find a path that would satisfy both the QoS constraint requirements.

4. QOS routing technique

In this section, the QOS routing technique related to different applications and how to prioritize these applications was discussed. The node routing table is created using bandwidth offered by different nodes. This node routing table is used for QOS routing between nodes. The scoring function is designed to prioritize the neighbour node for QoS routing algorithms.

4.1. Application priority analusis

Inside MANET there are many different types of applications are running. There are r applications assumed to be executed in MANET and these are denoted by $A_1, A_2, A_3, \ldots, A_r$. The routing path of every single application is tabulated in table 1. The application priority levels are represented as per the equation (1). The priority of application $P(A_i)$ specifies the level of priority of application A_i and is $1 < i < r$.

Table 1: QoSTable for node Nj

Neighbor-node	Available Band-width	Induced Delay	Energy Cost
Nji	B(Nji)	D(Nji)	C(Nji)
...	...	...	...
...	...	...	...

$$P(A_1) \geq P(A_2) \geq \dots P(A_r) \dots \tag{1}$$

Prioritization of traffic based on QoS measures such as delay, jitter and loss can be used to accomplish various objectives. Time-sensitive real-time voice and multimedia (like gaming and conferencing) services need to be prioritized over best-effort applications (email/ internet browsing). The prioritization of application in MANET for achieving QoS is to effectively utilize the bandwidth available for different types of QoS parameters for different types of services. For example, the real-time multimedia applications are delay sensitive but can able to tolerate loss to some extent while the other internet applications are packet loss sensitive but will tolerate delay in delivering packet.The allocation of network resources among these applications plays an important role and hence needs to have control and prioritization of these network resource allocation. This method will allocate bandwidth to network applications efficiently without disturbing other applications bandwidth.

The QoS network resource allocation can be achieved by extracting the type of data present in the data packet and categorise the data packets into different categories based on the type of data. These traffic classes are now prioritized before forwarding the packets on the communication network based on the equation (1). The advantage of prioritizing the applications network traffic is to allow the highest priority applications (critical applications) to communicate first than low priority network applications. It also helps to get very good control over the amount of bandwidth allocated to different prioritized applications and efficient bandwidth utilization.

The applications QoS requirements are satisfied by the degree of application during routing. Equations 2 and 3 represents the factors defined for applications A_i.

Equation 2 related to the first limiting factor represents the maximum delay constant. Equation 3 related to the second limiting factor represents minimum bandwidth constraint. Here, $0 \leq \alpha(A_i)$ and $0 \leq \beta(A_i)$.

$$first\ limiting\ factor = \alpha(A_i) \dots \tag{2}$$

$$second\ limiting\ factor = \beta(A_i) \dots \tag{3}$$

4.2. QoSnode table

In MANETs there are multiple routing paths, let us assume Nj be a node in it. The QoSNode Table will be built by node N_j reactively using application prioritization based on QoS parameters and using equation (1). The node cooperative table is used at the stage of the routing of data packets of prioritized applications. The QoSNode Table gets updated at regular intervals. The node N_j, reactively builds a cooperative table to be used in the routing stage, and which is updated in predefined intervals. The QoS Node table for node N_j is shown in Table 1. The N_{ji} represents one of the neighbor nodes for $Nj, B(N_{ji})$ represents the bandwidth of the node N_{ji} offered, $D(N_{ji})$ is the N_{ji} data packets induced delay and $C(N_{ji})$ is the transmitting data packet energy cost from node N_{ji}.

4.3. Neighbour node scoring function

The routing of the data packet may be done directly between source and destination or may require intermediate neighbour node. There may be more than one neighbour node that exists in the network. The selection of a neighbour node among multiple neighbour nodes is a tedious task. To overcome this difficulty, a scoring function is designed for a QoS node. The scoring function for each neighbour node of N_j is calculated and updated in the table. The equation 4 represents the scoring function. Here, score $S(N_{ji})$ represents the score of neighbor node N_{ji}. Where, $B(N_{ji})$ represents the bandwidth of node $N_{ji}, C(N_{ji})$ specifies the Energy Cost of node N_{ji}, and $D(N_{ji})$ represents the Induced Delay of node N_{ji}. The QoSnode selection for QoS routing is based on the highest score. If the score of a node is high, the chances of selection of that node are more when compared with others in routing.

$$S(N_{ji}) = \frac{B(N_{ji})}{C(N_{ji}) + D(N_{ji})} \tag{4}$$

5. QOS routing algorithm

We present QoS Routing Algorithm in this section. The algorithm 1 describes about proposed routing scheme and flow chart diagram for the QoS Routing is shown in figure 3. The algorithm is based on the number of nodes N, the priorities of applications A_k, and the number of r paths P_r. In MANET consider an instance where node N_j is a part of the routing path $[P_1, P_2, \ldots, P_k]$. Each application A_k in a routing path Pk $(1 < k < r)$ and priorities of the applications are represented in equation 1. In this algorithm, two thresholds related to node energy are defined. $T_1(N_j)$ is the first node energy threshold defined for N_j and $T_2(N_j)$ is the second energy threshold defined for Nj where, $T_2(N_j) < T_1(N_j)$.

Algorithm 1: QoS Routing Algorithm

Step 1: Assumptions

Let, node $N_j[P_1, P_2, \ldots, P_r]$ Routing paths

Let, priority P_k application A_k where $1 \leq k \leq r$

As per equation 1 sort applications based on priority $[A_1, A_2, A_3, \ldots, A_r]$

Energy Level $EL(N_j)$ specifies the current energy of N_j

Step 2: If $T_1(Nj) \leq EL(Nj)$ then

The data routing will continue in all the routing paths

End if

Step 3: if $T_1(N_j) > EL(N_j)$ then

The node N_{jin} QoS routing table is QoSTable(N_j).

The routing of data packets for application A_1 with priority P_1.

For every $P_k = [P_1, P_2, \ldots, P_r]$ repeat

Let, the next-hop node in path Pk for node N_j specified in Next_hop($Nj|P_k$)

For every node in a QoS table where $N_{ji} \in QoSTable$ repeat

Let, the list of neighbours for node N_{ji} specified in neighbor_list(N_{ji}).

if $D(N_{ji}) \leq D(N_j) + \alpha(A_k)$ and $B(N_{ji}) \geq B(N_j) - \beta(A_k)$ and next_hop $(N_j|P_k)$ neighbor_list (N_{ji}) then

Find the score of node j by Equation 4

end if

end for

The highest score node N_{ji} for the neighbor list will be selected

The data traffic for path P_k for incoming packet N_{ji} is assigned

Inform about the new path P_k assigned to the source node and N_j will get separated from path P_k.

If there is no relevant node in QoSTable for node N_j for assigning traffic then

The new path should be discovered and the same is informed to the source node.

If unable to find a new route then

The data routing will happen from the same path which was used already.

End if

End if

end for

end if

Step 4: if $T_2(N_j) > EL(N_j)$ then

Repeat for every node $N_{ji} QoSTable$ of N_j do

if $D(N_{ji}) \geq D(N_j)$ and $B(N_{ji}) \geq B(N_j)$ and next_hop $(N_j|P_1)$ neighbor_list (N_{ji}) then

Find the score node j by Equation 4

end if

end repeat

The highest score node N_{ji} for neighbour list will be selected

The data traffic for path P_1 for incoming packet N_{ji} is assigned

Inform about the new path P_k assigned to the source node and N_j will get separated from path P_k.

If there is no relevant node in NodeTable for node N_j for assigning traffic then

The new path should be discovered and the same is informed to the source node.

If unable to find a new route then

The data routing will happen from the same path which was used already.

end if

end if

end if

The node energy level of the current node N_j falls below the first threshold energy, then the routing services offered by node N_j will continue in path P_1. During this, the node N_j comes out of all the low priority paths from P_2 to P_r. To come out of the low priority paths from P_2 to P_r two methods are used by node N_j.

Firstly, the neighbor node will be identified for low priority path Pk, which will be acting as a QoSneighbor node for N_j, in which the low priority path can be directly communicated with next-hop N_j. Choosing these neighbors also need to satisfy the QoS requirement conditions $D(N_{ji}) \leq D(N_j) + \alpha(A_k)$ and $B(N_{ji}) \geq B(N_j) - \beta(A_k)$. Here, $B(N_{ji}) > \beta(A_k)$. In case of no appropriate path available, then find a node score using the scoring function represented in equation 4. The incoming traffic of low priority paths from there onwards will be diverted by node N_j to such qos neighbour nodes, then the node N_j will separate from all the low priority paths. The low priority applications will approximately satisfy the QoS requirements with the new routing path. In case of the non-availability of neighbour nodes for the data traffic migration in low priority path then, the source node will be informed by the node N_j about new route discovery of that route path in which it does not include node N_j. If the discovery of a new route is not able to find by the source node, then the old registered path will be used for routing.

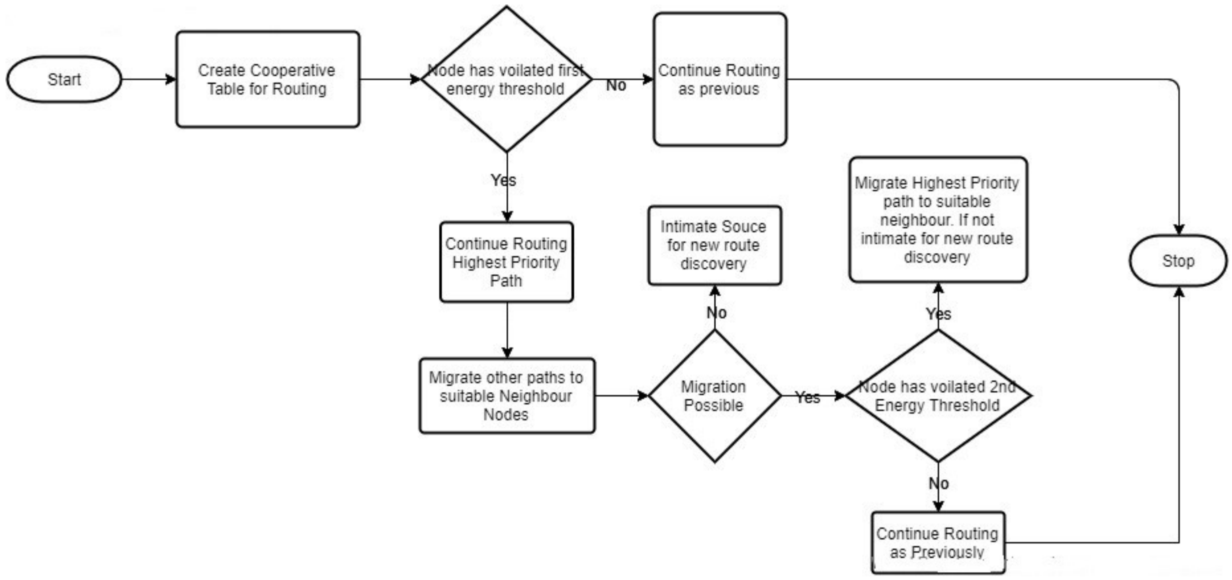

Figure 3: Algorithm flow diagram

Secondly, the node energy of the current node N_j drops below the second threshold value, then, an appropriate qos neighbour node will be selected which has almost the same QoS constraints. The selected neighbour node will directly communicate with the next hop of node Nj for the path P_1. In the case of such a neighbour, a node is present, the most advantage neighbour node will be selected by the scoring function represented in equation 4. The node N_j will divert the incoming traffic of the path P_k of the selected neighbour. The higher priority of applications will get a new routing path always and also it satisfies the QoS constraints exactly. In the case of QoS satisfied nodes are available, the source node will be informed by node N_j for discovering a new route for the particular path excluding node N_j. In case the new route is not available for the source node then the source node will use the existing routing path of already registered one.

6. Results and discussions

The proposed QoS Routing Protocol is implemented in Network Simulator 3. The parameter configurations for the simulation are specified in table 2. In the future to refer easily the QoS Routing Protocol as QRP. The comparison of QoS proposed in [22] referred to as NQRP with our proposed QRP. The new route will be discovered by NQRP by a node only when the node lost all its energy in its routing path but in QRP the new route discovery will be done when the energy falls below the threshold value.

The experimental analysis is performed between QRP and NQRP is based on the metric defined by equation 5 and 6 called average node energy consumption AVGNEC. Where, Ni represents one of the nodes used by application A_k which has involved in the routing of the data packet and the same is used by an application to route the packets using QoS routing technique in multiple paths. The total energy cost experienced by node N_i is represented as energy_expenses (N_i) for application Ak to route all its packets in the routing path. The $N(A_k)$ represents the number of nodes involved in routing

Table 2: Simulation Parameter Settings

Simulation Parameter	Values
Number of nodes in MANET	200
The average number of neighbors per node	26
Number of applications	10
Path per application	1
$\alpha(a_i)(1 \leq i \leq 10)$	Varied b/w 0ms to 30ms
$\beta(a_i)$	varied b/w 0Kbps to 30 kbps
Node delay	Varied b/w 10ms to 100ms
Node bandwidth	Varied between 20kbps to 150 kbps
Node data packet energy cost	Varied b/w 50kj to 150kj
Node energy reserve	Varied b/w 50mj to 150mj
The first node energy threshold	40% of the total node battery energy
The second node energy threshold	70% of the total node battery energy
Application bandwidth requirements	Varied between 60Kbps to 130Kbps per node
Application maximum delay requirements	Varied between 100 ms to 400 ms

all the data packets for an application A_k and the AVGNEC(A_k) define the energy consumption for A_k as Average Node Energy Consumption.

$$AVGNEC(Ak) = \sum_{N_i \in A_k} \frac{(energy\_expence(N_i))}{N(A_k)} \tag{5}$$

$$AVGNEC = \sum_{A_k} AVGNEC(A_k) \tag{6}$$

The performance of the proposed QRP with NQRP is analyzed and represented in the graph. The first experiment shows the performance analysis in terms of the total number of nodes in MANET with reference to the AVGNEC metric. The graph shows the performance of QRP and NQRP with the AVGNEC metric for a varied number of nodes in MANET. The results obtained in the simulation experiments are shown in figure 4. The usage of cooperative neighbour nodes increases with the increase in the number of nodes. The performance of QRP has improved due to more number of neighbour nodes involved in routing.

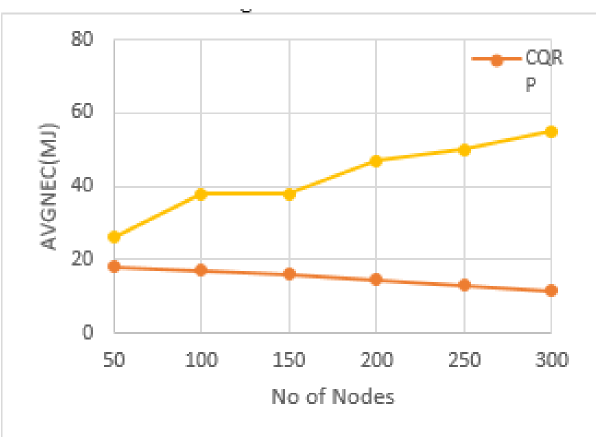

Figure 4: The avgcp vs No of MANET Nodes

The next experiment is conducted based on the number of data packets of different applications are being varied. The performance of QRP and NQRP with reference to AVGNEC metric by varying the application data packets and the experiment results obtained are presented in the form of a graph in figure 5. When you send more data packets then it results in the nodes reaching their energy threshold. Due to its energy threshold reaching, it leads to the use of more nodes to cooperate with each other for routing. Thus the performance of QRP has improved when compared with NQRP.

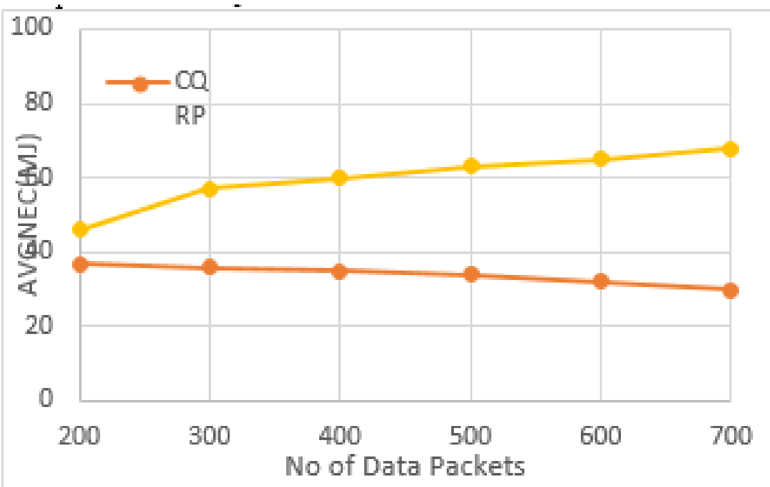

Figure 5: The avgcp vs No of data packets

The performance of our proposed QRP versus NQRP is analysed per node by varying the number of an average number of its neighbour nodes. The increase in the average number of qos neighbour nodes will also increase more nodes to route with each other. The node cooperation tends to improve energy efficiency. The obtained results are presented in the graph and shown in figure 6. The graph clearly shows the improved performance of QRP versus NQRP in terms of the AVGNEC metric.

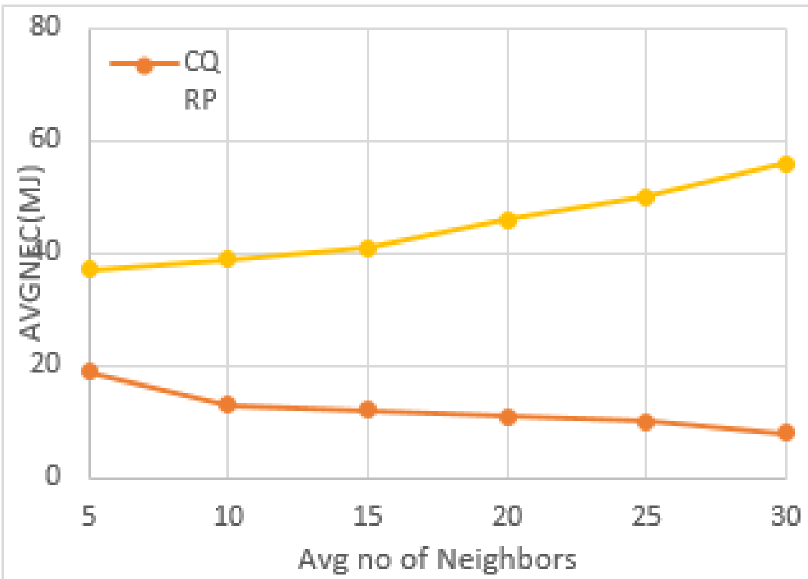

Figure 6: The avgcp vs Avg no of Neighbors

The next experiment is performed based on the bandwidth parameter of the network and the results are analysed for the performance of QRP with NQRP. In this experiment the minimum bandwidth is varied for applications. The minimum(B) represents the minimum bandwidth of application refers to the value of minimum bandwidth required for different applications. The increase in minimum bandwidth minimum(B) will reduce the number of nodes involved in cooperation for routing. If less number of nodes are involved in QoS routing, it will reduce the performance of QRP. The results of the experiment are shown in figure 7.

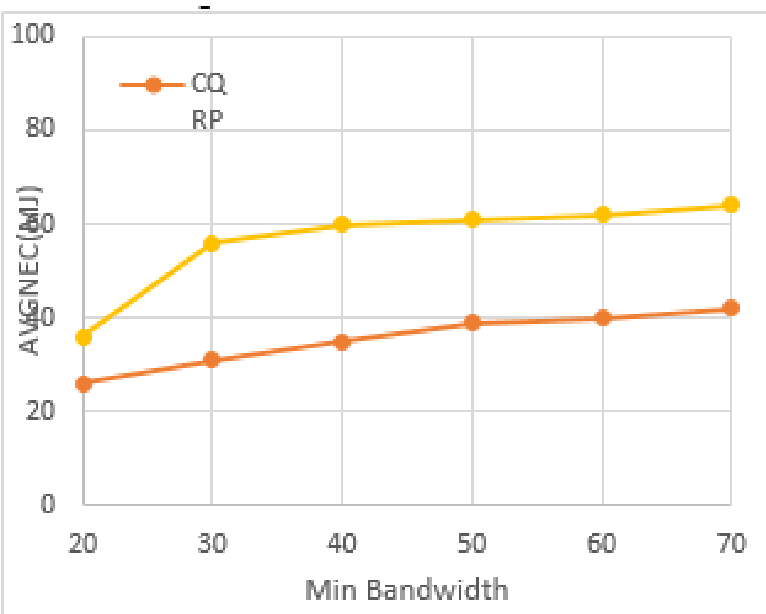

Figure 7: The avgcp vs min(bw)

The important parameter of network performance is the delay in the network. The variation in the maximum delay parameter in the network for all applications is simulated. The term minimum(D) represents the applications minimum value for the maximum delay requirement. The results of this experiment are presented in Figure 8. If the value of the minimum(D) decreases, there will be few nodes available for performing cooperation. The performance of QRP versus NQRP will be reduced. The maximum delay requirement for an application is mandatory for better performance.

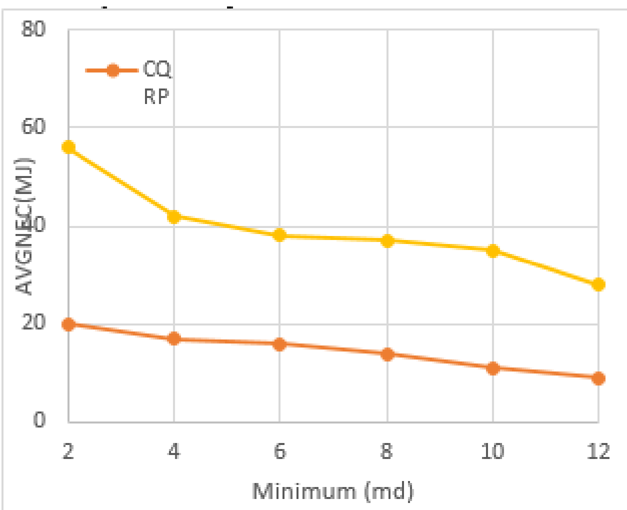

Figure 8: The avgcp vs min(md)

energy threshold value of the first node. The performance of QRP with NQRP is analysed and compared for various values of the first node energy threshold. The results show that an increase in the frequency of node cooperation when the value of first node T1 is less. Thus, if the value of T1 is less the QRP performance is good and the results are plotted in the graph and presented in figure 9.

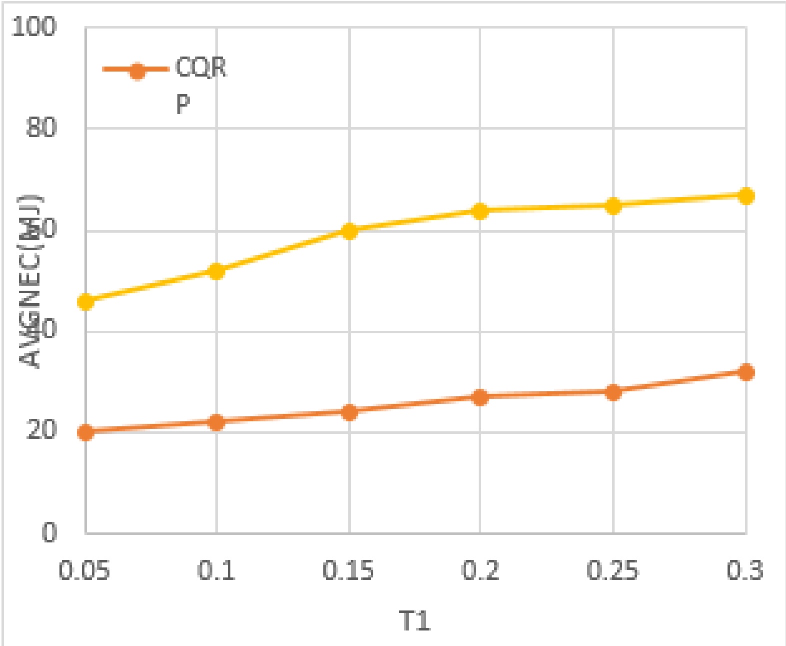

Figure 9: The avgcp vs T_1

From all the above results and graphs, the performance of QRP is good and due to the non-cooperation feature in NQRP the performance will suffer with reference to the AVGNEC metric. Our proposed algorithm has satisfied the QoS requirements and performed well in MANET.

7. Conclusion

The proposed node QoS Routing Protocol was presented in this chapter for the QoS energy efficiency of the network and extended the routing mechanism of [22]. In the proposed algorithm the QoS mechanism was achieved through two QoS parameters for application priority. The proposed routing algorithm was developed and designed using a mathematical framework. The results are obtained from the above proposed work through simulation using NS3. The analysis of results shows that the benefits of the proposed scheme compared to the existing scheme [22]. A better mathematical framework may be designed for obtaining better energy conservation results.

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