Energy and Congestion Aware Routing in MANET using Minmax Game Theory

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Abstract**:** *MANET is a kind of infrastructure less Wireless network, which have more challenges due to its dynamic in nature. The performance of the network mostly affected by the energy and congestion. If we properly handle these parameters, the life span of the network also extended. Many optimisation techniques were applied by the researchers to achieve the performance of the network. Here, we have enhanced the GPSR protocol with Minimax game theory based optimization. Minimax game theory has applied with energy and congestion parametersto select the next neighbour node in the routing process. We have simulated this work in the NS2, from the results, we come to the conclusion that our proposed protocol perform well.*

Key words***: MANET, Minimax Theorem, Energy Aware, Congestion Control, Cross layer Design***

1. Introduction

In MANET, the devices can detect the neighboring devices to establish communication without any central authority. The devices will do the necessary steps to establish communication, sharing of information and services to other devices. Since these types of devices have more limitations, they present more challenges for researchers. In MANET, movement of the nodes are unpredictable, so the network topology may change randomly.

GPSR protocol follows the greedy forwarding approach to transmit the data whereas each transmitted data packet contains identification of destination node and its geographic location. These nodes periodically send beacon messages and finally synchronizes the communication.

Discovery of nearest neighbour nodes using an efficient method significantly improves the reliable communication and improves the performance. The position based protocols get their location information of the distributed nodes to carry out the routing decisions. To dynamically update the position in the mobility environment, each node receives the beacon updates from its neighbours' position and velocity in its neighbour list. Incorporating the geographic routing method in large scale networks, significantly reduces the communication, routing and storage overhead. The scalability of the Adhoc network will improve, if we are using Geographic routing. In the packet forwarding approach, when a void node is found then the process encounters failure. GPSR is the best protocol to handle such situations. To monitor and trigger the proper decision an optimal communication can be carried out by decision theory with game theory strategy.

2. Related Work and Scope for Proposed Research

Vinay Rishiwal et al. [24] designed an energy stable routing algorithm with QoS. They concentrate route discovery, bandwidth and energy constraints of QoS. This protocol is enhanced with DSR protocol. D.Athukoralage et al. [7] suggested there was a need for energy aware routing protocol design.Vishnu Kumar Sharma et al. [25] found out that load balancing and congestions are the major issues in mobile Adhoc network. They enhancing AODV protocol with agent-based congestion Control. S.Santhoshbabooet.al. [22] investigated and compared with internet and found that MANET congestion not only affected the mobile nodes but overloaded the entire network. They suggested a congestion aware routing protocol that performed well in mobile Adhoc network. They used rate-based congestion control algorithms. Their algorithm can perform Hop-by-Hop Congestion-Aware. It can also work for the Heterogeneous Mobile Ad-hoc Networks.

Xiaoqin Chen et al. [28] identified that congestion control was a challenging job in mobile Adhoc network. They came up with a congestion aware routing protocol for VANET. To prevent congestion, they applied a link data rate categorization technique. They implemented Mean Opinion Score based congestion window updating policy. This will work better in a multimedia network. ReetaBourasi et al. [19] found out that the packet dropper node lead to congestion in mobile Adhoc network. To control the congestion, there was a need to detect and remove the packet dropper nodes. They suggested to improve the network performance, we have to detect the congestion dynamically and control them.

Xiaomao Mao et al. [26] compared the traditional convex optimization algorithm with the MiniMax scheduling strategy and found that the MiniMax was superior to the traditional strategy. Abu Sayeed Saifullah, et al. [1] designed a minimax strategy for channel allocation in WSN. It is solved with minimum channels and maximum interference. Liu et al. [12] implemented the intrusion detecting system with MiniMax strategy. This strategy minimized the possible losses while maximizing potential gain. They commented that the MiniMax strategy was the only system to able to detect computer intrusion.

Banks et al. [4] considered minimax game theory solutions for risk analysis. This also solved uncertain payoffs in a terrorist attack scenario. Minimax approach was applied to prevent smallpox terrorist attacks. Ciancarini et al. [6] used a board game to solve with incomplete information. They choose MiniMax approach to solve the uncertainty of the situation. Jiang et al. [10] concludes that the MiniMax theorem is used to defend against network attacks. This strategy either kill the process or block the IP. Xiaosong et al. [27] used MiniMax approach for guarding a territory. This approach, intercepting the invader before he reached the territory. Oberti, et al. [17] implemented MiniMax strategy for surveillance systems. Their system is able to detect the suspicious behaviours.

2.1 Comparative Analysis of Existing Research

Table 1 consolidated and compared the importance of existing research related with energy. The existing research focuses on the importance of power aware routing. The power aware routing can reduce transmission power, active communication energy, load distribution energy and sleep mode energy. Simply, we can say that residual energy and progressive energy. Further to reduce the energy consumption, we can have a cluster of small groups.

Table 1. Comparative Analysis of Existing research related with Energy

Sl. No.	Researchers	Techniques Applied	Observations and Remarks
1	Goldsmith et al. [8]	Power Aware Routing	Reduce - Transmission power, Active Communication Energy, Load distribution energy and Sleep mode energy
2	Bulent Tavli et al. [5]	Multicast architecture- DSR	Cross layer approach using MAC and Network layer
3	Annapurna P. Patil et al. [2]	Enhanced AODV	Alternatively select node which has maximum remaining energy node selection and minimum remaining energy transmission node
4	MohammadA. et al. [14]	Location aided routing	Limiting area discovery – small zone
5	Seyesd-Amin Hosseini-Seno et al. [20]	Clustering – 2 hop	More energy node as a cluster header

According to theresearcher, table 2 points out to avoid congestion in the network. We can form a congestion aware protocol or design multiple paths to distribute the load. Again, instead of unicast, we can have multicast communication. Some of the nodes that do not forward the packet are called selfish nodes. Researchers recommended that we must find out such kind of nodes to reduce congestion. Cross layer-based congestion aware routing provides reliable communication.

Table 2. Comparative Analysis of Existing Research Related With Congestion

Sl. No.	Researchers	Techniques Applied	Observations and Remarks
1	M.Ali et al. [15]	Adaptive multipath routing	Better load balancing
2	Makoto Ikeda et al. [13]	OSLR - Multi-flow traffic; cross-layer approach	Congestion control techniques Reliable routing
3	HariomSoni et al. [9]	Predictive approach	Implemented in MAC
4	K.Srinivasa Rao et al.[11]	Multicast-	nodes place only as many packets- limit the node capacity
5	ReetaBourasi et al. [19]	Reduce congestion	Identify and elimination of packet dropper nodes.

Table 3 expresses the research with cross layer design. Existing researches suggest that, if more than one parameter like power control, congestion control, admin control, failure management, scheduling, bandwidth, low delay and throughput is considered, then cross layer design is the best design.

Table 3. Comparative Analysis of Existing research related with MANET Cross layer

Sl. No.	Researchers	Techniques Applied	Observations and Remarks
1	Venkatachalam et al. [23]	Multiple cross-layer based designs	To handle admission control, failure management, congestion control, power management
2	PremaLatha et al. [18]	MAC and Transport layer	Design a transmission scheduling technique Without centralized coordination multiple mobile stations has communicated
3	A.N.Al-Khwildi, S. Khan et al. [3]	Adaptive Link-Weight routing protocol- combine application and physical layer	Optimum route – Parameters: low delay, available bandwidth, long route lifetime.
4	Xinsheng Xia et al. [29]	Fuzzy logic	Coordinated application layer, data link layer and physical layer
5	S. Aziz et al. [21]	Distributed Cross-Layer QoS	Increased the throughput; real-time traffic.

Table 4 points out the importance of research related with Prisoner's Dilemma. Prisoner's Dilemma based optimisation is applied when we are considering more than two parameters. Researchers implemented Prisoner's dilemma strategy on bandwidth allocation with admin control, steady state execution with steady state identification, selfish user with cooperative user and reliability with resource limitation.

Table 4. Comparative Analysis of Existing research related with MiniMax Theorem

Sl. No.	Researchers	Techniques Applied	Observations and Remarks
1	Abu Sayeed Saifullah, et al. [1]	Design a MiniMax strategy for channel allocation in WSN	Solved with minimise channel with the maximum interference.
2	Banks et al. [4]	Solutions for risk analysis.	Solved uncertain payoffs in a terrorist attack scenario
3	Jiang et al. [10]	Defense network attack	Strategies to kill a process or block IP's.
4	Oberti, et al. [17]	Surveillance systems	To detect faces and suspicious behaviours respectively.

2.2 Observations from the Existing Research and Motivation for the Proposed Research

From the literature survey, a comparative analysis was made and the following issues were identified:

- Performance of the routing will decrease, if the routing process does not consider the energy and congestion.
- Non-Optimum values of input parameters of nodes will decrease the performance of the network.
- Cross layer design will expand life span of the network, and increase throughput.

The Proposed research is carried out with the aim to develop a new Routing protocol using Minimax game theory based optimization, Which will consider energy and congestion.

3. Game Theory and Minimax Theorem

Game theory is a decision theory which provides solution to selection of a particular thing by taking decision then and there. The essential elements of game theory are players, actions and payoffs. The objective of the players is to maximize the payoff and they will devise certain plans to make it happen. Those plans are called strategies.

Game theory is one of the techniques to determine the optimality. MiniMax is a game theory algorithm used to find optimal moves of a player based on their decision. It uses backtracking approach. It is used in two player game; one player is called maximiser and another player is called minimiser. The player maximizer and minimizer always tries to get the highest profit and lowest loss of the game respectively. This game can easily be represented with a binary tree.

Von Newman developed the MiniMax theorem. It is a zero-sum game. Assume both players are rational. A person must select the strategy based on the strategies of the competitors. Both players are try to minimize the loss and maximum the profit.

This type of game has following assumptions:

1) This game has two players and they are rational.
2) Both players are try to avoid loss and gain profit.
3) If one player has win and the other has loss, then they will get +1 and -1 respectively. So, it is a zero-sum game. All equilibria give the same payoffs to each player
4) No hidden information in this game.
5) Both players know all the possible moves.
6) This is not a repeated game.

Only two choices for a player. Player 1 and Player 2 are called row player and column player respectively. Players' payoff was described by a Bimatrix.We can calculate the column maximum and the row minimum values in the Bimatrix. From this we must calculate the Nash equilibrium to find the next neighbour node.

Nash Equilibrium

A strategy profile $S = (S_1, \ldots, S_n)$ is a Nash equilibrium if for every i,

- S_i is a best response to S_{-i} , i.e., no player can do better by unilaterally changing his/her strategy

Theorem : (Nash, 1951): Every game with a finite number of players and action profiles has at least one Nash equilibrium;

- If either player unilaterally switches to a different strategy, his/her expected utility goes below 1
- A dominant strategy equilibrium is always a Nash equilibrium

Maximin and Minimax

Minimax theorem is a zero sum game. The relation between the rewards of player P_1 and P_2 are, Player P_1 always maximise his reward. Player P_2 maximises his reward means that player P_2 minimises his reward. Reward for player P_2 is always equivalent to negative value of player P_1. This can be represented using single matrix A, where Player P_1 wants to maximise his rewards and playerP_2 wants to minimise his rewards.

Say Player P_1 uses mixed strategy $X_1= [X(_{1,1}), X(_{1,2}), X(_{1,3}), \ldots)$. The rewards for player P_1 corresponding to different possible actions of player P_2 is defines as $[X(_{1,1}),X(_{1,2}), X(_{1,3}), \ldots] * S_j$. Where$S_j= (X_1 T*A)$j.

Rewards for P_1 when P_1 uses mixed strategy X_1 and P_2 uses mixed strategy X_2 are

$$[(X_1^T *A)_1,(X_1^T*A)_2, (X_1^T *A)_3, \ldots] * X_{2,2}, X_{2,3} = X_1^T * A * X_2$$

For Player P1 , Choose player P1's strategy to maximize his reward, worst case over player P2's response is

$$V_1^* = \max(X_1) \min(X_2) \quad X_1^T * A * X_2$$

For Player P2 , Choose player P12s strategy to manimizeplayer P1's reward, worst case over player P1's response is

$$V_1^* = \min(X_1) \max(X_2) \quad X_1^T * A * X_2$$

Where

V_1* :maximin valueof P_1

V_2* : minimax value of P_2

X_1* (maximiser) : maximin strategy of P_1

By playing X_1* player P_1 guarantee to himself/herself at least V_1*.

John Von Neumann solved this and called as Neumann Minimax Theorem.

The Minimax Theorem :

Theorem : For any two person zero sum game, $V_1^* = V_2^* = V^*$ is called the minimax value of the game.

Set of Nash Equilibria(NE) $= \{(X_1^*, X_2^*) : X_1^* =$ maximin for $P_1, X_2^* =$ minimax for $P_2\}$

Corollary : X_1^* is best response to X_2^* and vice versa.

Proof :

$$V_2^* = \min(X_2) \max(X_1) \ X_1^T * A * X_2 \leq \max(X_1) \ (X_1)^T A X\tilde{}_2 = V\tilde{} = \min(X_2) \ (X\tilde{}_1)^T A X_2 =\leq \max(X_1) \ \min((X_2) \ X_1^T * A * X_2 = V_1^*$$

$$V_1^* = V_2^*$$

There fore

$$V_2^* = \min(X_2) \max(X_1) \ X_1^T * A * X_2 = \max(X_1) \ (X_1)^T A X\tilde{}_2 = V\tilde{} = \min(X_2) \ (X\tilde{}_1)^T A X_2 = \max(X_1) \ \min((X_2) \ X_1^T * A * X_2 = V_1^*$$

When $(X_1\tilde{}, X_2\tilde{})$ is a NE, $X_1\tilde{}$ and $X_2\tilde{}$ must be maxmin and minimax strategies for P_1 and P_2, respectively.

4. Enhancing GPSR Routing Protocol with Minimax Theorem

4.1 Energy as a Parameter

The energy of the node is calculated based on the two elements, i.e., Residual Energy and Progressive Energy. Both residual energy and progressive energy can be combined and calculated as weighted energy for each node. The calculation for the Residual energy, progressive energy and weighted energy has given in the Equation (1), (2) and (3)

$$\text{Residual Energy}(i) = \frac{\text{Average Energy}(i)}{\text{Initial Energy}(i)} \quad \ldots\ldots\ldots\ldots (1)$$

$$\text{Progressive Energy}(i) = (a - b) / a \quad \ldots\ldots\ldots\ldots (2)$$

$$\text{Weighted Energy}(i) = \text{Residual Energy}(i) + \text{Progressive energy}(i) \quad \ldots\ldots\ldots\ldots (3)$$

Where

i = Current Node

a = Distance from neighbor node to destination node

b = Distance from current node to destination node

4.2 Congestion as a Parameter : Cross Layer Design Based Congestion Aware System

MANET congestion may occur at transport layer and MAC layers. Due to heavy traffic congestion may occur in the transport layer. Number of data packets received for the retransmission by the node is greater than the number data packets sent is called congestion. Simply, if the throughput is less, then we conclude that the node is facing congestion.

To measure the occurrence and degree of congestion level of a node we have applied the Eq.(4) The congestion level of a node is measured as total received packet subtracted by the total transmitted packets. We define the congestion metric β based on the Eq.(4).The proposed technique was tested on Znn.com which is a model problem by Cheng et al. in the repository of the Software Engineering for Self-Adaptive Systems community[12]. The Znn.com system has been used in numerous papersfor evaluating their adaptation approaches[13, 14, 15, 16, 17]. This is why Znn.com has been used to assess the proposed methodology.

$$\beta = PR - PT \quad \ldots\ldots (4)$$

Here,

β - buffer occupation growing rate

PR - packet generated/ received rate

PT - packet service/retransmission rate

- The probability of congestion level is low or there is no congestion, if the value of β is less than or equal to 0,
- The probability of congestion level high, if the value of β is greater than 0,

For effective data transfer, the nodes has to maintain good signal strength. To continuous maintenance of link between nodes they often exchange control signals. Due to interference, movement, power and nature the strength of the signal may become poor in quality and packet may loss during the transaction. This leads to congestion in the nodes. So we need to detect congestion based on the link layer signal strength. The strength of the signal is calculated based on the Eq. (5).

$$Sc = Pr + \partial t \quad \ldots\ldots (5)$$

Here,

Sc - Estimated Strength of the signal received at current time(in db)

Pr - Exponential average power of received signal in T

T - Predefined window size

t - Time period from the last received to till now

∂ - slope of Pr

Pthr - Threshold value of Pr (in db)

If (Sc < (Pthr) then

link failure in MCA layer

else

Congestion in MAC layer

For convenient, we have converted all the Data congestion and Signal congestion values into percentages. Again it converted into grading from 1 to 10. Now we calculated the weighted average for the Congestion using the Eq. (6)

$$\text{Weighted Congestion } (i) = \text{Data Congestion } (i) + \text{Signal Congestion } (i) \quad \ldots\ldots [6]$$

4.3 Comparing Energy and Congestion of a Node

To calculate the optimum node based on energy and congestion, we formed 2 x 2 matrix, with Row and Column assigning Energy and Congestion respectively. For easier calculation and understanding, we converted the actual values into percentages. Each node will maintain the neighbour table. It contains the information of neighbour node ID, Energy and Congestion of the neighbour node, % of Energy and % of Congestion. We have created a neighbour table using single hop. The percentage of the energy of a node can be calculated using the Eq. [7].

$$\%\,EnergyOf\,Node(i) = \frac{EnergyOfNode(i)}{MaxEnergyof\,Node} \times 100 \qquad \ldots\ldots\ldots\ldots(7)$$

To apply MiniMax theorem, we have analysed the situation, where we can apply this strategies. Table 5 tabulated the situation of the game.

Table 5. Situation - Where Game Theory applied

	Node A	Node B	Selection Procedure
Situation 1	High Congestion Low Energy	Low Congestion High Energy	Node B
Situation2	Low Congestion High Energy	High Congestion Low Energy	Node A
Situation 3	High Congestion High Energy	Low Congestion Low Energy	Game theory Based optimization
Situation 4	Low Congestion Low Energy	High Congestion High Energy	Game theory Based optimization

Here, neighbour nodes (|Node(i) and Node(i+1) were compared with MiniMaxoptimization.

To compare the Energy and the Congestion, we must form a Bimatrix. The Row contain the Node(i) and the Column contain the Node(i+1). For each node the Column wise Maximum and the Row wise Minimum will be calculated. This process will be enhanced with the GPSR protocol.

Algorithm1 expresses the MiniMax strategy. We can form a bimatrix of all neighbour nodes. PlayerA and the playerB are the neighbour nodes Node(i) and Node(i+1) respectively. In the row we must fill the congestion of the nodes and the column we must fill the energy of the nodes. Then we must calculate the column maximum and the row minimum values. From this we must calculate the Nash equilibrium to find the next neighbour node.

Algorithm 1 : MiniMax Theorem

MiniMaxTheorem(Nodes, Depth, MaximisingPlayer)
begin
if (Depth = 0)
return Value

if (MaximisingPlayer)
BestValue ← ∞
for each child in Nodes
Value ← *MiniMaxTheorem(Child, Depth − 1, FALSE)*
BestValue ←*Maximum(BestValue, Value)*
end for
returnBestValue

else(Minimisingplayer)
BestValue ← ∞
for each Child in Nodes
Value ←*MiniMaxTheorm(Child, Depth − 1, TRUE)*
BestValue ←*Minimum(BestValue, Value)*
end for
returnBestValue
end if

end

5. Result and Discussion

In the proposed work, the enhanced version of GPSR protocol is used. The modified GPSR protocol adopted the MiniMax theorem. This protocol finds the best route and optimal forwarding decisions by means of adapting game theoretic strategy. So, the routing overhead is durably reduced and the network performance is made reliable. The simulation parameters used this research are tabulated in the table 6.

Table 6: Description of Simulation Parameters

S.No.	PARAMETERS	VALUE
1.	Simulator	NS2
2.	Simulation Time	150 s
3.	Routing Protocol	GPSR
4.	Traffic Type	CBR
5.	Simulation Area	1000m x 1000m
6.	Channel Type	Wireless
7.	Propagation Type	Radio Model
8.	Interface Type	Network Interface Type
9.	Queue Type	Priority
10.	Layer Type	Link Layer
11.	Antenna	Omni Model
12.	Protocol	GPSR

To compare the performance, we used the metrics like Packet Delivery Ratio, Throughput, Network Delay, and Routing Overhead. Table 7shows the performance of these protocols with different metrics.

Table 7: Performance of GPSR and MiniMax protocols

No. of Nodes	Network Delay (in m sec.)		Throughput (kbps)		Packet Delivery Ratio (%)		Routing over Head (m sec.)	
	GPSR	Mini Max	GPSR	Mini Max	GPSR	Mini Max	GPSR	Mini Max
20	75.321	75.502	53.65	61.84	0.9211	0.9461	602	647
40	76.463	76.044	64.67	69.92	0.9401	0.9516	697	656
60	77.794	76.436	67.73	72.37	0.9541	0.9714	783	782
80	77.601	77.801	69.70	76.63	0.9612	0.9787	921	825
100	78.912	78.351	73.35	78.22	0.9651	0.9953	1032	903

The result of the simulation is represented in the following graphs. Figures from 1 to 4 show the performance of the MiniMax protocol and GPSR protocol.

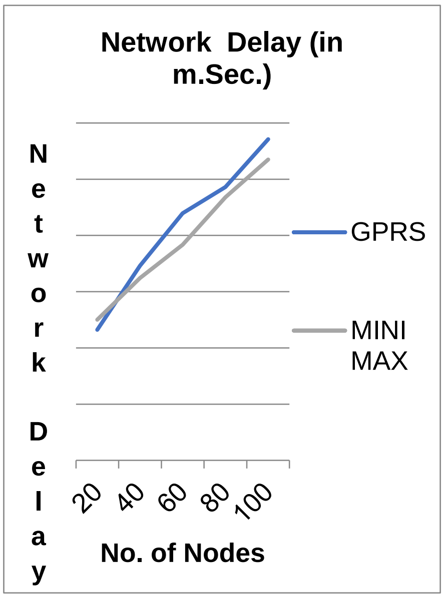

Figure 1: Network Delay vs No. of Nodes (MiniMax)

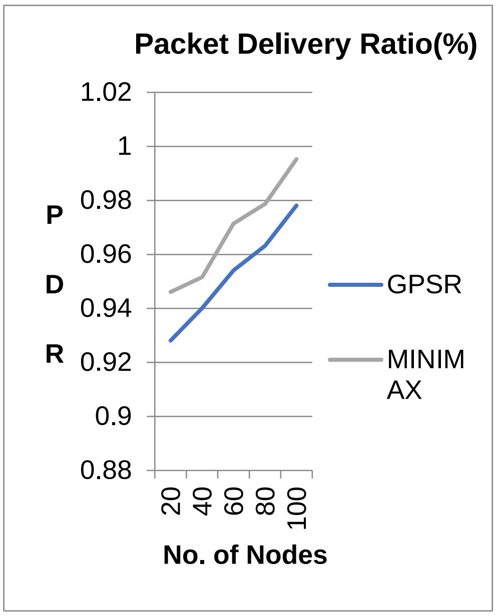

Figure 2:Packet Delivery Ratio vs No. of Nodes (MiniMax)

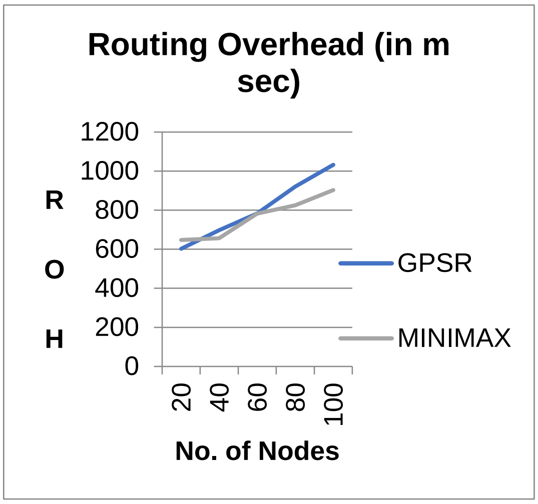

Figure 3: Routing Overhead vs No. of Nodes (MiniMax)

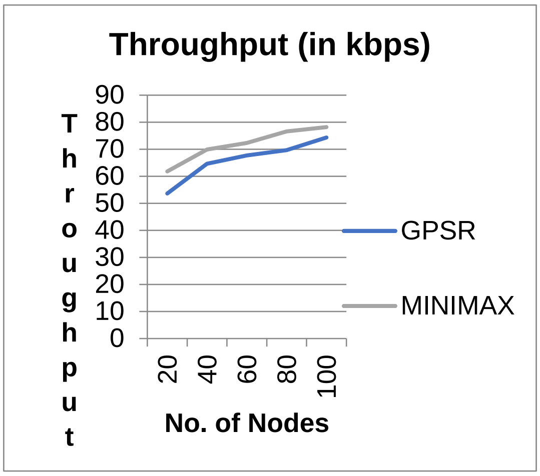

Figure 4: Throughput vs No. of Nodes (MiniMax)

Observations

- The performance of the Minimax and the GPSR protocol is tabulated in the Table3.
- The Network delay (fig.1) of the MiniMax protocol is 0.50% better than the GPSR protocol.
- Considering Throughput (fig.4), MiniMax protocol achieved 9.36% more than GPSR protocol.
- MiniMax protocol performed 2.14% better Packet Delivery Ratio (fig. 2) than GPSR protocol.
- MiniMax protocol has less Routing Overhead (fig.3) and it performed 4.29% better than the GPSR

6. Conclusion

This research work has implemented with MiniMaxtheorem-basedNeighbour Node Selection strategy. This will do the optimal Forwarding Action. MiniMax theorem based enhanced version of the GPSR protocol is better in network delay, throughput packet delivery ratio and routing overhead. This research can be extended with different parameters likenode movement, link stability, QoS, etc. Researchers can also apply any other optimization techniques to extend this research.

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