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Congestion Control for Mobile Robots

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Abstract: Small group of robots are being used at different places to gather information. The proclivity for the usage of a team of robots in order to gather information is likely to increase in the upcoming future. The efficient and lossless communication becomes vital for these robots. In our research paper we propose an algorithm that focuses on minimizing congestion and data losses amongst a team of robots. Our algorithm prevents congestion beforehand and can be divided into two part. A detailed description of these parts have been given in the paper. The algorithm was also tested on various grounds. These results have been discussed in the paper. The algorithm focuses on labelling each node depending on its congestion status and discovering an alternate path having a lower congestion status as soon as the path becomes liable to come in the congested zone.

Keywords: Traffic and Congestion free routing, Mobile ad-hoc network, Congestion control, Swarm robots, reliable communication.

I. INTRODUCTION

A team of robots collectively assigned a task such as gathering data must be well informed about the location of other members present in the team. Since these robots are mobile, the nearest neighbour for each robot may change. As well as the communication range may vary. Congestion control becomes tedious due to the mobile nature of these robots. Therefore, there is a strong need for a congestion control algorithm that can prevent data loss.

Congestion can occur due to multiple reasons in a group of robots and can result into loss of information and a reduced throughput. This may further lead to incorrect decisions made by the robots. There can be several causes of congestion in mobile robots operating together .Excess traffic may be one of the reasons whereas the dynamic nature of the network might be another.

Traditional techniques used for controlling congestion may not be used for a network containing mobile robots. One of the primary reasons that robots in such a network have a restricted bandwidth and limited transmission ranges and can only use a curtailed power supply. So, it becomes necessary to develop congestion techniques that take into considerations these factors that are essential for a wireless network consisting of mobile robots.

In order to combat congestion for a network consisting of mobile robots it becomes imperative to combat congestion in different way. Therefore, there is a need for the development of congestion control technique that takes into account factors such as the dynamic nature, lower bandwidth and power constraints of the network.

In our study we propose a novel approach to reduce congestion for a wireless network consisting of robots. We emphasize on developing a dynamic approach that prevents the occurrence of congestion. Our algorithm basically consists of two parts. The detection of congestion on a particular path and the detection of an alternate path in case congestion takes place.

II. METHODOLOGY

Our algorithm can further be subdivided into 2 parts. The first section of the algorithm deals with the dynamic estimation of congestion that predicts congestion in a node. The second part of our algorithm stresses on creating an alternative path once congestion has been confirmed in our algorithm.

A. *Dynamic Congestion Estimation technique*

For a team of robots working collectively it is imperative to acknowledge the presence of congestion beforehand. Congestion may further result into packet loss. The dynamic congestion technique is utilized by all the nodes or robots in order to update themselves about the status of congestion. The algorithm relies on three parameters Wq, maxim and minim for deciding the weights, maximum and minimum values for threshold respectively. The mean queue size is responsible for deciding the value of the maxim and minim. We have decided to take 40 % of the queue size as our minimum threshold.

minim = 0.4 *queue_size (1)
maxim= minim *2 (2)

The mean queue size gives us an idea of the fluctuations in traffic and is also representative of the dynamic nature of the network. It provides us with a good idea about the present condition of the network. The equation for mean queue length is given as.

$$\text{Queue\_mean} = (1 - w_q)*\text{Queue\_mean} + \text{Queue\_Instant}*w_q \quad (3)$$

Wq is the weight factor on which the efficiency of controlling congestion of a mobile network depends. A small Wq may result into the mean queue length not representing an extensive range of congestion making the dynamic estimation technique inefficient. Whereas, a large Wq also hampers congestion control as the mean queue length follows the instant queue.

Our technique focuses on dynamic assignment of values to Wq that are in context with the flow of traffic. Wq has initially been assigned a value of 0.004 and the values changes throughout. The packet rate P and the packet lively flows N are responsible for determining the flow are

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the factors on which the values of Wq depends. Wq is updated in the following manner.

Wq=Wq*N*P (4)

The node is classified into zones depending upon the relation between the mean queue length and the minim and the instant queue. Four zones have been allocated depending on this relationship. In Zone I or the safe zone the mean queue length is smaller than the minim. There are very little chances of congestion. Hence no action of congestion is taken. For the moderate- safe zone or Zone II the mean queue length is between the (minim + maxim)/2. The process of alternate route discovery is initiated in this zone. When the value of the mean queue size is in between (maxim + minim)/2 the node is said to be in Zone III or the moderate congestion zone. Now part of the data is being transmitted through the alternate path.

When the mean queue size has a greater value than maxim the node is said to be in the congestion zone and data is completely send from the alternate path.

B. TRAFFIC AND CONGESTION FREE ROUT DISCOVERY

While the first part of our algorithm focused on determining the state of congestion for a node. The second part of our algorithm lays stress on the discovery of the alternate congestion free path. The process of the discovery of the alternate path is initiated as soon as the network is in zone II.

In the initial step all mobile robots or nodes select their set of 1 hop neighbours that that are either in Zone I, Zone II or Zone III. The selection is done in such a manner that it covers all the 2 hop nodes. This step is followed by random selection of a subset S of all the neighbours that have their two hop neighbours in the direction of the destination and do not fall in congested zone. All the nodes transmit their congestion status that has been estimated with the help of the dynamic congestion estimation technique. The Congestion Status Packet (CSP) of each node is transmitted to all the nodes denoting the congestion status of the node. A preference is given to the nodes in Zone I and zone II. A node lying in Zone III is accounted only under adverse traffic conditions. The congestion status is updated periodically by all the nodes.

The first step for communication between the source and the destination is marked by the creation of the RREQ packet by the source that is transmitted to all nodes present in subset S. the hop list of the source node is verified in order to check the presence of the destination node in the 2 hop list.. In case the destination node list is present in the 2 hop list then the RREQ packet is directly transmitted to the destination node via the intermediate node. If multiple intermediate nodes point towards the destination node then the RREQ packet is transmitted to the node lying in the safest zone.

Upon the reception of the RREQ packet the nodes in the subset initially check their two hop neighbour list. A similar procedure is followed by the intermediary upon receiving the RREP packet and it check whether the destination node lies in the list of its two hop neighbours. The RREPQ packet is either forwarded to the next intermediary node or is transmitted to the destination node. The destination node upon receiving the RREQ packet acknowledges it by resending an RREP packet via the same path to the source node.

The route discover process has been illustrated in figure 1. Different nodes have been represented n different colour depending upon their congestion status. The red coloured nods are the ones lying in zone 4 or highly congested zone. The green coloured nodes lie in the safe zone or Zone I. The yellow coloured nodes lie in zone II and the blue coloured nodes lie in zone III. The source node has 1 and 3 as 1 hop safe node neighbours and 6 and 7 as two hop safe node neighbours. Node 4 lies in Zone II and can be considered as an option in case there is no node in the safe zone. The node selects node 3 for transmission as the destination does not lie in two hop neighbours list and transmits the RREQ packet to node 3. Node 3 checks its list and then transmits the packet to the next node 6.Now none of the neighbours attached to the next node lies in the safe Zone. Hence node 6 transmits the data further to node 10 as node 10 lies in Zone II. Node 10 now checks it's 2 two hop neighbours list and finds that the destination is present in its two hop neighbours list. The path to the node is via node 12 and hence the path between the source and destination is formed.

The destination on receiving the RREP packet acknowledges it by sending a RREQ packet via the same path. Now the path is S-3- 6-10-12-D.

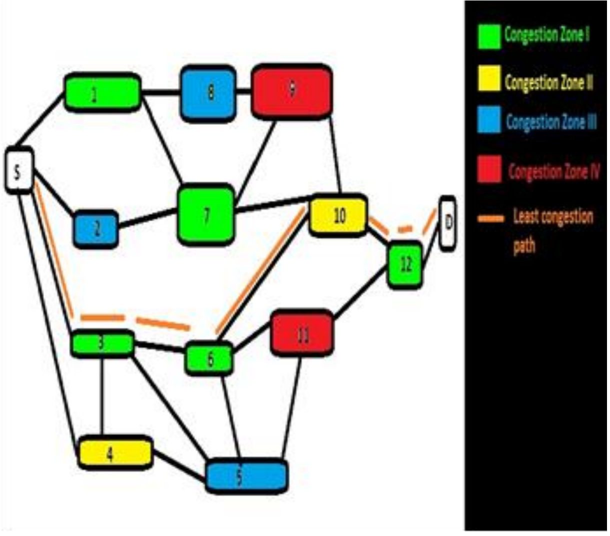

Figure 1. The process of discovering a route. Each node selects the neighbour lying in the safest zone and pointing towards the destination.

One of the salient feature of this algorithm is the detection of an alternate path in a case an intermediary node lies in any zone other than Zone I. In the scenario mentioned above node 10 lies in Zone II. Hence, it triggers the process of alternate route discovery from node 6. As soon as the congestion status of node 11 changes the network switches its route via node11. The following has been demonstrated in figure .All the nodes are updated about the congestion status of all other nodes after a fixed interval of time. All the nodes keep a track of the congestion status of their subsequent nodes.

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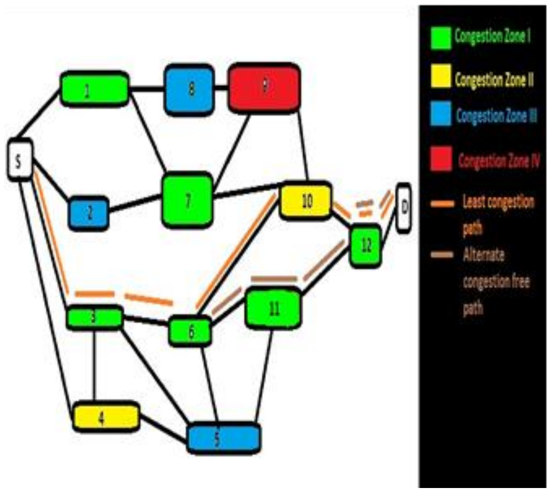

Figure 2. The process of alternate route discovery as soon as any node in the route lies in Zone II, III or IV. Here, node 10 lies in Zone II hence the network discovers an alternate path via node 11 as soon as the congestion status of node 11 becomes safe.

In the alternate route discovery process. The nodes prior to the higher level congestion nodes starts keeping a tracking of all the nodes that have lower congestion status than the next node. Therefore, a path towards the destination is discovered in such a way that the path have the least amount of congestion. A comparison between the total congestion in the active path and the alternate path is made. If the alternate path has an overall lower congestion then the alternate path starts acting as the new path. This comparison is made by comparing the total number of nodes and the congestion of each node.

A path is rejected if it has greater number of nodes in the path lying in Zone IV or Zone III. The length of alternate path is taken into consideration only if there are equal number of nodes in Zone III and Zone IV or all the nodes are present in Zone I and Zone II.

III. RESULTS

The algorithm was tested on various grounds and the results have been discussed in this section.

A. VARIABLE CONNECTIONS

The algorithm has been tested on a number of connection varying in between 50 and 10.The node speed is less than 10m/s and the packet rate is 9 packet per second with a pause time of 35 seconds.

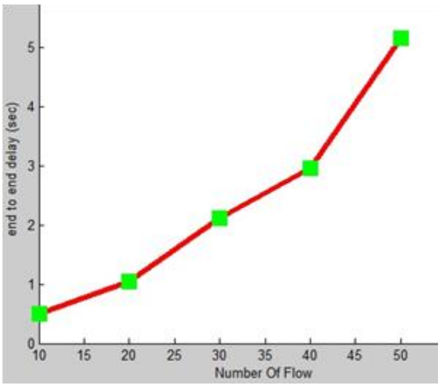

Fig 3(a). The relationship between the number of flows ad end to end delay for the algorithm.

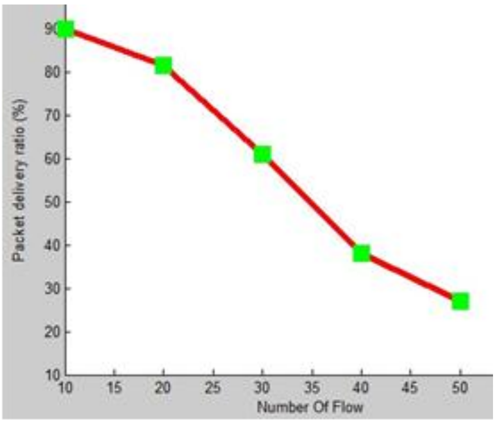

Figure 3(b). The relationship between the number of flows and the packet delivery ratio.

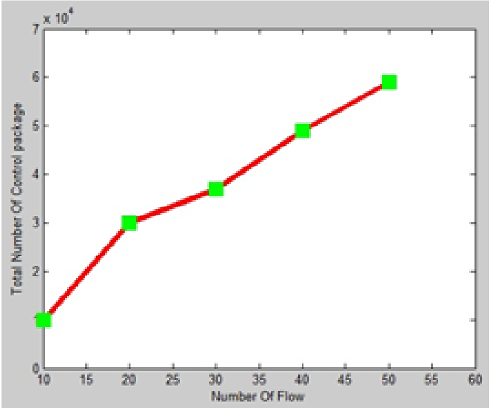

Fig.3.c – The relationship between the number of flows and total number of control inputs.

Figure 3.a shows the relationship between the number of flows and the and to end delay .The end to end delay grows steadily until the number of flows are less than 40. However, there is sharp rise in the end to end delay when the number of flows increases from 40 to 50.

Figure 3.b shows the relationship between the packet delivery ratio and the number of flows. The percentage decrease of the percentage delivery ratio is the most when the number of flows is between 30 and 40. The number of flows is between 90 to 80 percent when the number of flows is between 10 and 15 and 30 to 20 % when the number of flows is between 45 and 60.

Figure 3.c demonstrates the relationship between the number of flows and total number of control packages. When the relationship is almost linear. Though initially there is a steep rise with increasing number of flows.

IV. CONCLUSION

An algorithm to control congestion for a team of mobile robots was presented in this paper. The algorithm may be applied in case of other mobile ad hoc networks as well.A novel approach based on the labelling of nodes based on their congestion status has been introduced in this paper. The decision of discovering a new path is based on the congestion status of nodes. The algorithm was explained with help of a suitable example and was tested on multiple grounds. The results were discussed in this paper. The algorithm aims at preventing data loss and increasing the reliability of a network. The algorithm also prevents

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congestion taking place between subsequent nodes and the alternate route discovery process may initiate from the node prior to the congested node

Though the suggested approach is highly suitable for the mobile robot networks. A lot of improvisations can be made in this approach. A better route discovery mechanism can be deployed that takes into account the route length and other factors such as transmission ranges of the nodes or robots more appropriately.

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BIOGRAPHIES

Shashi Kantis an Electronics and Telecommunication Engineer who completed his engineering in the year 2014 from College of Engineering Roorkee. His field of interest is VLSI. He has a great affinity for electronic gadgets.

PushkarShukla is an Electronics and Telecommunication Engineer who completed his engineering in the year 2014 from College of Engineering Roorkee. He is a robotics enthusiasts and loves making robots. Apart from robotics he is also interested in embedded systems, machine learning, probabilistic graphical models and digital image processing.

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