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RESEARCH ARTICLE

ROUTING WITH LOAD BALANCING IN WIRELESS MESH NETWORKS

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ABSTRACT

Wireless mesh networks technology has drawn considerable attention as a promising broadband access technology despite the increase in the number of internet access technologies. It has been found that increasing the number of the gateways ordinarily, does not results in network throughputs as it is intended unless load balancing scheme is also employed in the network. A load balancing scheme is required to balance the traffic in the network across the various gateways nodes and avoids overloading any gateway node. In this paper, AODV routing protocol is modified to combine the route discovery process with a load balancing technique. The modified AODV selects a route to the destination based on the current load of the intermediate nodes and selects a gateway from the available mesh network gateways based on its current load, the simulations show that this load balancing technique will improve the performance of the wireless mesh networks.

INTRODUCTION

Wireless mesh networking (WMN) is another option of scaling wireless network. A wireless mesh network is a type of wireless network in which each node can communicate directly with one or more peer nodes. It is a form of ad hoc network that forms mesh of wirelessly interconnected nodes. The difference between this type of network and the conventional ad hoc network is the nature of packet movement in the network which is always from the clients to the gateway node or vice versa in wireless mesh networks, while the packet movement in ad hoc networks is between arbitrary pair of the network nodes [1]. In wireless mesh networks the host nodes (typically stationary) can also serve as routers to forward the clients' traffic in a multi-hop fashion to destination (normally gateway nodes connected to the internet) when the network is deployed to provide internet access. Wireless mesh networks offer advantages over other wireless networks; these include easy deployment, greater reliability, self-configuration, self-healing, and scalability. The nodes in the network are able to establish and maintain mesh connectivity automatically [2]. Wireless mesh networks technology has drawn considerable attention as a promising broadband access technology despite the increase in the number of internet access technologies. Very large areas can have access to broadband wireless using wireless mesh networks without need for costly infrastructures. Wireless mesh networks can also be employed for wide variety of applications such as cellular radio access networks or WLAN hotspot multi-hopping, citywide surveillance systems, wireless sensor networks (WSNs), broadband home and office Indoor networking, intelligent transport system networks, community and neighbour networking, micro base station backhaul and others [3,4]. While wireless mesh networks offer broadband wireless access to community and enterprise users, the problems that limit the network capacity must be addressed to exploit the optimum network performance. The capacity of wireless mesh networks is affected by many factors such as network architecture, node mobility, node density, traffic pattern, number of channels used [5].

Load balancing is another important issue that needs to be addressed in wireless mesh networks. The nodes in a wireless mesh network communicates in multihop fashion, this makes the nodes near the graphical centre of the network to have higher traffic load as they will be more often on the shortest path to the destination [6]. Load balancing is essential to utilise the entire available paths to the destination and prevent overloading the nodes near the graphical centre of the network. Wireless mesh network throughput capacity does not improve with increasing the number of the gateway nodes unless load balancing scheme is also employed in the network [7]. A load balancing scheme is required to balance the traffic in the network across the various gateways nodes and avoids overloading any gateway node.

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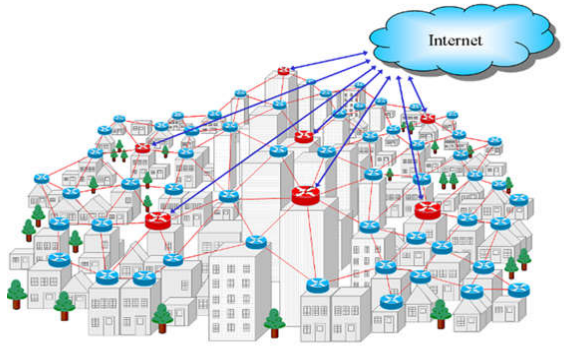


Fig.1. Wireless Mesh Network for broadband Internet access [1]

II. Related Work

[7] Has proposed a technique to balance the traffic load among the available gateways nodes in the network. In this technique, an average queue length in the gateway is used to estimate congestion over that period of time and an alert is raised by the congested gateway upon which selective active sources are sent notification messages to switch their internet attachment to an alternative less-congested gateway. This technique can reduce overloading the gateway nodes, but a technique that balance the network load across not only the gateway nodes, but also intermediate nodes in the network thus avoiding centre loading problem is also needed. Sending notification to some sources will also increase the overhead traffic in the network. [6] Have worked on incorporating load balancing in AODV using grouping mechanism to partition all available nodes into logical groups, A, B, C, D, and E. They classified the groups into source nodes and common node groups. The common nodes assigned to group E are allowed to relay packets from any group towards the gateway, while each source node group can only relay packets from their group. When a node receives an RREQ packet, it first of all checks to see if the packet is from a node in their group, it then broadcasts it otherwise it drops the packet. This technique will require administrative work of grouping the network nodes and assigning any additional node in to a group. For each node to recognize the RREQ from the nodes in their group the node must be aware of all the nodes in the group and this will make the node to be complicated.

[8] Have proposed modification to AODV routing metrics to use aggregate queue length instead of hop counts to provide load balancing. In their modified AODV each node that received an RREQ packet modifies the packet by adding its queue length before re-broadcasting it. The destination selects path with smaller aggregate queue length. This method will help in choosing the best path in the network but it will add delay in creating routes because of the RREQ packet modification at each node and the method does not balance load among the gateway nodes in the network.

III ROUTING IN WIRELESS MESH NEWORKS (WMNs)

Routing in a network is a means of finding a source to destination path to forward message. Communication within a network or internetworks can be achieved using a routing protocol. Due to the unpredictable nature of wireless networks surroundings, the routing protocols must be quick in adapting to the change in a path when there is path break due to mobility of the nodes. The main routing concern in wireless mesh networks is finding a reliable and high throughput path to the destination. Wireless mesh networks are multi-hop networks with some characteristics common to ad hoc networks. This makes protocols designed for ad hoc networks to also work in wireless mesh networks. The Current deployments of WMNs make use of routing protocols proposed for ad hoc networks such as AODV, DSR, and OLSR.

A. AODV ROUTING PROCESS

The popular AODV and many other ad hoc routing protocols use hop by hop routing and shortest path (based on the number of hops) to the destination as routing metric. Using AODV ad hoc routing protocol, the node with traffic to send begins the route discovery in order to set up a route to the destination as shown in the flow chart in *Appendix A*. AODV finds route to the destination using route RREQ and RREP messages. The route discovery starts by broadcasting a route request (RREQ) message by a source to its immediate neighbours, the neighbours further broadcast the RREQ message received to their own neighbours forming a reverse path, the broadcast continues until the route request message arrives at the destination [9]. Upon receiving the route request (RREQ) message the destination replies by sending a route reply (RREP) message. This message use the route followed by the route request (RREQ) message (the reverse path formed) and is unicast to the source node from the destination. The RREP sets up the path by updating the routing table at the intermediate nodes with information regarding the traversed path. The source node can start transmitting its first packet after receiving the RREP message [10].

B. AODV ROUTING PROCESS IN WIRELESS MESH NETWORKS

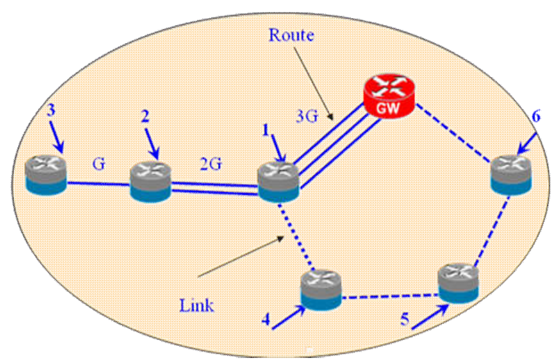


Fig.2. A wireless mesh network scenario

Let consider a wireless mesh networks scenario in fig.2.0 above with a gateway (GW) to connect the network to the internet, while the remaining nodes are the mesh routers. Node_3, node_2, and node_1 send traffic to the gateway using the routes formed through node_1using the AODV routing protocol. Assume each node sends offered load of G, then node 1 send traffic load of 3G. When node_4 has data to send to the gateway node, it tries to create route to the destination. Using the AODV routing protocol both node_1 and node_6 within its transmission range receive its route request message

(RREQ packet) and rebroadcast it. Node_1 further broadcast the RREQ packet to reach the gateway and a reverse path is formed through it. In the same way after receiving node_4' RREQ packet, node_6 rebroadcasts it and the RREQ packet reaches the gateway node through node_5 and node_6, a reversed path is also formed through these nodes as shown in Fig.2.0 The gateway node has two RREQ packets now from two different paths with different number of hops, it then selects the path with lowest number of hops (route through node_1 in this scenario) and send a route reply message (RREP package) to create a route through the already formed reverse path as shown in Fig.3.0

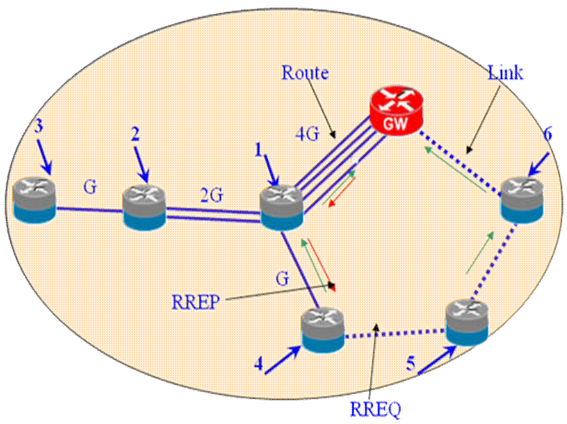
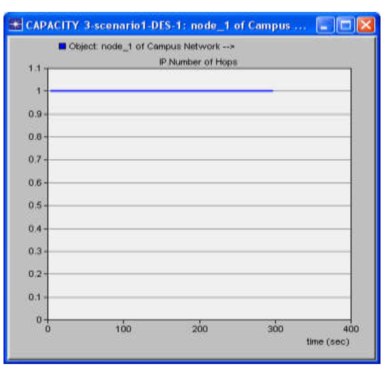


Fig.3. A wireless mesh network scenario using the AODV Routing protocol

C . SIMULATION RESULTS

The network scenario in fig.3 above has been simulated to confirm the route selection. Node_3, node_2 node_1 and node_4 generate traffic to the gateway node. The packet inter arrival rate was assumed to be equal for all the nodes and set to 0.01; to make each node generates 100 packets per second.



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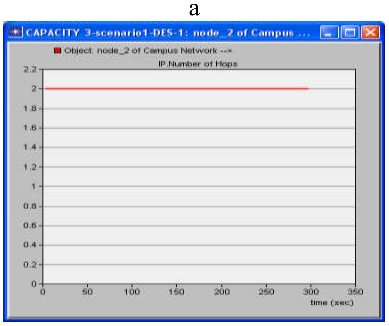

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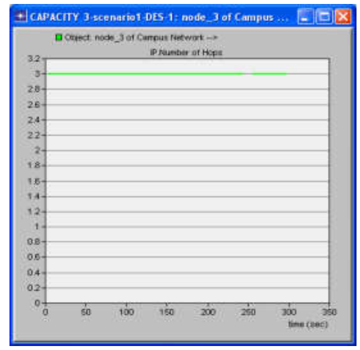

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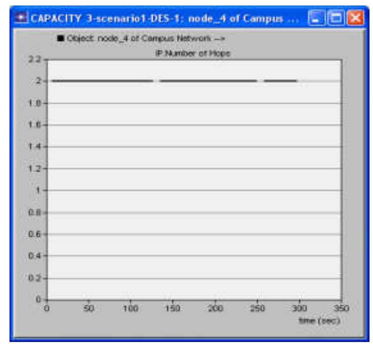

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Fig.4. Number of hops passes by each source node to the destination using the conventional AODV routing protocol

Fig.4 above shows the number of hops that form a route from each source node in the network to the destination. The above results confirm the analysis of conventional AODV route selection procedure. Node_1 is only one hop to the destination as shown in Fig.4a, node_2 and node_4 two hops to the gateway as shown in Fig.4b and Fig.4d respectively, while node_3 three hops to the gateway as shown in Fig.4c.

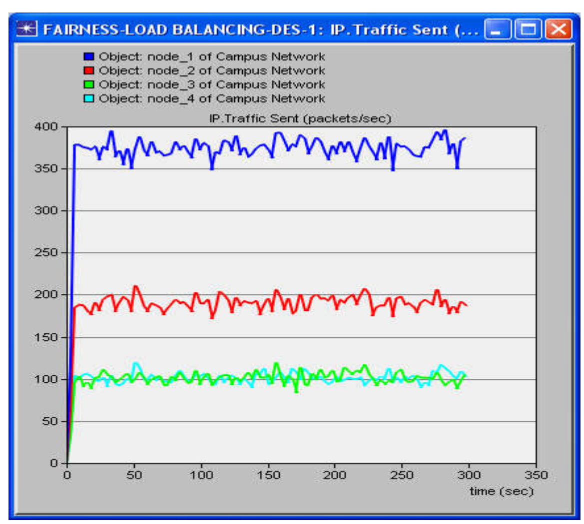


Fig.5.Traffic sent by individual nodes in the network scenario (packets/sec)

Fig.5 shows the traffic flows from the individual nodes to the destination. The result shows node_3 and node_4 with no relayed traffic can send 100% of their generated traffic (100 packets per second). Node_2 has to transmit both its traffic and traffic of node_3 so its processing overhead must be increased. Node_1 relays traffic of node_4, node_3 and node_2 the node becomes overloaded because of the increase in the processing overhead with increasing the number of nodes that forward traffic through the node. Node_1 sends less than 100% of what it supposed to send. Observed the peak of traffic Node_1 sent reaches up to 400 packets/sec. The above simulation results for the network scenario show the inefficiency of the AODV routing protocol in terms of balancing the network load across the available nodes in the networks as Node_1 close to the gateway is overloaded with relayed traffic of other nodes.

IV. AODV WITH LOAD BALANCING ROUTING PROCESS IN WIRELESS MESH NETWORKS

Load balancing in a network can be achieved if the routing protocol used is a load aware routing protocol (a routing protocol that includes a load balancing scheme in its route discovery). This research proposes a modification to the popular AODV routing protocol to make it perform the route discovery process while keeping load balancing in mind. The proposed routing protocol is the AODV routing protocol enhanced with load balancing capability. The routing protocol selects a route to the destination based on the current load of the intermediate nodes and selects a gateway from the available network gateway nodes based on its current load.
To achieve this load balancing solution, a maximum load will be defined (based on the number of packets buffered in the queue) on each node beyond which it will not allow any incoming flow through it. The new traffic flow must find another alternative route to the destination. In WMNs for broadband access most of the traffic flows in the network are from/to internet through a gateway node, this technique also balance the load across the gateway nodes by allowing the gateway with a load greater than the defined maximum to reject the flow and then use another available gateway.

Using the AODV routing protocol with load balancing technique, any mesh node that received a route request message (RREQ packet) from another node, first of all checks the status of its buffer for its current load, if the current load is beyond the defined maximum the node drops the message, this prevents another route being formed through it. Another node with low load in the mesh network forwards the route request message (RREQ packet), so the route can be formed through it as an alternative path in the network as shown in Fig.7. The flow chart in fig.6 below shows the processing of a received RREQ packet at an intermediate node. The same process is applied to gateway nodes as well. Using this approach, load balancing across all the mesh nodes to the destination can be achieved and all the available gateway nodes in the network can be utilised to prevent a network bottleneck at any of the gateways.

V. SIMULATION OF THE NETWORK SCENARIO USING THE MODIFIED AODV

The wireless mesh network scenario in fig.7 has been simulated with the proposed AODV with load balancing capability. The conventional AODV was used in the simulation with some assumptions and a little modification to the network scenario deployment in the OPNET.

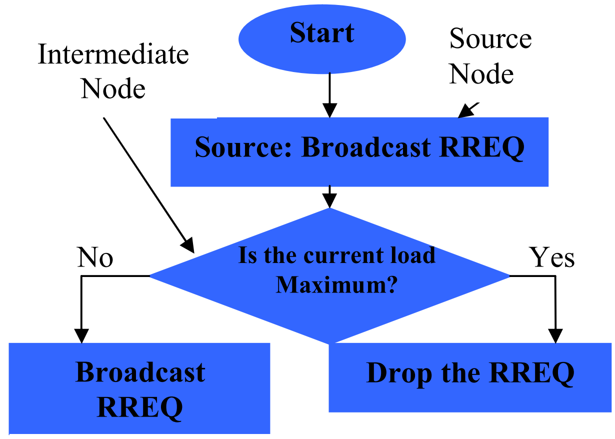


Fig.6. Decision taken by a node upon receiving an RREQ packet

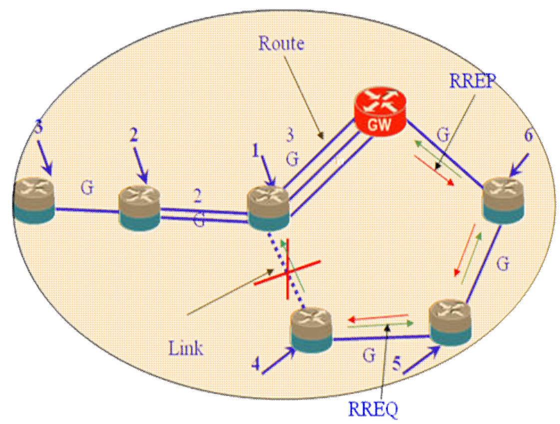
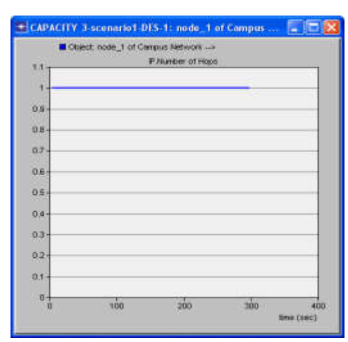


Fig.7. A wireless mesh network scenario using proposed AODV routing protocol with load balancing capability

It was assumed that node_1 sending three different traffic flow (flow from node_3, node_2 and its own flow) has reached the defined maximum load (another flow would not be allowed through it, it drops any received RREQ message). The distance between node_1 and node_4 in fig.7 was increased so that node_4 RREQ message would not reach node_1. The source nodes (node_3, node_2 node_1 and node_4) was set to generate 100 packets per second traffic to the gateway node using the packet inter arrival rate of 0.01 at each node. Fig.8 and fig.9 below show the simulation results, with fig. 8 showing the number of hops from the source nodes in the network to the destination, and fig.9 showing the traffic sends by the individual nodes.

A. SIMULATION RESULTS



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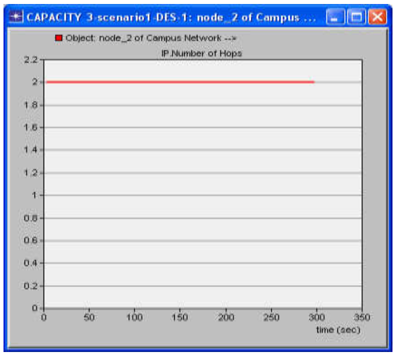

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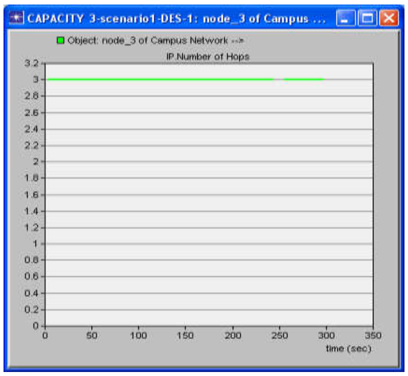

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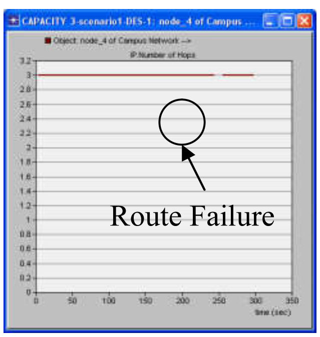

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Fig. 8. Number of hops passes by each source node to the destination using the modified AODV routing protocol

Node_1 is only one hop to the destination as shown in fig.8a, node_2 two hops to the destination as shown in fig.8b while node_3 and node_4 three hops to the destination as shown in fig.8c and fig.8d respectively. Using the proposed AODV with load balancing capability a route from node_4 to gateway node is now formed through another available network path though is a longer path, but is better than the congested path (path via node_1) and this balance the load across the network nodes and utilises all the available paths. Forming a longer route to the destination increases the chance of the route failure as shown in fig.8d, this is the main limitation of the proposed approach, but AODV routing protocol has a route maintenance capability as shown in fig.8 in which the route also formed after breaking. Fig. 9 above shows the throughput of the source nodes (nodes with data to send) in the network scenario. Node_3 and node_4 with no relayed traffic send 100 packets per second; node_2 sends 200 packets per second (its local traffic and relayed traffic of node_3), node_1 sends 300 packets per second (its local traffic and relayed traffic of node_2 and node_3).

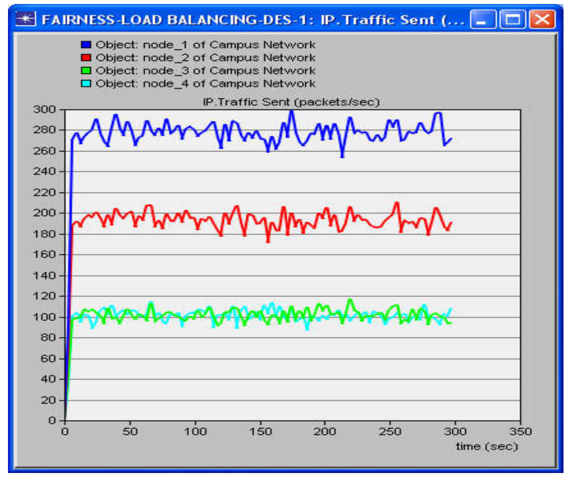

Fig.9. Traffic sent by individual nodes in the network scenario (packets/sec) using the AODV with load balancing capability

The proposed modification to AODV routing protocol enhances the performance of the routing protocol to be used in wireless mesh networks by combining the route discovery process with the load balancing technique. Observed that the peak traffic Node_1 sent is 300 packets/sec which 100 packets decrease in the load compared with the conventional AODV process where Node_1 sent 400 packets/sec.

Conclusion

Wireless mesh networks technology has drawn considerable attention as a promising broadband access technology despite the increase in the number of internet access technologies. Very large areas can have access to broadband wireless using wireless mesh networks without need of costly infrastructures. The proposed modification to AODV routing protocol to combines the route discovery process with the load balancing technique enhances the performance of the routing protocol to be used in wireless mesh networks. From the results obtained, by comparing the conventional AODV process and the proposed method, the amount of locally generated and relayed traffic sent by Node_1 decreases from 400 packets/ sec to 300 packets/sec. These represent about 25% decrease in the load for Node_1 This simple modification to AODV prevents overloading any node and utilises all the gateway nodes in the network efficiently.

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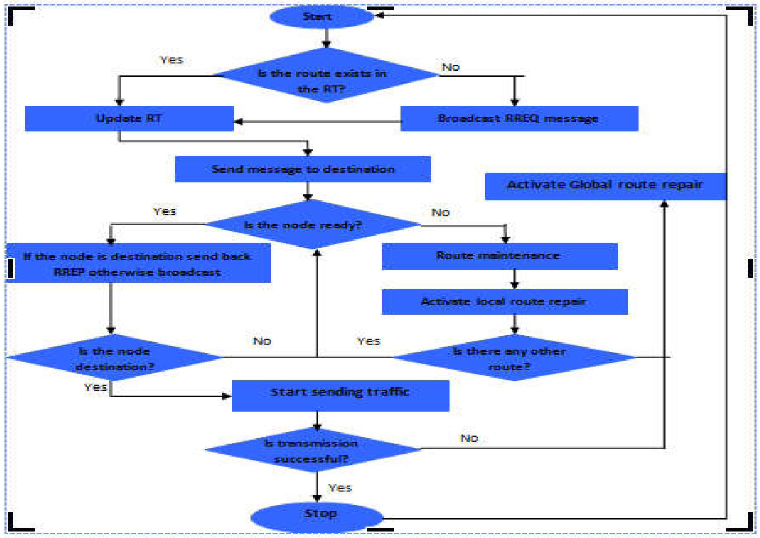

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