Adaptive Distributed Game Theory Based Congestion Moderation in RPL Networks

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Abstract – In low power and lossy networks (RPL) routing nodes are affected due to low data rate, longer time delay, and high loss rates. The rate of congestion in such lossy network is large as the network configuration that supports sink to node, node to sink and node to node. Congestion detection method involves detection of rate of packets arrival, queuing length, buffering load and detect the existence of accumulation. To overcome congestion in RPL networks, a game theory based congestion control protocol is proposed. The proposed game theory based congestion control algorithm aims every participating node to dynamically adapt to the network threshold and collectively cooperate to lower and avoid congestion. In our model the congestion is avoided beforehand so that the corresponding node finds its alternate parent or node that can accommodate its packet forwarding request.

1. INTRODUCTION

Congestion is considered as threatening to network performance, where congestion is involved with many parameters based on the networks. In a network when many packets try to access a path, crowding or congestion is created which might result in dropping of data packets. To maintain the network stability corrective action should be made to lessen the congestion, so that the networks throughput is maintained. This corrective action ensures that the network performance is high and controlled. Congestion is the difference between demand and supply and usually takes place when there are more users requesting than the accommodation level and when the accommodation level is low. Adjusting the traffic flow based on the users is traditionally followed through service denial, service disruption and scheduling the request based on the importance. Presently poor network policy and service policy creates traffic loads and congestion, like improper route selection and resource allocation can result in congestion.

The characteristics of WSN largely vary from application to application and the type of purpose the network serves defines their network's properties such as flexibility, fault tolerance, security, lowered cost and easy and quick deployment. WSN is largely used for information sensing, detecting, tracking, and monitoring services involving sensor nodes. The amount or quantity of sensors nodes depends on the type of application and its needs. Designing optimal WSN which would satisfy the primary purpose of the network is becoming tough due to newer types of threats, unpredictable environmental conditions, congestion etc. To meet the growing needs of the WSN network, building a network that can adjust to the network state and acts according the given situations satisfying the networking conditions can be achieved through Game Theory. Game theory can be used to carry out network's goal and has become an attractive area for researchers and proved to be fitting for many network problems. Game theory was introduced in Mathematics and soon researchers realize the potential of GT and started utilizing Game Theory in many areas of research. In the Network, game theory is widely used for decentralized operations and self organizing networks which require adaptability to change along with its changing environments.

Wireless ad hoc networks and WSN are distributed in their nature. They do not rely on a preexisting infrastructure. They are self configurable. They can promptly be deployed in case of disaster recovery. Packets go through a multi-hop communication route from a sender to a destination if the destination is not in the communication range of the sender. Therefore, each node is at the same time a terminal and a router. As a terminal, a node sends and receives its own packets. As a router, a node is requested to relay packets from other nodes. Most routing protocols in multi-hop networks assume full cooperation of nodes to participate in route discovery, route maintenance, and packet forwarding. The assumption of full node cooperation is true when the nodes have the same managers. Only the collective interest of the global network is taken into consideration. Individual nodes follow all the recommendations of the routing protocols and so there is no conflict of interests in those networks. However, in a multi-hop network without a central authority, the decision to cooperate becomes decentralized and, in extreme cases, each node is autonomous and decides only for its own best interests. This creates conflict between self and collective interests. A selfish node is tempted to drop packets from other nodes to save energy and bandwidth. In fact, many other applications in the future will require autonomous devices to interact, and cooperation will be the first problem to solve in such networks.

In a game, players are the decision makers whose results depend on other players' actions.

Table 1 Component of a game

Components of a game	Elements in an Ad hoc network
Players	Nodes in the network
Strategy	Action related to the functionality (forward packets, packet limits etc)
Utility Function	Performance Metrics (Delay, Throughput, Congestion)

2. RELEATED WORKS

Shamshirband Ahmed Anuar Abrahame, 2014 studied game theoretical model to detect attack's in WSN. Using cooperative defense mechanism the players take decisions to avoid attacks. Using game theory and q-fuzzy learning, if any node is compromised, then all nodes in the network cooperatively attacks through different game plans to protect from flooding. The detection and counteracting rate was found to be high.

Chitra, Chandrasekaran, 2017 proposed a model to avoid congestion by finding alterative paths using stackelberg algorithm. It uses leaders and followers for efficient path management. The leaders are the decision makers and the followers follow leader's policy while forwarding the data packets. During their study, the game theory, alternate path and energy are well balanced to yield the best possible out.

Periyasamy, Perumal, 2015 suggested a game theory based method for reducing the energy consumption at the node level. Using time efficient division multiple access and game theory based nanoMAC protocol to establish communication between the cluster heads and the nodes within the cluster. The results indicated that a greater level of energy can be conserved using game theory and the network life time is largely increased.

Zhang, Li, Zhou, Du, 2015 studied game theory in times of disaster management, since wireless network is unavailable at the time of disaster. In such times, game theory based approach selects its alternate channel to device to device communications when it detects the networks and sensors physical conditions. Using multicast scheduling, the communication is established maintaining all Qos requirements.

Qian Tana, Wei Ana, Yanni Hana, Yanwei Liua, Song Cia, 2014) proposed game theory based approach for solving energy congestion. Energy harvest nodes when met with energy saturation, using cooperative game theory, a game that finds the saturated nodes and allows to actively participate in the transmission is studied. This method intends to save the harvested energy by avoiding congestions at the energy level. The proposed system performed well in terms of energy distribution and energy availability.

3. RESEARCH PROPOSED

The main goal of game theory is to understand how players act when presented with a scenario where there are conflicts of interest. In a given conflict of interest scenario, each player must make a choice from a given set of options. In game theory nomenclature, the choice is known as the player's strategy and the set of possible choices the strategy set. The joint decision of all players will determine the outcome of the game and each player has some preference over the set of possible outcomes.

In general, one is interested in determining the choices that players will make when faced with a particular game, which is sometimes referred to as the solution of the game. We will adopt the most common solution concept, known as Nash equilibrium: a set of choices, one choice made by each player, where no individual player can improve his utility by unilaterally changing his choice.

Based on game-theory, the basic setting has been implemented during simulation process in order to analyze the performance of proposed congestion control. The simulation process running under simulation settings is shown in the table 2. The simulation consists of set of 50 nodes distributed in a 500x500m Ad Hoc network with the transmission range of 80m and simulation time is fixed to 32000 ms, i.e 32 seconds. The packet flows are transmitted from sources to destination. Each player plays routing game to select the forwarding path for each iteration of multipath routing algorithm. The data packets are transmitted to the sink based on two module (i) load adjustment and (ii) path selection

Proposed Methodology

The proposed methodology is a combination of congestion detection and congestion moderation. In MRPL congestion is discovered on any sending node and the control of congestion is treated using multipath routing at nodes before the congested node.

Congestion detection

The congestion detection algorithm is set off on the reception of any incoming packet at a node. The Packet Delivery Ratio (PDR) calculated for all the nodes between source and sink. To arrive PDR, a node must bear the details of expected data rate of each child node. Using the average PDR at a node the network calculates the congestion interval. The length of CI defines the detection of congestion and decision making. For small CI, it means frequent congestion decisions are made and for large CI, it means higher delay in congestion decisions which would affect packet drops largely. If the packet delivery ratio surpasses a fixed limit then a message is forward to the child node.

Congestion information's are sent to the child node by its parent node using recurring DIO message. Hence the excess of additional transmission of packets are stopped in M-RPL.

Congestion moderation

Congestion moderation is activated once a child node receives a DIO message. Upon receiving this message, the child node starts multipath routing by splitting their forwarding PD rate into one-half. The child node sends one packet to its original parent who is congested and forwards the next packet to any other node from the parent list maintained in parent table (PT). Therefore, during congestion mitigation a node drops its forwarding rate to the congested node to half. The rest of the data is forwarded through alternate path using any other parent node. Thus the child nodes reach to reduce forwarding packets to the congested node and helps in the cutting of the congestion at their parent node.

Pseudo algorithm for Game theory based congestion control

Preliminaries (threshold 3; simulation time 32000 msec; time slot 32 sec)

for each arriving packet, denoted by pk do

t= pk1...pkn

For each t (arrival time)

t1...tn = (sn1, s1 id, sn2, s2 id....snn, sn id)

if sn= ((s, id)+1) then no loss

end

else

if limit t < 100 send acknowledgement

end

else if

limit t < 100 drop acknowledgement

if (s, id) < 3 congestion TRUE

else

t= (tpk1+tpk2..tpkn)

if t < limit forward;

else

drop

end

reset time [s,id] t;

new parent[s, id] 0;

end

end

4. EXPERIMENTAL SETUP

The Network Simulator 2 (NS-2) is a discrete event network simulator targeted at networking research. NS provides a packet level simulation over a lot of protocols, supporting several forms of unicast and multicast protocols including TCP and UDP transport protocol s among many others, wired networking, several ad-hoc routing protocols and propagation models, data broadcasting, satellite, etc. Also, NS-2 has the possibility of using mobile nodes. The mobility of these nodes may be specified either directly in the simulation file or by using a mobility trace file. Hence it is heavily used in ad hoc networking research and has become popular in research due to its open source model and online documentation.

In order to evaluate our proposed game theory based congestion control scheme, we build a network game scenario which comprises of common nodes, parent nodes, and Sink node. In any real world network, we cannot assume the number of nodes deployed in the network, if the nodes and agents are not fixed, then some of the utilities of the participating nodes and agents goes unnoticed, and unutilized. So we fix the number of nodes to be 50 and one Sink. Of the total 50 nodes, we split the parent and the children nodes so that any children node that forwards a packet is done through predetermined parent nodes. While starting the game, the participants are parent nodes and common nodes. Parent nodes are the one who receives the data packet, while common nodes are the one who forwards the data packet. The process of forwarding and receiving packets is done through prior acknowledgement.

To create a bottle neck in the nodes, all parent nodes are fixed with a capacity of 100 bytes allowing congestion to take place. The parents are capable of accommodating 100 bytes from more than one users but the limited to a total byte of 100, so if we Node 1 with 100 bytes is acknowledged from parent 1 then no more nodes can participate in forwarding packets to parent 1, at the same time, if node 1 and node 2 achieves a 100 byte limit, then node 3 cannot participate and it is not accommodated in Parent 1, so that the node 3 will have to wait or to find another parent node to forward its packet, thus avoiding a congestion. On the other hand, if node 3 can change its parent, then its delay time and packet loss are minimized and the network efficiency is improved. We build a tcl script with the scenarios discussed. The results and simulations are discussed in the next section.

5. RESULT AND DISCUSSION

End to End delay represents the time when packet was received at destination minus the time when packet was created by the source divided by the Number of packet delivered at destination According to Fig 2, the delay Time of the network increases considerably with increase of bytes by 40% as a result of processing the congestion and validating the limits of each request. With the decrease in end to end delay the network's lifetime & performance is improved, we would be concentrating on this, in our next work. The node once received a packet size of more than 100 bytes, the time to acknowledge is lesser than the node with less than 100 bytes, and this time latency is due to the threshold the node size and its corresponding data size.

The packet delivery fraction represents the ratio of the number of packet generated at the source to the number of packets delivered by the destination. It specifies the packet loss rate, which limits the maximum throughput of the network. The better the delivery ratio, the more complete and correct the routing protocol. Throughput is the rate of successful delivery of data over a communication channel. Throughput metric represents the number of packets delivered at each node in the network over the time interval taken due packets delivery. The throughput is usually measured in data packets per second or data packets per slot. Throughput is essentially synonymous to digital bandwidth consumption. The throughput of the network scenario was fair enough to conclude as efficient, Fig 3. The congestion control mechanism proved to be best in keeping the network efficiency to its maximum; this is due to the fact that our mechanism has mitigated the nodes to accumulate on a single parent node thus suspending the congestion formation in advance.

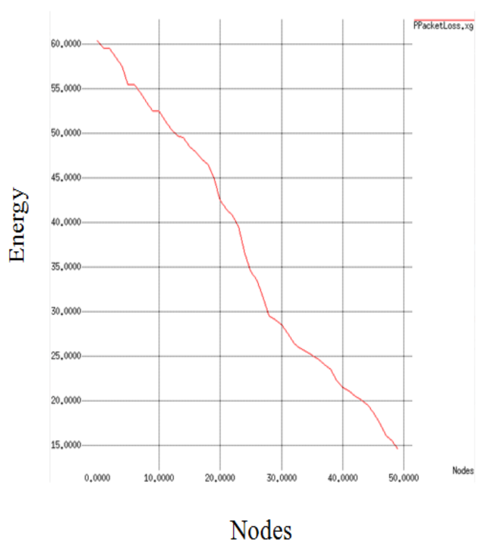

Fig 1 Energy

The congestion avoidance is the best kept part of the control system, allowing nodes to take part in cooperative game play to forward its packets and reach the destination. We set our mechanism to adjust its parent on the route to its destination so that every node that participates through the acknowledgment that receives from its corresponding parent node. Packet loss from an average of 60%/m2 is gradually decreases to 15%/ m2 thus enabling the network efficiency to a greater level, Fig 4.

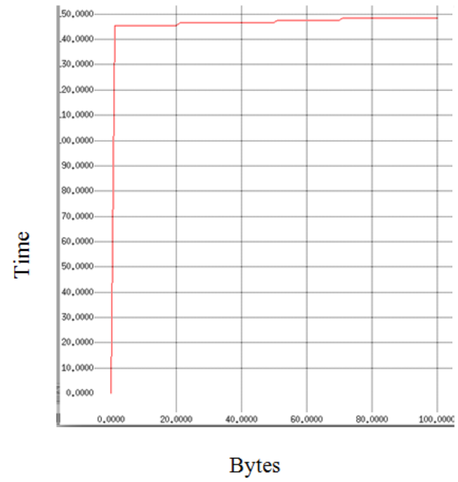

Fig 2 Delay time

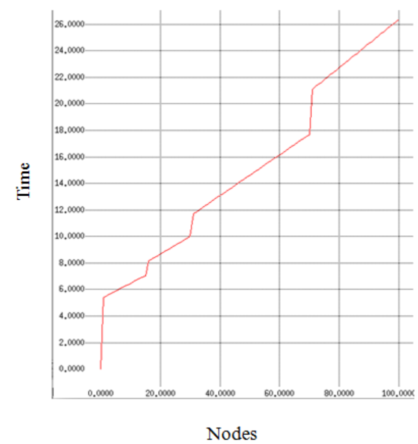

Fig 3 Throughput

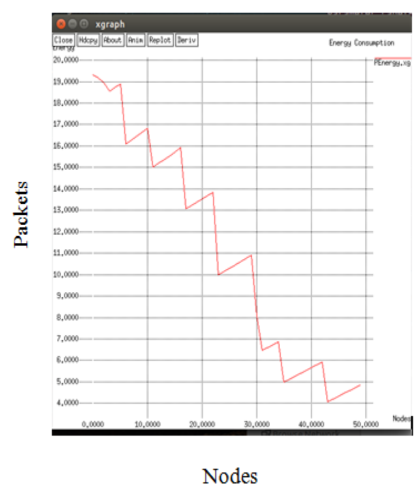

Fig 4 Packets

The simulation results revealed that the performance metrics such as delay time, packet loss, Throughput and energy are considerably good in our congestion control mechanism. Thus the path selection model and rate reduction model are highly effective in terms of avoiding network congestion and improving the network throughput with less energy level, Fig 1. The model comparison Fig 5 shows better performance of our proposed model in terms of transmission rate and throughput of the network.

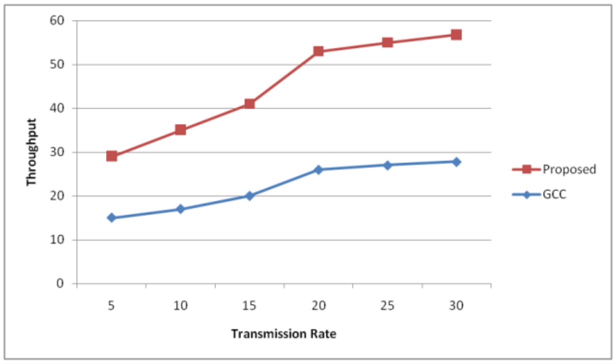

Fig5. Model Throughput Performance

6. CONCLUSION

Congestion control schemes attempts to reduce the rate of congestion, which in turn reduces the throughput of the network. In our study we propose a new scheme of congestion control through avoiding congestion beforehand. Similarly, the rate reduction scheme and path selection allows congestion less network performance. Our path selection scheme improves network throughput whereby every request from an application in RPL network is utilized and this leads to lower packet drop. On the other hand rate reduction scheme allows every request to participate in the game and engage its neighboring parent in order to complete the transmission process.

The performance metrics such as throughput, packet loss, and delay time for our proposed algorithm is greater. The delay Time of the network increases considerably with increase of bytes by 40% as a result of processing the congestion and validating the limits of each request. The Packet loss from an average of 60%/m2 is gradually decreases to 15%/ m2 thus enabling the network efficiency to a greater level. This increased delay time was due to reason that the acknowledgement from the corresponding parent rely to the children node took a few seconds more to calculate its threshold limit of accommodating bytes. In our future study, the problem with delay time will be addressed.

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