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Analytical Model for Assessing the Impact of MANETs' Bottleneck Nodes

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Abstract:

Objectives: Due to few resources, the most challenging task in mobile ad hoc networks is determining a route with the highest probability of success between a source and a destination. The objectives of this assignment are as follows: The limited power provided by batteries is one of the most significant challenges in routing. A great number of routing protocols have been devised to deal with the problem of limited battery power. Reliability, low energy consumption, and preferential treatment of nodes with greater energy levels are the cornerstones of the routing path made possible by these protocols. On the other hand, these protocols result in the creation of a bottleneck intermediate node, which is a node that must forward packets from numerous sources. The loss of packets is the most significant issue that emerges with a bottleneck intermediate node.

Methods and Statistical Analysis: In this study, we employ a poison random process to assess an intermediate's performance of bottleneck node within a mathematical model we developed. Findings: The model that is being proposed calculates the typical length of the queue at the input buffer, the typical amount of time spent waiting in the buffer and the lifetime of the network.

Application and enhancements: This model is put to use to regulate the incoming traffic of an intermediate node and to determine whether or not that node will participate in the route.

Keywords - MANETs, Bottleneck node, Poison random Process, and Energy Efficiency.

I. Introduction

There are two distinct models of network communication that are used in wireless communication. The first is a communication-based infrastructure that includes both stationary and mobile nodes. The mobile nodes can talk to any of the nearby static nodes through radio communication. Nevertheless, this idea requires a permanent, fixed infrastructure to function. 2 A wireless ad hoc network is the second type of network paradigm. It is infrastructure less and relies instead on the connectivity using movable nodes to produce a network that is transient, dynamic, and autonomously structured. As the name suggests, this architecture builds its networks with nomadic nodes. If two mobile nodes are within radio range of one another, they can exchange data with just one hop of transmitting information through intermediate nodes; otherwise, communication must take place across many hops. This feature allows MANETs4 to operate as a P2P MHPRN (multi-hop radio-hop network). Battery-powered nodes have limited transmission range, which might make effective communication challenging. In a network, nodes that are too far away from other battery-powered nodes to participate independently must rely on their neighbors for help.

Self-organizing nodes are a key component of MANETs5 because they allow for autonomous communication between nodes in the network. The MNs that make up a network exhibit a variety of characteristics about the communication parameters of the network. These characteristics include battery power, transmission range, buffer size, and processing capability. MNs are only able to connect via a multi-hop network due to the limited battery life and communication range they have. This network is formed by intermediate nodes. With this kind of network, every node serves not only as a host but also as a router, moving data packets on to the next hop in the chain. As a result, the hop count and the radio range of the MNs is an essential elements in the context of MANETs when mobility is taken into consideration.

Researchers are showing a lot of interest in MANETs6 as a result of the qualities described above. During the past few years, a substantial number of different routing protocols have been developed. These many sorts of protocols may be broken down into three categories: There are three types of routing

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protocols: reactive, proactive, and hybrid. Proactive protocols decide the route that must be taken between the source and the destination regardless of whether or not this step is required. On the other hand, in the case of the reactive protocol, the route is not constructed until it is required to do so. Other kinds of MANETs8 routing protocols are tailored to the particular characteristics of certain networks. While some protocols are dependent on the amount of battery power that a mobile node has, others are based on where the node is located. Other protocols regard a network to be flat, while others believe it to be peer-to-peer between all of the nodes in the network. Certain protocols ensure that many pathways are kept open between the source and the destination.

Energy efficiency is one of the most vital and major design difficulties for MANETs since diverse mobile nodes are often provided with batteries with low capacity. This makes it one of the most important design challenges. The loss of a node's power supply will generate an effect that will affect the network's lifetime if the routing protocol is determined by the route with the shortest distance and does not take into consideration the power problem of the nodes. As a consequence of this, it is of the utmost importance to reduce the amount of money spent on energy throughout the process of data transfer. In addition to enabling reliable routing over the connections and making use of the nodes' residual energy, the purpose of the routing protocol is to determine the total amount of energy that is consumed from the beginning to the end of the transmission of packets. This is one of the many purposes of the routing protocol. This not only enhances the Quality of Service but also extends the amount of time that the network will be operational. Because of this, it is essential to continue taking into consideration the possibility that intermediate nodes will act as stumbling blocks inside the network. When the residual energy or node satisfies the threshold level of energy, which is the metric used to calculate the routing path from source to destination, one cannot guarantee a reliable route for heavy traffic. This is because the threshold level of energy is the measure used to determine the routing path. This is due to the fact that the measurement that is utilized to select the routing path is the threshold level of energy. When anything like this takes place, the pathway becomes blocked up, and the intermediate nodes that are present along that pathway become bottlenecks. If a node is willing to process a high volume of traffic due to the energy it has available, then the node will discard the packets because of the size of its buffer and the amount of processing power it has, and the node will also lose its energy instantly.

As a component of this project, we are attempting to develop a mathematical model that, via the use of a poison random process, will make it possible for us to investigate the efficiency of a bottleneck node that is intermediate. The proposed model would estimate the typical length of the queue at the input buffer, in addition to the typical amount of time spent waiting in the buffer and the lifetime of the network. This approach is utilized to regulate the incoming traffic of an intermediate node and determine whether or not that node will participate in the route.

Bottleneck node

The nodes that are part of Peer-to-peer networking is essential for wireless systems that don't rely on any centralized infrastructure. These systems must be able to perform the functions of both a host and a router. For a node to function as a router, it must be configured with network intelligence that can make decisions regarding the communication that takes place between nodes, as well as provided with a buffer that can information and energy that can both receive and deliver information are stored in a memory device [7]. Nevertheless, the resources of the nodes are extremely unpredictable and restricted, particularly the quantity of energy that is accessible and the amount of buffer space. Due to the fact that the missions of wireless infrastructure-less networks are either military or disaster relief, it is forbidden for these resources to undergo renovations while the mission is still active. Thus, the function that intermediary nodes play in communication is extremely important [8].

Consider, for example, a node that acts as an intermediary node for many communication pathways; in this case, the node is subject to an additional overflow, either in terms of available buffer space or available energy, and it is unable to interact with other nodes to facilitate communication. The information is then lost accidentally by the bottleneck node due to a lack of resources, such as an overflowing buffer and/or a limited amount of energy [5]. As a consequence of this, it is of the utmost importance to take into account the intermediary nodes for communication and serious challenge for routing protocols, given that the performance of the network is significantly influenced by intermediate nodes.

There is a possibility that the nodes currently in the routing route will become the bottleneck and will be unable to work together for communication. Consider, for example, a node that acts as an intermediary node for many communication pathways; in this case, the node is subject to an additional overload in terms of either buffer space or energy, and it is unable to interact with other nodes to facilitate communication. The information is then lost accidentally by the bottleneck node owing to a lack of resources, such as buffer overflow and/or restricted energy. As a result, taking into account the intermediate nodes for communication is an essential and serious challenge for routing protocols, given that the

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performance of the network is significantly influenced by intermediate nodes.

II. Mathematical representation of a bottleneck intermediate node

(i) We take into consideration a multi-hop mobile ad hoc network that consists of a collection of different mobile nodes that are randomly dispersed throughout a geographical region. Each node possesses its supply of energy, capacity for computing, and buffer space.

(ii) When the source node and the destination node are not within communication range of one another, the intermediate node is required to perform the duties of a router to forward packets. Cooperation between intermediary nodes is required to realize the goal of successful communication. The transmission of packets from many sources can be slowed down by an intermediary node if the energy awareness or residual energy of the node is evaluated to determine whether or not the node satisfies the threshold quantity of energy for the route selection measure. Poisson point distribution is the best approximation for dealing with heterogeneous mobile nodes that are spread out across a vast geographical area.

(iii) Before the beginning of communication can begin, there must first be the establishment of an intermediary node for there to be successful communication between the source and the destination. As a result, some of these nodes may drop some of the packets they receive since they are also acting as routers for another communication session. To maintain as much flexibility as possible, we shall assume nodes on mobile devices that are diverse and have the following properties. An intermediary node may be either an active or a dormant node. A node that is ready to handle the packets is considered to be an active intermediate node. For the packets to be sent from an intermediate node, there must be sufficient amounts of both energy and buffer space. An intermediate node has an inline buffer as well as buffer in outline form; it can store up to L packets. A link in the middle is the one that receives packets from the source node, stores them in the inline queue, and then decides what to do with them before moving them into the outline queue. An intermediate node may process an "n" number of packets with a 'Ŧ' time interval, where (n> 1) is a positive integer greater than one, provided that there is sufficient energy and little traffic.

(iv) During a period shown by the symbol 'α' The given value is the maximum packets per second (pps) that an intermediate node may process on its way from inline to outlined connectivity. A node's typical power consumption is defined as the number of 'Ed joules' with 'α/ Ŧ' packets that occur within a certain period. It is possible for there to be congestion at the intermediate node will delete packets with a drain rate over 'Ed joules' if more than packets arrive at the station during a time period within a period of Ŧ interval. If this condition persists for longer than the specified time interval, the node will eventually be destroyed to compute the packet loss due to congestion and the rate at which it is exceeded at an intermediate node.

(v) If we assume that an intermediate node's energy reduction occurs randomly, we may determine the number of packets that arrive in the node's input buffer at a given period by using the notation "n," where n can take on the values 0, 1, 2, etc.

(vi) n-1 Let the symbol 'ϑ' stand for the constant that indicates the average amount of energy that is lost in a node during a brief period. Δt,, and let 'ϑ' be the constant that stands for the value.

$$\vartheta = \frac{\text{energy drain rate of node}}{\text{numbernumber of packets}}$$

In light of the following presumption

The probability of a node's energy consumption decreasing as a result of one packet process during an interval of t Δt seconds, denoted by (t, Δt) is ϑΔt and is unaffected by the energy consumption decreasing ratio of any other period.

1-ϑΔt is the likelihood that there will be no change in energy level within Δt seconds.

It is possible to determine, under such circumstances, The Poisson distribution approach determines the likelihood that a node will experience exactly δ a predetermined quantity of energy loss as a result of n arrivals within a certain period t.

$$\boldsymbol{p(\delta)} = \frac{(\vartheta t)^{\delta}\, e^{-\vartheta t}}{\delta!}$$

$$\textit{Where}\ \delta \geq 0, t > 0$$

Let $\omega > t$ then

$$p(0) = p(\omega > t) = e^{-\delta t}$$

It's what's known as an exponential distribution, and it indicates that there is no decrease taking place in the interval [0, t]. The probability distribution function is thus given by

$$\mathbf{A(t) = 1 - e^{\delta t}}\ \textbf{, where t>0}$$

The formula for the probability density function is as follows:

$$\mathbf{f(t)} = \frac{\partial\, \mathbf{A(t)}}{\partial \mathbf{t}} = \boldsymbol{\delta}\mathbf{e^{-\delta t}}$$

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The amount of energy saved is directly proportional to the number of packets that enter the input buffer over a certain period. The number of active stations that are transmitting packets to the destination through an intermediate node will determine how many interns there are.

The information about the network lifetime might be important for designing an optimal method for regulating the multipath mobile ad hoc Network, which would increase the quality of service.

The probability that there are 'n' packets in the queue may be calculated using the:

$$\mu/\alpha^{n}\,(1+\mu/\alpha)$$

Where

$$\mu = Input\ traffic\ towards\ node$$

$$\alpha = Node\ packet\ forwading\ capacity$$

The number of seconds that a packet waited in a queue before being processed is denoted by "t."

$$\mu/\alpha\ \mathrm{e}^{-(\mu-\alpha)t}$$

It is determined if a node will take part in a route based on whether or not the packet loss estimation is employed to regulate the traffic heading toward the input buffer.

III. Performance Results

We take into account the environment of a multi-hop mobile ad hoc network, which consists of two hundred mobile nodes, each of which has a different radio range and is spread out throughout a space measuring one thousand by one thousand square units. Each mobile node has a buffer capacity that can hold up to 20 packets, and the average duration of a packet's lifespan is 10 packets. The amount of time it takes for a node to process a packet is between 0.005 and 0.0045 seconds, while the source generates packets at an interval of 5 milliseconds. We determined the amount of time that a packet waited to be processed in the intermediate node's input buffer, the average length of the queue, and the chance of the number of packets being processed by utilizing probability distribution.

1. The average amount of time that a packet spends in the before it is processed, the information is stored in the input buffer of an intermediary node.

By determining the length of time a packet spent waiting in the input buffer of an intermediary node before it was dispatched from that node, we were able to determine the total amount of time the packet spent waiting. Regarding growth in the volume of traffic heading its way, we estimated it for different packet processing durations of node (0.005 and 0.0045), respectively. This computing measure is used to compute the TTL value of a packet, and if the waiting time for a packet is greater than the TTL value, the packet will be removed from the queue as shown in Figure1.

In other words, the TTL value determines whether or not a packet is removed from the queue.

In addition to the length of the queue, the amount of time that it is anticipated that a probability packet will wait at the reception of an intermediate node. The various types of input traffic heading toward an intermediate node. This was done by taking into account the various packet processing times of the node, which were 0.005 and 0.0045, respectively, as shown in Figures 2,3, and respectively.

2. We estimated the length of the queue for an intermediate node by counting the number of packets that were already present in the input buffer of the intermediate node. This was done before a packet was sent from an intermediate node. Regarding growth in the volume of traffic heading its way, we estimated it for different packet processing durations of node (0.005 and 0.0045), respectively. The size of the input buffer of the node is determined by using this computation measure as a guide. As can be seen in Figure 4, the packets will be discarded from the input buffer if the queue length is greater than the capacity of the buffer.

In addition to calculating the length of the queue, we also determined the probability of the number of nodes that are present in an input queue. This was done by taking into account the various forms of traffic that are headed toward an intermediate node as well as the varying rates at which the node processes packets (0.005 and 0.0045), as shown in Figures 5,6, respectively.

3. Because the network is made up of different kinds of mobile nodes, the degree of traffic intensity at an intermediate node is unpredictable and fluctuates based on the quantity of traffic that is coming into the node as well as the node's capacity to process data at any one time. Determine then, using the poison random process, the risk of a packet being lost while it is traveling via an intermediary node, as illustrated in figure 7.

4. The probability that a node will see a decrease in its energy consumption as a result of one packet procedure in 0.005 seconds is 0.0045J. Under these conditions, it is possible to derive it for the Figure 8 illustrates the chance that a node will experience a decrease in its energy level of exactly 10 J as a result of distinct packets arriving to the node at the same time. This chance may be calculated by multiplying the likelihood that a node will experience an energy loss of exactly 10 J as a result of one of many possible packets. arrival Figure 8 shows the probability that a node will experience a decrease in energy

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equal to exactly 10 J as a result of distinct packets arriving at the same node at the same time.

The findings of the research make it abundantly evident that increasing the time it takes to process packets would produce better overall outcomes, then increasing the length of the queue is unnecessary. When there is a greater volume of traffic coming into the intermediate node, the lifespan of the network improves. If the node only has a short amount of time to process packets and a high pace of traffic coming towards it, it will discard the packet.

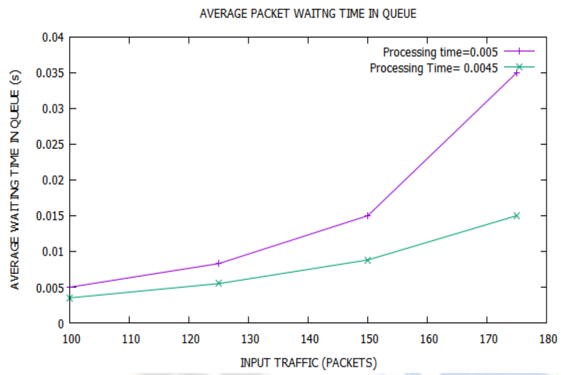

Figure 1 shows the typical amount of time spent waiting for a packet that is currently being held in an intermediate node's input buffer

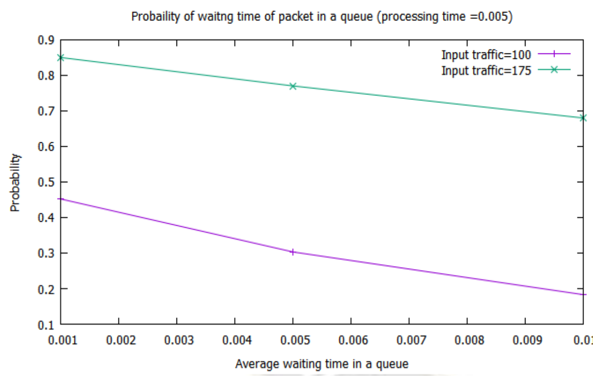

Figure 2 depicts the amount of time that a probability packet waits in an intermediate node's input buffer (with the processing time set at 0.005 seconds).

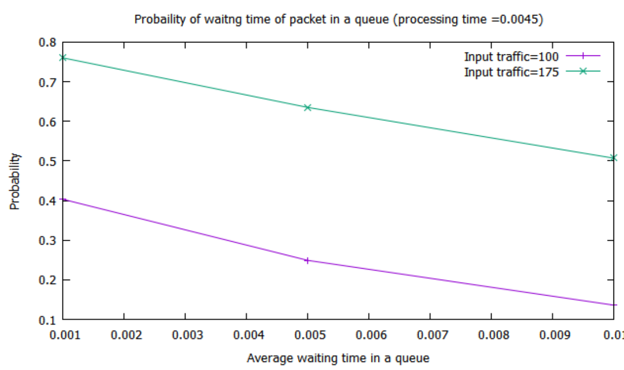

Figure 3 displays the amount of time that a probability packet is expected to wait at an intermediate node's input buffer (the processing time is equal to 0.0045 seconds).

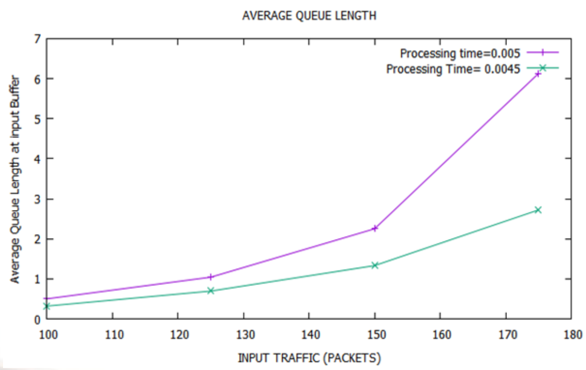

Figure 4 is a representation of the typical length of the queue at the input buffer of an intermediate node.

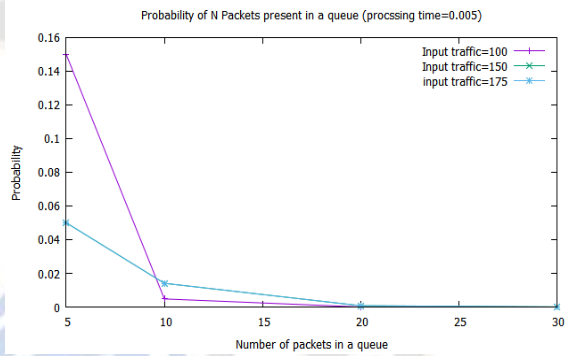

Figure 5 illustrates the likelihood of the average length of the queue at an intermediate node's input buffer (with a processing time of 0.005 seconds).

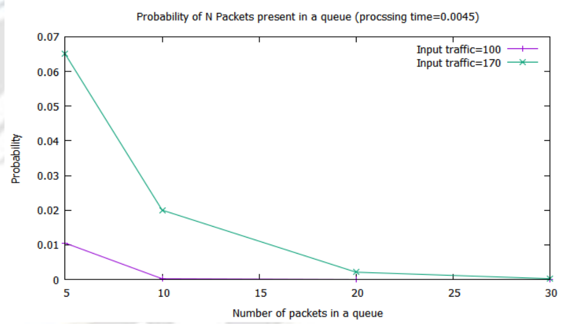

Figure 6 illustrates the likelihood of the average length of the queue at an intermediate node's input buffer (with a processing time of 0.005 seconds).

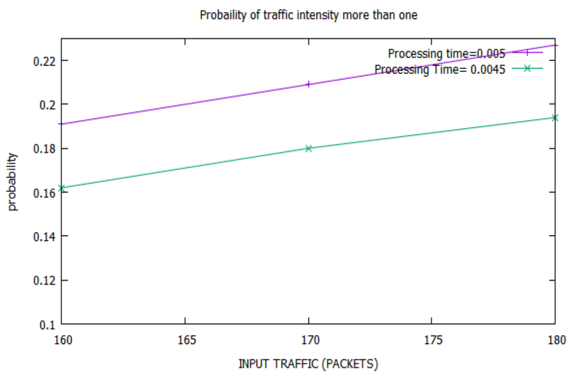

Figure 7: The likelihood of experiencing a lost packet about the volume of traffic

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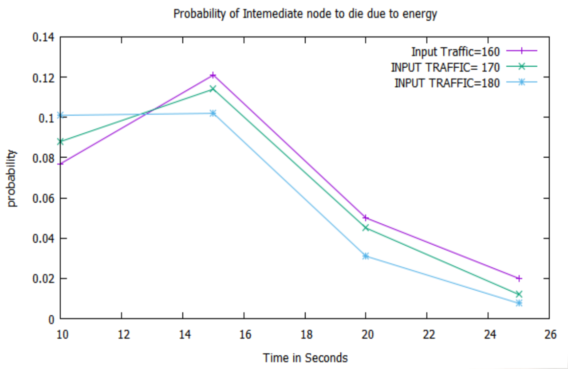

Figure 8: The likelihood of a node dying as a result of its exposure to energy

IV. Conclusion

To assess the state of a bottleneck intermediate node, which must convey packets from many sources, we develop a mathematical model that takes into account the typical length of the queue at the input buffer, the typical amount of time spent waiting in the buffer, and the typical lifespan of the network. Gaining insight into the network's lifetime might help in the design of a more effective method of regulating multi-path MANETs and so improving the quality of service. Controlling the flow of traffic towards the input buffer and determining whether or not a node will join the route are accomplished by using estimation of the amount of data lost, the typical amount of time spent waiting in the buffer, and the total number of items in the buffer's queue.

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