Modeling Delivery Delay for Flooding in Mobile Ad Hoc Networks

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***Abstract*—Mobile ad hoc networks (MANETs) can have widely varying characteristics under different deployments, and previous studies show that the characteristics impact the behavior of routing protocols for MANETs. To deploy applications successfully in MANETs, application developers need to comprehend the potential behavior of any underlying protocol used. In mobile networks, a major component of many of these routing protocols is some form of flooding, which facilitates message delivery over an entire network in a relatively reliable way. Several MANET protocols use flooding to support the distribution of route request messages as well as delivering broadcast packets. Therefore, to developers of applications for MANETs, a major task in understanding MANET protocols is estimating the performance of flooding in a given operating environment. In this work, we develop an analytical model for the delay experienced in flooding a message. We model the one hop delay of a flooding message in MANETs in terms of parameters that can be acquired either from a system configuration or from application designers.**

I. Introduction

Nodes in wireless mobile ad hoc networks (MANETs) create connections without the aid of any infrastructure, forwarding packets among neighboring nodes. The MANET research community has identified several fundamental challenges; the most prominent among these challenges is discovering an optimal route between two nodes. Existing work has proposed a plethora of routing protocols with their individual merits, but comparison studies illustrated different performance characteristics under various operating environments [3].

Delivering data packets utilized unicast communication, while other fundamental components of communication rely on flooding, which exhibits completely different properties from unicast. In this paper, we investigate the creation of an analytical model of the per-node delay exhibited by flooding.

Research communities in wireless networks have addressed the packet flooding phenomenon known as the broadcast storm problem [6]. Since each node rebroadcasts any packet it receives, the wireless network suffers from flooding of redundant and exponentially increasing packets. On the other hand, flooding provides a reliable method to disseminate data over the wireless network. Accordingly, many MANET routing protocols apply a flooding scheme to find an initial route to a target destination node. Since packet flooding is a basic building block in MANET systems, an analysis of the scheme is important to comprehend the behavior and performance of protocols in these networks.

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Performance metrics have been introduced in evaluating the flooding scheme in wireless networks. Since flooding causes, in nature, a problem of redundant packets, measuring efficiency in core flooding algorithm is important. Reachability is a popular metric that indicates how a portion of nodes in the network succeeds in receiving a flooded packet. In addition, characteristics of packet delay in flooding provide application designers a useful guideline in designing their applications.

Most existing work focuses on the design of efficient flooding schemes and the performance evaluation using complexity analysis and/or simulation results [6], [9]. In [8], the authors study comparisons of proposed flooding schemes providing simulation results among them. The work categorized broadcast protocols based on a core algorithm and compared them with respect to algorithm efficiency, performance in congested static networks, mobile networks, and combined networks providing simulation results. Other works analyzed packet reachability and efficiency of flooding scheme theoretically in MANETs [11], [7]. While previous works addresses reachability and efficiency, there is no work to analyze delay in a packet flooding to the best of our knowledge.

In this work, we introduce an analytical model of packet delay for flooding in MANETs. Our model accounts for an outflow of flooding packets in a node in a steady state. While more sophisticated flooding schemes have been proposed, this work focuses on a controlled blind broadcast algorithm where each node rebroadcasts a packet unless the node has received the packet before. In fact, the controlled blind broadcast is popular among several practical implementations; for instance, DSR, a well-known reactive MANET routing protocol, applies this flooding algorithm when it initiate a new request for a route toward a target destination.

The remainder of this paper is organized as follows. Section II presents the assumptions and system models that build a foundation of our analytical derivation. In Section III, we describe a delay model in a node under a controlled blind broadcast; we derive the closed form of the analytical model in Section IV. Section V provides simulation results that support our model, and we conclude with future work in Section VI.

II. SYSTEM MODEL

In this section, we list the basic assumptions and properties of our system model used throughout the remainder of the paper.

A. Assumptions

1) All nodes have an equal radio range *R*. Bi-directional links exist between any nodes within the range.
2) Nodes move in a pattern of random mobility (e.g., random walk model). In addition, nodes “wrap-around,” re-entering the area from the opposite border when nodes head for the boundary of the network.
3) The flooding scheme we model achieves almost complete packet delivery over the network. While some packets drop during relaying, redundant receptions in flooding can compensate for failure in packet delivery.
4) The MAC layer does not perform packet fragmentation. This assumption is justified by restricting a payload size of a packet from the link layer.

B. System Properties

1) In an initial state, n nodes are distributed uniformly over a given space. This property in combination with assumption 2 results in uniform node distribution over the network at all times [2].
2) Each node creates broadcast packets at a rate of f packets per second on average, with the characteristics of i.i.d. Poisson process. Each packet is of size of L bits. The Poisson process has been shown to be a reasonable pattern for random packet generation [1].
3) The target destination for flooding is randomly chosen. Any incoming packet is destined to a particular node with the probability of p_{dst}.
4) To broadcast packets, each node uses a random access MAC model that is described in Section IV. This MAC model reasonably reflects the IEEE 802.11 specification in packet broadcast and guides a simple and tractable analytical derivation.

According to our system model, each node shows similar characteristics in terms of movement pattern and traffic; each node moves randomly and independently and generates the same amount of flooding traffic on average. In a real world, nodes' movements may rely on a specific scenario, and different types of traffics might coincide (i.e., unicast and/or multicast traffic as well as flooding traffic). However, our system model provides a statistically reasonable intuition for modeling delivery delay of a flooding approach. Furthermore, our system model leads to a relatively simple model that is expressed with feasible parameters in a closed form. Based on the system model, the following section describes our analytical derivations of packet delivery delay under a controlled blind broadcast.

TABLE I
NOTATIONS USED IN THE DERIVATION

Notation	Meaning
n	Number of nodes in the system
a,b	Width and height of the territory
R	Radio range
W	Transmission rate in the MAC layer
L	Data packet size
f	Average flooding packet generation rate in a node

III. DELAY MODEL FOR MANETS

In this section, we provide a queueing network model for MANETs that is the foundation of the flooding delay analysis in Section IV. Specifically, we first state effects of packet collisions on packet arrivals to and departures from a node and then describe a queueing model for MANETs using Kleinrock Independence Approximation [1]. Table I shows a summary of basic parameters used in this paper .

A. Flooding Behavior in MANETs

We study a simple but popular flooding scheme where each node broadcasts a packet on receiving it unless the packet has been received before. In MANETs, packets that are broadcast by a node can fail to be delivered to neighboring nodes due to various reasons. While a node is in the process of broadcasting a packet to its neighbors, the receiving nodes can move outside of the sending node's radio range. In Fig. 1 (a), a neighbor that broadcasts packets to node *i* moves out of the transmission range, resulting in delivery failure to node *i*. Similarly, in Fig. 1 (b), when node *i* broadcasts a packet, a neighboring node moves out of the radio range of node *i*. However, according to the system model described in Section II, each node maintains the same number of neighboring nodes on average at all time. This mobility property leads to a result that some nodes might move out of node *i*'s radio range, but the same number of nodes would move into the range on average. In addition, nodes which become neighbors of node *i* will relay flooding packets. When we focus on the flow of broadcast packets, the total amount of successfully received packets to or broadcasted packets from node *i* is conserved. Therefore, although packets fail to be delivered, node mobility does not effectively influence the flooding behavior in terms of the amount of packet flow.

On the other hand, the MAC model stated in the system description also causes failures in packet delivery, specifically due to packet collisions. In broadcast, the MAC model does not support any coordination function to prevent packet collisions but instead uses random medium access to alleviate collisions. Using the MAC scheme, packet collisions might not occur frequently under relatively low traffic, but the collisions become severe under high traffic. The reason is because in flooding, traffic is exponentially increasing as nodes rebroadcast received packets, and the random access scheme is not capable enough to prevent the packet collisions. Therefore, when we capture a flooding phenomenon, it is important to account for the delivery failure due to packet collisions.

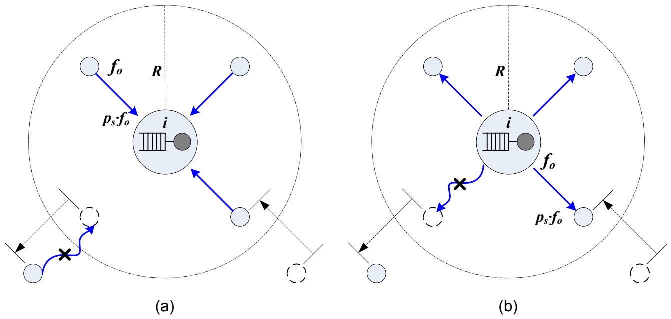

Fig. 1. Flooding scenario of (a) packet arrival and (b) packet departure in a mobile network

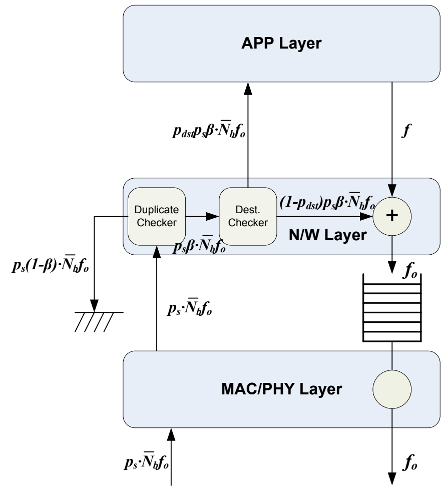

Fig. 2. Queueing model from the viewpoint of protocol stacks

In Fig. 1, node *i* is modeled as a FIFO queue. In a steady state, each node generates the same amount of flooding traffic and forwards an equal number of packets from the same number of neighboring nodes. Hence, node *i* should have a balanced influx and efflux of traffic, denoted as f_o, in a steady state. However, due to packet collisions, a portion of packets fail to be delivered. To express the successful delivery of flooded packets, we introduce a probability of successful delivery over one hop, p_s. Given this probability, $p_s{\cdot}f_o$ out of the original influx, f_o, from a neighboring node is finally delivered; $(1-p_s){\cdot}f_o$ fails. Using this statistical parameter, we can abstract the flooding effect on traffic in MANETs. Intuitively, as f_o increases linearly, p_s would decrease exponentially.

B. Approximate Queueing Model

Kleinrock suggested that an *M/M/1* queueing model is a good approximation for each link in a large network [5]. In fact, the approximation is valid for systems that have packet sources with Poisson arrivals on the links, several communication connections, and relatively heavy traffic uniformly distributed over the network. Although the approximation was originally proposed for virtual circuit networks, it also provides a good model for MANETs under certain conditions.

In Section II, we stated that each node generates flooding traffic with a property of a Poisson arrival, and flooding itself spreads packets in all directions due to the inherent nature of broadcast. Therefore, we can apply the Kleinrock Independence Approximation to our system model by adjusting parameters relevant to a node's density (i.e., a, b, n in Table I), the node's degree of network connections (i.e., n, R), and the node's traffic generation rate (i.e., f). The approximation allows us to apply a well-known and reasonable model reflecting the MANETs system we described in Section II. In the next section, we perform a queueing analysis for our model, which reasonably approximates an M/M/1 queueing model.

IV. Queueing Analysis

In this section, we apply analysis results for an M/M/1 queueing system to our model, based on the discussion in Section III. The analysis of the queueing model requires identifying two important queueing system parameters for our network model: an average arrival rate and an average service rate. In the following, we derive the arrival rate and the service rate and then provide results of a queuing analysis for broadcast packets given our MANET system model.

A. Packet Arrival Rate

Fig. 2 illustrates the packet flow in a mobile node *i*. Packets are generated from an application at the rate of f and are dispatched to the network layer. Before the node broadcasts the packets, they are temporarily buffered between the network layer and the MAC/PHY layer. When a node is allowed to access the transmission medium (i.e., the air), it broadcasts the packets stored in the buffer. According to the system model in Section II, each node has $\overline{N_b}$ neighbors on average. Consequently, node *i* receives packet streams at the rate of $p_s{\cdot}\overline{N_b}f_o$, and the packets are passed to the network layer for broadcast functions which rely on a specific flooding scheme. In a blind controlled flooding scheme, a node uses unique sequence numbers to filter out packets received previously. Then, the node checks whether the flooding packet is destined for itself. If the node is a destination, the packet is dispatched to the application layer. Otherwise, the packet heads for a transmission buffer to await rebroadcasting. As we model a node as an M/M/1 queueing system, the buffer maps to a queue and the MAC/PHY layer to a server of the queue.

To make our derivations tractable, we denote β as a probability that a received packet is not redundant. To specify β, let us examine incoming flooding packets. Basically, since each node has the same structure of a queueing model illustrated in Fig. 2, outgoing flooded packets consist of two sources: the application layer and packet forwarding. We decompose the non-duplicated packets denoted as $p_s\beta{\cdot}\overline{N_b}f_o$ into two components according to the sources. Let α denote as a probability that a forwarding packet is not duplicated. Then, we can write an equation in terms of α and β as:

$$p_s\beta{\cdot}\overline{N_b}f_o = p_s\left\{\overline{N_b}f + \alpha{\cdot}\overline{N_b}(f_o - f)\right\}. \qquad (1)$$

On the righthand side of Eq. 1, the first term addresses packets generated from each neighbor node, and the second term explains forwarding packets that are not duplicated. From our system model, we assume that each packet reaches almost every node in the network. The assumption leads to the fact that each neighboring node rebroadcasts all flooding packets that are not destined for the node.

To obtain α, let us focus on only rebroadcasted packets by neighboring nodes, that do not include packets generated from the neighbors themselves. Each neighboring node receives packets originated from all other nodes via wireless links to its neighbors and forwards these packets after checking whether they are destined to the node. In addition, relying on an assumption of the complete reachability, the forwarding packets after the duplicate checker are from all other nodes except the neighboring nodes and the node itself. Thus, based on the above discussion, we can write an equation for α as:

$$\alpha \triangleq \frac{\textit{\# of forwarding packets that are not duplicated}}{\textit{\# of all forwarding packets from neighbors}} = \frac{\sum_{k\in\mathbb{N}-\mathbb{N}_b} f_k}{\sum_{i\in\mathbb{N}_b}\left\{(1-p_{dst})\cdot\sum_{j\in\mathbb{N}} f_j\right\}}, \quad (2)$$

where $\mathbb{N}$ is the set of nodes in the network except the node itself, and $\mathbb{N}_b$ is the set of neighbor nodes of the node. In Eq. 2, f_i for $i = 1, 2, \cdots, n$ is a packet generation rate for node i, and f_i for all i is given by f from the system model. By definition, $|\mathbb{N}|$ and $|\mathbb{N}_b|$ are $n-1$ and $\overline{N_b}$ respectively. In addition, p_{dst}, the probability that a given node is the targeted destination of a given packet, is:

$$p_{dst} \triangleq \mathbb{P}(D|R) = 1/(n-1), \quad (3)$$

where *D* denotes the event that the packet is destined to the node, and *R* denotes the event that the packet is received by the node and has not been received previously. Therefore, α can be expressed as:

$$\alpha = \frac{n-1-\overline{N_b}}{(n-2)\overline{N_b}}. \quad (4)$$

In a steady state, referring to Fig. 2, the average flooding packet arrival rate at node i, f_o is expressed as:

$$f_o = (1-p_{dst})p_s\beta\cdot\overline{N_b}f_o + f.$$

By rearranging with respect to f_o and using Eq. 1, we obtain:

$$f_o = \frac{\left\{1+(1-p_{dst})p_s(1-\alpha)\cdot\overline{N_b}\right\}}{1-(1-p_{dst})p_s\alpha\cdot\overline{N_b}} f. \quad (5)$$

Now, we derived a packet arrival rate, f_o with parameters that can feasibly be obtained from system (e.g., n), application designer (e.g., f), and operating environment (e.g, $\overline{N_b}$).

B. Packet Service Rate

When packets arrive at the queue, the MAC/PHY layer serves them by broadcasting to neighbors. To obtain an average packet service rate, we indeed model the average packet service time, which is equal to the inverse of the service rate. First, we present a MAC model that conforms to specifications of the IEEE 802.11 protocol reasonably well. In this random access MAC model, a node does not perform either any RTS/CTS handshaking before broadcasting nor MAC-level acknowledging after broadcasting. To broadcast a packet, a node follows the basic access procedure of CSMA/CA. When broadcasting a packet, a node sets an expiration time for the back-off timer using a fixed contention window, CW_{min}. Once the node detects that the medium is idle for T_{DIFS}, it starts the back-off timer. If, while this timer is active, the node detects a busy medium, the node freezes the back off timer. After an idle time for T_{DIFS}, the timer is resumed; when the back off timer expires, the node starts to broadcast the packet.

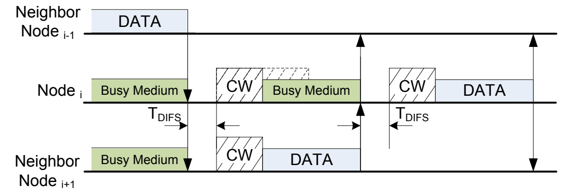

Fig. 3. Scenario in broadcasting a packet with neighboring nodes

Fig. 3 illustrates a scenario when node i who has two neighbors broadcasts a data packet. While node $i-1$ is broadcasting a packet, node i tries to broadcast its packet. In addition, node $i+1$ has started a back-off timer. Node i generates a random back-off time and starts the timer when the node detects an idle medium for T_{DIFS}. Since node $i+1$ also detects the idle medium, the node resumes a count-down for its back-off timer which is assumed to expire earlier than the timer in node i. Accordingly, node $i+1$ broadcasts its data packet while the timer in node i is frozen. After the timer in node i expires, finally, the node starts to broadcast the packet.

Based on the description of our MAC model, we can derive an average service time for a packet as follows. Let a random variable B_i denote a service time for packet broadcasting in node i. In addition, we denote random variables, T_{bf} and F_i as a random back-off time and the number of times the back-off timer is frozen before the timer expires in node i, respectively. Then, we have a following equation for B_i as:

$$B_i = T_{bf} + \overline{T_{frz}}\cdot F_i + T_{eff}^{data}, \quad (6)$$

where $\overline{T_{frz}}$ is an expected frozen time of the back-off timer in the node due to a transmission from a neighbor, and T_{eff}^{data} is an effective time taken to broadcast a data packet. Referring the IEEE 802.11 protocol specification, T_{eff}^{data} is given as:

$$T_{eff}^{data} = L/W + T_{DIFS}. \quad (7)$$

Since the timer is frozen during a transmission from a neighbor, $\overline{T_{frz}}$ is equal to T_{eff}^{data}. From our system model, each node keeps the same number of neighbors and has the same amount of outgoing flooding traffic on average in a steady state. Since a node in our system experiences the same number of interference events during a back-off time, this phenomenon exhibits the ergodic property. Relying on the ergodicity, we represent $E[F_i]$ as an expected number of nodes that are ready to broadcast among the interfering neighbors of node

i. Therefore, applying a utilization factor of a server in node i, ρ_i, we can write $E[F_i]$ as:

$$E[F_i] = \rho_i \overline{N_b}. \tag{8}$$

Since all nodes generate equivalent traffic and serve that traffic in the same manner, the utilization factor in a node, ρ is given by:

$$\rho = \rho_i = f_o/\mu_i = f_o \overline{T_{svr}}, \tag{9}$$

where $\overline{T_{svr}}$ is an expected service time of a broadcasting packet.

As nodes are evenly distributed at all times from the system model, $\overline{N_b}$ is given by:

$$\overline{N_b} = \pi R^2 \cdot \frac{n}{a \cdot b}. \tag{10}$$

Now, referring to Eq. 6, we have an equation for an expected service time of a broadcast packet as:

$$\overline{T_{svr}} = E[B_i] = E[T_{bf}] + \overline{T_{frz}} \cdot E[F_i] + T_{eff}^{data}. \tag{11}$$

Since the back-off time is sampled at random from CW_{min}, an expected T_{bf} is given by:

$$E[T_{bf}] = CW_{min}/2. \tag{12}$$

Using above derivations, we obtain $\overline{T_{svr}}$ as:

$$\overline{T_{svr}} = \frac{CW_{min} + 2T_{eff}^{data}}{2\left(1 - \overline{N_b} f_o T_{eff}^{data}\right)}. \tag{13}$$

Finally, an average packet service rate, μ_i is given as the reciprocal of the average service time, $\overline{T_{svr}}$.

C. Broadcasting Jitter

When a node broadcasts a packet, multiple neighboring nodes receive the packet almost simultaneously. If each node has a similar hardware and protocol implementation, the neighbors are likely to schedule rebroadcast at the almost same time. These coincidence in broadcasts can create significant problems such as packet collisions and redundant packets. To resolve this predictable problem, many broadcasting protocols implement a random delay between receiving a packet and rebroadcasting it [8]. In our system, we model that jitter using a randomly sampled variable between 0 and T_{max}^{jit}. Since the broadcast jitter is comprised in the packet delay in a node, we capture this delay in our analytical model.

D. Probability of Successful Delivery

To complete our derivation, we still need to derive the probability of successful delivery over one hop, p_s. Since packets fail to be delivered mainly due to packet collision, we can restate this parameter as the probability that a transmission on the shared channel with neighbors is successful. In [4], the authors provide the analytical model for the probability, relying on a Markov chain model, but they derive the probability for unicast, not broadcast. However, by modifying the model for our broadcast MAC model[1], we can obtain a simple but reasonably good model for p_s. We omit the detailed derivation due to limitation in space, but present the result.

$$p_s = \frac{\overline{N_b}\tau(1-\tau)^{\overline{N_b}-1}}{1-(1-\tau)^{\overline{N_b}}}, \tag{14}$$

where τ is a probability that a node transmits at a random slot time and is given as a function of f_o, T_{eff}^{data}, and CW_{min}. From Eq. 14, p_s is represented as a function of τ and $\overline{N_b}$.

E. Node Delay Analysis

Under a flooding scheme, the delay in a node consists of two major factors: a broadcasting jitter and a delay in packet transmission. Applying the analysis result of an M/M/1 queueing system, we obtain an average delay in a node under flooding, $\overline{T_f}$ as:

$$\overline{T_f} = \frac{T_{max}^{jit}}{2} + \frac{1}{\mu_i - \lambda_i} = \frac{T_{max}^{jit}}{2} + \frac{\overline{T_{svr}}}{1 - \overline{T_{svr}}\lambda_i}. \tag{15}$$

In Eq. 15, the first term addresses an average jitter, and the second term explains an average delay in the queueing system.

V. Simulation Results

TABLE II
SIMULATION PARAMETERS

Parameter	Value
Network size($a \times b$)	350 m × 350 m
Simulation time	200 sec.
Number of mobile hosts(n)	30
Radio range(R)	100 m
Packet size(L)	64 byte
Broadcast jitter(T_{max}^{jit})	110 ms
Transmission rate in MAC(W)	1 Mbps

In this section, we present simulation results which support our assumptions in Section II and evaluate the analytical results from Section IV. We performed simulations with ns-2.33, using IEEE 802.11 as the MAC protocol. We implemented a controlled blind flooding protocol, and applied it as the routing protocol. A node does not generate any control packets but creates data traffic with a property of Poisson arrival. We generated 50 independent mobility scenarios using the Random Waypoint Mobility Model [10] with '0' pause time and ±10% of an average speed. In addition, since we are interested in the steady state, we ignored the simulation data earlier than 10 seconds from the simulation start time. Table II lists detailed parameters we used in the simulations.

We first validate our assumption that a flooding packet reaches almost all nodes. For each simulation run, we calculated a packet reachability, defined as the proportion of the number of nodes that receive a packet to the total number of nodes. Fig. 4 depicts the results with 95% confidence intervals. As shown, in our scenarios more than 92% of nodes receives a flooding packet, though the proportion decreases as f increases. The reason is because, under heavier traffic, it is more probable that a packet is lost due to packet collisions. In addition, the packet reachability does not seem to depend on node mobility but on the amount of traffic.

[1]We simplify the model in [4] by ignoring non-ideal transmission channel and capture effects

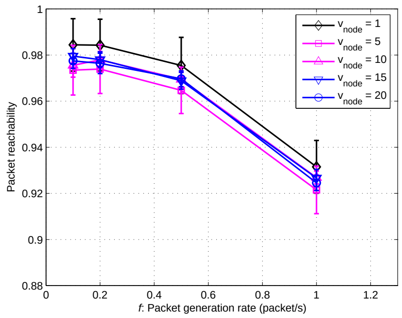

Fig. 4. Packet reachability over the network

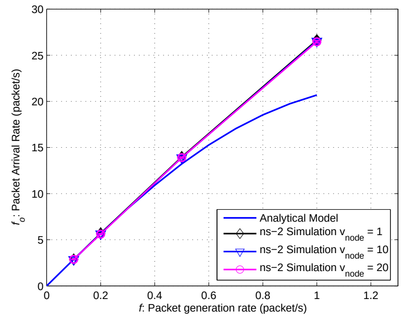

Fig. 5. Comparison of analytical results for flooding traffic with simulation results

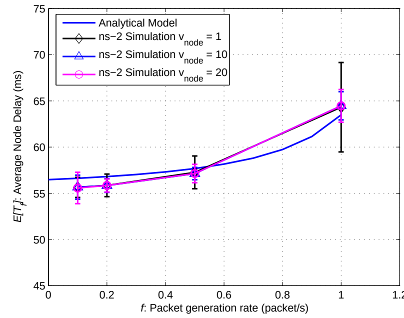

Fig. 6. Comparison of analytical results for a node delay with simulation results

To validate the model for outgoing flooding traffic (i.e., f_o in Eq. 5), we measured total flooding traffic during the whole simulation and calculated an average amount of traffic in a unit time per node. We represent both analytical evaluations and simulation measurements in Fig. 5. The simulation results are consistent with the analytical model, but under relatively heavy traffic they begin to diverge. Although we assumed perfect delivery of a flooding packet over the network, in fact, the packet reachability decreases as traffic increases. Specifically, when the traffic is heavy, an increasing number of packet collisions reduces the number of forwarding packets from neighbors. Referring to Eq. 2, α has a larger value with heavier traffic because the denominator decreases[2]. We leave a more accurate model for α as the future work.

Fig. 6 depicts a node delay under flooding (i.e., $\overline{T_f}$ in Eq.15) from numerical evaluations and simulation results with 95% confidence intervals. Overall, simulation results validate our analytical model for a node delay under flooding. Under relatively lighter traffic (i.e., $f = 0.1$), the delay from simulations has a smaller value than the delay from the analytical model. The reason is because our model does not account for border effects. Specifically, while we derived the number of interfering nodes assuming a torus-shape place, the interfering nodes in the simulation may be less than that in Eq. 10. On the other hand, under relatively heavier traffic (i.e., $f = 1.0$), we observe a larger value of delay from the simulation. Fig. 5 explains the reason; simulations show larger flooding traffic than our model, and accordingly, a delay from simulation measurements has a larger value.

VI. Conclusion and Discussion

In this paper, we derived a model of a node delay in MANETs for packet flooding and validated with extensive simulations. The delay model is expressed with parameters from application specifications (e.g., average flooding packet generation rate, f), system information (e.g., size of the minimum contention in the MAC layer, CW_{min}), and operating environments (e.g., average number of neighbors, $\overline{N_b}$). Consequently, the model is highly adaptable to various operating situations where the required parameters are available.

To guide our analytical derivation, we assume that an almost complete flooding over the network regardless of an amount of traffic. While the assumption is good for moderate traffic, under relatively heavy traffic, this introduces a deviation from simulation measurements to our model. To compensate for the difference, it is necessary to capture the effect of traffic on packet reachability under flooding.

Our analytical results can be applied to estimate a packet delay for flooding in a varying operational environment. This quantitative information is good guidance for a designer to create applications that are especially sensitive to a timing requirement. Based on the analytical result, an application designer can refine applications' requirements or adapt applications' properties.

[2]While the number of all forwarding packets decreases, non-redundant packets will hardly decrease due to a property of packet redundancy in flooding

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