Effect of Topology on BGP Traffic

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Abstract— **The Border Gateway Protocol (BGP) is a critical part of the Internet, as it is the mechanism by which Autonomous Systems (ASes) exchange routing and reachability information about their networks. However, the dynamics of BGP are not well understood. In particular, most BGP traffic does not reflect underlying changes in topology. There have been theoretical studies that suggest that BGP can in some circumstances generate sustained periodic traffic in response to a single network event. This effect is dependent on the network topology (mesh, bus, ring or some combination). We attempted to understand the effect of different topologies on BGP propagation. We found that the topology of network has significant effect on BGP traffic and BGP is sensitive to certain topological characteristics of Internet.**

I. INTRODUCTION

The current BGP version is version 4 (BGP-4) codified in RFC 4271[1]. The major enhancement in BGP-4 is support for Classless Inter-Domain Routing and use of route aggregation to decrease the size of routing table.

There is a great deal of oscillatory behavior in BGP propagation, but the reason why and the dynamics of BGP are not well understood. Earlier work by Nicholas C. Valler [2] provides motivation for this work. The authors identify a number of features in BGP routing updates and developed modeling studied of BGP churn instability. Our work are based on their theoretical BGP propagation model.

To ground our work, we focus on the BGP updates responds to a single network update. First, we did Scilab simulation to find out as the number of router in the Internet changes, the effect of different topology on BGP traffic. From the Scilab simulations, we gain some theoretical measurements of the effect of the number of routers. Then we use Packet Tracer build different topologies BGP network models to see if we can observe a similar effect with Scilab simulation.

The goal of this research report is to ascertain the effect of number of routers and different topologies on BGP traffic. Especially, we focus on the full mesh connection network which has significant effect on BGP propagation when the number of routers in the network has changed. We also compare our theoretical results with results for real network experiments.

II. SIMULATION MODELS

In this section, we describe our Scilab simulation model of BGP route flapping and show how it can describe BGP updates.

A. Scilab Simulation Model

A critical part of our model is how an update in one router can propagate update information to its neighbors. We use a model from earlier work by Nicholas C. Valler[2] to simulate BGP propagation. This propagation model is based on the so-called logistic equation which has been used widely in dynamic system[3]. We consider our network as a dynamic system with feedback: a router send updates to its neighbor routers when there is a network event and the neighbor routers will send more updates back due to this network change. The feedback depends on the topology of the network.

To explore a connection with dynamic system theory, we use the following dynamic system, **Logistic map.** This system corresponds to the trivial case of one node feeding packets to itself [2].

$$x_{t+1} = \frac{r \times x_t \times (M - x_t)}{M}$$

where, t is time, x_t is the number of packets at time t, and *r* and *M* are the parameters of the system. *r* can control the behavior of the system; either die-outs, reach non zero steady state or oscillates. *M* is a dampening factor which only has a scaling effect on the system but does not affect the behavior of the system. *M* is effectively a bound of how much can be propagated in one time. For our simulations, we always assign a larger value of *M* than x_t. x_{t+1} is the number of packets that this node feeds back to itself, but it also can be considered as the number of packets this node propagates to its neighbor nodes.

The propagation model we used for our simulation is based on logistic map[2].

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$$S_{i,t+1} = \delta_i S_{i,t} + \frac{\sum(1-\delta_{j,t})h_j S_{j,t}(M_j - S_{j.t})}{M_j}$$

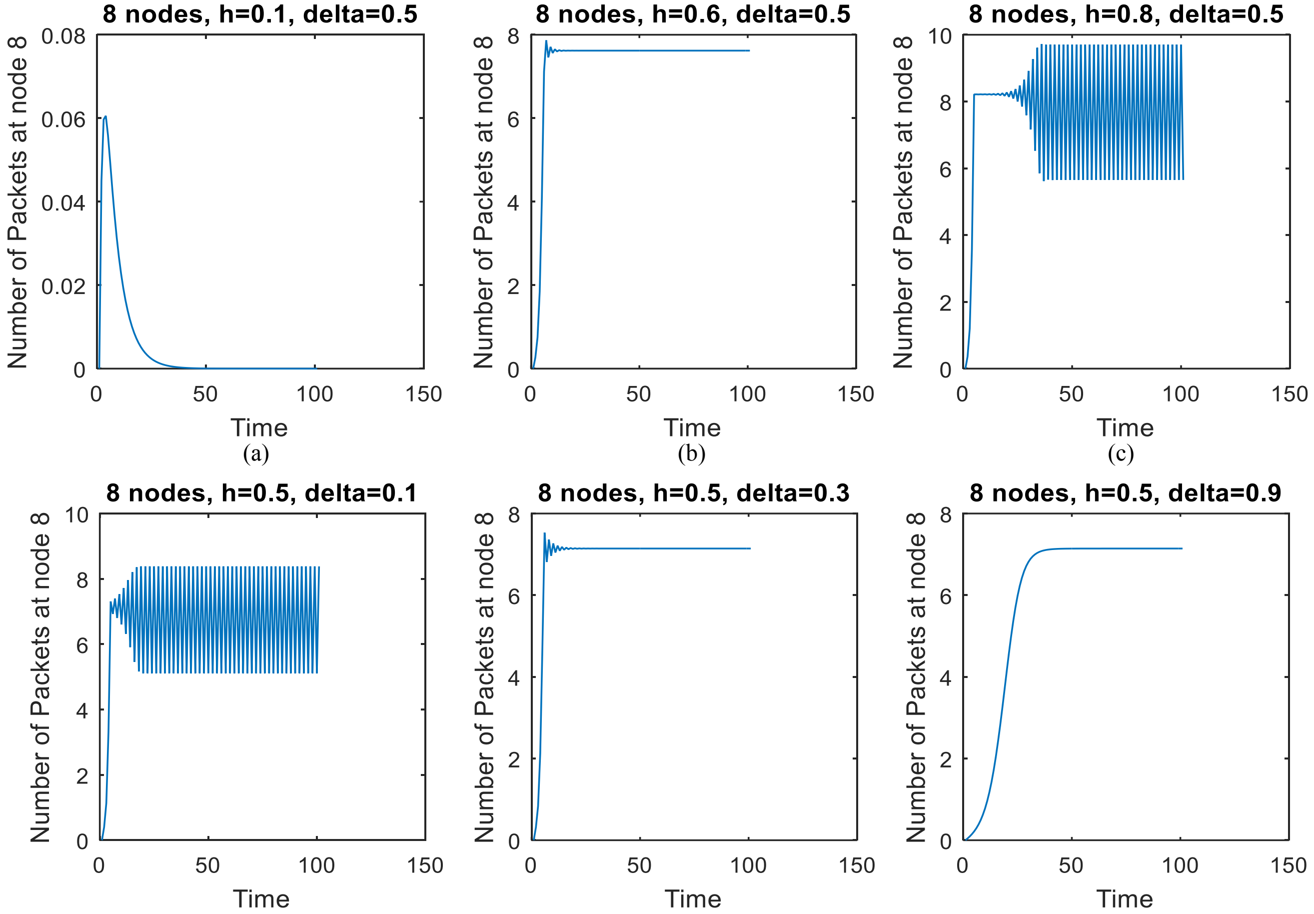
Explanation of symbols: j are the neighbor nodes of i.$S_{i,t}$ is the quantity of packets at node i at time t. Parameter δ is retention parameter which represent in every time step, a node i defers δ_i amount of its current packets for later propagation. So $\delta_i S_{i,t}$ is the number of packets that is not sent to node i neighbors, but kept at node i for time t+1. Similarly, $(1 - \delta_{j,t})$ is the number of packets that node j contributes to node i. Parameter h is the transmission parameter which quantifies the percentage of the arriving packets will create outgoing packets. Parameter h_j is the percentage of incoming packets at node j that will be outgoing to node i. The second term represents the total number of packets that node j contributes to node i.

B. Simpler Model for Full Mesh Connection

In the process of our Scilab simulations, we found that full mesh connection is a very complicated scenario. Since the propagation model in part *A* causes a great deal of looping for full mesh connection, as the number of nodes increases to a certain number, the number of packets received by the last node will exceed the allowance of Scilab. Propagation model in part *A* also make it harder to observe the effect of the number of nodes since there are effects from other parameters. Consequently we decided to use a simpler model for full connection.

This model does not include the retention and transmission parameters or any other system parameters and assumes every transmission succeeds.

Explanation of the model: we choose 4 nodes full mesh connection as a example here. There is a single packet input which represents a single BGP update at the first node and we observe how many packets have been received by the last node. At time t=1, the first node broadcasts 1 packet, the fourth node received 1 packet directly from the first node. At time t=2, the second and third nodes broadcast the packet they received from the first node, but the packets which have been sent to node 1 will be deleted to avoid looping because the packets already passed the first node. At the same time, the fourth node received 2 packets at time t=2. At time t=3, the second and the third node only passed the packets they received from each other to the forth node, then the forth node receives 2 packets at time t=3. Then the fourth node will no longer receive any more packet.



(a) (b) (c)

(e) (f) (g)

Fig.1. (a-c) Examples of Effect of Parameter *h*, (d-f) Examples of Effect of Parameter *δ*.

III. SIMULATION AND EXPERIMENTS RESULTS

In this section, we present the results of our Scilab simulations and Packet Tracer experiments. We also make a comparison of the results.

A. Scilab Simulation and Results

Our simulations focus on three types of topologies, bus connection, ring connection and full mesh connection. The simulations were selectively repeated on 5, 10, 15, 20, 25, 30 and 35 nodes for all three types topology. For each type of connection, we applied the propagation model. Also, apply a single pulse input of $S_{i,1}$=1 at the first node and M=10 to make sure M has a larger value than $S_{i,1}$so that the system allow efficient amount of packets can be propagated in one time. By varying the value of h, δ and number of nodes and then observe the behaviors of the system from the last node to find out the effect of those parameters.

Effect of transmission parameter *h*. In order to find out the effect of h, the value of δ has been fixed to 0.5. A similar effect can be observed for all three types topology. Fig1 (a)(b)(c) are the graphs of 8 nodes full mesh connection which we chose to be an example here. Increasing h increases the amplitude of the system output. The increasing of the amplitude can be seen from Fig1 (a)(b)(c). We can see that as h increases, the behavior of the system changes from die out to non-zero steady state then to oscillate.

Effect of retention parameter *δ*. Similar effects can be observed for all three types topology as well. The value of h has been fixed to 0.5 in order to find the effect of δ. Fig1 (d)(e)(f) are an example of 8 nodes full mesh connection. From the graph, we see that δ has opposite effect on the system with transmission parameter h. Increasing δ decreases the amplitude of the system output and the behavior of the system changed from oscillates to stabilize.

Effect of the number of nodes. The value of δ and h has been set to 0.1 and 0.9 respectively for this part simulations. From Fig2 (a)(b)(c)(d), we can see that for bus connection and ring connection, as the number of nodes increases, the effect on the values of system output is not significant. The amount of packets that received by the last nodes remains the same. But we can observe a significant delay as the number of nodes increased from 5 to 35 since as the number of nodes increases it takes longer to propagate the packets. However, for full mesh connection, the number of nodes has a significant effect on the system as we can see from Fig2 (e)(f). When the number of nodes increases from 3 to 5, the amount of packets received by the last node increases 53%.

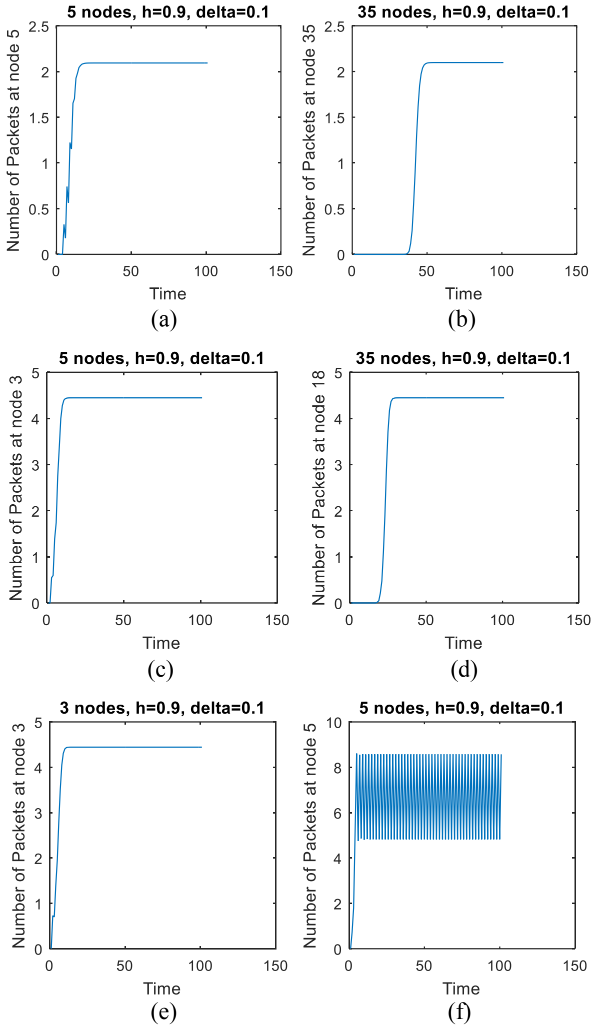


Fig. 2. Graphs of effect of number of routers. (a)(b) Bus Connection. (c)(d) Ring Connection. (e)(f) Full Mesh Connection.

Since it is hard to observe the effect of number of nodes from simulation model A, we use model B to simulate full mesh connection. We repeated the simulation for 3-10 nodes. Fig3 is the graph of number of nodes vs. the number of packets received by the last node. We can see that as the number of nodes increases, the number of packets received by the last node increase exponentially.

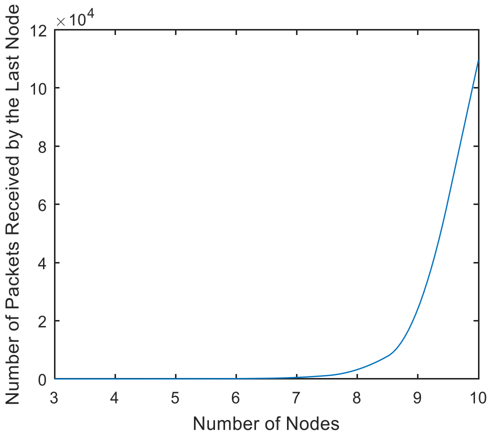


Fig. 3. Full Mesh Connection: Number of Nodes vs. Number of Packets Received by the Last Node

B. Packet Tracer Experiments and Results

All of our Packet Tracer experiments use Cisco Packet Tracer version 6.0. For Packet Tracer experiments, we still use the same three topologies with Scilab simulations which are bus connection, ring connection and full mesh connection. The experiments were repeated on 3 to 8 nodes for bus connection and ring connection. For full mesh connection we were only able to do 3 to 6 nodes since Packet Tracer is not able to process the overwhelming amount of data when the number of routers is larger than 6. Also, due to the limitation of Packet Tracer, we were not able to find out the exact number of packets received by the last node and how long the BGP flapping last. The duration was timed by using iPhone. To increase the accuracy, we repeat the experiments for each number of routers 5 times at least and calculate the average BGP flapping duration.

For Each type of connection. Each router belongs to different Autonomous Systems and they are the eBGP router of each Autonomous System. For each experiment, we shut down one of the serial interfaces of the first router which represents a single BGP update, then observe BGP updates from the router which has the furthest distance with the first router. The experiment procedures are the same for ring connection and full mesh connection.

Fig4 (a)(b)(c) are the graphs of BGP updates duration vs. number of routers for bus connection, ring connection and full mesh connection respectively. For bus connection, as the number of routers increases, the duration of BGP updates increases slightly as we can see in the graph. However, from our observation, for bus connection, the number of packets received by the last router remains 8 no matter how many router in the network. Then the reason that the duration of BGP updates increases could be it takes longer to propagate the packets when the number of routers increases. For ring connection, as the number of routers increases, the duration of BGP updates increases linearly. For full mesh connection, the duration of BGP increases exponentially as the number of router increases.

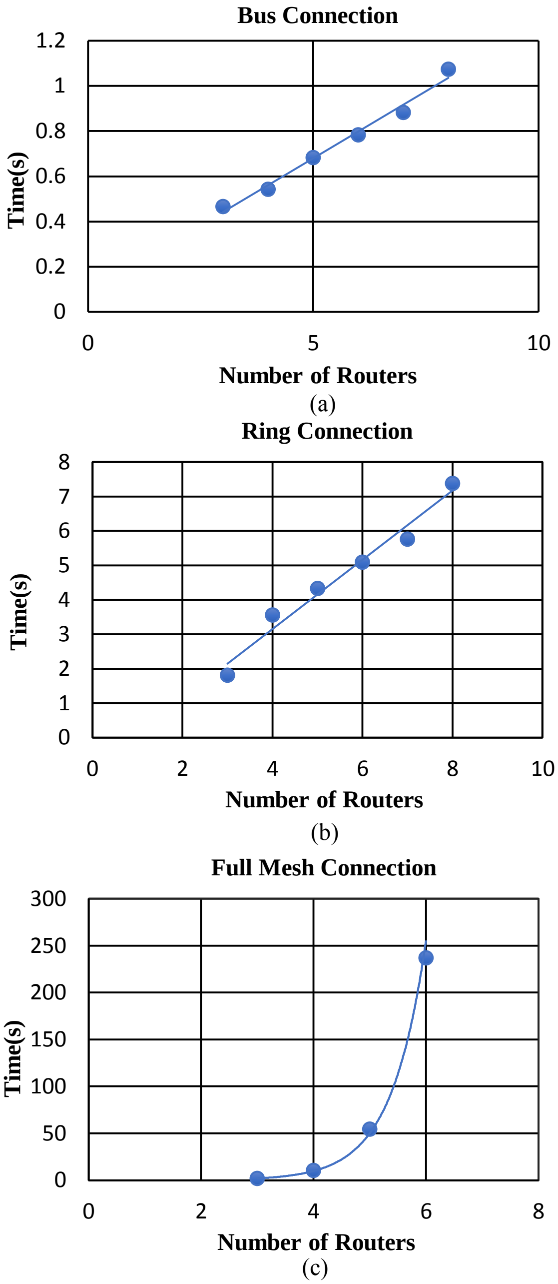


Fig.4. Packet Tracer Experiments Graphs

IV. CONCLUSION

In this paper, we begin to explore the effect of different topologies on BGP updates theoretically and experimentally. By using the discrete-time, continuous non-linear propagation model [2] which is based on part of the logistic function, we discover that BGP traffic may be sensitive to certain topological characteristics of the network. We also observe interesting behaviors of the system including die-outs, reach non-zero steady state and oscillations. Then we develop a simpler model to make our experiments more feasible. Finally, we use Packet Tracer to develop network models for different topologies to verify our conjecture that in a full mesh connection network, a small alteration of the system configuration will result a huge effect on BGP traffic. For further work, we hope to correlate those effects we observed from Scilab simulations and Packet Tracer experiments with real network experiments.

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