365

Performance Comparison of BGP in Multi-AS Network with OPNET Simulator

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Abstract: All the BGP speakers in an autonomous system should be connected in a full mesh manner. This type of connection increases implementation cost and routers utilization as the network grows. The solution is to divide a large AS into some smaller ASs with a border router for each to speak with other AS border routers. BGP in *Route Reflection* mode or *Confederation* mode will enhance BGP with this feature. In this paper we compare the performance of these three BGP types using OPNET simulator.

Keywords: BGP; Simulation; Route Reflection; Confederation; OPNET

1. Introduction

BGP (Border Gateway Protocol) is a routing protocol which propagates routing information between BGP speakers. BGP speakers are routers with the ability of running BGP protocol. BGP has two extensions: Internal BGP and External BGP.

1.1. EBGP vs. IBGP

IBGP is used when BGP packets are transmitted between routers in the same AS (autonomous system). In this mode, when a BGP speaker receives routing information from one of its IBGP neighbor, it does not broadcast the information to other connected BGP peers. Each BGP speaker should have an IBGP connection to all other BGP speakers in the same AS to achieve consistency across the network.

In EBGP when a BGP speaker receives new routing information from a connected peer from another AS, it distributes the information to all other connected peers. It is not needed for a router to connect to all other BGP speakers and it is enough to be connected to at least one other BGP speaker, because all the BGP peers' information would be consistent after some hops automatically as the information is broadcasted.

Some general specifications of this protocol is mentioned below:

- It is a path vector protocol not a distance vector
- Supports VLSM and CIDR
- Connects to other neighbors on port TCP 179 and maintains the session by sending keep-alive packets
- Maintains and independent routing table

- Metric is named attribute in this protocol
- It is flexible and is supports professional policy-based routing. By the way routing is done by a hop-by-hop manner through the Internet and the policies might not be maintained by the midway routers which there is no control on them.
- As private IPs are specified by RDC 1918, AS numbers above 6512 (through 65535) are reserved for private use.

1.2. BGP Messages

There are four kinds of BGP messages:

Open Messages: are used for creating connection between peers.

Keep-alive: is used frequently to keep-alive connections across peers. If its timer is set to zero, keep-alive packets are not sent.

Update Messages: contain route information and route attributes. One update is sent for each link.

Notification messages: is used to inform neighbors of error and disconnecting the connection.

1.3. BGP Connection Types

BGP should fully realize it's relationship with other neighbors. It services two kinds of neighbors: internal and external neighbors. Internal neighbors are in the same AS with the BGP, but external neighbors are in different ones. Usually internal neighbors are adjacent and in one subnet but external neighbors can be in any part of system. The protocol is named EBGP If the protocol is

used to connect two networks and if it is used within a network it is named IBGP.

While using IBGP, each node in the AS should have full mesh connectivity which causes increase in implementation cost and network power consumption. There are two proposed solutions to overcome this problem.

1.3.1. Route Reflector

With this feature a router would be configured to act as a router reflector (RR). RRs are used in large Autonomous systems to reduce BGP connections. To do so, an AS would be divided into one or more clusters in which there might be one or more RRs. Each client in an AS can connect to each of the RRs to get the routing information. All the RRs within an AS should be connected in full mesh manner to update routing information synchronously.

1.3.2. Confederation Configuration

It configures a BGP router as it belongs to a confederation. In this model, a large AS would be configured as a confederation to reduce the IBGP sessions which should be kept. In other words, an AS is divided into some smaller Autonomous systems with each router in these systems has same AS number.

2. Definition of Emulation and Simulation

OPNET is a network simulator. Since there are several definitions regarding simulation and emulation, the meaning of simulator and, likewise, simulation has to be determined. Most of the times, emulation is defined as hardware-based, i.e. a piece of hardware reproducing the functionality of another piece of hardware; for example, a modem behaving like a fax machine. Simulation is in this context defined as a purely software based solution; for instance, a C-64 simulator running on a PC, or VirtualPC for MAC. This definition, however, is not apt for this paper. VN-UML, which is an alternative OPNET, would be considered a simulator, too, since it requires no specialized hardware. Therefore, in the context of this paper, the definitions shall be as followed:

• Emulation is a software-based simulation of hardware. This means the virtual hardware is able to communicate with other, not emulated hardware. For example, an emulated network interface card would be able to communicate with a 'real' network interface on the same machine. Also, depending on the kind of emulator, native software written for the emulated hardware can be run on the virtual machine.

• Simulation is a software-based simulation of the behavior of hardware and software inside the simulator. The simulator acts similar to a sandbox; nothing from outside the simulator can interact with the simulated objects.

The main difference between simulation and emulation is the scope. While emulation emulates hardware and allows native software and other machines to interact with an entirely virtual machine, as in Virtual PC, simulation simulates only the behavior of a system.

While emulation allows more control, such as capturing data with an outside tool, for example using Ethereal in a VNUML/Quagga emulation, or simply stopping the emulation at any point of time, it is also more resource intensive. Simulation is generally faster and allows simulating even large nets on the same machine. However, due to its black-box approach there is no possibility to let outside programs (there are exceptions; compare) or machines communicate with the simulated objects. All means to manipulate the simulation have to be provided by the simulator; this limits visibility and control severely.

As a rule of thumb, emulation tends to be more effective (i.e. more exact, better controllable), while simulation is more efficient.

3. Related Works

The performance of routing protocols has already been explored in earlier research given in (Huitema, 2000; Bellman, 1957; McQuillan et al., 1977; Malking, 1998). The authors emphasize the fact that the routing protocol selection is a key component in determining the performance of a network. However, these studies never consider the context as given in our simulation framework.

A number of recent papers (Malking, 1998; Moy, 1998; Talal, 2006) have analyzed the performance of routing protocols in multi-hop networks. In our study, we use a hybrid topology based framework to analyze the performance of BGP protocol and observe how it performs under Route Reflection and Confederation Scenarios.

4. Describing BGP model in Opnet

4.1. Route Reflector Configuration

There are some steps to configure a router as RR in Opnet:

1- Set "status" field to enabled in router reflector configuration table
2- Enter all clients' IP addresses which are connected to the RR in "client list" field
3- If there are more than one RR in a cluster, the cluster id of all of them should be considered unique, but if there is only one RR in the cluster the field could be set to "use router id"
4- Usually routers transmit routing information between clients and other BGP routers, but if we want exchange clients' information, the "Client-to-Client Reflection" should be enabled.

4.2. Confederation Configuration

There are some steps in Opnet to configure a BGP router in this mode:
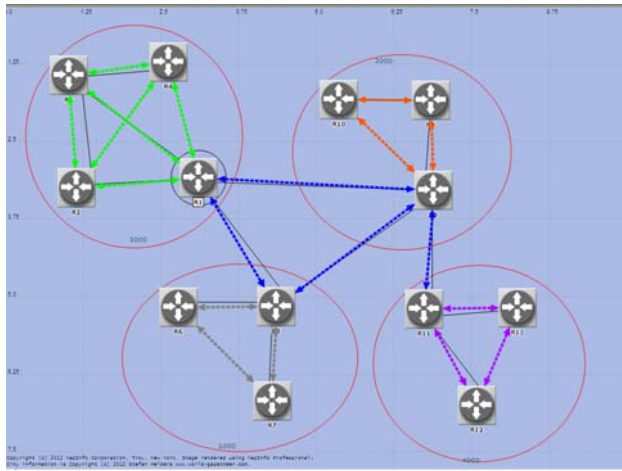
1. Set confederation ID which the router belongs to in "configuration id" field. When an AS is divided to some sub ASs, the former AS ID is considered to be set in this field for all the routers in the AS.
2. After that, IDs of other sub ASs in the confederation is entered in "confederation peers" field.

5. Setting up Simulation

In this evaluation we configure all the routers in each scenario to act as BGP routers and exchange routing information between themselves properly. Three different scenarios are set up and BGP performance is evaluated and compared in each of them.

5.1. Flat BGP Configuration

There are two ASs in this scenario within each IBGP is used and EBGP is used among them. As it is shown in Figure 1, there are many peers in AS 1. The evaluation will show that it impress extensibility, cost and performance of the network.
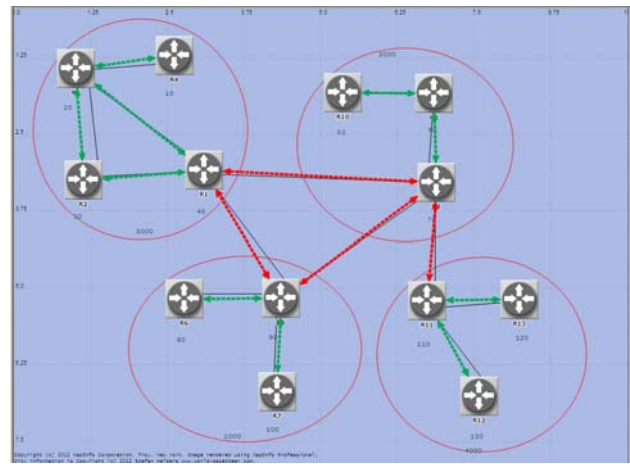

Figure 1. Setting up BGP configuration without RR or Confederation which leads to too many logical peers. Each router is peer to all other routers.

5.2. Confederation Configuration

In this mode AS1 is divided into three and AS2 is divided into two member ASs and each one is assigned a separate member AS number. Peer links in AS1 is reduced so much (Fig. 2) but the member AS routers are yet fully meshed. It would reduce network overhead so much but in the other hand so much cost is spent to replace hardware of routers.
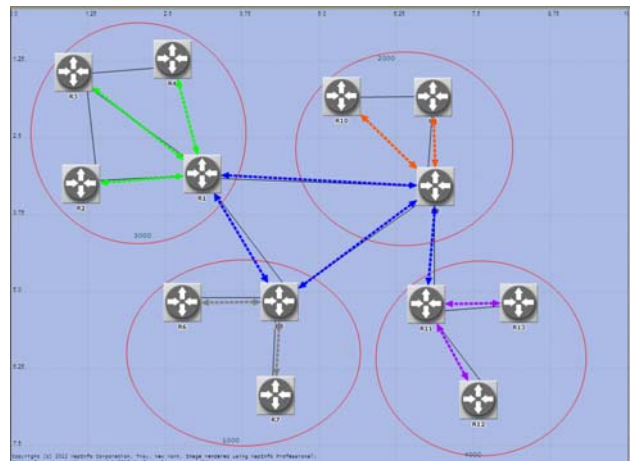
A member AS is located in the center and other member ASs are connected together through central AS. It should be mentioned that peering means that two routers should mention each other in their neighbor tables and know a route to the other end. The route should be advertised to all other neighbors while advertising neighbor table.

Figure 2. Setting up BGP configuration with Confederation and reducing BGP peers.

5.3. Route Reflection Configuration

In this last scenario (Route Reflection) all member ASs have a router as route reflector. All the clients in member ASs are paired to the proper router reflector. RRs between member ASs are fully meshed which is done using RRs (Fig. 3). Route reflection topology has much less cost than confederation, so it is used much more.
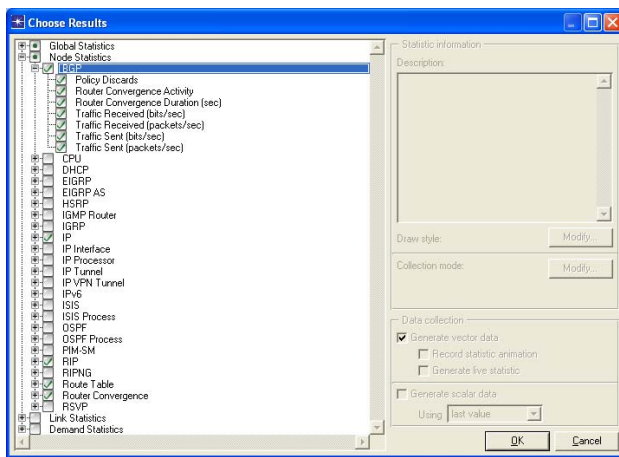

Figure 3. Setting up BGP configuration with Route Reflection.

6. Results and Conclusions

Result field should be set to collect in Manage Scenarios to view the results in one diagram, so we can compare the results of three scenarios. The project results would be shown with selecting Compare Results after running the project.

Average BGP sent traffic for each scenario would be shown by selecting Average and BGP Traffic Sent in Global Statistics. The result for 20 minutes of simulation is shown in figure 4.
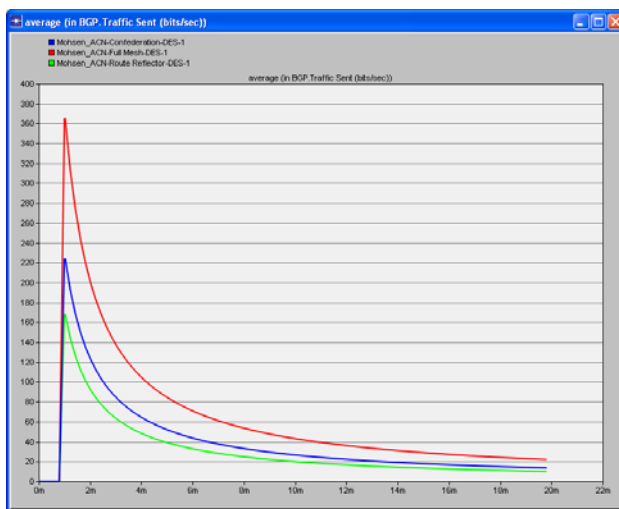
Figure 4. Comparing average BGP sent traffic in three scenarios

Figure 5 shows the convergence time in different routers. It is the time which each of the routers can reach all the networks available in the network. The time varies among the routers but all of them are under 15 seconds. It means that the entire network is fully converged in at most 15 seconds and all the routers can reach all parts of network.

Figure 5. Routers convergence duration

Implementing BGP without RR or Confederation has the most routing traffic overhead as all the speakers should be connected in full mesh manner. This will also increase implementation costs and router processing utilization. But implementing with the functionality of RR or Confederation would decrease these parameters by means of dividing one large AS to some smaller ASs. This will increase overall network throughput by decreasing BGP routing traffic.

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