Islamic University of Technology

CSE 4840

Internetworking Protocols Lab

Lab 4

Comparative analysis on Routing Protocols in ns3

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Contents

1 Task

1.1 Objective

The objective of this lab is to gain practical experience in implementing and comparing different routing protocols available in NS-3. Students will run simulations for various routing protocols and analyze their performance based on key metrics.

2 Introduction to Routing Protocols

2.1 Routing Protocols

Routing protocols are essential components of computer networks, responsible for determining the optimal paths for data packets to travel from a source to a destination. These protocols play a crucial role in ensuring efficient and reliable communication by dynamically managing network routing tables and adapting to changes in network topology and traffic conditions. Depending on the network architecture and requirements, various routing protocols are employed.

2.2 Classification of Routing Protocols

The Routing Protocols can be classified into the following -

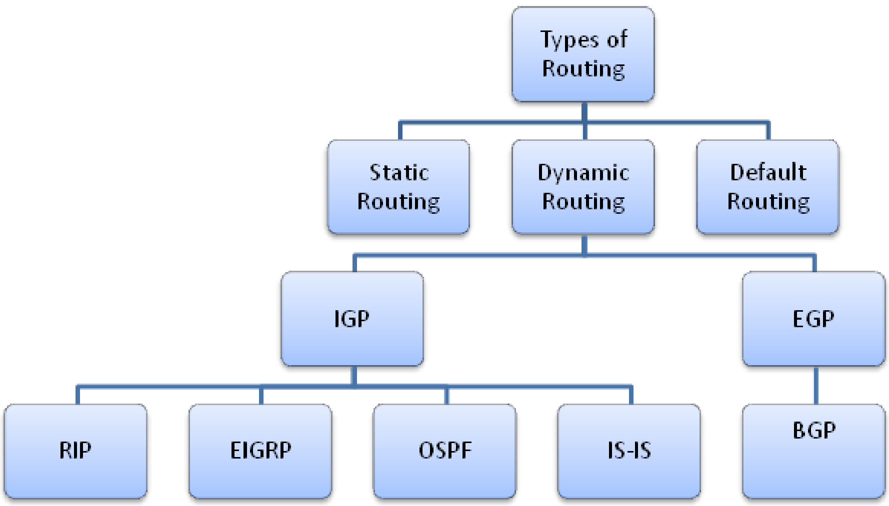

Figure 1: Routing Protocol Classification

3 Routing Protocols

The routing protocols that has been compared for this lab are as follows -

3.1 Static Routing

Static routing is a fundamental technique used in computer networks to manually configure routing tables on network devices, such as routers and switches, to determine the paths data packets should follow to reach their destinations. Unlike dynamic routing, where routing decisions are automatically calculated based on real-time network conditions, static routing involves manually specifying the routes within the network. Administrators configure static routes by defining the next hop or exit interface for each destination network or IP address. These routes remain unchanged unless explicitly modified by network administrators. While static routing offers simplicity and predictable behavior, it lacks the flexibility and adaptability of dynamic routing protocols. Static routes are commonly used in small-scale networks, where the network topology remains relatively stable and predictable, or for specific cases where route stability is preferred over dynamic adjustments. However, static routing may become cumbersome and impractical to manage in larger and more complex networks due to the need for manual configuration and potential scalability issues.

3.2 Global Routing

Global Routing can further be classified into 3 categories -

3.2.1 Simple Global Routing

Simple Global Routing, also known as Static Global Routing, is a routing method where routing decisions are pre-configured and remain fixed unless manually updated. In Simple Global Routing, administrators manually define routes in the network's routers, specifying the path packets should take to reach their destinations. These routes do not change dynamically based on network conditions or changes in topology. Simple Global Routing is straightforward to implement and understand, making it suitable for small networks with stable topologies and predictable traffic patterns. However, it lacks the flexibility and adaptability of dynamic routing protocols, and network changes require manual intervention to update routing tables.

3.2.2 Dynamic Global Routing

Dynamic Global Routing is a routing strategy where routing decisions are made dynamically based on real-time network conditions and changes. In this approach, routers communicate with each other to exchange routing information and update their routing tables accordingly. Dynamic routing protocols such as OSPF (Open Shortest Path First) and RIP (Routing Information Protocol) are commonly used in Dynamic Global Routing. These protocols calculate the shortest path to each destination based on factors like link cost, network congestion, and link availability. Dynamic Global Routing offers scalability and adaptability to network changes, making it suitable for large and complex networks.

3.2.3 Mixed Global Routing

Mixed Global Routing is a hybrid routing approach that combines elements of both dynamic and static routing strategies. In Mixed Global Routing, some routes are dynamically determined by routing protocols, while others are manually configured by network administrators. This approach allows for a balance between the flexibility and adaptability of dynamic routing and the predictability and control of static routing. Mixed Global Routing is often used in networks with varying requirements or where certain routes need to be prioritized or optimized. It offers the benefits of dynamic routing for dynamic network conditions while providing the stability and control of static routing for critical or fixed paths.

3.3 RIP

Two forms of RIP has been shown in this experiment

3.3.1 RIP (Routing Information Protocol):

Routing Information Protocol (RIP) is one of the oldest distance-vector routing protocols used in computer networks. It operates based on the Bellman-Ford algorithm and is commonly used in small to medium-sized networks. RIP uses hop count as its metric to determine the best path to a destination. Each router running RIP maintains a routing table that contains entries for reachable destinations along with their associated hop counts. RIP routers exchange routing updates periodically, broadcasting their entire routing tables to neighboring routers. Upon receiving an update, a router compares the information with its own routing table, updates its entries if necessary, and propagates the changes to other routers. While RIP is simple to configure and deploy, it has limitations such as slow convergence and a maximum hop count of 15, making it less suitable for large or complex networks.

3.3.2 RIPng (RIP Next Generation):

RIPng, also known as RIP version 2 for IPv6, is an extension of RIP designed to support IPv6 networks. It addresses the shortcomings of RIP in handling IPv6 addresses and introduces additional features to support the next-generation Internet Protocol. Similar to its predecessor, RIPng operates as a distance-vector routing protocol and uses hop count as its metric. However, RIPng includes support for IPv6 address families and larger hop counts, accommodating the larger address space of IPv6. RIPng routers exchange routing information using IPv6 multicast addresses, and updates are sent using the UDP protocol. RIPng retains the simplicity and ease of configuration of RIP while providing compatibility with modern IPv6 networks. However, like RIP, it suffers from limitations such as slow convergence and a lack of support for advanced features compared to more modern routing protocols like OSPFv3.

4 Static vs Dynamic Routing

Feature	Static Routing	Dynamic Routing
Configuration	Manual configuration of routes in each router	Automatic route discovery and updates
Scalability	Limited, difficult to manage in large networks	Scales well, suitable for complex networks
Convergence	Slow, requires manual updates after network changes	Fast, automatically adapts to network changes
Flexibility	No real-time adaptation, limited path optimization	Adapts to changing network conditions, optimizes paths
Security	Less vulnerable to routing attacks	May be more vulnerable depending on protocol
Resource Usage	Low resource overhead	May have higher processing and memory requirements
Suitability	Small, simple networks where predictability is important	Large, dynamic networks requiring flexibility and adaptation

5 Flowmonitor

In NS-3 (Network Simulator 3), FlowMonitor is a module used for monitoring and analyzing packet flows within a network simulation. It allows users to track various network metrics such as packet loss, throughput, delay, and jitter for individual flows or aggregated traffic. FlowMonitor is particularly useful for evaluating the performance of network protocols and applications in simulated scenarios. By collecting statistics on packet flows, users can gain insights into network behavior and identify potential bottlenecks or performance issues. FlowMonitor provides a powerful tool for network researchers and developers to assess the effectiveness and efficiency of their designs and algorithms.

5.1 Header File

This is how flowmonitor header is included in a file.

```
#include "ns3/flow-monitor-module.h"
```

5.2 Implementation

```
NS_LOG_INFO("Run Simulation.");
Ptr<FlowMonitor> flowMonitor;
FlowMonitorHelper flowHelper;
flowMonitor = flowHelper.InstallAll();

Simulator::Stop(Seconds(1000.0));
Simulator::Run();

flowMonitor->CheckForLostPackets();
FlowMonitor::FlowStatsContainer stats = flowMonitor->GetFlowStats();
for (auto& flow : stats)
{
    auto& stat = flow.second;
    NS_LOG_UNCOND("Flow ID: " << flow.first << " (" << stat.txPackets
     ↪  << " tx packets)");
    NS_LOG_UNCOND("Packet Delivery Ratio: " << stat.rxPackets * 100.0
     ↪  / stat.txPackets << "%");
    NS_LOG_UNCOND("Average End-to-End Delay: " <<
     ↪  stat.delaySum.GetSeconds() / stat.rxPackets
                                               << "s");
    NS_LOG_UNCOND("Throughput: " << stat.rxBytes * 8.0 /

                                            ↪  (stat.timeLastRxPacket.GetSeconds()
                                            ↪  -

                                             ↪  stat.timeFirstTxPacket.GetSeconds())
                                             ↪  /
                                          1000
                                   << " Kbps");
    NS_LOG_UNCOND("Overhead: " << (stat.txBytes - stat.rxBytes) * 8.0
     ↪  / stat.txBytes * 100.0 << "%");
```

```
}


Simulator::Destroy();
NS_LOG_INFO("Done.");

return 0;
```

In this code snippet, a simulation is run using NS-3 (Network Simulator 3). First, the ‘FlowMonitor‘ module is set up using the ‘FlowMonitorHelper‘, allowing for the monitoring of packet flows within the simulation. The simulation is then run for a specified duration using ‘Simulator::Stop‘ and ‘Simulator::Run‘. After the simulation ends, the ‘FlowMonitor‘ checks for any lost packets using ‘CheckForLostPackets()‘. Flow statistics are then retrieved using ‘GetFlowStats()‘, and for each flow, various metrics are calculated and printed out. These metrics include the flow ID, packet delivery ratio, average end-to-end delay, throughput, and overhead. Finally, the simulation environment is destroyed, and a completion message is logged. Overall, this code snippet demonstrates the process of running a simulation, monitoring packet flows, and analyzing various network performance metrics using NS-3.

6 Result

6.1 Static Routing

Flow ID	Tx Packets	Packet Delivery Ratio	Average End-to-End Delay (s)	Throughput (Kbps)	Overhead
1	13	100%	0.0057344	6.85067	0%

Summary

Average Packets : 13

Average Packet Delivery Ratio : 100

Average End to End Delay : 0.0057344 s

Average Throughput : 6.85067 Kbps

6.2 Simple Global Routing

Flow ID	Tx Packets	Packet Delivery Ratio	Average End-to-End Delay (s)	Throughput (Kbps)	Overhead
1	984	100%	0.0157579	472.153	0%
2	973	100%	0.0157579	472.149	0%

Summary

Average Packets : 978.5

Average Packet Delivery Ratio : 100

Average End to End Delay : 0.0157579 s

Average Throughput : 472.151 Kbps

6.3 Dynamic Global Routing

Flow ID	Tx Packets	Packet Delivery Ratio	Average End-to-End Delay (s)	Throughput (Kbps)	Overhead
1	24	100%	0.002128	1.74096	0%
2	20	100%	0.0153186	2.14628	0%
3	14	100%	0.002128	1.89743	0%
4	10	100%	0.0147083	3.43762	0%

Summary

Average Packets : 17

Average Packet Delivery Ratio : 100

Average End to End Delay : 0.008570725 s

Average Throughput : 2.3055725 Kbps

6.4 Mixed Global Routing

Flow ID	Tx Packets	Packet Delivery Ratio	Average End-to-End Delay (s)	Throughput (Kbps)	Overhead
1	6	100%	0.0167427	0.560364	0%

Summary

Average Packets : 6

Average Packet Delivery Ratio : 100

Average End to End Delay : 0.0167427 s

Average Throughput : 0.560364 Kbps

6.5 RIP

Flow ID	Tx Packets	Packet Delivery Ratio	Average End-to-End Delay (s)	Throughput (Kbps)	Overhead
1	1	100%	0.0143828	51.1722	0%
2	1	100%	0.0153828	47.8456	0%
3	1	100%	0.0153828	47.8456	0%
4	1	100%	0.0073828	99.6912	0%
5	1	100%	0.0064788	187.689	0%
6	1	100%	0.0083828	87.7988	0%
7	1	100%	0.0064788	187.689	0%
8	1	100%	0.0104788	116.044	0%
9	1	100%	0.0145108	94.8259	0%
10	1	100%	0.0064788	187.689	0%

Summary

Average Packets : 1

Average Packet Delivery Ratio : 100

Average End to End Delay : 0.0094868 s

Average Throughput : 146.561975 Kbps

6.6 RIP NG

Summary

Average Packets : 6

Average Packet Delivery Ratio : 100

Average End to End Delay : 0.002433 s

Average Throughput : 828.607 Kbps

Flow ID	Tx Packets	Packet Delivery Ratio	Average End-to-End Delay (s)	Throughput (Kbps)	Overhead
1	1	100%	0.006562	185.309	0%
2	1	100%	0.011594	118.682	0%
3	1	100%	0.007562	160.804	0%
4	1	100%	0.006562	185.309	0%
5	1	100%	0.002433	828.607	0%
6	1	100%	0.007562	160.804	0%
7	1	100%	0.002433	828.607	0%
8	1	100%	0.002433	828.607	0%
9	1	100%	0.002433	828.607	0%
10	1	100%	0.002433	828.607	0%

7 Result Comparison

7.1 Tabular Comparison

The tabular Comparison is as follows -

Routing Protocol	Tx Packets	Packet Delivery Ratio	Average End-to-End Delay (s)	Throughput (Kbps)	Overhead
Static	1	100%	0.006562	185.309	0%
Simple Global	978.5	100%	0.0157579	472.151	0%
Dynamic Global	17	100%	0.008570725	2.3055725	0%
Mixed Global	6	100%	0.0167427	0.560364	0%
RIP	1	100%	0.0094868	146.561975	0%
RIP NG	1	100%	0.002433	828.607	0%

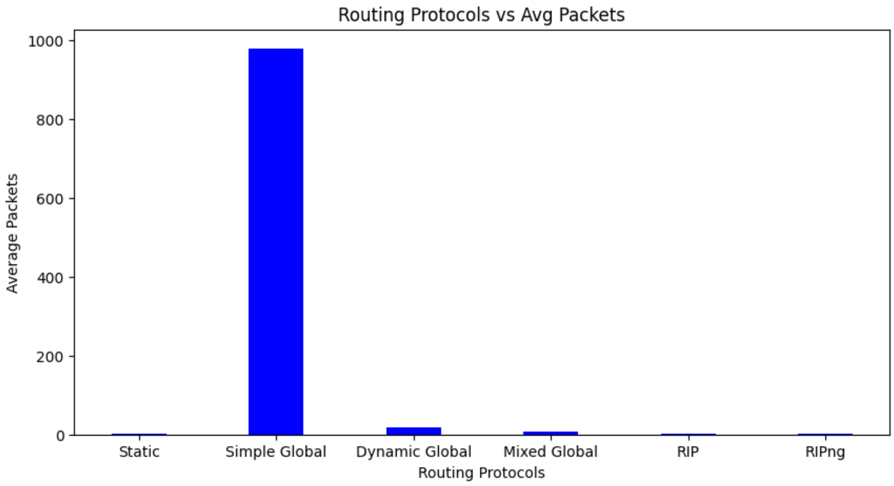

Figure 2: Average Packets Received

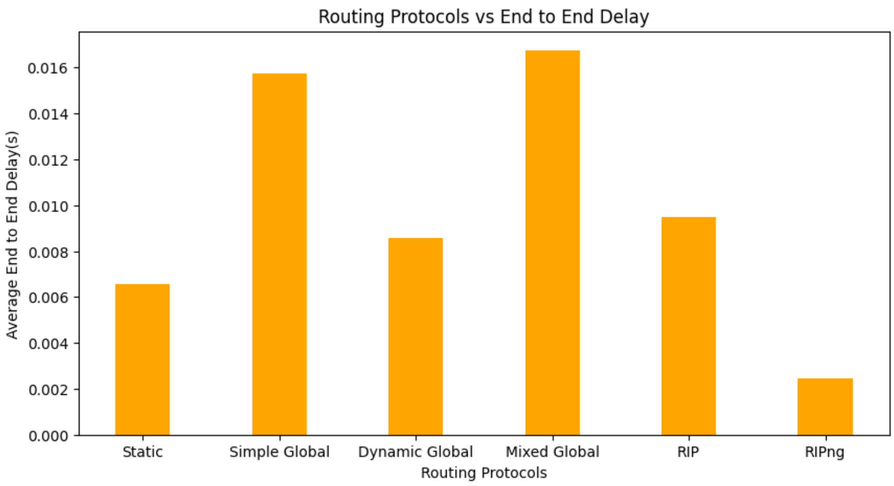

Figure 3: End to End Delay

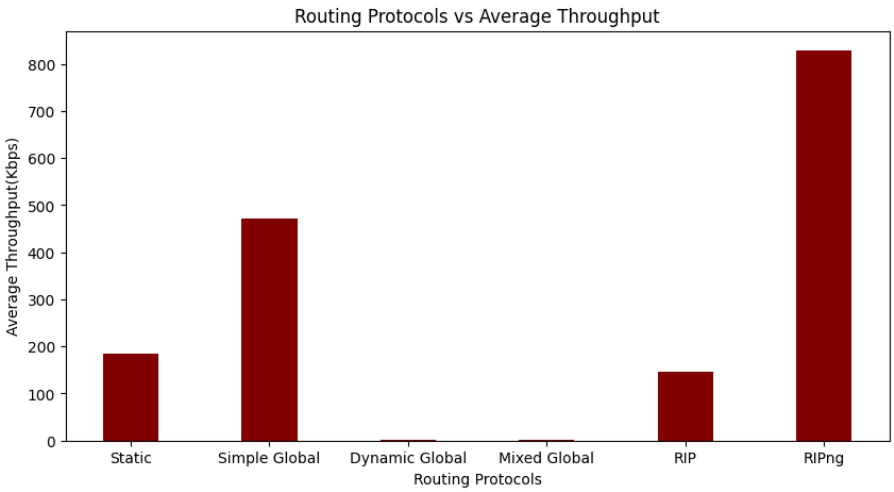

Figure 4: Throughput

7.2 Graphical Analysis

7.2.1 Average Packets Received

7.2.2 End to End Delay

7.2.3 Throughput

8 Result Analysis

- **Packets Received**
  The average packets received in Simple Global protocol may be higher compared to other protocols due to its simple and straightforward nature. In Simple Global routing, each router maintains a single routing table containing all possible destinations in the network, along with the next-hop router to reach each destination. This ensures that packets are forwarded along the shortest path to their destination, minimizing delays and packet losses. Additionally, Simple Global routing does not involve complex algorithms for route calculation or exchange of routing information between routers, resulting in lower overhead and faster packet delivery. As a result, Simple Global protocol may achieve higher packet reception rates compared to other routing protocols, especially in scenarios with low network congestion and stable topology.

- **End to End Delay**
  The end-to-end delay in routing protocols is influenced by several factors, including the network topology, routing algorithm, and traffic patterns. In the case of Simple Global and Mixed Global routing protocols, the end-to-end delay may be higher due to the following reasons:

  Topology Changes: Simple Global and Mixed Global routing protocols rely on periodic exchange of routing updates between routers to adapt to changes in the network topology. When there are frequent changes in the network, such as link failures or additions of new routers, these protocols may take longer to converge and update their routing tables, leading to increased end-to-end delays. Route Calculation Complexity: In Simple Global and Mixed Global routing protocols, routers need to calculate routes to all destinations in the network based on the global view of the network topology. This calculation process may be more complex compared to other routing protocols, especially in large-scale networks with a high number of routers and destinations, resulting in higher end-to-end delays.
  Routing Overhead: The overhead associated with exchanging routing updates and maintaining routing tables can contribute to increased end-to-end delays in Simple Global and Mixed Global routing protocols. As routers exchange routing infor-

mation frequently to ensure consistency across the network, this overhead can add latency to the packet delivery process. On the other hand, the end-to-end delay may be lower in RIPng and static routing protocols for the following reasons:

Simplicity: RIPng and static routing protocols are simpler compared to Simple Global and Mixed Global protocols. They typically involve less complex route calculation algorithms and require minimal routing table updates, leading to lower end-to-end delays.
Fast Convergence: RIPng and static routing protocols often converge more quickly in response to changes in the network topology. Since these protocols do not rely on exchanging routing updates across the entire network, they can adapt to topology changes more efficiently, resulting in shorter end-to-end delays.

- **Throughput**
  RIPng typically achieves the highest throughput due to its efficient convergence and dynamic routing mechanisms. Simple Global routing may have slightly lower throughput compared to RIPng due to increased overhead associated with maintaining a global view of the network. Static routing, while simple and predictable, may offer lower throughput compared to dynamic routing protocols due to its lack of adaptability and optimization capabilities.

9 Attachments