Simulation and Analysis of BGP Policies in ns-3

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Abstract

This report investigates the real-world BGP (Border Gateway Protocol) connectivity of IIT Delhi and simulates BGP-like routing behavior using the ns-3 network simulator. Three scenarios were studied: a baseline linear routing setup, an enhanced configuration with a direct high-capacity link between source and destination, and a policy-driven setup mimicking BGP's Local Preference mechanism. The analysis reveals how technical metrics and administrative policies influence routing paths across Autonomous Systems (ASes) and highlights the resulting impact on traffic flow and symmetry in inter-domain networks. All referenced screenshots and simulation logs are provided within the respective folders submitted alongside this report. Additionally, XML files containing the results for both simulation and animation have been generated and are included with the report folder.

Part 0: Background Research – IIT Delhi's BGP Connectivity

Before beginning any simulation work, an analysis was conducted of IIT Delhi's actual BGP connections using public monitoring tools. By examining data on `bgp.he.net`, it was determined that IIT Delhi (AS132780) primarily connects to the global Internet through the NKN core network(AS55824) then National Knowledge Network (AS9885) and the National Informatics Centre (AS4758)government of India network. These organizations, in turn, connect to major upstream ISPs such as Airtel(AS9498), Tata(AS4755), and Jio(AS55836), forming a multi-level broadcast and transit hierarchy: IIT Delhi is connected to NKN/NIC, which relay traffic to major ISPs, who finally connect to the wider Internet.

A screenshot illustrating IIT Delhi's upstream BGP providers is included in the `figures` folder. (See screenshot in submitted folder.)

Part A: Baseline Simulation – Simple Linear Topology

Implementation

The first scenario modeled a basic linear topology consisting of three Autonomous Systems: AS1, AS2, and AS3. These ASes were connected in a line (AS1–AS2–AS3) with no direct link between AS1 and AS3. Each link was configured with **10 Mbps bandwidth** and **2 ms delay**. A UDP echo client was set up on AS1 and a server on AS3 to generate test traffic.

Results and Analysis

Simulation logs, provided as screenshots within the folder, confirmed that packets traveled exclusively via AS2. The observed round-trip delays were around 5–6 milliseconds, consistent with the sum of the 2 ms link delays per hop plus processing time. (Refer to the appropriate log screenshot in the designated folder.)

Part B: Introducing a Direct High-Capacity Link

Implementation

A parallel direct link between AS1 and AS3 was introduced with **15 Mbps bandwidth** and **1 ms delay**, surpassing the baseline link's capacity and latency. This allowed the routing protocol in the simulation to evaluate a faster, lower-latency path in addition to the original AS1–AS2–AS3 route.

Results and Analysis

Following recalculation of routes, simulation logs showed traffic shifting to the AS1–AS3 direct link, bypassing AS2. This demonstrated the routing protocol's preference for path selection based on improved performance metrics such as bandwidth and delay. (Screenshots are available in the folder.)

Part C: Policy Preference – Mimicking BGP's Local Preference

Implementation

In this scenario, a policy-based routing preference was enforced on AS1 to mimic BGP's Local Preference attribute. Although the direct AS1–AS3 link offered higher bandwidth and lower latency, a static route was configured on AS1 to force all outgoing traffic destined for AS3 to traverse AS2. This manual route override ensured that forward traffic followed the AS1 $\rightarrow$ AS2 $\rightarrow$ AS3 path, reflecting an administrative decision to prefer a particular provider despite the availability of a faster link.

Results and Analysis

The simulation logs confirmed that forward traffic from AS1 to AS3 strictly followed the AS1 $\rightarrow$ AS2 $\rightarrow$ AS3 path as per the policy. However, since no static route or policy was set on AS3, return traffic naturally took the shortest and fastest path directly from AS3 to AS1. This resulted in asymmetric routing—a common real-world characteristic caused by differing local policies among Autonomous Systems. (Screenshot demonstrating this behavior is included in the submitted folder.)

Files Provided

- All screenshots showing BGP connectivity and simulation log outputs are organized within the appropriate folders that accompany this report.
- XML files generated from ns-3 representing both the animation and simulation results are also included in the submitted report folder for further reference and reproducibility.

Conclusion

This investigation began by mapping the real-world BGP connectivity of a major institution, showing how connectivity is layered through academic and governmental networks to large ISPs. Simulations demonstrated:

- Baseline routing where packets follow the only available AS1–AS2–AS3 path (10 Mbps, 2 ms links).
- Introduction of a faster direct link (15 Mbps, 1 ms delay) causes routing to shift to that path.
- Policy-enforced static routing overrides performance optimization, resulting in asymmetric paths.

The provided screenshots and XML files support these conclusions and allow external verification.

References

- RIPEstat public analytics
- BGP Looking Glass (https://bgp.he.net)
- ns-3 Documentation (https://www.nsnam.org/documentation/)