Routing Concepts and Protocols

Tommaso Liardo
Edinburgh Napier University
40452307
CSN09113

I. Introduction

When an extremely large amount of ASs (Autonomous Systems) that are owned and controlled by different entities (companies, institutions, ISPs) is connected to each other, the Internet is created.[1]

Now picture yourself on holiday. You're visiting the city centre and decide it would be a very good moment to buy a postcard to send to a relative. Once ready, you'd probably have two possible delivery services available: one that is often a bit more expensive but is faster as it takes the shortest possible path, and one that is less expensive but may take a few extra days to arrive. In the end you will choose the solution that best suits you. On the Internet, networking devices make this choice every day to share information with other networking devices.

This choice is called "routing", and it relies on the many routing protocols that exist to choose the best possible path depending on which is employed.

Each Autonomous System manages its own internal routing using intra-domain protocols (RIP, OSPF, IS-IS, EIGRP), and then connects to the public Internet using an inter-domain protocol (BGP).

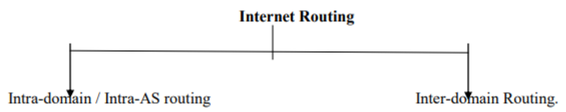

Figure 1. Internet Routing

OSPF and EIGRP are known as the leading IGP protocols, but IS-IS is more widely used by ISPs thanks to its large scalability. BGP is the only EGP protocol currently viable and as such is the official routing protocol used by the Internet.[2]

In section II I will review the main theoretical concepts and protocols that I've learned during this year, in section III I will briefly summarize the different design principles discussed over the course of this module, and finally in section IV I will conclude with my personal opinion regarding the future of the internet.

II. Theoretical Review

A. IP Addressing

The Internet has to face an incredibly difficult issue: scaling. This issue takes two forms:

- The exhaustion of IPv4 addresses
- The growth of routing tables

Both problems were initially cushioned with the introduction of classless routing (CIDR), which uses a more flexible and less wasteful scheme for addressing. This allowed route aggregation (which helped to vastly reduce the size of routing tables) and thus reduced the overall overhead. Later on, a new solution was presented: the IPv6 Protocol, which completely solved the first problem by increasing the address size to 128bits, while also offering some solutions for the second problem.

B. Routing protocols

As previously stated, routing protocols are divided into two main categories: intra-domain protocols (IGP) and inter-domain protocols (EGP). An IGP protocol can be one of two types:

- Link-State: These protocols use the Djikstra algorithm to calculate the best possible paths, and then routers share information regarding their connected links to all of the other routers in the network. OSPF and IS-IS are most used link-state protocols.
- Distance-Vector: These protocols calculate the shortest path using the Bellman-Ford algorithm, usually using the distance as metric. Routers will then share the entire routing table only to connected neighboring routers. EIGRP and RIP are two examples of distance-vector protocols.

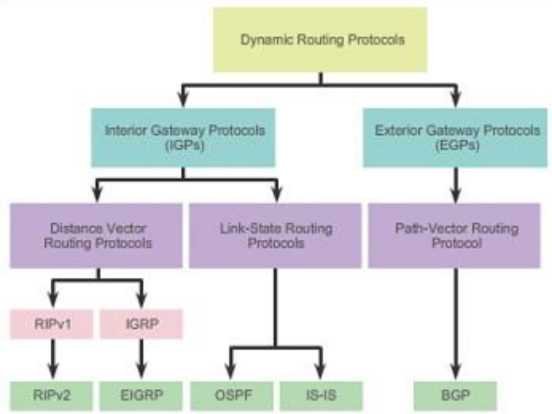

Figure 2. Hierarchical view of routing protocols [2]

C. IS-IS

The Intermediate System to Intermediate System protocol is widely used by Internet Service Providers because of its better scalability, stability and because it is simpler. It has a lot in common with OSPF as it divides the domain into smaller areas, finds neighbors through Hello packets and exchanges information through Link State Packets.

D. OSPF

The Open Shortest Path First protocol was originally designed to replace RIP by improving the convergence time. It establishes adjacencies by sending Hello packets and sharing updates periodically through LSAs. Even though it offers the possibility to break down large networks into smaller areas for easier management, it does not offer a good scalability because as the network grows and routers are added into the network, the risk of routing loops increases as well.

E. RIP

It is one of the oldest routing protocols. Routers that use the Routing Information Protocol will send a copy of their routing table once every 30 seconds to all of their adjacent routers, while also sending updates every time a metric changes. RIPv2 was introduced later to support VLSM.
It is supported by most routers and fairly easy to configure, but has slow convergence time and high bandwidth usage.

F. EIGRP

It is a hybrid protocol as it has traits of both types. Enhanced Interior Gateway Routing Protocol will only send updates when there is a change, reducing overhead. It uses a particular algorithm (DUAL) to update and has a larger hop count compared to RIP, which makes it a more suitable choice for larger networks.

G. BGP

The Border Gateway Protocol is the only current EGP used by the Internet. It is a vector protocol mainly designed to exchange routing information between ASs. It uses TCP to ensure reliable delivery, supports CIDR and uses multiple metric to ensure the best possible path. However, it may be easy to misconfigure (or to attack).

III. Practical Reflection

A. IP Multicast

It refers to a method of communication where data is sent to a specific group of receivers. It is widely used by multimedia applications (such as streaming, conferences, etc.) as it doesn't require to know in advance the number of receivers nor their identity. In order to be successfully implemented it requires: A multicast group address, a mechanism to handle the joining and leaving of members inside a group, a multicasting routing protocol to create a delivery tree, and a transport protocol to create and manage the data that is distributed during sessions. The main protocols used are IGMP, DVMRP, MOSPF, PIM-DM/PIM-SM.

B. Mobile IP

Mobile IP was designed by the IETF to allow users to move from one network to another while maintaining their permanent "Home Address" that was assigned to them in their home network.
A node will send data to a mobile device. The data contains the node's source address, and the device's Home Address as its destination, but the mobile devices has just moved from its home network to a new one. When the device connected to a new network, the Foreign Agent of that network assigned it a Care-of Address and sent it to the device's Home Agent. This establishes a tunnel between the Home Agent and the Foreign Agent, and when the Home Agent receives data directed to the mobile device, it will forward it to the Foreign Agent in order for the latter to deliver it to the mobile device.

C. Redundancy

Redundancy is a crucial component for any network that desires to ensure high availability. Its presence aims to protect against single points of failure.
At Layer 3, it works by keeping routing services available even if a device fails. This can be achieved through different protocols depending on the needs. These protocols include: IRDP, HSRP, VRRP and GLBP.
IRDP works by sending router advertisement broadcast through every interface it is set. Then host receiving such advertisement may change their routing tables and adapt to a new gateway.
HSRP and VRRP are very similar as a group of routers will share one virtual IP address and one virtual MAC address. The main difference is that HSRP is a Cisco proprietary protocol while VRRP is an IETF standard protocol, but HSRP is more commonly used due to the vast presence of Cisco devices. GLBP is similar to VRRP and HSRP, but offers load balancing by sharing multiple MAC addresses instead of one and thus sharing the traffic.

IV. Conclusion

The future still holds many challenges for the Internet. In a world that is beginning to care and search solutions for the global warning and carbon footprint there is no place for an Internet infrastructure that produces already 3.5% of all carbon emissions (almost twice the amount produced by the airline industry) and that is predicted to grow even more by 2030.
Another great challenge is to overcome the trust crisis that affects the Internet after the many proved exploitations of internet weaknesses operated by governments all around the world. Finally, the last important challenge is to build new protocols that can replace the current ones offering more scalability (solving the routing tables issue) and offering a better security through encryption. The Next Generation Internet program is trying to rebuild the Internet during the next few years with these goals in mind [3], and these problems *must* be addressed otherwise the Internet risks collapsing and that could have catastrophic consequences for society as a whole.

References

[1] L. Gao, J. Rexford, "Stable Internet Routing Without Global Coordination", IEEE/ACM Transaction on Networking, Vol. 9, No. 6, 2001

[2] "Cisco Networking Academy's Introduction to Routing Dynamically", ciscopress.com, 2014

[3] M. Leenaars, C. Valayer, C. Peyralbe, K. Billeskov, M. Gauw, "Next Generation Internet 2025", 2018