INGI2141
Project : Implementation of a Link-State Router

1 Introduction

This project has two objectives: program a simple network application using the Socket API, and deepen the mechanisms behind a link-state IGP.

The project consists in programming a router that uses a simple Link-State protocol to compute its routing table. You can use the programming language you feel more comfortable with (Java, Python or C). At the end of the project, an interoperability session will be organized, in order to check that the routers are able to communicate with each other.

2 Description of the project

2.1 Router

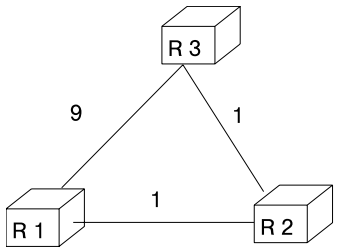
A router is a device acting at the network layer. It serves as a relay for the transmission of packets from a source to a destination. In this project, the router will be implemented as a Java software. Transmissions lines between routers will be simulated using UDP Sockets. The router must be able to discover the topology of a network composed of similar routers, thanks to the routing protocol described in the rest of this document. They must also build their routing table, and be able to route data packets sent by any router of the network to any router in the same network.

Each router is identified by a unique ASCII string, representing its name. A configuration file with the following format is attached to each router (assuming that it has N neighboring routers).

```
[Router name]
[Local UDP port number]
[Neighbor1 name] [Neighbor1 IP] [Neighbor1 UDP port] [Link cost]
...
[NeighborN name] [NeighborN IP] [NeighborN UDP port] [Link cost]
```

All link costs are positive integers.

An example configuration is shown in Figure 1.




```
R1
30000
R2 130.104.78.8 31000 1
R3 130.104.78.37 30000 9

R2
31000
R1 130.104.78.8 30000 1
R3 130.104.78.37 30000 1

R3
30000
R2 130.104.78.37 31000 1
R1 130.104.78.8 30000 9
```

Figure 1: Example of network topology

2.2 Routing protocol

The Link-State routing protocol presented in this section will allow routers to build their routing tables via the exchange of information describing the state of their links. Each router sends messages to all of its neighbors. Those messages are used to gather information about the network topology and share this information with all the other routers in the network.

We now describe the types and format of messages to be used in the protocol.

- **HELLO** : Used to discover active neighbors (adjacency establishment). Hello messages are PERIODICALLY sent to all neighbors, every `HELLO_DELAY` seconds. `HELLO_DELAY` is a constant that must be configurable at startup. The default value of seconds between two consecutive HELLOs (`HELLO_DELAY`) is 5.
  - The format of HELLO messages is: `HELLO [Sender Name] [Receiver Name].` For example, an HELLO sent by a router R1 to a router R2 must be compliant with format "HELLO R1 R2".
- **LSP** : Link-State Packet, used to inform routers of the state of network links such that they can build their routing table. A router generates an LSP whenever : i) A link becomes active or inactive; ii) The last LSP emitted by the router has been generated since more than `MAX_LSP_DELAY` seconds. `MAX_LSP_DELAY` is a constant that must be configurable at startup. Its value is 60 by default.
  - The format of LSP messages is: `LSP [Sender Name] [Sequence Number] [List of Adjacent Active Links].` Each link in the *List of Adjacent Active Links* is represented by a pair (`[Neighbor] [Cost of the Link]`). Inactive links are not included in the LSP. For example, "LSP R1 12 R3 9 R2 1" is the LSP message sent by router R1, with sequence number 12, that specifies that R1 (the sender) has two adjacent active links, one with R3 with cost of 9, and another with R2 with cost of 1. Note that R1 can have other adjacent inactive links, but they are not specified in the LSP.

The sequence number is a string of two characters. When an LSP is generated, its sequence number must be greater (modulo the limitation in the number of characters in it) than the one of the previous LSP. Each router keeps track only of the last received LSP from each neighbor, that is, each router discards all the previous LSPs from one neighbor when it receives a new LSP from the same neighbor.

- **LSACK** : Acknowledgement of LSP packets, used to enforce the reliability of LSP message exchange. To prevent routers from having incoherent descriptions of the network topology, each received LSP must be acknowledged. If an LSP has not been acknowleged on an interface for more than 5 seconds after it was sent, it must be retransmitted on that interface.
  - The format of LSACK messages is: `LSACK [Router Name] [Sequence Number].` For example, "LSACK R1 12" is the LSACK message that acknowledges the reception of LSP 12 originated by router R1. Observe that each router has to keep track of the interface from which each acknowledgement is received in order not to retransmit the LSP on the wrong interface after the expiration of the 5 second timeout.

All messages are represented as ASCII strings. Note that integers (e.g., link costs) must also be encoded as strings.

2.3 Building the routing table

In order to build a map of the network topology, each router must maintain a link state database (LSDB). This database contains the most recent link state packets (i.e. with the higher sequence number) generated by each router of the network.

When a router generates a link state packet, it starts by adding it to its LSDB, then transmits the packet to all its neighbors. It also keeps a reference of this transmission until it is acknowledged by each neighbor.

When a router receives a LSP, it first checks if that packet is already in the LSDB. If not, it is added in the database, then transmitted to all neighbors. It also keeps the reference of the transmission time on each interface for that packet.

The LSDB is used to build the routing table of the routers in the three-steps process described in the following.

1. Transform the database into a directed graph with routers as nodes and network links as weighted links. A link is only considered in the graph if it is bidirectional (2-way Connectivity Check), i.e., both routers connected to the link announced it in their LSP.

2. Use Dijkstra Algorithm to build the shortest path tree rooted at the router[1].

3. For each destination in the network (i.e., any other router), store the next-hop on the shortest path to the destination in the routing table.

To simplify the project we assume that, in case of multiple shortest paths between one source and one destination, each router selects only one next-hop towards each destination.

The routing table is then a data structure containing an entry for each router in the network. Each entry specifies the destination and the next-hop to which data packets have to be forwarded.

For example, in the topology of figure 1, the routing table of R3 must contain the following two entries:

[1] Existing software libraries can be used for graph representation and implementation of the Dijkstra algorithm.

- R1 : via R2
- R2 : via R2

2.4 Data Packets

The routing table described in the previous paragraph is used by router to forward data packets to their destination.

A data packet has the following format : `DATA [Source Name] [Destination Name] [Message]`

Observe that DATA is the identifier of data packets, "[Source Name]" and "[Destination Name]" are the identifiers of the original source and destination of the messages (not changed by intermediate routers traversed by the message), and "[Message]" is a string of maximum 300 characters representing the content of the data packet.

When a router receives a data packet, it first checks if the destination is itself. If yes, the packet is at destination and the content is for example displayed in the console. If not, the packet must be forwarded towards its destination. If no entry in the routing table matches the destination of the packet (like for a `Destination Unreachable`), then the router shows an error message on the console ("[Destination Name]: Destination Unreachable") and discards the packet.

3 Recommended steps

As with any implementation project, you should of course start with the design of the global architecture. Take a few days to carefully think about the number of threads you need, the classes that you will implement and the relations between the different objects. Once you have a clear idea of what your application will look like once finished, you should start implementing incrementally.

In order to facilitate this implementation process, you are suggested to follow four implementation steps:

3.1 Exchanging data packets with the neighbor

First, you should focus on the communication between your router and its neighbors. Once you have parsed the configuration file and opened your communication socket, you should be able to exchange UDP datagrams with the configured neighbors. For now, focus on neighbor-to-neighbor exchanges of data packets.

When receiving data, you should first verify that the UDP datagrams are valid, i.e. they come indeed from a valid neighbor and their content respects the format given in section 2.4, then display the content of the message in a console.

Also, if you want to check the sending capability of your router, you should provide an interface such that a human can ask the router to send a message to some other router. Typically, this interface will be a command line with a syntax like : `send [Router Name] [''message'']`. For example, if the administrator of R1 wants to send a message to R2, it will type `send R2 ''Hi R2, I'm R1''`.

Also, you should already implement control packets in case of forwarding error (e.g., `Destination Unreachable`).

3.2 Data packet forwarding

Now that your router is able to send and receive data packets from its neighbors, you should focus on the forwarding of data packets that are not destinated to the local router. You will then need a routing table to find to which neighbor you will forward the data packet such that it will finally reach its destination. For the moment, build a static routing table that you configure manually, and check that your router is able to route messages to distant destinations.

3.3 Managing routing protocol messages

Once the router is able to route data packets, it is time to consider the routing protocol itself. Add the protocol control messages to your implementation (`HELLO`, `LSP` and `LSACK`), and implement the corresponding behavior. You will have to build a Link State Database and maintain different information about the received protocol control packets.

Don't forget to carefully test each new functionality (LSP reception, acknowledgement, retransmission...), for example by displaying in a console the received/sent messages and the corresponding actions.

3.4 Dynamic management of the routing table

Now that you are able to exchange information about link states with all routers of the network, you will build the routing table from the LSDB. This step is already detailed in subsection 2.3. You are allowed to reuse existing code for your graph representation and for computing the shortest path trees, of course at the condition that you provide your source. Data structure libraries are referenced in section 4

4 Bibliography

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