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Routerlab SoSe 2018
Worksheet 8: Intra-Domain Routing (OSPF)

The purpose of this worksheet is to continue to work on Intra-Domain Routing. In particular, the Open Shortest Path First (OSPF) protocol is used as an example. The goal is to understand the difference between distance vector routing protocols and link-state routing protocols and their respective advantages and disadvantages.

Configurations must be grouped per-question and submitted in your response.
The basic network topology for this worksheet is the same as the one you developed in the previous worksheets in terms of VLANs, except that we are now in addition using the direct links between, on the one hand, aac-rc1 (cgn-rc1, lev-rc1) and aac-rj2 (cgn-rj2, lev-rj2) and, on the other hand, aac-rj2 (cgn-rj2, lev-rj2) and aac-rj1 (cgn-rj1, lev-rj1). These form the basic connectivity between network elements and should be replicated as seen in the diagram:

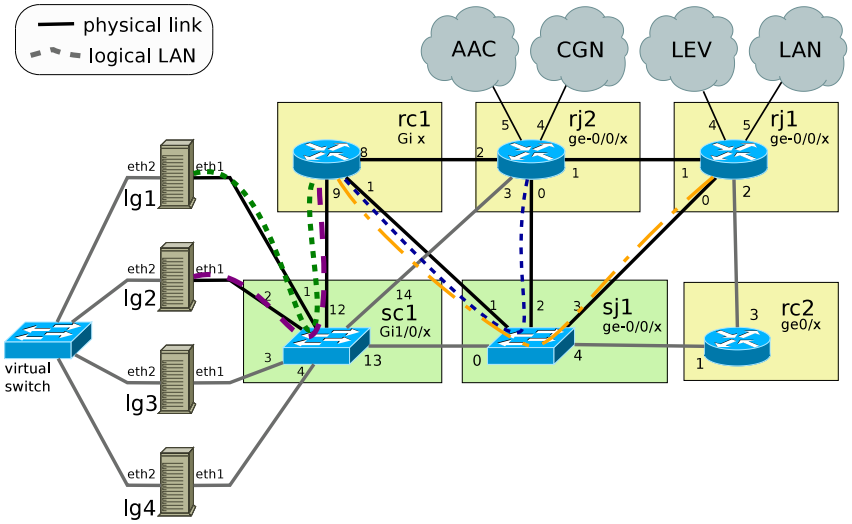

Figure 1: Topology: Mapping of VLANs to physical links.

Table 1: Device and Address Overview

Cloud	Aachen	Köln	Leverkusen
Router	aac-rc1, aac-rj1, aac-rj2	cgn-rc1, cgn-rj1, cgn-rj2	lev-rc1, lev-rj1, lev-rj2
Switches	aac-sc1, aac-sj1	cgn-sc1, cgn-sj1	lev-sc1, lev-sj1
IPv4 range		10.Z.0.0/16	
Loadgens		groupX-lg1,2	
VLAN IDs	$Z0 - Z9$		

Note: Replace X with the number of your group with leading zero, e.g., $X = 03$ for group 3. Replace Y with the number of your group without leading zero and use hex encoding, e.g., $Y = 3$ for group 3 and $Y = a$ for group 10. Finally replace Z with the decimal group number without leading zero, e.g., $Z = 3$ for group 3.

Question 1: (10 Points) *Open Shortest Path First (OSPF)*

OSPF belongs to the class of link-state routing protocols. For more information on OSPF, please have a look at RFC 2328 (https://www.ietf.org/rfc/rfc2328.txt).

a) Which entities exchange routing information (DD packets)?
b) When are LSA messages sent?
c) How do routing entities detect that a neighbor is not reachable anymore?
d) Does OSPF suffer from the "Count-to-Infinity" problem like RIP? Explain your answer briefly (2-3 sentences).
e) What is the main advantage of link-state routing protocols? (1-2 sentences)
f) What is a possible disadvantage of link-state routing protocols? (1-2 sentences)

Read Section 4.3 "Routing Protocol Packets" and Section 4.4 "Basic Implementation Requirements"of RFC 2328 and answer the following questions:

g) Does OSPF rely on a transport protocol such as TCP or UDP?
h) What types of packets does OSPF define and when are they used?
i) What types of LSAs does OSPF define?

In OSPF, the routing updates are propagated by a procedure called *reliable flooding*. Read the first two paragraphs of Section 13 in RFC 2328.

j) How is flooding made reliable?

Question 2: (10 Points) *OSPF: Calculating the Routing Table*

OSPF uses the information in the Link State Database to calculate the routing table using Dijkstra's algorithm. If you missed the tutorial and are not familiar with this algorithm, there is plenty of information in the Web (even with cool animations). For simplicity, we assume that if two paths have equal lengths, the path over the shortest IDs (compared from destination to source) is preferred.

Figure 2 shows a simple topology where each router is identified by one IP address (for simplicity we don't consider interfaces) and the cost of each link is written in the middle of the arc connecting the routers. Compute the shortest-path tree for `10.1.1.1` toward every possible destination using the simple version of the algorithm *from the tutorial slides*.

a) Show each iteration of the algorithm with the same notation used in the tutorial (in form of a simple table or well-structured ASCII).
b) Once the algorithm has finished, write down the routing table (for node `10.1.1.1`), again in the same format as in the tutorial (in form of a table or well-structured ASCII).

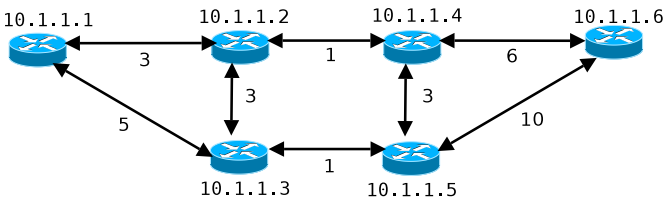

Figure 2: Simple network example.

Question 3: (30 Points) *OSPF: Basic Configuration*

Take the basic topology from the previous worksheet (including configured VLANs and IP addresses). Here we assume that you already created the same *VLANs* and that you have reset (deleted) the previous RIP configuration and any static routes on the routers and the loadgens. Please ensure that each link in the topology is assigned a subnet from within your defined subnet range. Make sure to include all links in your topology map. Make also sure that the loadgens *groupX-lg1* and *groupX-lg2* are configured according to the new topology, i.e., that static routes are added in order to reach all configured subnets.

Now, instead of using RIP to make these *subnets* communicate, we will use OSPF. Manuals explaining how to configure OSPF with Cisco and Juniper devices can be found at

http://www.cisco.com/c/en/us/support/docs/ip/open-shortest-path-first-ospf/7039-1.html

(pdf at http://www.cisco.com/c/en/us/td/docs/ios-xml/ios/iproute_ospf/configuration/12-4t/iro-12-4t-book/iro-cfg.pdf)

and

https://www.juniper.net/documentation/en_US/junos12.3/information-products/pathway-pages/config-guide-routing/config-guide-ospf.html

(pdf at https://www.juniper.net/documentation/en_US/junos12.3/information-products/pathway-pages/config-guide-routing/config-guide-ospf.pdf),

respectively.

Configure OSPF on all routers respecting the following:

- Create one single area with ID `0.0.0.0`.[1]
- Do not assign OSPF costs yet.

After convergence, aac-rc1 (cgn-rc1, lev-rc1), aac-rj1 (cgn-rj1, lev-rj1), and aac-rj2 (cgn-rj2, lev-rj2) in the network should have a route towards each subnet you configured.

a) Perform a traceroute from *groupX-lg1* to the interfaces of the routers and *groupX-lg2*. Same with *groupX-lg2* as source and the interfaces of the routers and *groupX-lg1* as destination. Provide the traceroute output for each case in your response.

b) Which routes does aac-rc1 (cgn-rc1, lev-rc1) have in its routing table to reach the subnet formed by aac-rj1 (cgn-rj1, lev-rj1) and aac-rj2 (cgn-rj2, lev-rj2)? Provide the routing table output in your response.

c) What total costs do these routes have? Read Section 2.4 and 16.8 of RFC 2328 and explain. (4-6 sentences)

[1] Areas can be specified either as a decimal value or in IPv4 address representation format.

Question 4: (30 Points) *OSPF: Neighbor Discovery, Link-State Database*

In this question, we study how OSPF routers get to know their neighbors and how they learn about the topology. The topological information is kept in the *link-state database* in the form of so-called *Link State Advertisements* (LSAs).

Based on the OSPF configuration in the previous question, study the Link State Database of aac-rc1 (cgn-rc1, lev-rc1) and aac-rj2 (cgn-rj2, lev-rj2):

a) Which LSAs (IDs and types) are currently in the database? Explain. Provide a trace of the database on both routers in your response.

Whenever an OSPF neighborhood between two routers is established, the two routers have to synchronize their LSAs. We will now study which packets are exchanged in such a situation. For this purpose, enable detailed monitoring for OSPF traffic on aac-rj2 (cgn-rj2, lev-rj2), using the following command:

```
monitor traffic interface ge-0/0/2 detail
```

and enable debugging mode for OSPF adjacencies on aac-rc1 (cgn-rc1, lev-rc1). Now, temporarily disable the interface Gi9 on aac-rc1 (cgn-rc1, lev-rc1). Wait a few seconds until aac-rc1 (cgn-rc1, lev-rc1) and aac-rj2 (cgn-rj2, lev-rj2) have noticed that the link is "broken".

Finally, activate the interface Gi9 again and observe both the debug output and the traffic monitor. Answer the following questions and provide the debugging output from both devices in your response:

b) Which OSPF packet types do you see in which sequence?

c) Which LSA headers (LSA IDs) does aac-rj2 (cgn-rj2, lev-rj2) send to aac-rc1 (cgn-rc1, lev-rc1) within *database description packets*?

d) Are complete LSAs exchanged between aac-rc1 (cgn-rc1, lev-rc1) and aac-rj2 (cgn-rj2, lev-rj2)? If yes, which LSAs (LSA IDs)?

e) Read Section 10.3 "The Neighbor state machine" of RFC 2328. What is the evolution of the adjacency state that you can observe on the output of the debugging mode of aac-rc1 (cgn-rc1, lev-rc1)? Explain. (2-4 sentences)

Question 5: (20 Points) *OSPF: Costs and Routing Hierarchy*

OSPF has a much more flexible management of link costs compared to RIP. On aac-rc1 (cgn-rc1, lev-rc1), configure OSPF for the link aac-rc1 (cgn-rc1, lev-rc1) – aac-rj1 (cgn-rj1, lev-rj1) with a cost of 100.

a) Perform another traceroute from *groupX-lg1* to the interface ge-0/0/1 of aac-rj1 (cgn-rj1, lev-rj1) and provide the output. Briefly explain why your measurement is (not) affected by the cost increase.

b) Which routes does aac-rc1 (cgn-rc1, lev-rc1) have in its routing table to reach the subnet formed by aac-rj1 (cgn-rj1, lev-rj1) and aac-rj2 (cgn-rj2, lev-rj2)? Provide the routing table output and briefly explain the differences to the output in question 3.b.

OSPF supports a hierarchical routing scheme through the use of OSPF areas. Each OSPF area is identified by a 32-bit Area ID. Read Section 3, 3.1, 3.2 and 3.3 of RFC 2328. Answer the following questions:

c) Which ID is used for the backbone area?

d) Is it possible for the path on which a packet travels to span four areas? Explain why or why not.

e) How can routers be classified in terms of their role w.r.t. areas in OSPF?

Activate or deactivate links, modify routing rules and change your OSPF and VLAN configurations (e.g., switch on ge-0/0/3 on aac-rj2 (cgn-rj2, lev-rj2)) such that the following three different areas are created (Note: maintain the cost of 100 from aac-rc1 (cgn-rc1, lev-rc1) to aac-rj1 (cgn-rj1, lev-rj1)):

- Area `0.0.0.0` consists of the networks aac-rc1 (cgn-rc1, lev-rc1)/aac-rj2 (cgn-rj2, lev-rj2), and aac-rc1 (cgn-rc1, lev-rc1)/aac-rj1 (cgn-rj1, lev-rj1).
- Area `0.0.0.1` consists of the networks aac-rj2 (cgn-rj2, lev-rj2)/aac-rj1 (cgn-rj1, lev-rj1), and aac-rj1 (cgn-rj1, lev-rj1)/*groupX-lg2*.
- Area `0.0.0.2` is formed by the network aac-rj1 (cgn-rj1, lev-rj1)/*groupX-lg1*.

f) Which route is selected by aac-rc1 (cgn-rc1, lev-rc1) to *groupX-lg1*?

g) Why is this route selected by aac-rc1 (cgn-rc1, lev-rc1) to *groupX-lg1*?

h) What are the ABRs in this configuration?

i) Study the routing table and Link State Database of aac-rc1 (cgn-rc1, lev-rc1) (you have to provide a trace for both in your response). Which LSA types can you see now (compared to question 4.d) and why?

OSPF areas allow to reduce the routing state that needs to be kept in individual areas. The idea is that certain details of an area are not visible in other areas. However, there is another way to further reduce this state: Aggregation. *Area Border Routers* (ABR) can aggregate prefixes in order to reduce the number of prefixes announced. First configure area `0.0.0.2` as area `0.0.0.1` (so we have only two areas now). Then configure the ABRs such that only aggregated prefix ranges (i.e., `10.x.0.0/16` rather than `10.x.x.0/24`) are announced from area `0.0.0.1` to area `0.0.0.0`. For this purpose, take a look at "`area-range`" in the documentation.

j) Which route is selected by aac-rc1 (cgn-rc1, lev-rc1) to *groupX-lg1*? Is it different from question 5.f)? (Provide the output of traceroute in your response.) Explain the reason for what you observe. (2-3 sentences)

Submission details (more in ISIS):
Please submit an archive (.tar.gz or .zip) containing a *directory*, which contains all files you want to submit. Please have *your group number* in the file name and the directory name.
A report (one single PDF file, named *worksheet(num)-group(num).pdf*) containing the following elements is mandatory:

- Your group number on the first page
- Topology map with relevant routers, switches, *loadgens*, and interfaces, IPs and subnet masks (CIDR).
- For each question, the written answers with the **relevant** portions of output from all commands such as ping, tcpdump, etc in a text format. **No** screenshots of terminal windows are accepted. For ping 3-4 lines of ping requests are usually sufficient.
- For each question all commands needed to configure the *loadgens*.
- For each question all **changed parts** in the configuration of routers and switches (differences to the default config).
- **Never** include the full verbatim switch or router configuration in the pdf report.
- For all questions, state your assumptions, say what you did, describe what you observed, explain your conclusions.

Additionally, please include your config files in the archive.
For each question, please provide the full switch and router configuration in a separate text file named after the device and question, e.g.: *q01-config-sc1.txt*. This makes it easier for us to reproduce your configuration and understand what you did.
We can only grade what we find in your submission and what we understand. Please state your assumptions and observations as clearly as possible.
Due Date: 28.06.2018 till 11:55 PM