EPFL
9th semester DSC course

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LCA

Mid-term exam "Réseaux et Mobilité"

Duration: 2 hours. Authorized documents: Lecture notes and Lab reports.

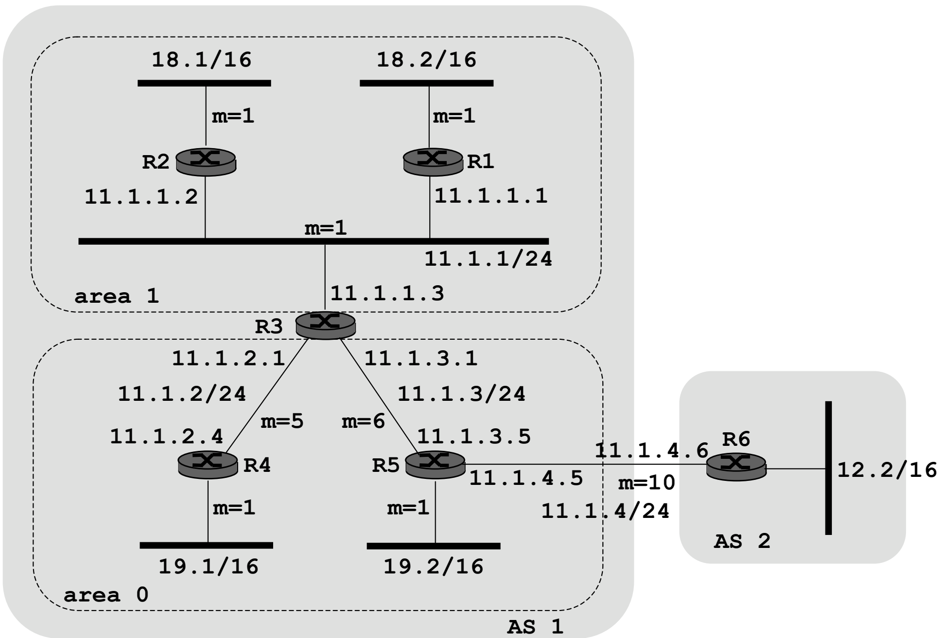
Family name:

Frist name:

1 OSPF

Consider an example network presented in Figure 1. It is composed of several routers, the figure gives the IP addresses of their interfaces and prefixes for stub networks. Links have metrics denoted by `m`. `AS 1` runs OSPF as IGP routing protocol. Router `R5` learns through BGP the information about the networks in `AS 2` and injects it into `AS 1`. Area `1` is not a stub area.
Give all advertisments either generated or transmitted by `R3`: fill in the table below. `area` column should indicate the area to which an advertisment is sent. Use `other` column to provide any information that does not fit otherwise.

Figure 1: Example OSPF network



Solution:

area	LS-type	LS-id	adv. router	link id.	link data	link type	metric	other
1	1-rtr	11.1.1.3	11.1.1.3	11.1.1.3	11.1.1.3	2-transit	1	R3 is Desig. Rtr.
0	1-rtr	11.1.1.3	11.1.1.3	11.1.2.4	11.1.2.1	1-p-to-p	5	
0	1-rtr	11.1.1.3	11.1.1.3	11.1.3.5	11.1.3.1	1-p-to-p	6	
1	2-net	11.1.1.3	11.1.1.3				1	mask 255.255.255.0 att-rtr 11.1.1.3 att-rtr 11.1.1.2 att-rtr 11.1.1.1
0	3-sum	11.1.1.0	11.1.1.3				1	mask 255.255.255.0
0	3-sum	18.1.0.0	11.1.1.3				2	mask 255.255.0.0
0	3-sum	18.2.0.0	11.1.1.3				2	mask 255.255.0.0
1	3-sum	11.1.2.0	11.1.1.3				5	mask 255.255.255.0
1	3-sum	11.1.3.0	11.1.1.3				6	mask 255.255.255.0
1	3-sum	19.1.0.0	11.1.1.3				6	mask 255.255.0.0
1	3-sum	19.2.0.0	11.1.1.3				7	mask 255.255.0.0
1	4-sum	11.1.3.5	11.1.1.3				6	
1	5-ext	12.2.0.0	11.1.3.5				10	mask 255.255.0.0 fwd address 0.0.0.0

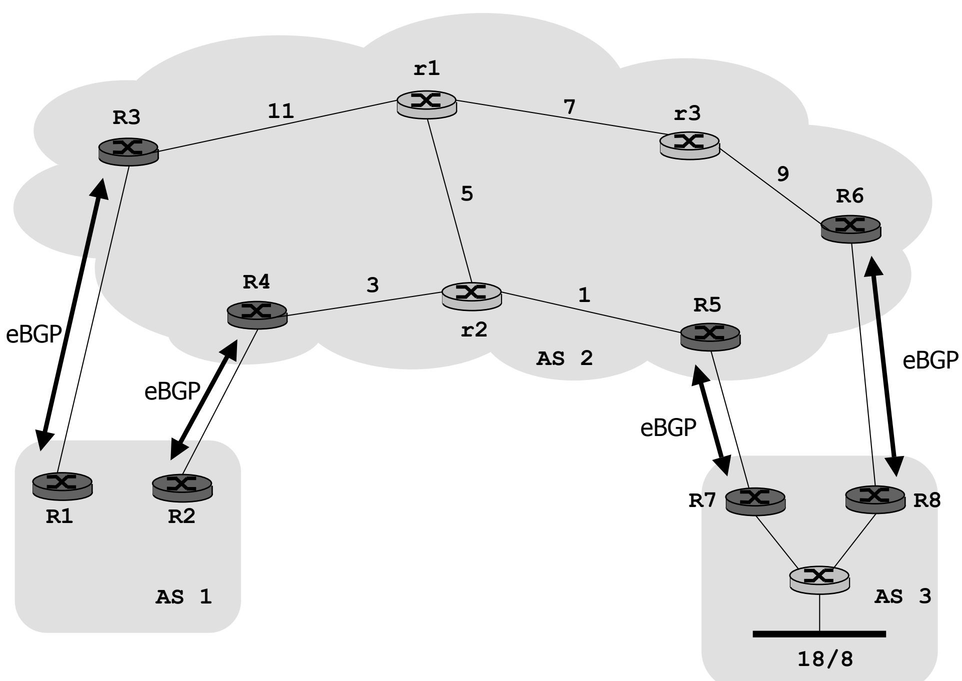
2 BGP

Consider an example network presented in Figure 2. All three AS use an IGP routing protocol such as OSPF (link metrics are given in the figure). All border routers maintain internal iBGP sessions.

Assume that AS 3 advertizes network 18/8 to AS 2 at only one exchange point via its border router R7. AS 2 learns the route from AS 3 via its border router R5. In turn AS 2 advertizes network 18/8 to AS 1 through its two border routers R3 and R4. In an effort to limit burden of transit traffic on its infrastructure, AS 2 always wants traffic flowing from AS 3 to AS 1 to take the shortest path trough its network.

- Explain how AS 2 can achieve this goal using BGP, more specifically—what should it advertize via eBGP to AS 1?
- Give an example of BGP advertisements by R3 and R4.

Figure 2: Example BGP network



Solution:

AS 2 can dynamically map the MED value on eBGP routes based on the IGP metric for the iBGP path to the preferred border router for each route.

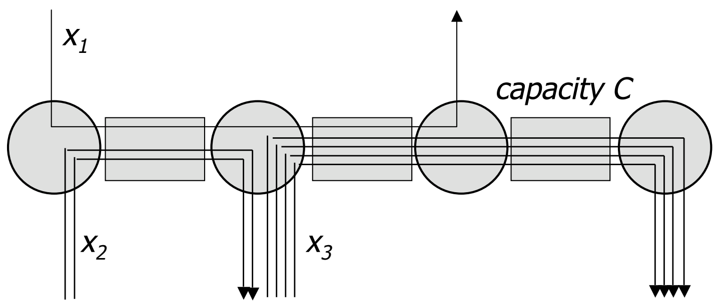
router	NLRI	ORIGIN	NEXT_HOP	AS_PATH	MED
R4	18/8	I	R4	2 3	4
R3	18/8	I	R3	2 3	17

3 Congestion control

Consider the network presented in Figure 3. We have six sources: one source with rate x_1, two sources with rate x_2, and three sources with rate x_3. Each of the links has the same capacity C.

1. Compute x_i assuming that the rates are distributed according to the max-min fairness.
2. Compute x_i assuming that the rates are distributed according to the proportional fairness.

Figure 3: Example network with flows



Solution.

1. max-min fairness:
   $x_1 = C/5$, $2x_2 = C - C/5 = 4C/5$, $x_2 = 2C/5$, $x_3 = C/5$
2. proportional fairness:
   $x_1 + 2x_2 = C$, $x_1 + 4x_3 = C$, so we can maximize the function:
   $f(x_1) = ln(x_1) + 2ln((C - x_1)/2) + 4ln((C - x_1)/4)$
   and we obtain:
   $x_1 = C/7$, $x_2 = 3C/7$, $x_3 = 3C/14$

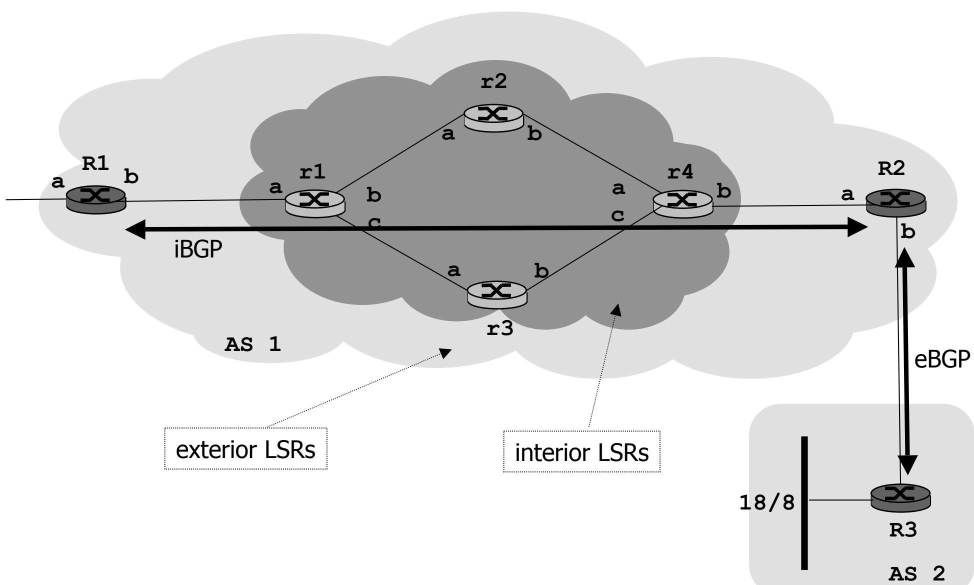
4 MPLS

Consider an Autonomous System `AS 1` that carries transit traffic between other Autonomous Systems using MPLS (cf. Figure 4). Its network consists of two "classes" of LSR: exterior LSRs (e.g. `R1` and `R2`) that interface to other networks, and interior LSRs (e.g. `r1, r2, r3, r4`) that carry traffic between exterior LSRs. Suppose that the exterior LSRs are BGP speakers. We want to deliver the transit traffic from an exterior LSR to another exterior LSR by the interior LSRs. We suppose that BGP speakers use an extension to BGP that allows to distribute a label for an address prefix.

Consider the case in which router `R1` has BGP route information about prefix `18/8` with `NEXT_HOP` attribute set to router `R2`. `R2` binds label L_1 to prefix `18/8` and passes this information to `R1` via iBGP. We assume that an IGP protocol provides required information about routing inside `AS 1`—the route to `R2` goes through `r1, r2, r4`.

- Describe how to set up a LSP inside the `AS 1` MPLS network to forward the traffic to `18/8`.
- Give the switching tables at `R1, r1, r2, r4`, and `R2`.
- Give the MPLS encapsulation along the LSP path of a packet arriving at `R1`.

Figure 4: Example MPLS network



Solution:

- Describe how to set up a LSP inside the AS 1 MPLS network to forward the traffic to 18/8.

  We need a hierarchial LSP with two levels of MPLS labels: one between R1 and R2, and a second one for the set of the interior LSRs. The two level LSP works as follows. R1 knows the label with which a packet should arrive at R2—it is L_1. If R1 wants to send the packet to R2, it needs to use a LSP going through the interior LSRs. Assume that the IGP next hop for the address of R2 is r1. r1 has bound label L_2 to the address of R2 (this label is distributed to R1 by standard LDP). Then before sending the packet to r1, R1 must create a label stack for the packet, then push on label L_1, and then push on label L_2. L_2 is used to go through the set of the interior LSRs. The last interior LSR r4 pops the label stack and uses L_1 to forward the packet to R1.

- Give the switching tables at R1, r1, r2, r4, and R2.

- Give the MPLS encapsulation along the LSP path of a packet arriving at R1.

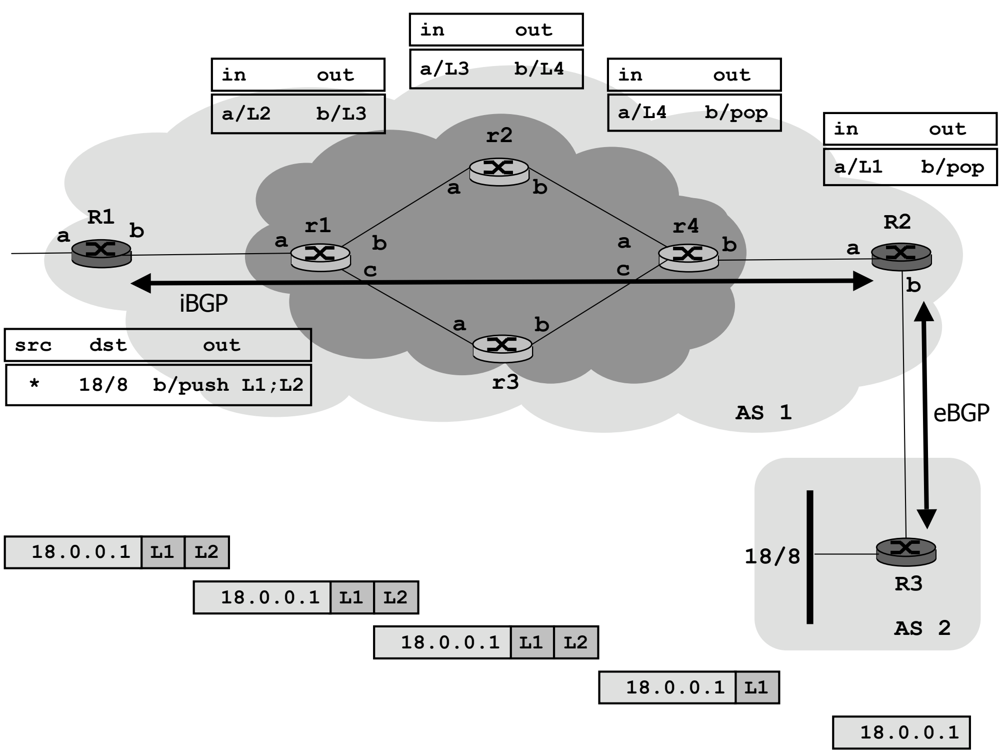


Figure 5: Switching tables and encapsulation