Test 1: NET3012 – IP Architectures & Solutions

Winter 2018

Time: 80 minutes; Test scored out of: 60 Total Marks available: 65
(Allocation of marks is shown beside each question)

Instructions:

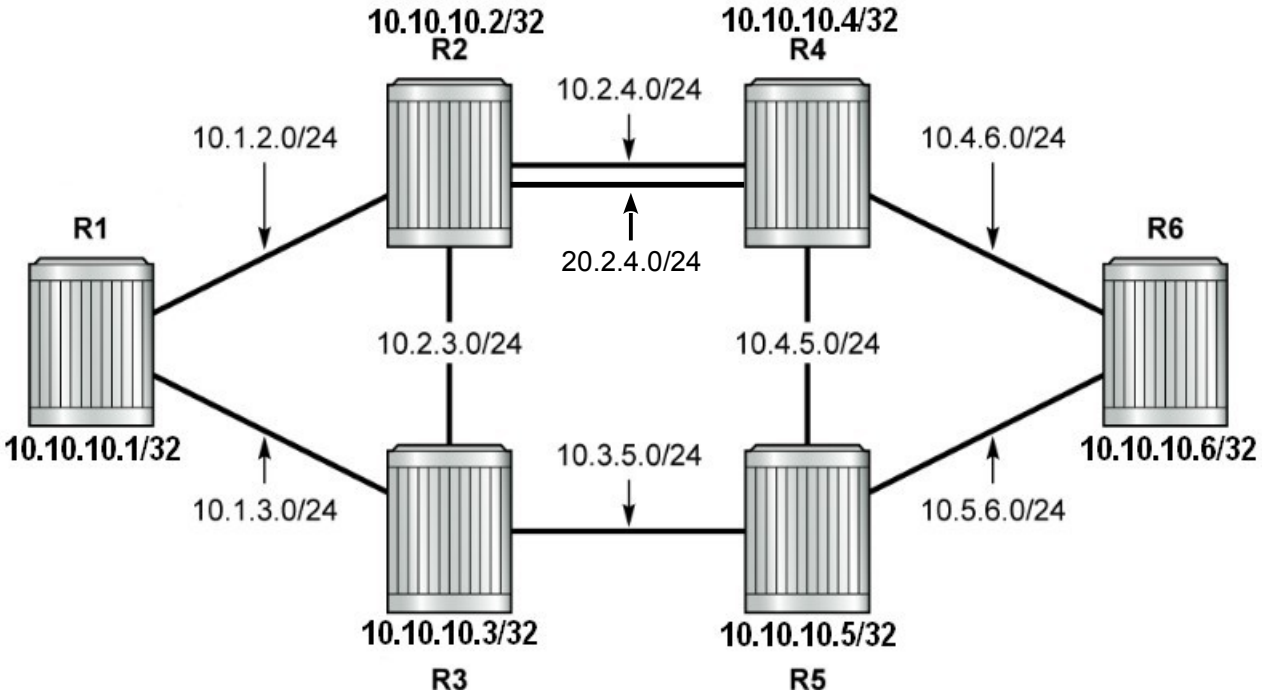
1. BEFORE answering any questions, please check that your copy of the test has all pages (as indicated in the footer at the bottom of each page). Please **read all questions** carefully, then answer question 0 first!
2. This is a **closed book** test. No textbooks, notes, electronic devices, or any other aids are permitted.
3. Recall from NET1002 that PDU means Protocol Data Unit.
4. Be sure to carefully examine the reference topology provided below.
5. If you are uncertain what a question is asking, make reasonable assumptions, write those assumptions down on this test paper, and continue answering the question.

0. What is your:

NAME? Answers

Reference Topology

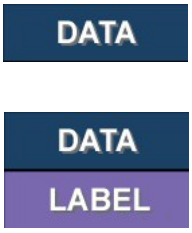
Use the topology below for questions which refer to R1-R6 but do **not** have a topology diagram. Note that this is similar to the topology used throughout the MPLS courseware and slide decks.



1. A. [6 marks] Imagine three routers which implement a Label Switched Path.
Using the diagrams of the routers provided below:

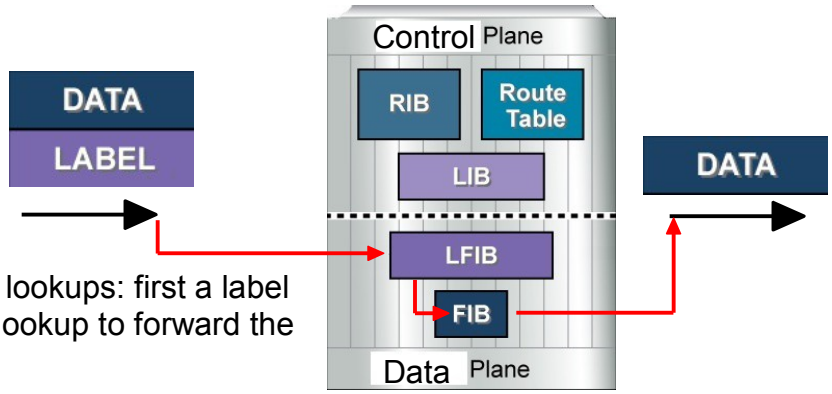
- ☐ clearly identify which *type of PDU* ingresses and which *type of PDU* egresses (i.e. re-draw them at each location where they should be!)
- ☐ clearly illustrate the flow of the frame *through* the router (i.e. which tables are used to process the frame), according to the role labeled for each router. (Ref: Mod 1.39-40)

Sample PDU Types

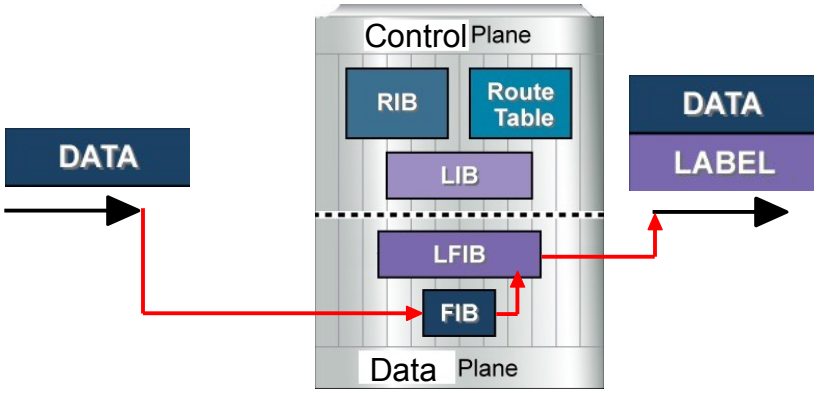


"MPLS egress router performs two lookups: first a label lookup, and then an IP forwarding lookup to forward the unlabeled packet" NRS-II, p. 505

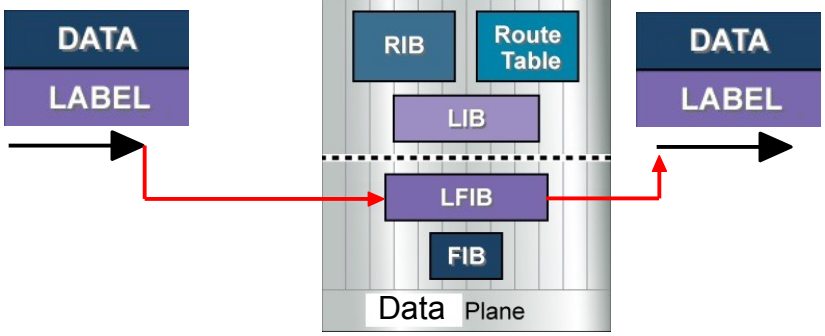
eLER (Label op = Pop)



iLER (Label op = Push)



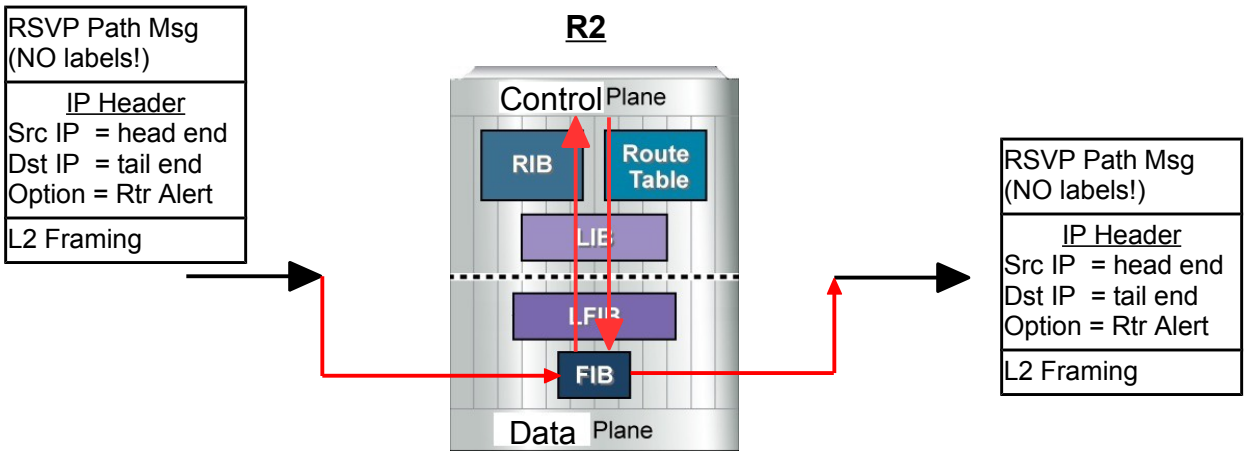
LSR (Label op = Swap)



B. [2 marks] Next, clearly label the different **planes** for each of the three types of routers.

C. [1 mark] Lastly, clearly label the type of label operation that's occurring at each router.

2. A. [2 marks] Similarly to the previous question, clearly identify the flow of a ***PATH message*** through a MPLS router. Ref: Module 4.18, 20, 21



B. [2 marks] Assuming the *PATH message* is sent by R1 to R6:
- ☐ draw a simple sketch of the ingress packet and egress packet in the correct locations;
- ☐ clearly identify actual values of key fields (and any important options) in the IP header, and any label values (if appropriate).

3. [1 mark] Clearly identify which protocol(s) contribute information that is used to populate the LFIB.

[1 mark; all-or-nothing] LDP and RSVP

4. A. [1 mark; all-or-nothing] So far in the course, we've treated "FEC" as equivalent to a IPv4 subnet but the definition given in the course materials has three aspects to it. The full, proper definition for a FEC is "a group of frames/packets that are forwarded ..."

a. in the same manner

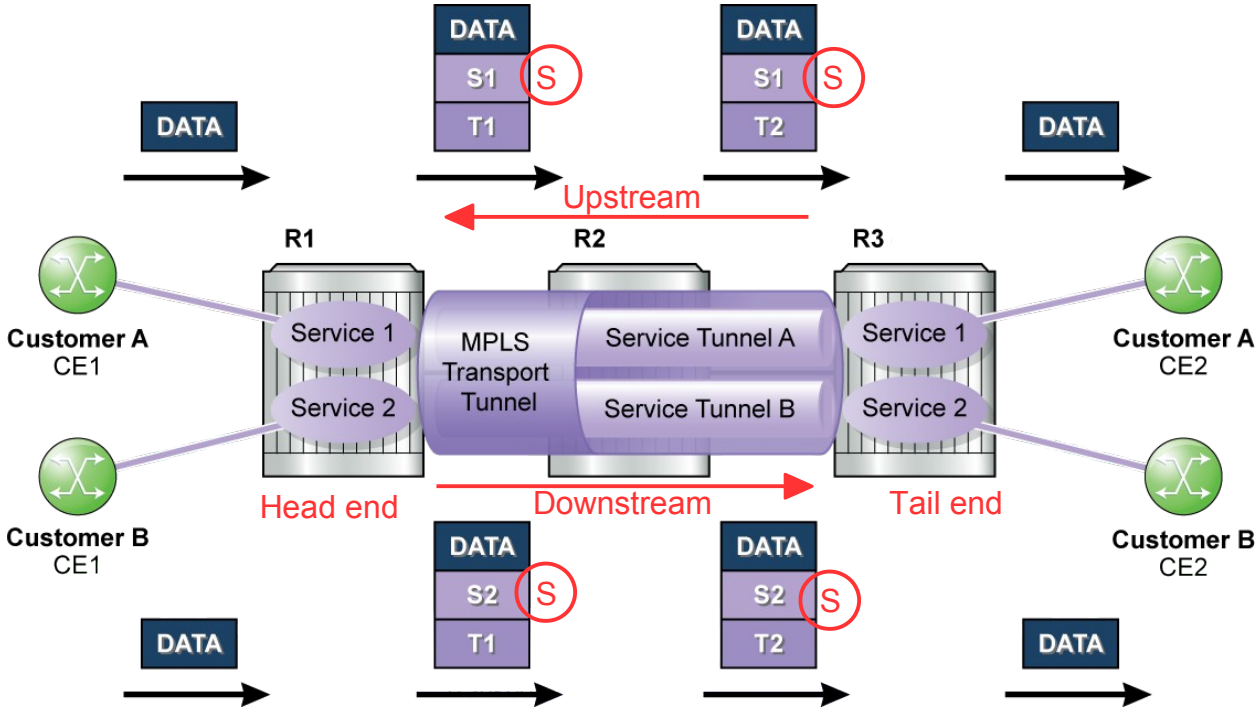
b. over the same path

c. with the same forwarding treatment

B. [1 mark] A key distinction between *pure IP routing* and *MPLS label switching* is **where** [*at which router(s)*] FEC lookup is done. (Ref: Mod 1.30-31)

- For IP routing, where is FEC lookup done? at ***every*** router
- For MPLS label switching, FEC lookup is done only at the iLER

5. Carefully examine the diagram below of a Service Provider network (adapted from Mod 2.7)



A. [1 mark] Clearly identify the following terms by *labeling the diagram* appropriately:
☐ Downstream, Upstream
☐ Head end, Tail end (assuming RSVP for this one item)

B. [1 mark] Use an "S" to clearly mark all labels with the "S" bit set.

C. [1 mark] What *exact* protocol(s) could have been used to distribute:

service labels: t-LDP/MP-BGP transport labels: LDP, RSVP

D. [2 marks] How were the labels distributed? Give full details below. Include all possible routers and protocols, as appropriate. **BE CAREFUL; many students don't read the Q!**

Label S1: distributed by R_3_ to R_1_ using protocol(s) t-LDP

Label S2: distributed by R_3_ to R_1_ using protocol(s) t-LDP

Label T1: distributed by R_2_ to R_1_ using protocol(s) LDP, RSVP

Label T2: distributed by R_3_ to R_2_ using protocol(s) LDP, RSVP

E. [2 marks] Assuming a VPN with Traffic Engineering, list *all* the labels that were sent:

Downstream on Demand: T1, T2 Downstream Unsolicited: S1, S2

Ordered Control: all Independent Control: none

Liberal Retention: S1, S2 Conservative Retention: T1, T2

F. [1 mark] Assuming a VPN with Traffic Engineering, how many additional "**T**" labels *must* exist (if any)? # of extra labels = 0

6. [3 marks]
A. Within an LSR in a **L1** MPLS VPN service running over ethernet, what is the *minimum* and *maximum* total number of L2 headers that could appear in a PDU?

Minimum: __2_____ Maximum: _____2_____

B. Within an LSR in a **L2** MPLS VPN service running over ethernet, what is the *minimum* and *maximum* total number of L2 headers that could appear in a PDU?

Minimum: __2_____ Maximum: _____2_____

C. Within an LSR in a **L3** MPLS VPN service running over ethernet, what is the *minimum* and *maximum* total number of L2 headers that could appear in a PDU?

Minimum: __1_____ Maximum: _____1_____

7. [4 marks] Did you completely understand our lab work with LSPs and TTL values? If yes, read these next questions carefully so that you can give the correct answer!

A. Clearly explain what property of OAM commands makes it possible for **`oam lsp-trace`** and **`ping`** to show a different number of hops?

OAM command tests only the outbound *LSP*; responses are routed back via the *IGP*

B. Clearly explain what property of LSPs makes it possible to have a different number of hops between a **`traceroute`** command and a **`ping`** command?

LSPs are unidirectional, so outbound path (traceroute) isn't tied to return path (ping)

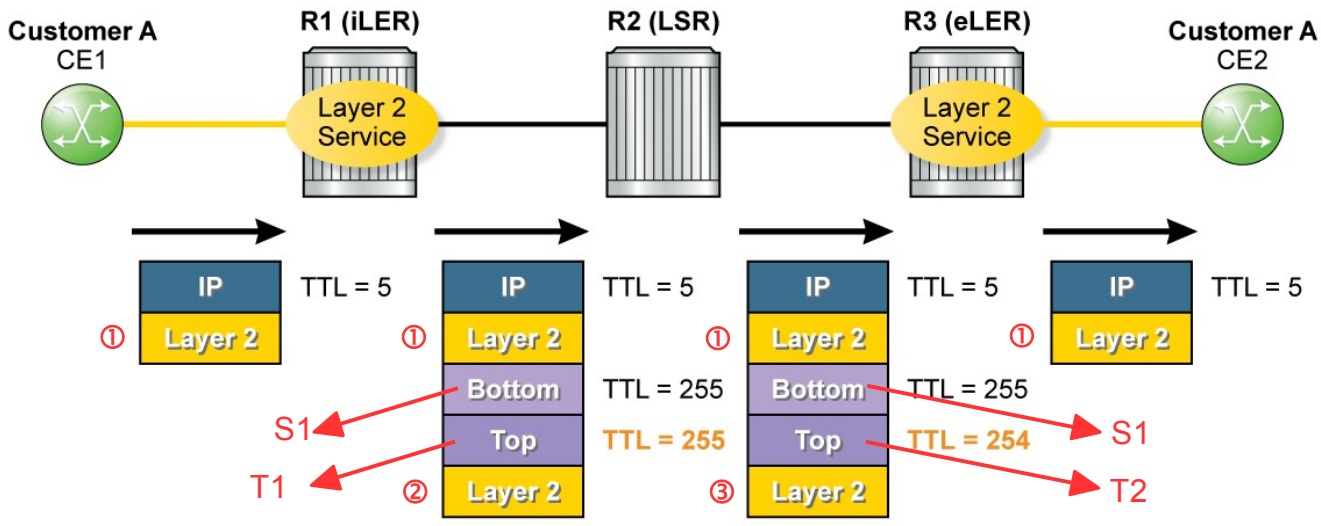
C. Clearly explain what *two* commands (or parameters) act as on/off switches to influence the number of hops seen by **`traceroute`** and **`ping`** commands?

IGP shortcuts (**`configure router ldp-shortcuts`**)
Pipe vs Uniform mode (**`config router ldp shortcut-local-ttl-propagate`**)

D. Clearly explain the difference (or give example usages) between using OAM commands to test an LDP LSP vs a RSVP LSP?

LDP LSPs require the keyword "prefix" and a /32 (IPv4) target
RSVP just uses the LSP name

8. A. [4 marks] The course notes give clear, specific diagrams showing how customer data frames are handled by L2 & L3 services in Pipe mode, and L3 services in Uniform mode. They omit any diagram of L2 services operating in uniform mode. Prove your knowledge and understanding of MPLS by completing the diagram below for a *L2 service in Uniform mode*. Be sure to show all: ☐ L2 headers [1 mark] ☐ L3 headers [1 mark] ☐ Labels [1 mark] ☐ TTL values. [1 mark]



There is **no** difference to customer PDUs between pipe & uniform mode for L2 services!! This is simply the figure from Module 2.17

B. [2 marks] Use symbols (e.g. ①, ②, ③, …) to mark all L2 headers. Use the *same symbol* if/wherever headers are identical.
[1]Customer framing ① is preserved; [1] other framing ②, ③ is unique to each segment

9. [1 mark] Consider only routers R2-R5 of the reference topology (cover page). Assume LDP is fully and correctly configured on all four routers. In total, how many RSVP LSPs are needed so there's as many as LDP LSPs?

LSPs are uni-directional, and LDP is full mesh, so RSVP needs **12 LSPs** configured

10. **A**. [1 mark] The Cisco routers in T108 *are* capable of basic MPLS functionality. Based on your exposure to Cisco routers in NET2001 (and NET3008?) and your existing knowledge of MPLS, are the routers capable of demonstrating *cell mode*? *Why or why not*?

[0 marks] Yes:
[1 mark] cell mode is used for Frame Relay (and ATM) and Cisco routers can do F.R.

B. [1 mark] Based on your response above, what kind of label-space would be used?

Per-interface (if answered Yes), or per-platform (if answered No)

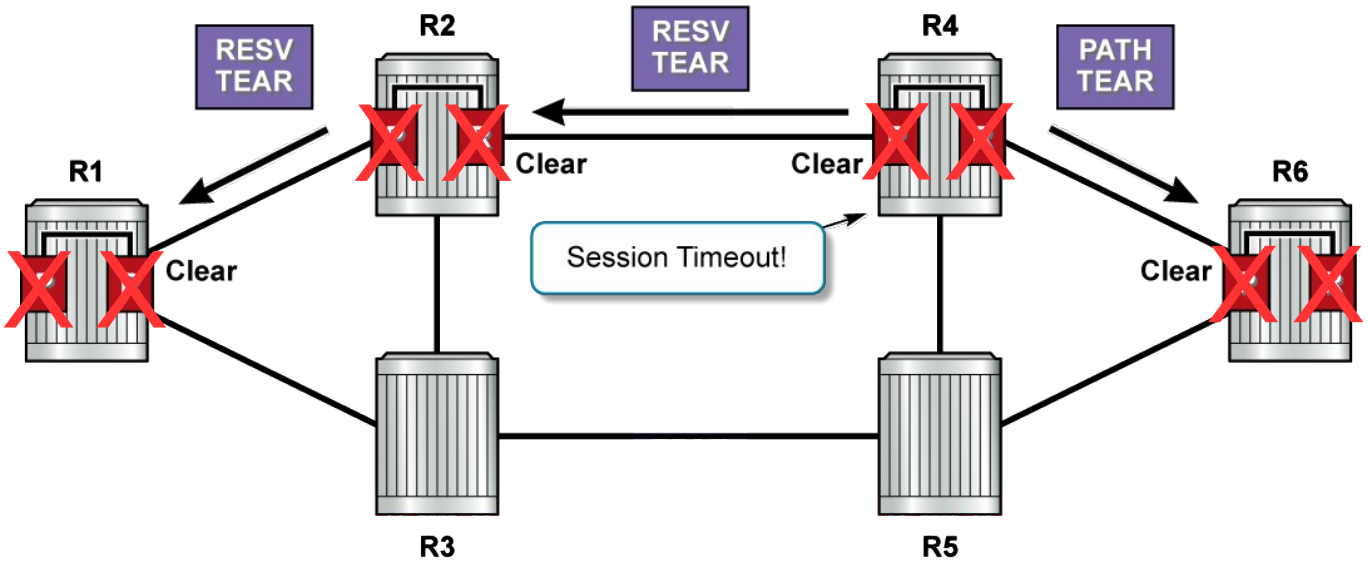
11. **A**. [1 mark] 3rd year BIT-NET is *filled* with acronyms, in all courses. Python is a well known and well-used programming language for web applications; it's also available on the Nokia SR OS for Triple Play. **Clearly** describe what is "Triple Play" (i.e. in a networking context, not a baseball context).

    Ref: Module 1.20: Triple Play is the combination of voice, (streaming) video, and data

    B. [1 mark] You'll also recognize PHP from NET3010 - Web Programming. PHP is also available on the Nokia SR OS. **Clearly** describe the details of Nokia's PHP implementation. (e.g. When is it used? Why? Etc)

    Penultimate Hop Popping (PHP) gets it's name from the fact that the label is popped by the second last router on the LSP instead of the last router.
    PHP is requested by an egress router that would suffer a performance penalty for doing two look-ups: a label lookup plus an IP routing lookup.
    Refs: Module 2.45-46; NRS-II p. 505

12. [3 marks] Pictured below is an LSP from R1 → R6 that had been Up/Up for some time when a timeout occured at R4. (Ref: 4.39)
    RSVP is Conservative! No distinct "error" but LSP is just not "needed" so tear it down.



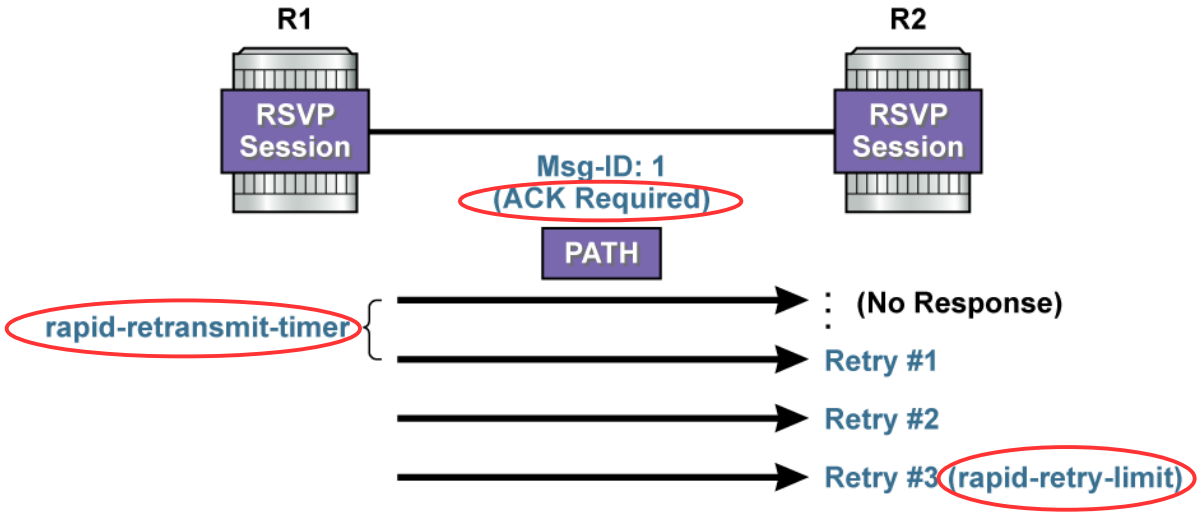
    A. Clearly identify the LSP protocol shown above. RSVP

    B. How does R4 respond to the session timeout? i.e. By *annotating the diagram*, **clearly** identify the type(s) of message(s) it will send out, and in which direction(s).
    R4 sends out both Path Tear and RESV Tear messages (and clears PSB+RSB blocks)

    C. By annotating the diagram, **clearly** show two ways that the *other routers* respond.
    Other routers respond by: (1) propagating the Tear msgs; (2) clearing PSB + RSB blocks

13. [3 marks] Timeouts are always undesirable. The protocol above has several optimizations for very busy networks. There's a specific pair of optimizations that work together to provide protection against *lost messages* [somewhat "similar" to the error protection in TCP but perhaps better?]. (Ref: Module 4.54)

    Clearly explain the pair. A diagram could be an excellent way of explaining.



    (Will also accept Msg-ID + rapid-retransmit-timer for 2/3 marks)

14. [1 mark] **Clearly** explain the connection between Special Use labels and PHP.

    The Special Use labels are the "ON" switch for PHP!
    The Special Use label **3** is used by a tail-end ("ultimate") router to request PHP by the next-to-last ("penultimate") router.
    The Special Use labels **0** & **2** (Explicit Null) can also be considered a form of PHP, since processing is still simplified for the ultimate router (Ref: NRS-II p. 506)

15. **A**. [1 mark] Explain **clearly** how the SR OS ensures that RSVP (7) and LDP (9) tunnels are used instead of sending data via regular IP routing when IGP shortcuts are enabled?

    Each protocol has a Pref[erence] value (similar to Admin Distance in IOS) for the forwarding option(s) that it provides. The routing table is populated with the *lowest* valued pref for any given route. RSVP tunnels have a pref of 7; LDP tunnels have a pref value of 9. FWIW, the only lower preference values are directly connected networks and static routes.

    B. [1 mark] Explain **clearly** how an intermediate MPLS router (running in frame mode) knows whether it's receiving a simple, regular IP packet or MPLS data plane traffic? (… So that it knows how to process it properly!)

    Simple: the router examines the Type/Len field in the ethernet header. MPLS PDUs have an ethertype of 0x8847; IPv4 traffic has ethertype of 0x0800 and IPv6 has an ethertype of 0x86DD. Ref: classroom discussion of Module 1.39

16. Carefully examine the output of "show router ldp bindings active" below (Ref: NRSII p. 554)

```
*A:R1# show router ldp bindings active
=============================================================
Prefix            Op    IngLbl     EgrLbl   EgrIntf/LspId  EgrNextHop
-------------------------------------------------------------
10.10.10.1/32     Push              131070     1/1/X          10.6.X.X
10.10.10.1/32     Swap  131071      131070     1/1/X          10.6.X.X
10.10.10.2/32     Push    --        131071     1/1/X          10.6.X.X
10.10.10.2/32     Swap  131070      131071     1/1/X          10.6.X.X
10.10.10.3/32     Push    --        131070     1/1/X          10.6.X.X
10.10.10.3/32     Swap  131069      131070     1/1/X          10.6.X.X
10.10.10.4/32     Push    --                   1/1/X          10.6.X.X
10.10.10.4/32     Pop   131068        --         --             --
10.10.10.5/32     Push    --        131071     1/1/X          10.6.X.X
10.10.10.5/32     Swap  131067      131071     1/1/X          10.6.X.X
10.10.10.6/32     Push    --        131071     1/1/X          10.6.X.X
10.10.10.6/32     Swap  131066      131071     1/1/X          10.6.X.X

-------------------------------------------------------------
```

A. [2 marks] If this command was executed on **R4**, how would the table look? Modify the table accordingly.

Changes marked in red; 1 mark R1=Push/Swap; 1 mark R4 = Pop only

B. [2 marks] Give examples for all egress labels in the table. Label values *must be plausible*
Tip: Are there values which *must* be identical? Are there values which *must* be different?

Changes marked in blue

1 mark = Push+Swap identical; 1 mark = labels different when sent to same egress

C. [2 marks] From our lab work, modify the label table to show how it would look on a Nokia router if the prefixes were all /24 subnets (i.e. 10.10.10.1/32 → 10.10.1.0/24, etc)

Changes marked in green; 2 marks = simply remove all Push labels

17. Have you been keeping up with lab work? Route redistribution is done differently under the Nokia SR OS than on Cisco IOS.

A. [1 mark; Bonus] What statements are used to a *define* redistribution policy?

```
policy-options
begin
  policy-statement {policy-name}
      entry 10
            from protocol direct
            exit
            action accept
      (etc)
```

Acceptable answer: any number of statements which clearly indicates some knowledge of SR OS policy statements.

B. [1 mark] What statement(s) *activate* (or put into use) a redistribution policy?

the "*export {policy name}*" statement included within the global level of the protocol.

18. [1 mark + 1 bonus mark] Have you been keeping up with the lab work? We've already implemented one or more direct applications for LDP and/or RSVP LSPs. **Clearly** identify as many of these variants or uses as you can for LSPs, based on our lab work.

    [1 mark for the first pair; 1 mark for the third]
    – ldp-shortcuts for IGP routing
    – ldp-shortcuts for full-mesh iBGP
    – ldp-over-rsvp for IGP routing

19. [2 marks] What aspect impressed you the most during William Vail's talk about his work at CENGN? Explain clearly with as much detail as possible.

    Looking for any answer which shows some appreciation of and attention paid to the presentation. Half marks for answers which lack sufficient detail(s).

20. [1 mark; Bonus] During the field trip, what impressed you the most about the technology in use, or in development, at Nokia? Alternatively, you could also discuss any one of the product teams. Explain clearly with as much detail as possible.

    Looking for any answer which shows some appreciation of and attention paid during the field trip. No half marks are available for this question.

END

Extra Work

Extra Work