

Assignment 01: Expand the VLAN-Based Network

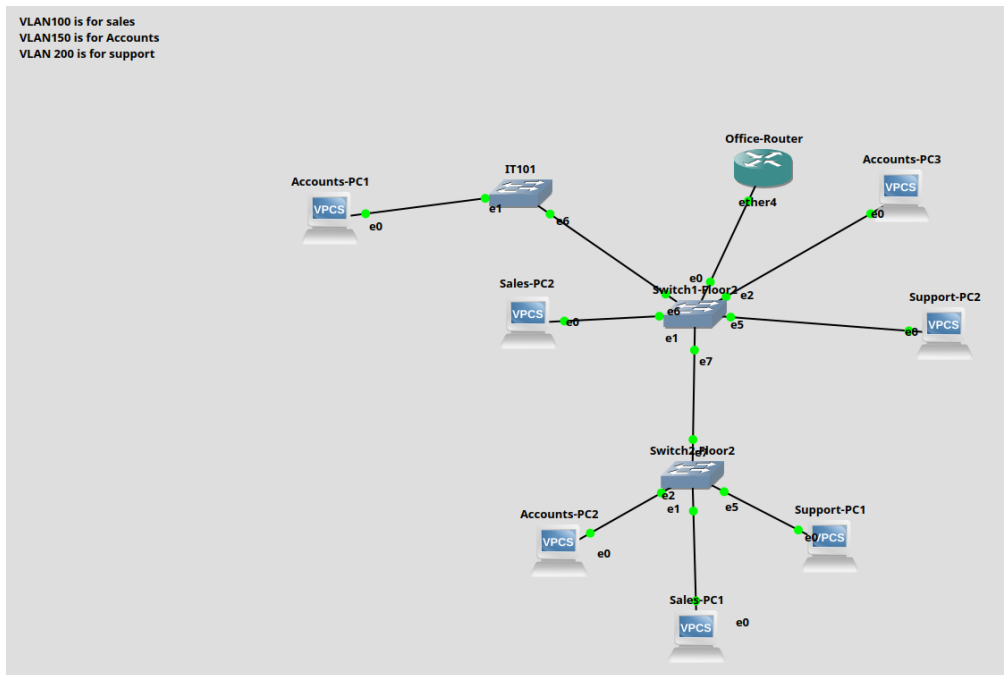


Figure 1: Network Topology

```
[admin@Office-Router] > export
# oct/12/2023 10:51:24 by RouterOS 6.49.6
# software id =
#
#
#
/interface ethernet
set [ find default-name=ether1 ] disable-running-check=no
set [ find default-name=ether2 ] disable-running-check=no
set [ find default-name=ether3 ] disable-running-check=no
set [ find default-name=ether4 ] disable-running-check=no
set [ find default-name=ether5 ] disable-running-check=no
set [ find default-name=ether6 ] disable-running-check=no
set [ find default-name=ether7 ] disable-running-check=no
set [ find default-name=ether8 ] disable-running-check=no
/interface vlan
add interface=ether4 name=VLAN100 vlan-id=100
add interface=ether4 name=VLAN150 vlan-id=150
add interface=ether4 name=VLAN200 vlan-id=200
/interface wireless security-profiles
set [ find default=yes ] supplicant-identity=MikroTik
/ip pool
add name=dhcp_pool0 ranges=192.168.100.2-192.168.100.254
add name=dhcp_pool1 ranges=192.168.200.2-192.168.200.254
add name=dhcp_pool2 ranges=192.168.150.2-192.168.150.254
/ip dhcp-server
add address-pool=dhcp_pool0 disabled=no interface=VLAN100 name=dhcp1
add address-pool=dhcp_pool1 disabled=no interface=VLAN200 name=dhcp2
add address-pool=dhcp_pool2 disabled=no interface=VLAN150 name=dhcp3
/ip address
add address=192.168.100.1/24 interface=VLAN100 network=192.168.100.0
add address=192.168.200.1/24 interface=VLAN200 network=192.168.200.0
add address=192.168.150.1/24 interface=VLAN150 network=192.168.150.0
/ip dhcp-client
add disabled=no interface=ether1
/ip dhcp-server network
add address=192.168.100.0/24 gateway=192.168.100.1
add address=192.168.150.0/24 dns-server=8.8.8.8 gateway=192.168.150.1
add address=192.168.200.0/24 gateway=192.168.200.1
/ip firewall nat
add action=masquerade chain=srcnat out-interface=ether1
/system identity
set name=Office-Router
[admin@Office-Router] >
```

Figure 2: Router Configuration

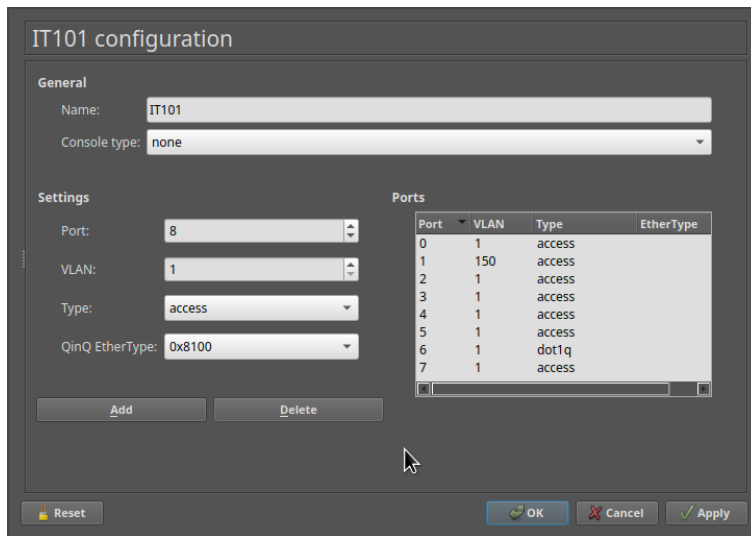


Figure 3: Configuration of the New IT101 Switch

```
Trying ::1...
Connected to localhost.
Escape character is '^]'.

Welcome to Virtual PC Simulator, version 0.8.3
Dedicated to Dalling.
Build time: Oct 10 2023 18:46:25
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Source code and license can be found at vpcs.sf.net.
For more information, please visit wiki.freecode.com.cn.

Press '?' to get help.

Executing the startup file

Accounts-PC1> ip dhcp
DORA IP 192.168.150.254/24 GW 192.168.150.1

Accounts-PC1> ping 192.168.150.253

84 bytes from 192.168.150.253 icmp_seq=1 ttl=64 time=0.259 ms
84 bytes from 192.168.150.253 icmp_seq=2 ttl=64 time=0.351 ms
84 bytes from 192.168.150.253 icmp_seq=3 ttl=64 time=0.367 ms
84 bytes from 192.168.150.253 icmp_seq=4 ttl=64 time=0.363 ms
84 bytes from 192.168.150.253 icmp_seq=5 ttl=64 time=0.346 ms

Accounts-PC1> █

Trying ::1...
Connected to localhost.
Escape character is '^]'.

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Press '?' to get help.

Executing the startup file

Accounts-PC2> ip dhcp
DORA IP 192.168.150.253/24 GW 192.168.150.1

Accounts-PC2> █
```

Figure 4: Verifying that The New VPC Devices in the Accounts VLAN Can Ping Each Other

```

Connected to localhost.
Escape character is '^J'.

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For more information, please visit wiki.freecode.com.cn.

Press '?' to get help.

Executing the startup file

Accounts-PC1> ip dhcp
DORA IP 192.168.150.254/24 GW 192.168.150.1

Accounts-PC1> ping 192.168.150.253

84 bytes from 192.168.150.253 icmp_seq=1 ttl=64 time=0.259 ms
84 bytes from 192.168.150.253 icmp_seq=2 ttl=64 time=0.351 ms
84 bytes from 192.168.150.253 icmp_seq=3 ttl=64 time=0.367 ms
84 bytes from 192.168.150.253 icmp_seq=4 ttl=64 time=0.363 ms
84 bytes from 192.168.150.253 icmp_seq=5 ttl=64 time=0.346 ms

Accounts-PC1> trace 192.168.150.253 -P 1
trace to 192.168.150.253, 8 hops max (ICMP), press Ctrl+C to stop
 1 192.168.150.253 0.257 ms 0.224 ms 0.257 ms

Accounts-PC1>

```

Figure 5: Running a Trace from a VPC to Another VPC in the Same VLAN (Same VPCs as in Above Figure)

When we run a trace from Accounts-PC1 to Accounts-PC2 (which are both on VLAN150), we can see that it only takes one hop to get from Accounts-PC1 to Accounts-PC2. Because these devices are in the same VLAN, they do not need to go through the router to address each other, and can reach each other directly. When devices share a VLAN, they can communicate directly at the Data Link Layer.

<pre> Build time: Oct 10 2023 18:46:25 Copyright (c) 2007-2015, Paul Meng (mirnshi@gmail.com) All rights reserved.  VPCS is free software, distributed under the terms of the "BSD" license. Source code and license can be found at vpcs.sf.net. For more information, please visit wiki.freecode.com.cn.  Press '?' to get help.  Executing the startup file  Accounts-PC1&gt; ip dhcp DORA IP 192.168.150.254/24 GW 192.168.150.1  Accounts-PC1&gt; ping 192.168.150.253  84 bytes from 192.168.150.253 icmp_seq=1 ttl=64 time=0.259 ms 84 bytes from 192.168.150.253 icmp_seq=2 ttl=64 time=0.351 ms 84 bytes from 192.168.150.253 icmp_seq=3 ttl=64 time=0.367 ms 84 bytes from 192.168.150.253 icmp_seq=4 ttl=64 time=0.363 ms 84 bytes from 192.168.150.253 icmp_seq=5 ttl=64 time=0.346 ms  Accounts-PC1&gt; trace 192.168.150.253 -P 1 trace to 192.168.150.253, 8 hops max (ICMP), press Ctrl+C to stop  1 192.168.150.253 0.257 ms 0.224 ms 0.257 ms  Accounts-PC1&gt; trace 192.168.200.254 -P 1 trace to 192.168.200.254, 8 hops max (ICMP), press Ctrl+C to stop  1 192.168.150.1 0.362 ms 0.295 ms 0.315 ms  2 192.168.200.254 0.929 ms 0.559 ms 0.579 ms  Accounts-PC1&gt; █ </pre>	<pre> Trying ::1... Connected to localhost. Escape character is '^J'.  Welcome to Virtual PC Simulator, version 0.8.3 Dedicated to Daling. Build time: Oct 10 2023 18:46:25 Copyright (c) 2007-2015, Paul Meng (mirnshi@gmail.com) All rights reserved.  VPCS is free software, distributed under the terms of the "BSD" license. Source code and license can be found at vpcs.sf.net. For more information, please visit wiki.freecode.com.cn.  Press '?' to get help.  Executing the startup file  DDD Can't find dhcp server  Support-PC1&gt; ip dhcp DORA IP 192.168.200.254/24 GW 192.168.200.1  Support-PC1&gt; ip dhcp DORA IP 192.168.200.254/24 GW 192.168.200.1  Support-PC1&gt; █ </pre>
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Figure 6: Running a Trace from a VPC to Another VPC in Different VLANs

When we run a trace from Accounts-PC1 to Support-PC1 (which are on different VLANs), we can see that it takes two hops to get from Accounts-PC1 to Support-PC1. Communication between separate VLANs requires routing, and therefore communicating between two devices on two different VLANs requires that the packets go through a router. The first IP in the trace is that of the router: 192.168.150.1 (or rather the IP of the gateway of VLAN150 on the router). The second IP in the trace is that of Support-PC1: 192.168.200.254.

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000	Private 66:68:04	Broadcast	ARP	68	Who has 192.168.150.17 Tell 192.168.150.254
2	0.000337	0c:f2:9f:a7:00:03	Private 66:68:04	ARP	46	192.168.150.1 is at 0c:f2:9f:a7:00:03
3	0.001021	192.168.150.254	192.168.200.254	ICMP	110	Echo (ping) request id=0xebcc, seq=0/0, ttl=1 (no response found!)
4	0.001243	192.168.150.254	192.168.150.254	ICMP	138	Time-to-live exceeded (Time to live exceeded in transit)
5	0.002098	192.168.150.254	192.168.200.254	ICMP	110	Echo (ping) request id=0xebcc, seq=0/0, ttl=1 (no response found!)
6	0.002311	192.168.150.1	192.168.150.254	ICMP	138	Time-to-live exceeded (Time to live exceeded in transit)
7	0.003199	192.168.150.254	192.168.200.254	ICMP	110	Echo (ping) request id=0xebcc, seq=0/0, ttl=1 (no response found!)
8	0.003414	192.168.150.1	192.168.150.254	ICMP	138	Time-to-live exceeded (Time to live exceeded in transit)
9	0.004258	192.168.150.254	192.168.200.254	ICMP	110	Echo (ping) request id=0xebcc, seq=0/0, ttl=2 (no response found!)
10	0.004482	192.168.150.254	192.168.200.254	ICMP	110	Echo (ping) request id=0xebcc, seq=0/0, ttl=1 (reply in 13)
11	0.004763	Private 66:68:04	Broadcast	ARP	68	Who has 192.168.200.17 Tell 192.168.200.254
12	0.004905	0c:f2:9f:a7:00:03	Private 66:68:01	ARP	46	192.168.200.1 is at 0c:f2:9f:a7:00:03
13	0.005770	192.168.200.254	192.168.150.254	ICMP	110	Echo (ping) reply id=0xebcc, seq=0/0, ttl=64 (request in 10)
14	0.005970	192.168.200.254	192.168.150.254	ICMP	110	Echo (ping) reply id=0xebcc, seq=0/0, ttl=63
15	0.006389	192.168.150.254	192.168.200.254	ICMP	110	Echo (ping) request id=0xebcc, seq=0/0, ttl=2 (no response found!)
16	0.006586	192.168.150.254	192.168.200.254	ICMP	110	Echo (ping) request id=0xebcc, seq=0/0, ttl=1 (reply in 17)
17	0.006722	192.168.200.254	192.168.150.254	ICMP	110	Echo (ping) reply id=0xebcc, seq=0/0, ttl=64 (request in 16)
18	0.006919	192.168.200.254	192.168.150.254	ICMP	110	Echo (ping) reply id=0xebcc, seq=0/0, ttl=63
19	0.007481	192.168.150.254	192.168.200.254	ICMP	110	Echo (ping) request id=0xebcc, seq=0/0, ttl=2 (no response found!)
20	0.007635	192.168.150.254	192.168.200.254	ICMP	110	Echo (ping) request id=0xebcc, seq=0/0, ttl=1 (reply in 21)
21	0.007760	192.168.200.254	192.168.150.254	ICMP	110	Echo (ping) reply id=0xebcc, seq=0/0, ttl=64 (request in 20)
22	0.007931	192.168.200.254	192.168.150.254	ICMP	110	Echo (ping) reply id=0xebcc, seq=0/0, ttl=63
23	3.385736	0.0.0.0	255.255.255.255	MNDP	149	5678 - 5678 Len=107
24	3.385838	0c:f2:9f:a7:00:03	CDP/VTP/DTP/PagP/...	CDP	92	Device ID: Office-Router Port ID: ether4
25	3.385893	0c:f2:9f:a7:00:03	LLDP Multicast	LLDP	88	MA/0c:f2:9f:a7:00:00 IN/ether4 120 SysN=Office-Router SysD=MikroTik RouterOS 6.49.6 (stable) CHR
26	3.385914	192.168.150.1	255.255.255.255	MNDP	162	5678 - 5678 Len=116
27	3.385964	0c:f2:9f:a7:00:03	CDP/VTP/DTP/PagP/...	CDP	114	Device ID: Office-Router Port ID: VLAN100
28	3.385997	0c:f2:9f:a7:00:03	LLDP Multicast	LLDP	117	MA/0c:f2:9f:a7:00:00 IN/VLAN100 120 SysN=Office-Router SysD=MikroTik RouterOS 6.49.6 (stable) CHR
29	3.386029	192.168.200.1	255.255.255.255	MNDP	162	5678 - 5678 Len=116
30	3.386069	0c:f2:9f:a7:00:03	CDP/VTP/DTP/PagP/...	CDP	114	Device ID: Office-Router Port ID: VLAN200
31	3.386121	0c:f2:9f:a7:00:03	LLDP Multicast	LLDP	117	MA/0c:f2:9f:a7:00:00 IN/VLAN200 120 SysN=Office-Router SysD=MikroTik RouterOS 6.49.6 (stable) CHR
32	3.386167	192.168.150.1	255.255.255.255	MNDP	162	5678 - 5678 Len=116
33	3.386222	0c:f2:9f:a7:00:03	CDP/VTP/DTP/PagP/...	CDP	114	Device ID: Office-Router Port ID: VLAN150
34	3.386268	0c:f2:9f:a7:00:03	LLDP Multicast	LLDP	117	MA/0c:f2:9f:a7:00:00 IN/VLAN150 120 SysN=Office-Router SysD=MikroTik RouterOS 6.49.6 (stable) CHR
35	4.995707	0c:f2:9f:a7:00:03	Private 66:68:04	ARP	46	Who has 192.168.150.254? Tell 192.168.150.1
36	4.995906	Private 66:68:04	0c:f2:9f:a7:00:03	ARP	46	192.168.150.254 is at 00:50:79:66:68:04
37	5.005634	0c:f2:9f:a7:00:03	Private 66:68:01	ARP	46	Who has 192.168.200.254? Tell 192.168.200.1
38	5.005804	Private 66:68:01	0c:f2:9f:a7:00:03	ARP	46	192.168.200.254 is at 00:50:79:66:68:01

Figure 7: Packet Capture on the Link Connecting the Switch & the Router During a Ping between VPCs on Different VLANs

The general outline of what happened in this packet capture is as follows:

1. An ICMP ping is sent from Accounts-PC1 (which is on VLAN150) to Support-PC1 (which is on VLAN200). Ethernet frames that travel between VLANs need a tag that identifies the VLAN as per the 802.1Q protocol. However, the 802.1Q is not added by the VPC sending the ping; instead, the tag is added by the first switch that the frame passes through, in this case the IT101 switch. The IT101 switch will have encapsulated the packet with an 802.1Q header and added the VLAN information, including the priority bits, the VLAN ID of the VLAN to which the packet belongs, & the Canonical Format Indicator which indicates the canonical format of the MAC address. Therefore, by the time the packet reaches the Switch1-Floor2 switch, the VLAN tag has already been added to the frame.
2. The Switch1-Floor2 switch then forwards the encapsulated packet which now contains the 802.1Q header to the Office-Router router. This can be seen in the first ICMP packet that we captured going from 192.168.150.254 (Accounts-PC1) to 192.168.200.254 (Support-PC1):

```

> Frame 3: 110 bytes on wire (880 bits), 110 bytes captured (880 bits) on interface -, id 0
> Ethernet II, Src: Private 66:68:04 (00:50:79:66:68:04), Dst: 0c:f2:9f:a7:00:03 (0c:f2:9f:a7:00:03)
> Internet Protocol Version 4, Src: 192.168.150.254, Dst: 192.168.200.254
  0100 .... = Version: 4
  .... 0101 = Header Length: 20 bytes (5)
  Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)
  Total Length: 92
  Identification: 0x0000 (0)
  0100 .... = Flags: 0x2, Don't fragment
  ... 0 0000 0000 0000 = Fragment Offset: 0
  Time to Live: 1
  Protocol: ICMP (1)
  Header Checksum: 0x9853 [validation disabled]
  [Header checksum status: Unverified]
  Source Address: 192.168.150.254
  Destination Address: 192.168.200.254
> Internet Control Message Protocol

```

Figure 8: ICMP Packet Containing the 802.1Q Tag

3. We can tell what links require an 802.1Q header by checking whether they are trunks or access links: trunks expect packets to have an 802.1Q header so that the switches or routers that they are linking can know which VLAN they belong to. Access links do not expect an 802.1Q header, as the ports which access links join are specified to belong to a certain VLAN when the switch is configured. Therefore every packet traversing one of the trunk links, i.e. IT101 ↔ Switch1-Floor2, Switch1-Floor2 ↔ Office-Router, & Switch1-Floor2 ↔ Switch2-Floor2, requires a 802.1Q header. The last switch (Switch2-Floor2) before the destination VPC (Support-PC1) will remove the 802.1Q header, extracting the original ICMP echo request packet, and send it down the access link to Support-PC1.
4. The router is needed to facilitate the inter-VLAN communication; although, in purely physical terms, data could be transferred via the switches from Accounts-PC1 to Support-PC1 without having to go to the router, the router is needed to facilitate inter-VLAN communication over IP, as the VLANs have separate broadcast domains and the individual VPCs do not know which VLAN they belong to, if any. The router forwards the packets to the switch Switch1-Floor2, which passes them to Switch2-Floor2.
5. When the ICMP packets reach Switch2-Floor2, the 802.1Q header is stripped from them, as they have now traversed the last trunk link that they need to and are now going to pass over an access port to Support-PC1. Since we are capturing the

packets over the trunk link between a Switch1-Floor2 & Office-Router, we will never see a packet without an 802.1Q header, although they are in use for this ping.

6. When the echo request reaches Support-PC1, it send back an echo reply via Switch2-Floor2. The 802.1Q header will be added at Switch2-Floor2, and the process will repeat to route the packet across the trunks to the router, and then to the IT101 switch, where the 802.1Q header will be stripped and the packet forwarded back to Accounts-PC1, completing the ping.