Secure Connectivity
Course code: MMI126276

Title: Building and Troubleshooting a Dual-Hub DMVPN Network with BGP and OSPF
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1. Introduction:

Dynamic Multipoint Virtual Private Network (DMVPN) is a Cisco VPN solution enabling the dynamic, scalable creation of secure IPsec tunnels between remote sites without each tunnel requiring manual configuration. It employs multipoint GRE (mGRE) tunnels, dynamic endpoint mapping using NHRP (Next Hop Resolution Protocol), and optional encryption with IPsec. DMVPN is popular among enterprises to connect numerous branch offices to one or more central hubs over the internet or MPLS, streamlining configuration and inter-branch routing.

We have implemented DMVPN Phase 3 in this topology. In addition to standard spoke-to-hub communication, Phase 3 allows dynamic spoke-to-spoke tunnel creation. This phase is selected because it permits the more efficient end-to-end spoke-to-spoke traversal after some initial communication and learning through the hub (NHRP redirection and shortcut mechanisms). Other notable features of Phase 3 are increased routing freedom and rapid recovery from failure switching between dual hubs (CORE-HUB1 and BACKUP-HUB2). These make phase 3 ideal for high-availability, failure-resistant, scalable enterprise deployments.

2. Topology and Design

- CORE-HUB1
- BACKUP-HUB2
- Glasgow Branch (Spoke-1)
- Paisley Branch (Spoke-2)
- Cloud(Switch)
- Glasgow Office PC-1
- Paisley Office PC-2

3. Configuration Summary

The switch Cloud was configured with VLAN 100 and underlay routing. Each router was assigned an IP address for both underlay (Ethernet) and overlay (Tunnel0) interfaces. DMVPN tunnels used multipoint GRE with NHRP mappings for both hubs. BGP was configured for routing across tunnels, and OSPF was used inside LANs at each spoke. Implemented IPsec over DMVPN in my topology. The DMVPN tunnel was first configured using GRE multipoint mode along with NHRP mappings to establish dynamic connectivity between the spoke and the hubs. Once the tunnel was fully configured, I applied IPsec encryption on top of it using the tunnel protection ipsec profile command. This ensures that all traffic passing through the DMVPN tunnel is securely encrypted without interfering with the underlying DMVPN control mechanisms.

4. Tool Used : CML

5. Desgin/ Topology
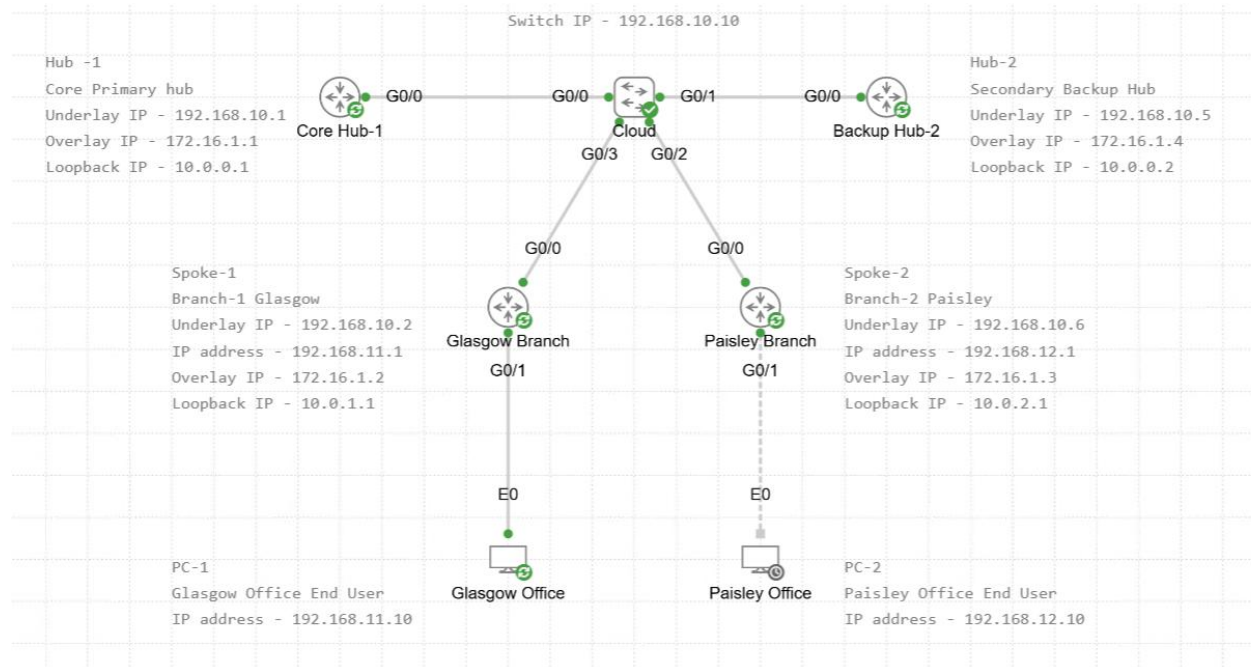
6. Details:

Device	Interface	IP Address	Description
Core Hub-1	g0/0	192.168.10.1/30	To Switch
Core Hub-1	loopback 0	10.0.0.1/32	NHRP ID
Glasgow branch Spoke-1	g0/0	192.168.10.2/30	To Switch
Glasgow branch Spoke-1	loopback 0	10.0.1.1/32	NHRP ID
Backup Hub-2	g0/0	192.168.10.5/30	To Switch
Backup Hub-2	loopback 0	10.0.0.2/32	NHRP ID
Paisley branch Spoke-2	g0/0	192.168.10.6/30	To Switch
Paisley branch Spoke-2	loopback 0	10.0.2.1/32	NHRP ID
tunnel	tunnel0	172.16.1.1/24	DMVPN Overlay
Cloud	g0/0-3	192.168.10.10	Switch
Glasgow Office PC-1	Eth0	192.168.11.10	To Glasgow branch
Paisley Office PC-2	Eth0	192.168.12.10	To Paisley branch

Issue and Troubleshooting

Issue-1 : Glasgow Branch not able to ping Core hub

Resolution:

a. Verified all interface are up or not on both Glasgow branch and Core hub

b. Core hub interface were down

```
Hub-1#show ip int brief
Interface              IP-Address      OK? Method Status                 Protocol
GigabitEthernet0/0     192.168.10.1    YES NVRAM  administratively down down
GigabitEthernet0/1     unassigned      YES NVRAM  administratively down down
GigabitEthernet0/2     unassigned      YES NVRAM  administratively down down
GigabitEthernet0/3     unassigned      YES NVRAM  administratively down down
Loopback0              10.0.0.1        YES NVRAM  up                     up
NVI0                   10.0.0.1        YES unset  up                     up
Tunnel0                172.16.1.1      YES NVRAM  up                     down
```

c. Commands:

```
Hub-1(config)#int g0/0
Hub-1(config-if)#no shutdown
Hub-1(config-if)#int tunnel0
Hub-1(config-if)#no shutdown
```

d. Verified all interface are up

```
Hub-1#show ip int brief
Interface              IP-Address      OK? Method Status                 Protocol
GigabitEthernet0/0     192.168.10.1    YES NVRAM  up                     up
GigabitEthernet0/1     unassigned      YES NVRAM  administratively down down
GigabitEthernet0/2     unassigned      YES NVRAM  administratively down down
GigabitEthernet0/3     unassigned      YES NVRAM  administratively down down
Loopback0              10.0.0.1        YES NVRAM  up                     up
NVI0                   10.0.0.1        YES unset  up                     up
Tunnel0                172.16.1.1      YES NVRAM  up                     up
```

e. Ping all networks from Glasgow branch to Core hub

Issue-2 and Issue -3 : During testing, Glasgow Branch spoke-1 was unable to reach the overlay IP of Backup Hub-2 (172.16.1.4). Ping to the underlay IP (192.168.10.5) was successful, but no NHRP or DMVPN mapping appeared in `show dmvpn`. Routing through Core Hub-1 (172.16.1.1) worked as expected, but redundancy was not functioning.

Resolution

The root cause was identified as a missing NHRP NHS and map configuration for Backup Hub-2 on Glasgow Branch spoke-1. The following commands were applied to Tunnel0 on Glasgow Branch spoke-1 :
int tunnel0
ip nhrp nhs 172.16.1.4
ip nhrp map 172.16.1.4 192.168.10.5
ip nhrp map multicast 192.168.10.5

Verification commands

Show ip interface brief	From Glasgow Branch spoke-1
| | ```
Spoke-1#show ip int brief
Interface              IP-Address      OK? Method Status                Protocol
GigabitEthernet0/0     192.168.10.2    YES NVRAM  up                    up
GigabitEthernet0/1     192.168.11.1    YES NVRAM  up                    up
GigabitEthernet0/2     unassigned      YES NVRAM  administratively down down
GigabitEthernet0/3     unassigned      YES NVRAM  administratively down down
Loopback0              10.0.1.1        YES NVRAM  up                    up
NVI0                   192.168.10.2    YES unset  up                    up
Tunnel0 _              172.16.1.2      YES NVRAM  up                    up
``` |
| | From Backup Hub-2 |

| | ```
Hub-2#show ip int brief
Interface                IP-Address      OK? Method Status                 Protocol
GigabitEthernet0/0       192.168.10.5    YES NVRAM  up                     up
GigabitEthernet0/1       unassigned      YES NVRAM  administratively down  down
GigabitEthernet0/2       unassigned      YES NVRAM  administratively down  down
GigabitEthernet0/3       unassigned      YES NVRAM  administratively down  down
Loopback0                10.0.0.2        YES NVRAM  up                     up
NVI0                     192.168.10.5    YES unset  up                     up
Tunnel0                  172.16.1.4      YES NVRAM  up                     up
``` |
| Show bgp summary | From Glasgow Branch spoke-1 |
| | ```
Spoke-1#show bgp summary
BGP router identifier 10.0.1.1, local AS number 65001
BGP table version is 5, main routing table version 5
4 network entries using 576 bytes of memory
6 path entries using 504 bytes of memory
2/2 BGP path/bestpath attribute entries using 320 bytes of memory
0 BGP route-map cache entries using 0 bytes of memory
0 BGP filter-list cache entries using 0 bytes of memory
BGP using 1400 total bytes of memory
BGP activity 4/0 prefixes, 6/0 paths, scan interval 60 secs

Neighbor        V           AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down   State/PfxRcd
172.16.1.1      4        65001      82      81        5    0    0 01:10:27            2
172.16.1.4      4        65001      82      81        5    0    0 01:10:22            3
``` |
| | From Backup Hub-2 |

| | ```
Hub-2#show bgp summary
BGP router identifier 10.0.0.2, local AS number 65001
BGP table version is 7, main routing table version 7
5 network entries using 720 bytes of memory
5 path entries using 420 bytes of memory
3/2 BGP path/bestpath attribute entries using 480 bytes of memory
0 BGP route-map cache entries using 0 bytes of memory
0 BGP filter-list cache entries using 0 bytes of memory
BGP using 1620 total bytes of memory
BGP activity 5/0 prefixes, 5/0 paths, scan interval 60 secs

Neighbor        V           AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
172.16.1.2      4        65001      82      83        7    0    0 01:11:11           1
172.16.1.3      4        65001      81      83        7    0    0 01:11:02           1
``` | |
| Show dmvpn | From Glasgow Branch spoke-1<br><br>```
Spoke-1#Show dmvpn
Legend: Attrb --> S - Static, D - Dynamic, I - Incomplete
        N - NATed, L - Local, X - No Socket
        T1 - Route Installed, T2 - Nexthop-override
        C - CTS Capable, I2 - Temporary
        # Ent --> Number of NHRP entries with same NBMA peer
        NHS Status: E --> Expecting Replies, R --> Responding, W --> Waiting
        UpDn Time --> Up or Down Time for a Tunnel
================================================================================

Interface: Tunnel0, IPv4 NHRP Details
Type:Spoke, NHRP Peers:2,

 # Ent  Peer NBMA Addr Peer Tunnel Add State  UpDn Tm Attrb
 ----- --------------- --------------- ----- -------- -----
     1 192.168.10.1         172.16.1.1    UP 01:18:49       S
     1 192.168.10.5         172.16.1.4    UP 01:18:44       S
```<br><br>From Backup Hub-2 | |

| | ```
Hub-2#Show dmvpn
Legend: Attrb --> S - Static, D - Dynamic, I - Incomplete
        N - NATed, L - Local, X - No Socket
        T1 - Route Installed, T2 - Nexthop-override
        C - CTS Capable, I2 - Temporary
        # Ent --> Number of NHRP entries with same NBMA peer
        NHS Status: E --> Expecting Replies, R --> Responding, W --> Waiting
        UpDn Time --> Up or Down Time for a Tunnel
==========================================================================

Interface: Tunnel0, IPv4 NHRP Details
Type:Hub, NHRP Peers:2,

 # Ent  Peer NBMA Addr Peer Tunnel Add State  UpDn Tm Attrb
 ----- --------------- --------------- ----- -------- -----
     1 192.168.10.2          172.16.1.2    UP 01:18:53     D
     1 192.168.10.6          172.16.1.3    UP 01:18:53     D
``` |
| show ip nhrp | From Glasgow Branch spoke-1 ```
Spoke-1#show ip nhrp
172.16.1.1/32 via 172.16.1.1
   Tunnel0 created 01:20:23, never expire
   Type: static, Flags: used
   NBMA address: 192.168.10.1
172.16.1.4/32 via 172.16.1.4
   Tunnel0 created 01:20:23, never expire
   Type: static, Flags: used
   NBMA address: 192.168.10.5
``` |
| | From Backup Hub-2 |

| | ```
Hub-2#show ip nhrp
172.16.1.2/32 via 172.16.1.2
    Tunnel0 created 01:19:49, expire 00:09:51
    Type: dynamic, Flags: registered nhop
    NBMA address: 192.168.10.2
172.16.1.3/32 via 172.16.1.3
    Tunnel0 created 01:19:49, expire 00:09:44
    Type: dynamic, Flags: registered used nhop
    NBMA address: 192.168.10.6
``` |
| show crypto session | From Glasgow Branch spoke-1 |

```
Spoke-1#show crypto session
Crypto session current status

Interface: Tunnel0
Session status: UP-ACTIVE
Peer: 192.168.10.5 port 500
  Session ID: 0
  IKEv1 SA: local 192.168.10.2/500 remote 192.168.10.5/500 Active
  IPSEC FLOW: permit 47 host 192.168.10.2 host 192.168.10.5
        Active SAs: 2, origin: crypto map

Interface: Tunnel0
Session status: UP-ACTIVE
Peer: 192.168.10.1 port 500
  Session ID: 0
  IKEv1 SA: local 192.168.10.2/500 remote 192.168.10.1/500 Active
  IPSEC FLOW: permit 47 host 192.168.10.2 host 192.168.10.1
        Active SAs: 2, origin: crypto map
```

From Backup Hub-2

```
Hub-2#show crypto session
Crypto session current status

Interface: Tunnel0
Session status: UP-ACTIVE
Peer: 192.168.10.6 port 500
  Session ID: 0
  IKEv1 SA: local 192.168.10.5/500 remote 192.168.10.6/500 Active
  IPSEC FLOW: permit 47 host 192.168.10.5 host 192.168.10.6
        Active SAs: 2, origin: crypto map

Interface: Tunnel0
Session status: UP-ACTIVE
Peer: 192.168.10.2 port 500
  Session ID: 0
  IKEv1 SA: local 192.168.10.5/500 remote 192.168.10.2/500 Active
  IPSEC FLOW: permit 47 host 192.168.10.5 host 192.168.10.2
        Active SAs: 2, origin: crypto map
```

Ping verification from	Tunnel up to secondary hub - 172.16.1.4 (overlay)

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| Glasgow Branch Spoke-1 to Backup Hub-2 | ```
Spoke-1#ping 172.16.1.4
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.1.4, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 6/6/7 ms
``` |
| Ping verification from Backup Hub-2 to Glasgow Branch Spoke-1 | Same test via backup hub - 192.168.11.10<br>```
Hub-2#ping 192.168.11.10
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.11.10, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 6/7/8 ms
``` |

Issue-4: Backup Hub unable to ping Paisley Branch
Resolution:
commands in ospf on Paisley Branch where missing

```
Spoke-2(config)#router ospf 1
Spoke-2(config-router)#network 10.0.2.1 0.0.0.0 area 0
```

Ping all loopback address from all devices

Others Ping verification

From	To	Verification of
| Glasgow Branch Spoke-1 | Core Hub-1 | Tunnel up to primary hub - 172.16.1.1 (overlay)<br>```
Spoke-1#ping 172.16.1.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.1.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 5/6/7 ms
``` |

Glasgow Branch Spoke-1	Core Hub-1	192.168.10.1 (underlay)
| | | ```
Spoke-1#ping 192.168.10.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.10.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 3/3/4 ms
``` |
| Glasgow Branch Spoke-1 | Backup Hub-2 | 192.168.10.5 (underlay) |
| | | ```
Spoke-1#ping 192.168.10.5
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.10.5, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 3/4/5 ms
``` |
| Glasgow Branch Spoke-1 | Paisley Branch Spoke-2 | Phase 3 spoke-to-spoke tunnel - 192.168.12.1 |
| | | ```
Spoke-1#ping 192.168.12.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.12.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 10/13/21 ms
``` |
| Glasgow Branch Spoke-1 | Paisley Office PC-2 | Full LAN-to-LAN reachability - 192.168.12.10 |
| | | ```
Spoke-1#ping 192.168.12.10
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.12.10, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 9/11/14 ms
``` |
| Glasgow Branch Spoke-1 | Glasgow Office PC-1 | Full LAN-to-LAN reachability - 192.168.11.10 |

| | | ```
Spoke-1#ping 192.168.11.10
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.11.10, timeout is 2 seconds:
.!!!!
Success rate is 80 percent (4/5), round-trip min/avg/max = 1/1/1 ms
``` |
| Paisley Branch Spoke-2 | Core Hub-1 | Tunnel up to primary hub - 172.16.1.1 (overlay)<br>```
Spoke-2#ping 172.16.1.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.1.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 6/6/8 ms
``` |
| Paisley Branch Spoke-2 | Core Hub-1 | 192.168.10.1 (underlay)<br>```
Spoke-2#ping 192.168.10.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.10.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 3/4/5 ms
``` |
| Paisley Branch Spoke-2 | Backup Hub-2 | Tunnel up to secondary hub - 172.16.1.4 (overlay)<br>```
Spoke-2#ping 172.16.1.4
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.1.4, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 5/6/7 ms
``` |
| Paisley Branch Spoke-2 | Backup Hub-2 | 192.168.10.5 (underlay) |

| | | ```
Spoke-2#ping 192.168.10.5
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.10.5, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 3/3/4 ms
``` |
| Paisley Branch Spoke-2 | Glasgow Branch Spoke-1 | Tunnel + routing back to Spoke-1 - 192.168.11.1<br>```
Spoke-2#ping 192.168.11.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.11.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 7/12/16 ms
``` |
| Paisley Branch Spoke-2 | Glasgow Office PC-1 | Full LAN-to-LAN reachability - 192.168.11.10<br>```
Spoke-2#ping 192.168.11.10
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.11.10, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 8/9/11 ms
``` |
| Paisley Branch Spoke-2 | Paisley Office PC-2 | Full LAN-to-LAN reachability - 192.168.12.10<br>```
Spoke-2#ping 192.168.12.10
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.12.10, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/2 ms
``` |
| Core Hub-1 | Glasgow Office PC-1 | Routing from hub to Spoke-1's LAN - 192.168.11.10 |

| | | ```
Hub-1#ping 192.168.11.10
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.11.10, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 6/7/8 ms
``` |
| Core Hub-1 | Paisley Office PC-2 | Routing from hub to Spoke-2's LAN - 192.168.12.10<br>```
Hub-1#ping 192.168.12.10
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.12.10, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 6/7/8 ms
``` |
| Backup Hub-2 | Paisley Office PC-2 | Same test via backup hub - 192.168.12.10<br>```
Hub-2#ping 192.168.12.10
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.12.10, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 5/6/7 ms
``` |
| Glasgow Office PC-1 | Paisley Office PC-2 | Pc to pc |

| | | | ```
inserthostname-here:~$ ping 192.168.12.10
PING 192.168.12.10 (192.168.12.10): 56 data bytes
64 bytes from 192.168.12.10: seq=0 ttl=42 time=10.524 ms
64 bytes from 192.168.12.10: seq=1 ttl=42 time=10.900 ms
64 bytes from 192.168.12.10: seq=2 ttl=42 time=11.859 ms
64 bytes from 192.168.12.10: seq=3 ttl=42 time=11.051 ms
64 bytes from 192.168.12.10: seq=4 ttl=42 time=11.577 ms
^C
--- 192.168.12.10 ping statistics ---
5 packets transmitted, 5 packets received, 0% packet loss
round-trip min/avg/max = 10.524/11.182/11.859 ms
``` |
|---|---|---|---|

7. Conclusion

This highlights the importance of complete NHRP configuration in DMVPN Phase 3 deployments. Redundancy via dual hubs requires that all spokes are fully aware of and mapped to both hubs. By using BGP with fallback tunnels, network resiliency is improved, making this design suitable for critical branch-to-branch or branch-to-core communication.