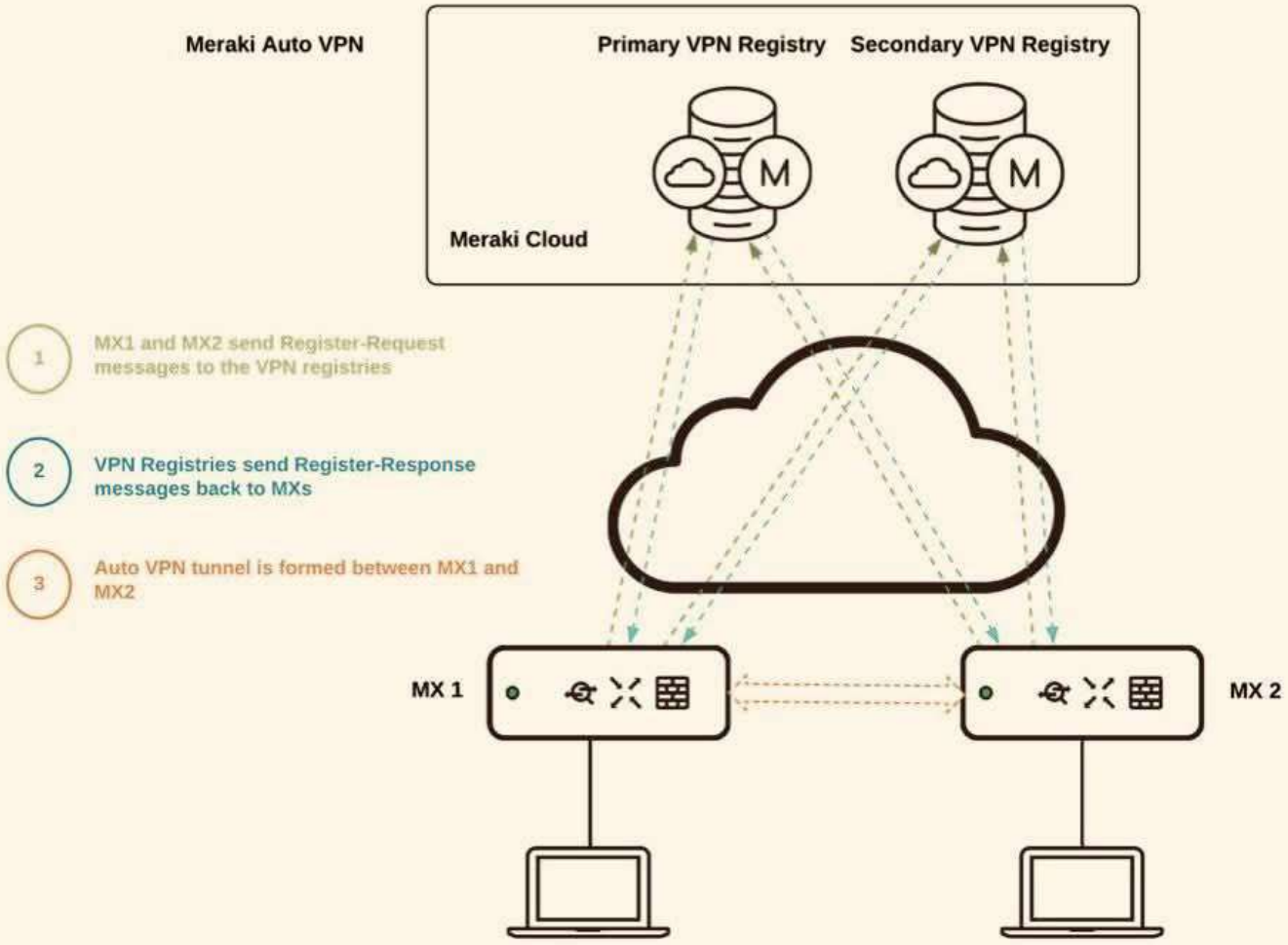
How Auto VPN Works



1. MX1 and MX2 are part of the same organization. MX1 and MX2 are configured to participate in Auto VPN. Both MX1 and MX2 send a Register Request message to their VPN registry in order to share their own contact information, and to get the contact information of the peer MX(s) that it should form a VPN tunnel with. The Register Request message contains the IP address and the UDP port that the MX communicates on, and the MX requests the contact information of its peer MX(s).
2. VPN registries send the Register Response messages to the MXs with the contact information of the peers the MXs should establish a tunnel with.
3. Once the information is shared with the MX about its peers, a VPN tunnel is formed MX to MX. The Meraki cloud already knows the subnet information for each MX, and now the IP addresses to use for tunnel creation. The cloud pushes a key to the MXs in their configuration which is used to establish an AES encrypted IPsec-like tunnel. Local subnets specified by dashboard admins are exported/shared across VPN. During this process, VPN routes are pushed from the dashboard to the MXs. Finally, the dashboard will dynamically push VPN peer information (e.g., exported subnets, tunnel IP information) to each MX. Every MX stores this information in a separate routing table.

Ports used to contact the VPN registry:

- Source UDP port range 32768-61000
- Destination UDP port 9350-9381

Ports used for IPsec tunneling:

- Source UDP port range 32768-61000
- Destination UDP port range 32768-61000

The VPN connection can be monitored under **Security & SD-WAN > Monitor > VPN Status** page. The status of each MX is displayed, along with their exported subnets, latency, connectivity and routing decisions that are being made over the Auto VPN domain in near real-time.

> **VPN Registry: Connected.** This security appliance is able to connect to multiple VPN registries using UDP port 9350.
>
> **NAT type: Friendly**. This security appliance is behind a VPN-friendly NAT, locally using 172.20.0.123:52899, which is NAT-ed to 192.195.83.215:52899
>
> **Encrypted.** Using IPsec and AES encryption.

Auto VPN vs Non-Meraki Site-to-Site VPN

- Auto VPN is a VPN connection between/among the MXs in different networks of **the same Meraki dashboard organization**.
- Non-Meraki site-to-site VPN is used when you form a VPN tunnel with a **third-party/non-Meraki device** or when you establish a VPN connection with **an MX in a different dashboard organization**.
- Like Non-Meraki Site-to-Site VPN, Auto VPN has encryption, authentication and a key. The traffic is encrypted using an AES cipher. However, all of this is transparent to users and does not need to be (and cannot be) modified.

Auto VPN - A Component of Meraki SD-WAN

SD-WAN Characteristics	Meraki SD-WAN Component
Support for VPNs	Meraki Auto VPN
Multiple connection types (MPLS, Internet, LTE, etc.)	MX uplink options allow for multiple connection type.
Dynamic path selection (allows for load sharing across WAN connection)	MX devices can perform uplink load balancing across WAN connections
Simple WAN Configurations Interface (Must support zero-touch	Meraki dashboard & API configuration interfaces

provisioning at a branch, should be easy to set up)

Auto VPN, as a component of SD-WAN, transitions the manual steps for setting the VPN tunnel into a simple automated process. It takes only a few clicks and makes it easy to deploy and manage an SD-WAN environment. It gives resilience, security and application optimization. It has automatic VPN route generation using the IKE/IPSec-like tunnels and all this is done in the Meraki cloud.

If you have two uplinks on your MX, Auto VPN as a component of SD-WAN allows you to decide the flow preferences within the VPN tunnel under **Security & SD-WAN > Configure > SD-WAN & Traffic Shaping page > Uplink Selection > Active-Active Auto VPN**. Active-active Auto VPN allows you to create a VPN tunnel with flow preferences over both the uplinks.

If active-active Auto VPN is disabled, the tunnel will be formed over the primary WAN link and will failover to the secondary if the primary fails.

Auto VPN Configuration

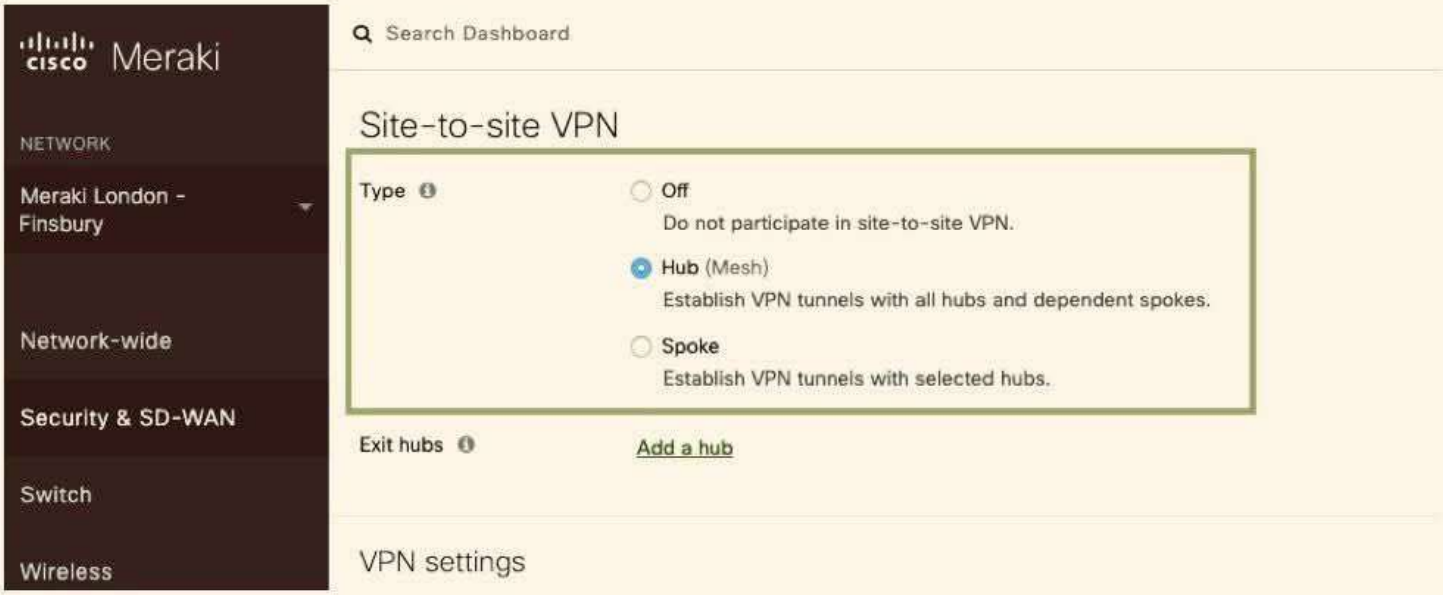
To enable site-to-site VPN between MX Security & SD-WAN appliances, simply login to the Meraki dashboard and navigate to the **Security & SD-WAN > Configure > Site-to-Site VPN** page, and select **Hub** or **Spoke** and save the page. That's all that is required to enable VPN connectivity. Auto VPN takes care of all connection settings and brokers the connections immediately.

Note that Auto VPN is a simple **opt-in process**. You can think of the MXs dashboard organization an existing VPN hub and spoke mesh topology environment, and **every MX that has Auto VPN turned on is simply choosing to participate in that mesh**. By default, all hubs contact all other hubs, and all spokes contact specified hubs. Additional configuration options can be found below.

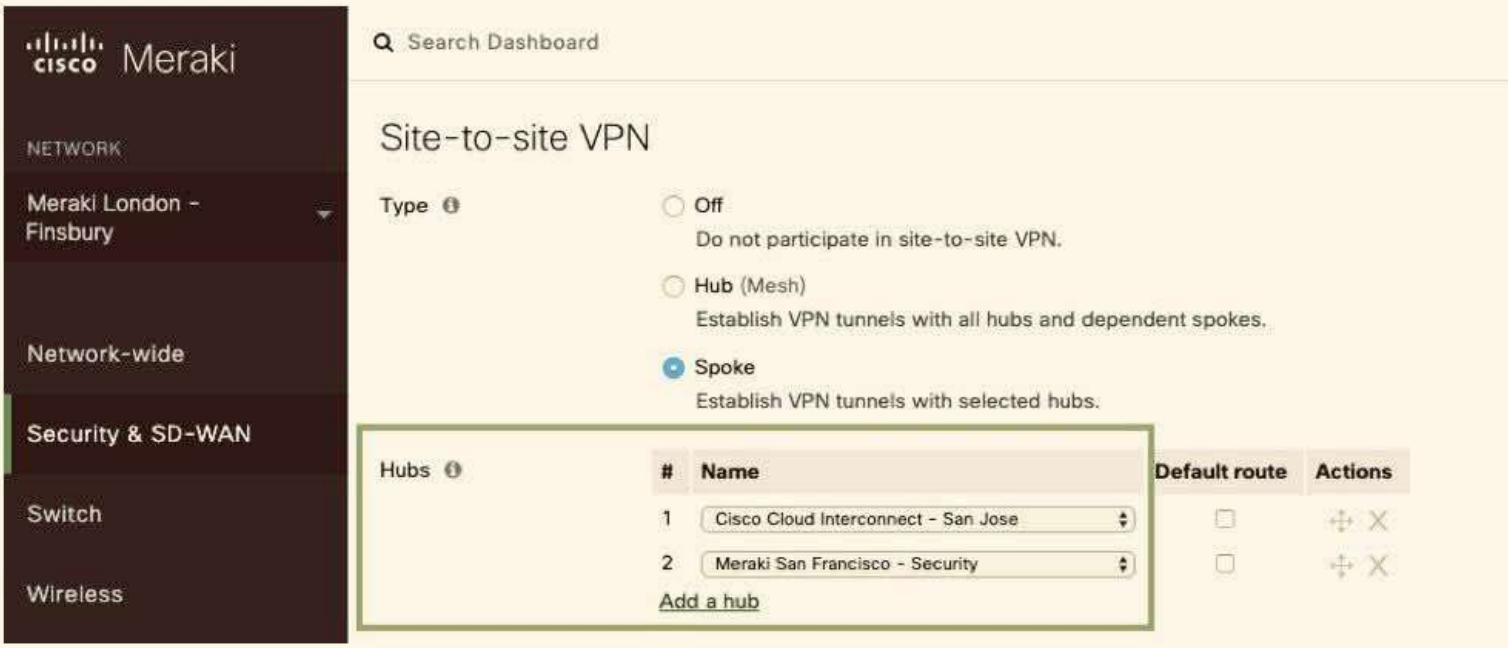
Auto VPN Configuration Details

Enable Auto VPN by defining how the MX will communicate with the rest of the Auto VPN domain

If the MX is configured as a **Hub**, it will build VPN tunnels to **all other Hub MXs** in the Auto VPN domain (in the same dashboard organization). It will also build VPN tunnels to all Spoke MXs in the Auto VPN domain that have this MX configured as a hub. If all MXs in the Auto VPN domain are configured as **Hub** then the Auto VPN has a full mesh topology.



If the MX is configured as a **Spoke**, it will build tunnels to only the MXs that are configured as its **Hubs**. If the majority of MXs in the Auto VPN domain are configured as **Spoke** with only a few key locations (such as data centers or headquarters) configured as hubs, then the Auto VPN environment has a **hub-and-spoke topology**.



Full Tunnel or Split Tunnel

By default all MXs in the Auto VPN domain (dashboard organization) will only send traffic to an Auto VPN peer if the traffic is destined for a subnet contained within the Auto VPN domain. This is often referred to as 'split-tunnelling,' meaning that VPN-subnet-bound traffic is sent over VPN, and other traffic is routed normally via the primary MX WAN uplink. If an organization wants to route **all traffic** (including traffic not contained within the Auto VPN domain) through a specific hub site, this is referred to as 'full-tunneling.'

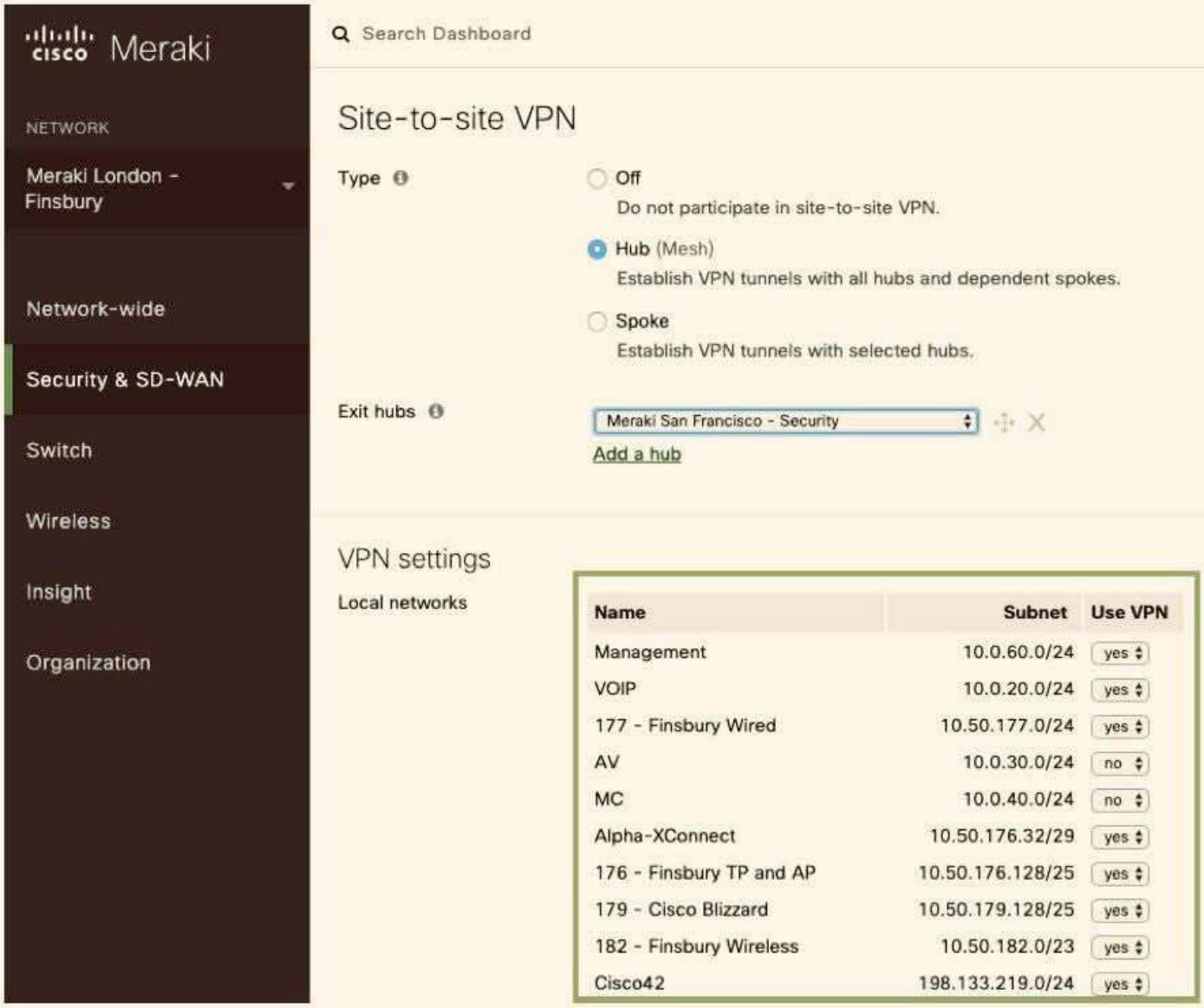
Note that full-tunneling only affects client data and all Meraki management traffic will egress directly via the primary WAN regardless.

To configure **full-tunneling in a full mesh topology** simply define an **Exit hub** from the MXs in the Auto VPN domain.

To configure **full-tunneling in a hub-and-spoke topology**, simply associate a 'Default route' with one or more hub MXs:

Choose which subnets (local networks) to export over VPN

Earmark which locally defined or available subnets are to be exported to the Auto VPN domain. To do this simply set the relevant subnets as **yes** under **Use VPN**, and set **no** for the non-relevant subnets.



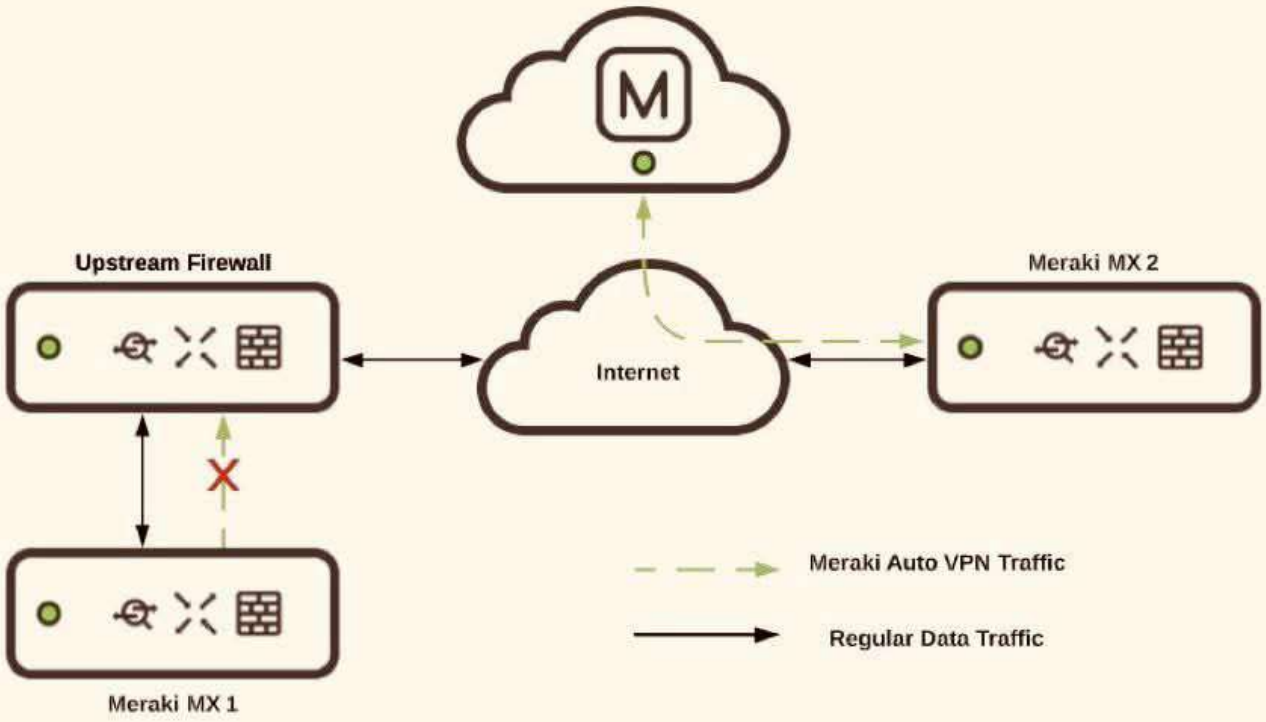
Then save the changes so the MX fetches the configurations from the cloud.

Troubleshooting VPN Registration

When using VPN functionality to securely tunnel traffic between Cisco Meraki devices, such as the MX Site-to-site VPN, or MR Teleworker VPN, the devices must first register with the Dashboard VPN registry. This allows their connections between each other to be dynamic, and automatically establish without manual configuration. However, sometimes issues can occur with this process, which will be discussed in this article.

In order to ensure connectivity, each Meraki node sends a keepalive message to the VPN Registry every 10 seconds. If more than 6 keepalives are not received by the registry, that node is marked as disconnected. For information on how connectivity to the VPN Registry works, please read the article on Automatic NAT Traversal.

Both Meraki peers must be in communication with the VPN registry in order to get the correct information to form a valid VPN tunnel. If one Meraki device, such as an MX security appliance, is able to reach the VPN registry, but the intended peer MX is not, the tunnel will not form. A common occurrence of this is when an upstream firewall blocks VPN registry communication on UDP port 9350-9381. This issue is explained in the section VPN Registry Disconnected.



If the appliance/concentrator is successfully connected to the VPN registry, but is disconnected from another VPN peer, refer to the article on troubleshooting VPN connections between peers.

VPN Registry Disconnected

When the "VPN Registry: Disconnected" message appears on the **Security & SD-WAN > Monitor > VPN status** page for MX networks, it indicates that the appliance has been unable to establish connectivity with the VPN registry. This means that a firewall or other upstream device is either preventing traffic from reaching the VPN registry, or from returning to the appliance.

VPN Registry: Disconnected. This appliance is unable to connect to VPN registries using outbound UDP port 9350.

Expected behavior. If the MX losses connectivity to the VPN registry, peer information gets purged over time but not immediately. Connectivity to the registry matters when a node changes its contact information after losing connectivity to the VPN registry.

Both the hub and spoke will still be able to form the tunnel if the contact information remains the same, and they lost registry connectivity. Peer information will purge after a few hours causing the tunnel to be marked down.

Examples

In the example packet capture below, an MX appliance is attempting to reach the VPN registry on UDP port 9350, but is receiving no response because an upstream firewall is preventing the outbound traffic:

Source	Destination	Protocol	Info
184.	64.62.142.12	UDP	Source port: 60032 Destination port: 9350
184.	64.156.192.245	UDP	Source port: 60032 Destination port: 9350
184.	64.62.142.12	UDP	Source port: 60032 Destination port: 9350
184.	64.156.192.245	UDP	Source port: 60032 Destination port: 9350
184.	64.62.142.12	UDP	Source port: 60032 Destination port: 9350
184.	64.156.192.245	UDP	Source port: 60032 Destination port: 9350

In this example, the appropriate firewall rules have been added to allow the traffic to the VPN registry, and responses can be seen:

Source	Destination	Protocol	Info
184.	64.62.142.12	UDP	Source port: 60032 Destination port: 9350
184.	64.156.192.245	UDP	Source port: 60032 Destination port: 9350
64.156.192.245	184.	UDP	Source port: 9350 Destination port: 60032
64.62.142.12	184.	UDP	Source port: 9350 Destination port: 60032
184.	64.62.142.12	UDP	Source port: 60032 Destination port: 9350
184.	64.156.192.245	UDP	Source port: 60032 Destination port: 9350
64.62.142.12	184.	UDP	Source port: 9350 Destination port: 60032
64.156.192.245	184.	UDP	Source port: 9350 Destination port: 60032

Solution

If this occurs, make sure that any upstream firewalls are configured to allow traffic to the IP addresses and ports listed on the **Help > Firewall info** page. Particularly for the VPN registry. It should also allow return traffic from established connections (this is allowed by default for stateful firewalls):

Firewall Rules

This list is intended to help guide you in creating firewall rules for the Cisco Meraki cloud.

Source IP ▲	Destination IP	FQDN	Ports	Protocol	Direction	Description
Your network(s)	64.62.142.12/32, 158.115.128.0/19, 209.206.48.0/20, 216.157.128.0/20		7351, 9350-9381	UDP	outbound	Meraki cloud communication, VPN registry

NAT Type: Unfriendly

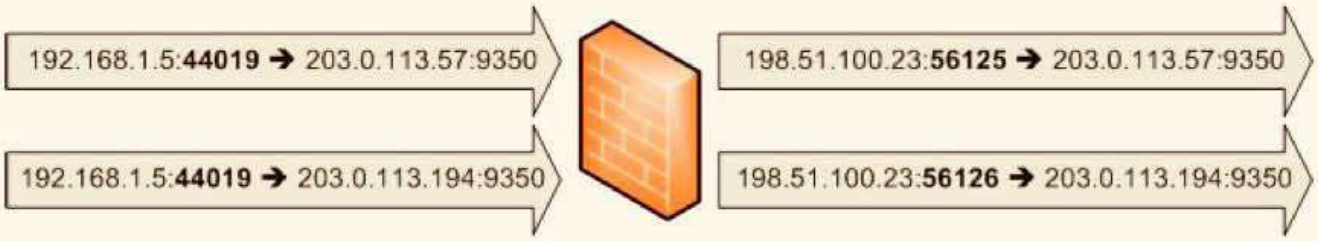
UDP hole-punching, the mechanism used to establish the VPN connections between Cisco Meraki devices, relies on a consistent IP address and port for both devices involved. Two VPN registry servers are used for redundancy, and both expect to see the device as available on the same public IP address and port.

However, some NAT devices (such as a firewall) will rewrite the source ports differently for each VPN registry server. Other NAT devices or load balancers will attempt to spread the connections to each VPN registry server across two different public IP addresses. Both of these cases will result in the VPN connection

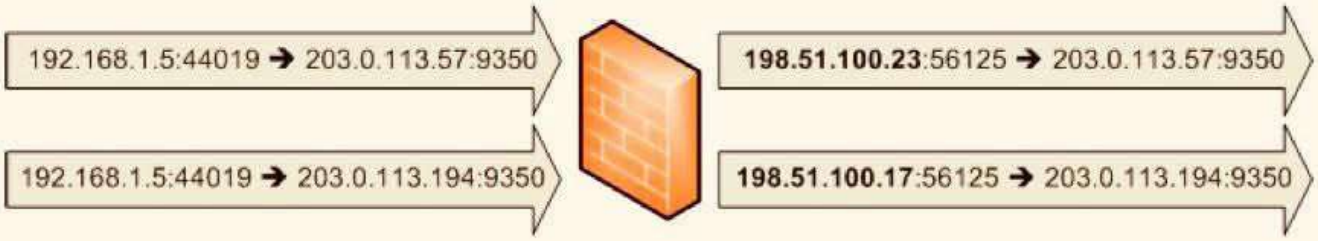
NAT type: Unfriendly. This appliance is behind a VPN-unfriendly NAT, which can be caused by upstream load balancers or strict firewall rules.

Examples

In this example the upstream firewall rewrites the source port for each outbound connection differently. Notice that the first connection is changed to port 56125 while the second is instead 56126. When the registry servers see different source ports, the NAT unfriendly error will appear:



In this example, the upstream firewall is load balancing connections over two WAN connections, and then performing NAT using two different public IP addresses. Notice that the first connection is sent from the 198.51.100.23 address, while the second is sent from 198.51.100.17 instead. When the registry servers see different source IP addresses, the NAT unfriendly error will appear:



Solutions

If using a load balancer, or NAT across multiple public IP addresses, map traffic from the internal address of the appliance to a single public IP address. This will keep the public IP address seen by the VPN registry consistent.

-OR-

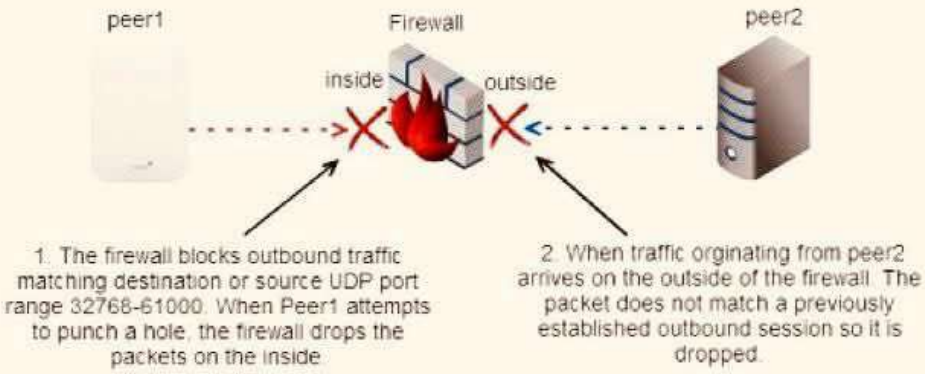
Select an arbitrary port that will be used for all VPN traffic to this MX (e.g. UDP port 51625). Manually create a port mapping on the upstream firewall that will forward all traffic received on a specific public IP and port to the internal address of the appliance on the selected port. In Dashboard on the **Security & SD-WAN > Configure > Site-to-site VPN** page use the **Manual: Port forwarding** option for **NAT traversal**, and provide the public IP address and port that was configured. All peers will then connect using this IP address and port combination.

Troubleshooting Automatic NAT Traversal

Cisco Meraki VPN peers can use Automatic NAT Traversal to establish a secure IPsec tunnel through a firewall or NAT. When ACLs on an upstream firewall block source ports or more likely the case destination UDP ports in the range 32768-61000 on outbound traffic, a peer will not be able to punch a hole in the firewall and establish a tunnel with other remote peers.

> **Note:** Cisco Meraki VPN peers must be able to use high number UDP ports to communicate with each other. Security systems such as firewalls that disallow this traffic may prevent successful traffic flow over the VPN. Please follow the diagnostic and troubleshooting steps below to resolve such issues.

In the example below, the firewall blocks peer1 from sending outbound UDP packets in the necessary destination port range. This prevents a hole punch. Now when peer2 tries to send inbound packets, its packets are dropped on the outside interface of the firewall because they do not match an existing outbound session. In this instance the tunnel will not be established between peer1 and peer2.



Failed connectivity tests or a VPN status of 'disconnected' indicates a tunnel failure between peers in Dashboard.

In a site-to-site VPN if two peers are unable to establish a VPN connection they will show as disconnected on each other's VPN status page. In this case, a packet capture should be taken on the primary Internet interface of both peers to analyze which firewall is blocking IPsec communication.

Analyzing a Packet Capture for IPsec Connectivity

Packet captures can be taken from Dashboard and downloaded as a .pcap file for analysis and filtering using Wireshark packet analyzer. They are invaluable for troubleshooting connections between hosts and isolating connectivity issues.

In the example below there is an MR to VPN concentrator tunnel that will not establish. We take packet captures from different points in the path to help determine which firewall is blocking the peer-to-peer communication.

The first capture, shown below, was taken from the wired interface of MR 10.0.8.99. We can see the MR attempting to punch a hole in its local upstream firewall by sending packets to 208.72.143.11, which is the outside IP address of the NAT that the VPN concentrator sits behind. Notice the the MR is sending traffic to the concentrator but there is no return traffic in the capture from the MX appliance behind the NAT.

MR 10.0.8.99:45540 -> MX 208.72.143.11:53654

Protocol	Source	Destination	Info
UDP	10.0.8.99	208.72.143.11	Source port: 45540 Destination port: 53654
UDP	10.0.8.99	208.72.143.11	Source port: 45540 Destination port: 53654
UDP	10.0.8.99	208.72.143.11	Source port: 45540 Destination port: 53654
UDP	10.0.8.99	208.72.143.11	Source port: 45540 Destination port: 53654
UDP	10.0.8.99	208.72.143.11	Source port: 45540 Destination port: 53654
UDP	10.0.8.99	208.72.143.11	Source port: 45540 Destination port: 53654

A second capture, shown below, was taken from the inside interface of the MX firewall upstream from the VPN concentrator. The VPN concentrator uses IP address 10.0.50.246 on the LAN. We can see the VPN concentrator sending packets to 208.72.143.18 which is the outside IP address of the NAT that the MR sits behind in an attempt to punch a hole in its local upstream firewall. Notice the VPN concentrator is sending traffic to the MR but no return traffic is present from the MR behind the NAT.

MX 10.0.50.246:53654 -> MR 208.72.143.18:45540

Protocol	Source	Destination	Info
UDP	10.0.50.246	208.72.143.18	Source port: 53654 Destination port: 45540
UDP	10.0.50.246	208.72.143.18	Source port: 53654 Destination port: 45540
UDP	10.0.50.246	208.72.143.18	Source port: 53654 Destination port: 45540
UDP	10.0.50.246	208.72.143.18	Source port: 53654 Destination port: 45540
UDP	10.0.50.246	208.72.143.18	Source port: 53654 Destination port: 45540
UDP	10.0.50.246	208.72.143.18	Source port: 53654 Destination port: 45540

A third capture was then taken, this time from the outside interface of the MX firewall upstream from the VPN concentrator. We can the see the VPN concentrator's traffic has been translated to 208.72.143.11, which is the firewall's outside IP address, and that it is being forwarded onto the Internet. This indicates the firewall is not blocking outbound IPsec traffic in the VPN concentrator site. However, we do not see any traffic originating from 208.72.143.18, the IP address of the NAT device the MR sits behind. From this we can conclude that the firewall upstream from the MR is blocking outbound IPsec traffic within the UDP port range 32768-61000.

MX 208.72.143.18:53654 -> MR 208.72.143.18:45540

Protocol	Source	Destination	Info
UDP	208.72.143.11	208.72.143.18	Source port: 53654 Destination port: 45540
UDP	208.72.143.11	208.72.143.18	Source port: 53654 Destination port: 45540
UDP	208.72.143.11	208.72.143.18	Source port: 53654 Destination port: 45540
UDP	208.72.143.11	208.72.143.18	Source port: 53654 Destination port: 45540
UDP	208.72.143.11	208.72.143.18	Source port: 53654 Destination port: 45540
UDP	208.72.143.11	208.72.143.18	Source port: 53654 Destination port: 45540

To confirm, we take a final capture from the outside interface of the MX firewall upstream from the MR, shown below. This capture shows packets originating from the VPN concentrator at 208.72.143.11 and arriving at the MR firewall's outside interface at 208.72.143.18. We still do not see any traffic originating from the MR being sent from the outside interface. This indicates the MX firewall is in fact blocking outbound IPsec traffic on the inside interface, specifically destination UDP port range 32768-61000.

MX 208.72.143.18:53654 -> MR 208.72.143.18:45540

Protocol	Source	Destination	Info
UDP	208.72.143.11	208.72.143.18	Source port: 53654 Destination port: 45540
UDP	208.72.143.11	208.72.143.18	Source port: 53654 Destination port: 45540
UDP	208.72.143.11	208.72.143.18	Source port: 53654 Destination port: 45540
UDP	208.72.143.11	208.72.143.18	Source port: 53654 Destination port: 45540
UDP	208.72.143.11	208.72.143.18	Source port: 53654 Destination port: 45540
UDP	208.72.143.11	208.72.143.18	Source port: 53654 Destination port: 45540

Once we reconfigure the firewall upstream from the MR to allow outbound destination port range 32768-61000, peers are able to form a tunnel. Although the first 4 captures are filtered by UDP ports 53654 and 45540, once the firewall is opened two-way traffic can occur on any dynamically chosen ports as shown below on a packet capture taken from the wired interface of the MR. Now the MR is registered with and using with port 41091 for VPN communication.

MR 10.0.8.99:41091 -> MX 208.72.143.11:53654

MR 10.0.8.99:41091 <- MX 208.72.143.11:53654

Protocol	Source	Destination	Info
UDP	10.0.8.99	208.72.143.11	Source port: 41091 Destination port: 53654
UDP	208.72.143.11	10.0.8.99	Source port: 53654 Destination port: 41091
UDP	10.0.8.99	208.72.143.11	Source port: 41091 Destination port: 53654
UDP	208.72.143.11	10.0.8.99	Source port: 53654 Destination port: 41091
UDP	10.0.8.99	208.72.143.11	Source port: 41091 Destination port: 53654
UDP	208.72.143.11	10.0.8.99	Source port: 53654 Destination port: 41091
UDP	10.0.8.99	208.72.143.11	Source port: 41091 Destination port: 53654

Below are two examples of ACLs that could be used to allow peer-to-peer communication between Cisco Meraki VPN peers. For the second option, X.X.X.X/32 represents the IP address of the Cisco Meraki device.

> allow inside to outside, protocol: udp, source ip: any, src port: any, dst ip: any, dst port: 32768-61000
> allow outside to inside established (may not be necessary with stateful firewalls)

-OR-

> allow inside to outside, protocol: udp, source ip: X.X.X.X/32, src port: 32768-61000, dst ip: any, dst port: 32768-61000
> allow outside to inside established (may not be necessary with stateful firewalls)