Cybersecurity Project Write-up

The aim of my cybersecurity end of semester project was to create a secure and reliable network which is designed based on the model of a small-to-medium business size. The project includes two physical locations, *Warszawa, Polska* and *Nottingham, UK*. The aim of the project is to demonstrate the types of network devices and configurations required in order to model a secure and reliable network for a small-to-medium business, plus demonstrate my own capabilities to design a network and implement security and reliability features.

My security design plan prior to the creation of the simulation was as follows:

- Dual WAN connections for ISP redundancy
- Dual edge firewalls running a Hot-standby redundancy protocol
- Firewall rules at the edge of the network to restrict what can enter and exit the network
- Site-to-Site VPN connection to allow secure connection between Polska and England sites
- DMZ connected to the firewalls to allow untrusted clients to reach publicly-accessible services, like a webserver or public DNS records
- Interior border gateway dynamic routing running in each site to automate route failure recovery
- Etherchannel connections to collapsed core switches for port failure redundancy
- VLAN segregation for each department to separate broadcast domains and reduce noise
- Core L3 switches running Hot-standby redundancy protocol to provide automatic failure recovery for default gateway devices

I managed to design the topology of the network, define the network addressing design and also implement the above reliability and security features. Please note that in this case, I consider reliability to also be security as it strengthens the “Availability” aspect of my network, which is one of the three core security fundamentals within the CIA Security Triad.

Configuration files for each device will be bundled with the project for download, along with this documentation.

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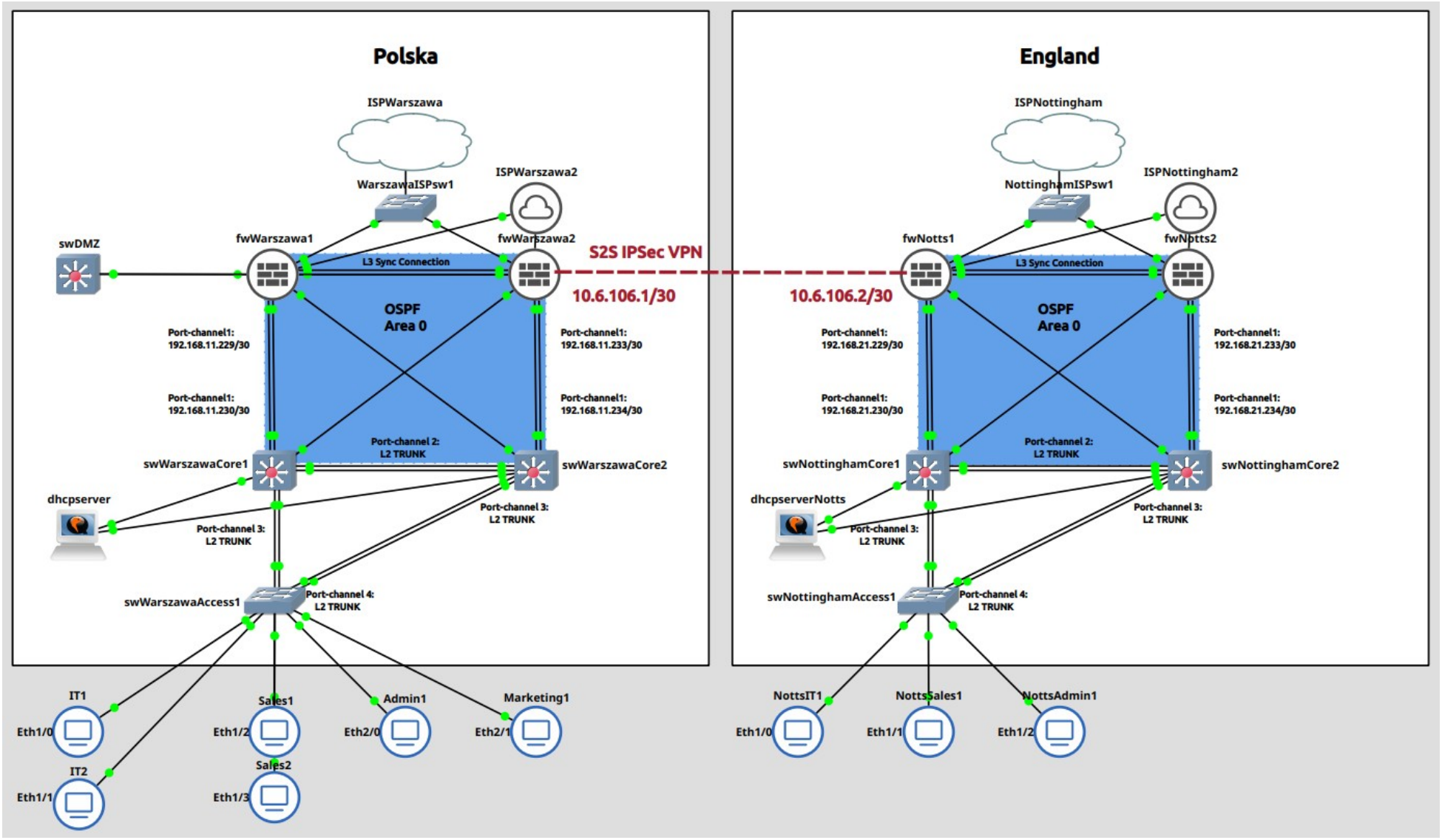
Network Diagram



IP Addressing Scheme

The below section shows the IP address schemes for the network, including the IP addresses for core network devices. Each site contained subnets to separate traffic for different teams/functions of the organisation. These functions are:

- IT
  - VLAN 10
- SALES
  - VLAN 11
- ADMIN
  - VLAN 12
- MARKETING
  - VLAN 13
- INFRASTRUCTURE
- SERVERS
  - VLAN 20
- DMZ

Warszawa Site

IT - 192.168.10.0/28 - VLAN 10

Net address: 192.168.10.0
First address: 192.168.10.1
Last address: 192.168.10.14
Broadcast address: 192.168.10.15

Core1 int: 192.168.10.2/28
Core2 int: 192.168.10.3/28
VRRP VIP: 192.168.10.1/28

Sales - 192.168.10.16/28 - VLAN 11

Net address: 192.168.10.16
First address: 192.168.10.17
Last address: 192.168.10.30
Broadcast address: 192.168.10.31

Core1 int: 192.168.10.18/28
Core2 int: 192.168.10.19/28
VRRP VIP: 192.168.10.17/28

Admin - 192.168.10.32/28 - VLAN 12
Net address: 192.168.10.32
First address: 192.168.10.33
Last address: 192.168.10.46
Broadcast address: 192.168.10.47

Core1 int: 192.168.10.34/28
Core2 int: 192.168.10.35/28
VRRP VIP: 192.168.10.33/28

Marketing - 192.168.10.48/28 - VLAN 13
Net address: 192.168.10.48
First address: 192.168.10.49
Last address: 192.168.10.62
Broadcast address: 192.168.10.63

Core1 int: 192.168.10.50/28
Core2 int: 192.168.10.51/28
VRRP VIP: 192.168.10.49/28

Infrastructure - 192.168.11.0/24
Net address: 192.168.11.0
First address: 192.168.11.1
Last address: 192.168.11.254
Broadcast address: 192.168.11.255

Core1-P2P-TO-FW1 – 192.168.11.228/30 - VLAN 14
Net address: 192.168.11.228
First address: 192.168.11.229
Last address: 192.168.11.230
Broadcast address: 192.168.11.231

Core1-BACKUP-TO-FW2 - 192.168.11.8/30
Net address: 192.168.11.8
First address: 192.168.11.9
Last address: 192.168.11.10
Broadcast address: 192.168.11.11

Core2-P2P-TO-FW2 – 192.168.11.232/30 - VLAN 14
Net address: 192.168.11.232
First address: 192.168.11.233
Last address: 192.168.11.234
Broadcast address: 192.168.11.235

Core2-BACKUP-TO-FW1 - 192.168.11.12/30
Net address: 192.168.11.12
First address: 192.168.11.13
Last address: 192.168.11.14
Broadcast address: 192.168.11.15

FW CARP SYNC - 192.168.11.16/30
Net address: 192.168.11.16
First address: 192.168.11.17
Last address: 192.168.11.18
Broadcast address: 192.168.11.19

Servers - 192.168.11.208/28 - VLAN 20
Net address: 192.168.11.208
First address: 192.168.11.209
Last address: 192.168.11.222
Broadcast address: 192.168.11.223

DMZ - 192.168.11.240/29
Net address: 192.168.11.240
First address: 192.168.11.241
Last address: 192.168.11.246
Broadcast address: 192.168.11.247

Nottingham Site

IT - 192.168.11.0/28 - VLAN 10
Net address: 192.168.11.0
First address: 192.168.11.1
Last address: 192.168.11.14
Broadcast address: 192.168.11.15

Core1 int: 192.168.11.2/28

Core2 int: 192.168.11.3/28
VRRP VIP: 192.168.11.1/28

Sales - 192.168.11.16/28 - VLAN 11
Net address: 192.168.11.16
First address: 192.168.11.17
Last address: 192.168.11.30
Broadcast address: 192.168.11.31

Core1 int: 192.168.11.18/28
Core2 int: 192.168.11.19/28
VRRP VIP: 192.168.11.17/28

Admin - 192.168.11.32/28 - VLAN 12
Net address: 192.168.11.32
First address: 192.168.11.33
Last address: 192.168.11.46
Broadcast address: 192.168.11.47

Core1 int: 192.168.11.34/28
Core2 int: 192.168.11.35/28
VRRP VIP: 192.168.11.33/28

Marketing - 192.168.11.48/28 - VLAN 13
Net address: 192.168.11.48
First address: 192.168.11.49
Last address: 192.168.11.62
Broadcast address: 192.168.11.63

Core1 int: 192.168.11.50/28
Core2 int: 192.168.11.51/28
VRRP VIP: 192.168.11.49/28

Infrastructure - 192.168.21.0/24
Net address: 192.168.21.0
First address: 192.168.21.1
Last address: 192.168.21.254
Broadcast address: 192.168.21.255
Core1-P2P-TO-FW1 – 192.168.21.228/30 - VLAN 14
Net address: 192.168.21.228
First address: 192.168.21.229

Last address: 192.168.21.230
Broadcast address: 192.168.21.231

Core1-BACKUP-TO-FW2 – 192.168.21.8/30
Net address: 192.168.21.8
First address: 192.168.21.9
Last address: 192.168.21.10
Broadcast address: 192.168.21.11

Core2-P2P-TO-FW2 - 192.168.21.232/30 - VLAN 14
Net address: 192.168.21.232
First address: 192.168.21.233
Last address: 192.168.21.234
Broadcast address: 192.168.21.235

Core2-BACKUP-TO-FW2 - 192.168.21.12/30
Net address: 192.168.21.12
First address: 192.168.21.13
Last address: 192.168.21.14
Broadcast address: 192.168.21.15

FW CARP SYNC - 192.168.21.16/30
Net address: 192.168.21.16
First address: 192.168.21.17
Last address: 192.168.21.18
Broadcast address: 192.168.21.19

Servers – 192.168.21.208/28 - VLAN 20
Net address: 192.168.21.208
First address: 192.168.21.209
Last address: 192.168.21.222
Broadcast address: 192.168.21.223

DMZ - 192.168.21.240/29
Net address: 192.168.21.240
First address: 192.168.21.241
Last address: 192.168.21.246
Broadcast address: 192.168.21.247

Network Devices Used

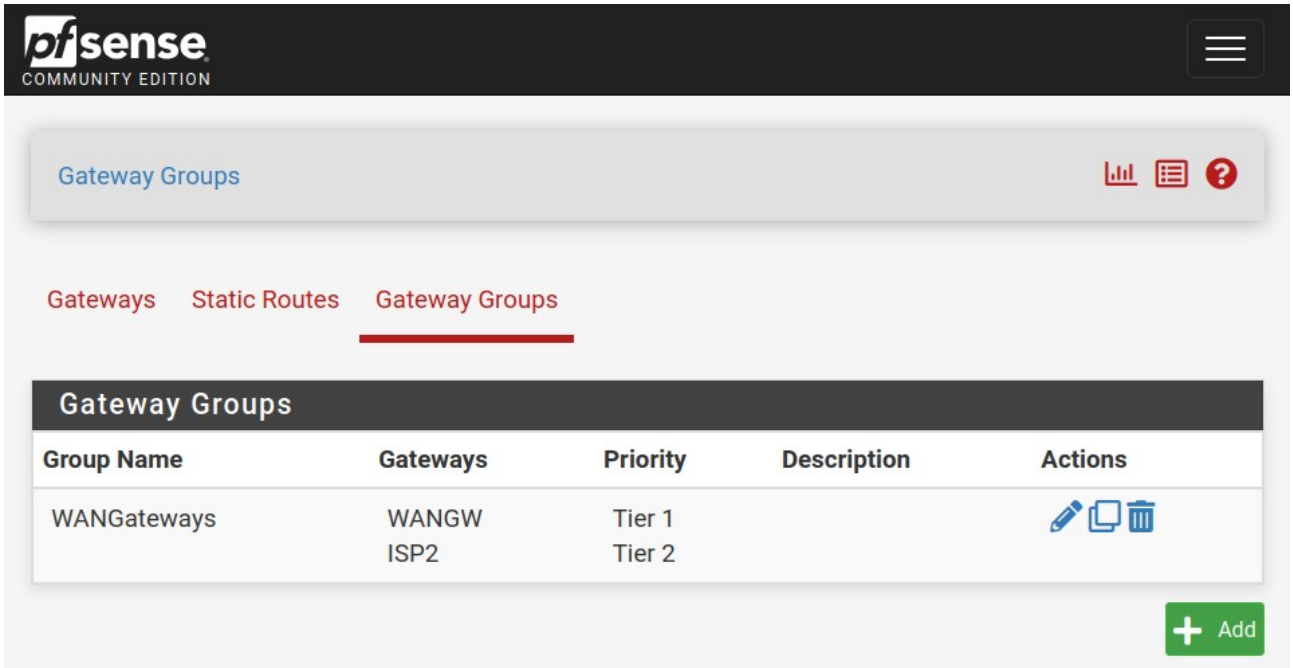
- **Firewalls**
  - PFsense Community edition
- **Core Switches**
  - L3 Cisco switch firmware
- **Access Switches**
  - L2 Cisco switch firmware
- **DHCP Servers**
  - Linux debian 6.1.0-28-amd64
- **Clients**
  - Linux tinycore 6.4

Security Feature Configurations

Dual WAN connections for ISP redundancy

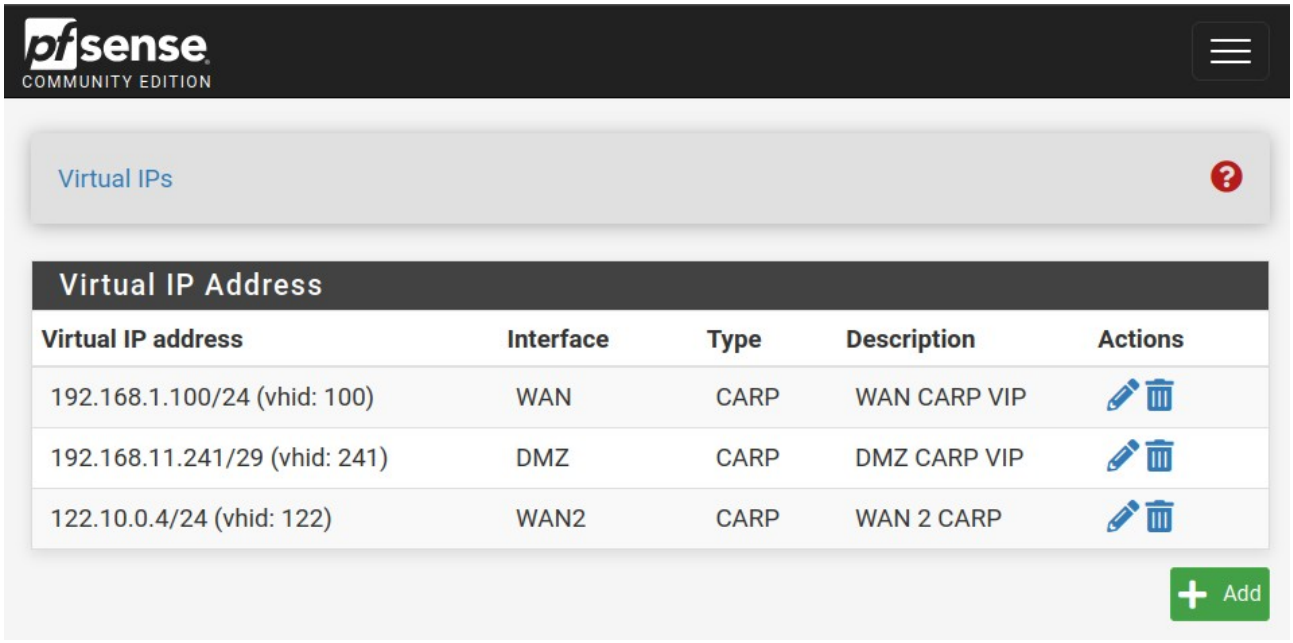
The edge firewalls at each site are configured to utilise two different ISP connections – ISP1 is always used as the primary connection but if the connection to ISP1 is lost, ISP2 kicks in as the backup ISP. This ensures that upstream ISP failures do not cause downtime for the network.

These configurations are made on the **System > Routing > Gateway Groups** page, where the two ISPs can be set as a primary (tier 1) and secondary (tier 2) default gateway. Sample config below from **fwWarszawa1:**



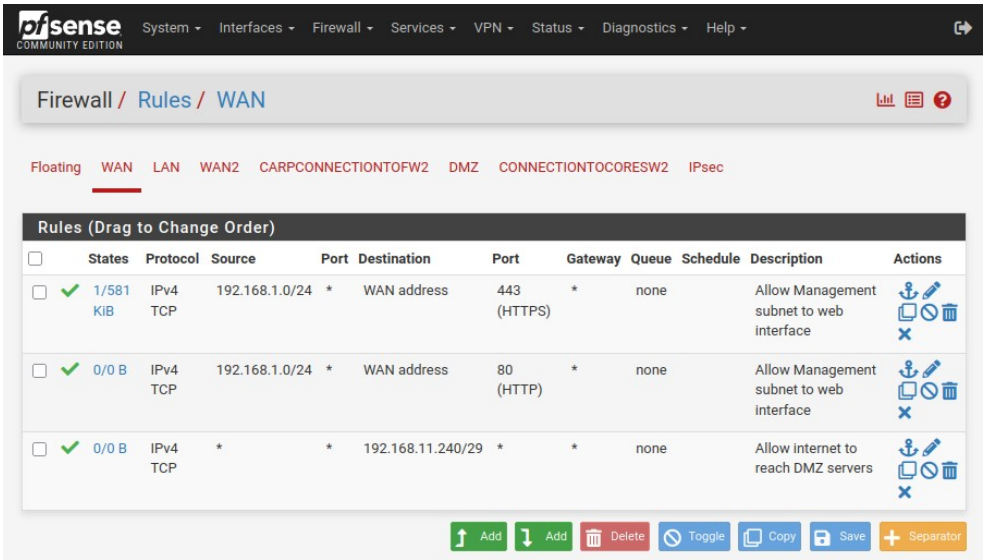
Dual edge firewalls running a Hot-standby redundancy protocol

The Common Address Redundancy Protocol (CARP) is used configure a group of gateways under a single Virtual IP (VIP) address in order to provide automatic failover in the case of some kind of interface or device failure. In this project, CARP VIP's are assigned on the WAN, WAN 2 and DMZ (Warszawa only) interfaces. This configuration is made in the **Firewall > Virtual IPs** page. Sample config below from **fwWarszawa1:**



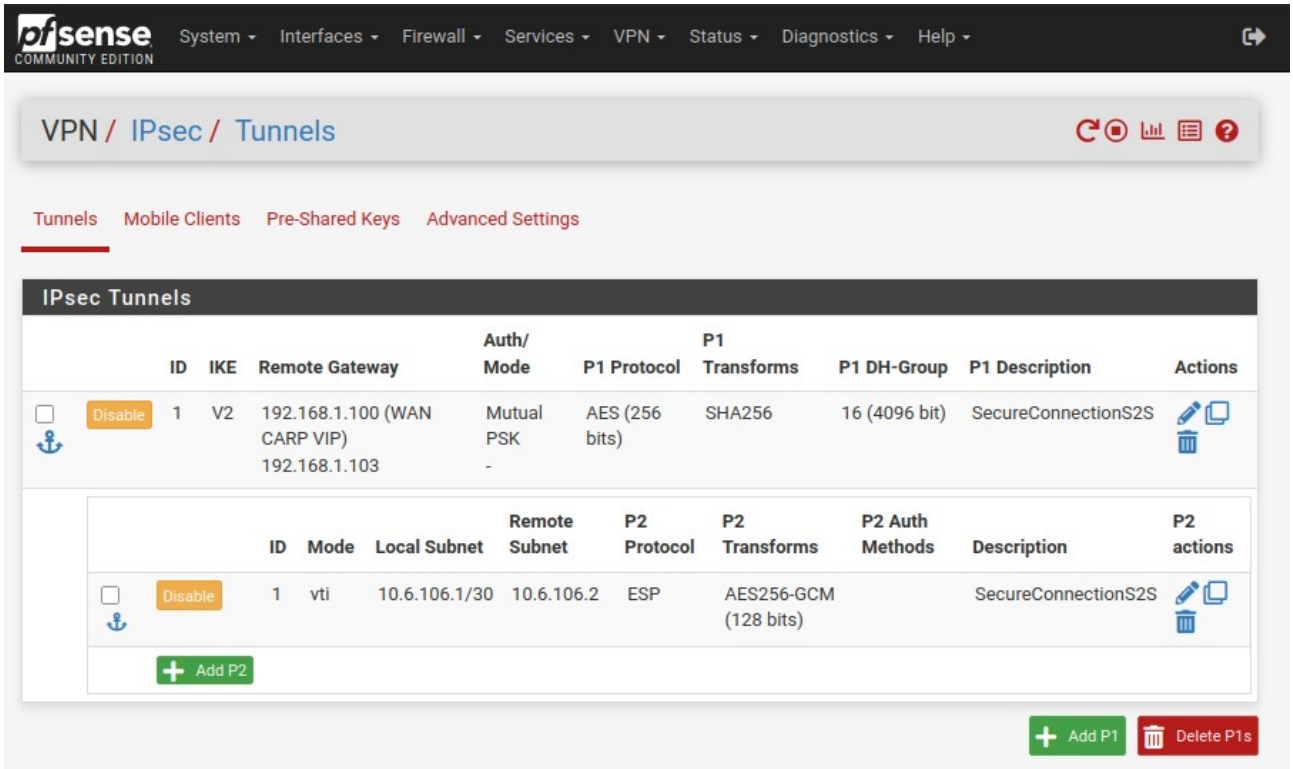
Firewall rules at the edge of the network to restrict what can enter and exit the network

Firewall rules are configured on each PFsense network edge firewall to control the flow of ingress and egress traffic on each interface (physical and virtual). These configurations are made from the **Firewall > Rules** page. Sample config below from **fwWarszawa1:**



Site-to-Site VPN connection to allow secure connection between Polska and England sites

A site-to-site IPSEC VPN was configured between fwWarszawa1 & fwWarszawa2 → fwNotts1 & fwNotts2. This allowed clients between both geographical locations communicate with each other over a secure tunnel, without exposing sensitive business traffic to untrusted networks (such as the ISP networks and any hops between them.) The IPSEC VPN configuration is configured first, both IKE phase 1 & 2, and then static routes are created to specify which subnets should be routed over the secure tunnel. The configuration can be done from the **VPN > IPsec** page. These configurations are made from the **Firewall > Rules** page. Sample config below from **fwWarszawa1:**

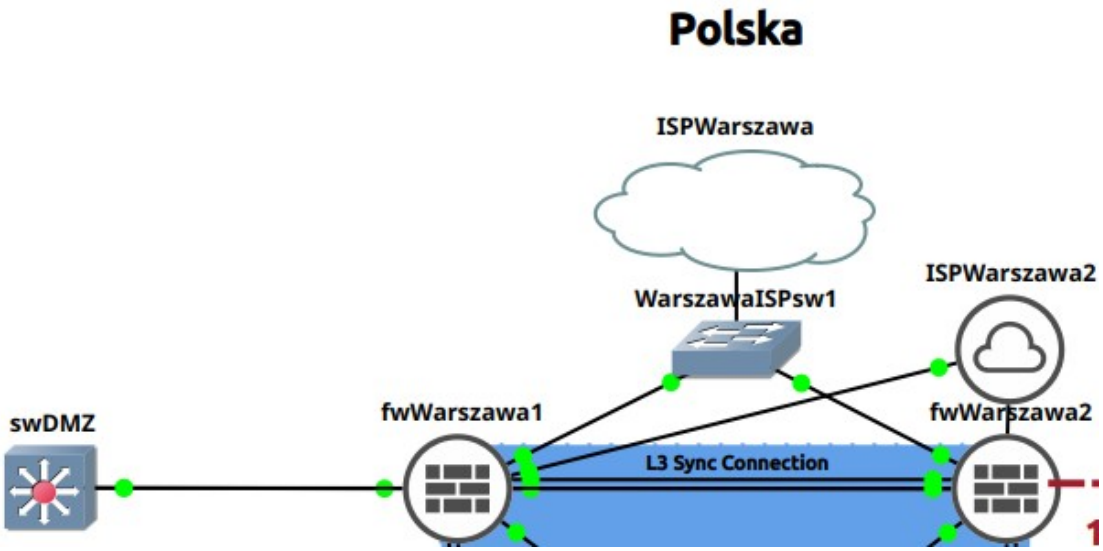


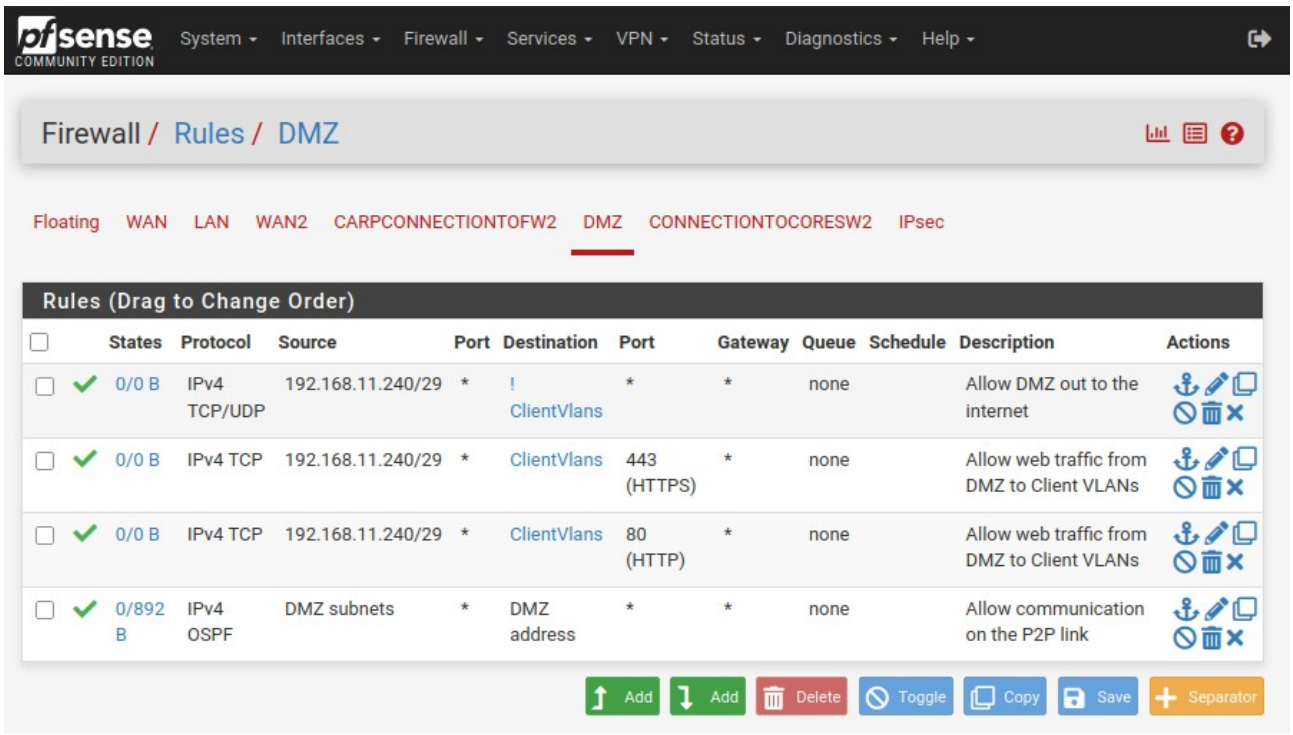
(Note: I have found the VPN performance within GNS3 to be sub-optimal – very often ping connections between clients hang for 5+ seconds, but connection can be tested and verified to be working.)

DMZ connected to the firewalls to allow untrusted clients to reach publicly-accessible services, like a webserver or public DNS records

A DMZ at the Warszawa site has been created so that publicly accessible services, such as a webserver or public DNS server, can be separated from the internal network. This means that untrusted devices, such as public clients, can access your public services but cannot communicate with your internal, private services. Since this is just a proof of concept I did not create a webserver or public DNS server (just an access switch is implemented currently), however I plan to do this in the future.

The PFsense firewalls control the flow of trusted and untrusted traffic. Some HTTP and HTTPS communications are allowed between the trusted clients and the DMZ for webserver access, but nothing else.



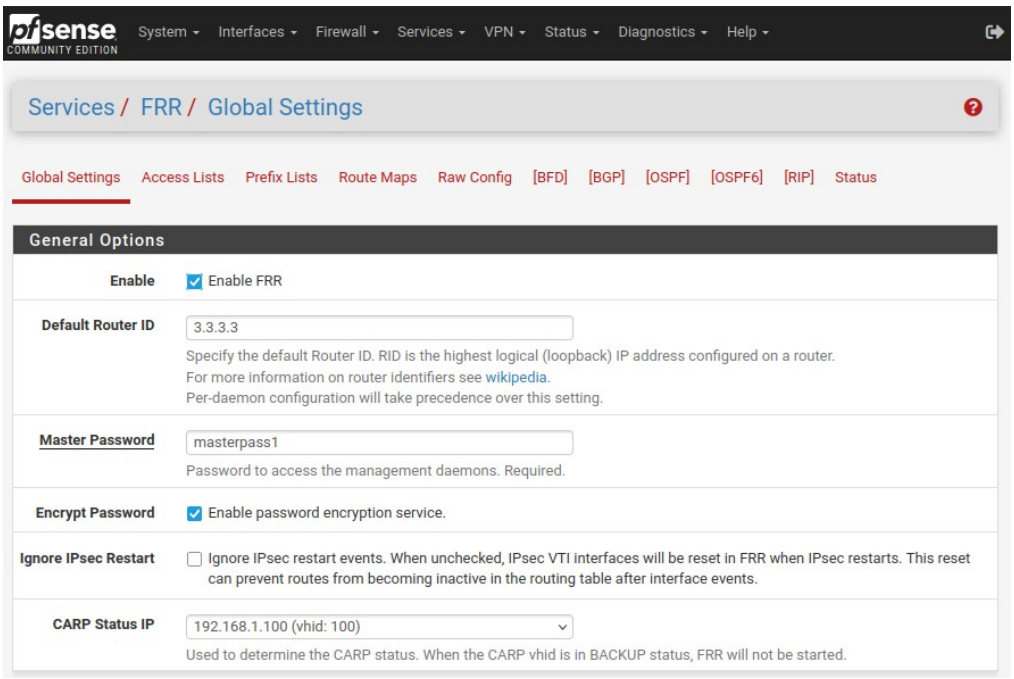


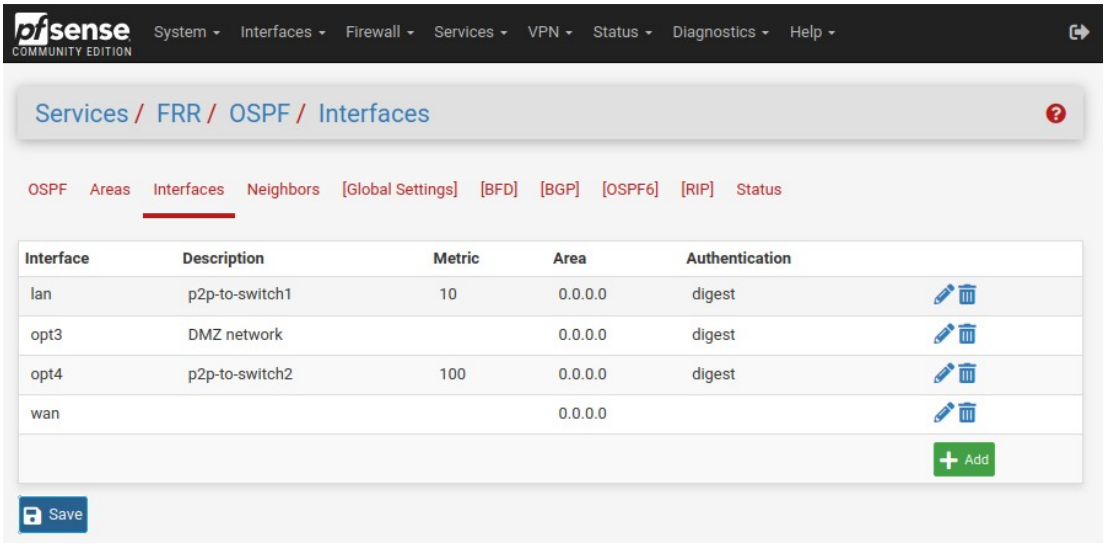
Interior border gateway dynamic routing running in each site to automate route failure recovery

The Open Shortest Path First (OSPF) protocol is used within the core network at each site in order to automate the sharing of routing information between the firewall and core switch devices, as well as to automate the failure recovery process when a device or link becomes unavailable.

If the main connection between core switch 1 and firewall 1 becomes unavailable or less desirable, the OSPF protocol will ensure that either core switch 2 or the backup link between core switch 1 and firewall 2 are used. This will all happen automatically without the need for administrator intervention.

On the PFsense firewalls, a package needs to be installed called “FRR”, which enables the OSPF protocol to be configured. OSPF can then be configured from the **Services > FRR Global/Zebra** and **Services > FRR OSPF** pages. A few pieces of configuration are displayed below for reference:





The below configuration is taken for the Cisco side is taken from **swWarszawaCore1**:

```
router ospf 1
 router-id 1.1.1.1
 area 0 authentication message-digest
 passive-interface default
 no passive-interface Ethernet1/3
 no passive-interface Vlan14
```

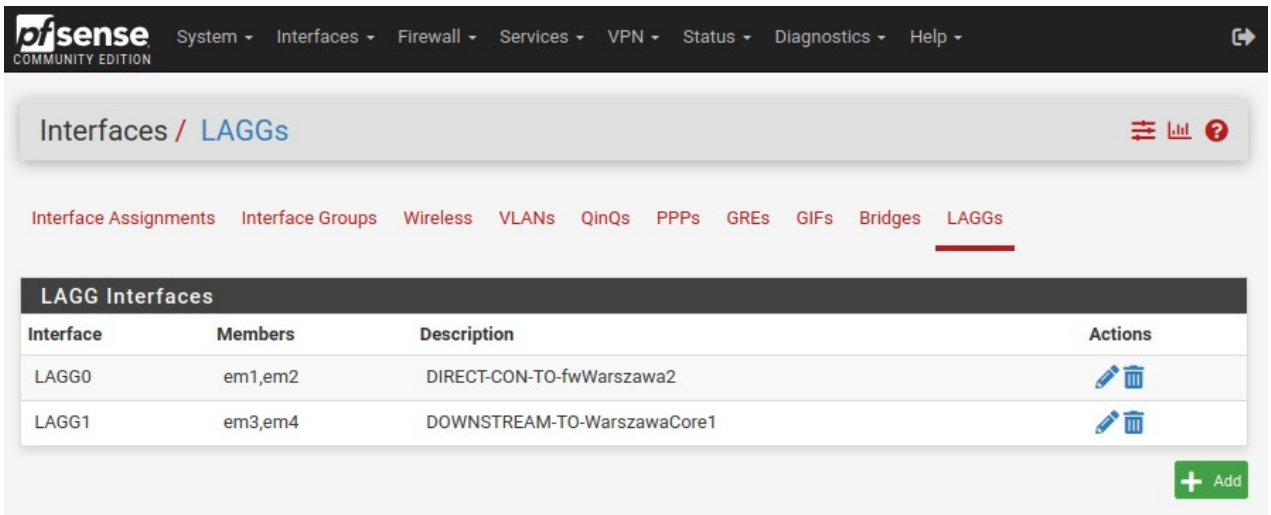
```
interface Vlan14
 description P2P-FW1
 ip ospf authentication message-digest
 ip ospf message-digest-key 1 md5 7 10652D180547055E2B5A687F660B180B
 ip ospf network point-to-point
 ip ospf 1 area 0
 ip ospf cost 10

interface Vlan10
 description DEPARTMENT-IT
 ip ospf 1 area 0
```

Etherchannel connections to collapsed core switches for port failure redundancy

The core switches, access switches and primary firewall-to-core connections are all etherchannel connections, comprised of two Ethernet interfaces per bundle. The Link Aggregation Control Protocol (LACP) is used on both the PFsense and Cisco devices to create the logical interfaces between the devices. If a single Ethernet port fails on one of the devices, there is always a secondary interface that can still be used for traffic flow.

On the PFsense firewalls, LACP configuration can be made within the **Interfaces > Assignments > LAGGs** page:



For the Cisco devices, a sample of the LACP configuration has been placed below:

```
interface Port-channel1
 description P2P-FW1
 switchport access vlan 14
 switchport mode access
!
interface Port-channel2
 description ETH2/0,1/2-BONDED-TO-CORE2
 switchport trunk allowed vlan 1,10-14,20
 switchport trunk encapsulation dot1q
 switchport mode trunk
!
interface Port-channel3
 description ETH2,3-BONDED-TO-ACCESS1
 switchport trunk allowed vlan 1,10-13
 switchport trunk encapsulation dot1q
 switchport mode trunk
```

```
Group  Port-channel  Protocol    Ports
------+-------------+-----------------------------
1      Po1(SU)         LACP      Et0/0(P)    Et0/1(P)
2      Po2(SU)         LACP      Et1/2(P)    Et2/0(P)
3      Po3(SU)         LACP      Et0/2(P)    Et0/3(P)
```

VLAN segregation for each department to separate broadcast domains and reduce noise

The different teams/functions/departments within the network design from the “IP Addressing Schemes” (Page4) section have been separated into different VLANs so that their traffic can be more easily controlled. It also separates the L2 traffic between each department, ensuring the traffic from IT (who have more access to network systems for administration) does not leak into the broadcast domains of the Sales, Admin and Marketing department.

The following status of VLAN configuration has been taken from the **swWarszawaAccess1** device:

```
swWarszawaAccess1#sh vlan br
VLAN Name                              Status    Ports
---- --------------------------------- --------- -------------
1    default                           active    Et2/2, Et2/3, Et3/0, Et3/1
                                                 Et3/2, Et3/3
10   IT                                active    Et1/0, Et1/1
11   SALES                             active    Et1/2, Et1/3
12   ADMIN                             active    Et2/0
13   MARKETING                         active    Et2/1
```

Core L3 switches running Hot-standby redundancy protocol to provide automatic failure recovery for default gateway devices

The core switches at each site are running the HSRP protocol to provide the same function as the CARP protocol on the Firewalls. It groups the core switch 1 & 2 gateways into a primary and secondary gateway for client devices within the network. It is configured for each VLAN in the network (each department), so that if core switch 1 goes down, the core switch 2 device will take over as the primary gateway for clients. The debian DHCP server is configured to provide the VIP (Group addr) seen below as the default-gateway IP for all clients in the network.

swWarszawaCore1:

```
interface Vlan10
 description DEPARTMENT-IT
 vrrp 10 ip 192.168.10.1
 vrrp 10 priority 110
 vrrp 10 authentication text ~'9e(y\
```

```
swWarszawaCore1#sh vrrp brief
Interface          Grp Pri Time  Own Pre State   Master addr     Group addr
Vl10               10  110 3570       Y  Master  192.168.10.2    192.168.10.1
```

```
Vl11                11  110 3570        Y  Master  192.168.10.18   192.168.10.17
Vl12                12  110 3570        Y  Master  192.168.10.34   192.168.10.33
Vl13                13  110 3570        Y  Master  192.168.10.50   192.168.10.49
Vl20                20  110 3570        Y  Master  192.168.11.209  192.168.11.211
```

swWarszawaCore2:

```
interface Vlan10
 description DEPARTMENT-IT
 vrrp 10 ip 192.168.10.1
 vrrp 10 authentication text ~'9e(y\

swWarszawaCore2#sh vrrp brief
Interface           Grp Pri Time  Own Pre State   Master addr     Group addr
Vl10                10  100 3609        Y  Backup  192.168.10.2    192.168.10.1
Vl11                11  100 3609        Y  Backup  192.168.10.18   192.168.10.17
Vl12                12  100 3609        Y  Backup  192.168.10.34   192.168.10.33
Vl13                13  100 3609        Y  Backup  192.168.10.50   192.168.10.49
Vl20                20  100 3609        Y  Backup  192.168.11.209  192.168.11.211
```