Secure Cloud for Azure (IaaS)

Design Guide

June 2021

Contents

Abstract

This design guide aligns with the Cisco® Secure Cloud Architecture guide. The Secure Cloud Architecture guide explains the secure architecture for cloud applications, critical business flows; attack surfaces and corresponding security controls required for the cloud environment. This guide proposes a Cisco Validated Design (CVD) for security in a tiered application architecture. The solution proposed in this guide leverages Cisco security controls along with Cloud-Native security controls to achieve the desired security posture for applications in the Azure cloud.

Scope

This document illustrates the design and security aspects of an application hosted in Azure Cloud. Along with the design and security specifications, this document also delves into the details of implementation and validation steps for the proposed architecture.

This guide covers the following security controls.

- Cisco Tetration
- Cisco Advanced Malware Protection for Endpoints (AMP4E)
- Cisco Stealthwatch Cloud (SWC)
- Cisco Umbrella
- Azure Network Security Groups (NSG)
- Cisco Firepower Next-Generation Firewalls (NGFW)
- Cisco Adaptive Security Appliance (ASA)
- Cisco Defense Orchestrator (CDO)
- Azure Web Application Firewall (WAF) and DDOS prevention
- Radware Cloud Web Application Firewall (WAF) and DDOS prevention
- Cisco Duo Beyond
- Cisco SecureX threat response

For setting up the web application, we used the following Azure cloud components and services.

- Azure Virtual Network (VNET) and Subnets
- Azure Route Tables
- Azure Database for MySQL
- Azure Virtual Machine Scale Sets (VSS)
- Azure Virtual Machines
- Azure Internal Load balancer (Standard)
- Azure External Load balancer (Standard)
- Azure Storage Containers
- Azure Resource Manager (ARM) Templates
- Azure Private Links

- Azure Front Doors (AFD)

SAFE Architecture – Introduction

As your data flows from an increasing number of devices to your data center or private/public cloud, you must understand your data flow, to be able to protect it. Cisco SAFE is an architectural approach that helps you visualize this transit of the data in terms of business flows, understand the attack surface associated with these flows and hence, devise appropriate capabilities to secure them. This framework provides complete guidance from the initial identification of business flows in a given architecture to securing it and then deploying and validating the solution.

These validated designs provide guidance that is complete with configuration steps that ensure secure deployments for your organization. Cisco Validated Designs (CVDs) for various SAFE PINs can be found at [SAFE home page.]

Cisco SAFE simplifies network security by providing solution guidance using the concept of 'Places in the Network' (PINs). This design guide is a recommended threat defense architecture for the Cloud PIN (see figure 1). Within the Cloud PIN, this design guide specifically covers the Azure public cloud.

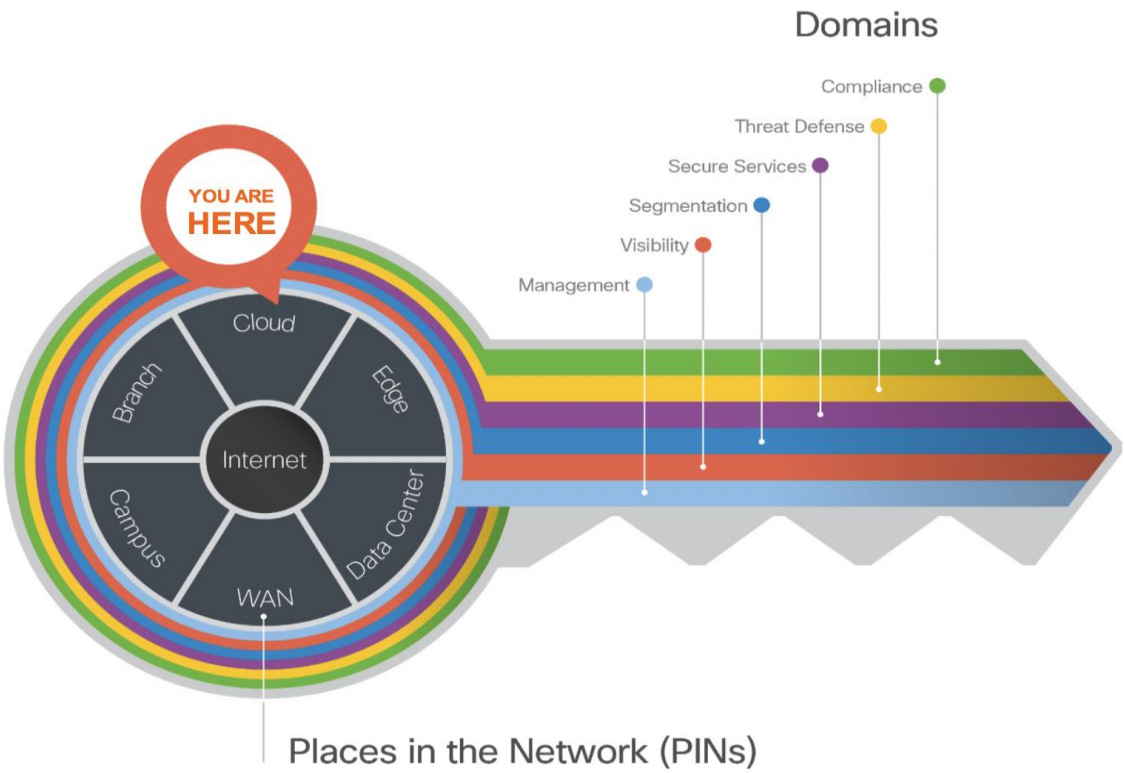


Figure 1.
Key to SAFE framework

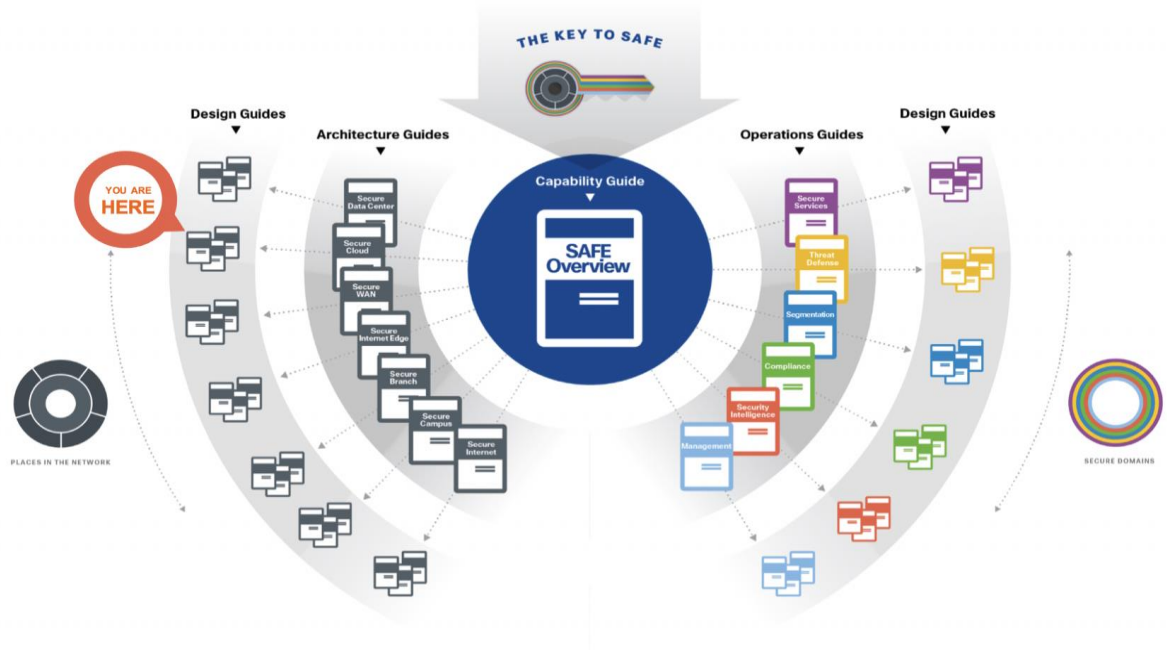


Figure 2.
SAFE Guidance Hierarchy

For more information on SAFE framework and architecture/design guides, check out the SAFE documentation (select architecture/design tab).

Cloud Business Flows

SAFE uses the concept of business flows to simplify the identification of threats. This enables the selection of very specific capabilities necessary to secure them.

This solution addresses the following business flows for a typical tiered web application hosted in the Azure cloud:

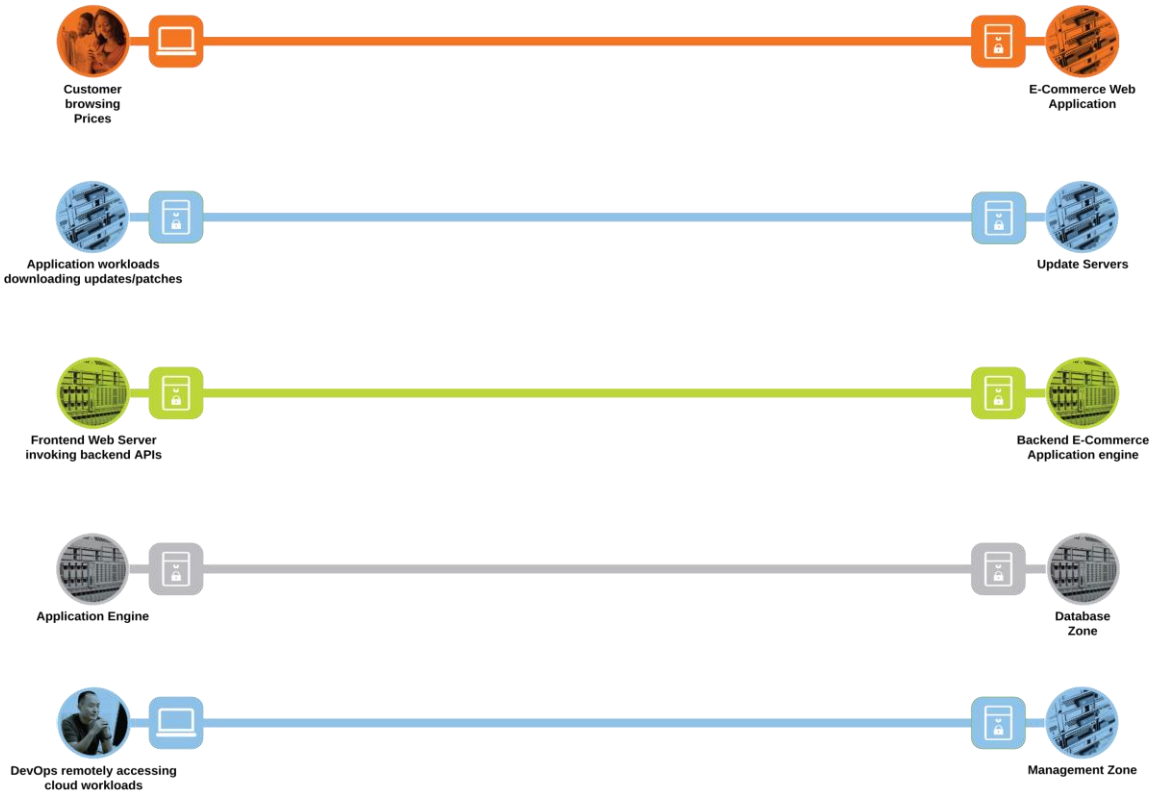


Figure 3.
Cloud business flows

- Customer browsing an e-commerce web application. The customer, sitting somewhere out on the Internet, browses the e-commerce web application hosted in the Azure cloud
- Application workloads downloading updates/patches from update servers outside the cloud (Internet). Application workloads sitting in the cloud need to reach out to various update servers to fetch the updates and patches at regular intervals
- Systems communicating east/west within the Azure cloud. For example- the frontend web servers will make HTTP requests to backend application engine or the application engine workloads will make API calls among themselves
- Application workloads transacting data with database server within the cloud
- DevOps remotely accessing the management zone for workload management/update/patching purposes

Public Cloud Attack Surface

The secure cloud design protects systems by applying security controls to the attack surface found in the public cloud. The attack surface in public cloud spans the business flows used by humans, devices, and the network.

Threats include; rogue identity, DDoS, web vulnerabilities, infections, and advanced persistent threats allowing hackers the ability to take control of your devices and networks.

Considering the business flows elaborated in the last section (Figure 3), a deep dive into the attack surface for each of those business flows can be showcased as below.

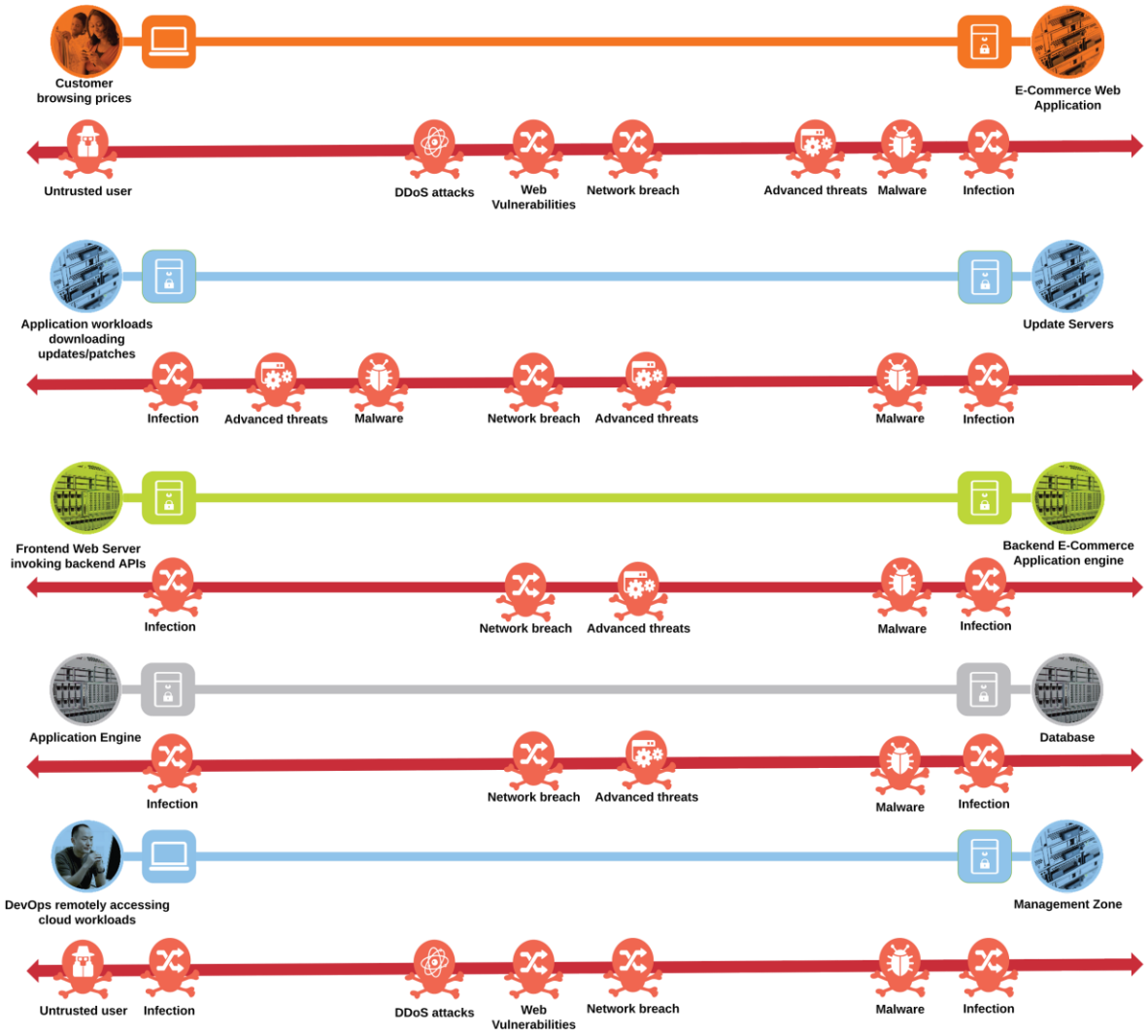


Figure 4.
Public cloud attack surface

- An untrusted/compromised user, out on the Internet, may try to exploit the cloud application or flood it with fake traffic to render it incapable of serving the genuine users
- The workloads need to communicate with update servers out on the untrusted public network. An attacker might compromise workloads to download malware to the application environment or upload crucial data to malicious servers
- Systems communicating east/west within the Azure cloud may spread the infection from one workload to another within the cloud, eventually compromising the whole application
- An attacker may compromise the application workloads to steal or corrupt data stored on the database servers
- A malicious user may try to gain the same privileged access as DevOps to compromise the complete application environment in Azure

Solution Overview

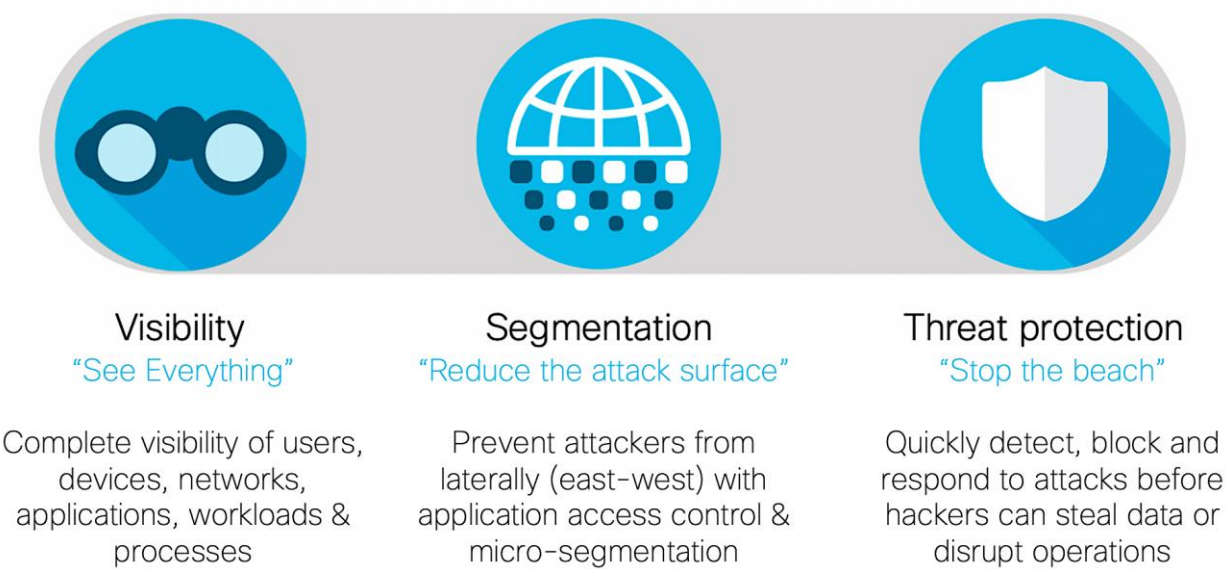
Cisco's security approach for the modern cloud applications allows companies to achieve:

- Improved resiliency to enable cloud availability and secure services
- Operational efficiency from automated provisioning and flexible, integrated security
- Advanced threat protection from Cisco TALOS – industry-leading threat intelligence to stay up to date, informed, and secure

What is our security approach?

Specific capabilities are necessary to protect the public cloud and build the appropriate layers of defense. These capabilities work together to create several layers of defense protecting the cloud applications. The top priorities or the three pillars that we keep in mind while designing the secure public cloud solutions are:

- **Visibility** - Complete visibility of users, devices, networks, applications, workloads, and processes
- **Segmentation** - Reduce the attack surface by preventing attackers from moving laterally, with consistent security policy enforcement, application access control and micro-segmentation
- **Threat Protection** - Stop the breach by deploying multi-layered threat sensors strategically in the public cloud to quickly detect, block, and dynamically respond to threats



Secure Cloud Business Flows

Developing a defense-in-depth architecture requires identifying existing threats and applying appropriate security capabilities to thwart them. Business flows and the corresponding attack surface and threat patterns that we defined earlier (Figures 3 and 4) are mapped to their corresponding security controls as below.

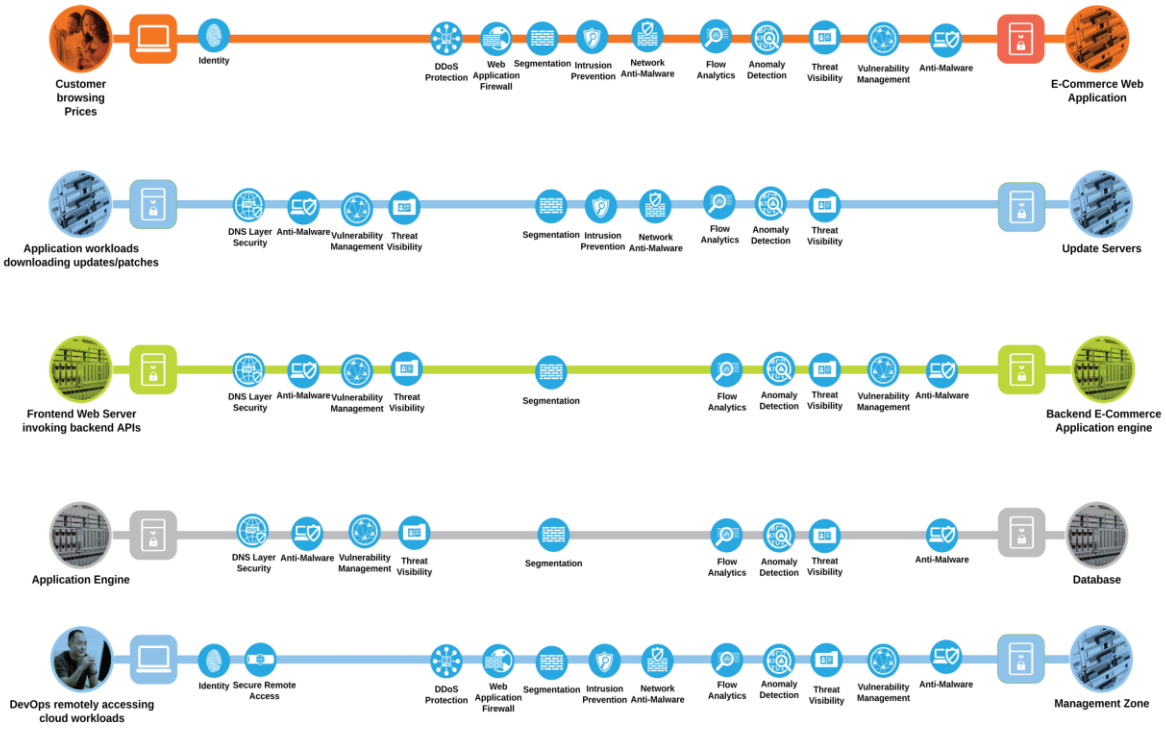


Figure 5.
Secure business flows

Cisco's Secure Architecture for Azure

The tiered architecture has been a popular underlying principle for web application deployment for over a decade now and it remains equally relevant to date.

The multi-tier architecture provides a general framework to ensure decoupled and independently scalable application components. Each tier is separately developed, scaled, maintained and secured.

In the simplest tiered architecture form, the web applications would have the following layers:

Web tier: The end-user directly interacts with this layer. This tier has all the static web content.

Application tier: This tier is responsible for translating the user actions to application functionality. This tier carries the core application code components. For example, application code performing the read/write database operations.

Database tier: Storage tier or the database tier holds the data relevant to the application.

In this document, we are securing a tiered web application in the Azure cloud. We add various security capabilities and controls, that we established in the previous sections, to a tiered web application model to make it much more robust, secure and transparent in its security posture.

Secure Cloud architecture

The Cisco Secure Cloud reference architecture solution includes all the security capabilities that we illustrated in previous sections.

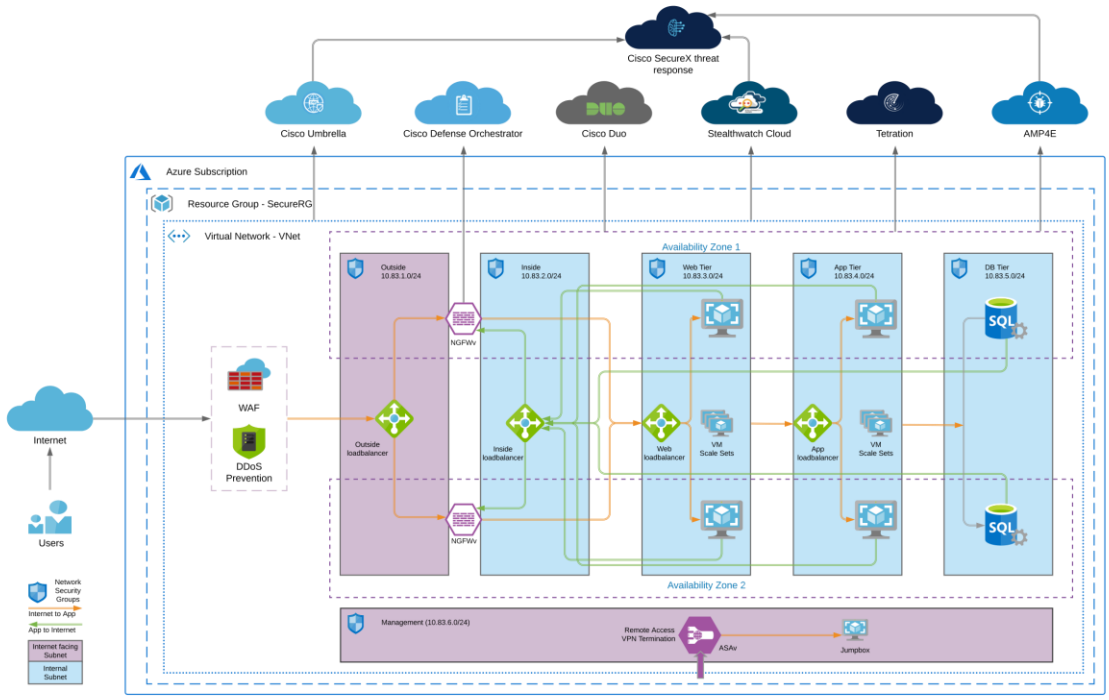


Figure 6.
Cisco Secure Cloud Reference Architecture

Business flows in Cisco's Reference Architecture

Considering the design above, all the threats, corresponding security capabilities and solutions required to attain those capabilities can be mapped as below.

Threat		Security Capability		Security Solutions
	Attackers or malicious users accessing restricted resources and information.		Identity based access	Cisco Duo – 2FA
	Massively scaled attacks that overwhelm services.		DDoS prevention	Azure DDoS prevention Radware DDoS prevention
	Attacks against poorly developed applications and web vulnerabilities.		Web Application Firewalls	Azure Web Application Firewall Radware Web Application Firewall
	Network breach causing unauthorized access and malformed packets between and within application in the cloud.		Segmentation	Cisco Firepower NGFWv Azure Network Security Groups Cisco Tetration
	Zero-day malware attacks and other forms of covert threats.		Threat visibility	Cisco Stealthwatch Cisco Tetration Cisco AMP4E Cisco Firepower NGFWv
	Attacks using worms, viruses, or other techniques.		Intrusion Prevention	Cisco Firepower NGFWv Cisco AMP4E
	Infections, attackers using a compromised workload to spread the damage.		Micro-segmentation	Cisco Tetration
	Malware distribution among workloads or between servers.		Anti-malware	Cisco Firepower NGFWv Cisco AMP4E
	Traffic, telemetry, and data exfiltration from successful attacks. Covert threats.		Flow Analytics	Cisco Stealthwatch Cisco Tetration Cisco Umbrella
	Exploiting privileged access to run shell code		Process Anomaly Detection & Forensics	Cisco Stealthwatch Cloud Cisco Tetration Cisco AMP4E
	Malware distribution across networks.		Network Anti-Malware	Cisco Firepower NGFWv

Threat		Security Capability		Security Solutions
	Exploiting unpatched or outdated applications.		Vulnerability Assessment and Workload Inventory	Cisco Tetration
	Redirection of session to malicious domains.		DNS Layer Security	Cisco Umbrella – DNS Layer Security
	Exposed services and data theft.		VPN Gateway or Concentrator	Cisco ASAv Cisco Firepower NGFWv

We have established the attack surface and, the capabilities and security solutions that we needed to secure the business flows mentioned previously.

- Customer browsing an e-commerce web application
  - Access to the web application is secured using Duo – Multi-Factor Authentication (MFA)
  - WAF and DDoS Services protect against web vulnerabilities and denial of service attacks. In this document, we will demonstrate two options for WAF and DDoS protection- Azure cloud native service and Radware cloud service. Based on your preference, you could choose either
  - Network segmentation is done using next-generation firewalls (NGFW) to protect against any network or perimeter level breaches. NGFWs also provide next-generation IPS and AMP capabilities along with stateful firewall, AVC (Application Visibility and Control) and URL filtering.
  - At the macro level, workloads are segmented into various tiers using Azure Network Security Groups. Micro-segmentation of workloads is done using the Tetration policy enforcement agents. This would prevent any malware or malicious movement within the pool of workloads in a specific tier
  - Stealthwatch Cloud provides enhanced threat visibility into workload activity and the Azure cloud. It looks for any anomalous activity within the application environment. It also facilitates the flow analytics
  - Tetration agents allow us to gain a deep visibility into vulnerable packages and processes on the workloads that an attacker may leverage. It also provides a very robust network flow analytics for workload communications
  - AMP4E detects and quarantines any malware that may infect the workloads
- Application workloads downloading updates/patches from update servers
  - Application workloads are segmented into App and Web tier using Azure Network Security Groups. No direct inbound public access is allowed to the App and Web servers, management access is allowed only from the management tier (also controlled via Azure Network Security Group)
  - DNS layer security is achieved using Cisco Umbrella. This prevents any accidental or deliberate exposure to a malicious domain
  - Stealthwatch Cloud and Tetration provide enhanced threat visibility and flow analytics
  - AMP4E detects and quarantines any malware that may get downloaded to application workloads

- Network segmentation is achieved using Cisco Firepower next-generation firewalls to protect against any network or perimeter level breaches. NGFWs also provide network IPS and AMP capabilities, that would prevent any malicious file download right at the network perimeter

- Systems communicating east/west within the Azure cloud
  - Workloads are segmented into tiers at the macrolevel using Azure Network Security Groups. Web, App, Database and Inside tier has no direct inbound public access/addresses. Only Management and the Outside tier is allowed Public IP addressing, hence exposing them to untrusted public network/internet
  - Micro-segmentation within Web and App tier is done using the Tetration enforcement agents. This restricts any internal movement within an application tier
  - DNS layer security using Umbrella provides visibility into workload activity
  - Stealthwatch Cloud and Tetration provide enhanced threat visibility and flow analytics for this flow. They also look for any anomalous movement within the application environment or among the workloads within a tier. Tetration agents provide deep visibility into the workloads
  - AMP4E protects against malware spread
- Application engine transacting data with database server within the cloud
  - Azure Network Security Groups restrict access to the database. Only App tier is allowed to communicate with database tier
  - DNS layer security using Umbrella
  - Stealthwatch Cloud and Tetration provide enhanced threat visibility and flow analytics. They also look for any anomalous movement within the application environment or among the workloads within a tier. Tetration agents provide deep visibility into the workloads
  - AMP4E protects the application workloads against any malware infection
- DevOps remotely accessing the management zone for workload management/update/patching purposes
  - Anyconnect VPN mobility client is used to provide Secure Remote Access to the management tier. An ASA or NGFWv can be used for VPN termination. We tested a standalone ASAv for this design. Refer to the Secure Remote Worker design guide for detailed information on secure remote access designs and deployments
  - Management zone is segmented using Azure Network Security Groups. This provides the control knob for restricting access to workloads or the various tiers
  - Stealthwatch Cloud and Tetration provide enhanced threat visibility and flow analytics. They also look for any anomalous movement or activity within the application environment or from the management tier. Tetration agents provide deep visibility into the workloads
  - AMP4E protects the jump servers and workloads against any malware infection

Security Integrations

Let's look at each of the security integrations in this secure design in more depth, we will start from the security controls on the workload itself and go all the way to the edge of our public cloud web application.

We start by looking at workload security using Tetration and Advanced malware protection, followed by an agentless deployment of Stealthwatch for greater visibility into the Azure cloud and workload activity. Then, we will look into Umbrella DNS layer security at the Azure VNET level.

Afterwards, we move to perimeter protection using Cisco Firepower NGFW (policy orchestrated by Cisco Defense Orchestrator), WAF and DDoS protection. We will explore two different options for WAF and DDoS protection – Azure Cloud Native Service and Radware Cloud.

Lastly, we will delve into securing authentication to our application using Duo MFA.

To connect all these security pieces together, we will look at Cisco SecureX threat response integrations to get a unified view of the Azure cloud security.

Cisco Tetration

Tetration has a SaaS offering that provides the capability to do micro-segmentation in a highly flexible manner along with an in-depth visibility into the workloads.

Tetration offers visibility and enforcement agents that are installed on the workloads. Enforcement agents provide an additional capability to enforce policies.

Tetration can dynamically learn various ongoing changes in the cloud workload environment and enforce an adaptive micro-segmentation. The Tetration portal allows us to create workspaces and graphical views for applications and enforce security from the web application point of view unlike the traditional network perspective.

The Tetration platform supports multi-cloud and hybrid environments and hence, make the whole process of security operations seamless across the board.

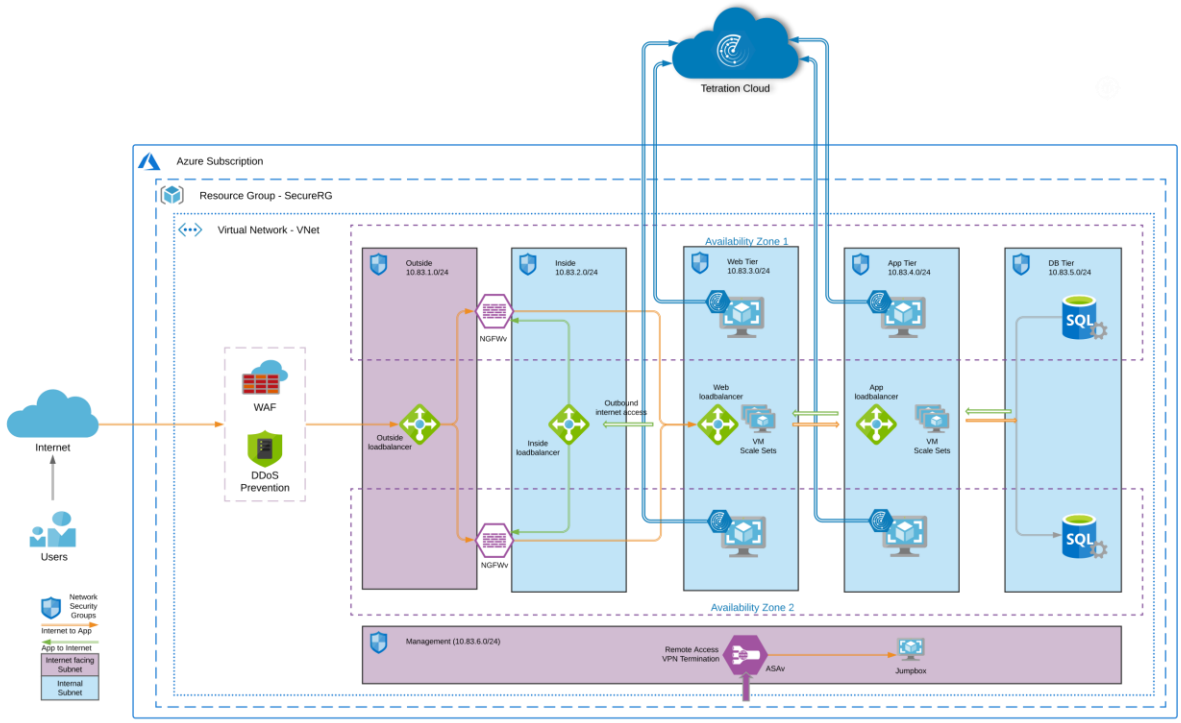


Figure 7.
Cisco Tetration

In this specific architecture, Web and Application tier has workloads in Virtual Machine Scale Sets (VSS). To enable the auto-provisioning of Tetration agents, we used the custom scripts provided under Azure VM extensions. When the VSS deploys a new workload, the custom script will install the Tetration agent on it as part of the initialization process. Refer to the implementation section of this guide for more details.

Once the Tetration agent on the new workload is registered with the Tetration cloud (SaaS), it starts exporting the network flow and process information to the Tetration cloud engine for analysis. Tetration ensures Cisco's Zero Trust model by offering key features like:

- Policy enforcement (Micro-segmentation)
- Visibility into workload process activity
- Network flow visibility
- Software vulnerability reports
- Forensic analysis
- Behavior deviations

Based on all these features and more, the Tetration dashboard provides us with a very convenient and flexible scoring mechanism to monitor the security compliance of cloud applications. Tetration considers six parameters to calculate this score (Figure 8), and these parameters can be adjusted based on one's preference or requirements.

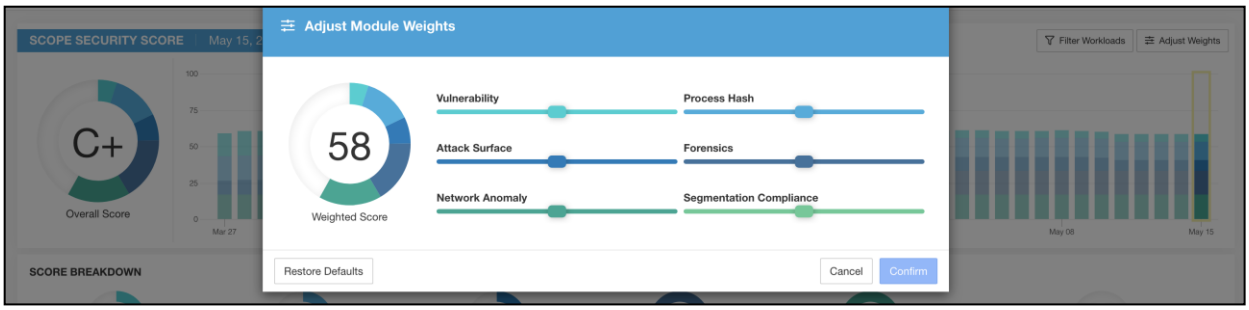


Figure 8.
Tetration Dashboard - Weighted Score

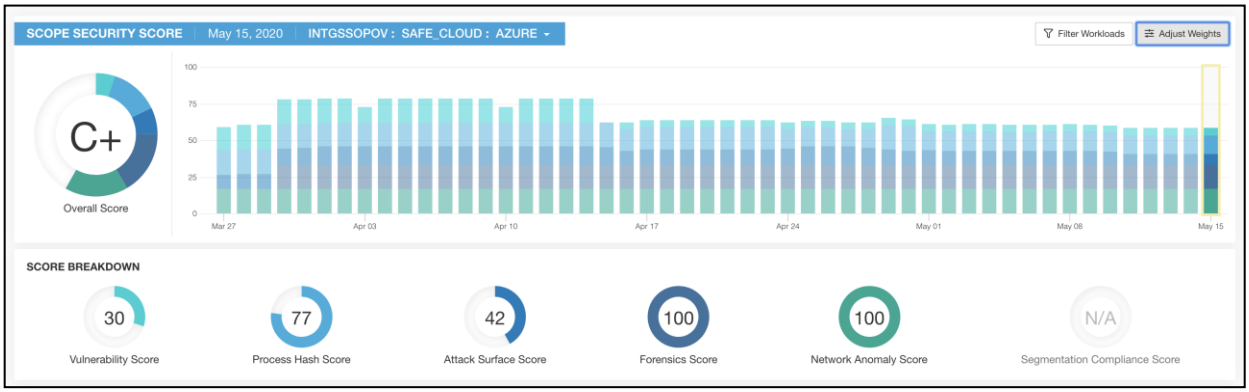


Figure 9.
Tetration Dashboard - Compliance Score Board

Refer to the Tetration documentation for more detailed information on cloud workload protection.

Cisco Advanced Malware Protection for Endpoints

The AMP4E agents installed on the cloud workloads provide us protection against zero-day attacks. Powered by Cisco TALOS, AMP4E not only relies on antivirus, but also uses machine learning and file reputation to block both file-based and file-less attacks. It also enables you to isolate the infected host before the malware is spread onto the others in the network. Advanced Malware Protection also supports taking forensic snapshots that help immensely with the security investigations.

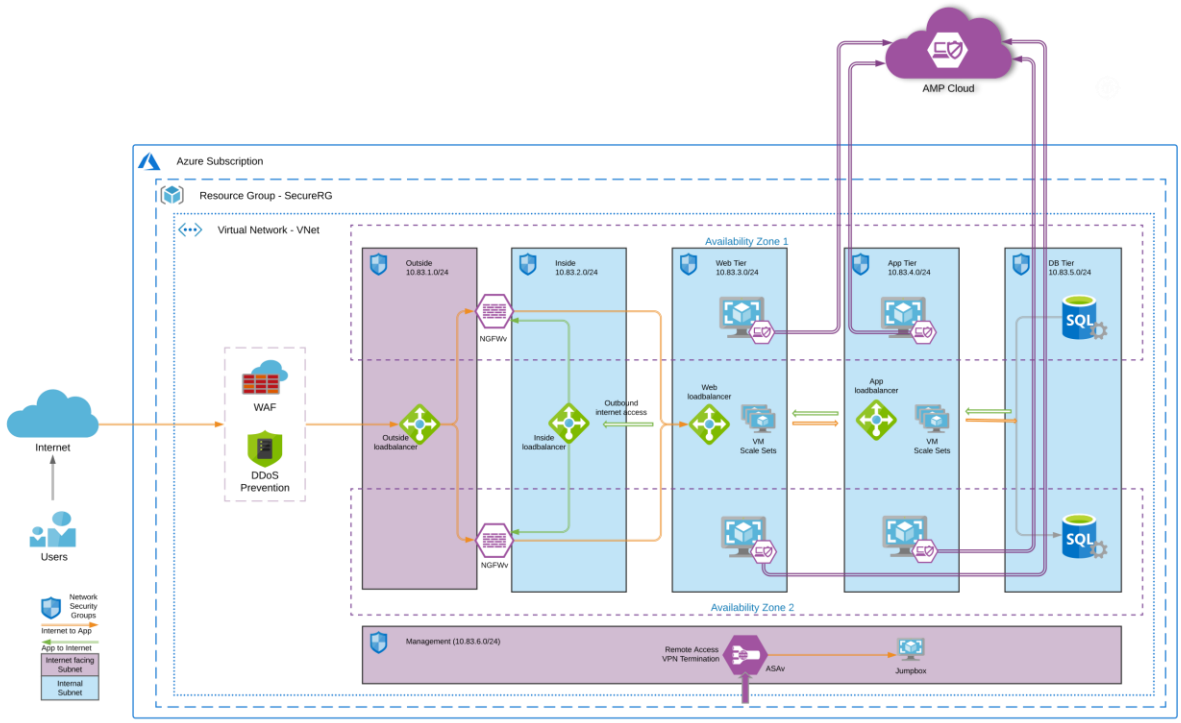


Figure 10.
Cisco Advanced Malware Protection for Endpoints

In this specific architecture, just like the Tetration agent, the web and application workloads in VSS are auto-provisioned with AMP4E agents using custom scripts option available via Azure VM extensions. When the VSS deploys a new workload, the custom script will install the AMP4E agent on the workload as part of the initialization process.

As soon as AMP4E agent on the new workload registers with the AMP cloud, the workload is continuously monitored and reported for any malicious activity. AMP's host isolation feature comes in very handy to contain any spread of malware in the cloud workloads.

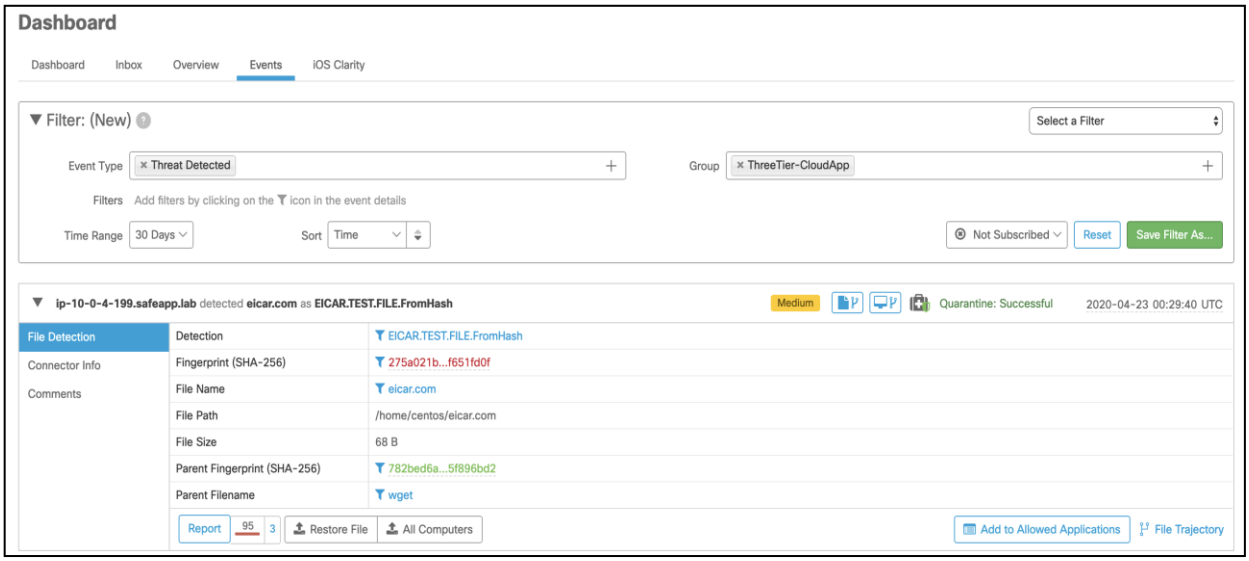


Figure 11.
AMP Dashboard – Threat monitoring

Cisco Stealthwatch Cloud

Stealthwatch Cloud (SWC) helps overcome the visibility challenge, especially in public cloud environments. It provides an agentless deployment in the Azure cloud.

Stealthwatch Cloud pulls the Network Security Group (NSG) flow logs from the designated Azure storage containers. It learns the Azure environment and baselines the resources. NSG flow logs have the flow information associated with various Azure resources, even for those that are not strictly tied to a static IP address. SWC is capable of correlating the IPs and then tying them back to their origin Azure service. In other words, SWC performs dynamic entity modeling and organizes all the Azure resources based on the functions that they're performing. For example, the entity could be categorized as a firewall, an application server or a load balancer and so on. This type of resource profiling and modeling is extremely important to look for any suspicious activity within the cloud application environments.

In addition to NSG flow logs, Stealthwatch Cloud also consumes other telemetry sources like Azure Activity logs for additional context and alerting.

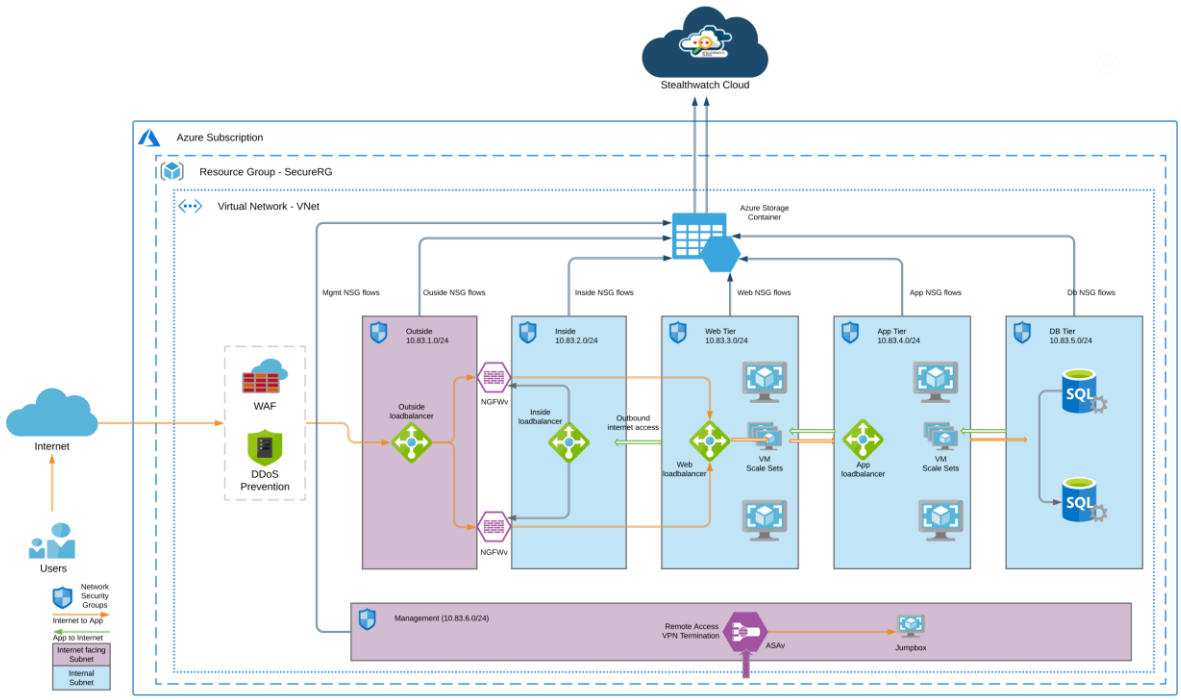


Figure 12.
Cisco Stealthwatch cloud

Once the Stealthwatch Cloud finishes identifying the entities, it baselines their behavior over a fixed period of time. As soon as the baselining is completed, any unexpected behavioral change of the entities and the way different cloud services communicate with each other is alerted on. This helps to maintain deep visibility into the cloud environment and hence, track and prevent any unauthorized transfer of data or resource access.

Some of the common Stealthwatch alerts related to the Azure cloud include:

- Azure Activity Log IP Watchlist Hit - This is triggered by an IP address that matched a user-defined or an integrated watchlist. This alert may indicate that an unauthorized user has gained access to Azure
- Azure Activity Log Watchlist Hit – This alert is triggered when Azure Activity Log reports an event on a user-supplied watchlist
- Azure Permissive Storage Account – If the storage accounts are identified by Azure Security Center as having unrestricted firewall settings then this alert is triggered
- Azure Security Event - Triggers when Azure Security Center reports a medium or high severity event
- Azure Virtual Machine in Unused Location - Triggers when an Azure Virtual Machine has been created in a previously unused location

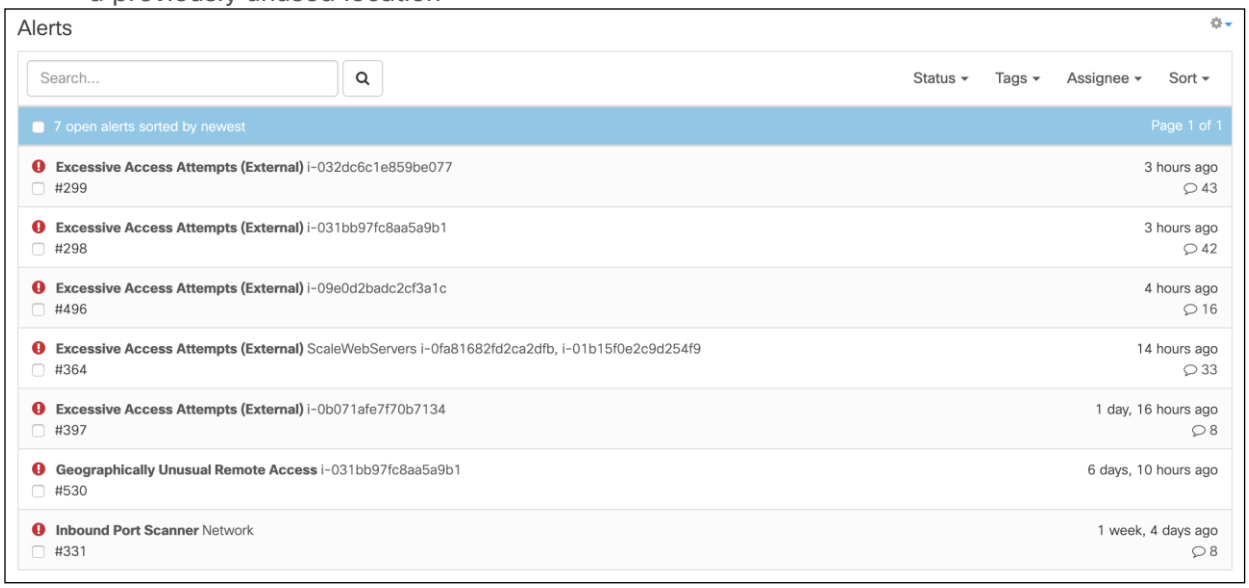


Figure 13.
Stealthwatch Cloud - Alerts

Cisco Umbrella

Cisco Umbrella offers flexible cloud-delivered security. It combines multiple security functions into one solution. Cisco Umbrella solutions provide DNS-layer security, secure web gateway, cloud-delivered firewall, cloud access security broker (CASB), and interactive threat intel. This document covers Umbrella DNS-layer protection for the workloads in the Azure Virtual Network (VNET).

The Umbrella DNS policies allow you to dictate block policy for a variety of pre-defined web categories. More details on web categories can be found in Umbrella documentation. It also gives you the flexibility to apply the policies to specific identities. For example, you could have one set of rules for your Azure cloud application and another set for a different site.

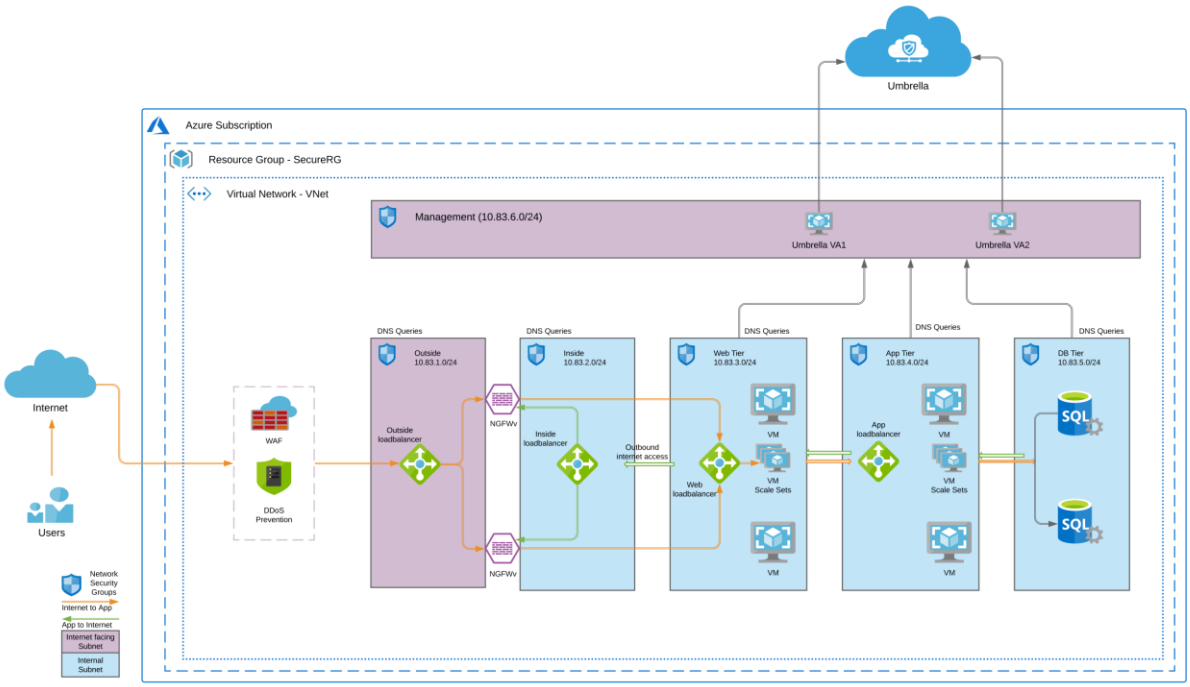


Figure 14.
Cisco Umbrella – DNS layer Security

We deploy Umbrella Virtual Appliances (VA) in the Management tier of the Azure VNET. These VAs act as DNS forwarders to Umbrella. The Azure VNET offers the option to configure custom DNS settings, allowing us to point the cloud resources in a given VNET to Umbrella VAs instead of Azure local DNS. Every resource, that is launched into the VNET, will use these Umbrella DNS forwarders, to provide a control knob for the DNS layer security.

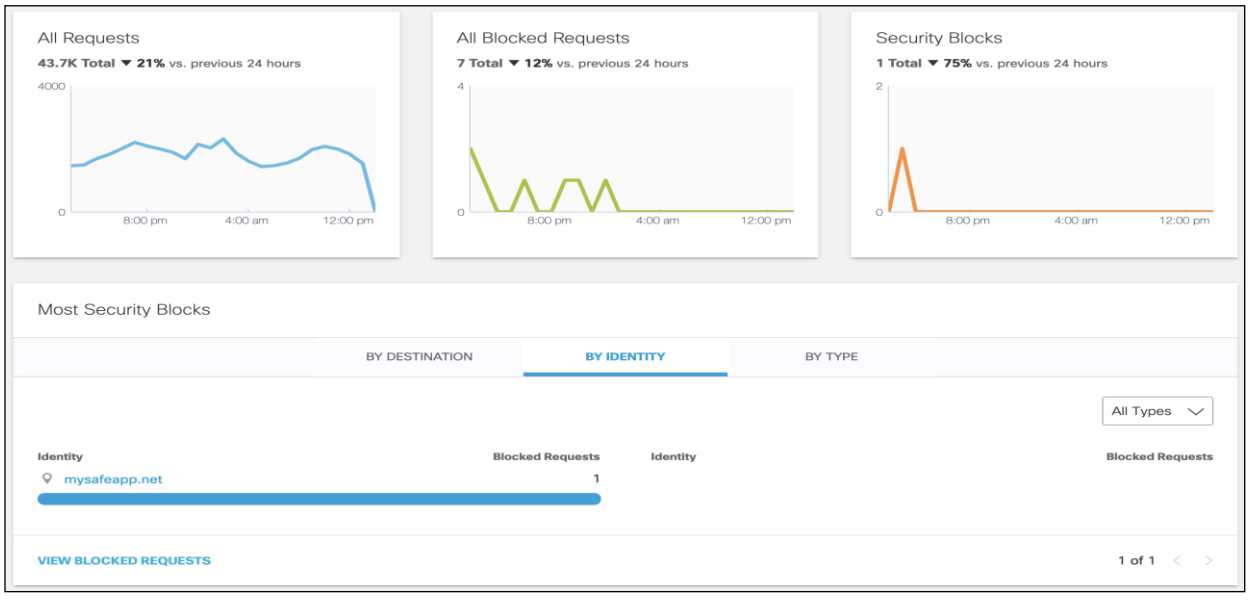


Figure 15.
Umbrella – DNS Traffic Monitoring

Cisco Firepower Next-Generation Firewall and Adaptive Security Appliance

Cisco® Firepower Next-Generation Firewall Virtual (NGFWv) appliance combines Cisco's network firewall with advanced next-gen IPS, URL filtering, AVC and malware detection (AMP). In this design, we use NGFWv to secure the network perimeter from all sorts of threats from public Internet. This ensures that we have security controls like filtering, intrusion prevention and malware detection right at the gateway to the cloud application.

To provide secure remote access to the Management tier, we use Cisco ASAv as a VPN headend. Cisco ASAv offers secure remote access capabilities using Anyconnect VPN mobility client. You could also use NGFWv for this purpose. For detailed information on secure remote access deployments, refer to the Secure Remote Worker SAFE design guide.

Cisco Defense Orchestrator (CDO) is used for management and policy orchestration. CDO provides one security policy, faster deployment, and smart configuration management. It eliminates the time-consuming complexity of managing policies across multiple FTDs and ASAs. Cisco Defense Orchestrator helps to correct issues such as unused, duplicate, and inconsistent objects hence ensuring consistent policies for firewalls.

We use CDO to manage both NGFWv and ASAv, providing centralized management.

Note: The terms Next-Generation Firewall (NGFW) and Firepower Threat Defense (FTD) are used interchangeably throughout this guide. Both these terms refer to Cisco Firepower Next-Generation Firewalls in the context of this document. Azure marketplace offering is available under the name 'Cisco Firepower NGFW Virtual (NGFWv)'.

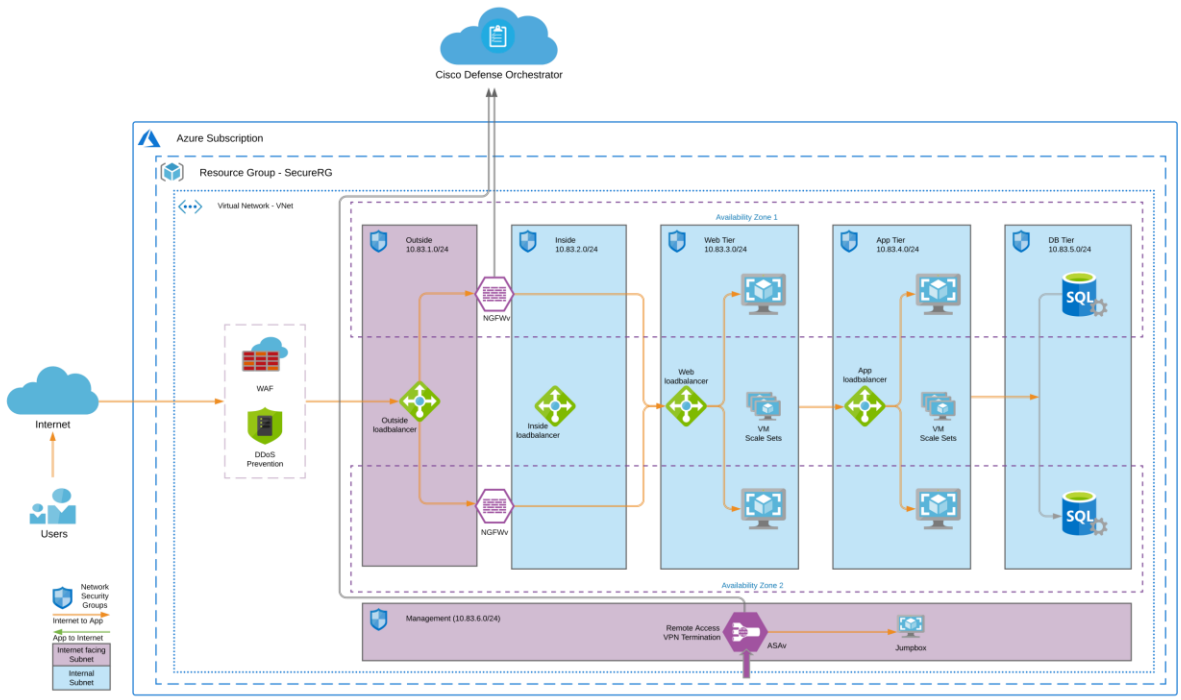


Figure 16.
NGFWv - Traffic flow from Internet User to application

User to application traffic flow

When the user out on the Internet tries to browse the cloud-hosted web application, it lands on ‘Outside’ load balancer after being scanned by WAF and DDoS protection system for any malicious activity. The destination IP at this point is the public IP of the ‘Outside’ load balancer. ‘Outside’ load balancer sits in the Outside tier (segmented using Azure Network Security Group) and load balances traffic onto the pool of outside interfaces of next-generation firewalls. The NGFW receiving the request then forwards this traffic to ‘Web’ load balancer, to be load-balanced on to web servers bundled in Web Virtual Machine Scale Set (VSS).

Before the traffic leaves the inside interface of the firewall (in the Inside tier), the source of this packet is translated (Network Address Translation) to inside interface IP of the firewall and the destination is changed to ‘Web’ load balancer IP. The source IP is translated here to ensure traffic symmetry.

Web server receiving this incoming request, after being load-balanced by the ‘Web’ load balancer, fetches dynamic content from app workloads and returns the final response directly to the firewall which forwarded the initial request. At this point, firewall routes this response back to the end-user via the outside interface.

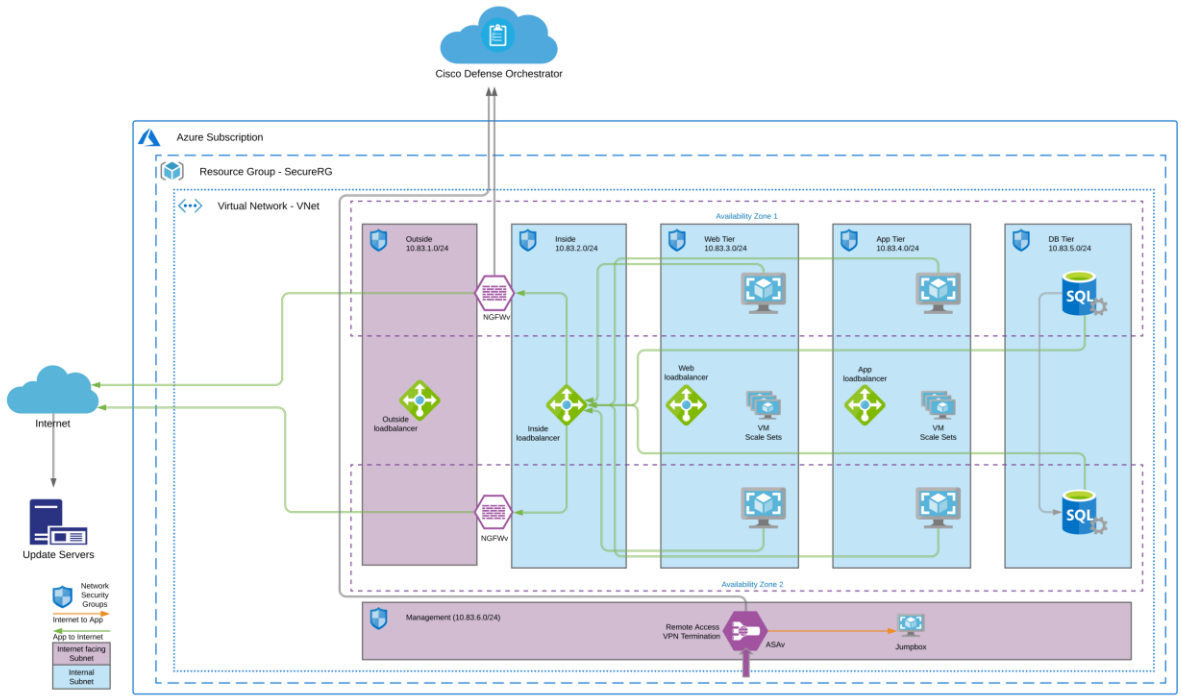


Figure 17.
NGFWv - Traffic flow from workloads out to the Internet

Application to update servers

For the traffic or requests initiated from the Web or Application tier, we use the Azure Route Tables to point the default route to ‘Inside’ load balancer sitting in the Inside tier. The ‘Inside’ load balancer load-balances all the outgoing requests to inside interfaces of the firewalls. The firewalls then route the traffic out to the Internet destination/update server after port address translation (PAT) to the outside interfaces. The outside firewall interfaces are assigned public IPs.

Web Application Firewall and DDoS Prevention

Public cloud has become a common place to host critical applications and make these applications available to end-users (internal or external). As a result, it is essential to ensure these applications receive the same level

of protection from distributed denial of service (DDoS) and advanced web attacks that on-premises applications do. For this design, we validated two different solutions i.e. Azure WAF & DDOS service and Radware Cloud WAF & DDoS service.

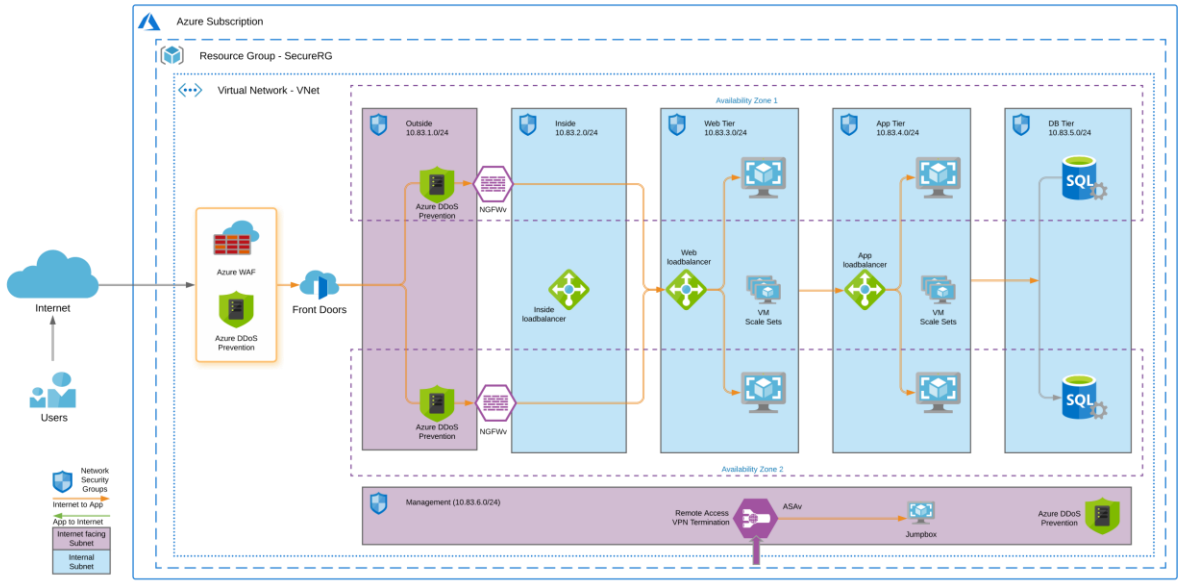


Figure 18.
Azure WAF and DDoS protection

Azure offers WAF and DDoS as native services that controls access to the application by allowing or blocking web requests. This protects web applications from common web exploits. In addition to web traffic protection, DDoS component provide network flow monitoring to protect against DDoS attacks.

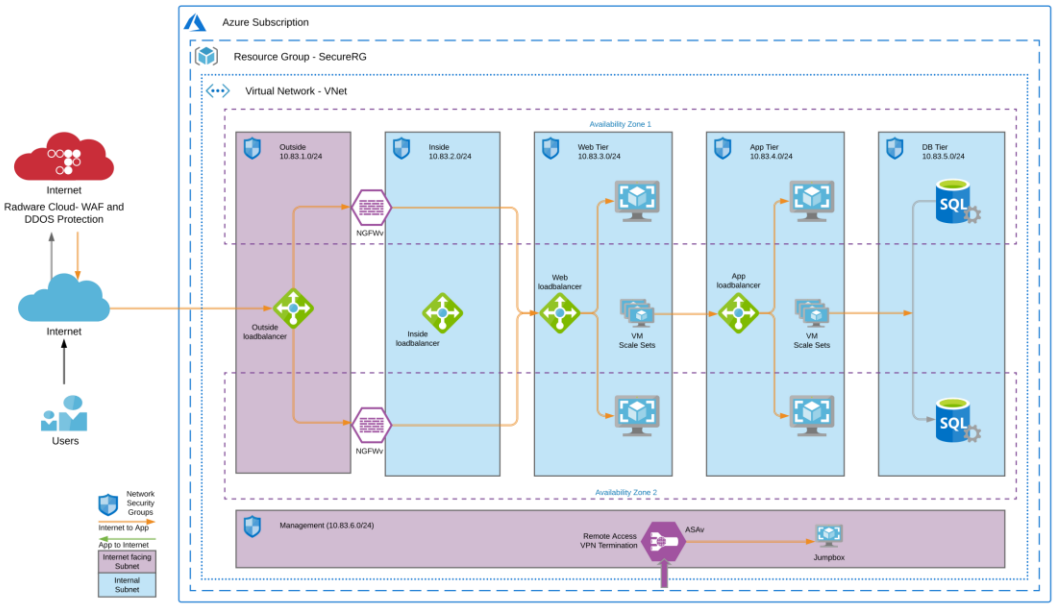


Figure 19.
Radware Cloud - WAF and DDoS Prevention

Radware's Cloud Security Services offer easy-to-deploy cloud-based security that can be integrated with your cloud environments to provide proactive, automated protection from advanced threats. Radware provides applications hosted in the cloud with the protection from the full breadth of DDoS attacks with real-time mitigation and no added latency in peacetime.

Radware acts as a man in the middle. Application's domain name points to the Radware Cloud service. Traffic is first routed to the Radware Cloud and scanned for any malicious activity. Post-inspection, the traffic is forwarded to the origin servers in the Azure cloud. Refer to the implementation section of this guide for more deployment level details.

Cisco Duo

Cisco Duo provides secure access to applications and data, no matter where the users are, on any device, and from anywhere. Cisco Duo's secure access solution creates trust in users, devices, and the applications they access. Cisco Duo provides the following functions:

- Multi-Factor Authentication: Verify the identity of all users with Duo's strong multi-factor authentication
- Single Sign-on: Seamless, single dashboard access to all applications
- Remote Access: Secure access to cloud and on-premises applications and servers, with or without VPN
- Device Trust: Check that user devices meet security standards before granting them access
- Adaptive Access Policies: Set policies to allow or block access attempts by a user or a device, based on contextual factors

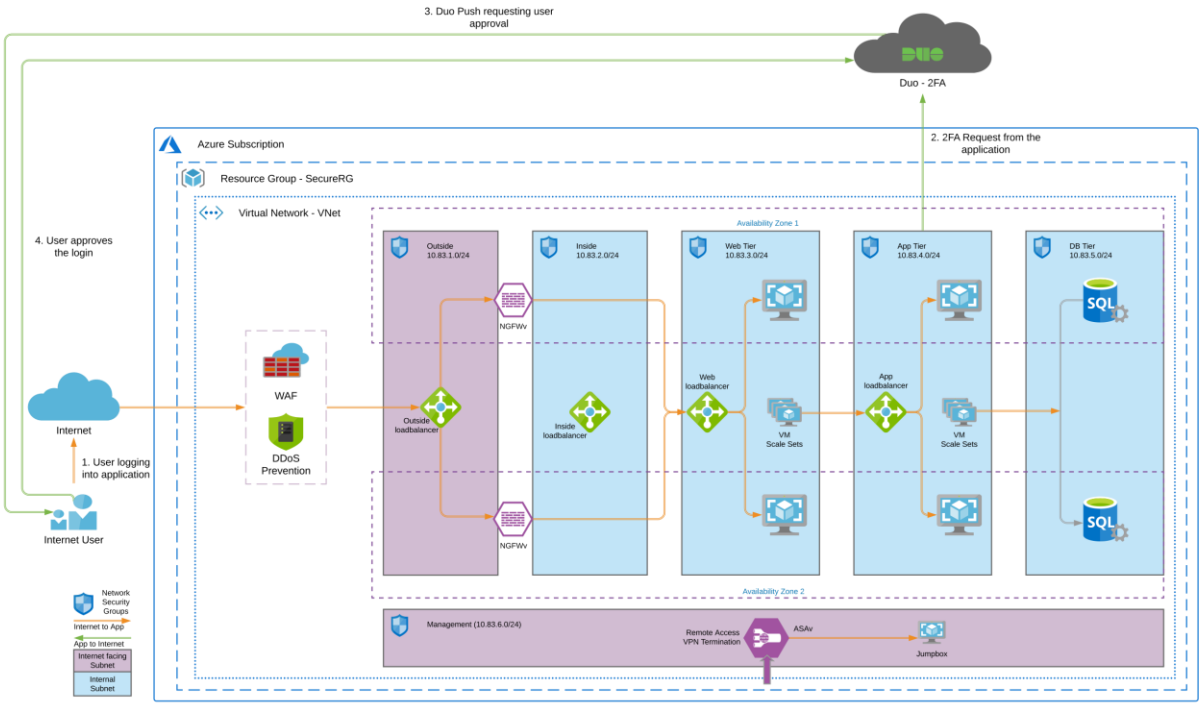


Figure 20.
Duo MFA Push

In this design, we used Duo's Multi-Factor Authentication (MFA) for our Azure cloud application. Multi-factor authentication from Duo protects the cloud applications by using a second source of validation, like a phone or token, to verify user identity before granting access. MFA not just allows you to build a zero-trust framework but is also essential for compliance purposes. Duo provides native integration for any application. Refer to the implementation section of this guide for more details.

Admins have several options when it comes to enrolling new users in Duo, such as self-enrollment, Azure sync, Active Directory sync, and OpenLDAP sync. Duo admin portal allows a highly convenient way to track any user activity.

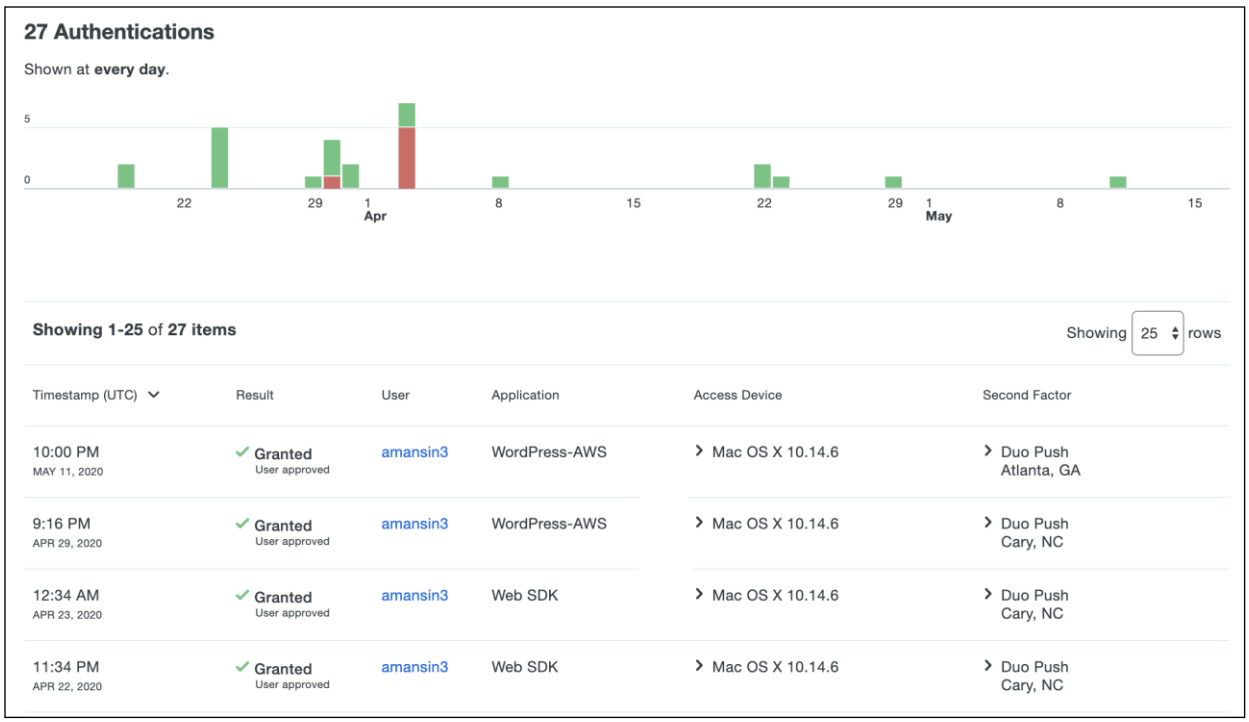


Figure 21.
Duo – User Activity

Cisco SecureX threat response

Cisco SecureX threat response leverages the integrated security architecture to accelerate investigations by automating and aggregating threat intelligence and data across your security infrastructure in one unified view. Some of the key features are:

- Aggregated threat intelligence: Integrates threat intelligence from Cisco TALOS and third-party sources to automatically research indicators of compromise (IOCs) and confirms threats quickly
- Automated enrichment: Automatically adds context from integrated Cisco Security products, so that you instantly know which of your systems was targeted and how
- Incident tracking: Provides the capability you need to collect and store key investigation information, and to manage and document your progress and findings
- Interactive visualizations – Shows your results on intuitive, configurable graphs for better situational awareness and quick conclusions
- Seamless drill down – Makes deeper investigations easy using integrated Cisco Security products. A single click takes you inside Cisco AMP for Endpoints
- Direct remediation – Lets you take corrective action directly from its interface. Block suspicious files, domains, and more without having to log in to another product

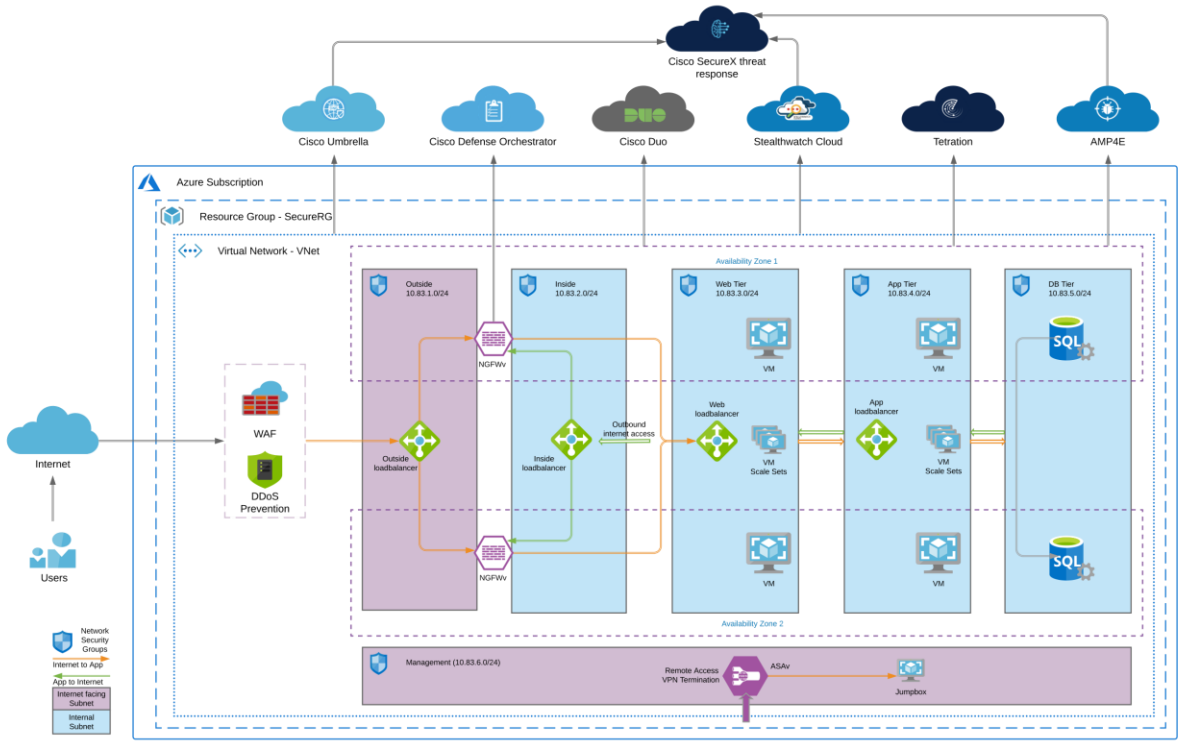


Figure 22.
Cisco SecureX threat response

In this architecture, we are receiving information from Umbrella and AMP Cloud to provide threat intelligence, contextual approach, and threat hunting capabilities. Integrations for Stealthwatch Cloud, Radware Cloud WAF and DDoS service, and Cisco Firepower NGFW are also available. Refer to the [Cisco SecureX threat response] documentation for more details on available Cisco and third-party integrations.

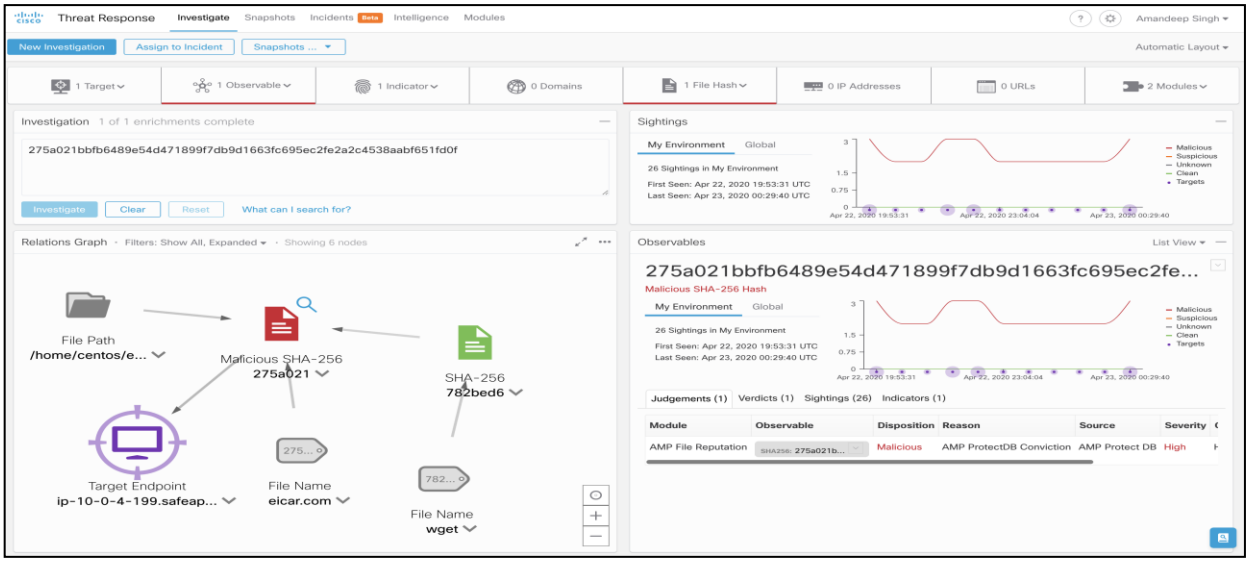


Figure 23.
Cisco SecureX threat response – Threat Hunting

Design Implementation

Now that we have established the design specifics of our tiered application in the Azure cloud, we will begin implementing and setting up the lab environment.

We will start by setting up the Azure VNET (Virtual Network) as per the tiered architecture specifications. Once our VNET is ready, we will integrate the Stealthwatch Cloud and set up the Umbrella VAs in the management tier and update the DNS server settings for the VNET.

We will then set up the Azure MySQL database and bring up VSS's (Virtual Machine Scale Sets) for the App and Web workloads followed by setting up the load balancers for each VSS.

Lastly, we will configure the firewalls, enable WAF and DDoS protection and then conclude our set up with Cisco SecureX threat response integration.

Note: Cisco Tetration, AMP, Cisco SecureX threat response, Stealthwatch Cloud, Umbrella, Duo and CDO offer EU based locations for customers having to follow EU rules.

Deployment Overview:

- Set up the Azure Virtual Network
- Integrate Stealthwatch Cloud to Azure environment
- Set up the Umbrella Virtual Appliances
- Set up Azure Database for MySQL servers
- Set up the App and Web Virtual machine Scale Sets (Includes Tetration, AMP4E and Duo Integration)
- Set up the App and Web load balancers
- Set up Cisco Firepower Next-Generation Firewalls and Cisco Defense Orchestrator
- Enable Web Application Firewall and DDoS prevention (Azure and Radware)
- Set up Cisco SecureX threat response

Set up the Azure Virtual Network

In this section, we will create a new Azure VNET and configure all the associated components that we need for our deployment.

Implementation procedure:

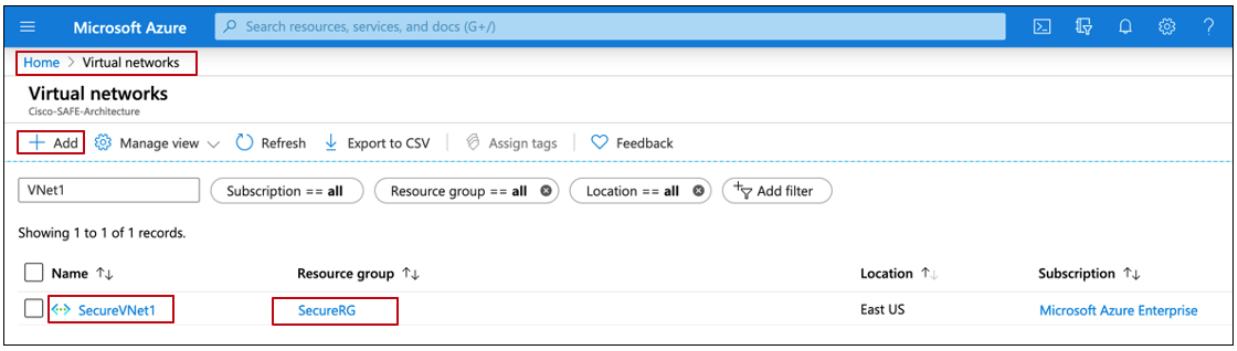
Step 1. **Create the VNet**

Step 2. **Create the Network Security Groups**

Step 3. **Set up the Routing Tables**

Step 4. **Define the Subnets**

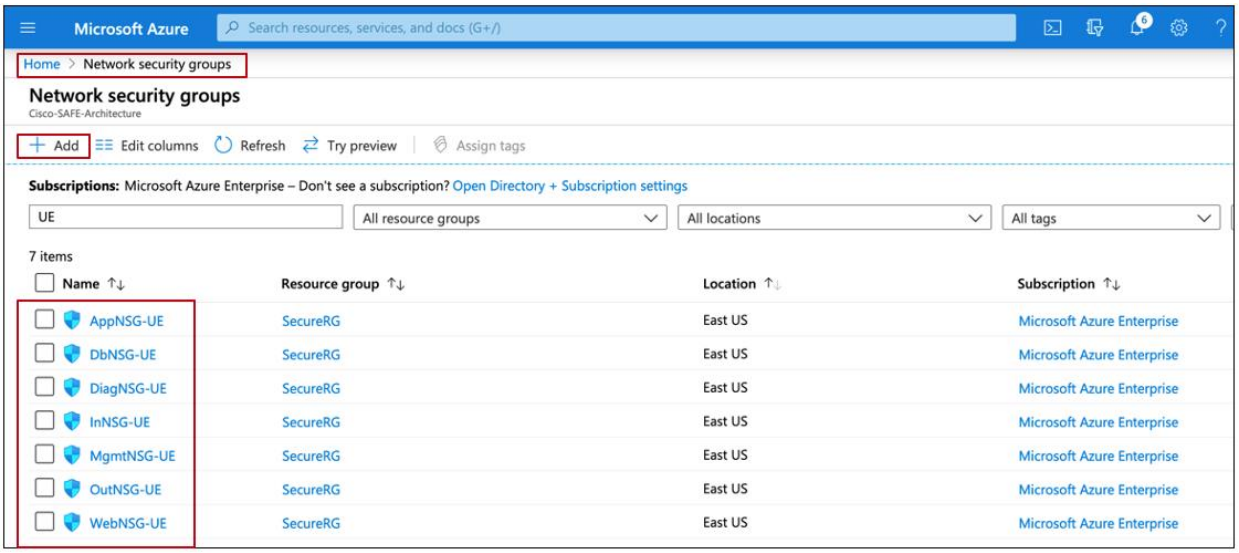
Step 1. **Create the VNet -** Log on to the Azure portal and add a new VNet in the 'Resource Group' and region of your choice. We had created a new 'Resource Group' for this specific implementation, but you can use an existing one. We chose the IPV4 CIDR block as 10.83.0.0/16.



Follow the Azure documentation for more details on Azure 'Virtual networks'.

Step 2. **Create the Network Security Groups –** Go to 'Network Security Groups' on the Azure portal, click on 'add' to set up NSGs corresponding to each tier in the design. Set up the access rules as per your application requirements.

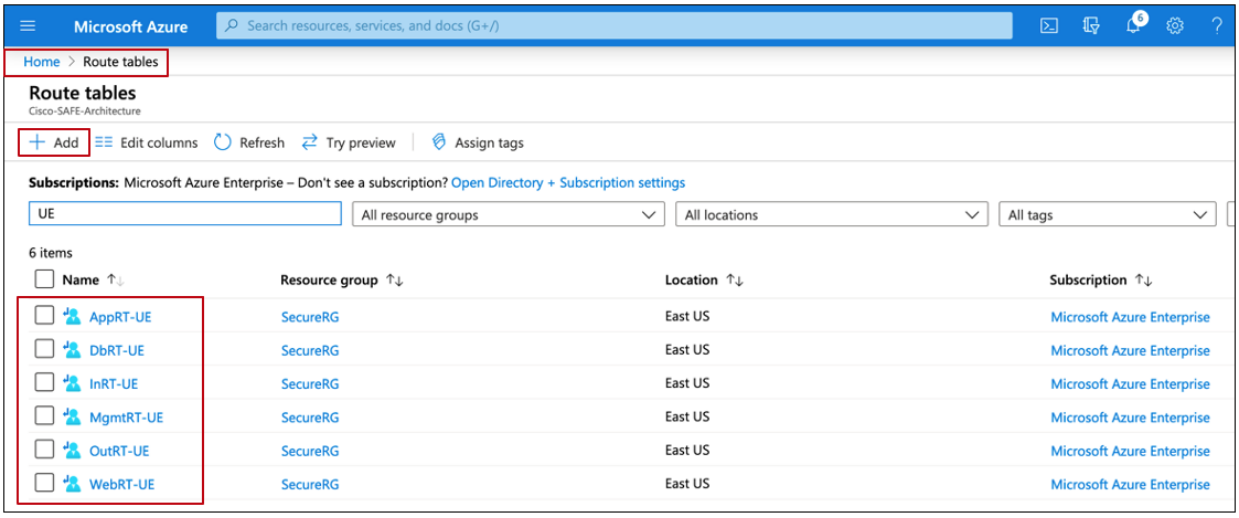
Based on our lab environment, we allowed TCP port 80 inbound to 'Outside' tier, to allow internet users to browse the application. Also, we opened TCP port 22 for specific source IPs to allow inbound access to management zone. For all other NSGs, we used the default settings which allow communication within the VNET, inbound load balancer probes, and outbound internet access for any resource deployed in the NSGs.



Follow the Azure documentation for more details on Azure 'Network Security Groups'.

Step 3. **Set up the Route tables –** Go to 'Route tables' on the Azure portal and create the routing tables for each tier. There is one routing table for each tier. The default routes allow all access among different tiers/subnets and to the outbound internet.

For now, we will leave the routes as default but when we get to firewall deployment, we will update some of these routing tables to force the traffic through our firewall for scanning and inspection.



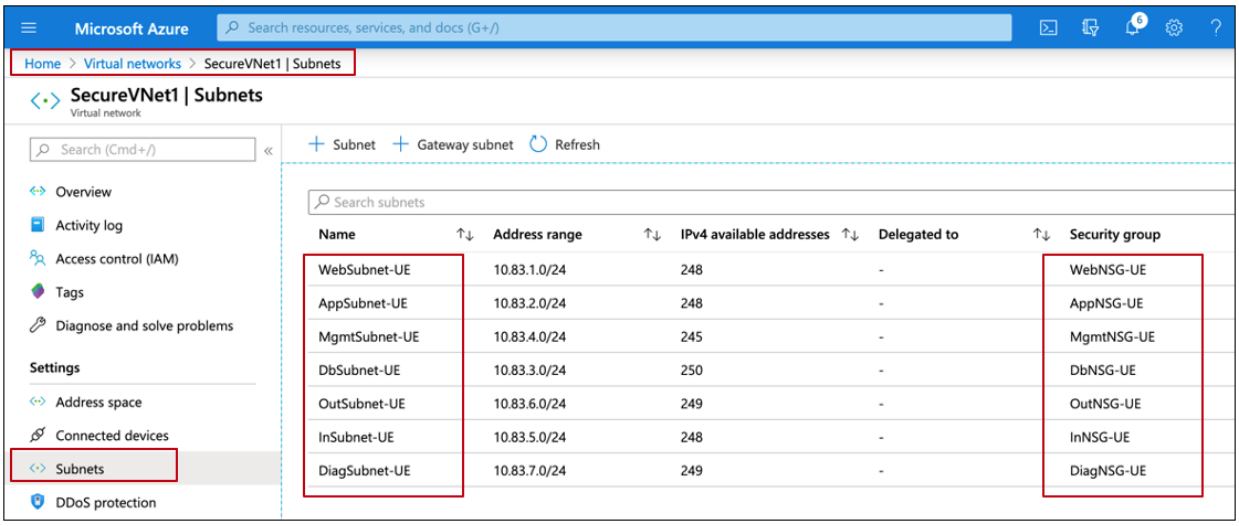
Follow the Azure documentation here for more detailed information on Azure traffic routing and route tables.

Step 4. **Define the Subnets -** At this point we have all the building blocks to define the subnets in our newly created VNET.

Based on the tiered architecture, we defined one subnet for each tier- web, application, database, management, inside and outside.

IPV4 CIDR Block	Azure Region	Tier
10.83.1.0/24	US-East	Database
10.83.2.0/24	US-East	Application
10.83.3.0/24	US-East	Web
10.83.4.0/24	US-East	Management
10.83.5.0/24	US-East	Inside
10.83.6.0/24	US-East	Outside
10.83.7.0/24	US-East	Diagnostic (for NGFWv deployment)

Go to 'Virtual Networks' and select the VNET created in Step 1. From the panel on the left-hand side, select 'Subnets' and then click on '+ Subnet' to add all the subnets above. Ensure that the subnet created is tied to the appropriate NSG.



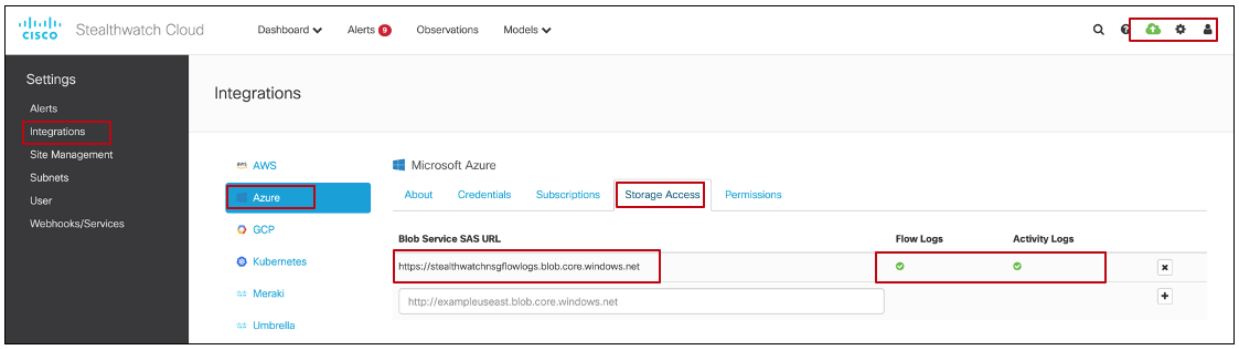
Integrating Stealthwatch Cloud

Implementation procedure:

Step 1. Set up the NSG flow logs and integrate Stealthwatch Cloud.

Step 1. **Set up the NSG flow logs and integrate Stealthwatch Cloud –** Follow the steps illustrated in Cisco Stealthwatch Azure Quick Start Guide to create the NSG flow logs and push them to the Stealthwatch cloud to be analyzed. Based on this flow log information, the Stealthwatch Cloud would generate security alerts and observations on any activity within the VNET.

After the SWC integration is done, go to 'Settings > Integrations >Azure > Storage Access' on SWC portal and you should see green check marks indicating a successful integration.



Setting up Cisco Umbrella

Implementation procedure:

Step 1. **Set up the Umbrella Virtual Appliance (VA) image**

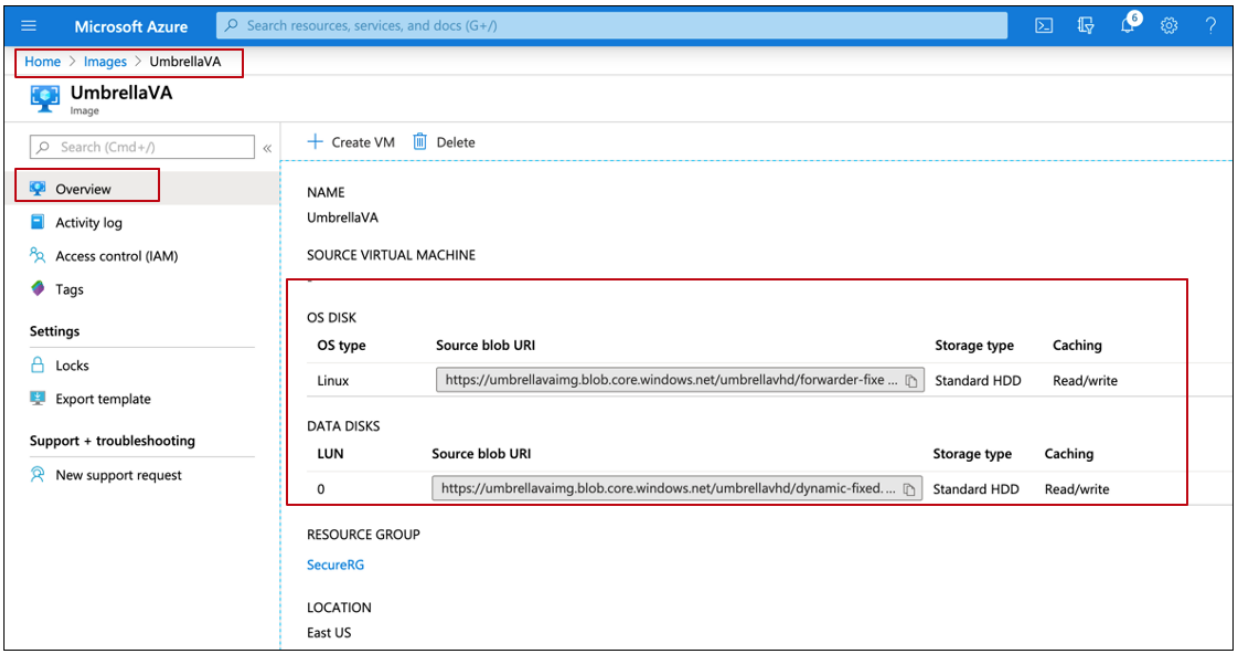
Step 2. **Create the Umbrella VA instances**

Step 3. **Configure the local DNS on Umbrella VA instances**

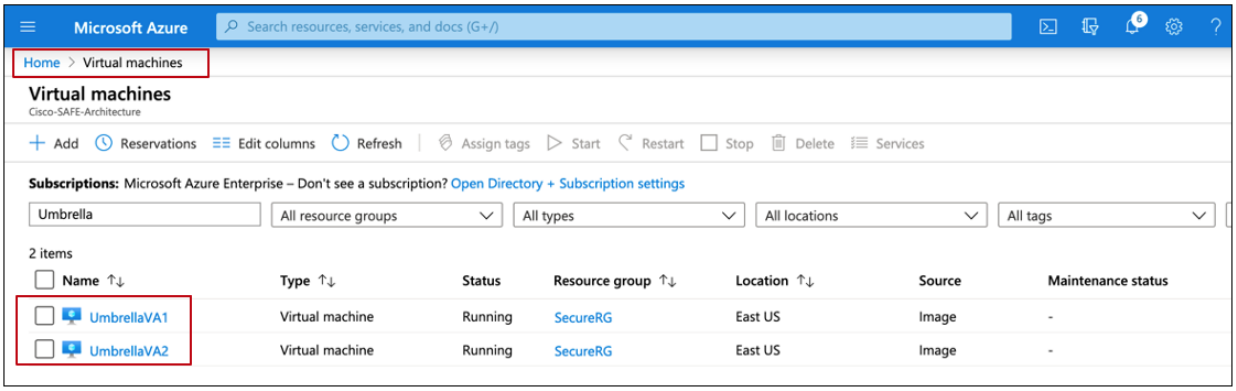
Step 4. **Set up the policies to exempt internal domains**

Step 5. **Update the DNS server settings for VNET**

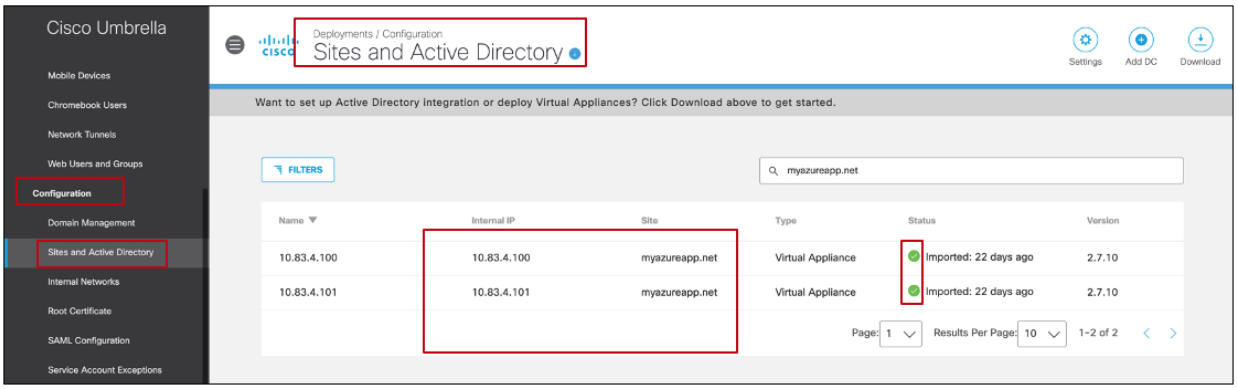
Step 1. **Set up the Umbrella Virtual Appliance image –** Follow the Umbrella documentation to deploy Virtual appliances (VA) in the Azure cloud. As per the documentation, create an Azure Image and then use it to launch VA instances.



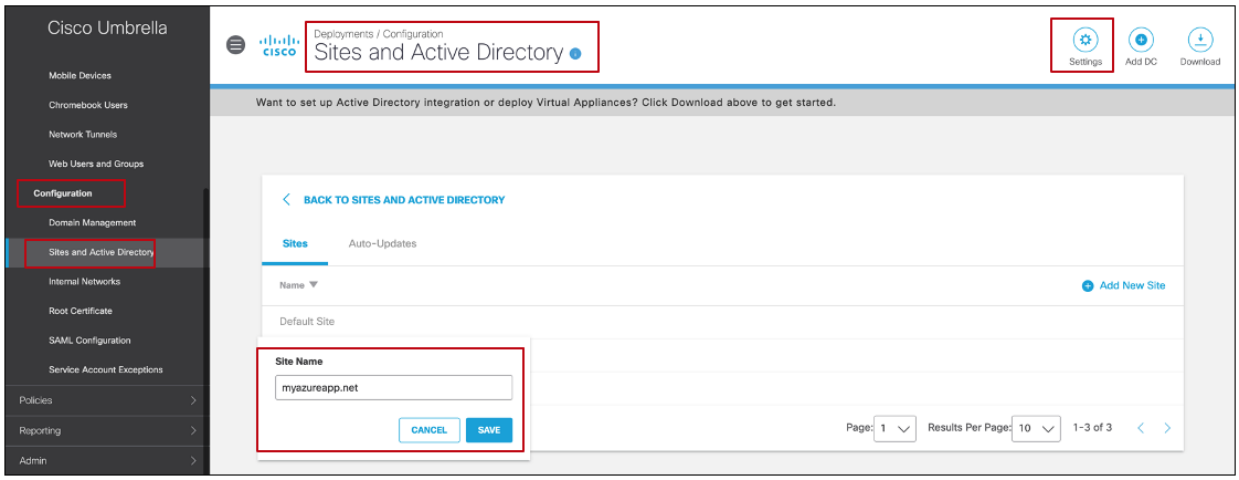
Step 2. **Create the Umbrella VA instances –** Create two VA instances using the Azure Image set up in Step1 and place these appliances in the management tier. We assign the static IP addresses 10.83.4.100 and 10.83.4.101 to these Umbrella Virtual Appliances. These VAs will act as DNS forwarders for the resources in our Azure application environment.



Once the appliances are fully up in Azure, login to the Umbrella portal and verify the green status under 'Deployments > Configuration > Sites and Active Directory'.



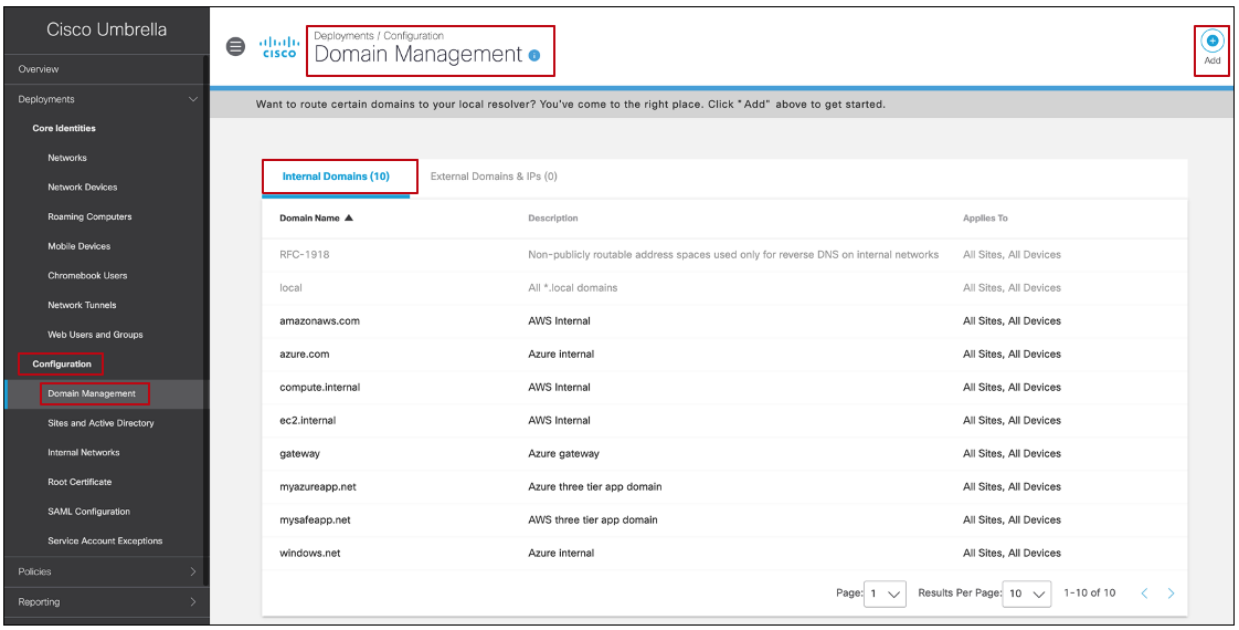
Optionally, you can create and assign a site name for your Azure VAs. This site name can be used as an identity to configure specific policies for Azure cloud. Click on 'Settings' on the same page to add site name and then update the VA entries above.



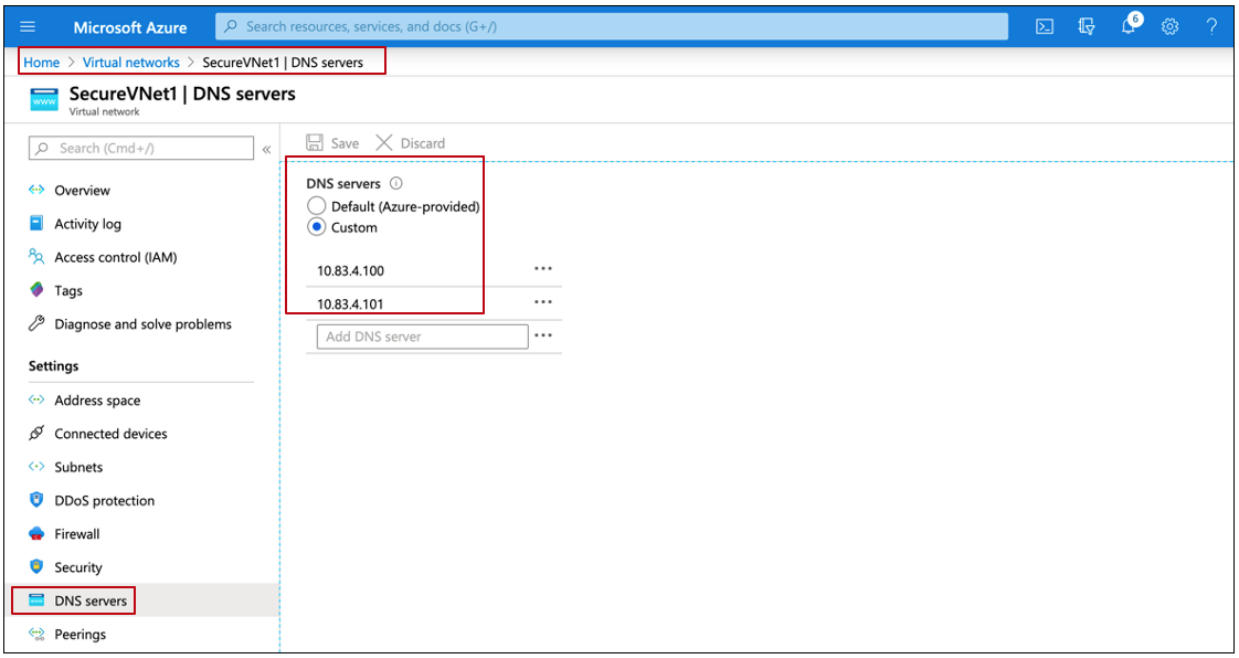
Step 3. **Configure the local DNS on Umbrella Virtual Appliances –** Follow the Umbrella documentation to configure local DNS on each VA. Access to the recursive resolvers in Azure is provided via the virtual IP 168.63.129.16. Set this IP as local DNS on both Umbrella VAs.

Note: We had set up secure remote access to management tier using ASAv, we use the secure VPN connection to SSH into the VAs via a jump server hosted in the management zone.

Step 4. **Set up policies to exempt internal domains** – Log on to the Umbrella portal, go to 'Deployments > Configuration > Domain Management' and add the internal domains that should be routed to the local Azure resolver. Based on your set up, the list of internal domains will vary.



Step 5. **Update the DNS server settings for VNET -** Go to the VNET that we created previously and update the 'DNS server' settings. We use the custom DNS option to add the Umbrella VA IP addresses. This will ensure that any instance deployed in this VNET is assigned the Umbrella VAs as DNS forwarders.



Setting up the Azure Database for MySQL servers

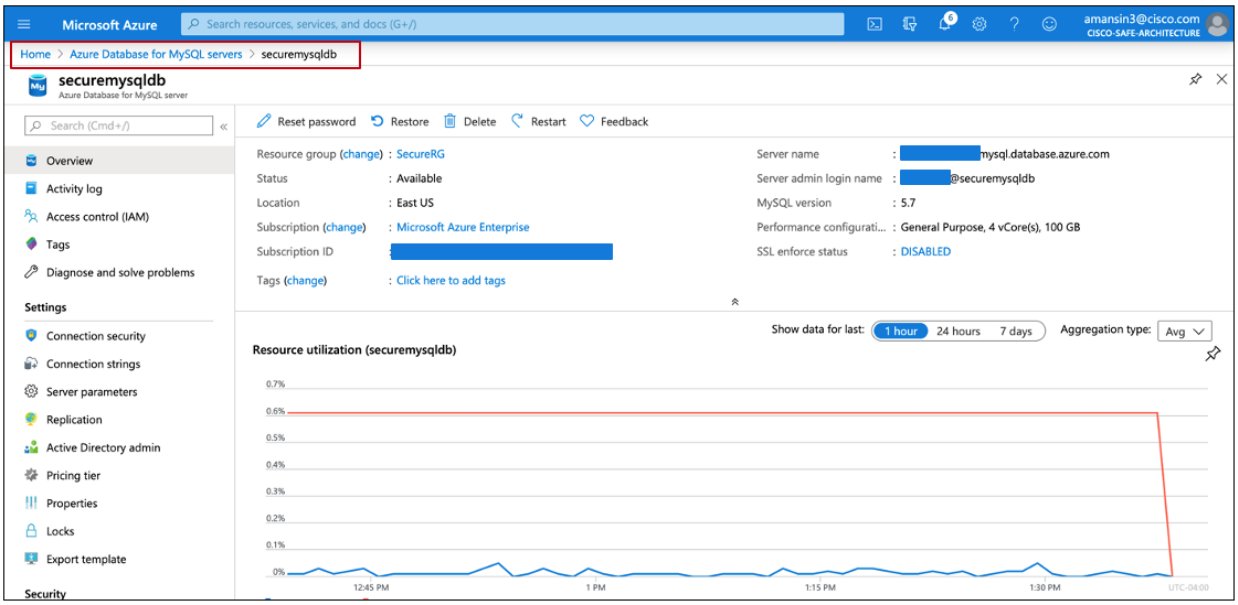
Implementation procedure:

Step 1. **Set up Azure database for MySQL server**

Step 2. **Create a private link to the database**

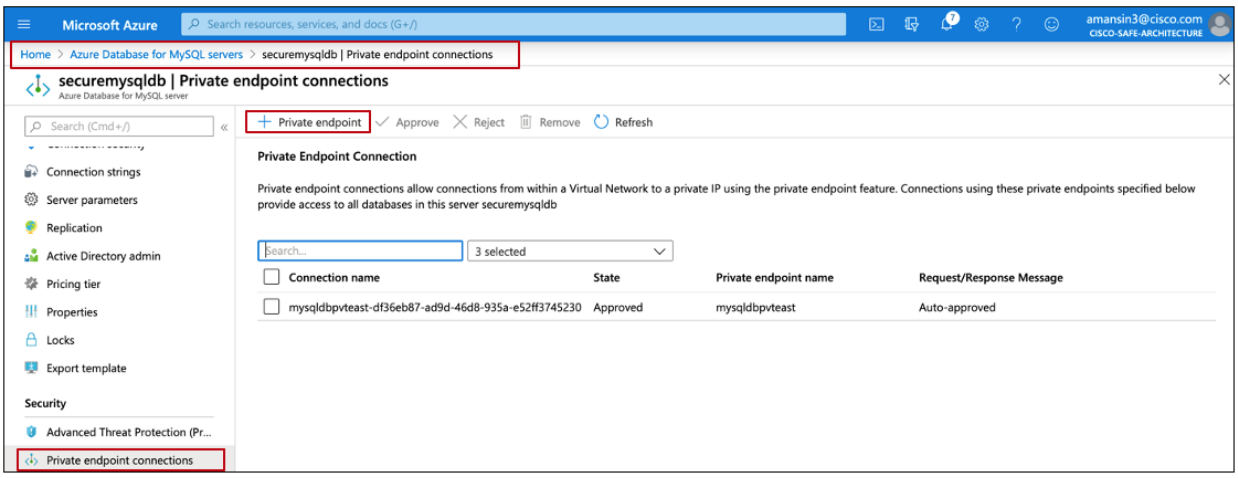
Step 1. **Set up Azure Database for MySQL server -** We set up an instance of MySQL database, this can vary based on application requirements. Follow the Azure documentation for help with setting up a MySQL server in Azure.

As part of the initial database set up, you will need to specify an admin username and password. Make sure you remember these credentials; we will need them while setting up the application servers for connections with the database.



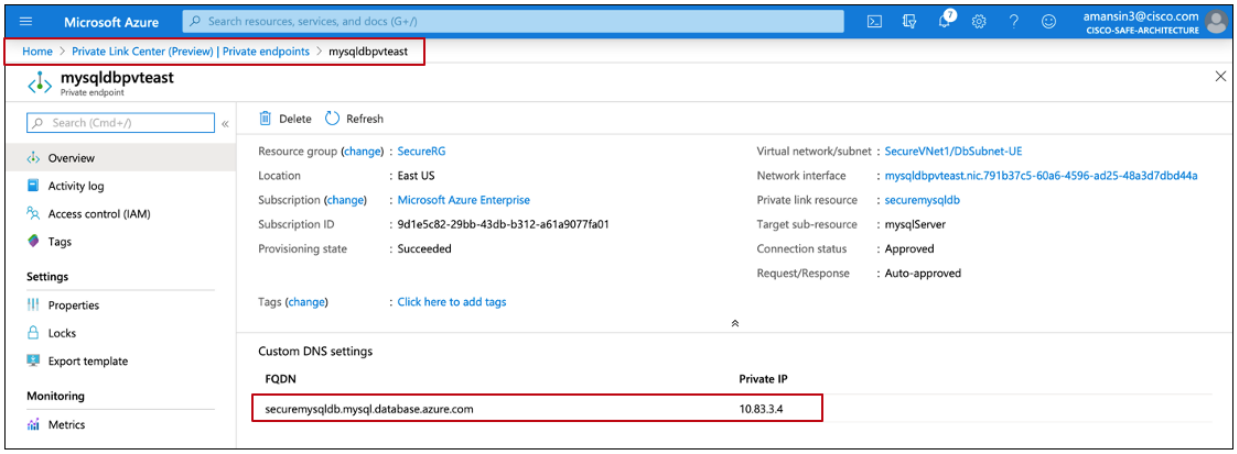
Step 2. **Create a Private Endpoint to the database –** Go to the newly created database under 'Azure Database for MySQL servers' and select 'Private endpoints connections' from the panel on the left-hand side. Click on '+ Private endpoint' to create a private endpoint link to this newly created MySQL database server.

Azure Private Link enables you to privately access Azure PaaS Services. This ensures that the database is not exposed to public access. This link would be set up via the database subnet and hence database NSG rules would apply. As per the default settings, inbound access from all Azure resources and unfiltered outbound access to Internet is allowed. These rules should be fined tuned to make sure that only the application subnet is allowed access to database.



A Private link allows DNS integration to assign an FQDN to the database server instance. This FQDN would resolve to a dynamically assigned IP address in database subnet, enabling access to the database server. Make sure you keep a note of this FQDN along with the admin username and password configured in Step 1.

You can go to the 'Private Link Center' to get detailed information about the newly created private link.



Check out the Azure documentation to learn more about private links.

Setting up the Virtual Machine Scale Sets

In this section, we will set up a pool of workloads for the web and application tier. We will use the Azure Virtual Machine Scale Set (VSS) service to achieve this. As part of workload initialization, we install Tetration and AMP4E agents on the web and app workloads along with other application-specific packages, including the Duo plugin.

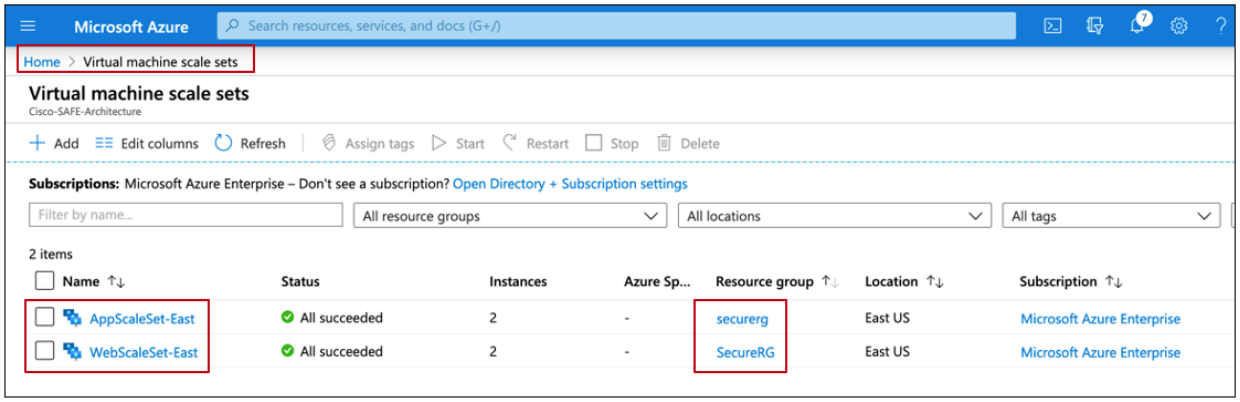
Implementation procedure:

Step 1. **Create VSS for app and web servers**

Step 2. **Install Azure VM extension for workload initialization**

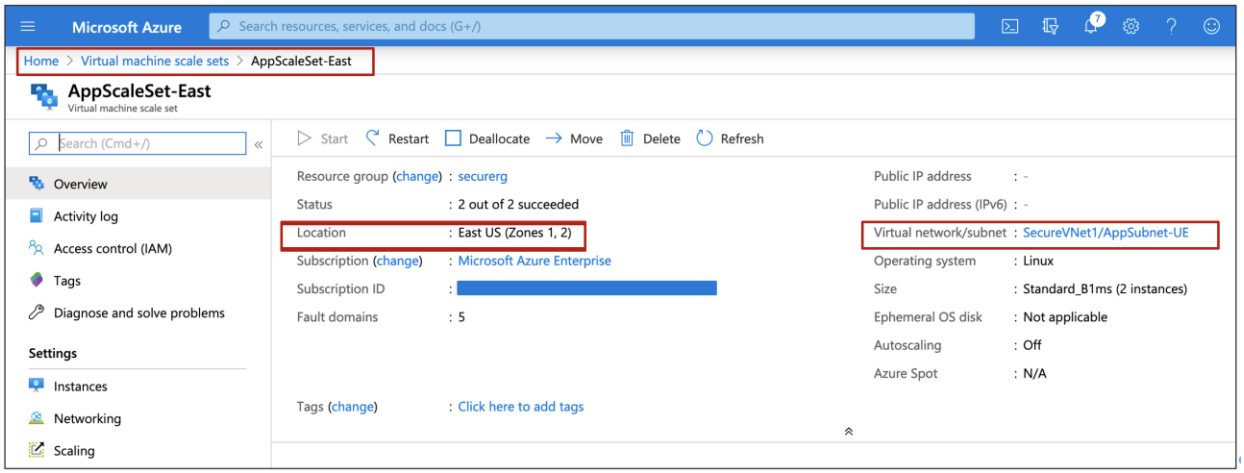
Step 1. **Create VSS for app and web servers -** Go to 'Virtual Machine Scale Sets' in the Azure portal and click on 'add' to create a VSS for both web and app workloads in the Resource Group created for application.

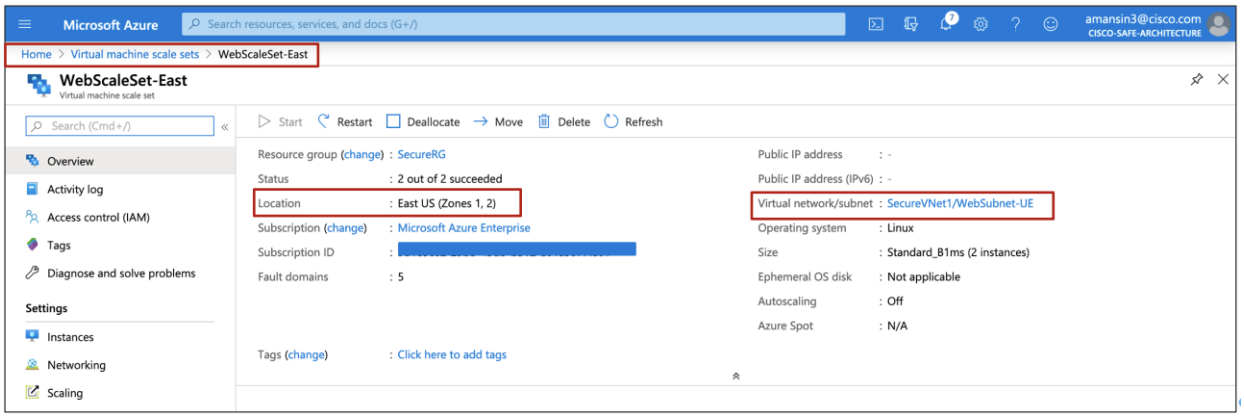
- The geographical regions remain the same, i.e. US East
- For availability zone, make sure you check the required number of zones. Since this design is zone redundant with two availability zones, we selected zone 1 and zone 2 in US East region. This ensures that when workloads are launched in the VSS they are distributed across the two zones
- For the base image/operating system we chose CentOS, we later used custom scripts to initialize them with required packages, code and security agents. You could also use a golden image with all the required applications and packages pre-installed to skip the custom scripts. For the purpose of this document, we have validated the custom scripts option
- Under networking options, choose appropriate subnets for app and web VSS (app subnet for app VSS and web subnet for web VSS without any public IPs). Leave the Network Security Group to basic settings since we use the NSGs at subnet level.



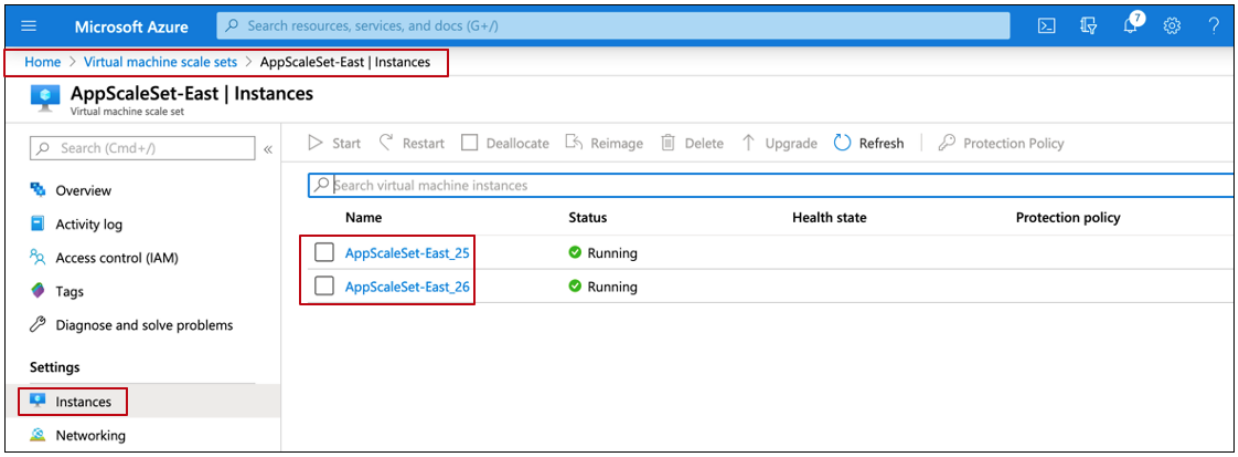
For detailed information on all other parameters regarding Virtual Machine Scale Set creation, check out the Azure documentation.

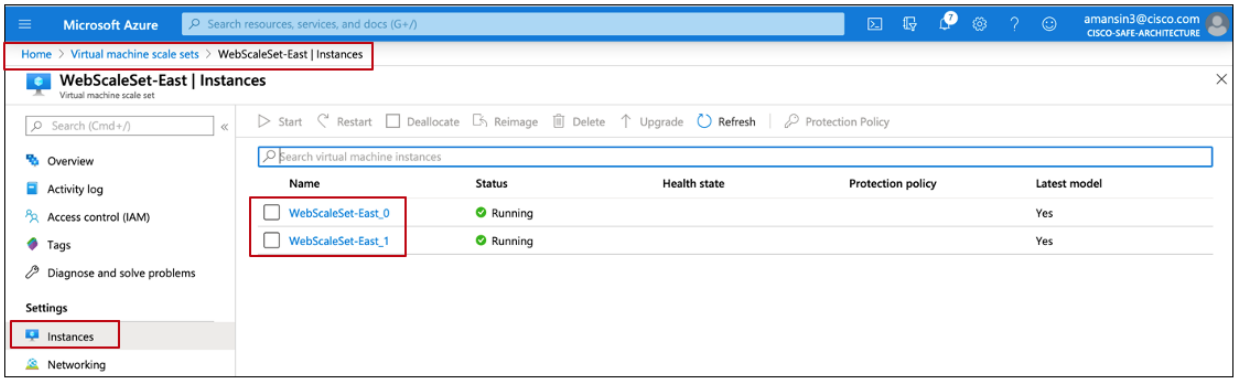
In the snapshot below for app and web VSS, you can see the location set to US east regions with redundancy in zone 1 and zone 2.





At this point, we have two base workloads each, in app and web VSS. We haven't set up the application on these workloads yet, we will do that in our next step.





Step 2. **Install Azure VM extension for workload initialization –** We set up a 'Storage Account' in US East region, same region as our application location. We upload all the files that we need for our application and web workloads into this storage account. If you choose to host config files in this manner, ensure that you set appropriate access privileges for these files.

These files include:

- Shell scripts (appservers and webservers) for initializing the application and web workloads
- Config files for our application and web workloads
  - App workloads – App configuration file has information about database connection (we recorded the details for this while setting up database previously).
  - Web workloads – Along with various other details, the web config file has the IP address of app VSS load balancer. We set apart the IP– 10.83.2.100 for the app load balancer. We haven't created the load balancers yet; we will do that in the next step and assign them the IPs
- AMP4E agent installer (AMP rpm and GPG). These were obtained from AMP portal
- Tetration agent installer (Enforcer and visibility). These are downloaded from Tetration portal

The initialization shell scripts perform the following tasks:

- Install packages (php, wget, unzip, lsof, httpd, ipset, nginx) on the workloads. Some of these are prerequisites for AMP4E and Tetration agents. Refer to the corresponding product documentation to understand these requirements.

- Download configuration files/code for the respective workloads.
  - For the application server, we used a publicly available 'WordPress' blog code. We download the zipped code from the WordPress site and then update the database config file from Azure Storage Account we set up above.
  - For web server, download the modified web configuration file from Azure Storage Account we set up above.
- Download and unzip the Duo plugin (available for 'WordPress' blogs) to the application workloads.
- Download and install the Tetration enforcement agent from Azure Storage Account we set up above.
- Download and install the AMP4E agent from Azure Storage Account we set up above.

Note: If you choose to include the Duo integration in your native application, follow the DUO Web SDK documentation.

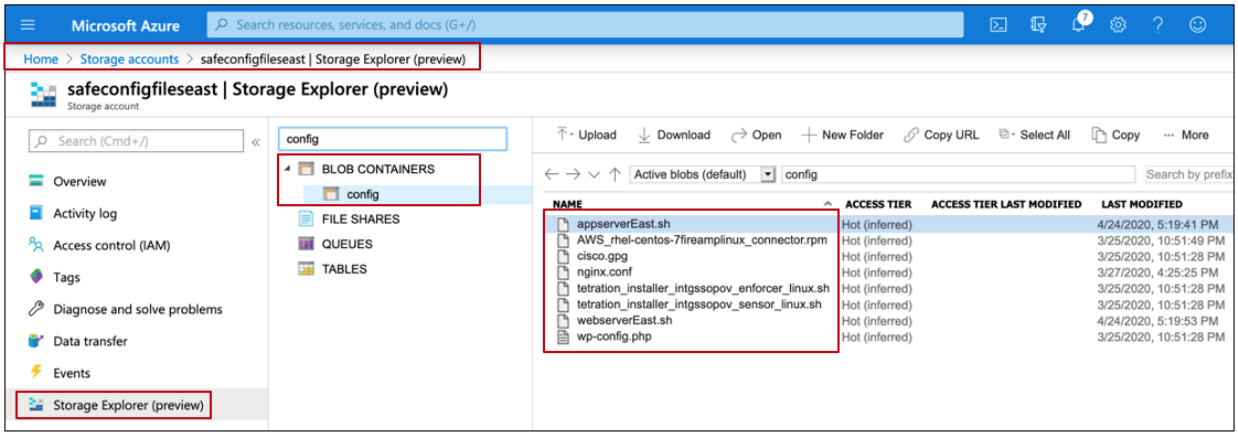
Below are sample initialization scripts that we used.

Web server initialization script:

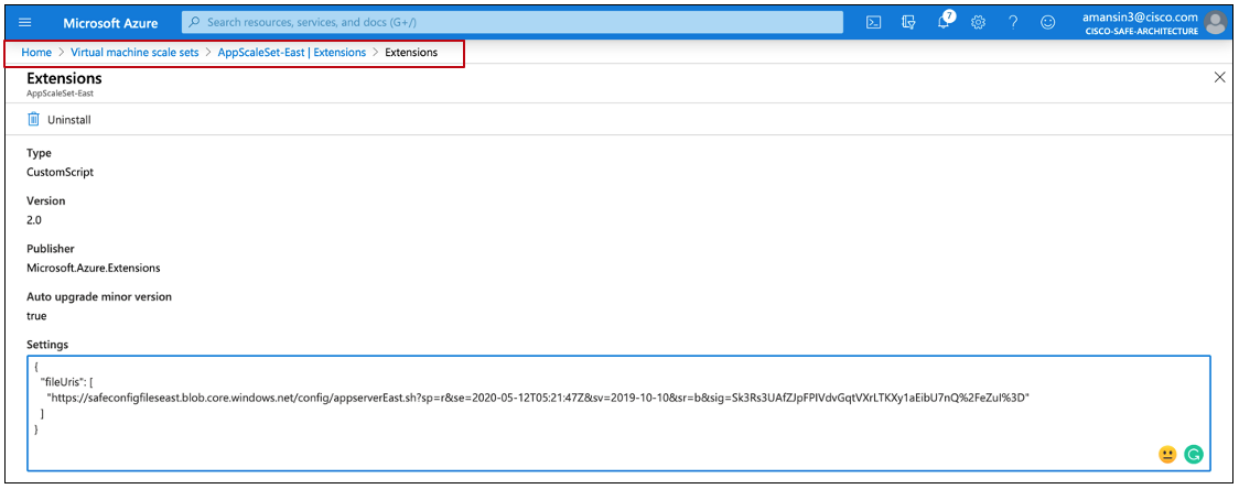
```
#!/bin/bash
sudo yum install -y wget
sudo yum install -y unzip
sudo yum install -y lsof    // lsof utility is required for enforcing tetration policies
sudo yum install -y ipset   // ipset utility is required for enforcing tetration policies
sudo yum install -y nginx   // Installing nginx

#Setting up the web server and updating it with hosted configuration file.
sudo mv nginx.conf nginx.conf.backup
sudo wget https://safelabfiles.blob.core.windows.net/config/nginx.conf
sudo systemctl restart nginx
sudo systemctl enable nginx

#Downloading the Tetration enforcement agent from Azure Storage account and installing it.
sudo wget https://
safelabfiles.blob.core.windows.net/config/tetration_installer_intgssopov_enforcer_linux.sh
sudo chmod 755 tetration_installer_intgssopov_enforcer_linux.sh
sudo ./tetration_installer_intgssopov_enforcer_linux.sh --skip-pre-check

#Downloading the AMP4E agent hosted in an Azure Storage account and installing it.
sudo wget https:// safelabfiles.blob.core.windows.net/config/cisco.gpg
sudo rpm --import ./cisco.gpg
sudo wget https:// safelabfiles.blob.core.windows.net/config/AWS_rhel-centos-
7fireamplinux_connector.rpm
sudo yum install -y AWS_rhel-centos-7fireamplinux_connector.rpm
```

Application server initialization script:

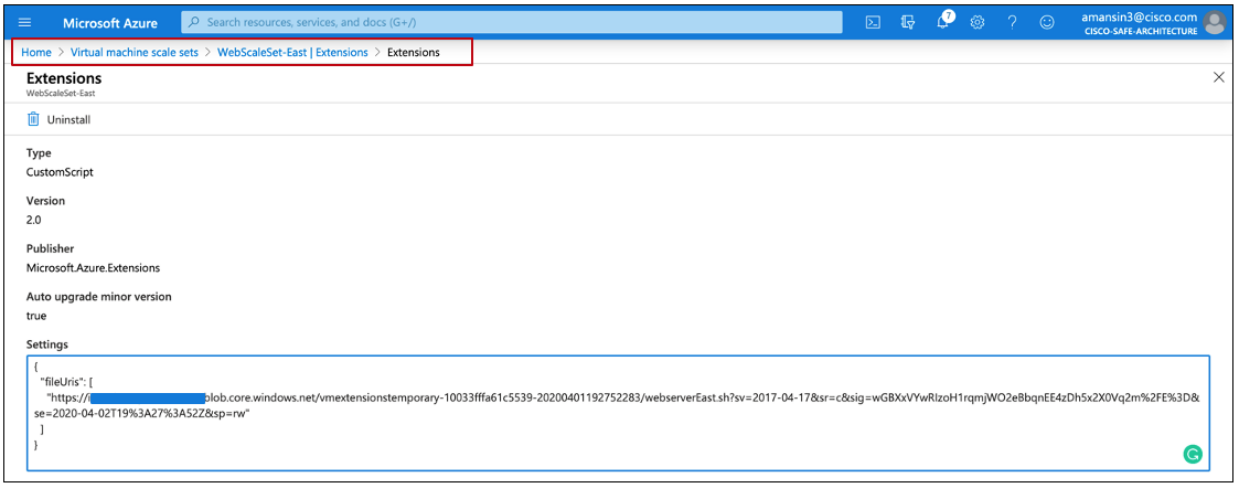
```
#!/bin/bash
sudo yum install -y wget
sudo yum install -y unzip
sudo yum install -y lsof    // lsof utility is required for enforcing tetration policies
sudo yum install -y ipset   // ipset utility is required for enforcing tetration policies
sudo yum install -y httpd   // Installing httpd

#Setting up the HTTPD server and downloading the application code and Duo plugin hosted in Azure Storage Account.
sudo systemctl start httpd
sudo systemctl enable httpd
sudo setsebool -P httpd_can_network_connect 1    //Allow outbound connections from HTTPD daemon
sudo wget https://safelabfiles.s3.us-east-2.amazonaws.com/wordpresscodefile.zip -P /var/www/html/
sudo unzip /var/www/html/wordpresscodefile.zip
sudo wget https://downloads.wordpress.org/plugin/duo-wordpress.2.5.4.zip -P /var/www/html/wp-content/plugins
sudo unzip /var/www/html/wp-content/plugins/duo-wordpress.2.5.4.zip
cd /home/centos/
sudo systemctl restart httpd

#Downloading the Tetration enforcement agent from Azure Storage Account and installing it.
sudo wget https://safelabfiles.blob.core.windows.net/config/tetration_installer_intgssopov_enforcer_linux.sh
sudo chmod 755 tetration_installer_intgssopov_enforcer_linux.sh
sudo ./tetration_installer_intgssopov_enforcer_linux.sh --skip-pre-check

#Downloading the AMP4E agent hosted in an Azure Storage Account and installing it.
sudo wget https://safelabfiles.blob.core.windows.net/config/cisco.gpg
sudo rpm --import ./cisco.gpg
sudo wget https://safelabfiles.blob.core.windows.net/config/AWS_rhel-centos-7fireamplinux_connector.rpm
sudo yum install -y AWS_rhel-centos-7fireamplinux_connector.rpm
```



Now that we have all the files hosted in Azure Storage Account, we will install the extensions. Go to 'Virtual Machine Scale Sets > [app VSS] > Extensions' and click on add. Choose 'Custom Script for Linux' from the panel on the left-hand side. Create the extension by choosing the web shell script from the Azure Storage Account we created earlier.



After adding the extension, go back to VSS and make sure you select all the running instances and click on upgrade to finish the installation.

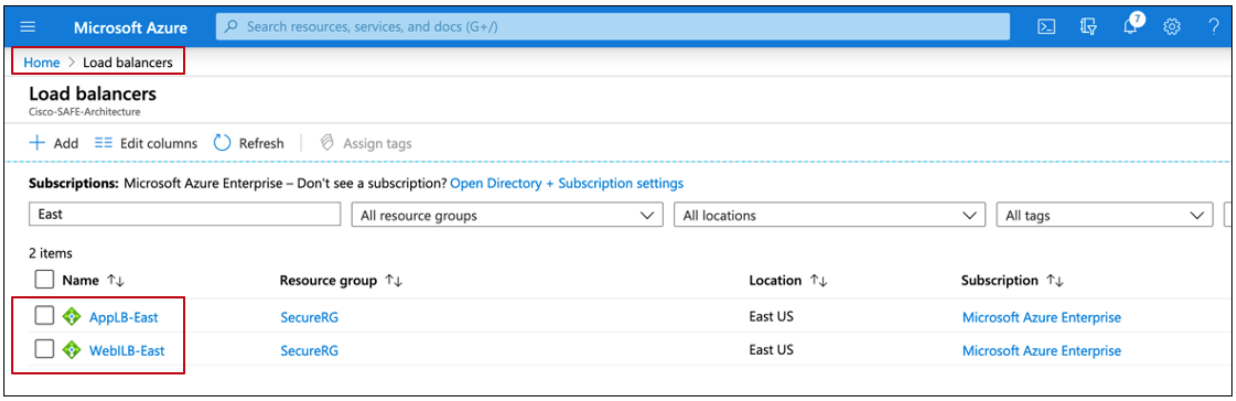


Repeat the same steps for web VSS.

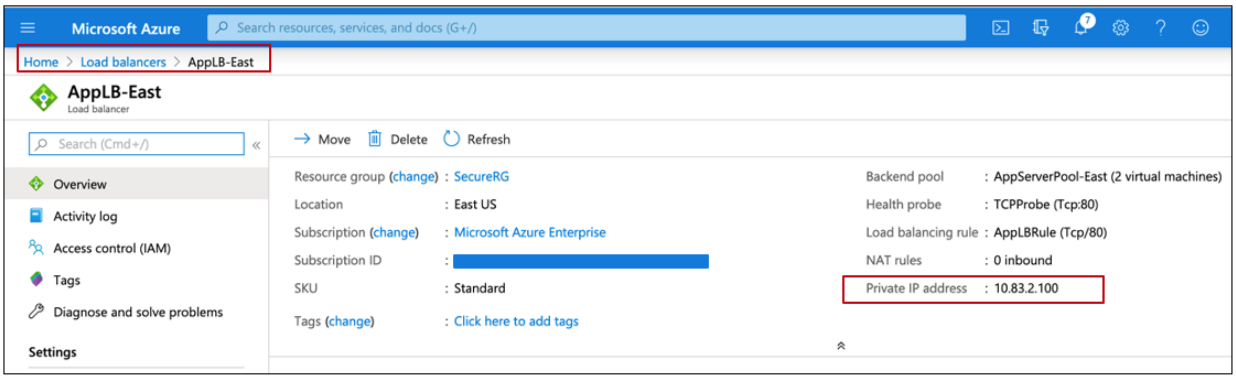
Setting up the App and Web load balancers

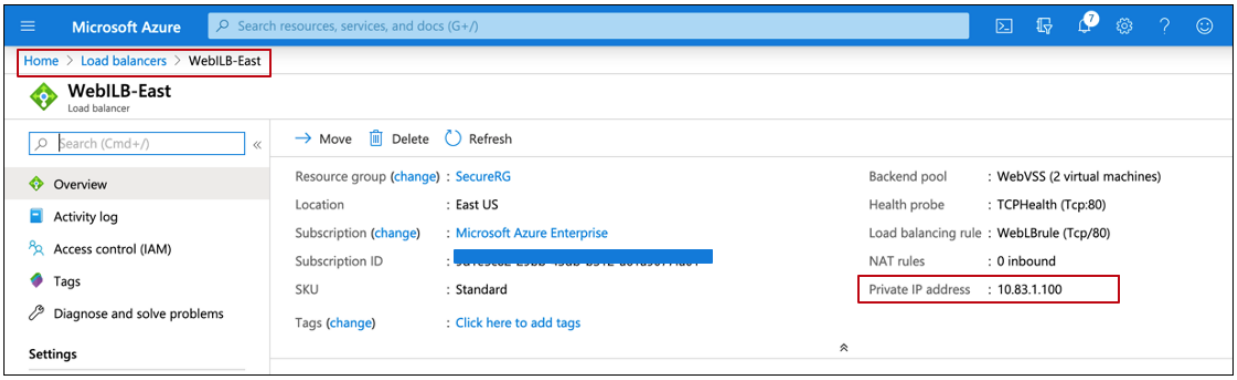
At this point we have a highly available pool of web and app workloads running in the corresponding Virtual Machine Scale Sets in web and app tier. Now, we need to create load balancers to load balance traffic onto these two Virtual Machine Scale Sets. We will create a web load balancer in web tier which receives web traffic from users and then load balances it onto the web servers running in web VSS in the Web tier. We will also create an app load balancer sitting in front of the app workloads in the App tier. When the Nginx web servers in web VSS receive web requests from web load balancer, they will forward them to app load balancer to be distributed onto the app workloads in app VSS.

Go to 'Azure load balancer' service and click on 'add' to create the web and app load balancer. Make sure you select the type as 'Internal' and SKU as 'Standard'. We need 'Standard' SKU to be able to integrate these load balancers with the zone redundant Virtual Machine Scale Sets.



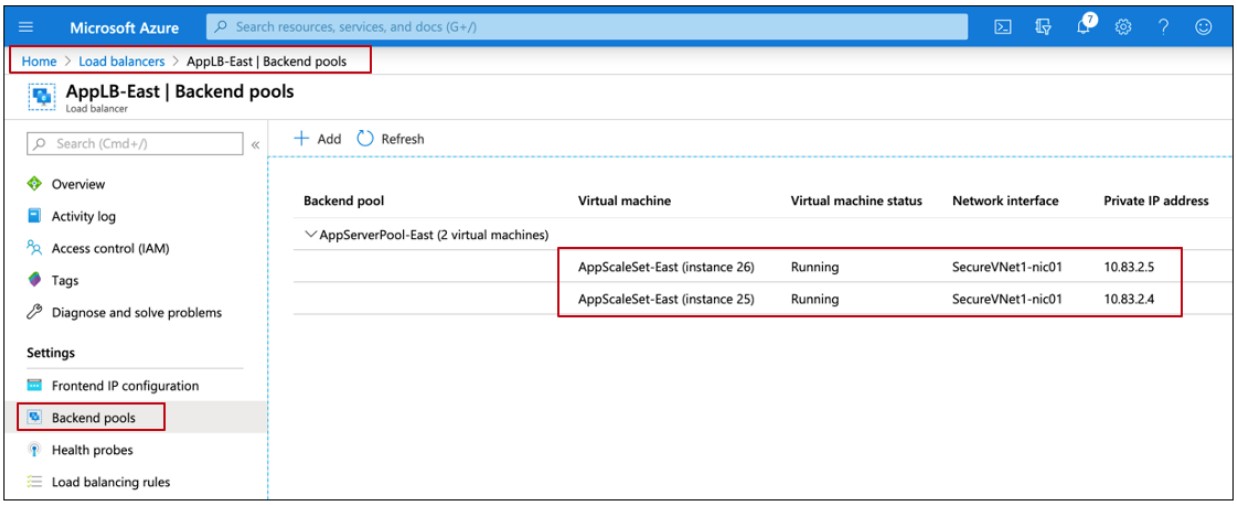
We assigned these load balancers with static IPs 10.83.1.100 and 10.83.2.100 in web and app subnet respectively. We had specified 10.83.2.100 in our web server configuration file in the previous step; hence web servers would make the requests to app load balancer IP if they need to fetch any dynamic content from app servers.

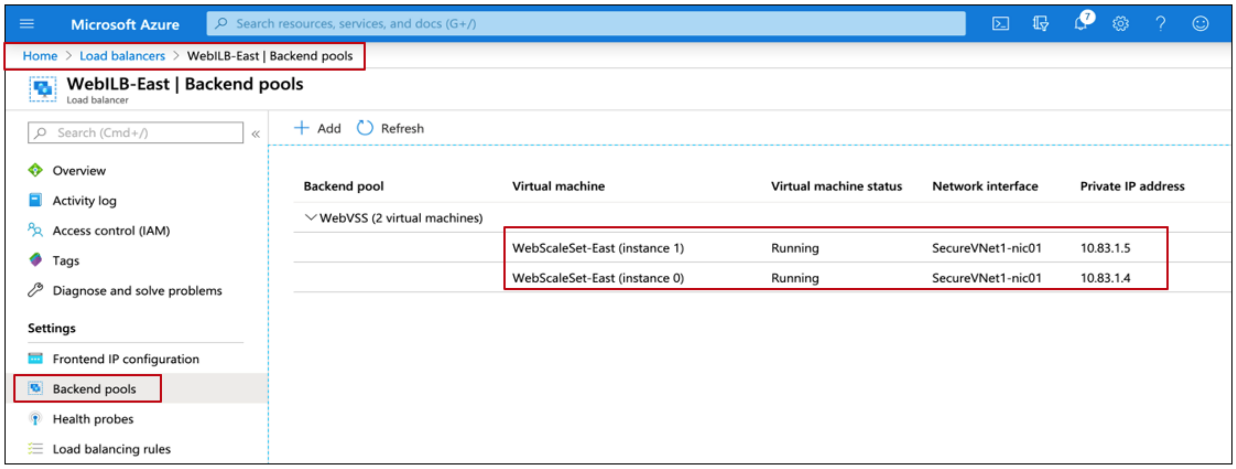




To finish our load balancer configuration, we need to add the backend pool, health probes and load balancing rules. For backend pools, we will add corresponding VSS for each load balancer. Make sure to upgrade VSS instances once the load balancer configuration is finished.

Refer to the Azure documentation for detailed steps on how to set up internal load balancers. Once the backend pool, the health probes and load balancing rules as set up, the app and web VSS instances would show as below under the load balancer service.





Setting up the Firepower Next-Generation Firewalls

In this section of the document, we will set up a pair of Cisco Firepower Next-Generation Firewalls at the network perimeter and onboard them to Cisco Defense Orchestrator for management. You could also use Cisco FMC (Firepower Management Center) available via the Azure marketplace (or an on-premise FMC) for management purposes.

Once the firewalls are set up, we will expose our application to public Internet via an External Azure load balancer. We will also set up an Internal Azure load balancer and update the App and Web tier routing tables to load-balance the outbound traffic from workloads to the Next-Generation Firewalls.

Implementation procedure:

Step 1. **Deploy NGFWv using Azure Templates**

Step 2. **Onboard the NGFWv to CDO**

Step 3. **Configure interfaces, routes, health probes, NAT and access control on NGFWv**

Step 4. **Set up the inside and outside load balancers**

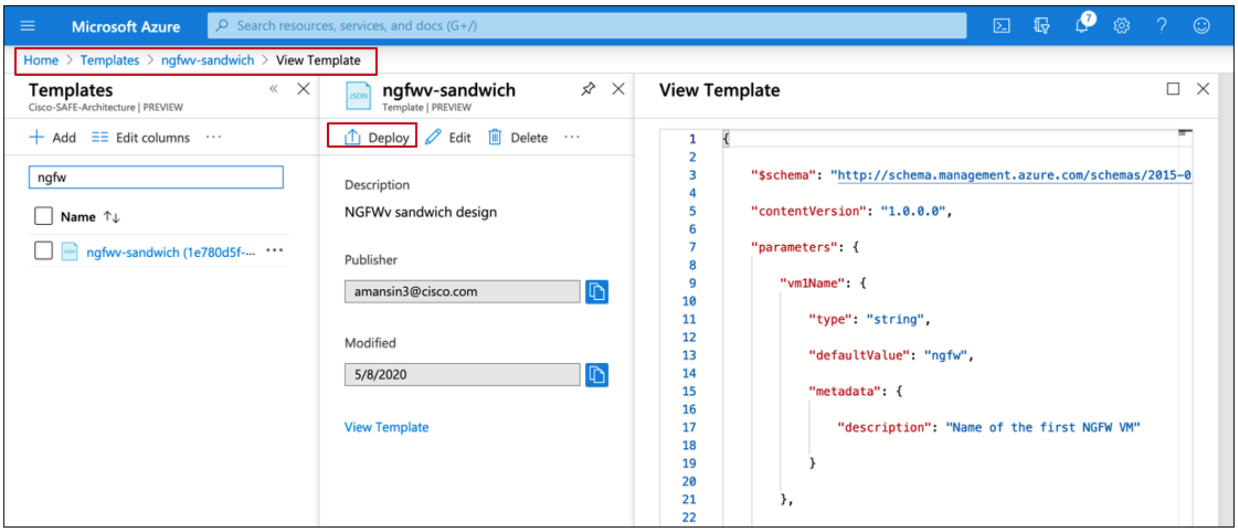
Step 5. **Access the application**

Step 1. **Deploy NGFWv using Azure templates –** Download the NGFW template available at GitHub. Go to 'Azure Templates' service on the Azure portal and add this template to deploy two Cisco Firepower Next-Generation Firewalls. Once you click on deploy, you will need to provide the IP addresses; we used the following IP addressing.

NGFWv	Interface Name	IPV4 Address	Azure NIC	Firepower Interface
Safengfw1	Management	10.83.4.10	NIC0	Management
Safengfw1	Diagnostic	10.83.7.10	NIC1	Diagnostic
Safengfw1	Inside	10.83.5.10	NIC2	Gig0/0
Safengfw1	Outside	10.83.6.10	NIC3	Gig0/1
Safengfw2	Management	10.83.4.11	NIC0	Management
Safengfw2	Diagnostic	10.83.7.11	NIC1	Diagnostic
Safengfw2	Inside	10.83.5.11	NIC2	Gig0/0
Safengfw2	Outside	10.83.6.11	NIC3	Gig0/1

Other details that you would be prompted for, while deploying the FTDs, include Resource Group (same as our cloud application), location (US East), hostname (safengfw1 and safengfw2), access credentials, storage accounts for firewalls (Storage-General purpose V1/LRS), Virtual Network (same VNET that we created earlier for the web application) and an Availability Set.

You will need to create an availability set prior to deploying this template and specify it when prompted. Refer to Azure documentation for information on how to create an Availability Set.



You can also customize the GitHub template to deploy the FTDs in different Availability Zones instead of an Availability Set. You will need to 'Edit' the JSON template file to remove Availability Set configuration and specify the Availability Zone for each NGFWv. Most of this lab validation was carried out using Availability Set, but we also validated the Availability Zones.

Note: An Availability Set ensures that the firewalls are deployed on separate hardware. The Availability Zones (AZ) on the other hand are two separate physical locations in the same region, connected with a high-speed link.

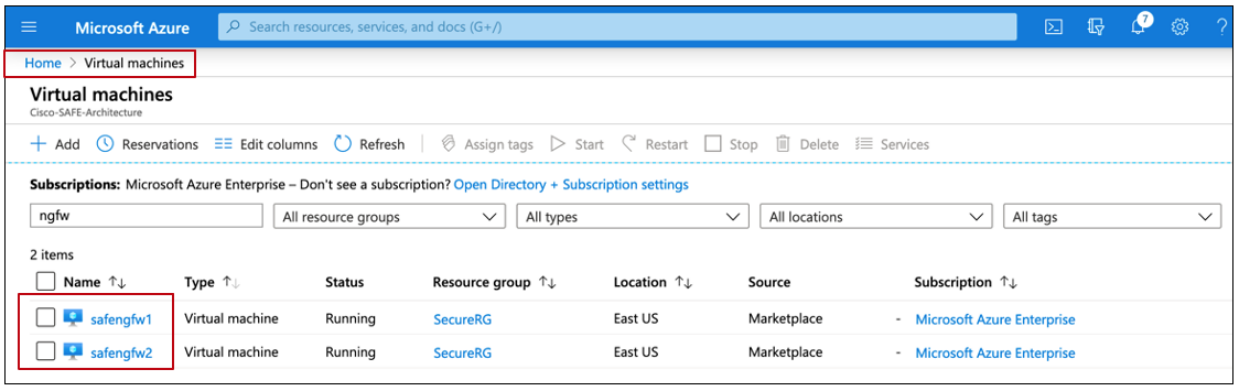
The sample template config snippet to add Availability Zones is as below:

```
"apiVersion": "2017-12-01",
"type": "Microsoft.Compute/virtualMachines",
"name": "[parameters('vm1Name')]",
"zones": [ "1"],

"apiVersion": "2017-12-01",
"type": "Microsoft.Compute/virtualMachines",
"name": "[parameters('vm2Name')]",
"zones": [ "2"],
```

You will also need to remove the following Availability Set config from the downloaded GitHub template:

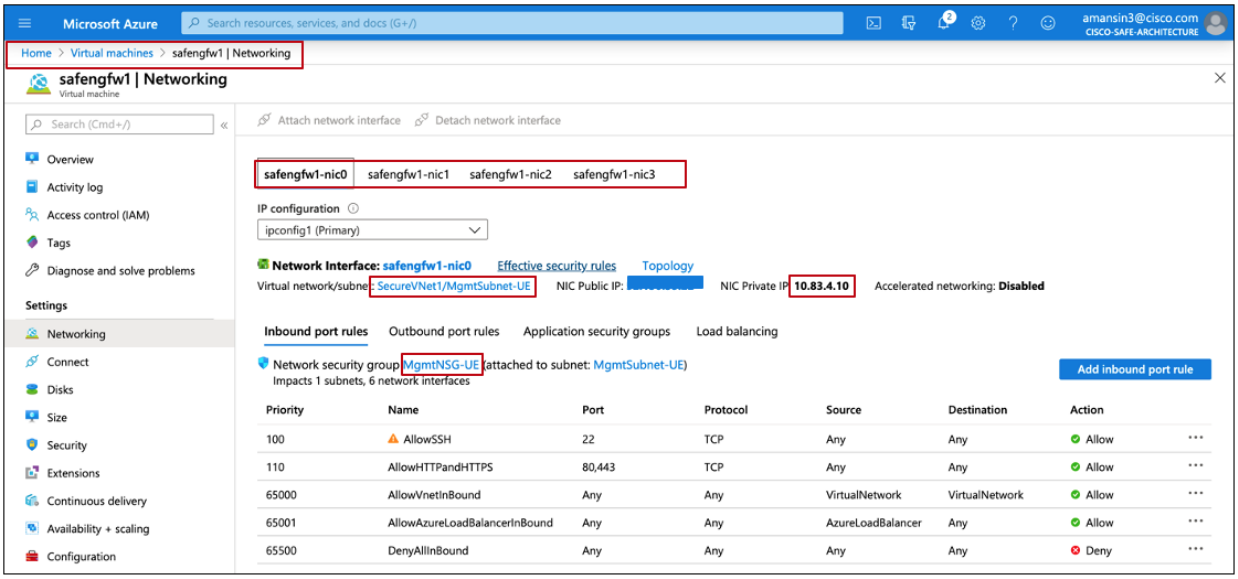
```
Parameters Section:
"availabilitySetResourceGroup": {
  "type": "string",
  "defaultValue": "",
  "metadata": {
    "description": "Name of the existing Availability Set's Resource Group"
    }
},
"availabilitySetName": {
  "type": "string",
  "defaultValue": "",
  "metadata": {
  "description": "Name of the existing Availability Set"
  }
},
Resources Section:
"availabilitySet": {
  "id":
"[resourceId(parameters('availabilitySetResourceGroup'),'Microsoft.Compute/availabilitySets/
', parameters('availabilitySetName'))]"
},
```

After a successful template deployment, the FTDs would show as below.

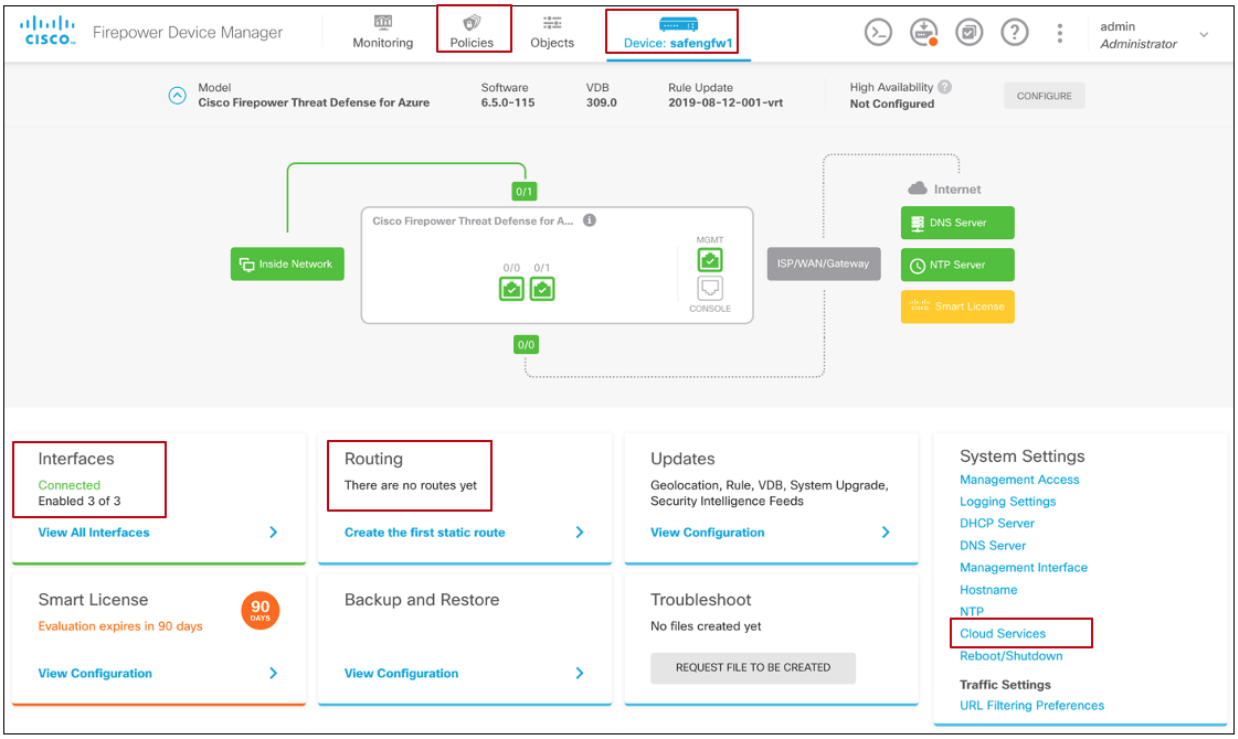


Each Firewall should have four network interfaces, assigned with IP addresses as specified in template while deploying.

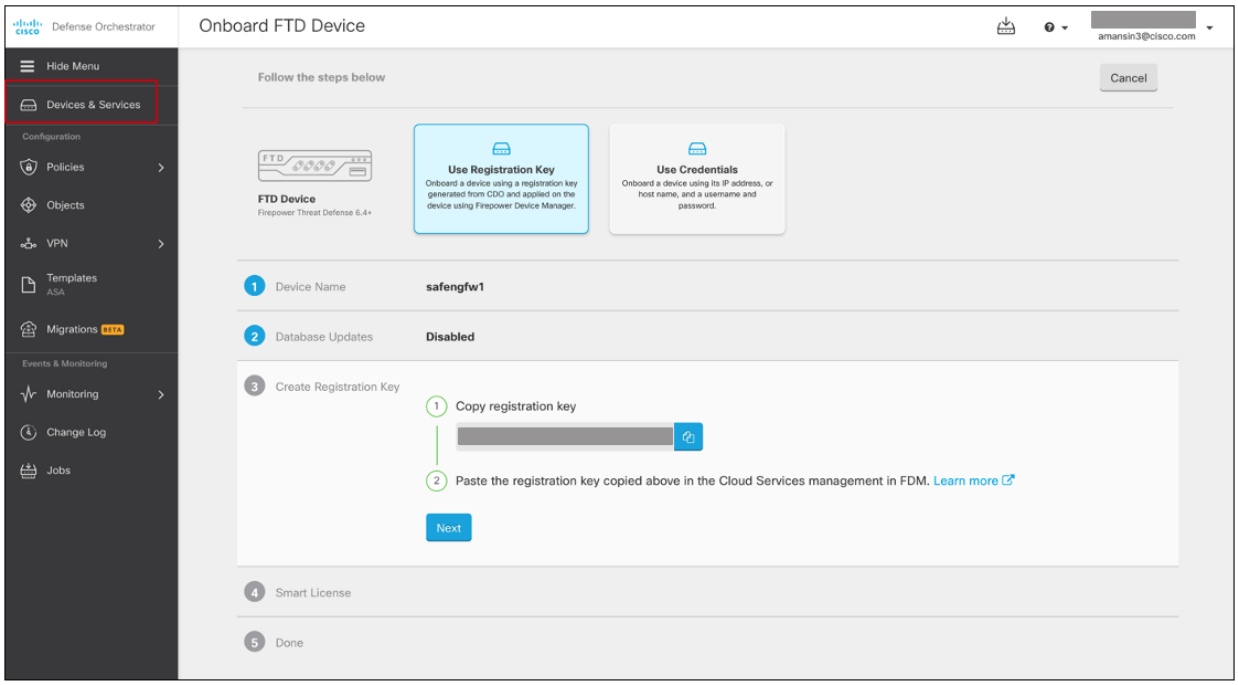
The Management interface will be assigned a public IP address automatically, we will use this IP to do the initial set up of these newly deployed instances. Additionally, associate a public IP to NIC3 (outside interface) of each firewall manually. Follow the Azure documentation for instructions.



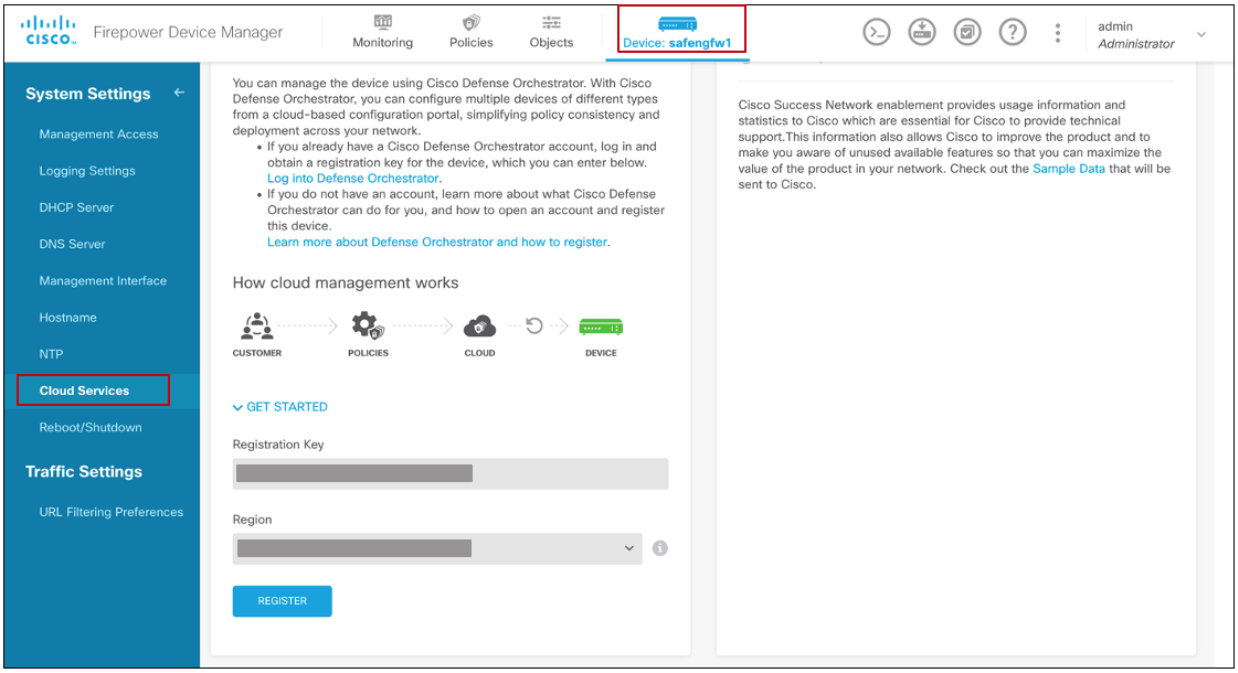
Step 2. **Onboard the NGFWv to CDO -** Access the Firepower Device Manager (FDM) using the management IP address. Click on skip device set up and acknowledge the 90-day trial license warning (we will configure smart licensing in subsequent steps). You will land at the following page.



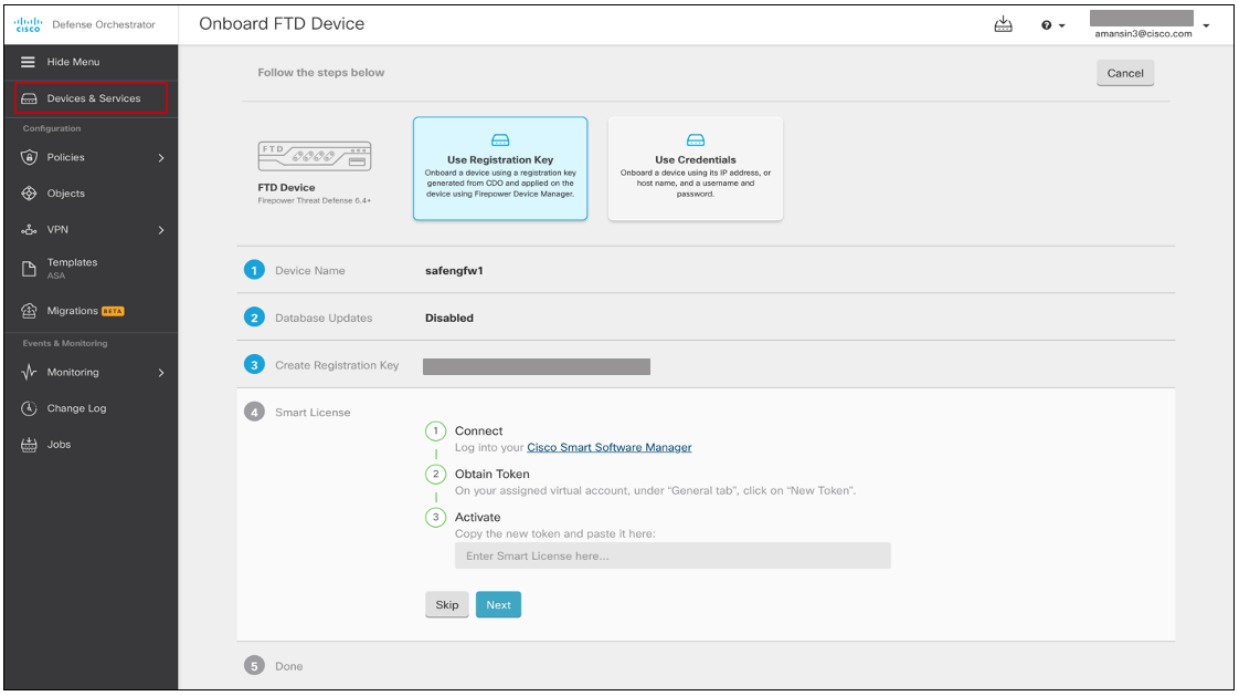
Log on to the CDO web portal and go to ‘Devices and Services’ and click on plus button on the top right-hand side to onboard a Firepower Threat Defense (FTD) device. We use ‘Registration Key’ option to onboard the FTD. Fill in the name of the FTD device and follow the wizard to copy the registration key.



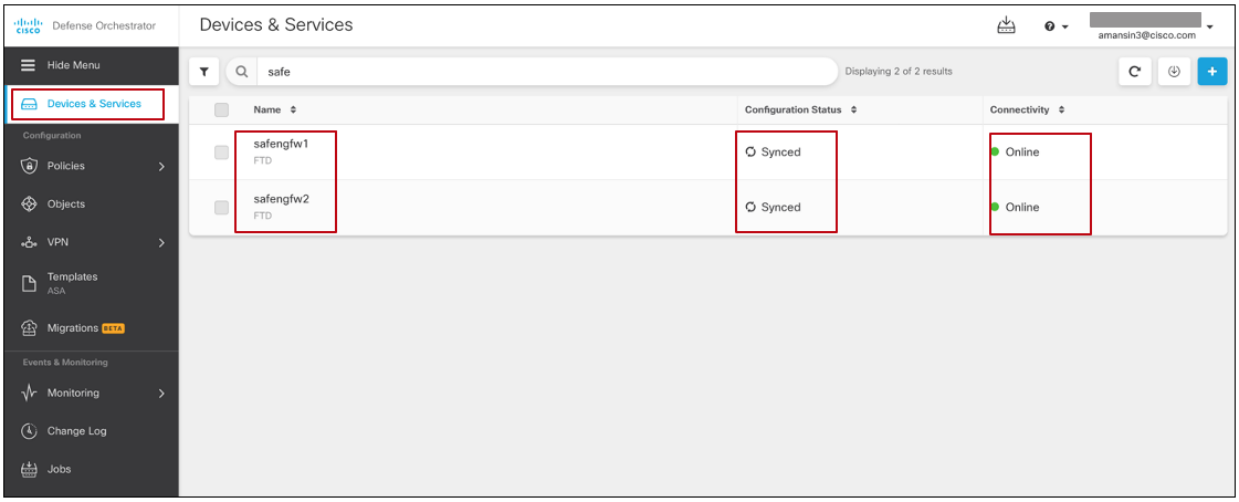
Go back to FDM portal and go to ‘Cloud Services’ option under ‘System Settings’. Paste the registration key, specify the ‘Region’ and click on register.



Come back to the CDO portal, click on next and log into your Cisco smart licensing manager and generate the token. Paste the token and click on next to finish the onboarding process.



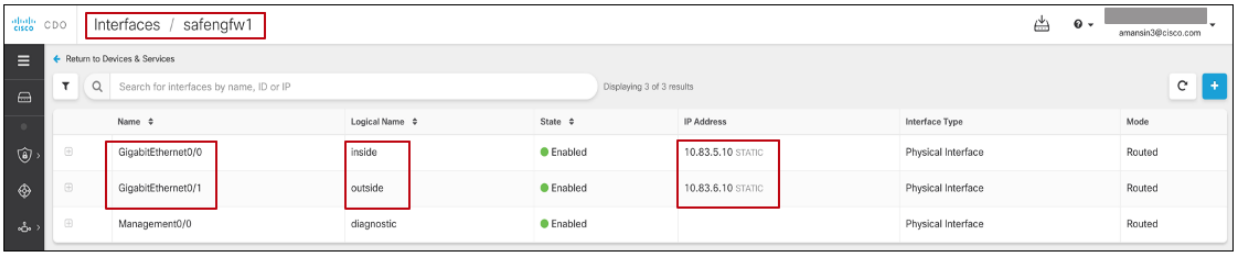
Repeat the same steps for the other firepower device, CDO will sync the configuration for both the devices. At this point we have successfully finished onboarding both the FTDs to CDO.



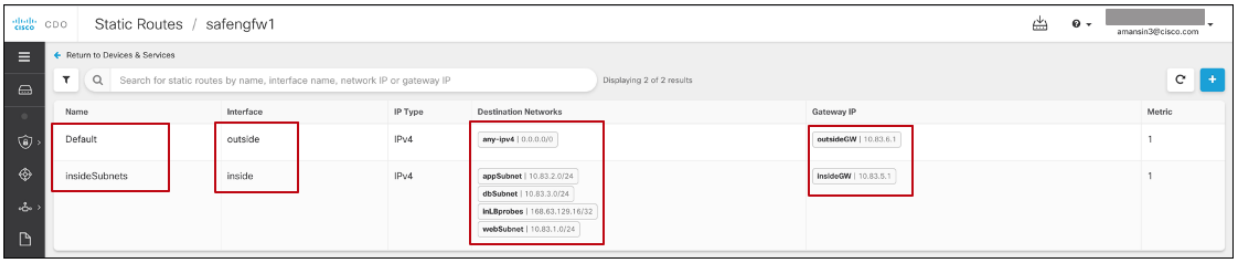
Step 3. **Configure interfaces, routes, HTTPS health probes, NAT and access control on NGFWv** – We need to configure the following five components:

- Network interfaces
- Static routes
- Enable HTTPS on inside and outside interface for load balancer probes
- NAT rules for inbound and outbound traffic
- Access rules to allow the necessary traffic

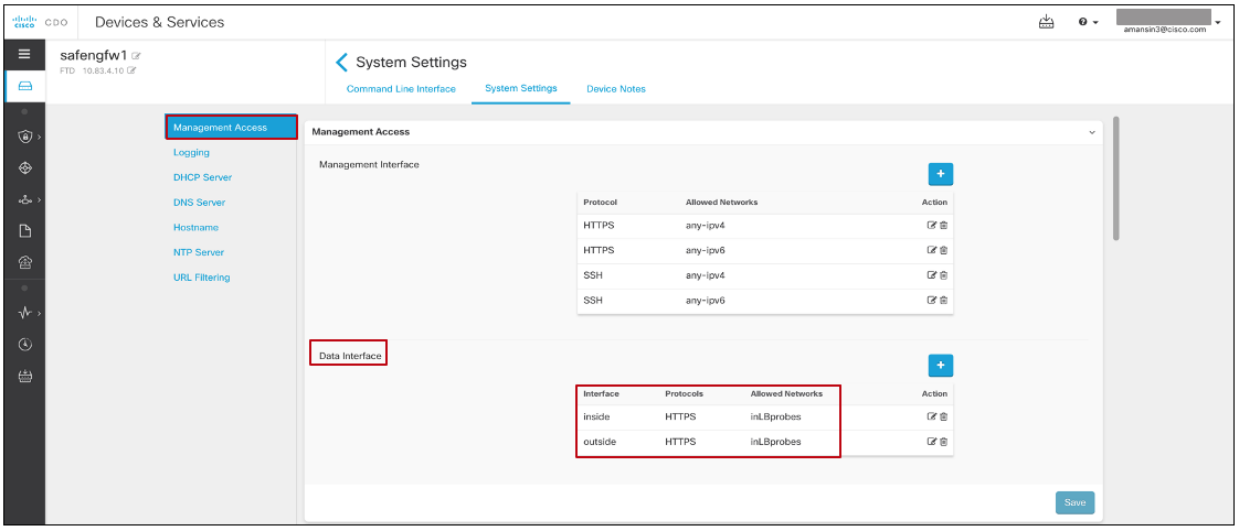
Click on the onboarded NGFW appliance on CDO dashboard and then go to 'Interfaces' option from the menu that appears on the right-hand side of the dashboard. Make sure Gig0/0 and Gig0/1 are assigned static IP addresses and names as defined in the table in Step 1.



Go back to the same menu and now go to 'Routing' option, set the default route pointing to the gateway on outside the subnet- 10.83.6.1. Also, add the route for internal subnets (web, app and database subnet) pointing to the gateway on the inside subnet- 10.83.5.1. Lastly, add a route for load balancer virtual IP address that sends the health probes, set the next hop as the inside subnet gateway. Find more details about Azure load balancer health probes, refer to the Azure documentation.



Next, we set up the inside and outside interfaces to listen on TCP port 443; we make sure that we only allow load balancer probe IP. We will need this allowed for inside and outside load balancers to do health check on inside and outside interfaces of the firewalls. Go back to the same device menu on CDO and this time, click on 'Settings'. Select the 'Data Interfaces' tab and click on 'add' to allow probes to inside and outside interfaces on port 443 from VIP sending the load balancer health probes. You might also need to update your inside NSG to allow these probes.



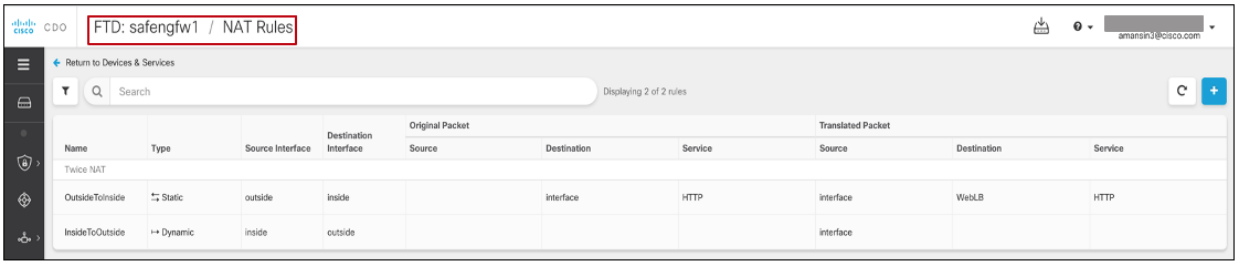
Next, we set up two NAT rules. We configure a dynamic PAT rule to allow outbound traffic to the Internet from the application workloads. The translation would be as below.

```
Source: WorkloadIP:Port => OutsideFWInterfaceIP:Port
```

We configure another static NAT rule to do the following translation for traffic from the Internet users accessing the application:

```
Source translation: InternetUserIP:Port => InsideFWInterfaceIP:Port
Destination translation: OutsideLBIP:HTTP => WebLBIP:HTTP
```

We need the source translation above to ensure that reply traffic is returned back to the same firewall's inside interface i.e. maintain the traffic symmetry. The destination is translated from public IP of outside load balancer to the IP address of the web load balancer i.e. 10.83.1.100. Web load balancer receives all the incoming traffic for the cloud application and distributes to the web servers in web VSS.



Lastly, we assign inside interface to inside zone and outside interface to outside zone. Then, we configure access control policies to allow traffic from inside zone to outside zone. We also allow HTTP traffic incoming from the Internet users who are trying to access the cloud application.

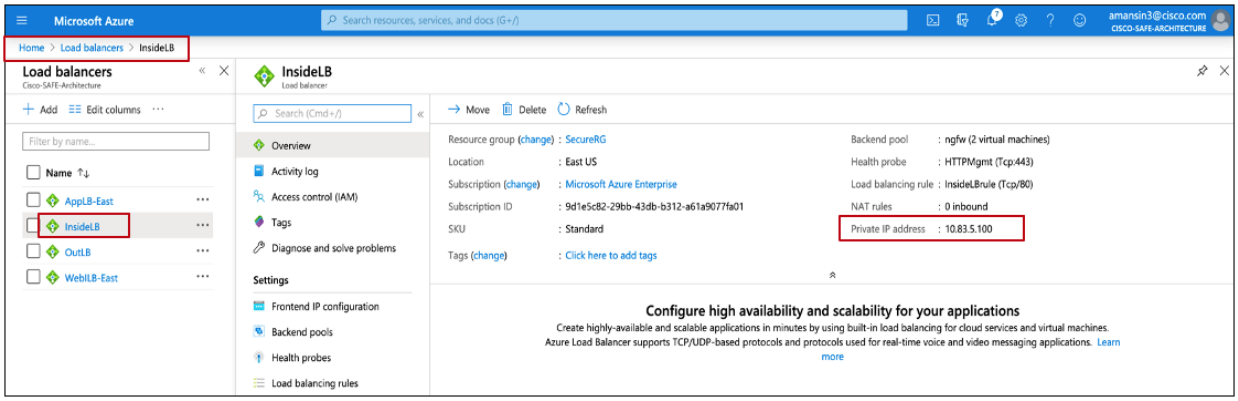
Go to 'Policies > FTD Rulesets' on CDO portal and click on plus button to add a an FTD ruleset. Within this newly created ruleset, add the access rules and attach it to the newly onboarded FTD appliances.

After this, we deploy all the changes and repeat the same for the second FTD device.

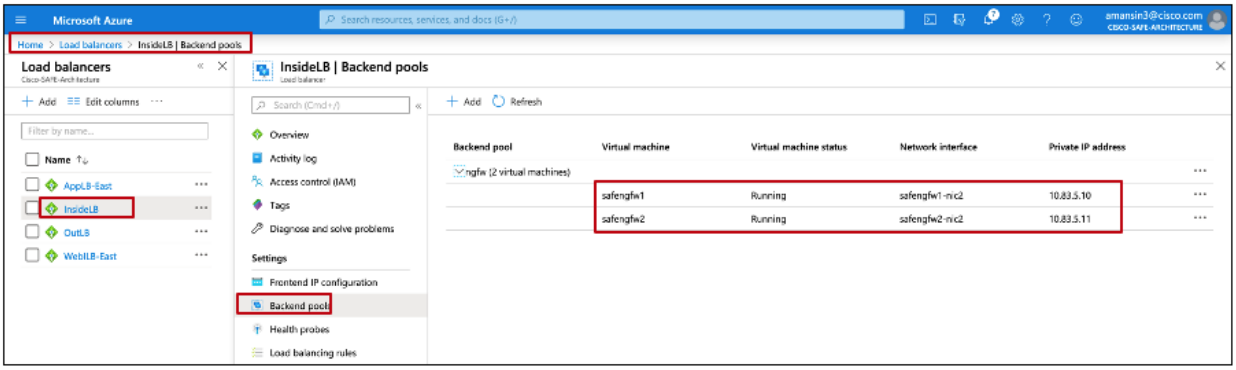
Step 4. **Set up the 'inside' and 'outside' load balancers –** In this step, we will set the 'inside' and 'outside' load balancers and the update the Azure Route Tables for web and app tier to point the default route to the 'inside' load balancer.

Go to 'Load balancer' service on the Azure portal. Click on 'add' to create an 'inside' load balancer. We assigned the static IP address 10.83.5.100 to the load balancer.

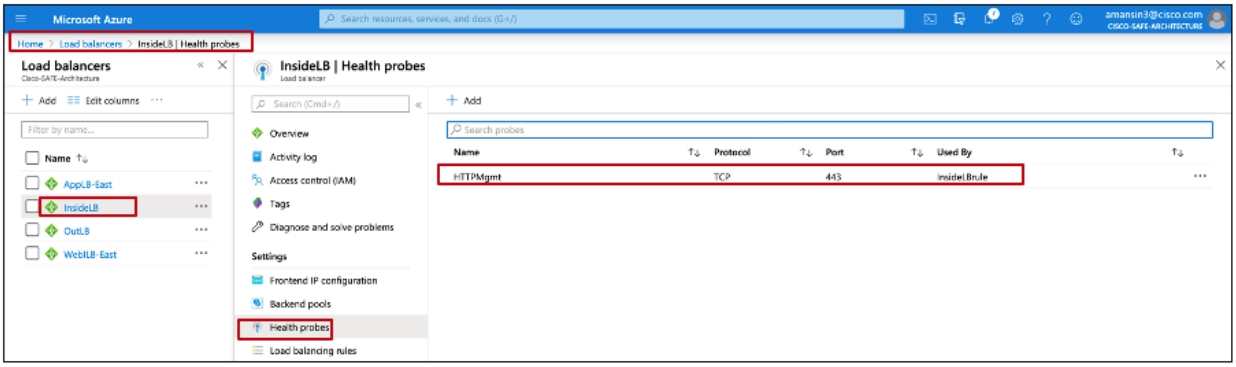
Refer to the Azure documentation for detailed information on creating load balancer. Make sure to choose 'Standard' SKU, it's required to integrate with highly available (Zone Redundant) resources like our firewall deployment.



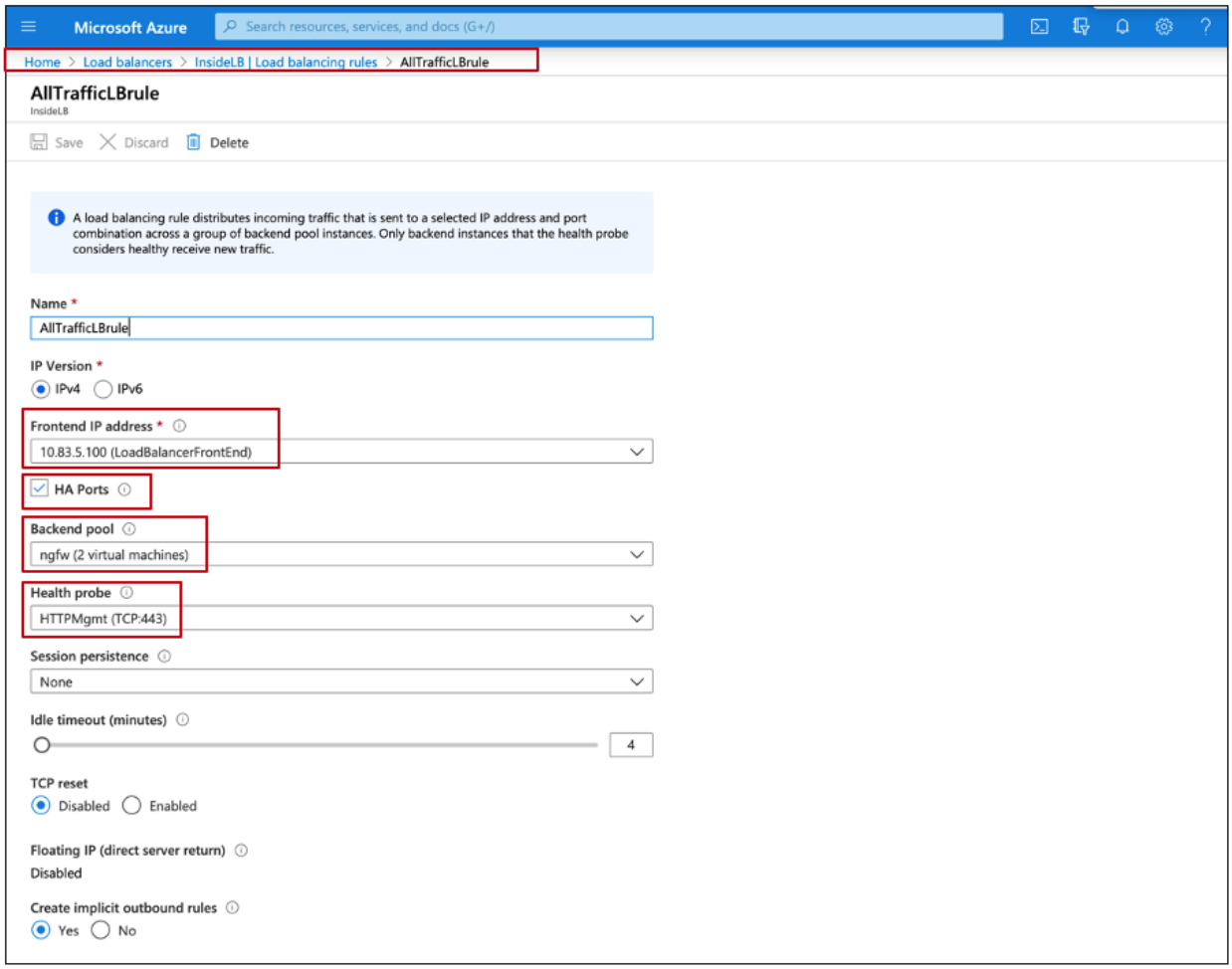
After the load balancer is created, add the backend pool. Click on the add button and add the inside firewall interfaces to the pool.



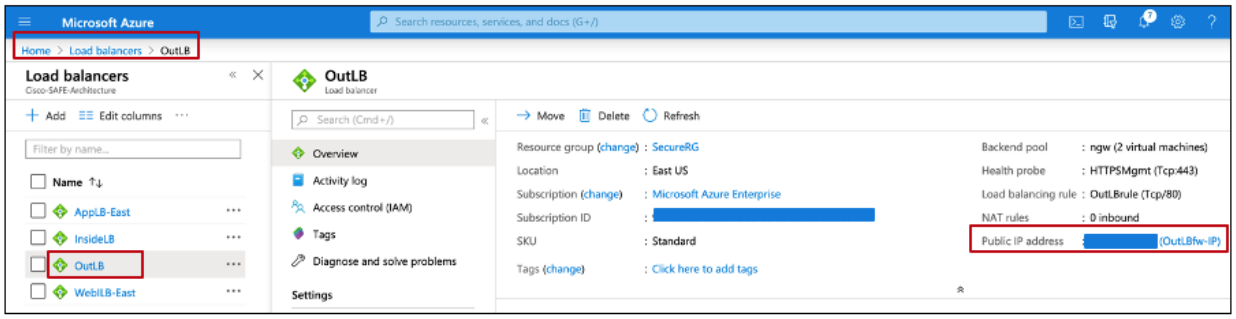
After adding the backend pool, next step is to define the probes to monitor the health status of inside interfaces. We had set up the FTD appliances to listen on port 443 from load balancer IP addresses, hence we set up the health probe for TCP port 443.



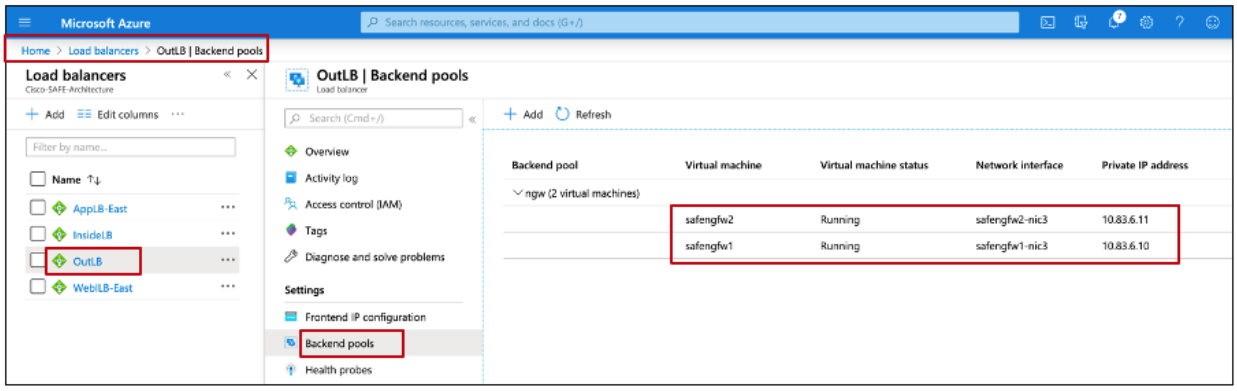
Last step is to configure the load balancing rule. For ‘inside’ load balancer, make sure to check the HA port option so that the load balancer can receive traffic for all the TCP and UDP ports.



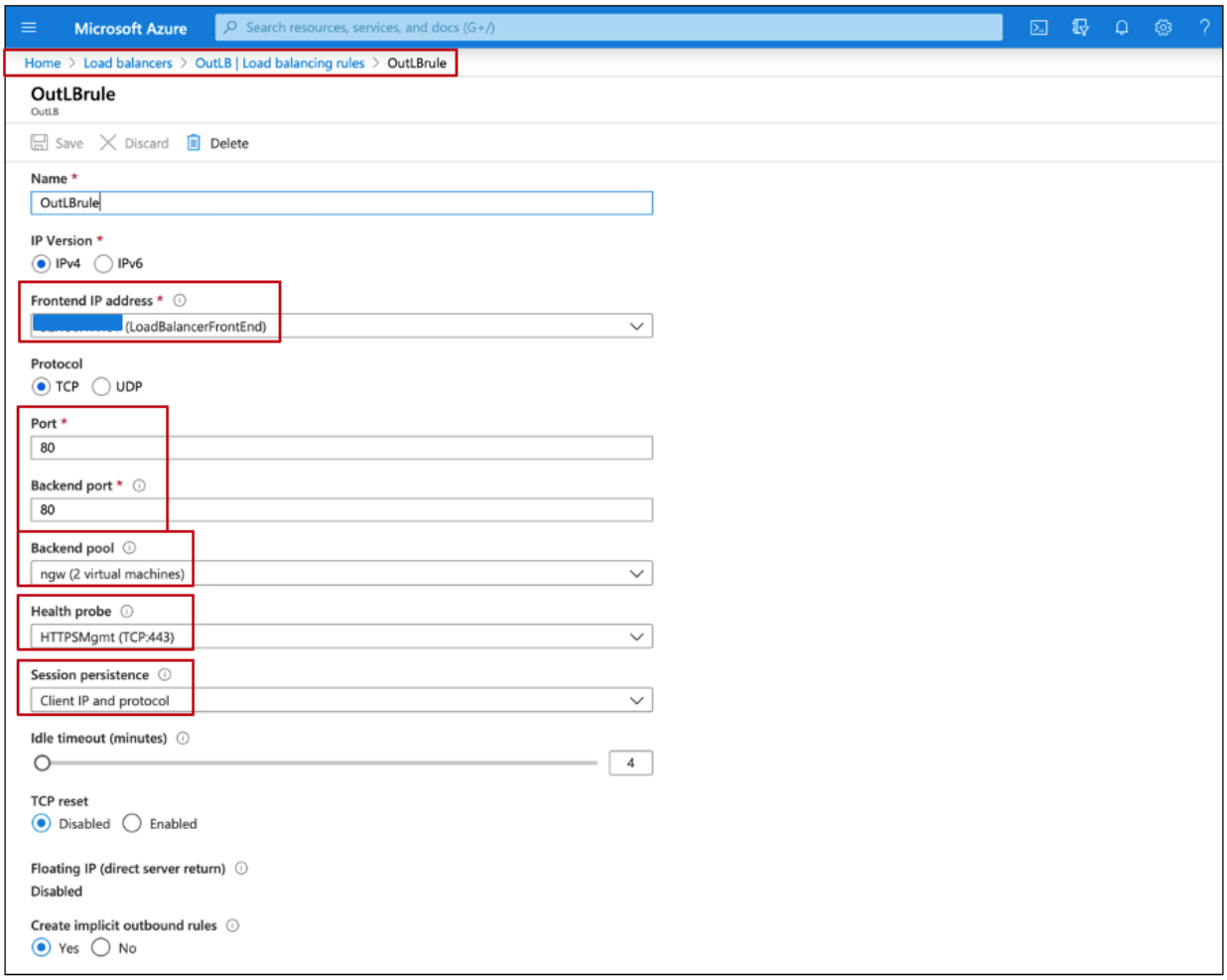
In a similar manner, we set up the 'outside' load balancer. The only major difference is that this is a public load balancer and hence is assigned a public IP. This public IP will be used to access our cloud application.



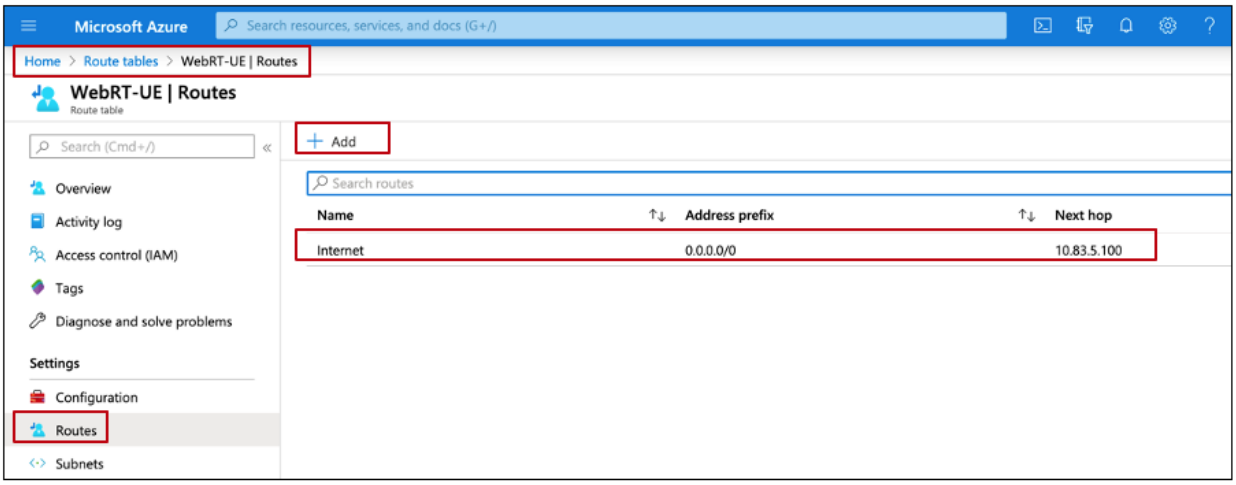
The backend pool will consist of the outside interfaces of the firewall.



The load balancer rule is set up to listen on TCP port 80 and forward the traffic to the backend pool consisting of outside interfaces of NGFWv devices on the same TCP port 80. Make sure to set the session persistence to 'Client IP and protocol' to ensure that traffic for the same session is forwarded to the same NGFW.



Now that we have the inside and outside load balancers set up, we need to update the routing tables for the Web and App tier to force the outbound traffic for Internet to inside interfaces of NGFW devices. We add the default routes in the web and app routing table with next hop as 10.83.5.100 i.e.. the 'inside' load balancer, this ensures load balancing of outbound internet traffic to inside interfaces of the NGFW devices.



Step 4. **Access the application –** The last step to setting up this application is to register a domain for the application and add an 'A' record to point the domain name to the public IP address of the 'outside' load balancer. When we access the newly registered domain name for the Azure application, we are prompted for the initial set up and then we land on cloud application home page as below.

Enabling WAF and DDoS protection

At this point we have finished setting up a fully functional cloud application. We will now add the WAF and DDOS protection capabilities in our design. For the purpose of this document, we will demonstrate two different options for adding these capabilities, you can pick either of these two options:

OPTION 1: Azure WAF and DDoS protection

Azure WAF can be deployed with Azure Application Gateway, Azure Front Doors, and Azure Content Delivery Network (CDN) service from Microsoft. We incorporate Azure Front Doors service to validate WAF integration with our application. Based on different application set ups, Azure native WAF may or may not be an available option for WAF capabilities. Refer to the Azure documentation for more details about Azure WAF service.

Azure provides two tiers for DDoS protection, Basic and Standard. Azure Front Doors platform is by default protected by Azure Basic DDoS Protection. For further security, Standard DDoS protection is enabled at the VNET level to protect any resource with a public IP in outside and management tiers. While Basic service is enabled by default at the VNET level also, Standard tier needs to be enabled manually. Find more details in Azure documentation here.

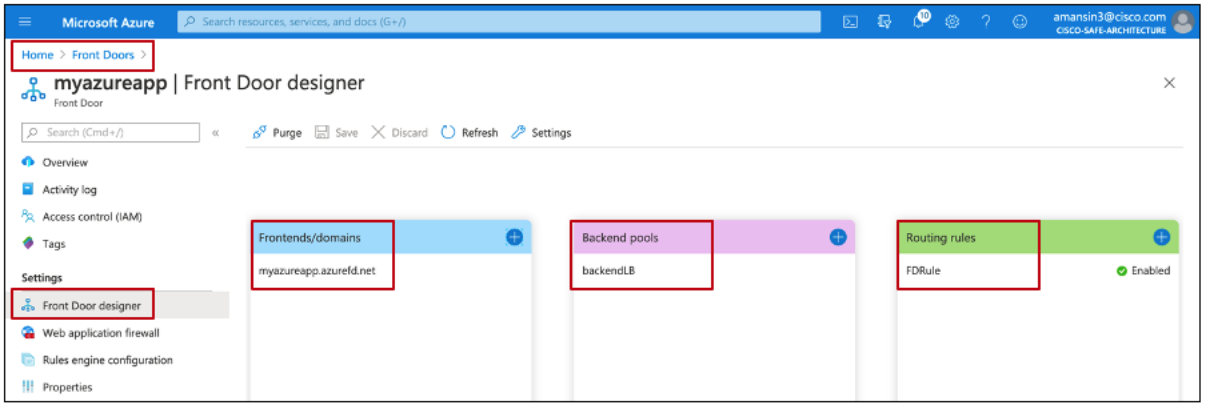
Implementation procedure:

Step 1. **Setting up Azure WAF service**

Step 2. **Setting up Azure DDoS protection for VNET**

Step 1. **Setting up Azure WAF service –** Go to 'Front Doors' service on the Azure portal and click on 'add' to create a new Front Door service for the newly set up cloud application. Configuring Front Door service involves three steps –you will need to specify a domain name for the application, the backend pool which consists of outside interfaces of the NGFWs and lastly the traffic routing rules.

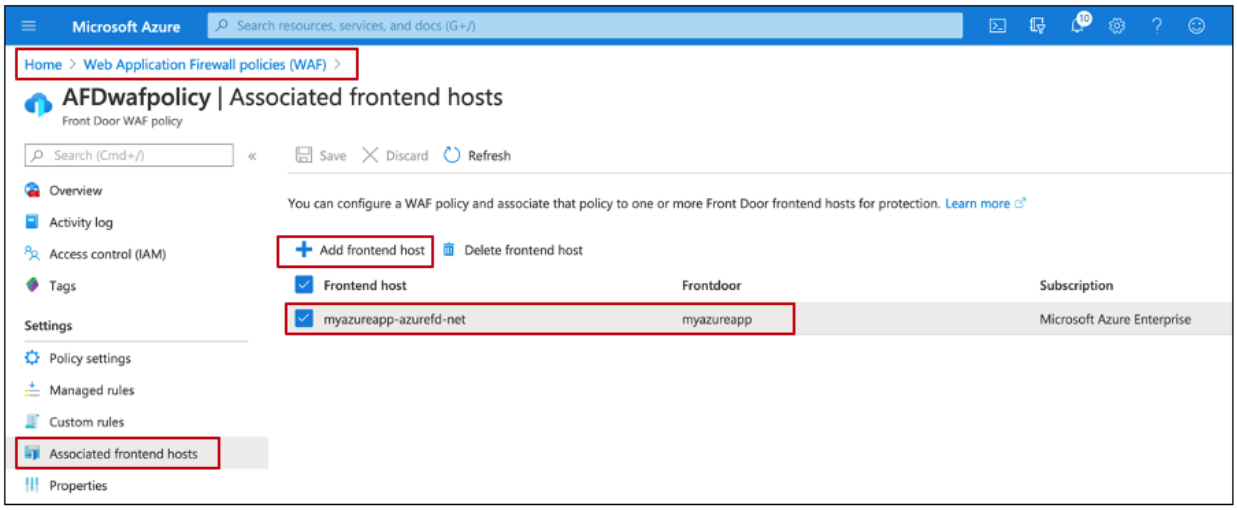
Azure Front Door will receive the traffic from internet users and load balance it to the outside interfaces of NGFWs. Make sure you enable session affinity at 'Frontend/domain' level if your application is stateful. For detailed steps on how to create Azure Front Doors, check out the Azure documentation.



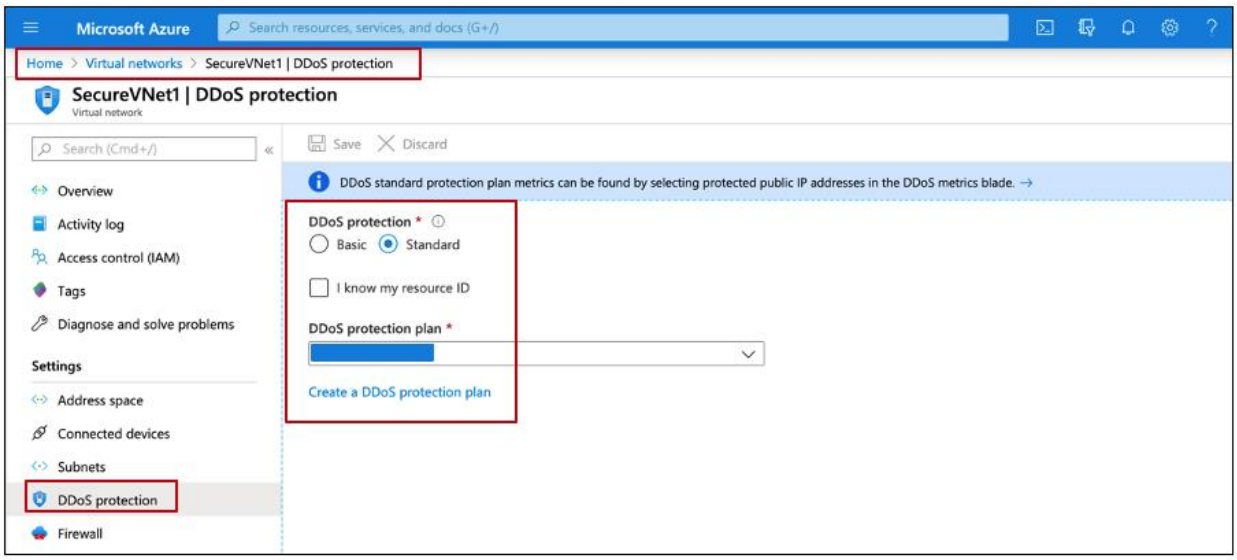
Optionally, you can customize the domain name for your Front Door, refer to Azure documentation.

To lock down the application to accept traffic only from this specific Front Door, you can use ACL on Firewall to lock down the access to Front Door backend IP space. Refer to the Q&A page here for more details on AFD IP space.

Now that we have our Front Door set up complete, we will enable the Azure WAF. Go to 'Web Application Firewall Policies' on the Azure portal and click on 'add' to enable the WAF service for Front Door that we created above.



Step 2. **Setting up Azure DDoS protection for VNET -** For enabling the Standard tier DDoS capability, go to 'Virtual Networks' on the Azure portal and select the VNET created for the cloud application. On the left-hand side panel, select DDoS to enable the Standard tier. For detailed instructions on how to configure DDoS, refer to the Azure documentation.



OPTION 2: Radware Cloud Service for WAF and DDOS protection.

Radware Cloud WAF and DDoS services are integrated by using CNAME DNS records. Its independent of any specific Azure Cloud service. For Radware integration, we use DNS to forward traffic to Radware cloud. After scanning the traffic, it is redirected to the Public IP of 'outside' load balancer.

Implementation procedure:

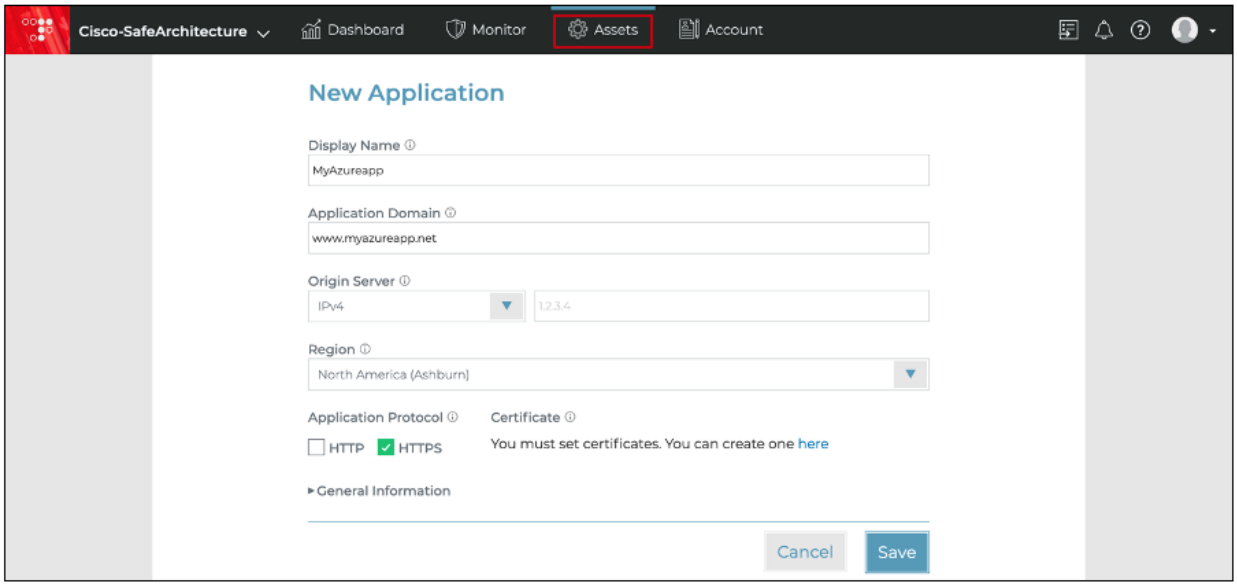
Step 1. **Onboard the application to Radware Cloud**

Step 2. **Update the DNS setting to point traffic to Radware Cloud**

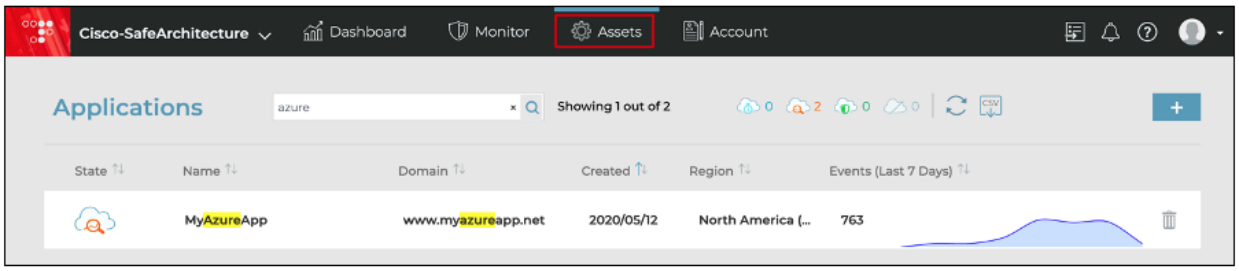
Step 1. **Onboard the application to Radware Cloud** - The first step to integrating Radware cloud service in your environment is to add the application onto the Radware cloud. On the Radware cloud portal, go to 'Assets > Application' and click on the plus button on the upper right-hand side of the screen. Add the prompted details i.e. the application domain name (www.myazureapp.net), the origin server (in this case it would be the 'outside' load balancer's

public IP address) and the protocol (HTTP). If your application is based on HTTPS protocol, you would need to add the certificate information as well.

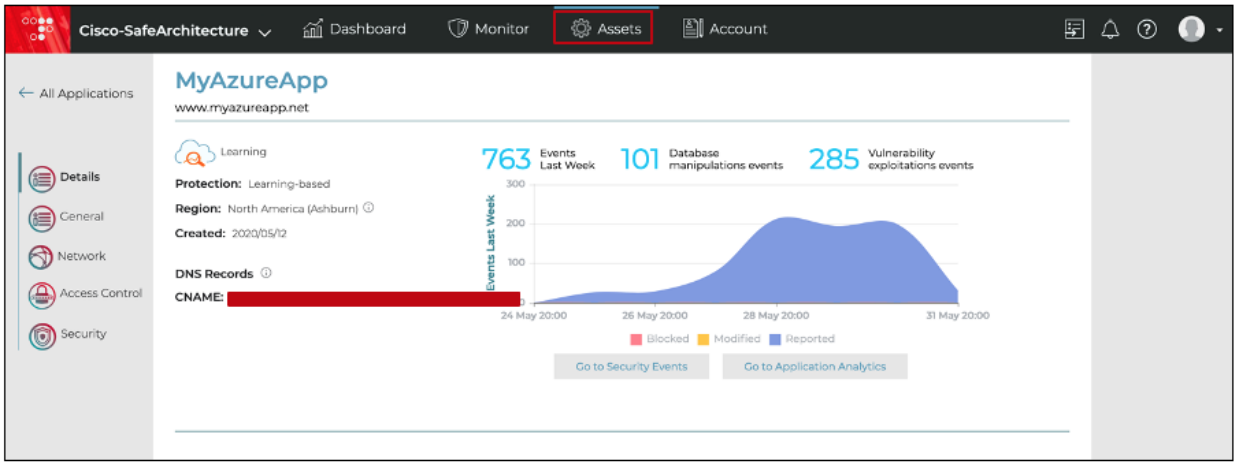
As part of the onboarding process, each customer can choose between immediate and learning based protection. Immediate protection will enforce a predefined security policy, preventing known attacks. In order to cover both known and unknown attacks, Radware recommends using the learning-based protection method. During the first 2 weeks (duration can vary depending on traffic), Radware evaluates traffic patterns and can automatically update both negative and positive security models by refining signatures, creating exceptions and building the allowed file extension list per application, greatly reducing false positives.



Once the details are saved, the application can be seen as below.

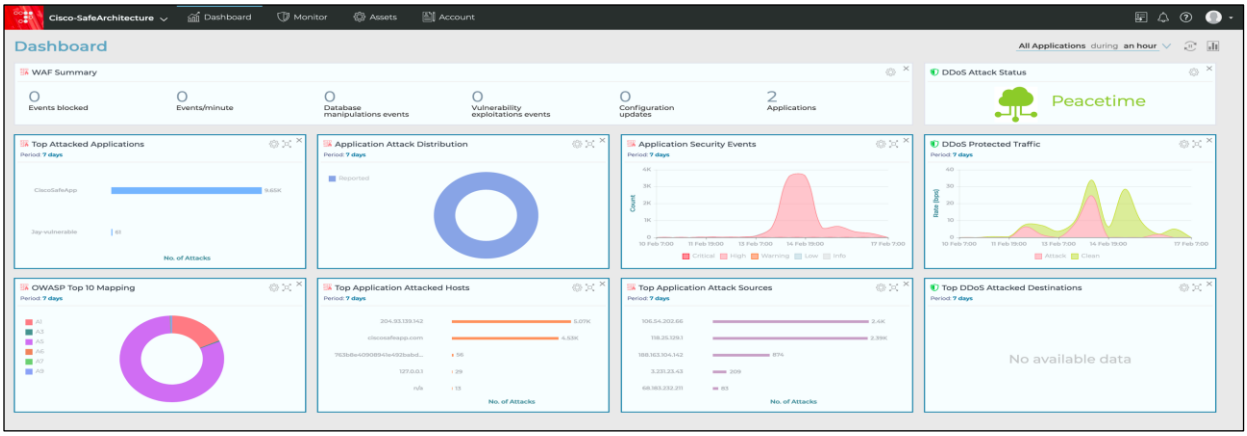


Click on the application and copy the allocated CNAME. We need to update the DNS records for our application with this Radware CNAME.



Step 2. **Update the DNS setting to point traffic to Radware Cloud** – Update the DNS record sets for the application domain with Radware CNAME (from the previous step) and corresponding IP address. After this change, it might take a few minutes for the DNS update to propagate. Once the DNS records are fully updated, the traffic will start getting redirected to Radware Cloud servers before it hits the 'origin server' in the Azure cloud. To eliminate direct origin attacks, Radware recommends configuring the perimeter firewall to only allow the Cloud WAF to access the application origin server directly. The service IP addresses can be requested from Radware Support Team. For more information, check out the [Radware Cloud WAF Quick Start guide (login required)].

Radware Cloud portal displays all the traffic statistics related to various onboarded applications. The dashboards are fully customizable based on your requirements.



Integrating with Cisco SecureX threat response

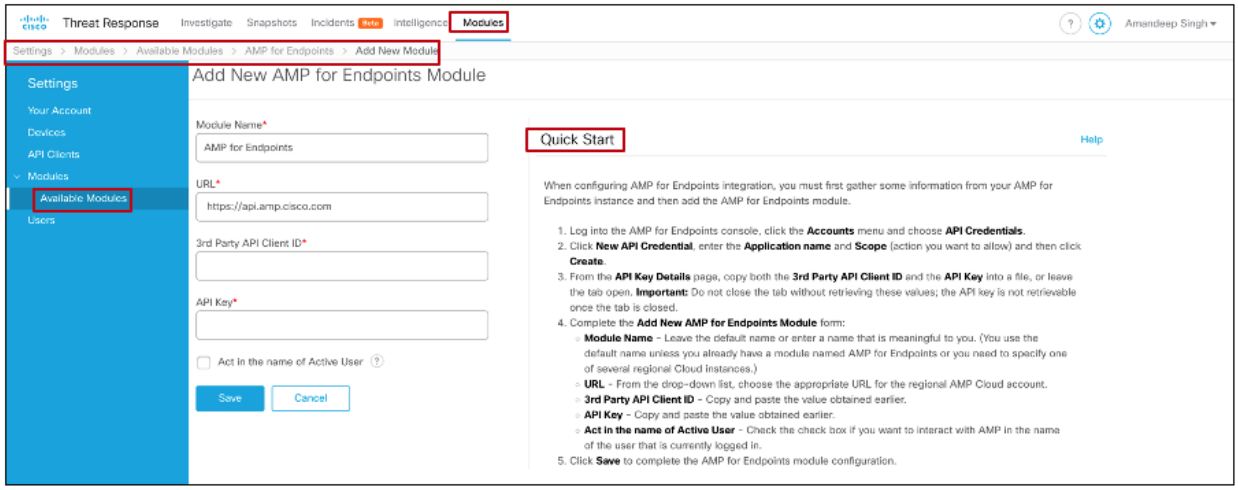
In this last implementation step, we will enable the AMP4E and Umbrella modules in the threat response portal to get a unified view into the Azure environment. We create API keys in AMP4E and Umbrella portals and then configure those keys in the threat response dashboard.

Implementation procedure:

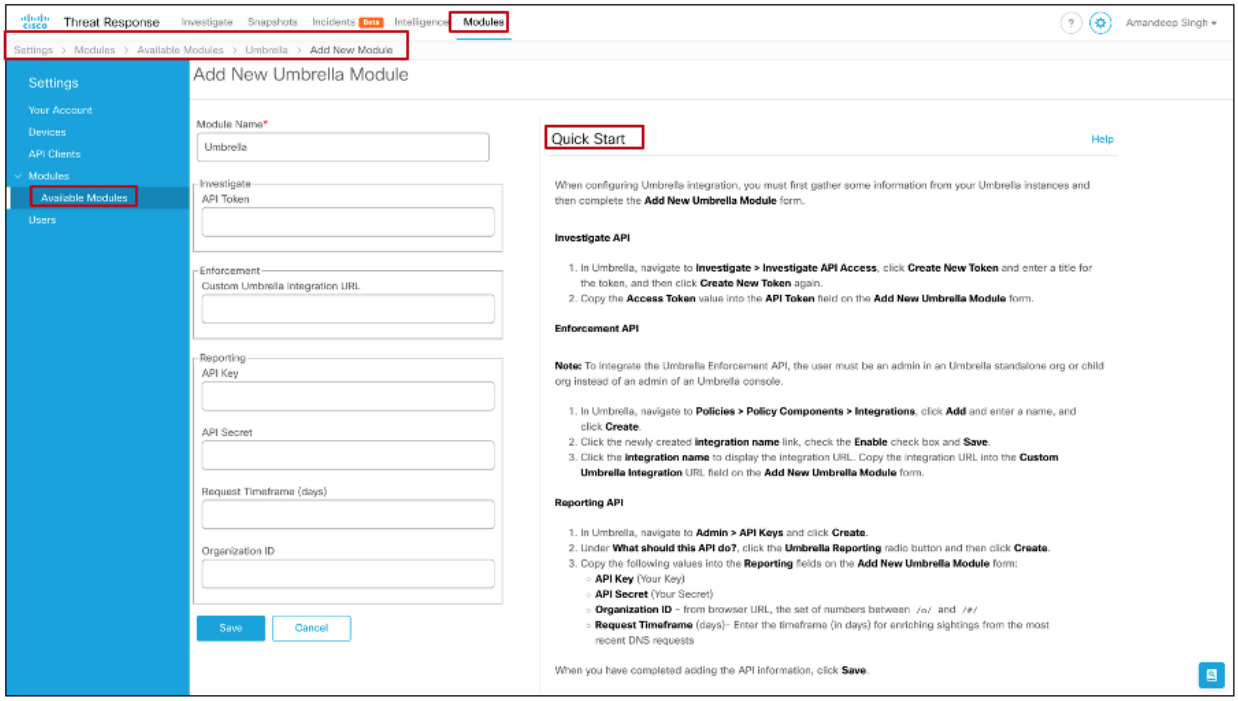
Step 1. **Add the AMP4E module**

Step 2. **Add the Umbrella modules**

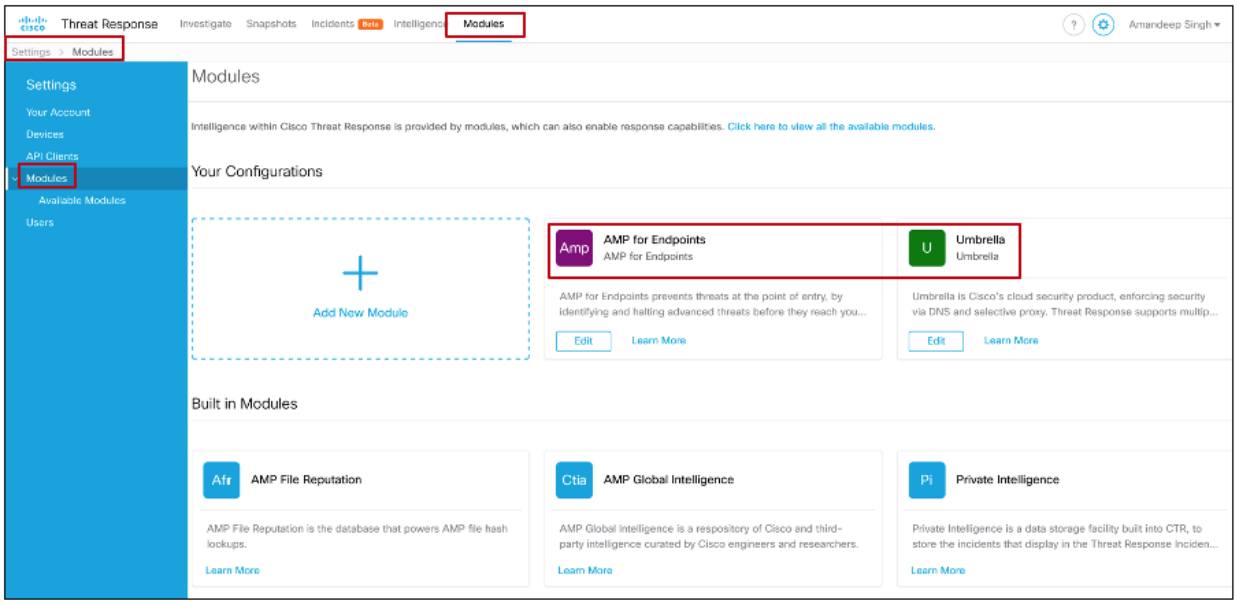
Step 1. **Add the AMP4E module –** Log on to the threat response dashboard and go to available modules, add a new AMP4E module. Threat response displays all the steps on how to integrate the AMP module once you click on 'add module' as shown in the snapshot below.



Step 2. **Add the Umbrella module –** Go to available modules again, this time, add a new Umbrella module. In a similar manner as AMP4E, the integration steps are listed on the threat response page. Create the API keys in the Umbrella portal as instructed and then add the it in the threat response configuration page.



After we have saved the module configurations, the modules will be listed under ‘Module’ as below.



Validation Testing

Tetration

Validation procedure overview:

- Test Case 1 – Creating the workspace for Azure cloud application
- Test Case 2 – Using ADM to discover the policies for Azure workloads and setting up an app view
- Test Case 3 – Enforcing the policies on workloads
- Test Case 4 – Discovering the vulnerable packages on the Azure workloads

Test case 1: Creating an application workspace for Azure cloud application

This test case involves defining annotations for the Azure environment. These annotated attributes are used later to segregate the tiers and segments within the Azure VNET and hence define a workspace for our tiered cloud application.

Validation procedure:

Step 1. **Build an inventory**

Step 2. **Define scopes**

Step 3. **Create a workspace**

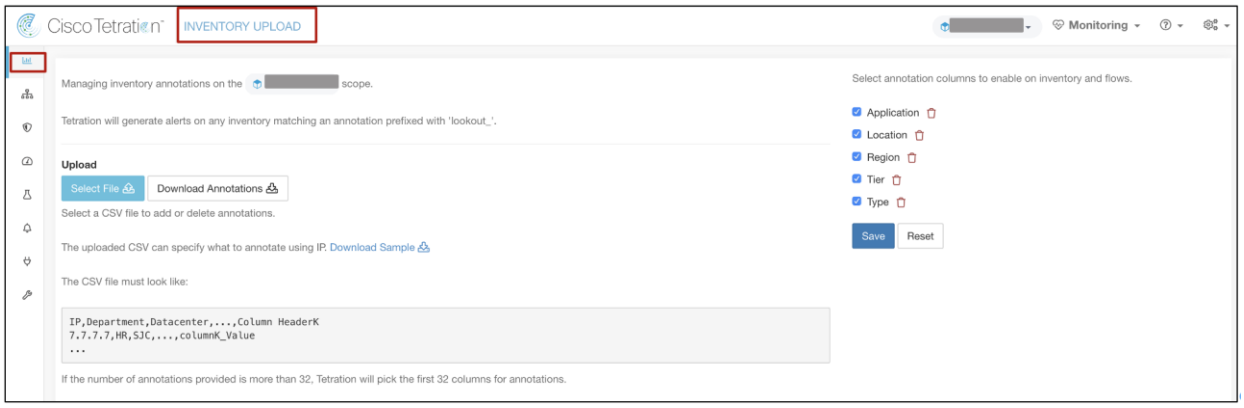
Step 1. **Build an inventory –** Define the attributes that would help you segregate your tiered application workloads in the cloud and hence construct policies for them. We will upload a CSV file with workload annotations for this purpose.

1.1: Based on the architecture of our tiered application (elaborated in the previous sections of this document), the following annotations were used (Table: Azure Cloud Inventory). Save this in a CSV file.

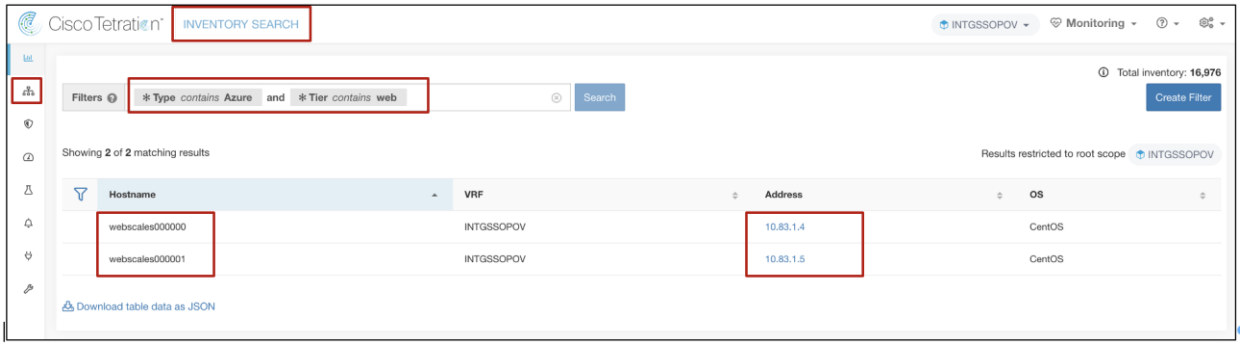
Table 1. Azure Cloud Inventory

IP	Application	Region	Tier	Type
10.83.1.0/24	Safe3tierApp	US-East	WebServer	Azure-Cloud
10.83.2.0/24	Safe3tierApp	US-East	AppServer	Azure-Cloud
10.83.3.0/24	Safe3tierApp	US-East	Database	Azure-Cloud
10.83.4.0/24	Safe3tierApp	US-East	Management	Azure-Cloud
10.83.5.0/24	Safe3tierApp	US-East	Inside	Azure-Cloud
10.83.6.0/24	Safe3tierApp	US-East	Outside	Azure-Cloud
10.83.7.0/24	Safe3tierApp	US-East	Diagnostic	Azure-Cloud

1.2: Now, log into the Tetration cloud portal and go to 'Visibility > Inventory Upload'. Click on 'Select File' and 'add' the CSV file.



1.3: After a few minutes, you can go to 'Visibility > Inventory Search' and test the filters generated, based on annotations from the Step 1.2.

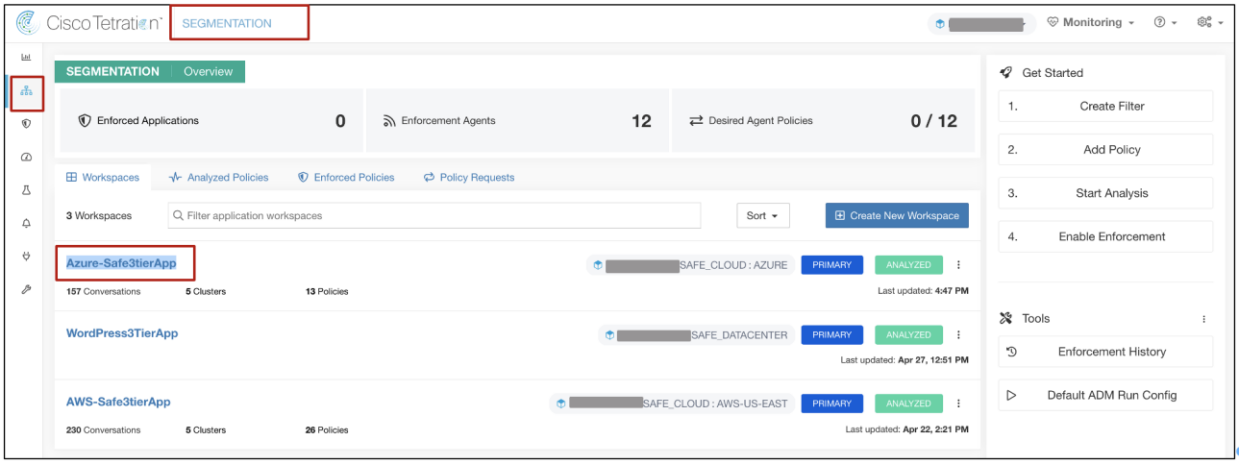


Step 2. **Define scopes –** We will define a scope to group together all the workloads in our tiered application in the Azure cloud. We will make use of the annotations/filters that we constructed in Step 1. We created the scope 'Azure-US-EAST', which includes all the workloads from our tiered app in 'US-East' region in Azure Cloud.

Click on the settings icon in the top right corner of the portal and then go to 'Scopes' option. Click on 'Create New Scope' and fill in the name of the Scope and a query as below.

Step 3. **Create a workspace -** Application workspaces are the containers for defining, analyzing and enforcing policies for a particular application. We will create a workspace for our tiered Azure cloud application in this step.

Click on 'Segmentation' and then click on 'Create New Workspace'. Give the workspace a name and select the Scope that we created in Step 2.



At this point, we have successfully built the inventory, created a scope and defined a workspace for our tiered cloud application.

Test case 2: Using ADM to discover the policies for Azure workloads and setting up an app view

This test case validates the use of 'ADM' to automatically discover the policies based on flow and other data received from workloads. We will refine the discovered workload clusters and update the inventory filters to eventually come up with a set of policies that can be enforced on our cloud workloads.

Validation procedure:

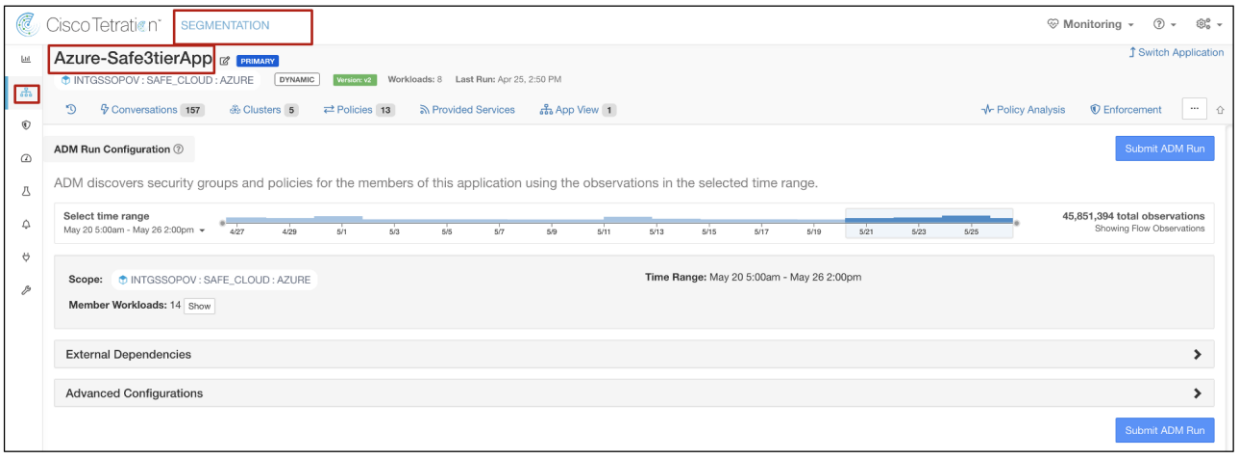
Step 1. **Discover policies using ADM**

Step 2. **Refine inventory filters, clusters and policies**

Step 3. **Create the App View**

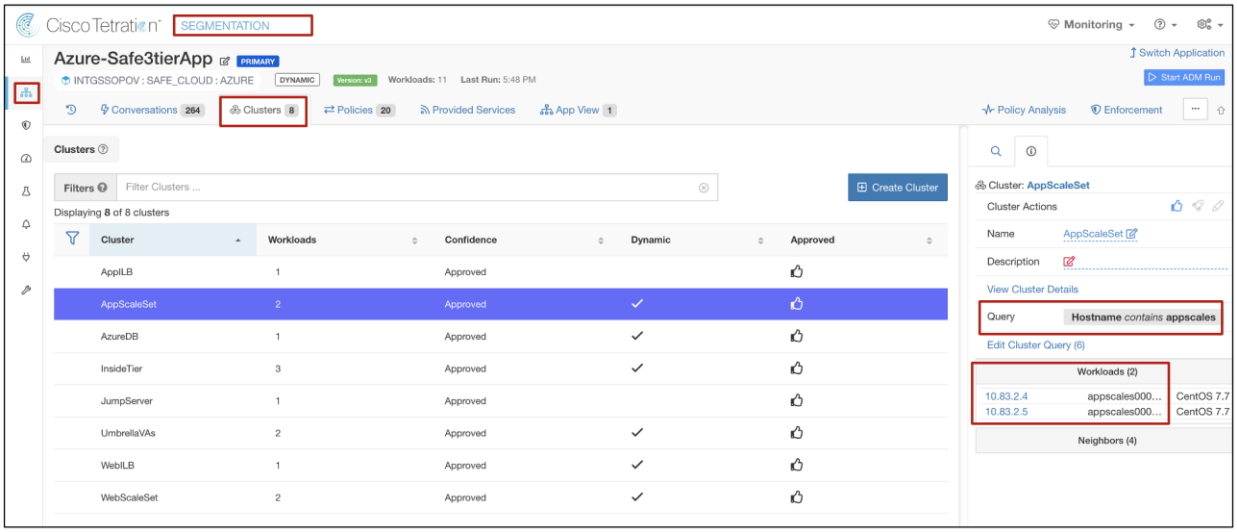
Step 1. **Discover policies using ADM -** Before running the ADM, ensure that all types of traffic flows are generated in the application environment. This would provide ADM the required data to generate an accurate policy set and hence ensure that we don't miss any critical but less common traffic flows.

Go to the newly created workspace and click on 'Start ADM Run' on the top right corner, select a suitable time range to ensure that you cover all the traffic flows.



Step 2. **Refine inventory filters, clusters and policies -** Post the ADM run, policies and clusters would be generated. At this point, we manually update and customize all the cluster queries and approve them.

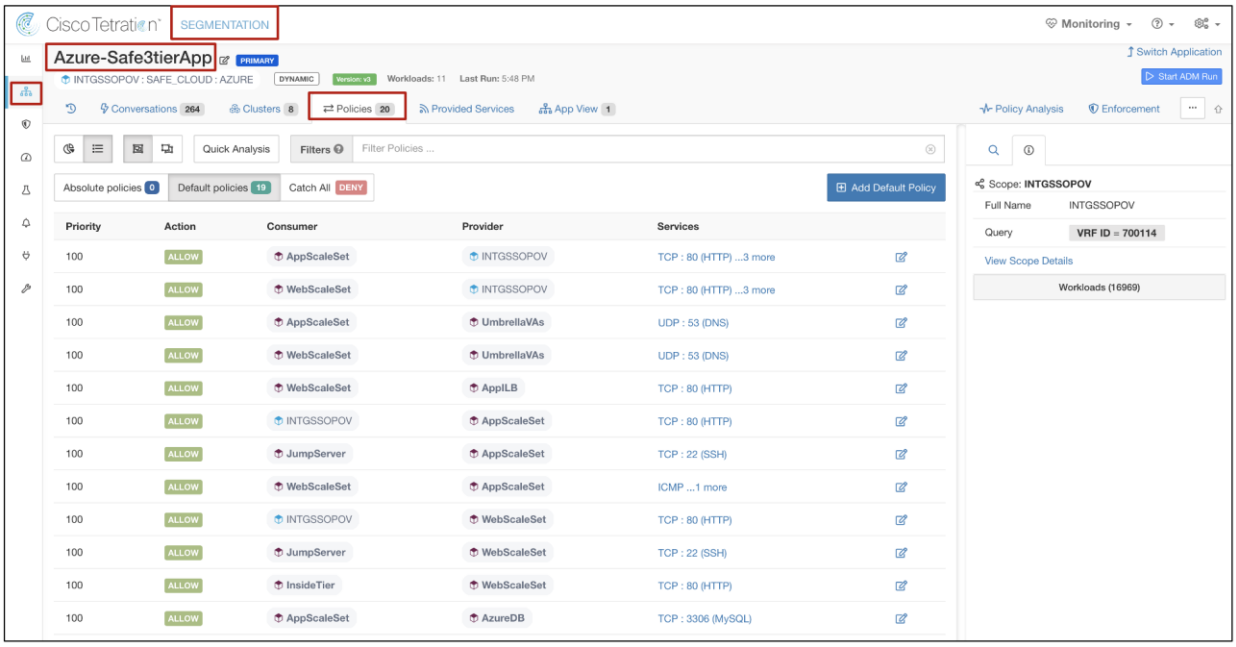
2.1: Go to 'Clusters' tab, click on any of the clusters, the panel on the right-hand side will show the cluster details like name, description, cluster query, workloads, neighbors. Update name and description to make it more intuitive, update the cluster query if need be. For example, we updated the cluster query for auto scaled workloads. We used previously defined annotation to dynamically identify the workloads in Virtual Machine Scale Sets like the web and application servers.



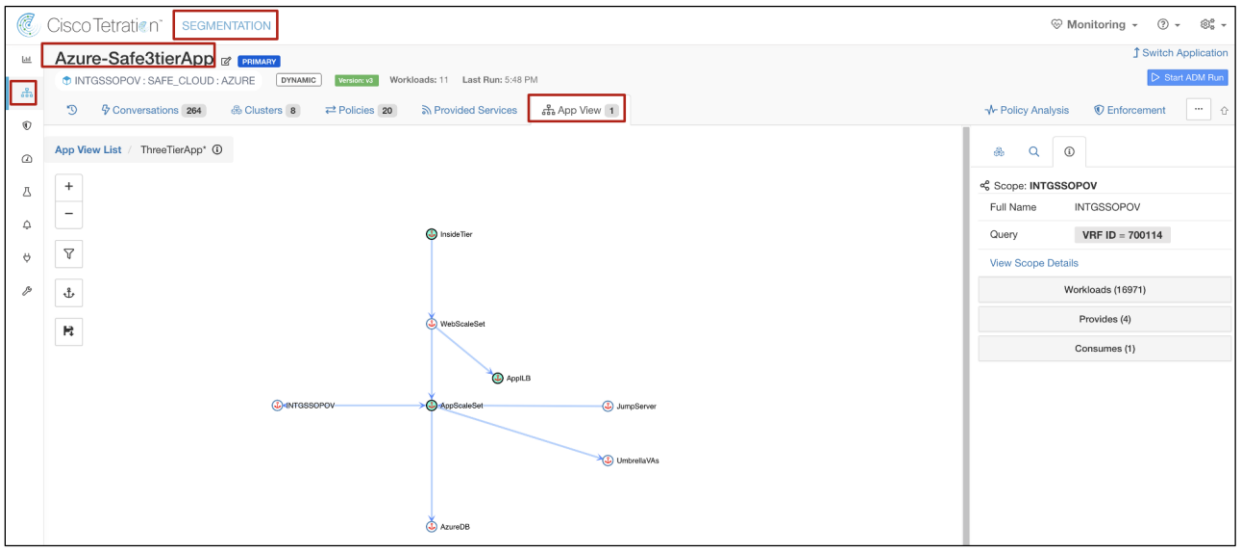
2.2: Click on 'Policies' tab, review the policies keeping the workload flows in mind. We considered the following flows for policies:

- User requests incoming to web workloads via firewall's inside interface
- Traffic between the workloads
  - Web servers to app load balancer
  - App load balancer to app servers
  - App servers to database
- Management tier to all the workloads

- Outbound internet access from all the workloads for updates/patches, DNS, DHCP, NTP



Step 3. **Create the App View –** Go to 'App view' tab and click on 'Create New App View'. Pin the workloads on the right-hand side panel to include them in your diagram. Double click on each pinned cluster on the view to automatically draw the traffic flows.



Test case 3: Enforcing the policies on workloads.

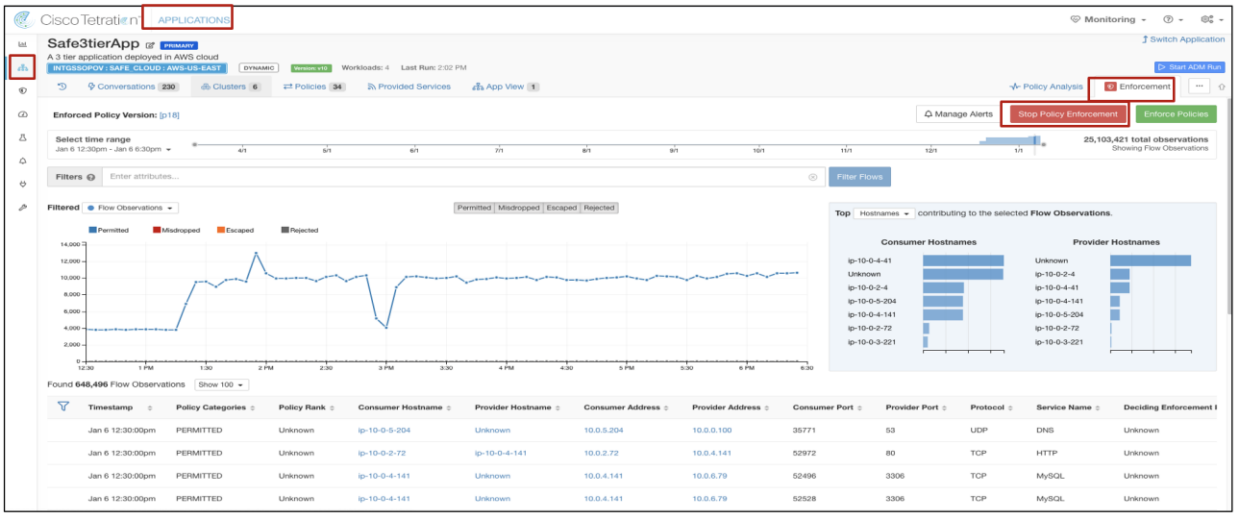
This test case focuses on enforcing the policy set that we formulated in Test Case 2. We will publish the policies and verify if those are enforced as expected.

Validation procedure:

Step 1. Publish the policies

Step 2. Verify policy enforcement on workloads

Step 1. **Publish the policies –** Select the ‘Enforcement’ tab on the Tetration portal within the application workspace and click on ‘Enforce Policies’.



Step 2. **Verify policy enforcement on workloads** – Since we had CentOS based workloads, we monitored the ‘/usr/local/tet/log/tet-enforcer.log’ to see if policies are successfully enforced. A simple ping or telnet test can also be used to verify the lockdown of ports and protocols.

```
I0107 04:25:25.275367   468 agent_controller.cpp:426] IPC is ready, start writing the message to IPC
I0107 04:25:25.275394   468 agent_controller.cpp:445] Done writing to shared memory
I0107 04:25:25.275499   471 agent_enforcer.cpp:813] Message from AgentController available, start processing

I0107 04:26:25.216424   468 ssl_client.cpp:410] Received message body length: 12


I0107 04:26:30.277519   468 ssl_client.cpp:510] Calling callback fn to process msg
I0107 04:26:30.277545   468 agent_controller.cpp:179] Start message processing from EFE
I0107 04:26:30.277563   468 agent_controller.cpp:222] Write the protobuf to AgentEnforcer
I0107 04:26:30.277696   472 agent_enforcer.cpp:966] Process EFE Message
I0107 04:27:05.342911   473 agent_enforcer.cpp:1283] Received Policy config version: 1545811665
I0107 04:27:05.344177   473 agent_enforcer.cpp:1392] Processing network policy config from EFE, version: 1545811665
I0107 04:27:05.344187   473 agent_enforcer.cpp:1396] Storing the policy and enforcing
I0107 04:27:05.344703   473 firewall_context.cpp:140] Policy has been validated, applying the policy
I0107 04:27:05.344712   473 firewall_context.cpp:169] Applying all firewall rules to the system firewall
I0107 04:27:05.714491   473 iptables_context.cpp:529] Staged rules have been committed
I0107 04:27:05.726775   473 agent_enforcer.cpp:1403] Policy config has been applied successfully, current version: 1545811665, highest version: 1545811665
```

Use the CLI command ‘ipset list’ to view the ipset firewall settings enforced by Tetration agent on the CentOS workloads.

```
Name: ta_520a2f879b4e9ab37a6e620e928b
Type: hash:net
Revision: 6
Header: family inet hashsize 1024 maxelem 65536
Size in memory: 504
References: 2
Number of entries: 2
Members:
10.0.3.196
10.0.2.57

Name: ta_58225b8365be52f7b49f8254d96e
Type: hash:net
Revision: 6
Header: family inet hashsize 1024 maxelem 65536
Size in memory: 440
References: 30
Number of entries: 1
Members:
10.0.2.16

Name: ta_9c21cc33b4bedbed655487444413
Type: hash:net
Revision: 6
Header: family inet hashsize 1024 maxelem 65536
Size in memory: 504
References: 6
Number of entries: 2
Members:
10.0.5.129
10.0.4.89

Name: ta_bdfa4e36735d84cc7cc983454a94
Type: hash:net
Revision: 6
Header: family inet hashsize 1024 maxelem 65536
Size in memory: 504
References: 8
Number of entries: 2
Members:
10.0.9.253
10.0.8.179
```

Test case 4: Discovering the vulnerable packages on the Azure workloads.

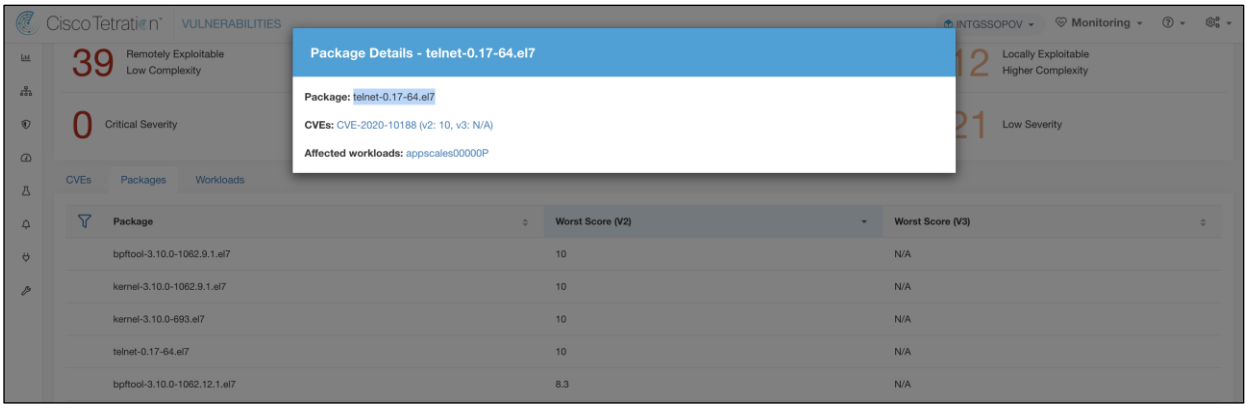
This test case looks for vulnerable packages/software installed on various workloads in our Azure cloud. We identify a vulnerable package/software on our workloads, patch those and then rerun the report.

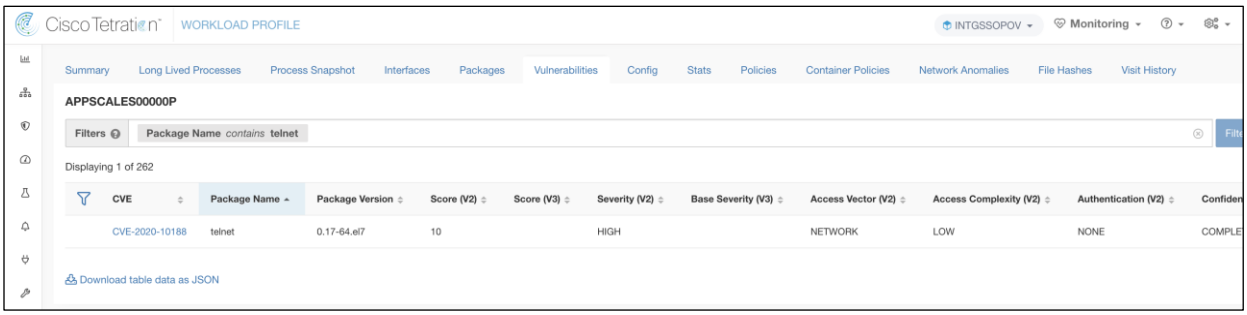
Validation procedure:

Step 1. **Check the vulnerability report**

Step 2. **Fix a vulnerability and rerun the report**

Step 1. **Check the vulnerability report** – Go to 'Security > Vulnerabilities', click on 'Packages' tab to see all the vulnerable packages installed on various workloads in our three-tier application. For the sake of this test, let's consider 'telnet-0.17-64.el7' as shown below.





We see that the workload 'appscales00000P' is affected by this CVE. Logon to this workload and verify the telnet package.

```
[centos@appscales00000P ~]$
[centos@appscales00000P ~]$ rpm -qa | grep telnet
telnet-0.17-64.el7.x86_64
[centos@appscales00000P ~]$
[centos@appscales00000P ~]$
```

Step 2. **Fix the vulnerability and rerun the report –** We uninstall the telnet package from this workload.

Wait for a few minutes after the uninstall, go back to Tetration portal and check the vulnerability report again. We can see that none of the CVEs related to Telnet show up anymore.

Advanced Malware Protection for Endpoints

Test Case: Quarantine a suspicious file

This test case involves the detection of using AMP for endpoint 'simple custom detections' to quarantine a suspicious PDF file.

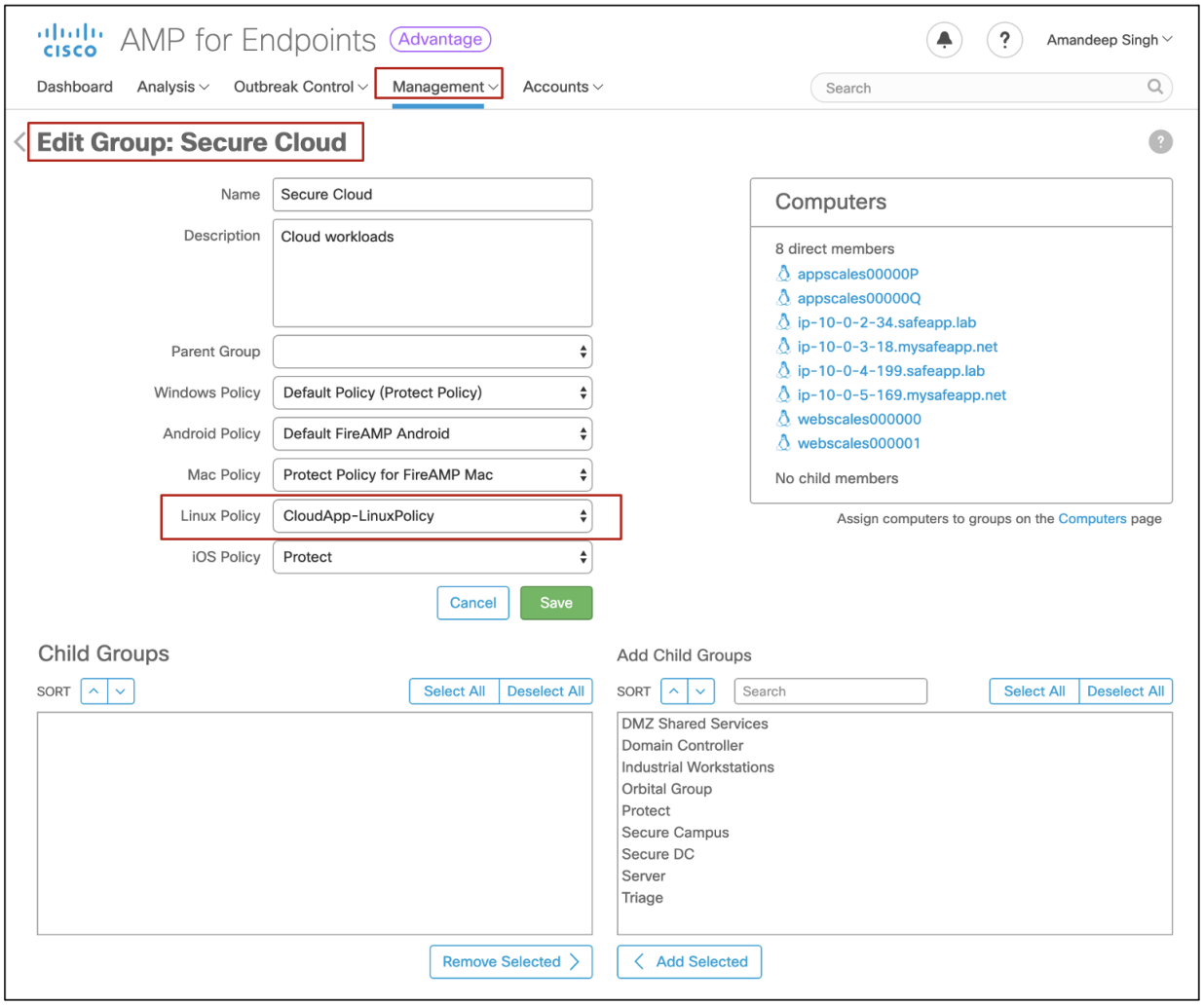
Validation procedure:

Step 1. **Setting up AMP4E policy to quarantine a suspicious file**

Step 2. **Verifying the deletion of a suspicious file**

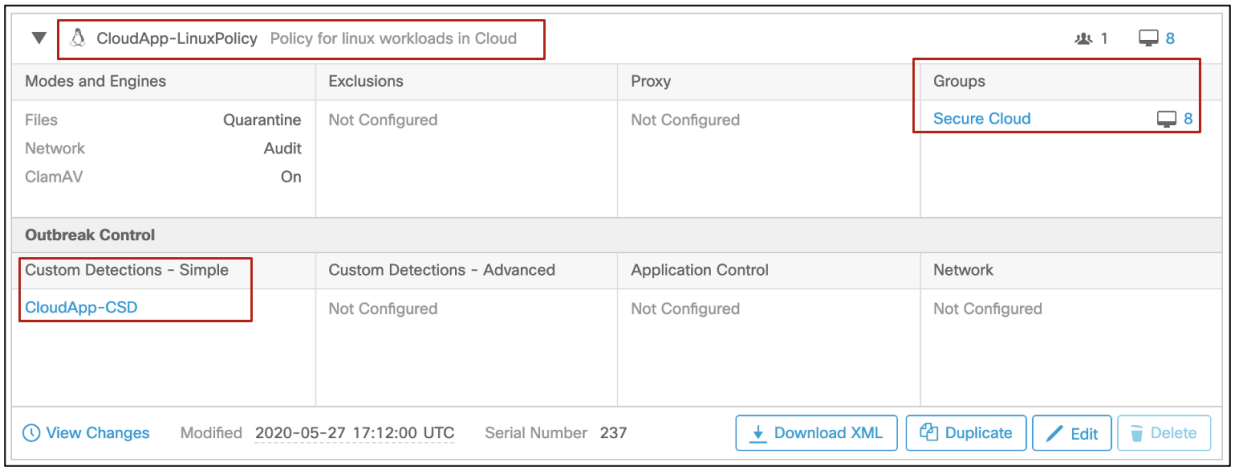
Step 1. **Setting up AMP4E policy to quarantine a suspicious file –** For the validation purpose, we consider a 1 MB PDF file that we will block list using AMP 'Simple Custom Detections'. We will then try to download the same PDF file on a cloud workload and assert that our policy works as expected.

As per our initial AMP4E set up, we had configured the group 'Secure Cloud' (Management > Groups) for our workloads in the Azure cloud.



Note: During our implementation phase we had used the AMP4E agent tied to this specific group 'Secure Cloud', which we had created as part of the initial AMP4E set up (not elaborated in this guide, follow AMP4E documentation for detailed steps on setting up AMP4E policies). All the workloads in Azure VNET register with AMP Cloud under this specific group.

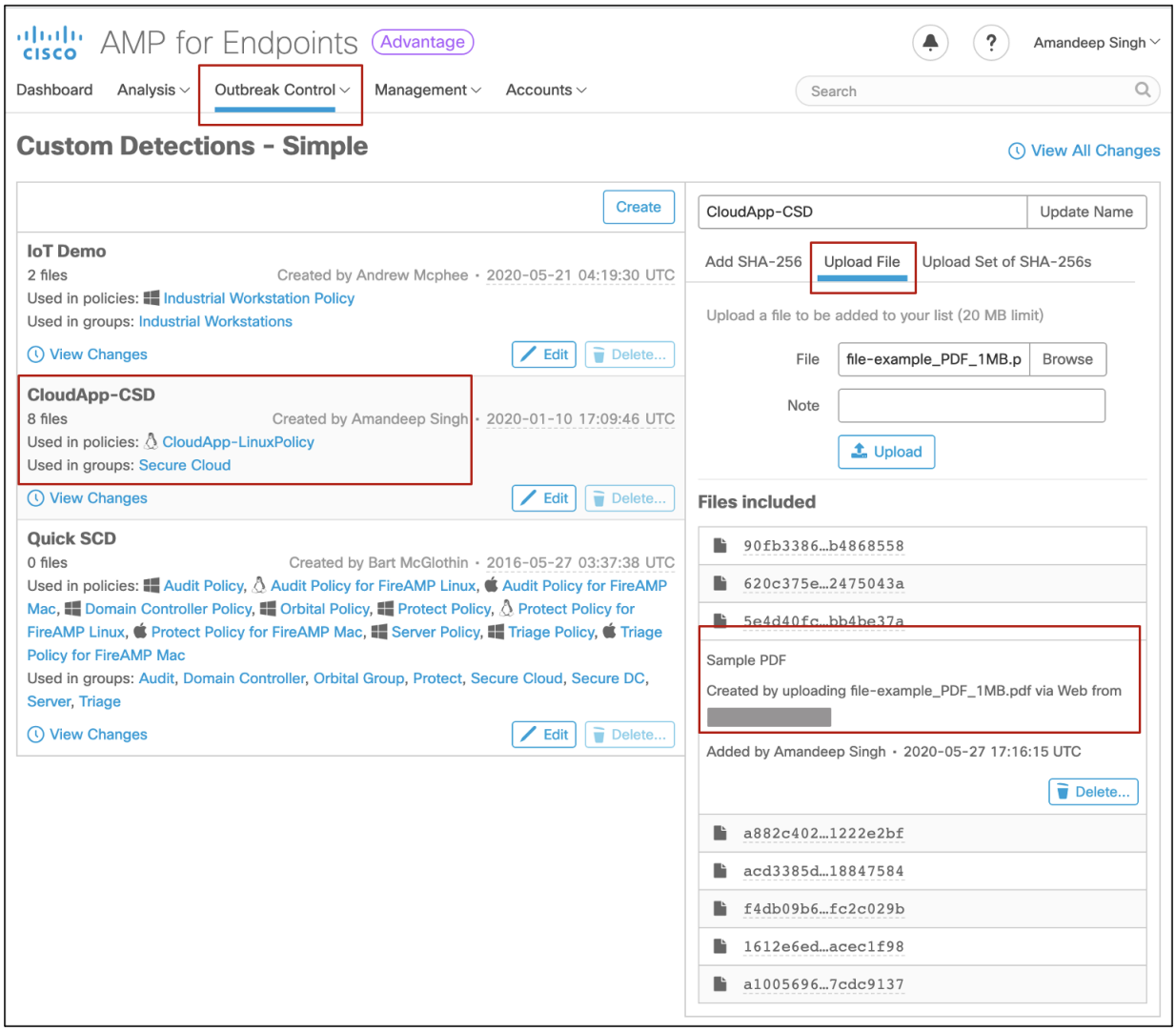
It can be seen in the snapshot above that we tied the specific group to Linux policy 'CloudApp-LinuxPolicy'. Go to 'Management > Policies' and select the specific Linux policy.



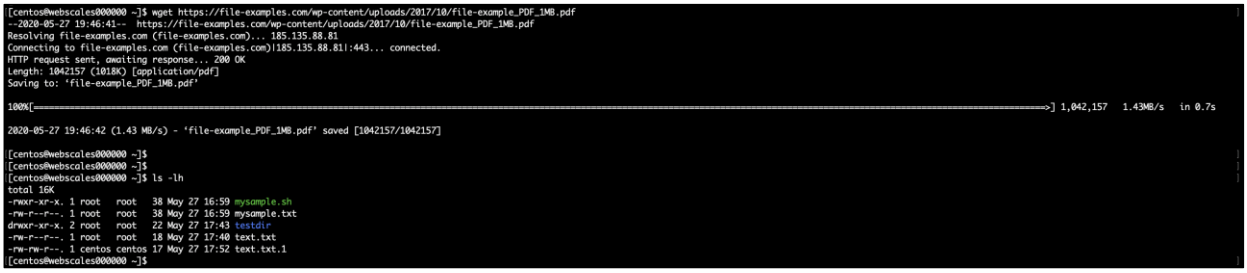
Note: We had preconfigured the Linux policy associated with AMP4E group 'Secure Cloud'. We also tied a new Simple Custom Detection 'CloudApp-CSD' to the Linux policy. If there was no initial config on AMP console, then you would see default policies here.

As we see in the snapshot, the Linux policy above is tied to Simple Custom Detections 'CloudApp-CSD' (Outbreak Control > Simple).

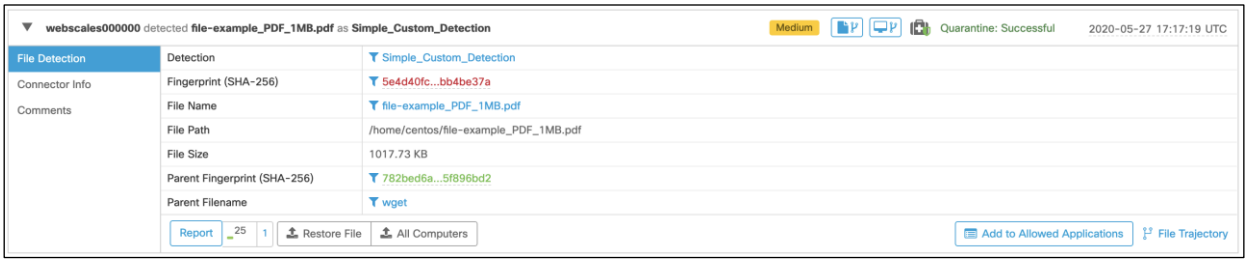
Go to 'Outbreak Control > Simple Custom Detections' and click on edit 'CloudApp-CSD' to upload the PDF file that we want to block list in the Azure cloud environment. Uploading the PDF file will add the SHA value to the SCD policy and quarantines the file associated with it from all the cloud workloads registered under the specific group.



Step 2. **Verify the deletion of the suspicious program –** Log on to a cloud workload, we picked one of the web servers in web VSS. We downloaded the PDF file that we block listed above. We can see that the file is immediately quarantined by the AMP agent on the workload.



We also confirm the quarantine event from the event logs on the AMP Cloud portal. Log on to the AMP Cloud portal and go to 'Analysis > Event', we see a 'Quarantine successful' event post our steps above.



Stealthwatch Cloud

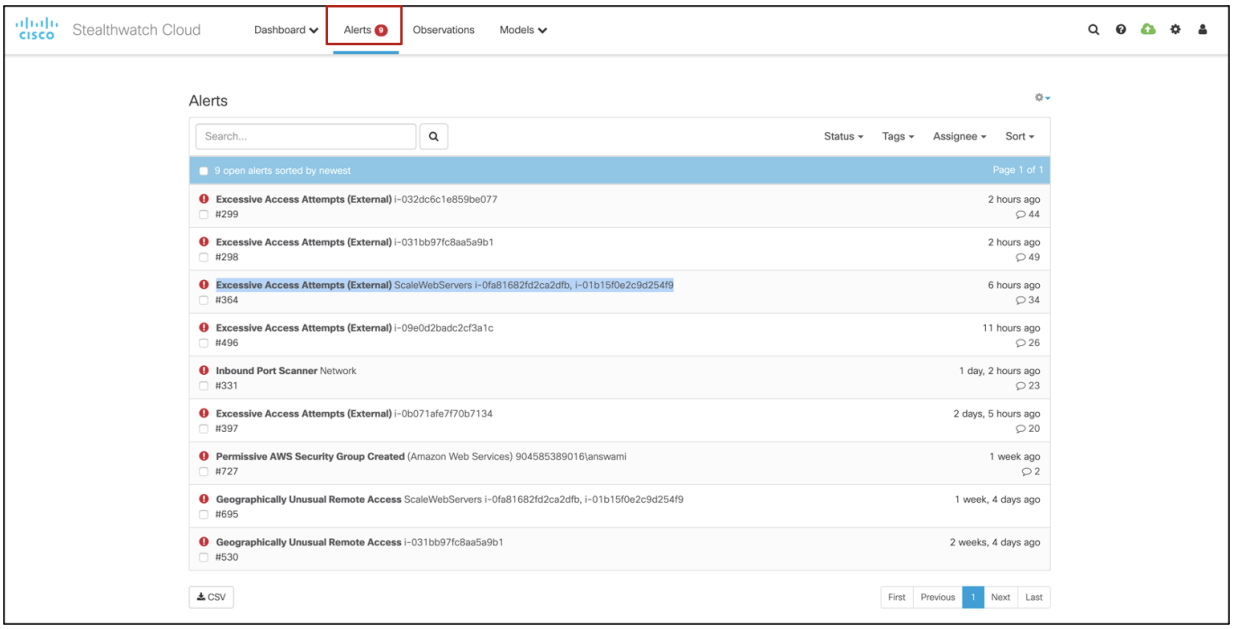
Test Case: Monitor suspicious activity

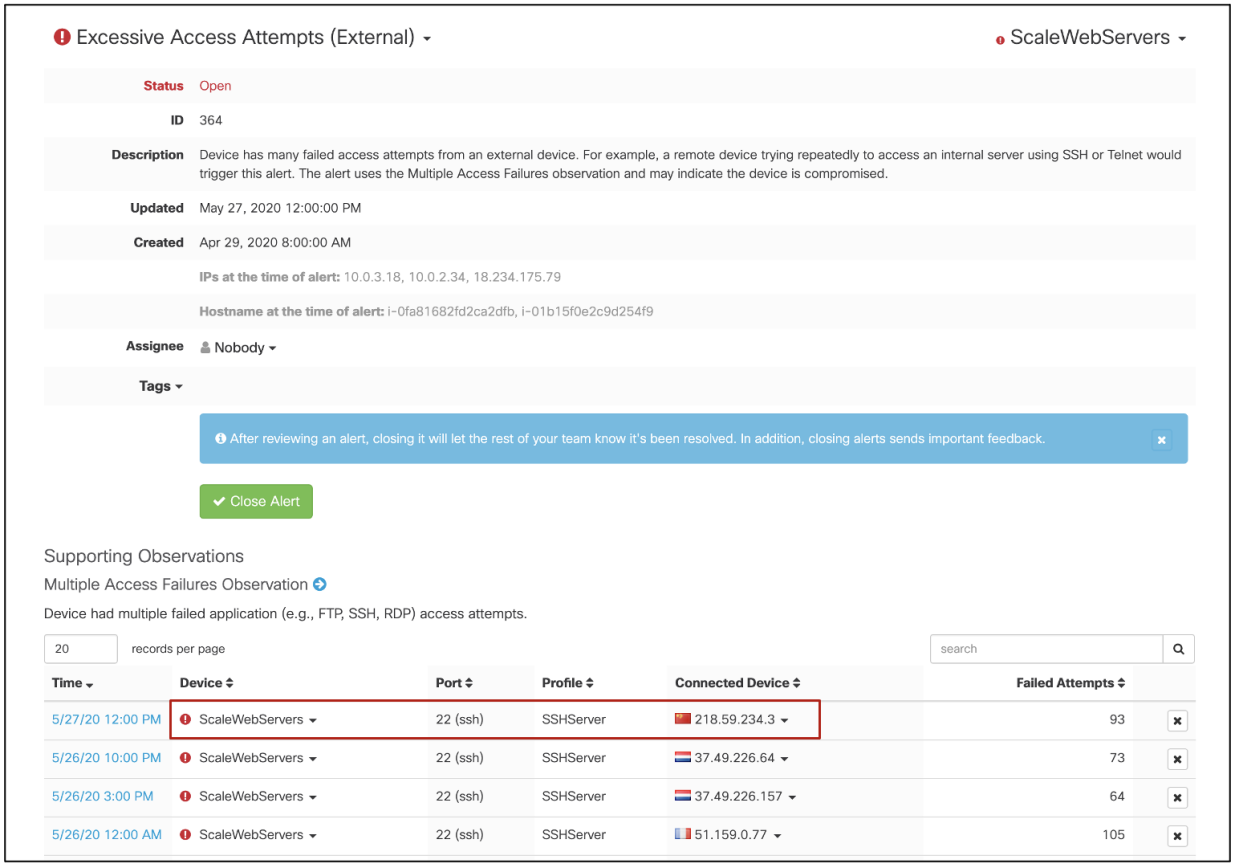
This test case involves using the Stealthwatch cloud to monitor the activity within the Azure cloud environment.

Validation procedure:

Step 1. **Monitor suspicious activity in Stealthwatch Cloud**

Step 1. **Monitor suspicious activity in Stealthwatch Cloud** – Login to the Stealthwatch cloud portal. Go to 'alerts', we see the alert 'Excessive Access Attempts' as shown below. This alert indicated that there were numerous attempts to get SSH access from an unexpected geo location, which is a suspicious behavior.





Cisco Umbrella

Test Case: DNS security

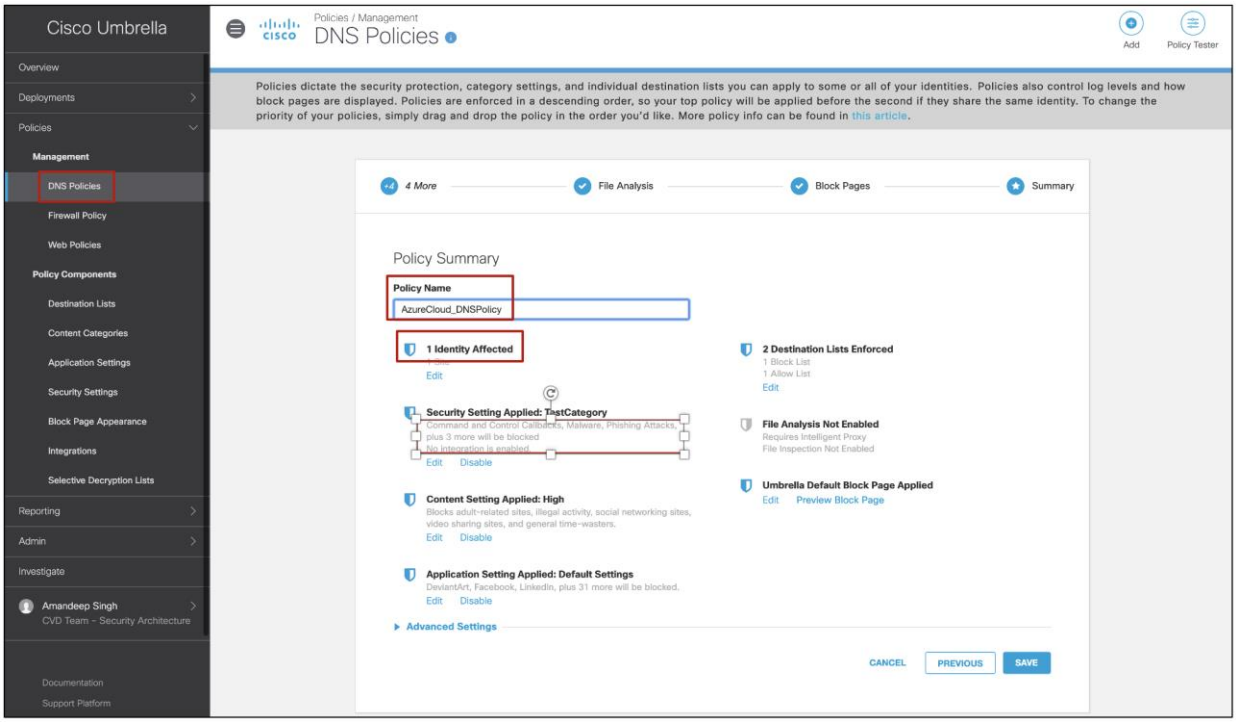
This test case involves adding DNS layer security to the Azure workloads. We created a DNS policy for our three-tier application workloads to block malicious domains. To verify the blocks, we accessed a test domain 'examplemalwaredomain.com' and then confirmed the same from Umbrella reporting.

Validation procedure:

Step 1. **Set up DNS policy for Azure workloads**

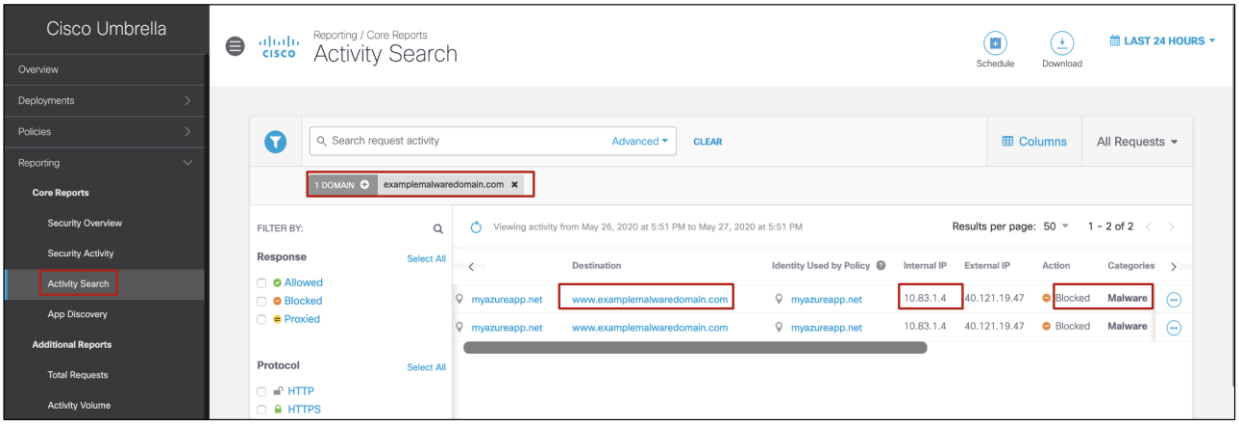
Step 2. **Confirm if malware domain is blocked**

Step 1. **Set up DNS policy for Azure workloads –** Go to 'Policies > Management > DNS Policies', add a new policy and make sure 'Malware' is set to block under security settings. Save the change.



Step 2. **Confirm if malware domain is blocked –** Run 'nslookup' on a test malware domain as shown in snapshot below. Utility returns Umbrella block page IP address as below.

To further confirm the block action, select 'Reporting > Activity Search' and filter the accessed malware domain. Events show the action as 'Blocked'.



Cisco Firepower NGFWv and CDO

Test Case: Enforce an access policy using CDO

In this test case, we will try to lock down the outbound access for our cloud workloads for specific TCP ports. We will use CDO to manage the FTDs we deployed in our Azure cloud. We already onboarded the FTDs to the CDO in the implementation section of this document.

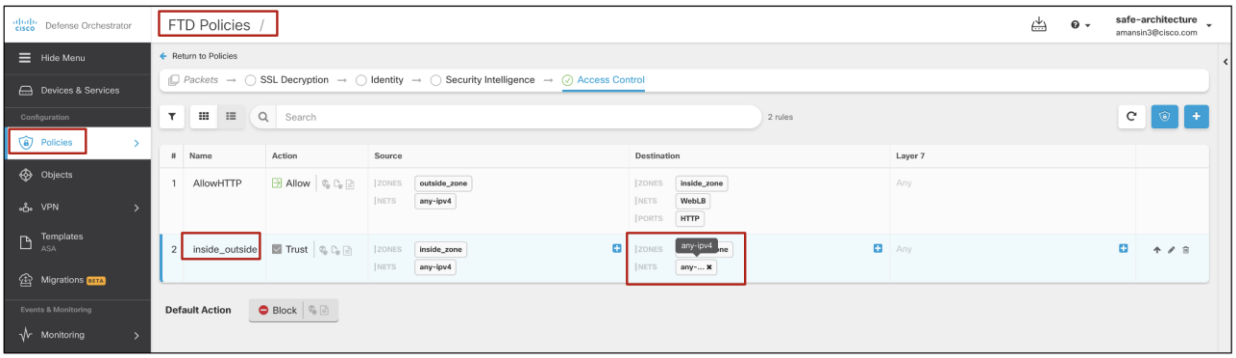
Validation procedure:

Step 1. **Configure and enforce the access policy**

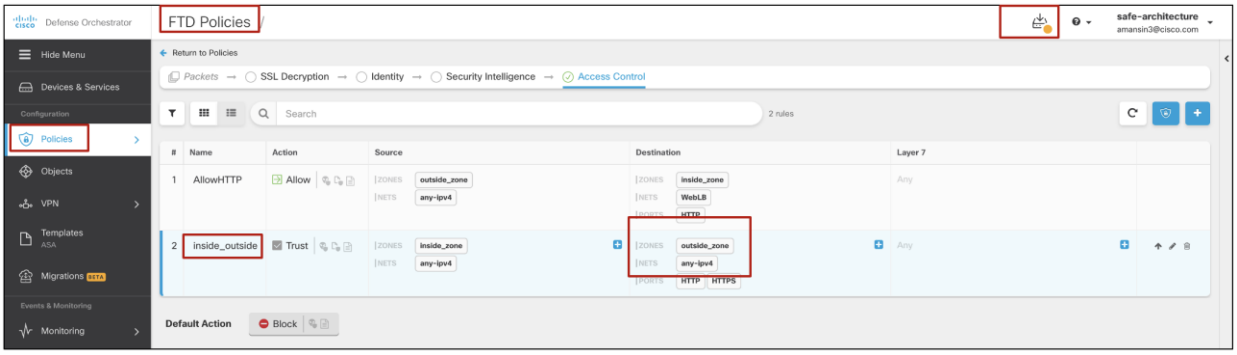
Step 2. **Verify the access block**

Step 1. **Configure and enforce the access policy –** We log on to a web server workload and try to access a non-standard TCP port on a server on the Internet. We can see in the snapshot below that the web server workload is able to connect at this point.

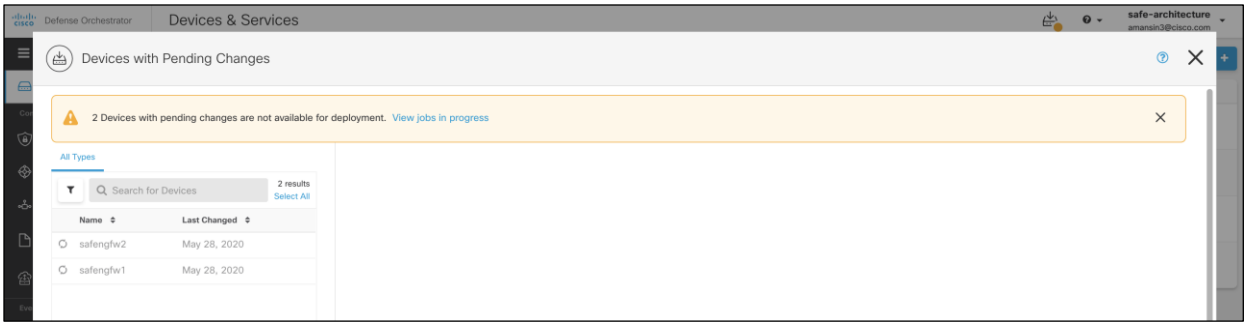
We want to block outbound access to such random TCP ports from our cloud workloads. Log on to the CDO portal and go to 'Policies > FTD policies' and select the policies corresponding to our Azure FTDs. We can see that the 'inside_outside' policy allows the cloud workloads to access any destination on any port on the Internet.



We update the policy to lock it down to just the HTTP and HTTPS ports going out to the internet.



After making the policy change, click on the notification on the top right-hand side of the portal to push the changes to the specific FTD devices.



Step 2. **Verify the access block -** Now that we have updated the policy, we will try and attempt to verify the access. We SSH to a web server again and try to access websites on a random TCP port 666. We can see the connection timing out or getting blocked now. We can also see that an outbound access to a server on the internet on standard HTTP and HTTPS is still allowed.

Likewise, we can leverage the FTDs for network IPS and AMP capabilities.

Web Application Firewalls and DDoS Protection

Azure WAF and DDoS

Test Case: Monitor Web and DDoS activity on Azure cloud

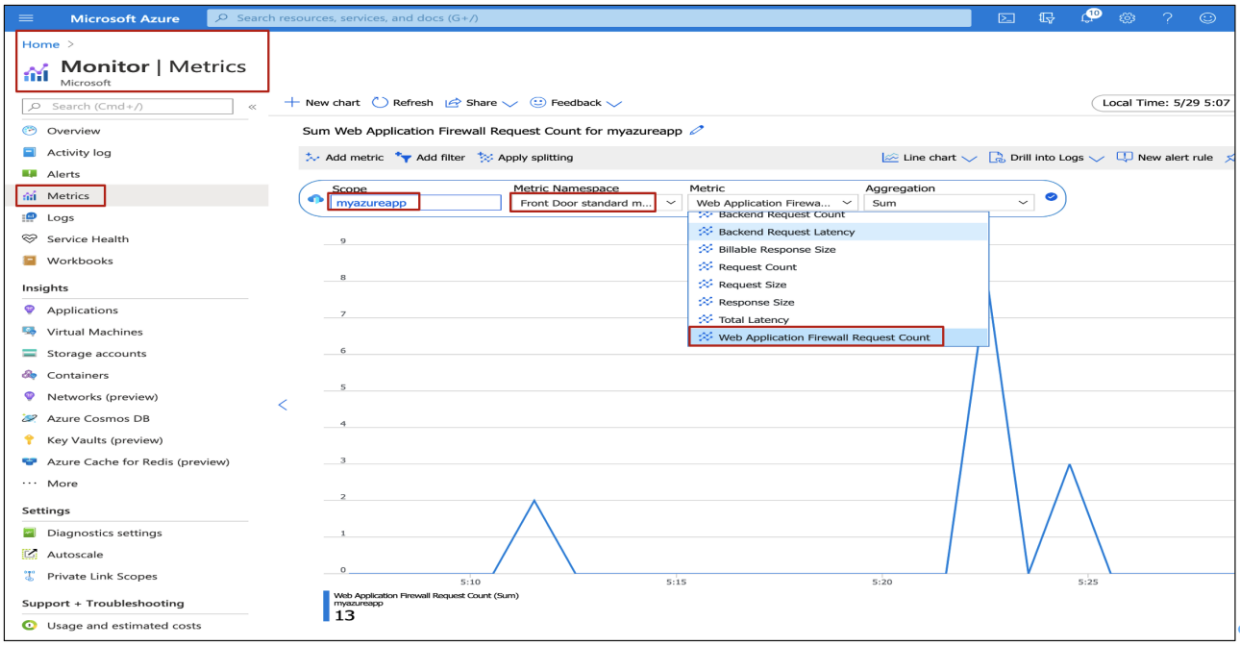
This test case involves monitoring the security events generated by the Azure cloud native WAF and DDoS service. For monitoring WAF and DDoS activity, you can either look at the Azure Metrics or do a deep dive using Azure log analytics. We will cover both the methods for each service.

Validation procedure:

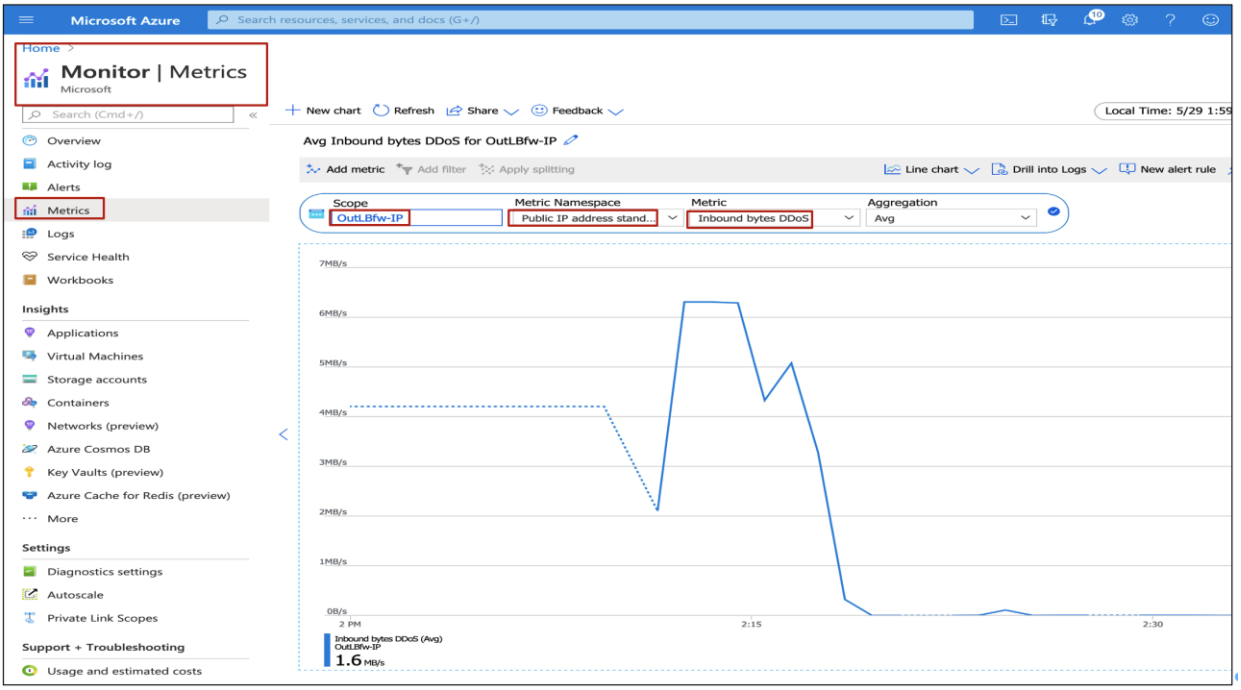
Step 1. **Monitor WAF and DDoS metrics on Azure cloud**

Step 2. **Analyzing WAF and DDoS logs on Azure cloud**

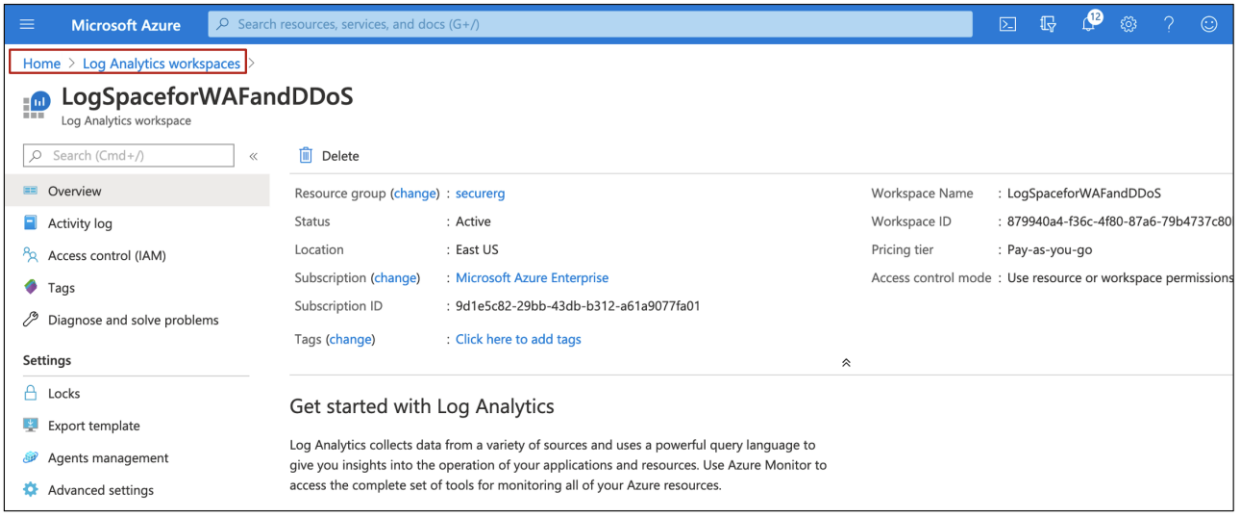
Step 1. **Monitor WAF and DDoS metrics on Azure cloud -** Go to 'Monitor' service on the Azure portal and select metrics option on the left-hand side panel. You will be prompted to select the Scope or the service that you want to look metrics for. For viewing the metrics associated with WAF, select Azure Front Doors service that we created earlier, and then select 'Web Application Firewall Request Count' from the drop-down under 'Metrics' option, and it will allow you to plot the WAF statistics.



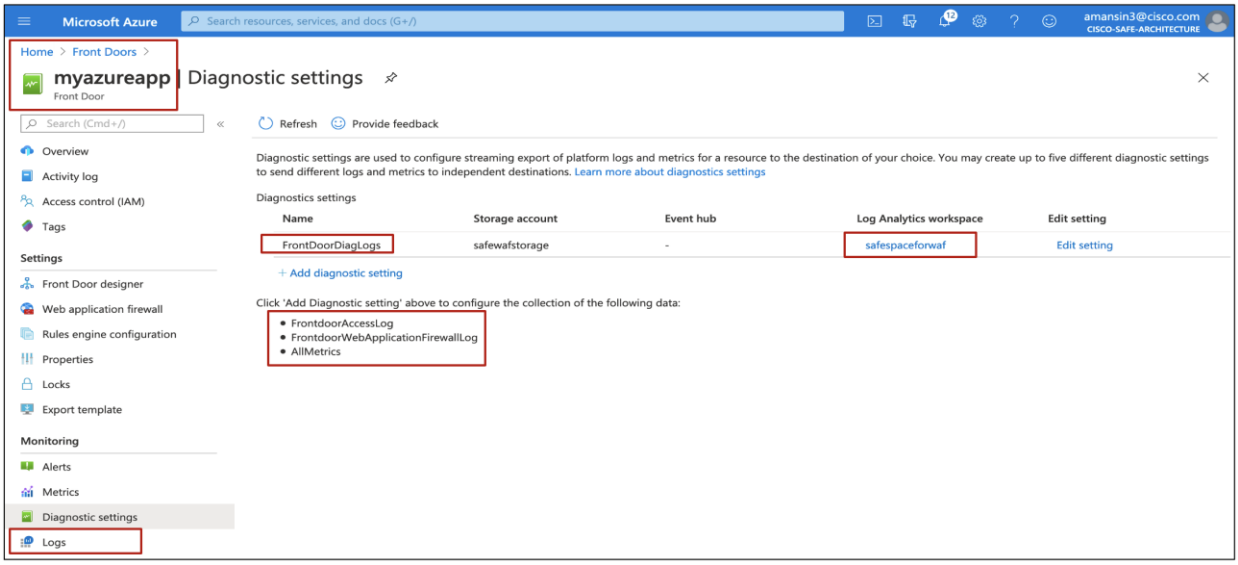
In a similar manner, you can select the Public IP of the outside NGFW interfaces under Scope and plot all the DDoS related metrics.



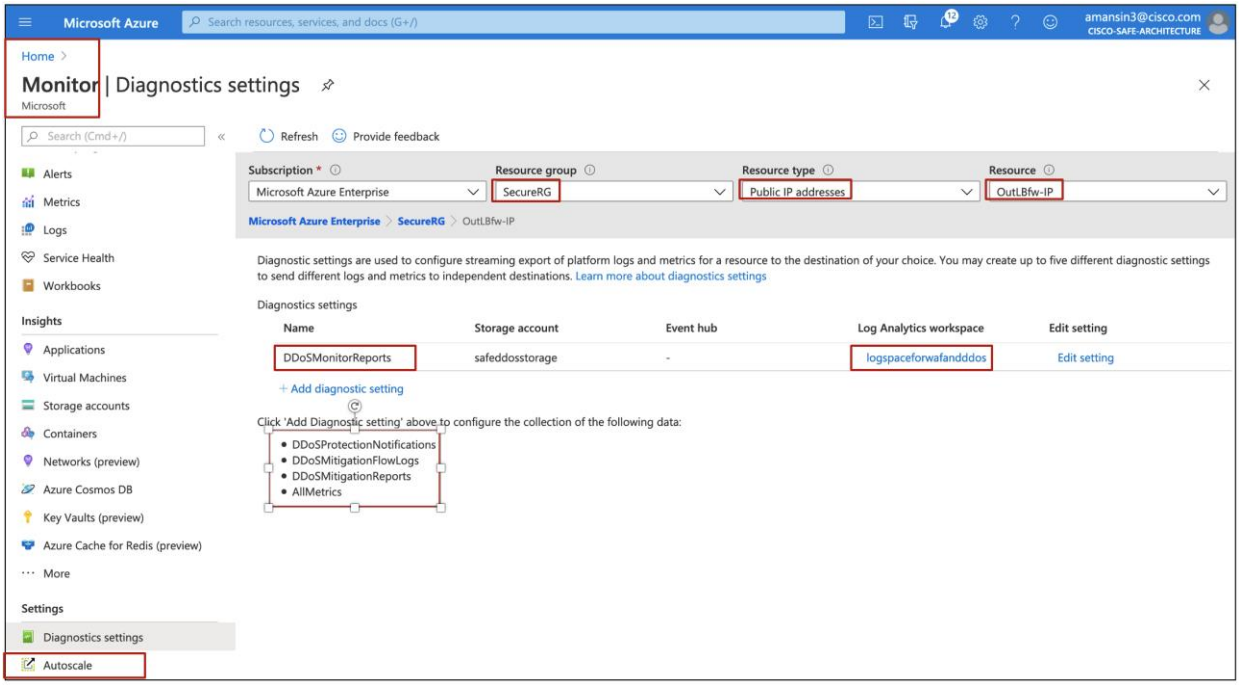
Step 2. **Analyzing WAF and DDoS logs on Azure cloud** – Now, we want to dive deeper into the logs, go to 'Log Analytics workspaces' and create a workspace for WAF and DDoS services.



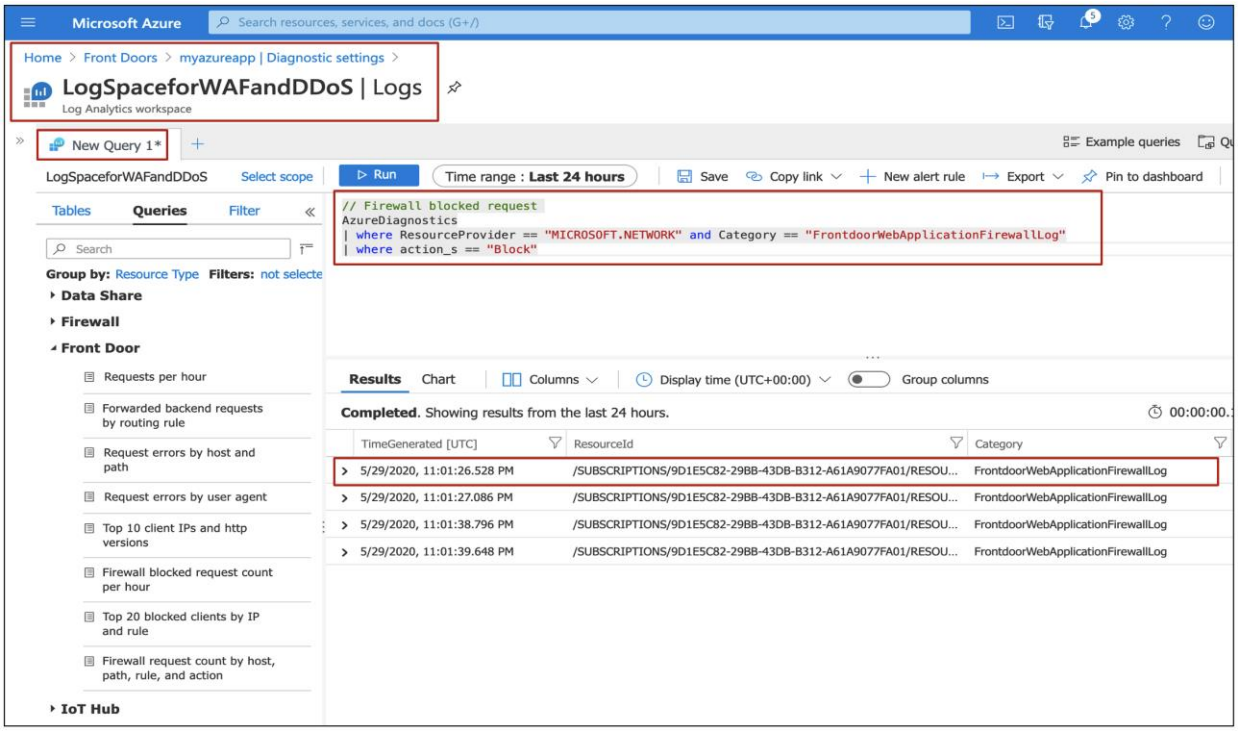
Go to 'Azure Front Doors' service that we created earlier and select 'Diagnostics Settings' from the panel on the left-hand. Click on '+ Add Diagnostic setting' to add a log subscription to the log analytics space we created above. Make sure you include 'FrontdoorAccessLog' and 'FrontdoorWebApplicationFirewallLog' to the diagnostic settings.



Now, go to 'Azure Monitor' service and select the 'Diagnostics Settings' on the left-hand side of the panel. Select the Public IP addresses of the NGFWv from the available selection panel and then click on '+ Add Diagnostic setting' to add a log subscription to the log analytics space we created above. Make sure you include 'DDoSProtectionNotification', 'DDoSMitigationFlowlogs', 'DDoSMitigationReports' in the diagnostic settings.



At this point we have added both the required logs for WAF and DDoS service to our log analytics space. Now, we can run queries to look for any events related to WAF block or DDoS for a deep dive and plot custom charts and dashboards based on these queries.



Radware Cloud WAF and DDoS

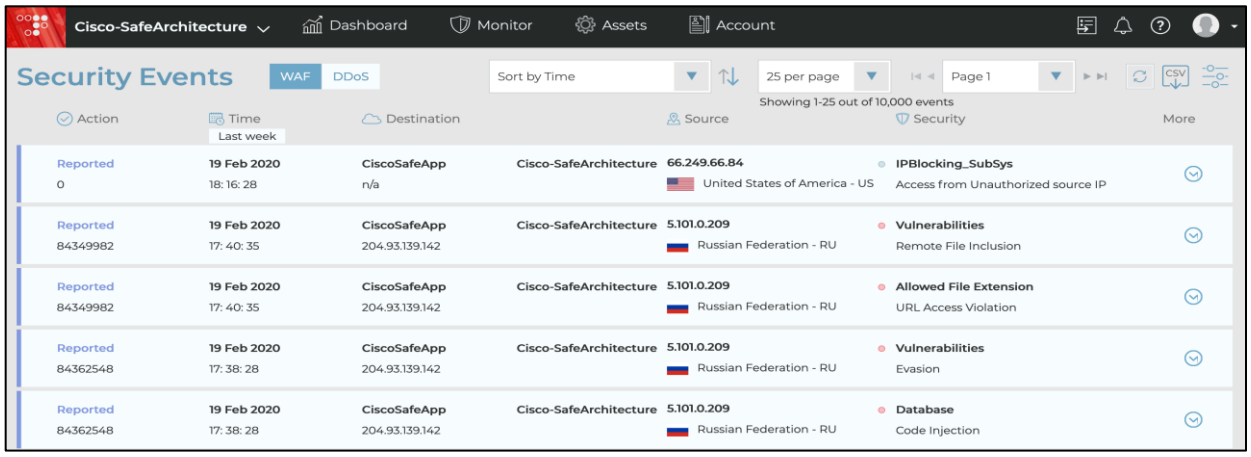
Test Case: Monitor Web and DDoS activity on Radware cloud

This test case involves monitoring the security events generated in the Radware cloud portal.

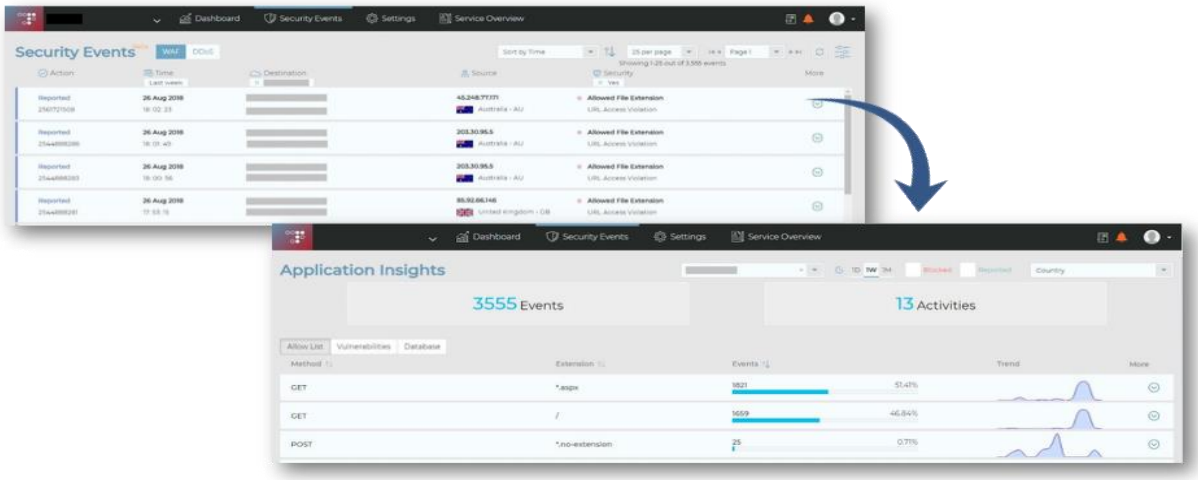
Validation procedure:

Step 1. Monitor Web and DDoS activity on Radware cloud WAF and DDoS Portal.

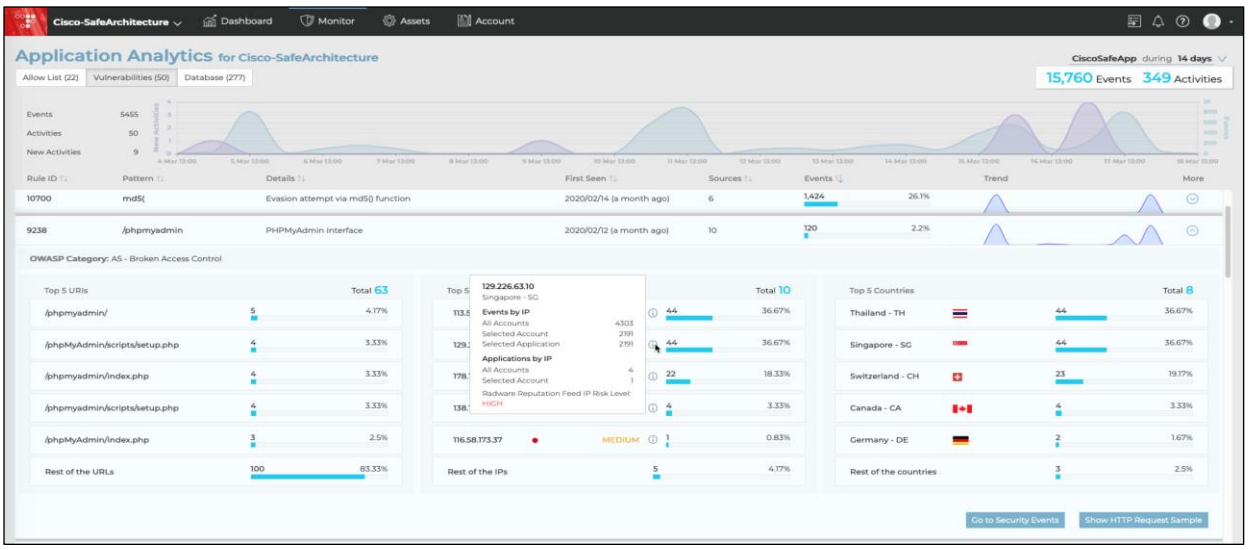
Step 1. Monitor Web activity and DDoS activity on Radware cloud – On the Radware Cloud portal, go to 'Monitor > Security Events' to see all the WAF and DDOS events generated from any malicious activity targeting your application.

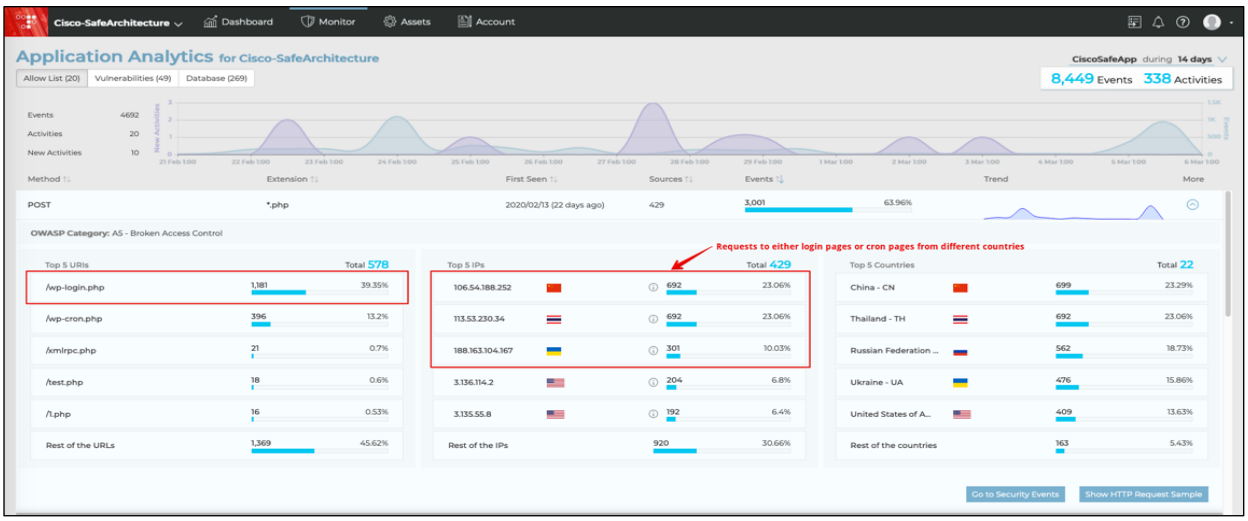


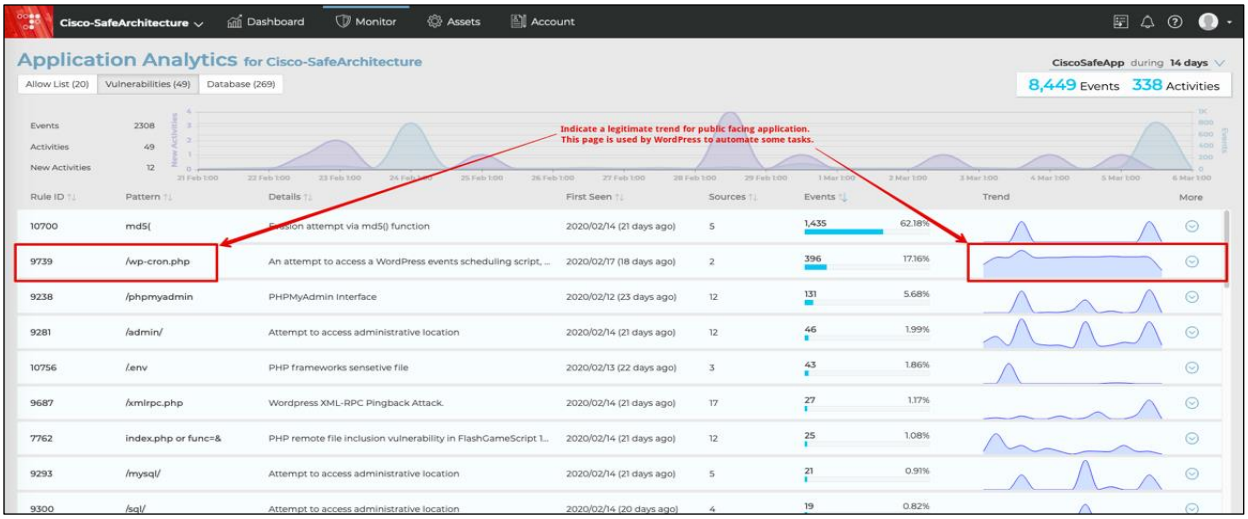
Radware's Application Analytics combines a large number of similar events and consolidating them into small, manageable sets of recurring activities. This helps to streamline response by providing additional context to security events needing attention.



In addition, the integrated ERT Active Attacker Feed will help you identify if listed requests are legitimate or not by identifying known attackers. As Illustrated below, we are able to gain intelligence if the IP's attempting to access the phpMyAdmin pages are from known malicious IPs (with risk level assessments).







Duo Beyond

Validation procedure overview:

- Test Case 1 – Set up the cloud application for Two-Factor Authentication (2FA)
- Test Case 2 – Monitor 2FA activity from Duo admin portal

Test Case 1: Set up the cloud application for Two-Factor Authentication (2FA)

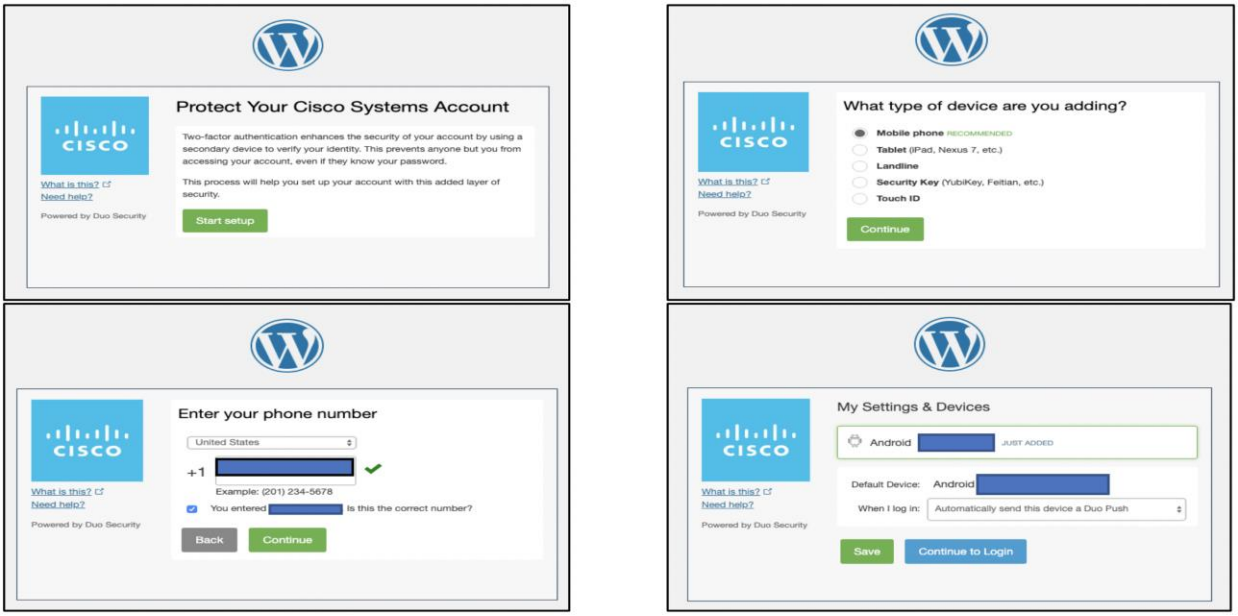
This test case involves logging into the application for the first time and activating the duo plugin. Previously, during the implementation phase, we had already downloaded the plugin to application workloads using custom scripts (Azure VM Extensions). Follow the Duo documentation (skip step 2 under 'Install and Configure the Plugin') to activate WordPress Duo plugin. After activating the plugin, log out and log in again. This time Duo will prompt the user to enroll their phone for 2FA. After successful enrollment, user gets the ability to approve subsequent login attempts.

Validation procedure:

Step 1. **Set up Duo 2FA for a new user**

Step 2. **Log onto the cloud application**

Step 1. **Set up Duo 2FA for a new user –** After the initial plugin activation, the Duo MFA kicks in and since this is the first authentication attempt, the user is prompted to enroll for MFA.



Step 2. **Log onto the cloud application –** After the enrollment, we continue to log onto the application, this time the user is presented with Duo authentication methods instead of 'setup'. Once the user approves the authentication request, they are allowed to login.

Test Case 2: Monitor 2FA activity from Duo admin portal

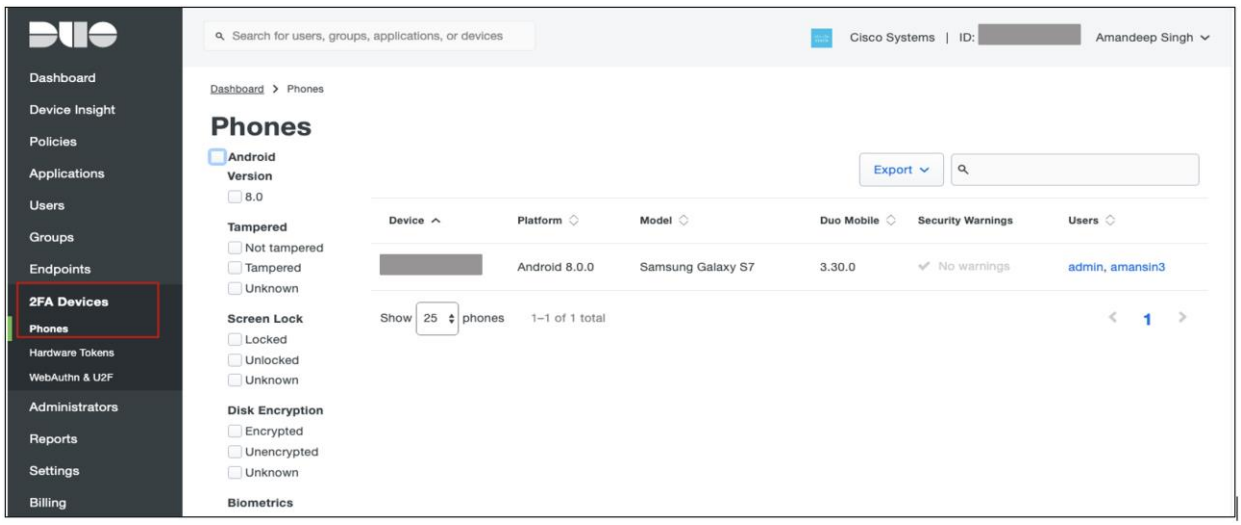
This test case involves monitoring the 2FA enrollment and login activity in the Duo admin portal.

Validation procedure:

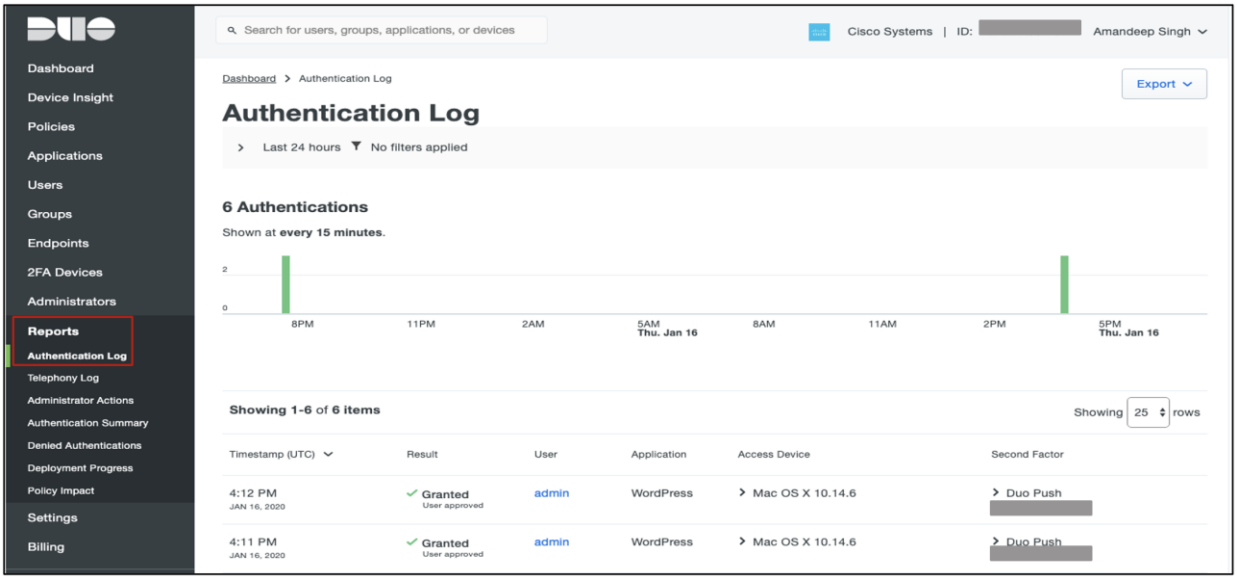
Step 1. **Verify the 2FA enrolled devices**

Step 2. **Track the user logins in authentication logs**

Step 1. **Verify the 2FA enrolled devices -** Logon to the Duo admin portal and select '2FA Devices', the portal shows the list of enrolled devices along with other details like platform, hardware model and usernames.



Step 2. **Track the user logins in authentication logs –** Go to 'Dashboard > Authentication log', to track user 2FA login activity as shown in the snapshot below.



Cisco SecureX Threat Response

Test Case: Track malicious Activity on threat response

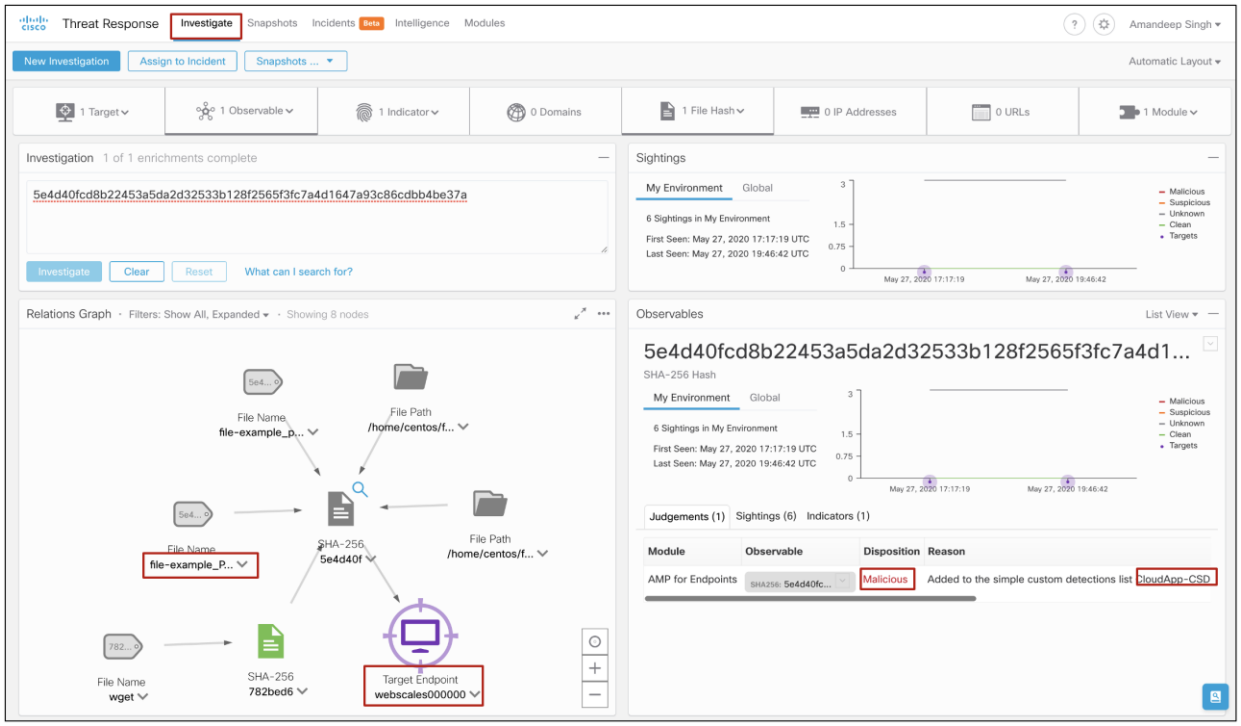
In this test case, we track the life cycle of the malicious PDF that we quarantined using AMP4E in previous steps. We will use the same SHA value and see what threat response offers in terms of visibility in our environment.

Implementation procedure:

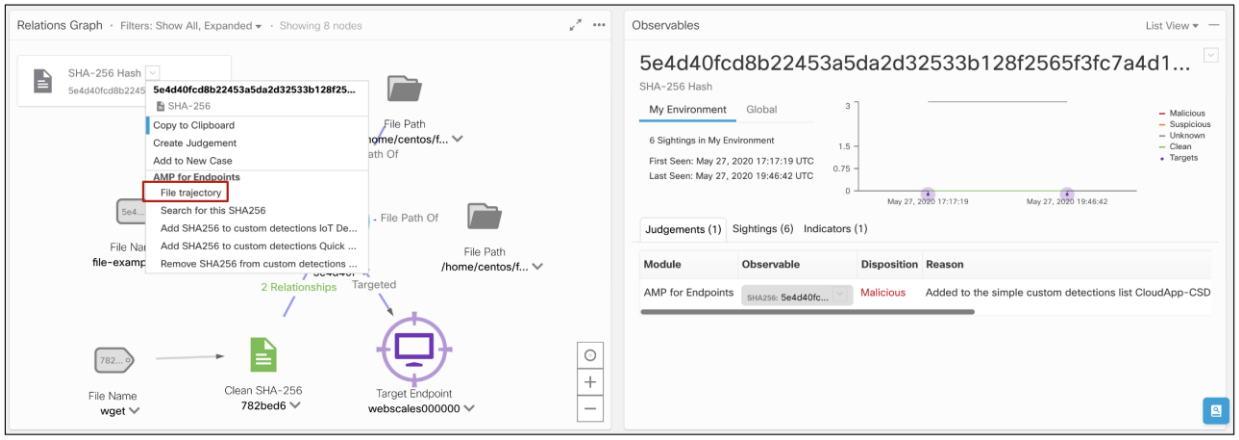
Step 1. **Investigate a malicious SHA value**

Step 2. **Track the file trajectory**

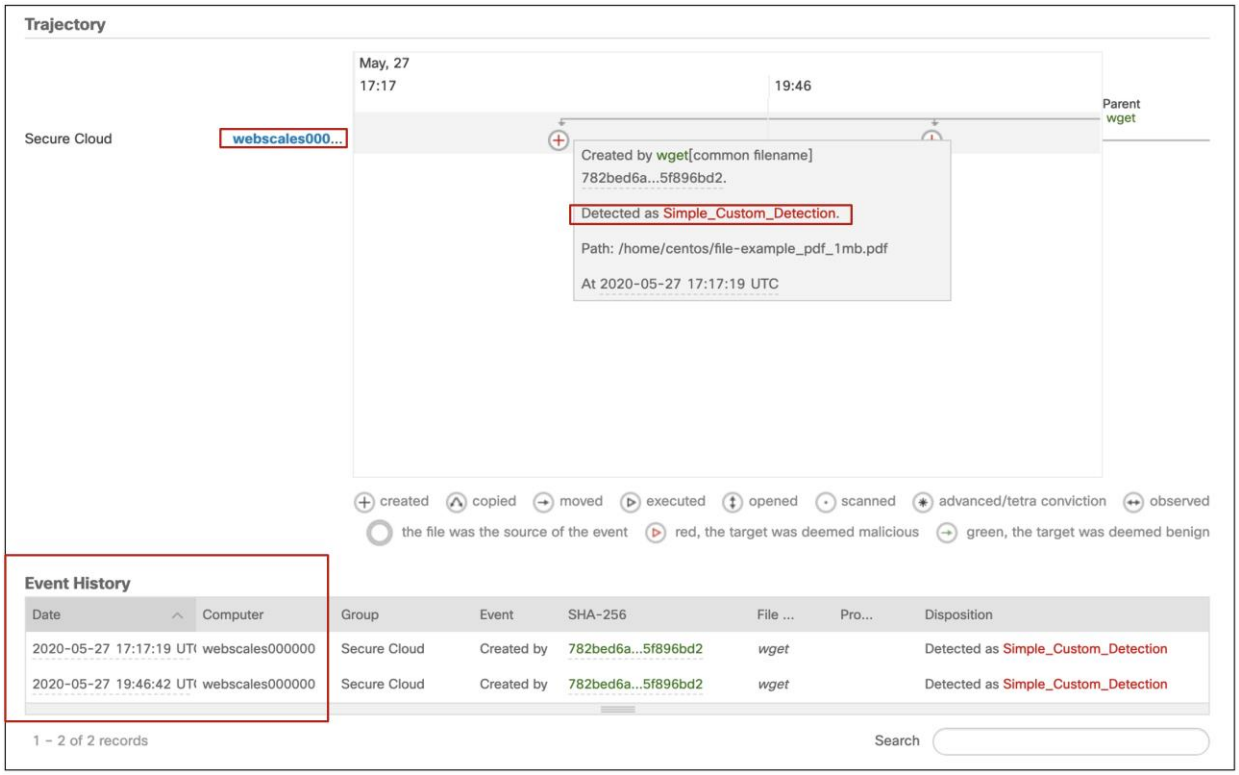
Step 1. **Investigate a malicious SHA value –** Log on to the threat response portal and select 'Investigate'. Add the SHA value in provided space and click on 'Investigate'. Threat response pulls all the information about the associated file and what workloads the specific file had interacted with. Under the 'Observables' section, we can see that AMP4E detected this SHA value as malicious based on our custom AMP policy, threat response displays the specific AMP4E policy name as well.



Step 2. **Track the file trajectory -** Click on the 'SHA-256 Hash' shown in the Relations Graph. Expand the drop-down menu and click on 'File trajectory'.



Clicking on 'File trajectory' should redirect you to AMP4E portal page which displays the trajectory of the malicious file on the specific workload. Clicking on a particular timestamp displays the related events. The event history shows all the events associated with the specific file.



Appendix

Appendix A- Acronyms Defined

AFD – Azure Front Doors

AMP4E – Advanced Malware Protection for Endpoints

AVC – Application Visibility and Control

CDO – Cisco Defense Orchestrator

CSD – Custom Simple Detection

CVD – Cisco Validated Design

ERT – Emergency Response Team

FDM – Firepower Device Manager

FMC – Firepower Management Center

FTD – Firepower Threat Defense

FQDN – Fully Qualified Domain Name

IOC – Indicators of Compromise

MFA – Multi-Factor Authentication

NGFW – Next Generation Firewall

NSG – Network Security Group

PaaS - Platform as a Service

PIN - Places in Network

SaaS - Software as a Service

SWC - Stealthwatch Cloud

VA - Virtual Appliance

VNET - Virtual Network

VSS - Virtual Machine Scale Set

2FA - Two Factor Authentication

Appendix B- Software Versions

Product	Platform	Version
Tetration	Software agent	3.3.2.35-enforcer
AMP4E	Software agent	1.11.1.663
Stealthwatch Cloud	Cloud Offering	SaaS
Umbrella VAs	Appliance (Azure VM Instance)	2.6.2
Cisco NGFWv	Appliance (Azure VM Instance)	6.5.0-115
CDO	Cloud Offering	SaaS
Duo WordPress Plugin	Software Plugin	Version 2.5.5
Radware Cloud	Cloud Offering	SaaS
SecureX threat Response	Cloud Offering	SaaS
Workloads (Azure VSS)	Linux	CentOS 7.7
Azure Database for MySQL	MySQL database	mysql-5-7

Appendix C- References

This section lists all the references.

- **Cisco SAFE:**
  https://www.cisco.com/c/en/us/solutions/enterprise/design-zone-security/landing_safe.html
- **Azure N-Tier Architecture**:
  https://docs.microsoft.com/en-us/azure/architecture/guide/architecture-styles/n-tier
- **Cisco Tetration:**
  https://www.cisco.com/c/en/us/products/security/tetration/index.html
- **Cisco Stealthwatch Cloud:**
  https://www.cisco.com/c/en/us/products/security/stealthwatch-cloud/index.html
- **Cisco AMP for Endpoint:**
  https://www.cisco.com/c/en/us/products/security/amp-for-endpoints/index.html

- **Cisco Firepower Threat Defense:**
  https://www.cisco.com/c/en/us/td/docs/security/firepower/quick_start/azure/ftdv-azure-qsg.html
- **Cisco Duo Beyond:**
  https://duo.com/docs/wordpress
- **Cisco Umbrella:**
  https://docs.umbrella.com/deployment-umbrella/docs/deploy-vas-on-microsoft-azure
- **Cisco Defense Orchestrator:**
  https://www.cisco.com/c/en/us/products/security/defense-orchestrator/index.html
- **Radware for AWS (WAF and DDoS):**
  https://www.radware.com/products/cloud-waf-service/
- **NGINX:**
  https://www.nginx.com/resources/wiki/start/topics/recipes/wordpress/
- **WordPress:**
  https://wordpress.org/download
- **Azure VNET:**
  https://docs.microsoft.com/en-us/azure/virtual-network/
- **Azure Route Tables:**
  https://docs.microsoft.com/en-us/azure/virtual-network/virtual-networks-udr-overview
- **Azure NSG:**
  https://docs.microsoft.com/en-us/azure/virtual-network/security-overview
- **Azure Database for MySQL:**
  https://docs.microsoft.com/en-us/azure/mysql/
- **Azure VSS:**
  https://docs.microsoft.com/en-us/azure/virtual-machine-scale-sets/overview
- **Azure Virtual Machines:**
  https://azure.microsoft.com/en-us/services/virtual-machines/
- **Azure Load balancer (Internal and External):**
  https://docs.microsoft.com/en-us/azure/load-balancer/load-balancer-overview
- **Azure Storage Containers:**
  https://docs.microsoft.com/en-us/azure/storage/common/storage-introduction
- **Azure Templates:**
  https://docs.microsoft.com/en-us/azure/azure-resource-manager/templates/overview
- **Azure Private Links:**
  https://docs.microsoft.com/en-us/azure/private-link/private-link-overview
- **Azure Front Doors:**
  https://docs.microsoft.com/en-us/azure/frontdoor/

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