Microsoft Azure Network Security

Nicholas DiCola
Anthony Roman
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Foreword

I am writing this foreword amid one of the largest and most invasive cybersecurity breaches in history—Solorigate. A sophisticated, nation-state actor was able to infiltrate a well-known supplier of network monitoring and management solutions. The threat actor injected a backdoor into the supplier’s build system, and the backdoor was then signed with a valid certificate and pushed to approximately 18,000 customers. What made this attack particularly novel was the fact that the threat actor leveraged their access to on-premises systems to then pivot and begin accessing cloud services, which appeared to be their primary target. The attacker also attempted to hide their level of access by leveraging Azure Service Principals to blend in with standard traffic and access patterns.

With attacks like Solorigate, it is essential to have a strong understanding of how to properly segment, protect, and monitor your cloud estate. Microsoft Azure is one of the dominant public clouds available in the market today and is used extensively by both governments and commercial enterprises. Microsoft Azure offers hundreds of different cloud computing solutions to organizations that allow them to innovate quickly, increase the digital experiences for customers and employees, and reduce large outlays in capital for data centers and hardware.

While cloud computing offers amazing benefits, it also introduces risks that security and IT teams must properly manage. In this book, Nicholas and Anthony cover the foundational security services and design patterns that organizations should adopt to protect and monitor their Azure workloads. I can think of no more qualified individuals than Nicholas and Anthony to provide practical, real-world implementation guidance regarding the design of secure Azure networking architectures. From preventing volumetric DDoS attacks to monitoring security logs with Azure Sentinel, this book covers everything you need to jump-start your journey into Azure security architecture and engineering.

For every IT leader using Microsoft Azure, put this on your team’s required reading list!

We are in the fight to deter cyberattacks together, and I applaud the effort that Nicholas and Anthony have put into making this essential material accessible to a broader audience. For all those who are working tirelessly to protect your organizations’ data and computer systems, thank you! Look after yourselves and each other.

—Jonathan C. Trull
Introduction

Welcome to Microsoft Azure Network Security, a book that is intended to provide detailed information about the capabilities of the major network security components of Azure along with recommendations for how to put them all together. We pay the closest attention to what we consider the core network security resources: Azure Firewall, Azure WAF, and Azure DDoS Protection Standard. Going beyond the function of the network security components themselves, we also emphasize the value of logging and integration with other security services like Azure Sentinel.

We wrote this book from a vantage point inside Engineering at Microsoft, working closely with both the product groups in control of the development of the technology and with customers who implement the technology in their networks. Network security is a complex intersection of networking, security, and cloud operations, and our hope is that we have covered the important pieces of all of these.

This book was finished just before the public release of Azure Firewall Premium, so details are as complete as possible. Please expect the product to evolve over time.

Who is this book for?

Microsoft Azure Network Security is for anyone who has a technical role that involves Azure deployments. Cloud administrators, engineers, and architects will find value in the how-to implementation details. Networking teams can gain context for how to integrate Azure native services into the broader architecture. Security professionals will be able to use this book as a guide for both secure Azure network architecture and network security monitoring strategy.

How is this book organized?

This book is arranged into nine chapters, which represent some broad themes:

- Chapters 1 and 2 discuss the broad theme of cloud network security and introduce the Azure components that address it.
- Chapters 3, 4, 5, and 6 concentrate on the core Azure network security resources: Azure Firewall, Azure WAF, and Azure DDoS Protection Standard.
Chapters 7 and 8 address logging, monitoring, and integration with other Azure security components such as Azure Sentinel and Security Center.

Chapter 9 brings everything together to connect the concepts of secure network architecture and security monitoring as they apply to all the Azure network security tools.

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Chapter 2
Secure Azure Network architectures

Chapter 1, “Introduction to Azure Network Security,” covers some basics to Azure networks and the current threat landscape. Given this, it is ever more important to define your Azure network architecture to meet needs but allow for network security and containment in the event of a breach.

Many organizations used perimeter-based networks that assume all systems behind the perimeter are trusted. This type of network defense is obsolete. Zero Trust networks are the next evolution that eliminates the trust based on network location. Zero Trust typically integrates user and device information, such as location and health state, which is run through a policy engine to determine whether access should be permitted or denied. In Zero Trust, a user in the corporate office on a managed machine might be able to access a cloud-based highly sensitive application, but when they go home, the same access may be limited (block downloading) or denied.

Layering cloud security into your Azure deployments as part of a Zero Trust approach allows for limiting or containing an attack if it does occur. In a simple form, having all IaaS VMs on one subnet would allow an attacker to quickly pivot between machines. Breaking the machines into groups by function and moving them to separate virtual networks (vNet) and applying Network Security Groups (NSGs) to the virtual networks can prevent an attacker from pivoting at all.

This chapter explains the best practices to a good network architecture, various types of network architectures in Azure, and how network security services can be layered in to protect these architectures.

Best practices

Before diving into network architectures, it’s important that we quickly mention Azure Well-Architected Framework. The framework consists of the following five pillars:

- Cost Optimization
- Operational Excellence
- Performance Efficiency
■ Reliability
■ Security

NOTE To read more on Azure Well-Architected Framework, see https://aka.ms/AzNSBook/AWAF.

The Azure Well-Architected Framework gives you a way to apply the best practices and principles to your applications or services. Security is one of the most important aspects of architecture. It provides assurance for the CIA (confidentiality, integrity, and availability) triad against attacks and loss of data. Losing these assurances can hurt an organization’s reputation, business operations, and revenue. If you don’t cost optimize your architecture, your return might be lower, but if you don’t secure your architecture, there might be no returns at all.

Under the pillar of security, network security and containment is a key topic that organizations must adhere to for protecting their cloud deployments. Here are the best practices for network security and containment:

■ Align network segmentation with enterprise segmentation strategy
■ Centralize network management and security
■ Evolve security beyond network controls
■ Build a security containment strategy
  ■ Define an internet edge strategy
  ■ Decide on an internet ingress/egress policy
  ■ Mitigate DDoS attacks
  ■ Design virtual network security technology
■ Decide use of legacy network security technology
■ Enable enhanced network visibility

The first best practice is to align network segmentation with enterprise segmentation. Organizations need to define how they will segment the enterprise starting from the top so that all teams (identity, network, app teams, and so on) are building and working to the same strategy. The following graphic depicts a reference enterprise segmentation from the Well-Architected Framework. Here the organization has created a central identity store, uses Management Groups to apply central policies and permissions, and has broken networks into segments that align with enterprise segments of subscriptions and resources. Figure 2-1 shows a segmentation reference model that can be used as a starting point.
FIGURE 2-1 Reference model for segmentation
Under the core services, the organization has centralized network management and security. This is the second best practice for network security. By centralizing network management and security, the organization can prevent applications or segments from being created that do not adhere to the network security strategy. Very often organizations that don’t centralize have new resources created in the cloud with a direct connection to the internet and little to no network security applied. This results in attacks against those resources that we know are unavoidable! Centralizing network management and security ensures new segments are protected and leverages the tools and expertise of the network and security teams. The following graphic depicts the reference for network security applied using the enterprise segmentation strategy. Figure 2-2 is a possible model for centralized network management and security.

In this design, the shared services segment is a hub virtual network providing core services, connectivity to on-prem, and public connectivity. By using this design, the organization can control ingress/egress (north-south) traffic from the hub and apply to all spokes. The next best practice is to define an internet edge strategy. Organizations need to choose how they will protect against from internet-based attacks. There are two primary choices:

- **Use cloud native controls, such as Azure Firewall and Web Application Firewall**
  This approach typically implements basic security that is good enough for common attacks but is well integrated into the platform.

- **Use partner virtual network appliances (available in the Azure Marketplace)**
  This approach often provides advanced features that protect against sophisticated attacks, but can cost more. An organization may also have existing knowledge/skills on the partner virtual network appliances.

The organization must decide based on experience and requirements. Once decided, the next detail is to apply ingress/egress policy baseline. In perimeter-based networks, many organizations would allow network traffic from internal to internet over HTTP/80 and HTTPS/443. This was fine until attackers started using HTTP(s) outbound to conduct command and control of exploited machines. In the era of Zero Trust, the concept starts with deny all outbound and only allows what is needed. It can’t be as broad as HTTP(s), and it must be more restrictive to allow HTTP(s) to specific domain names. Using this approach makes it significantly harder for attackers because they can’t use their command and control nodes and need to find another way.

Let’s take a look at the ingress side, too. By using cloud native controls, instead of having to allow RDP/SSH inbound on the firewall, organizations can use services like Azure Bastion and Azure Security Center (ASC) Just-in-time VM (JIT) access. Azure Bastion allows remote management access using HTTPS and would not require opening the firewall at all. Because Bastion is integrated into the Azure portal, organizations could apply Azure Active Directory Conditional Access to the Azure portal, which would apply Zero Trust to remote management of VMs. ASC JIT integrates with Azure Firewall, which again means RDP/SSH would not need to be open all the time to all sources but could be opened on demand to only specific sources (client machine IP or a specific subnet). Both of these examples are part of the best practice to evolve security beyond network controls. They now factor in identity, device, and application as part of access to the VM incorporating Zero Trust principles.
Best practices

Chapter 2

Reference enterprise design - Azure network security

Hybrid cloud infrastructure - network architecture

Microsoft Azure

Centralized network management and security

Legend

VNET PEERING
Subscription
Virtual network
Subnet
Network Security Group

FIGURE 2-2
For public-facing applications and services, it’s imperative to protect against DDoS attacks. Cloud providers, including Azure, provide DDoS protection at the network layer to protect the platform. Organizations should also apply DDoS protection at higher layers to protect their applications. This type of protection typically profiles the application usage and uses machine learning to look for anomalous traffic. The service should proactively protect the application before degradation. Azure provides DDoS protection service, which is covered in Chapter 6, “Mitigating DDoS attacks.”

Moving inward, organizations need to design network subnet security for their network segments. It is recommended that you plan for growth of resources in subnets over time and group resources in subnet by common roles and functions. Allow for larger IP address subnets on virtual networks to support expansion. If an organization has one subnet with five different resources, it needs to create NSG rules to support the different roles. Grouping resources allows for NSG configuration to be simplified and not get out of hand over time. It’s important to apply the principle of least privilege at the NSG to limit and contain traffic between subnets and virtual networks (east-west traffic). If an attacker somehow makes it into a virtual machine, maybe due to an application vulnerability, they won’t be able to pivot to other machines in other virtual networks. This is also referred to as micro-segmentation.

Organizations should enable enhanced network visibility as a best practice. Network logs should be integrated with the organization SIEM (security information and event management). This provides better visibility either through network log detection rules, the ability to query the data in the event of an incident for further investigation, or the ability to dashboard the data to look for trends and interesting changes for the central network and security teams. We cover monitoring in Chapter 8, “Security monitoring with Azure Sentinel, Security Center, and Network Watcher.”

Lastly, organizations have some existing or legacy network security technologies, like IDS/IPS, that they must decide whether to bring to the cloud. The recommendation is to evaluate these technologies and favor newer Zero Trust technologies where appropriate and look to cloud-native versions of where machine learning and artificial intelligence can be provided to replace or advance these types of technologies.

**Network architectures**

When planning or designing any service or application deployment to the cloud it’s imperative you start with a well-architected design. After defining a network strategy based on the previously discussed best practices, an organization can apply that to the architecture that meets their needs. The following architectures are just a few of the commonly used examples and how the best practices for network security are applied to them.
Cloud native

In recent years, it is entirely possible that a company was created and running with an entirely cloud-based set of services, which means they have no on-prem servers running, and they are using SaaS applications and hosting their service purely in the cloud. The following graphic depicts a simple cloud-native architecture where the organization might be using a few public services. The company has deployed its web application in Azure using purely PaaS services. This architecture is simple and can be secured by leveraging firewall features built into storage and SQL PaaS. Storage and SQL could be configured to block internet access and restrict it to the App Service web app. The following list covers some advantages and disadvantages:

- **Advantages**
  - Simple
  - Leverages network security services built into PaaS

- **Disadvantages**
  - Traffic is not routed through any central controlling service or device.
  - Each PaaS service has its own network security configuration.

Figure 2-3 shows a simple cloud-only set of services that an organization might be using.

![Diagram of cloud-only native services](image-url)
As you can see from the next example, most architectures are not that simple. A startup may be, but as the company’s service grows, it may need to expand to something more complex. Picture a company that has built a purely cloud-based application. It needs to deliver this application globally to its customers.

Here the application is global, which means traffic needs to be load balanced for both HTTP(s) and non-HTTP(s) traffic using Front Door and Traffic Manager. Front Door and Traffic Manager provide that load balancing. Web Application Firewall (WAF) is enabled on Front Door to defend the application at the network edge. Moving deeper in the stack, application gateway is then used in each region to load balance traffic to the VMs running the web application. WAF is also enabled on App Gateway to further protect the application. Why? WAF on Front Door supports geo-filtering, rate limiting, and Azure managed default rule sets, whereas WAF on App Gateway supports ModSec Core Rulesets (CRS). WAF is covered in depth in Chapter 5, “Secure application delivery with Azure Web Application Firewall.” As another protection, DDoS Protection Standard is enabled in the tenant and applied to all virtual networks. DDoS protects any public IPs (PIP) of the application gateways in this architecture. DDoS is covered in Chapter 6. Lastly, NSGs are added to control east-west traffic. This layered approach provides additional defense in depth to the application. Following are the advantages and disadvantages:

- Advantages
  - Leverages network security at all layers.
  - Various network security services provide protection against many types of attacks.
- Disadvantages
  - Traffic between virtual networks is not routed through any central controlling service or device.
  - Each PaaS service has its own network security configuration.

Figure 2-4 is an architecture for a global web application with the various services used across the regions.

Hybrid connectivity

Next up are more common architectures used as there are many organizations with existing on-premise networks that need to be connected to Azure and their workloads deployed there.
FIGURE 2-4  Complex global web application
ExpressRoute with VPN (ER/VPN) failover

In this architecture, ExpressRoute provides a connection that does not route over the internet and, in case of failure, a VPN backup path. The traffic is secured from on-premise to Azure. Once in Azure, WAF on App Gateway protects the web tier. Each subnet has an NSG to limit and contain traffic to only what is needed with rules appropriate for each subnet. For example, a rule to allow RDP or SSH from the management subnet IP range to the web tier and business tier IP range. The SQL database is configured with a service endpoint to provide direct connectivity to the service. No services or VMs have public internet access in this architecture. The following are the advantages and disadvantage:

- Advantages
  - Various network security provides protection against attacks.
  - Connectivity from on-premise is secure.
  - Remote management is secured from the management subnet only.

- Disadvantage
  - Traffic between virtual networks is not routed through any central controlling service or device.

Figure 2-5 is an ER/VPN architecture where on-premise connects to Azure over ExpressRoute and VPN.

DMZ

The DMZ (demilitarized zone) architecture enables a secure hybrid network that extends an on-premises network to Azure. This forces traffic coming from on-premise bound for the internet to route through the network virtual appliance (NVA) in the cloud. The advantage to this design is that all traffic passes through the NVA, which can control and provide advanced inspection of the traffic. Because the NVA has a PIP, applying DDoS to protection against
attacks adds another layer of protection to the workload. The following are the advantages and disadvantage:

- Advantages
  - Traffic is routed through a central device, which can control and limit traffic flows.
  - Various network security services provide protection against many types of attacks.
- Disadvantage
  - NVA requires additional management and configuration for HA.

Figure 2-6 shows the DMZ architecture and connections.

Expanding on this architecture, in Figure 2-7 we see that the architecture layers in Azure Bastion, which provides secure RDP (remote desktop protocol) and SSH (secure shell) access to the virtual machines. Azure Firewall has replaced the NVA to provide a cloud native approach. Azure Firewall has the advantages of being a fully managed PaaS. It can auto-scale as needed and provide built-in high availability. With an NVA, organizations must manage high availability, load balancing, and the appliance software themselves. Following are the advantages and disadvantage:

- Advantages
  - Cloud native services such as Azure Firewall and Bastion require less management and configuration.
  - Key traffic is routed through a central device, which can control and limit traffic flows.
  - Various network security services provide protection against many types of attacks.
- Disadvantage
  - Workloads are not fully isolated behind the firewall.

![Diagram of DMZ architecture with Azure Bastion]

**FIGURE 2-7** DMZ architecture with Azure Bastion

**Hub and spoke**

The hub virtual network acts as a central point of connectivity for on-premise networks, meaning on-prem is just another spoke. All traffic is routed through the hub virtual network. The spoke virtual networks create an isolated network to contain traffic to the specific workloads. This could be spokes for prod versus dev or workload or front end vs back end. Central services could be deployed in the hub as a separate subnet or a spoke virtual network. In the hub, Azure Firewall or an NVA is deployed to provide additional protection to east-west traffic between the spokes. This is an ideal architecture because it allows for expansion and contraction over time by adding or removing spokes. For multiregion, additional hubs are deployed to the region with region spokes connected. Hubs between regions can be connected using vNet peering, site-to-site VPN, or virtual WAN. The main difference between virtual WAN and hub and spoke is that virtual WAN is a managed offering. The following are the advantages and disadvantages:

- Advantages
  - Central services can provide cost savings by sharing them across workloads.
  - Hub virtual network can create separation of duties for IT (security, infrastructure) and workload (DevOps).

- Disadvantages
  - It is complex to manage as spoke numbers grow.
  - Spoke-to-spoke traffic must pass through the hub.

Figure 2-8 is a hub and spoke architecture.
Azure Virtual WAN

Azure vWAN is a service that brings together all of the benefits of previously discussed hybrid architectures into a single interface. Virtual WAN (vWAN) includes functionalities for branch, site-to-site VPN, point-to-site VPN, ExpressRoute, intra-cloud connectivity, routing, and Azure Firewall. vWAN is built on the hub and spoke architectures and enables global network connectivity.

The following resources are part of vWAN:

- **virtualWAN**  This resource is an overlay of the Azure network and contains multiple resources.
- **Hub**  This is a Microsoft-managed virtual network. It contains various endpoints like VPN Gateway and ExpressRoute gateway to provide connectivity to on-premise or mobile users.
- **Hub virtual network connections**  This is a connection resource to connect the hub to spoke virtual networks.
- **Hub-to-hub communication**  Hubs are deployed in regions and connected to each other in the virtual WAN. This creates a full-mesh architecture allowing traffic between virtual networks, on-premise, and branch sites.
- **Hub route table**  This allows the addition of routes to the hub route table.

Figure 2-9 is the basic diagram of vWAN.
Connectivity

Virtual WAN provides many types of connectivity, and the advantage is that an organization can use one or all of the various types. They can start with one that is needed today and expand over time as new connectivity requirements arise. There are various methods to connect on-premise to virtual WAN. Site-to-site VPN connections allow on-premise connectivity over an IPSec/IKE connection. Organizations must employ a VPN device or virtual WAN partner device on-premise to establish the S2S VPN. If there is a need for mobile users to have VPN access, a virtual WAN can be configured to provide VPN for users and require a VPN client on the endpoint. ExpressRoute lets organizations connect over a private connection.

Transit connectivity is also provided in virtual WAN. Once connected to the hub, on-premise traffic can be routed to spoke virtual networks. This means user traffic coming from on-prem will route over S2S VPN or ExpressRoute, hit the hub, and use the virtual network connection to the spoke to reach a server. This traverses the same path the opposite way. Virtual WAN also allows transit connectivity between VPN and ExpressRoute. A mobile user over VPN could reach on-premise via the hub. Spoke virtual networks can talk to each other through the hub.
Traffic can travel between two spokes via the hub. Multiple hubs can be added to virtual WAN as well. This will allow spoke virtual networks to talk over the hub-to-hub connection going from spoke to hub to the other hub to the other spoke.

Security

Virtual WAN allows organizations to apply virtual hub routing and manage traffic flow within the virtual WAN. Specifically, this can be used to isolate virtual networks, create shared services virtual networks, or route traffic through one of the Azure partner NVAs or Azure Firewall. There is also an option to use Azure Firewall in the hub and integrate partner offerings like zScaler, iBoss, and Checkpoint. In this configuration, Azure Firewall protects private traffic in the hubs and internet/SaaS traffic is routed to the partner service. An organization might have a need to isolate the virtual networks allowing traffic from on-premise to all virtual networks but not virtual network to virtual network. Or perhaps, the organization wants to configure shared services such as domain controllers or file services but doesn’t want to allow all virtual network to virtual network traffic. By applying routing these scenarios are achievable.

NOTE To route traffic in a virtual WAN, it must be a standard type virtual WAN. See more at aka.ms/AzNSBook/vWAN.

In the Shared Services example, nonshared services virtual networks do not learn routes to other nonshared virtual networks but do learn about the shared services virtual network. Shared services are propagated to all virtual networks and branches/VPN using the default table. It is important to understand how routing can be used to limit traffic to only sources and destinations needed. Figure 2-10 depicts an example of the shared services routing.

To layer in security, organizations can deploy an NVA into a virtual network. When using NVA, spokes must be created off of the NVA virtual network that resides in the virtual WAN. This will allow having traffic from workload virtual networks to pass through the NVA. Figure 2-11 shows the NVA VNet added with spokes behind it.
Figure 2-10  Shared services routing
If an organization wants to use cloud native network security, vWAN offers a secure virtual hub, which includes an Azure Firewall instead of using an NVA. Figure 2-12 shows the difference that additional spoke networks are not needed because Azure Firewall can be deployed in the vWAN hub.

**Summary**

In this chapter, we covered the importance of using Azure Well-Architected Framework to use best practices when designing networks and network security in Azure. We then reviewed various network architectures that can be used to deploy services and applications in Azure. Each architecture has its advantages and disadvantages and allows for network security in different ways. It is important to leverage the framework at the start and use those practices combined with the sample architectures to meet the needs and requirements of the application being deployed.
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