Secure your Microservices on AKS — Part 2

Agraj Mangal
Apr 19 · 12 min read ★

In the first article, we created a very simple Spring Boot App, dockerized it and deployed that to an Azure AD managed AKS cluster using Terraform and Azure Devops. In this article, we continue and make our setup more secure by

1. Using Managed Identities to access Azure Key Vault which contains secret connection strings, instead of using base 64 encoded Kubernetes Secrets and use Azure AD Pod Identity to enable Managed Identities for Pods.
2. Enable Azure Policy for our AKS cluster and enforcing some basic governance such as not allowing privileged containers to run, enforcing container CPU and memory resource limits to prevent resource exhaustion attacks in a Kubernetes cluster, use images from trusted registries to reduce the Kubernetes cluster's exposure risk to unknown vulnerabilities, security issues and malicious images.
3. Since we are not using a Private AKS Cluster, we should whitelist the IP addresses that are allowed to access the Kube API Server and make changes to the state of the cluster.
4. Enable Private Link for Key Vault & SQL db and communicate over the Microsoft backbone network instead of using a public endpoint for the Azure PAAS services.
5. Use Network Policies to limit network traffic between pods in the cluster. We will deploy an additional sample microservice to demonstrate this.
6. Deploy a Web Application Firewall with Application Gateway to protect against standard OWASP attacks such as XSS, CSRF, SQL injection etc.

Again its important to note that this is NOT an exhaustive list and one should refer to official documentation like AKS Security Baseline for comprehensive coverage on the subject. I also don't plan to cover the recently announced Open Service Mesh Add-on

for AKS (in public preview as of today) but very interesting to enable MTLS b/w your microservices and enabling further security features like restricting communication, monitoring & debugging capabilities etc.

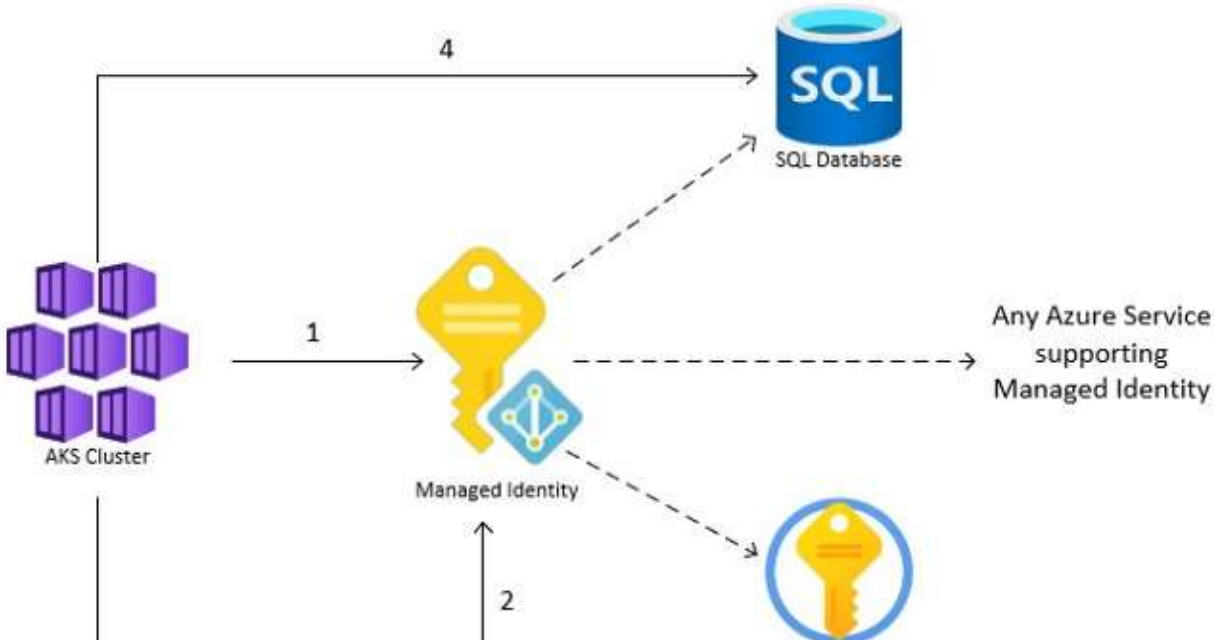
Key Vault + Azure AD Pod Identity

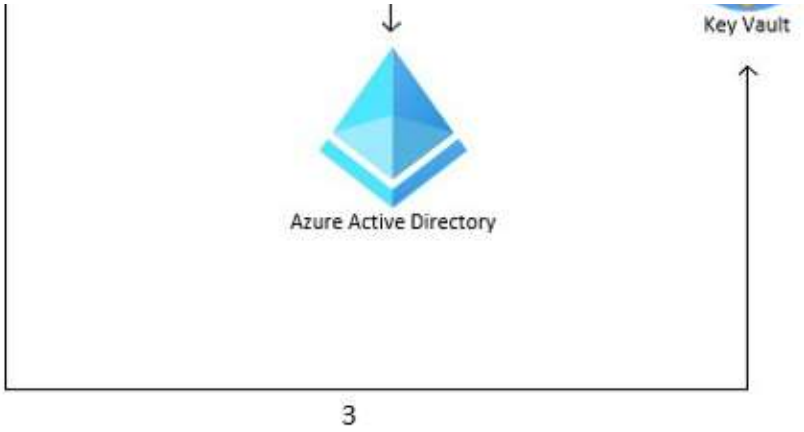
Azure AD Pod Identity is now available as an “add-on” with AKS. Although its in public preview (as of this writing) but it allows you to manage and associate Managed Identities for Azure resources with pods using Kubernetes Custom Resources.

AD Pod Identity Flow

We will do the following steps:

1. Create a User assigned Managed Identity, a Key Vault for holding secrets & grant it permissions on the Key Vault
2. Modify our Spring Boot App to use Azure Key Vault Integration for secrets.
3. Create Pod Identity & Associate that Managed Identity with the Spring Boot Application Pod
4. Now when the Spring Boot Application will try to talk to KeyVault, the User-assigned Managed Identity will get the access token from Azure AD and use that token to access KeyVault and get our secrets to the application.
5. Once the secrets are passed to the Spring Boot App it will try to connect to SQL using those secrets & run our sample Todos REST API successfully





How Azure AD Pod Managed Identities Can be Used to Access Azure Resources

Housekeeping

Since the feature is in preview now, so there are a few housekeeping items you need to perform to enable the feature on your subscription

```
az feature register --name EnablePodIdentityPreview --namespace
Microsoft.ContainerService
```

You would also need to update to the preview version of AZ CLI in order to use the CLI to create a pod-identity for your cluster.

```
az extension update --name aks-preview
az aks update -g $AKS_RESOURCE_GROUP -n $AKS_CLUSTER_NAME --enable-
pod-identity
```

Why using AZ CLI and not Terraform ?

It is to be noted that we are consciously not using Terraform for this step (although parts of it like creating the resource group & identity can be done via TF easily) as this feature is still in preview and neither the AKS module nor the AKS Kubernetes resource supports the AD Pod Identity at this time. We can still however use the local provisioner to run the update command on the cluster but until the Terraform resources gets better support its better to stick to AZ CLI for preview features.

Again also very important to note that — we do not recommend using any preview features for your production use cases. The preview features are not supported until

GA and may continue to evolve until they are released. So with that disclaimer in mind, lets get started:

Step 1: Create a User Managed Identity, Key Vault & Grant permissions to MI on Key Vault

We do this by modifying our Terraform templates and creating key vault and user-assigned Managed Identity using Terraform:

```
resource "azurerm_user_assigned_identity" "managed_identity" {
  resource_group_name = azurerm_resource_group.core.name
  location            = azurerm_resource_group.core.location

  name = var.managed_identity_name
}

resource "azurerm_key_vault" "secretstore" {
  name                        = var.keyvault_name
  location                    = azurerm_resource_group.core.location
  resource_group_name         = azurerm_resource_group.core.name
  enabled_for_disk_encryption = true
  enabled_for_deployment      = true
  tenant_id                   = var.tenant_id
  soft_delete_retention_days  = 7
  purge_protection_enabled    = false
  sku_name = "standard"

  depends_on = [azurerm_user_assigned_identity.managed_identity]
}

output "managed_identity_resource_id" {
  value = azurerm_user_assigned_identity.managed_identity.id
}

output "managed_identity_client_id" {
  value = azurerm_user_assigned_identity.managed_identity.client_id
}

output "managed_identity_principal_id" {
  value = azurerm_user_assigned_identity.managed_identity.principal_id
}
```

terraform_keyvault_managed_identity.tf hosted with ♡ by GitHub view raw

To assign the newly created user-assigned Managed Identity to be able to access secrets from Key Vault, we will now create an access policy for the key vault

```
export APP_KEYVAULT_NAME=spbootkeyv2021am  #ReplaceWithYourKeyVault
export MANAGED_IDENTITY_ID=$(terraform output -raw
managed_identity_principal_id)
az keyvault set-policy --name $APP_KEYVAULT_NAME --secret-
permissions get list --object-id $MANAGED_IDENTITY_ID
```

Step 2: Modify the App

We start by updating our Spring boot application by including the Maven dependency for the Azure Key Vault Integration

```
<dependency>
   <groupId>com.azure.spring</groupId>
   <artifactId>azure-spring-boot-starter-keyvault-
secrets</artifactId>
   <version>3.3.0</version>
</dependency>
```

The Azure Key Vault Integration makes the secrets in Key Vault available as Spring `PropertySource` values to your application, so you can easily access them without having to keep them in configuration files and modifying them at runtime via DevOps pipelines (as we were doing in the first article)

However for this Azure Key Vault integration to work, you would need to put the following properties in your configuration file — `application.properties`

```
azure.keyvault.enabled=true
azure.keyvault.uri=https://<Your_Key_Vault>.vault.azure.net/
azure.keyvault.client-id=<Client_Id_of_MSI_having_Acces_on_KV>
```

Spring Boot vs Azure Key Vault on Secret Names & Dot Notations !

Here we run into an interesting problem — It's a well known fact that Azure Key Vault does not support dots . in the names of the secrets and recommends using other characters like dashes - On the other hand, in the Spring world its very common to use dots in your property names -infact we have `spring.datasource.url` , `spring.datasource.username` and `spring.datasource.password` to specify the database connection strings for Azure SQL. So how we do we resolve this when we cannot create a secret with name `spring.datasource.url` in Azure Key Vault and `spring-datasource-url` will not be recognized by Spring ?

Thanks to Stack Overflow, the answer is to build your own `DataSourceConfig` that is annotated as a `Configuration` class so it can be processed by Spring to generate bean definitions & service requests for those beans at runtime. In our case, this is used to construct the `DataSource` that makes use of the secrets in Key Vault and override the built-in DataSource that reads the values with dots . in it. Our `DataSource` looks like:

```
1  @Configuration
2  public class DataSourceConfig {
3
4      @Value("${db-user}")
5      String dbUser;
6
7      @Value("${db-password}")
8      String dbPwd;
```

```
9
10      @Value("${db-url}")
11      String dbUrl;
12
13      @Bean
14      public DataSource getDataSource() {
15          DataSourceBuilder dataSourceBuilder = DataSourceBuilder.create();
16          dataSourceBuilder.url(dbUrl);
17          dataSourceBuilder.username(dbUser);
18          dataSourceBuilder.password(dbPwd);
19          return dataSourceBuilder.build();
20      }
21  }
```

DataSourceSpringKeyVault.java hosted with ♡ by GitHub view raw

Now we add the database connection string secrets (`db-url` , `db-user` and `db-password` as required by our custom DataSource) to the newly created key vault. Replace the values with the values for your SQL database (created in the first article)

```
export DATASOURCE_URL="jdbc:sqlserver://#{SQL-SERVER-
NAME}#.database.windows.net:1433;database=#{SQL-DB-
NAME}#;encrypt=true;trustServerCertificate=false;hostNameInCertifica
te=*.database.windows.net;loginTimeout=30;"
az keyvault secret set --name db-url --value $DATASOURCE_URL --
vault-name $KEYVAULT_NAME
az keyvault secret set --name db-user --value $DATASOURCE_USERNAME -
-vault-name $KEYVAULT_NAME
az keyvault secret set --name db-password --value
$DATASOURCE_PASSWORD --vault-name $KEYVAULT_NAME
```

Cannot Run MSI Locally !

Another catch here is that you cannot run this code locally on your laptop/desktop as with the Managed Identity flow, it would try to communicate with the Instance Metadata Service (IMDS) endpoint (a well known non-routable endpoint which is not reachable from outside Azure) to get an access token, which it then uses to access the Key Vault secrets.

Why its not really a problem in this case ? — If we zoom out for a second, we are probably using a Kubernetes cluster even in the Dev environment to deploy our application — so once you update your deployment (by Step 5 below) you would be able to test this. So let's keep our fingers crossed and move on !

As an aside, if its too important for you to test this right here & right now, then a simple workaround would be to spin up a new VM, assign this user-assigned MI to that VM and run your jar on that VM to verify that it works !

Step 3: Create Pod Identity & Associate MI with it

Before we move ahead with creation of *Pod identity*, we must assign the user-assigned Managed Identity (we created in Step1) the *Reader* permissions on the node resource group of the AKS cluster (in other words, the resource group that contains the VMSS for the AKS cluster)

```
# run these commands in the terraform directory
export MANAGED_IDENTITY_ID=$(terraform output -raw
managed_identity_client_id)
export MANAGED_IDENTITY_RESOURCE_ID=$(terraform output -raw
managed_identity_resource_id)

NODE_GROUP=$(az aks show -g $AKS_RESOURCE_GROUP -n $AKS_CLUSTER_NAME
--query nodeResourceGroup -o tsv)
NODES_RESOURCE_ID=$(az group show -n $NODE_GROUP -o tsv --query
"id")
az role assignment create --role "Reader" --assignee
"$MANAGED_IDENTITY_ID" --scope $NODES_RESOURCE_ID
```

Create Pod Identity

Let's create a Pod Identity that we can assign this user-assigned Managed Identity and use that Pod Identity with our Spring Boot Deployment so that the node on which the application pods run can communicate with the IMDS service to get access token and then can use the access token to get the secrets from the Key Vault.

```
export POD_IDENTITY_NAME="spboot-pod-identity"
export POD_IDENTITY_NAMESPACE="spboot-app"
az aks pod-identity add --resource-group $AKS_RESOURCE_GROUP --
cluster-name $AKS_CLUSTER_NAME --namespace $POD_IDENTITY_NAMESPACE
--name $POD_IDENTITY_NAME --identity-resource-id
$MANAGED_IDENTITY_RESOURCE_ID
```

The Pod Identity can be either created via Azure CLI (like above) — the `az aks pod-identity` subcommand or by creating Custom Resource Definitions like `AzureIdentity` and `AzureIdentityBinding` and deploying them to the AKS cluster. Infact the above command will create some of those custom resources in your cluster.

The Pod Identity we created above requires certain important parameters

1. `identity-resource-id` The Resource ID for the User-assigned Managed Identity. We got this value using terraform output command.
2. `namespace` The namespace in which this pod identity is created and available for Kubernetes deployments to use

The equivalent YAML for the `AzureIdentity` custom resource is

```yaml
apiVersion: aadpodidentity.k8s.io/v1
kind: AzureIdentity
metadata:
  name: spboot-pod-identity
  namespace: spboot-app
spec:
  clientID: $MANAGED_IDENTITY_ID
  resourceID: $MANAGED_IDENTITY_RESOURCE_ID
  type: 0
```

AzureIdentity.yaml hosted with ♡ by GitHub view raw

The `type: 0` here means user-assigned MSI, `type: 1` for Service Principal with client secret, or `type: 2` for Service Principal with certificate. More info here.

Step 4: Update the Deployment in AKS

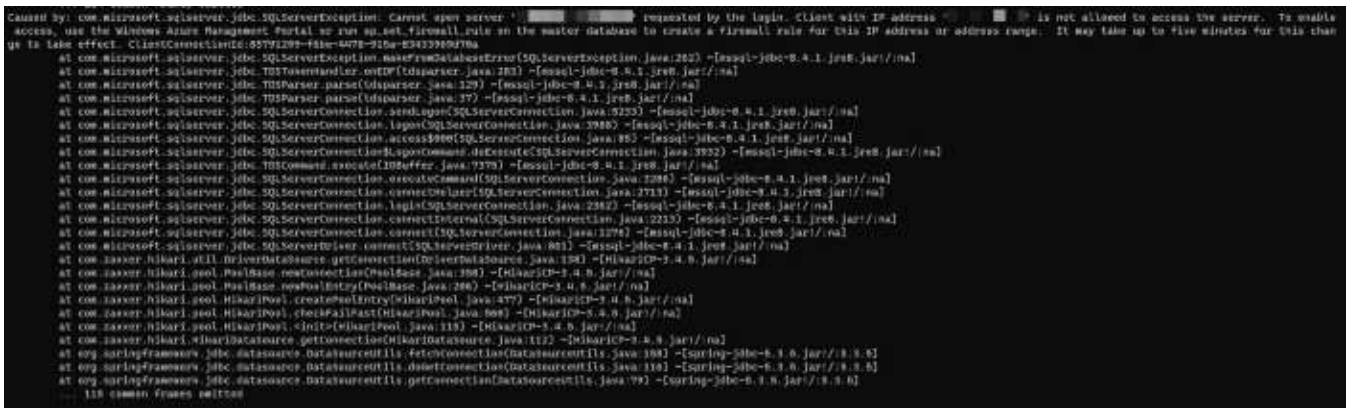
Next we update our deployment yaml to include the `namespace` and assign the Pod Identity we created above using the `aadpodidbinding` label on the Deployment as shown below

```yaml
apiVersion: apps/v1
kind: Deployment
metadata:
  name: spring-boot-aks                    # Name of the namespace in which Pod Identity is
  namespace: spboot-app
spec:
  replicas: 1
  selector:
    matchLabels:
      app: spring-boot-aks
  template:
    metadata:
```

```
      labels:
        app: spring-boot-aks
        aadpodidbinding: spboot-pod-identity    # Name of the Pod Identity
    spec:
      containers:
        - name: app
          image: spbootacr2021am.azurecr.io/spring-boot-aks:v1.0.3  #Replace this by your image
          ports:
          - containerPort: 8080
          imagePullPolicy: Always
```

updated-spring-boot-deployment.yaml hosted with ♡ by GitHub view raw

When you try & deploy this to the AKS cluster, it is able to fetch the secrets from Keyvault successfully but is not able to connect to the SQL database (duh!) and fails with the following error:



Connection Error !

Don't worry we solve this in Step 5 below.

Step 5: Virtual Network Service Endpoint & Firewall Rule for SQL Server

For pods running on AKS cluster to be able to access our SQL Server we need to whitelist the AKS subnet for the SQL Server by creating a Service Endpoint for the subnet hosting the AKS cluster. So we make the following changes in our Terraform template

```
    resource "azurerm_subnet" "akssubnet" {
    ....

    service_endpoints = [
      "Microsoft.Sql"
    ]
}
```

```
resource "azurerm_sql_virtual_network_rule" "aksvnetrule" {
  name                = "aks-vnet-sql-rule"
  resource_group_name = azurerm_resource_group.core.name
  server_name         = azurerm_sql_server.sqlserver.name
  subnet_id           = azurerm_subnet.akssubnet.id
}
```

updateserviceendpoitns.tf hosted with ♡ by GitHub view raw

Terraform Code Snippet for VNet Rule for whitelisting AKS Subnet

Apply these changes via `terraform plan` & then `terraform apply` & voila, we are done ! Check the pods logs — they are perfectly fine and the Spring App is running without any errors

Let's deploy a simple Kubernetes Service and access our Todos REST API

```
apiVersion: v1
kind: Service
metadata:
  name: spboot-svc
spec:
  type: LoadBalancer
  selector:
    app: spring-boot-aks
  ports:
  - protocol: TCP
    port: 80
    targetPort: 8080
```

springbootservice.yaml hosted with ♡ by GitHub view raw

Lets create this `Service` to access the API

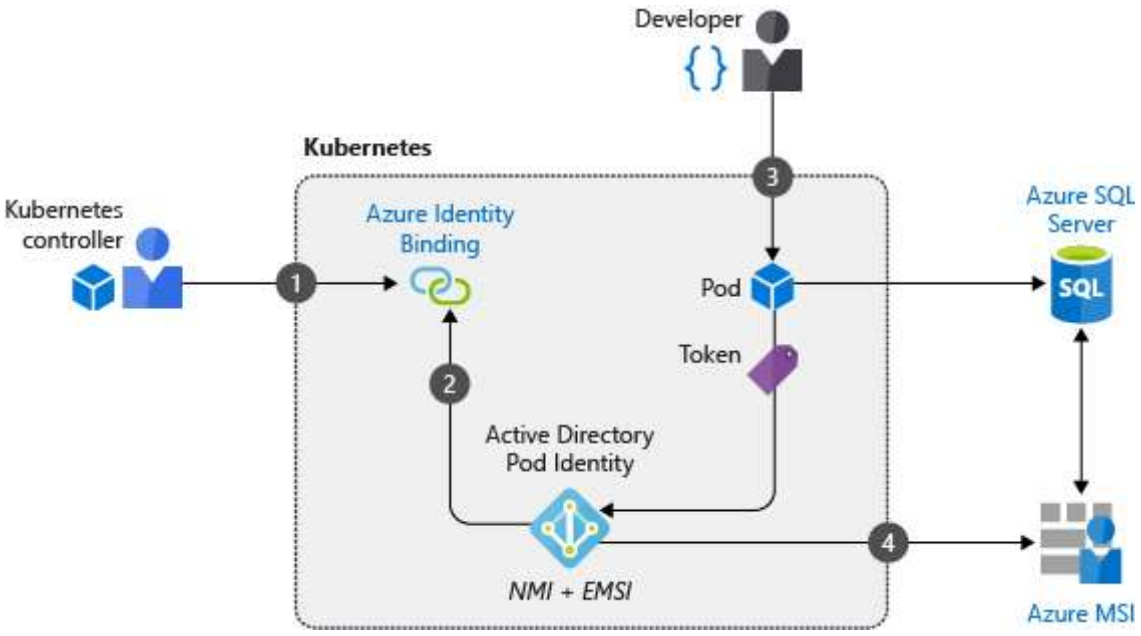
```
kubectl apply -f deploy/spring-boot-app-deployment.yaml
```

```
→  springboot-aks git:(AADPodIdentity) kubectl get service -n spboot-app
NAME         TYPE           CLUSTER-IP    EXTERNAL-IP     PORT(S)        AGE
spboot-svc   LoadBalancer   10.0.3.30     20.193.42.211   80:30219/TCP   25m
→  springboot-aks git:(AADPodIdentity)
→  springboot-aks git:(AADPodIdentity) curl http://20.193.42.211/todos
[]%
→  springboot-aks git:(AADPodIdentity)
```

Cool so we now have a working Spring Boot Application in AKS using AAD Pod Managed Identities to access Azure Resources like Key Vault. All the code changes done so far can be found in `aadpodidentity` branch of our repo.

The Big Picture

Before we close off this chapter it may be a good idea to take a look at the bigger picture of how it all works in AKS.



The Big Picture: Azure AD Pod Managed Identity

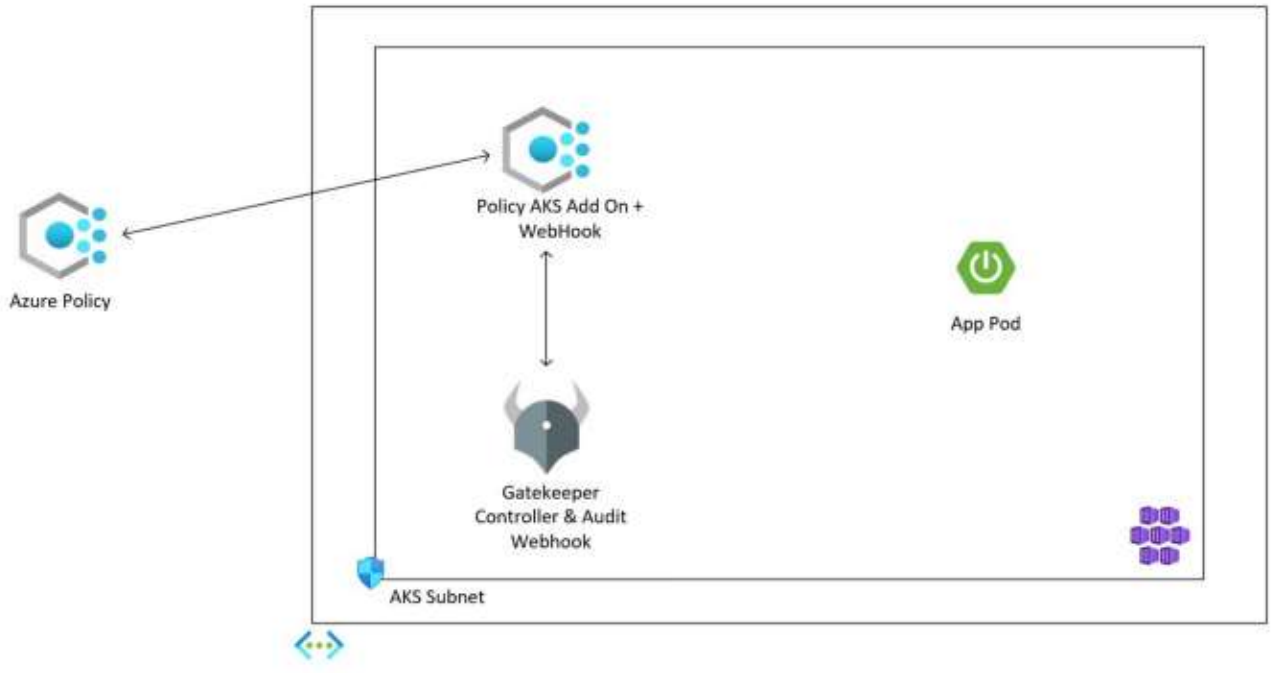
1. Once you enable the Pod Identity on the AKS cluster, the **Node Managed Identity (NMI) server** runs as a DaemonSet on each node on the cluster which intercepts calls to Azure services.

2. The NMI server talks to **Azure Resource Provider** to find the Azure Managed Identity associated with the Pod and then use that to get the access token from the AAD.

If your configuration for the AAD Pod Identity is not working, checking logs for the NMI server may help. You can read about the above authentication flow in more details on the official documentation here.

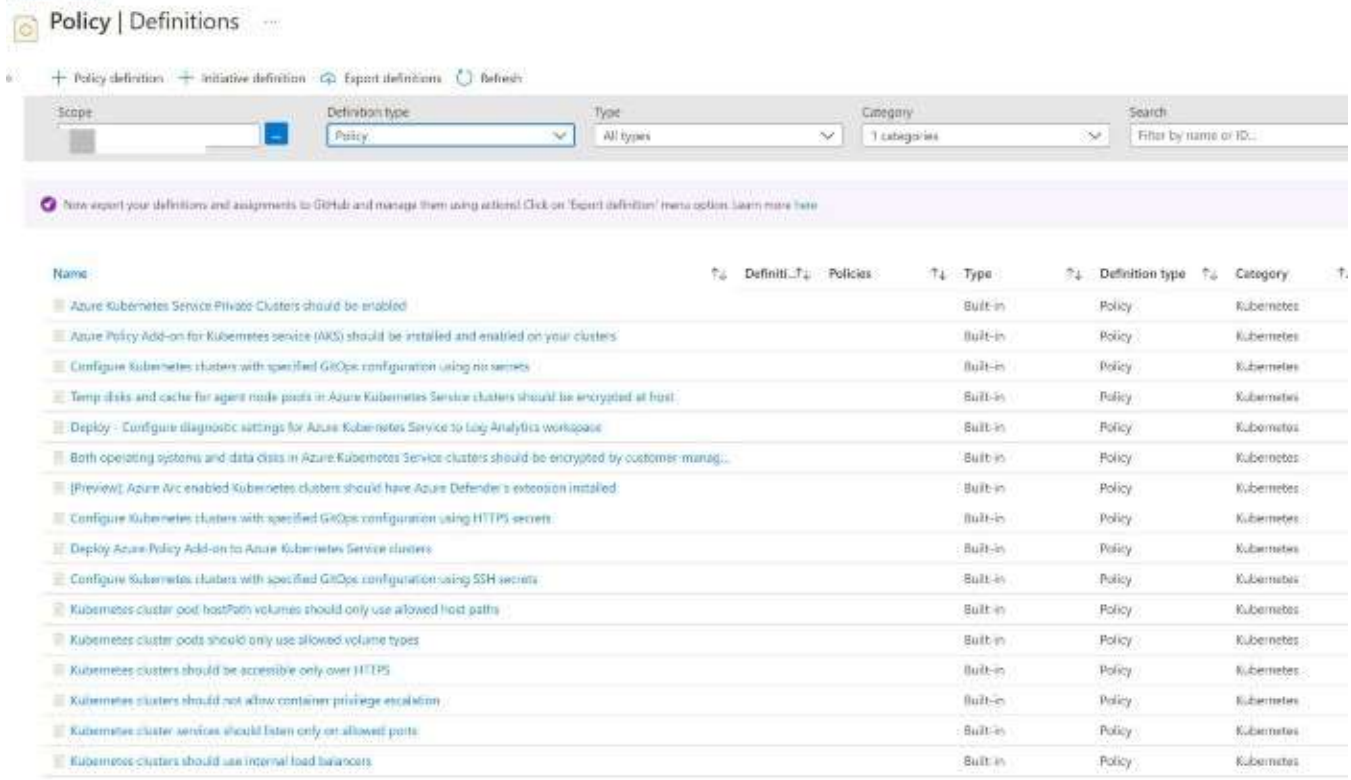
Azure Policy for AKS

Azure Policy should be your first stop to enforce organizational standards & to assess compliance at scale for any Azure resource & AKS is no different. The AKS add-on for Azure Policy is based on Gatekeeper v3 which uses Open Policy Agent CRD-based policies to audit & enforce governance. Gatekeeper v3 uses a **validating** admission controller & webhook(with mutating ones currently in development) with CRDs such as `ConstraintTemplate` & `Constraint` These CRDs uses a high level declarative language `Rego` (pronounced *ray-go*) to specify the actual policy that is evaluated by the Open Policy Agent. The idea is to validate the policy and reject the user request if a policy violation is found before persisting the object. Now Azure Policy has two different modes in which you can work — `Audit` and `Deny` So even with policy violations you can let the invalid user requests pass through and just log the policy violation for later use.



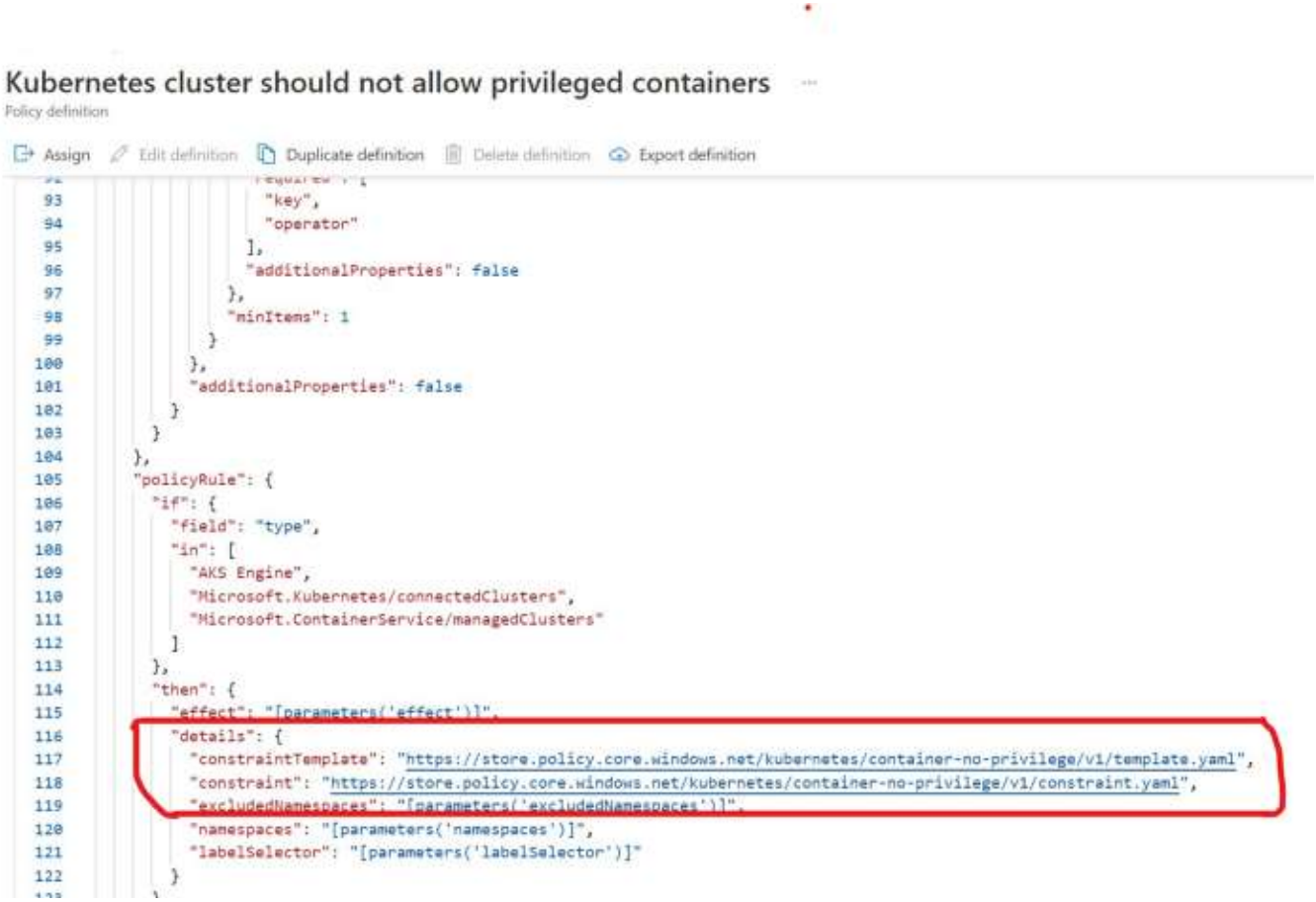
Azure Policy for AKS

Azure Policy provides a lot of built-in policies tailored for Kubernetes deployments that you can find via the Portal



Built-in Azure Policies for AKS

Some of these are defined using standard Azure Policy language and using known constructs. But most of them rely on `ConstraintTemplate` and `Constraint` Custom Resources. As an example, checking the Policy definition for one of the built-in policy for "**Kubernetes cluster should not allow privileged containers**" gives



```
    }
  },
  "id": "/providers/Microsoft.Authorization/policyDefinitions/95edb821-ddaf-4404-9732-666045e056b4",
  "type": "Microsoft.Authorization/policyDefinitions",
  "name": "95edb821-ddaf-4404-9732-666045e056b4"
}
```

The **ConstraintTemplate** custom resource referenced above looks like

```
apiVersion: templates.gatekeeper.sh/v1beta1
kind: ConstraintTemplate
metadata:
  name: k8sazurecontainernoprivilege
spec:
  crd:
    spec:
      names:
        kind: K8sAzureContainerNoPrivilege
        listKind: K8sAzureContainerNoPrivilegeList
        plural: k8sazurecontainernoprivilege
        singular: k8sazurecontainernoprivilege
  targets:
    - target: admission.k8s.gatekeeper.sh
      rego: |
        package k8sazurecontainernoprivilege

        violation[{"msg": msg, "details": {}}] {
            c := input_containers[_]
            c.securityContext.privileged
            msg := sprintf("Privileged container is not allowed: %v, securityContext: %v", [c.r
        }

        input_containers[c] {
            c := input.review.object.spec.containers[_]
        }

        input_containers[c] {
            c := input.review.object.spec.initContainers[_]
        }
```

constrainttemplate.yaml hosted with ♡ by GitHub view raw

ConstraintTemplate — Actual Policy Defined using Rego

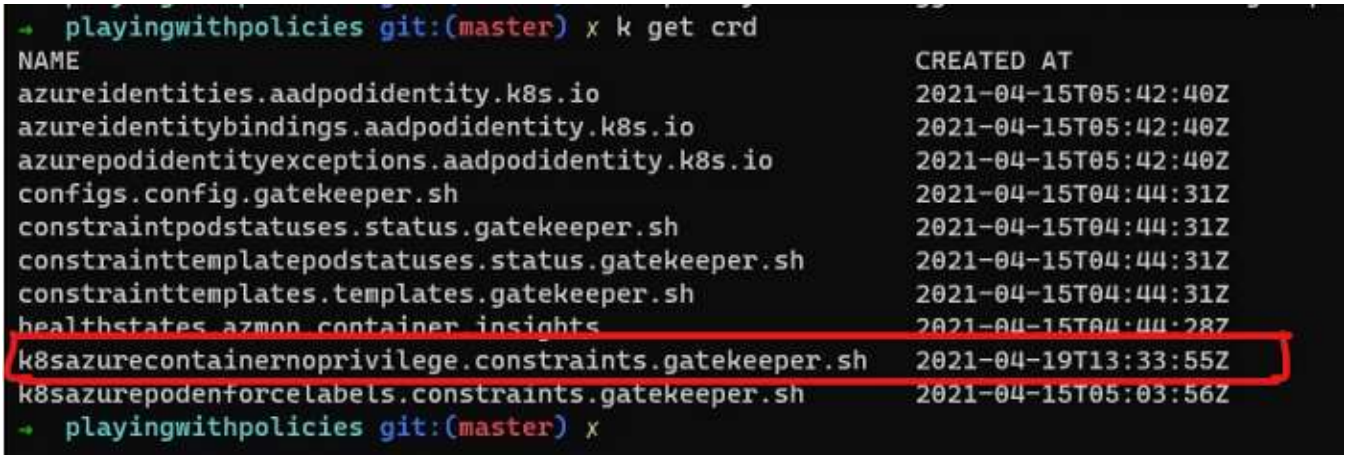
The **ConstraintTemplate** defines the `Rego` logic that defines the policy to be applied, as well as the schema of the CRD and the parameters that can be passed to the **Constraint,** which in this case looks like

```yaml
apiVersion: constraints.gatekeeper.sh/v1beta1
kind: K8sAzureContainerNoPrivilege
metadata:
  name: container-no-privilege
spec:
  match:
    kinds:
      - apiGroups: [""]
        kinds: ["Pod"]
```

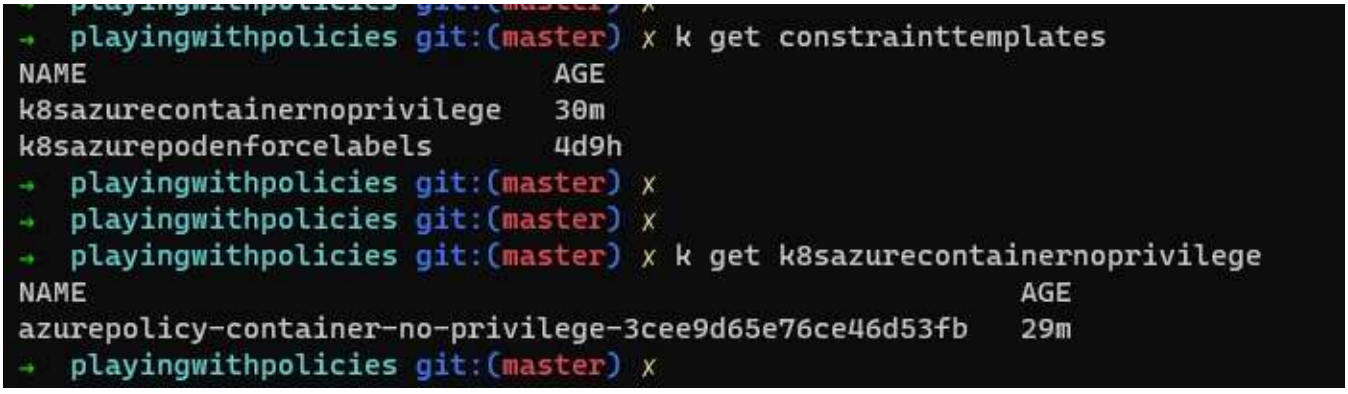
constraint.yaml hosted with ♡ by GitHub view raw

Essentially you can create one or more Constraints based on the same ConstraintTemplate

Once you assign this policy to your subscription or the resource group containing the AKS Cluster, **it takes around 30 minutes for the effect to take place** before you can enforce the constraints or can see the associated CRDs for `Constraint` and `ConstraintTemplate` for this policy in the AKS Cluster. Once the time has passed, you would be able to see new custom resources for this policy



CRD for the No Privileged Container Policy Constraint



By default the compliance is checked every 15 minutes by the add-on for Azure Policy & reported back to Azure Policy control plane and is also visible in Azure Portal. Once you can see the right set of CRDs in your cluster, time to test the policy — lets create a privileged pod

```yaml
apiVersion: v1
kind: Pod
metadata:
  name: nginx-privileged
spec:
  containers:
    - name: nginx-privileged
      image: mcr.microsoft.com/oss/nginx/nginx:1.15.5-alpine
      securityContext:
        privileged: true
```

privileged-pod.yaml hosted with ♡ by GitHub view raw

Denied !

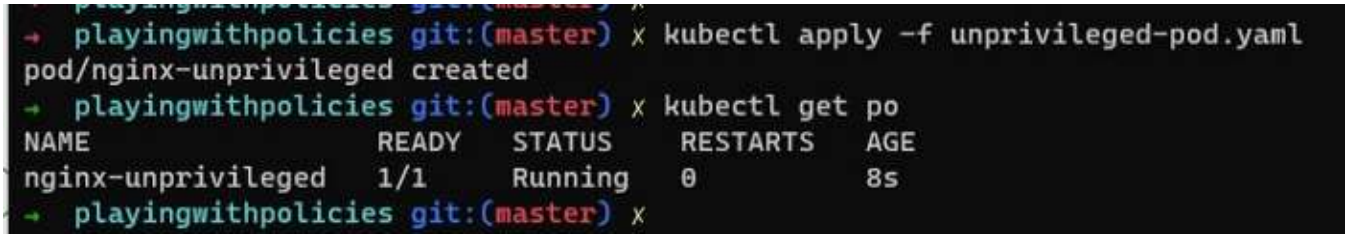
```
→  playingwithpolicies git:(master) x kubectl apply -f privileged-pod.yaml
Error from server ([denied by azurepolicy-container-no-privilege-3cee9d65e76ce46d53fb] Privileged container is no
t allowed: nginx-privileged, securityContext: {"privileged": true}): error when creating "privileged-pod.yaml": a
dmission webhook "validation.gatekeeper.sh" denied the request: [denied by azurepolicy-container-no-privilege-3ce
e9d65e76ce46d53fb] Privileged container is not allowed: nginx-privileged, securityContext: {"privileged": true}
→  playingwithpolicies git:(master) x
```

Also note that our Spring Boot Application is compliant with this policy (since it does not uses privileged containers) Any Application pods that are already deployed when this policy was applied to your cluster are not removed but are reported in the compliance status of Azure Policy — thus you can still remediate any effects of previous deployments against your organizational standards. To complete our testing, let's try and deploy a non-privileged pod running nginx — looks like

```yaml
apiVersion: v1
kind: Pod
metadata:
  name: nginx-unprivileged
spec:
  containers:
    - name: nginx-unprivileged
      image: mcr.microsoft.com/oss/nginx/nginx:1.15.5-alpine
```

unprivileged-pod.yaml hosted with ♡ by GitHub view raw

Apply this and boom it works !



Currently the only downside of Azure Policy over using Vanilla Gatekeeper is the limitation of not being able to write your own custom policy with a custom Rego

Cluster Control Plane IP Whitelisting

Since we are not using a Private AKS cluster — the next best thing you could do to secure your API Server (arguably the most critical component of your Control Plane) and the one that has a public endpoint today — is to whitelist the IP ranges from which the API server can be reached. This is mostly the place from where cluster administrators and/or users try to access the cluster but also take into account the IP address range for your DevOps agents (hosted or otherwise). Unfortunately the AKS module I'm using doesn't offer this yet — to whitelist the API Server authorized IP ranges but one can always use the local provisioner & Azure CLI to update the AKS cluster

```
az aks update -g $AKS_RESOURCE_GROUP -n $AKS_CLUSTER_NAME --api-
server-authorized-ip-ranges $IP_ADDRESS_RANGE
```

The article is already too long so we'll skip the rest (Private Link, Network Policies, WAF etc) for another time. Till then, enjoy hacking !

Kubernetes Security Azure Managed Identity Azure Policy