Create Your Own Serverless PKI with .NET & Azure Key Vault

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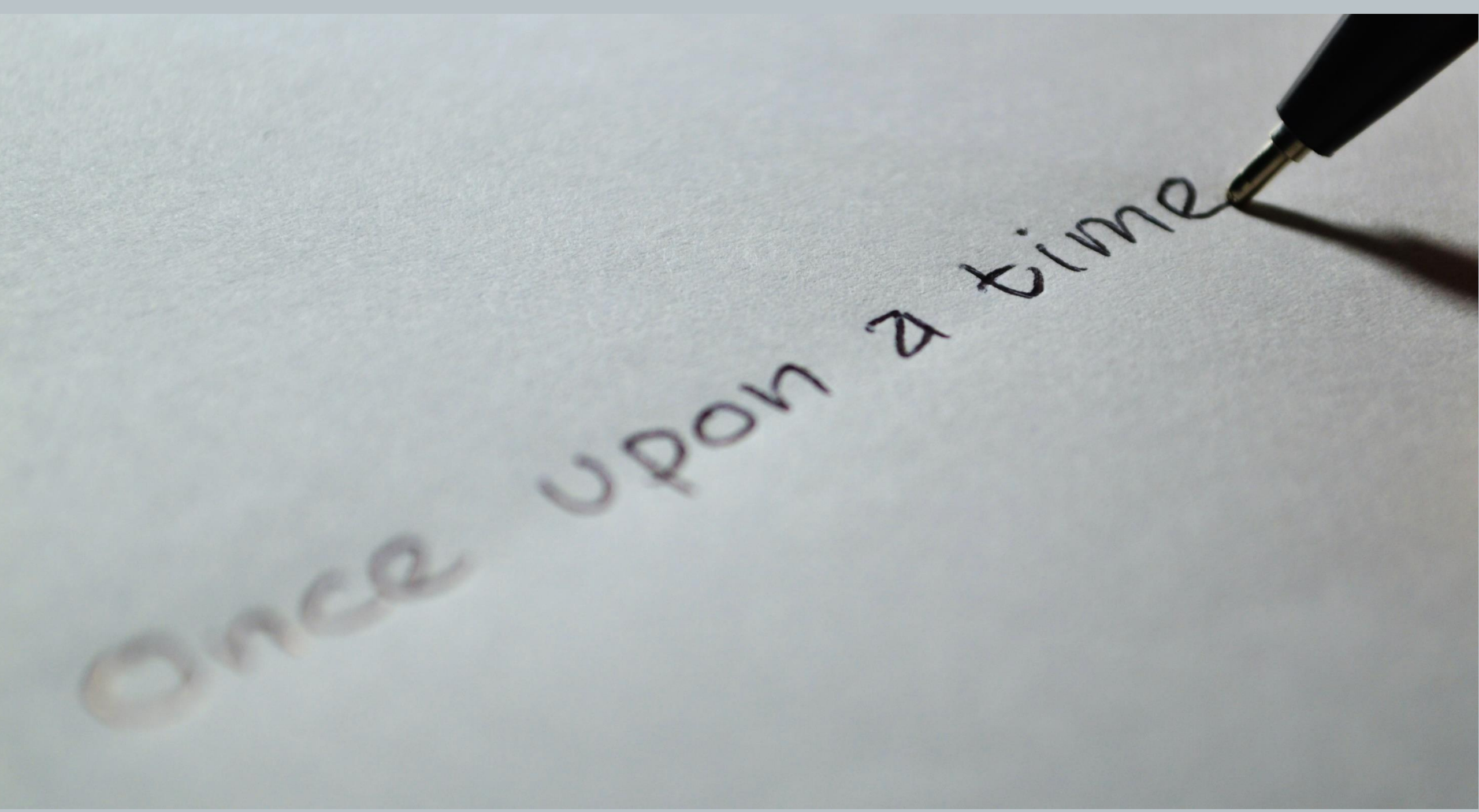
Once upon a time


SECURITY

Agenda

- IoT Data Ingestion
- PKIs, CAs & Certificates
- Building a Serverless CA using .NET
- Authoring Certificate Subscribers using .NET
- Using the Generated Certificates
  - Device Provisioning Service & IoT Hub

About Eran

Eran Stiller

- @eranstiller
- CTO & Founder at CodeValue
- Software architect, consultant and instructor
- Microsoft Regional Director & Azure MVP
- Founder of Azure Israel Meetup

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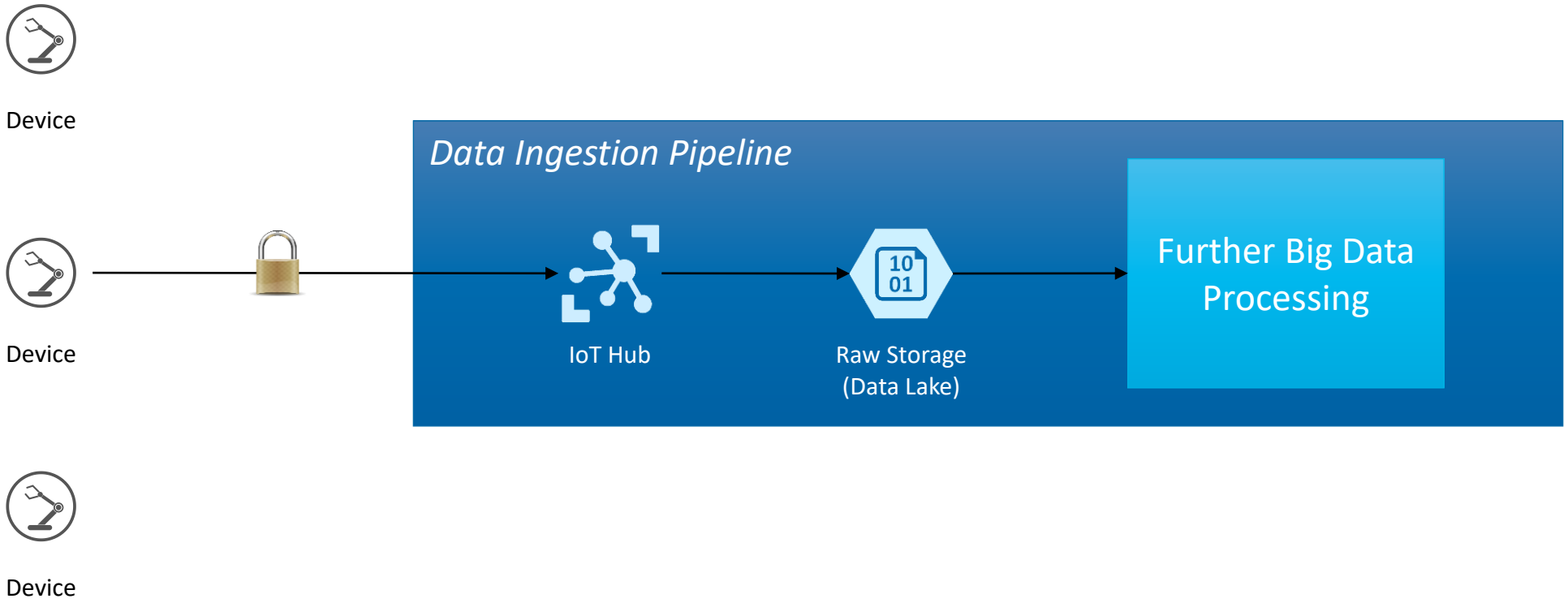
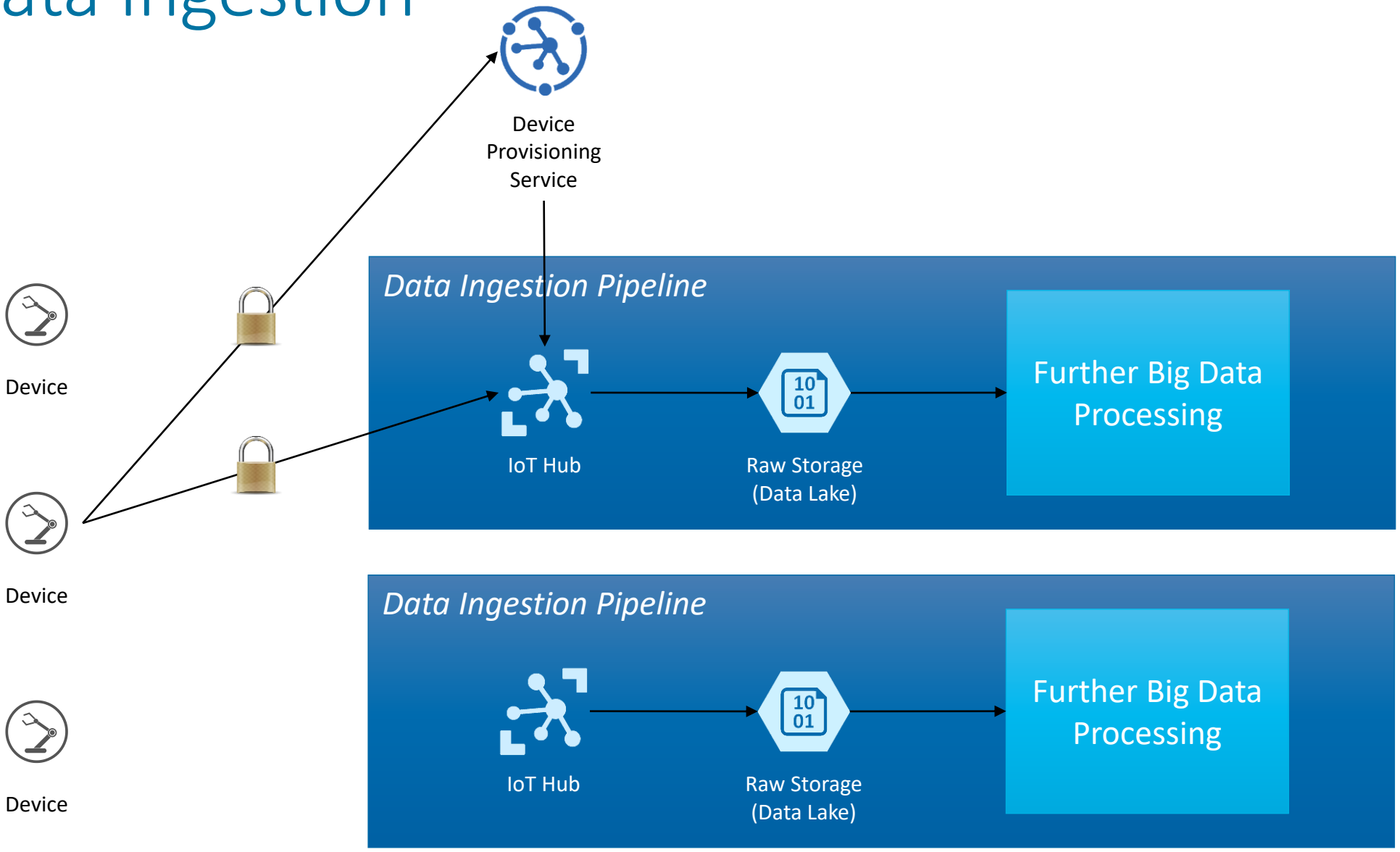
IoT Data Ingestion

IoT Data Ingestion

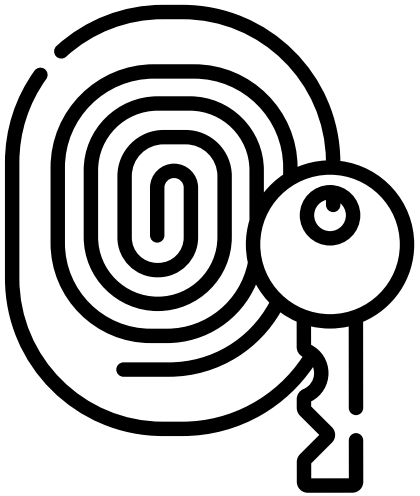


IoT Data Ingestion

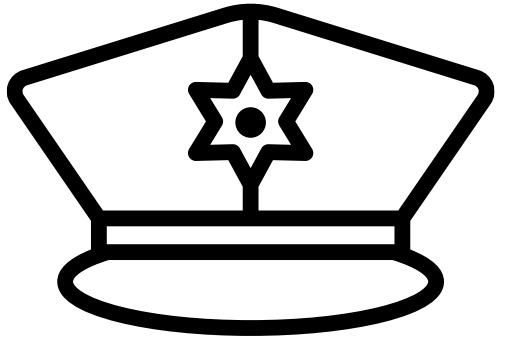


Securely Communicating with Devices

Confidentiality



Authentication



Authorization

Icons made by Freepik and Eucalyp for www.flaticon.com

Keep It Simple

PKIs, CAs & Certs

Public Key Infrastructure (PKI)

- An umbrella term for the stuff we need in order to:
  - Issue
  - Distribute
  - Store
  - Use
  - Verify
  - Revoke
  - and otherwise manage and interact with certificates and keys
- Don’t build from scratch
  - Can use an off-the-shelf solution
  - Can build some parts and rely on others

Certificates

- A driver's license for **computers and code**
- Basically, a binding between an identifier (name) and a public key
- Usually encoded as X.509

Icon made by Becris for www.flaticon.com

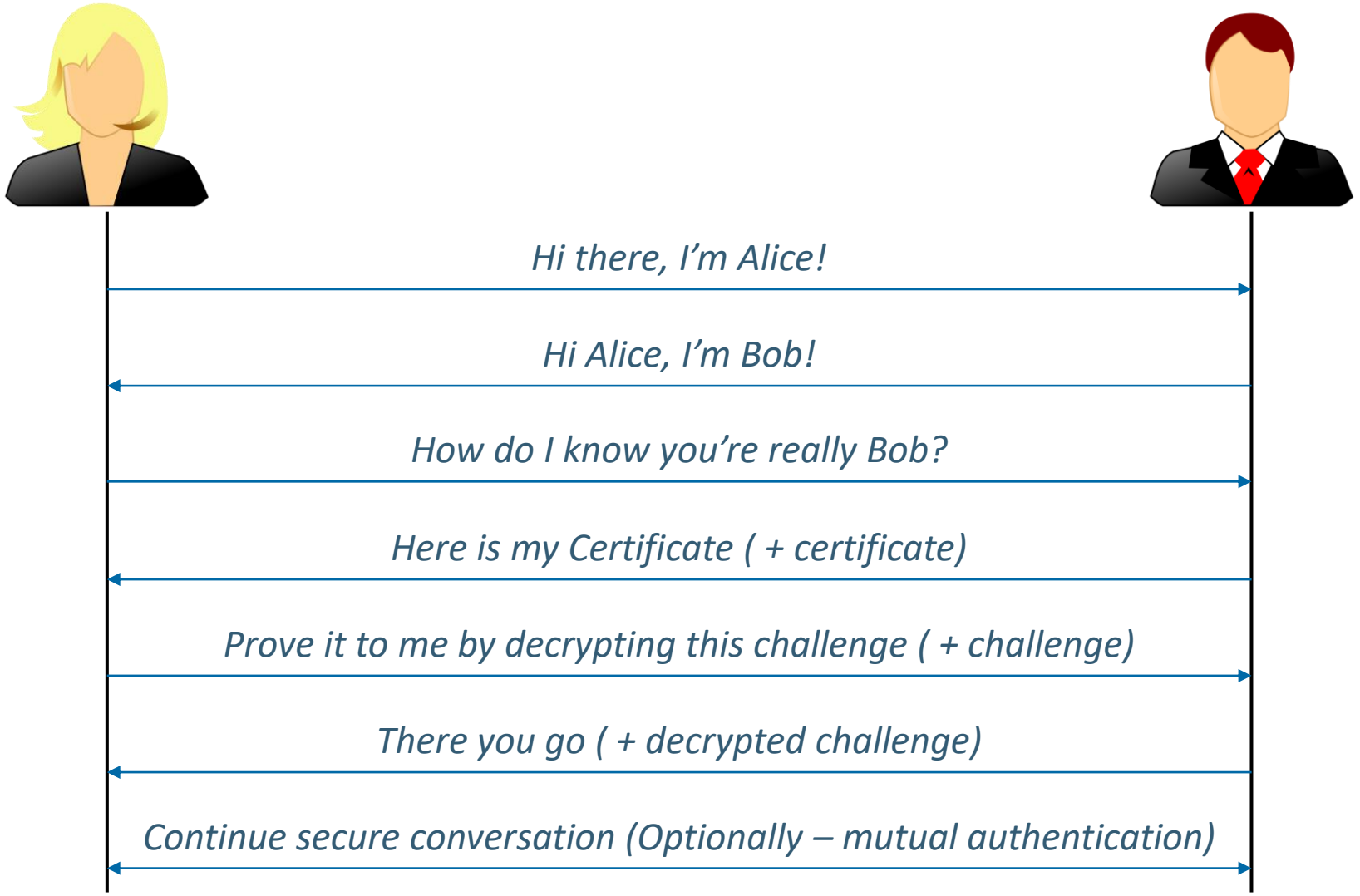
Certificate Authority

- The entity which issues certificates
- Trusted by the Relying Parties
  - Public trusted root certificates are pre-populated
- Various methods to verify identity

Demo

Certificate Content

Certificates 101



Building a Serverless CA using .NET

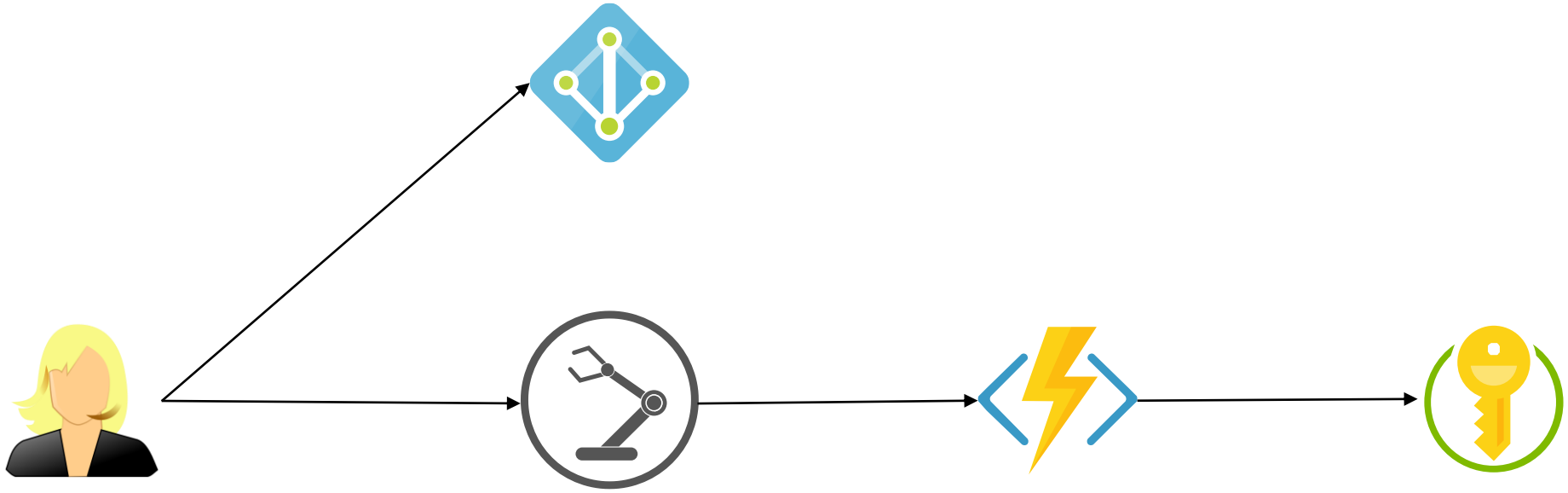
The Root Certificate

Azure Key Vault

- Safeguard cryptographic keys and other secrets
- Hardware Security Modules (HSM) as a service
- Can be replaced with AWS Certificate Manager
  - Principles will remain unchanged
  - Implementation details will defer

Scenario

Generating a new certificate on a new device

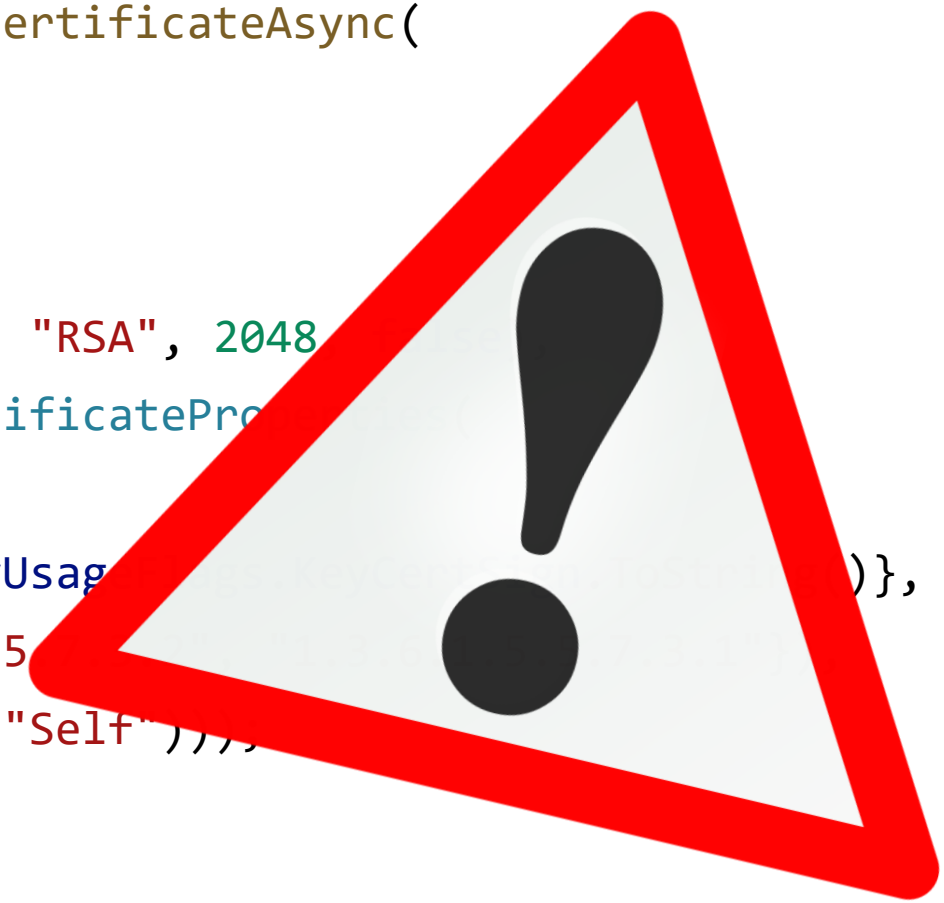


Demo

Setup Azure
Key Vault & Other
Resources

Generating the Root Certificate on Key Vault

```
var certificateOperation = await client.CreateCertificateAsync(
    _vaultBaseUrl,
    _certificateName,
    new CertificatePolicy(
        keyProperties: new KeyProperties(false, "RSA", 2048
        x509CertificateProperties: new X509CertificatePr
            "CN=" + RootSubjectName,
            keyUsage: new List<string> {X509KeyUsag
            ekus: new List<string> {"1.3.6.1.5.5
        issuerParameters: new IssuerParameters("Self")));
```



Generating the Root Certificate on Our Machine

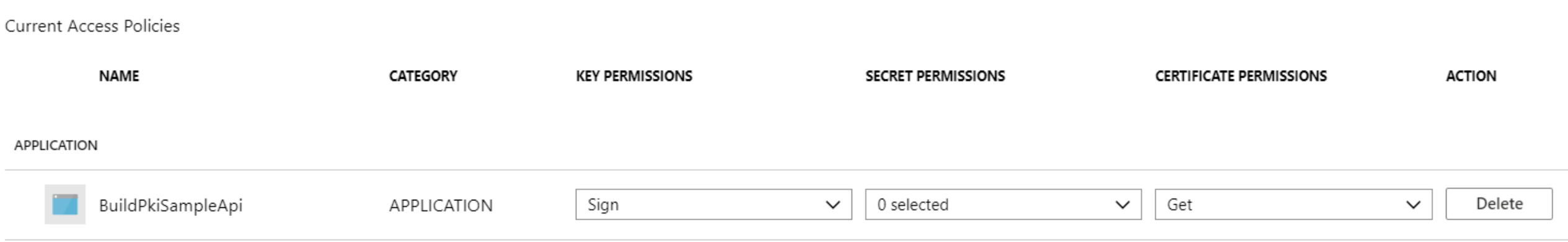
```
using var certificateKey = RSA.Create();
var subjectDistinguishedName = new X500DistinguishedName("CN=" + RootSubjectName);
var request = new CertificateRequest(subjectDistinguishedName, certificateKey,
    HashAlgorithmName.SHA256, RSASignaturePadding.Pkcs1);

request.CertificateExtensions.Add(
    new X509KeyUsageExtension(X509KeyUsageFlags.KeyCertSign, true));
request.CertificateExtensions.Add(
    new X509BasicConstraintsExtension(true, true, 1, true));
// Additional X509 extensions not shown for brevity

var certificate =
    request.CreateSelfSigned(DateTimeOffset.UtcNow, DateTimeOffset.UtcNow.AddYears(1));
```

Demo

Generating the
Root Certificate

Limiting Root Certificate Access

- Use Azure Key Vault Access Policies



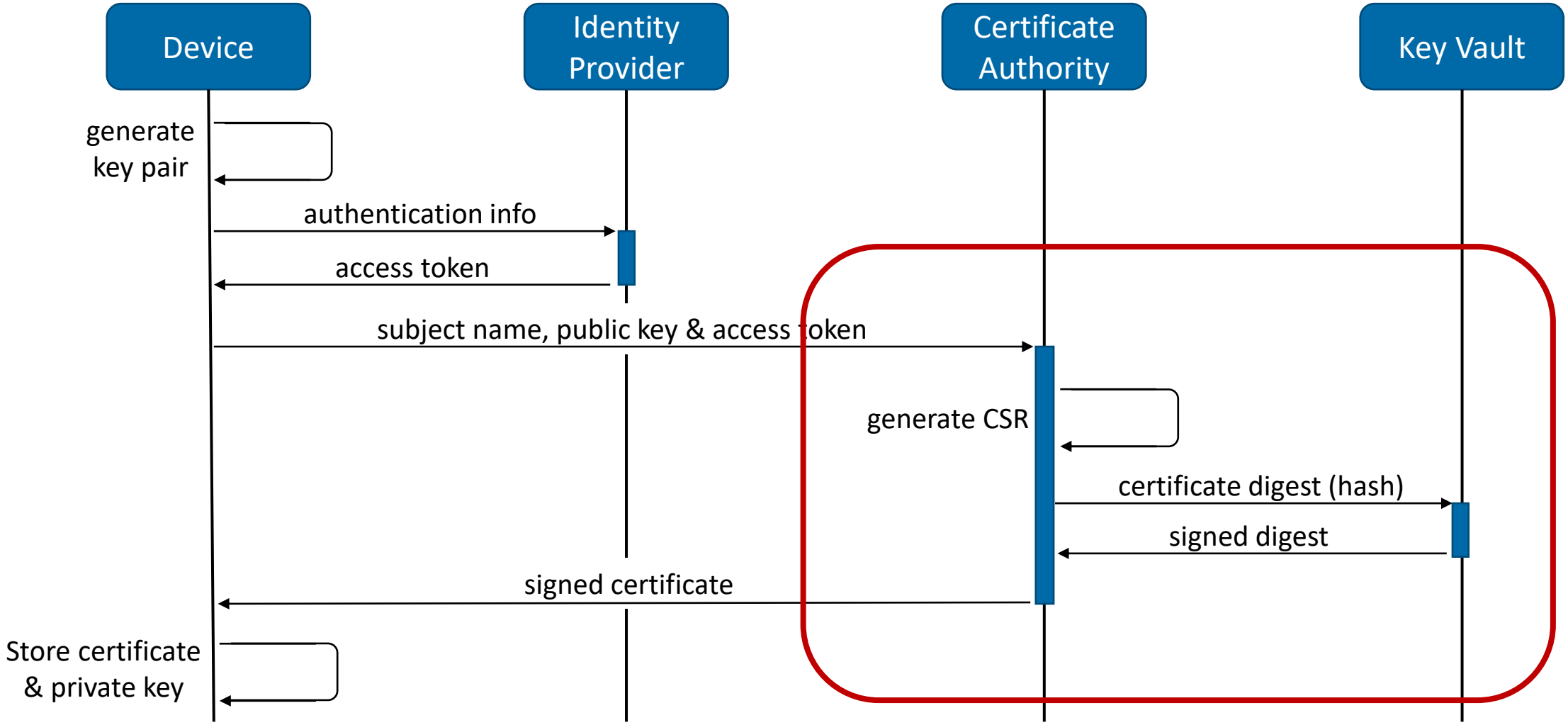
Auditing Root Certificate Access


```
{
    "time": "2016-01-05T01:32:01.2691226Z",
    "resourceId": "/SUBSCRIPTIONS/361DA5D4-A47A-4C79-AFDD-
XXXXXXXXXXXX/RESOURCEGROUPS/CONTOSOGROUP/PROVIDERS/MICROSOFT.KEYVAULT/VAULTS/CONTOSOKEYVAU
LT",
    "operationName": "VaultGet",
    "operationVersion": "2015-06-01",
    "category": "AuditEvent",
    "resultType": "Success",
    "resultSignature": "OK",
    "resultDescription": "",
    "durationMs": "78",
    "callerIpAddress": "104.40.82.76",
    "correlationId": "",
    "identity": {
        "claim": {
            "http://schemas.microsoft.com/identity/claims/objectidentifier":
                "d9da5048-2737-4770-bd64-XXXXXXXXXXXX"
```

```
    "durationMs": "78",
    "callerIpAddress": "104.40.82.76",
    "correlationId": "",
    "identity": {
        "claim": {
            "http://schemas.microsoft.com/identity/claims/objectidentifier":
                "d9da5048-2737-4770-bd64-XXXXXXXXXXXX",
            "http://schemas.xmlsoap.org/ws/2005/05/identity/claims/upn":
                "live.com#username@outlook.com",
            "appid": "1950a258-227b-4e31-a9cf-XXXXXXXXXXXX"
        }
    },
    "properties": {
        "clientInfo": "azure-resource-manager/2.0",
        "requestUri": "https://control-prod-
wus.vaultcore.azure.net/subscriptions/361da5d4-a47a-4c79-afdd-
XXXXXXXXXXXX/resourcegroups/contosoresourcegroup/providers/Microsoft.KeyVault/vaults/conto
sokeyvault?api-version=2015-06-01",
        "id": "https://contosokeyvault.vault.azure.net/",
        "httpStatusCode": 200
    }
}
```

Sign a Request Using the Root Certificate

Sign a Request Using the Root Certificate



Generate Certificate Signing Request (CSR)

```
var parameters = new RSAParameters
    { Modulus = publicKey.Modulus, Exponent = publicKey.Exponent };
var certificateKey = RSA.Create(parameters);

var subjectDistinguishedName = new X500DistinguishedName("CN=" + subjectName);
var request = new CertificateRequest(subjectDistinguishedName, certificateKey,
    HashAlgorithmName.SHA256, RSASignaturePadding.Pkcs1);
request.CertificateExtensions.Add(
    new X509KeyUsageExtension(
        X509KeyUsageFlags.DigitalSignature | X509KeyUsageFlags.KeyEncipherment, true));
request.CertificateExtensions.Add(
    new X509BasicConstraintsExtension(false, true, 0, true));
// Additional X509 not shown for brevity

return request;
```

Sign Certificate with Root Key

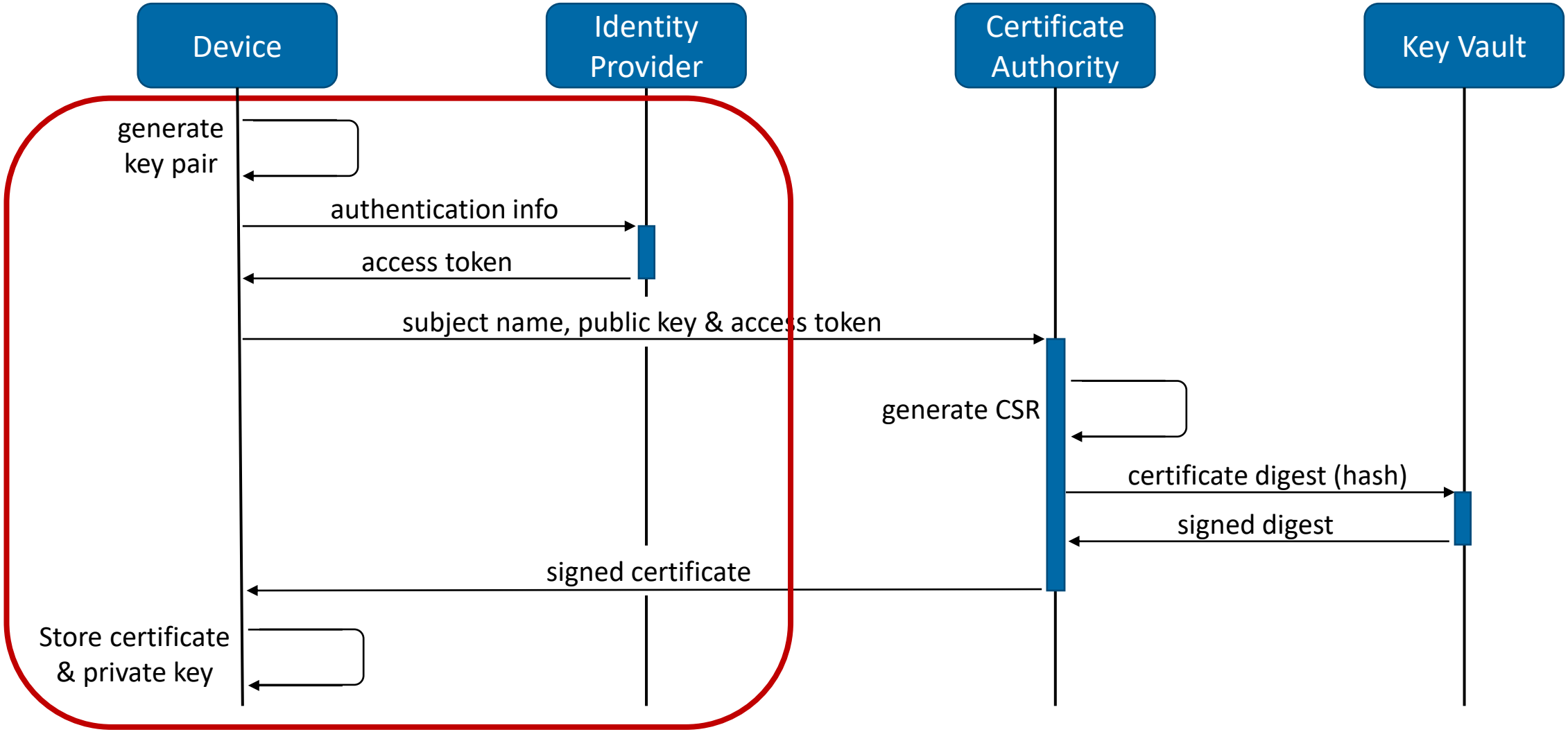
```
CertificateRequest request = CreateCertificateRequest(subjectName, certificateKey);
byte[] certificateSerialNumber = await _serialNumberGenerator.GenerateSerialAsync();

RSA rsaKeyVault = _keyVaultClient.ToRSA(
    certificateBundle.KeyIdentifier, issuerCertificate);
var generator = X509SignatureGenerator.CreateForRSA(
    rsaKeyVault, RSASignaturePadding.Pkcs1);

var certificate = request.Create(
    issuerCertificate.SubjectName, generator,
    DateTime.Today, DateTime.Today.AddYears(1),
    certificateSerialNumber);
```

Demo

Serverless CA using
.NET & Azure Functions

Authoring Certificate Subscribers using .NET

Sign a Request Using the Root Certificate



Getting an Access Token for Azure Functions

```
var auth = await authHelper.AcquireTokenAsync();  // AAD Token

var client = new HttpClient
    { BaseAddress = new Uri(configuration.BaseUrl) };
var request = new {access_token = auth.AccessToken};
var httpContent =  ... // JSON serialization
var responseMessage = await client.PostAsync(".auth/login/aad", httpContent);

var serializedResponse = await responseMessage.Content.ReadAsStringAsync();
dynamic response = JsonConvert.DeserializeObject<dynamic>(serializedResponse);
return response.authenticationToken;
```

Issue Certificate

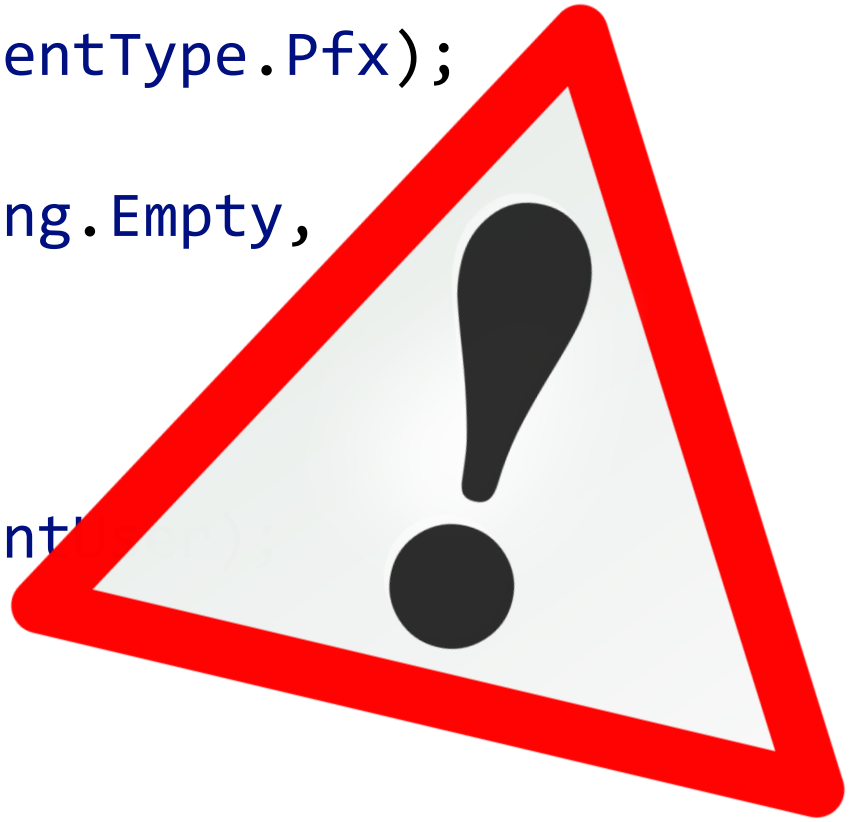
```
var key = RSA.Create();
var publicParameters = key.ExportParameters(false);
var request = new IssueCertificateRequest(
    subjectName, publicParameters);

var httpContent = new StringContent(
    JsonConvert.SerializeObject(request),
    Encoding.UTF8,
    MediaTypeNames.Application.Json);
```

Issue Certificate (Cont.)

```
var client = new HttpClient {BaseAddress = ...};
client.DefaultRequestHeaders.Add("X-ZUMO-AUTH", accessToken);
var responseMessage =
    await client.PostAsync("api/issueCertificate", httpContent);

var serializedResponse =
    await responseMessage.Content.ReadAsStringAsync();
var response = JsonConvert.DeserializeObject<IssueCertificateResponse>(
    serializedResponse);
var certificate = new X509Certificate2(
    Convert.FromBase64String(response.Certificate));
return certificate;
```

Store Certificate With Private Key

```
var certificateWithPrivateKey =
    certificate.CopyWithPrivateKey(key);
var rawCertificate =
    certificateWithPrivateKey.Export(X509ContentType.Pfx);
var persistableCertificate =
    new X509Certificate2(rawCertificate, string.Empty,
        X509KeyStorageFlags.PersistKeySet |
        X509KeyStorageFlags.UserKeySet);

var store = new X509Store(StoreLocation.Current
store.Open(OpenFlags.ReadWrite);
store.Add(persistableCertificate);
```

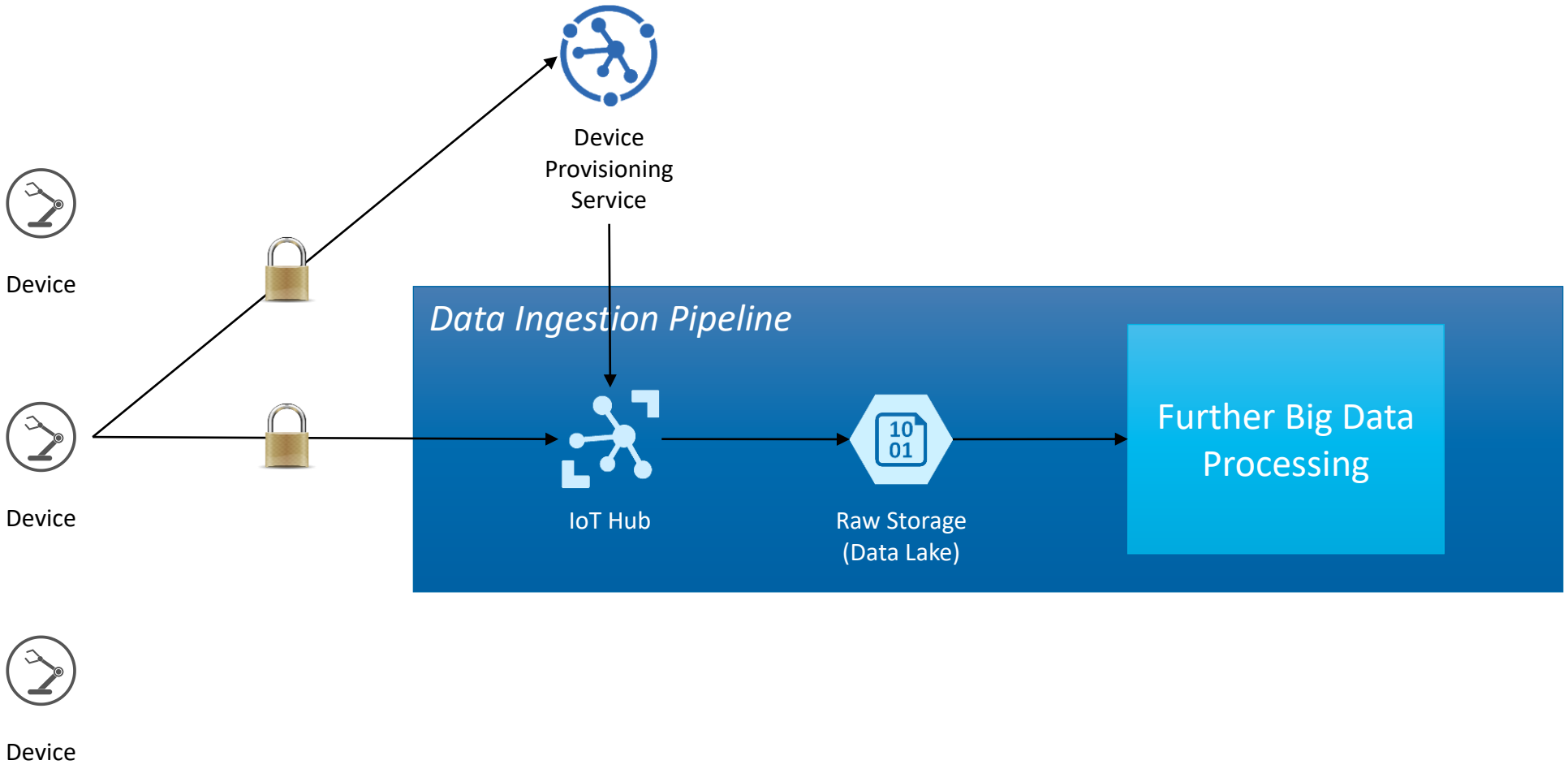


Demo

Certificate Subscribers using .NET

Using the Generated Certificates

IoT Data Ingestion (Reminder)



Sending Data Using the Generated Certificate

```
X509Certificate2 certificate =
    LoadCertificate(configuration.DeviceName);
var security =
    new SecurityProviderX509Certificate(certificate);
var transport = new ProvisioningTransportHandlerAmqp(
    TransportFallbackType.TcpOnly);

var provClient = ProvisioningDeviceClient.Create(
    GlobalDeviceEndpoint, configuration.DpsIdScope,
    security, transport);
DeviceRegistrationResult registrationResult =
    await provClient.RegisterAsync();
```

Demo

End-to-End Operation

Takeaways

Takeaways

- Certificates are hard, but crucial, to get right
- Don’t author an entire PKI from scratch
  - Customize an existing solution where appropriate
- IoT is one scenario where I encountered a need for a custom PKI
- Handling certificates with .NET is surprisingly undocumented
  - With and without Azure Key Vault
- Azure Key Vault is a great platform to base a CA on
- The sample is just a sample, but is derived from a production system
  - Can base on it and form your own solution

Resources

- Source Code
  - https://github.com/estiller/build-pki-net-azure-sample
- NuGet package to integrate Key Vault with .NET Cryptographic Keys
  - https://github.com/onovotny/RSAKeyVaultProvider
- Additional resources
  - https://smallstep.com/blog/everything-pki.html
  - https://docs.microsoft.com/en-in/azure/key-vault/certificate-scenarios
  - https://docs.microsoft.com/en-us/azure/key-vault/key-vault-logging

Thank you!

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