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FoggyWeb: Targeted NOBELIUM malware leads to persistent backdoor

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September 27, 2021



Threat actors

Credential theft

Midnight Blizzard (NOBELIUM)

Microsoft continues to work with partners and customers to track and expand our knowledge of the threat actor we refer to as NOBELIUM, the actor behind the [SUNBURST backdoor](#), [TEARDROP malware](#), and [related components](#). As we stated before, we suspect that NOBELIUM can draw from significant operational resources often showcased in their campaigns, including custom-built malware and tools. In March 2021, we profiled NOBELIUM’s [GoldMax](#), [GoldFinder](#), and [Sibot malware](#), which it uses for layered persistence. We then followed that up with another post in May, when we analyzed the actor’s early-stage toolset comprising [EnvyScout](#), [BoomBox](#), [NativeZone](#), and [VaporRage](#).

This blog is another in-depth analysis of newly detected NOBELIUM malware: a post-exploitation backdoor that Microsoft Threat Intelligence Center (MSTIC) refers to as **FoggyWeb**. As mentioned in previous blogs, NOBELIUM employs multiple tactics to pursue credential theft with the objective of gaining admin-level access to Active Directory Federation Services ([AD FS](#)) servers. Once NOBELIUM obtains credentials and successfully compromises a server, the actor relies on that access to maintain persistence and deepen its infiltration using sophisticated malware and tools. NOBELIUM uses FoggyWeb to remotely exfiltrate the configuration database of compromised AD FS servers, decrypted [token-signing certificate](#), and [token-decryption certificate](#), as well as to download and execute additional components. Use of FoggyWeb has been observed in the wild as early as April 2021.

Microsoft has notified all customers observed being targeted or compromised by this activity. If you believe your organization has been compromised, we recommend that you

- Audit your on-premises and cloud infrastructure, including configuration, per-user and per-app settings, forwarding rules, and other changes the actor might have made to maintain their access
- Remove user and app access, review configurations for each, and re-issue new, strong credentials following documented industry best practices.
- Use a [hardware security module \(HSM\)](#), as described in [securing AD FS servers](#) to prevent the exfiltration of secrets by FoggyWeb.

Microsoft security products have implemented detections and protections against this malware. [Indicators of compromise \(IOCs\)](#), [mitigation guidance](#), [detection details](#), and [hunting queries](#) for Azure Sentinel and Microsoft 365 Defender customers are provided at the end of this analysis and in the product portals. Active Directory Federation Services ([AD FS](#)) servers run on-premises and customers can also follow detailed guidance on [securing AD FS servers](#) against attacks.

FoggyWeb: Backdoor targeting AD FS

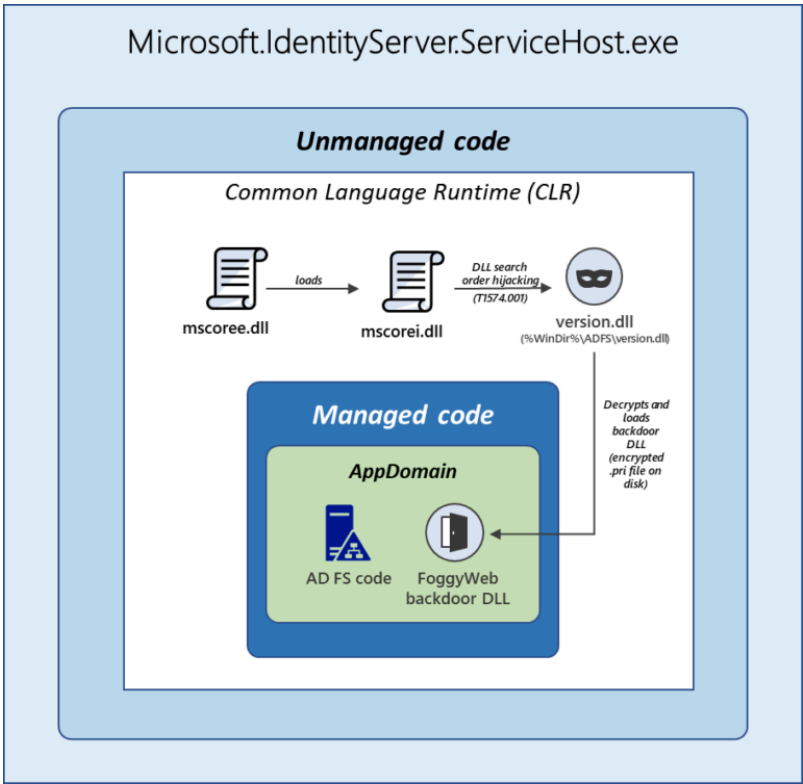
FoggyWeb is a passive and highly targeted backdoor capable of remotely exfiltrating sensitive information from a compromised AD FS server. It can also receive additional malicious components from a command-and-control (C2) server and execute them on the compromised server.

After compromising an AD FS server, NOBELIUM was observed dropping the following two files on the system (administrative privileges are required to write these files to the folders listed below):

- `%WinDir%\ADFS\version.dll`
- `%WinDir%\SystemResources\Windows.Data.TimeZones\pris\Windows.Data.TimeZones.zh-PH.pri`

FoggyWeb is stored in the encrypted file `Windows.Data.TimeZones.zh-PH.pri`, while the malicious file `version.dll` can be described as its loader. The AD FS service executable `Microsoft.IdentityServer.ServiceHost.exe` loads the said DLL file via the [DLL search order hijacking](#) technique that involves the core Common Language Runtime (CLR) DLL files (described in detail in the FoggyWeb loader section). This loader is responsible for loading the encrypted FoggyWeb backdoor file and utilizing a custom Lightweight Encryption Algorithm (LEA) routine to decrypt the backdoor in memory.

After de-obfuscating the backdoor, the loader proceeds to load FoggyWeb in the execution context of the AD FS application. The loader, an unmanaged application, leverages the CLR hosting interfaces and APIs to load the backdoor, a managed DLL, in the same Application Domain within which the legitimate AD FS managed code is executed. This grants the backdoor access to the AD FS codebase and resources, including the AD FS configuration database (as it inherits the AD FS service account permissions required to access the configuration database).



When loaded, the FoggyWeb backdoor (originally named `Microsoft.IdentityServer.WebExtension.dll` by its developer) functions as a passive and persistent backdoor that allows abuse of the Security Assertion Markup Language (SAML) token. The backdoor configures HTTP listeners for actor-defined URIs that mimic the structure of the legitimate URIs used by the target’s AD FS deployment. The custom listeners passively monitor all incoming HTTP GET and POST requests sent to the AD FS server from the intranet/internet and intercept HTTP requests that match the custom URI patterns defined by the actor. This version of FoggyWeb

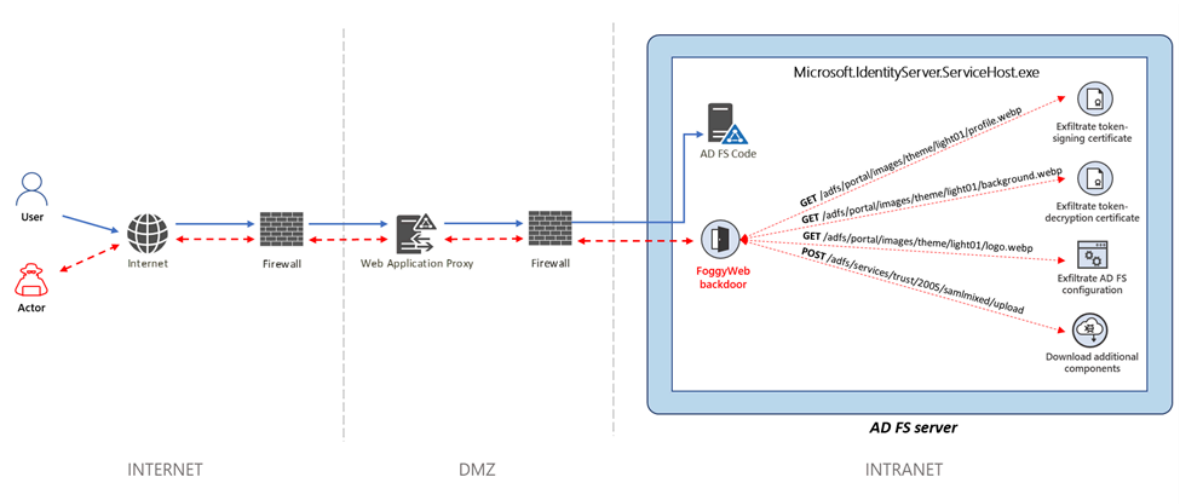
configures listeners for the following hardcoded URI patterns (which might vary per target):

- HTTP GET URI pattern:
 - `/adfs/portal/images/theme/light01/profile.webp`
 - `/adfs/portal/images/theme/light01/background.webp`
 - `/adfs/portal/images/theme/light01/logo.webp`
- HTTP POST URI pattern:
 - `/adfs/services/trust/2005/samlmixed/upload`

Each HTTP GET/POST URI pattern above corresponds to a C2 command:

- When the AD FS server receives an HTTP GET request containing the URI pattern `/adfs/portal/images/theme/light01/profile.webp`, the backdoor retrieves the **token signing certificate** of the compromised AD FS server and then obfuscates and returns the certificate to the issuer of the request.
- Similarly, when the AD FS server receives an HTTP GET request containing the URI pattern `/adfs/portal/images/theme/light01/background.webp`, the backdoor retrieves the **token decryption certificate** of the compromised AD FS server and then obfuscates and returns the certificate to the issuer of the request.
- When the AD FS server receives an HTTP GET request containing the URI pattern `/adfs/portal/images/theme/light01/logo.webp`, the backdoor retrieves the AD FS configuration data of the compromised server, obfuscates the data, and returns the obfuscated data to the issuer of the request.
- When the AD FS server receives an HTTP POST request containing the URI pattern `/adfs/services/trust/2005/samlmixed/upload`, the backdoor treats the obfuscated and compressed POST data as either .NET assembly or source code. If assembly, the backdoor executes the assembly in the execution context of the AD FS process. If source code, the backdoor dynamically compiles the source code and proceeds to execute the resulting memory-resident assembly in the execution context of the AD FS process.

The diagram below illustrates the methodology used by the actor to communicate with the FoggyWeb backdoor located on a compromised internet-facing AD FS server.



Since FoggyWeb runs in the context of the main AD FS process, it inherits the AD FS service account permissions required to access the AD FS configuration database. This contrasts with tools such as *ADFSDump* that must be executed under the user context of the AD FS service account. Also, because FoggyWeb is loaded into the same application domain as the AD FS managed code, it gains programmatic access to the legitimate AD FS classes, methods, properties, fields, objects, and components that are subsequently leveraged by FoggyWeb to facilitate its malicious operations. For example, this allows FoggyWeb to gain access to the AD FS configuration data without connecting to the WID named pipe or manually running SQL queries to retrieve configuration information (for example, to obtain the *EncryptedPfx* blob from the configuration data). FoggyWeb is also AD FS version-agnostic; it does not need to keep track of legacy versus modern configuration table names and schemas, named pipe names, and other version-dependent properties of AD FS.

FoggyWeb loader

The file *version.dll* is a malicious loader responsible for loading an encrypted backdoor file from the file system, decrypting the backdoor file, and loading it in memory. This malicious DLL, which shares a name with a legitimate Windows DLL located in the %WinDir%\System32\ folder, is meant to be placed in the main AD FS folder %WinDir%\ADFS\, where the AD FS service executable *Microsoft.IdentityServer.ServiceHost.exe* is located (for reasons described later in this section).

When the AD FS service (*adfssrv*) is started, the service executable *Microsoft.IdentityServer.ServiceHost.exe* gets executed. As a .NET-based managed application, *Microsoft.IdentityServer.ServiceHost.exe* imports an unmanaged Windows DLL named *mscoree.dll*.

The file *mscoree.dll* dynamically loads another unmanaged Windows/CLR DLL named *mscoreei.dll*. As shown below, *mscoreei.dll* has a delay load import (Delay Import) named *version.dll*.

NOBELIUM, with existing administrative permissions, was observed to drop a malicious loader named *version.dll* in the %WinDir%\ADFS\ folder where the AD FS service executable *Microsoft.IdentityServer.ServiceHost.exe* is located. Once the system or the AD FS service is restarted, *Microsoft.IdentityServer.ServiceHost.exe* loads *mscoree.dll*, which in turn loads *mscoreei.dll*. As mentioned above, *mscoreei.dll* has a delay load import named *version.dll*. Once loaded, instead of loading the legitimate *version.dll* from the %WinDir%\System32\ folder *mscoreei.dll* loads the malicious *version.dll* planted by the attacker in %WinDir%\ADFS\ folder (referred to as [DLL search order hijacking](#)), as shown in the call stack below.

The malicious loader *version.dll* behaves as a proxy for all legitimate *version.dll* export function calls. As shown below, it exports the same 17 function names as the legitimate version of *version.dll*.

The export functions of the malicious *version.dll* are all short stubs that call a single trampoline function labeled *TrampolineFunction*, as seen in the screenshot below.

Below is a pseudocode for the trampoline function.

This trampoline function is responsible for the following:

- Calling a function (labeled as *LoadDecryptExecuteBackdoor()* by the analyst) to load a backdoor file from the file system, and then decrypting and executing the file in memory
- Transferring execution to the initially called target function from the legitimate version of *version.dll*.

The trampoline function preserves the value of the arguments/registers intended for the function from the legitimate version of *version.dll* by saving the value of certain CPU registers. It first pushes them onto the stack before calling the

LoadDecryptExecuteBackdoor() function above and then restoring them before transferring execution to the function from the legitimate version of *version.dll*.

When called, *LoadDecryptExecuteBackdoor()* attempts to create a Windows event named *{2783c149-77a7-5e51-0d83-ac0566daff96}* to ensure that only one copy of the loader is actively running on the system. In a new thread, it then checks if the following file is present (hardcoded path string):

```
C:\Windows\SystemResources\Windows.Data.TimeZones\pris\Windows.Data.TimeZones.zh-PH.pri
```

Windows.Data.TimeZones.zh-PH.pri is an encrypted backdoor file that is placed in the folder above. MSTIC refers to this backdoor file as FoggyWeb, and our analysis is in the next section.

Microsoft.IdentityServer.ServiceHost.exe in and of itself is an unmanaged Windows executable that is generated when the high-level AD FS managed code is compiled. When executed, the unmanaged code inside *Microsoft.IdentityServer.ServiceHost.exe* leverages Common Language Runtime (CLR) to run the managed AD FS code within a virtual runtime environment. This virtual runtime environment is comprised of one or more application domains, which provide a unit of isolation for the runtime environment and allow different applications to run inside separate containers within a process. The managed AD FS code is executed within an application domain inside the virtual runtime environment.

The FoggyWeb backdoor (also a managed DLL) is intended to run alongside the legitimate AD FS code (that is, within the same application domain). This means that for the FoggyWeb loader to load the backdoor alongside the AD FS code, it needs to gain access to the same application domain that the AD FS code is executed within. Since the FoggyWeb loader *version.dll* is an unmanaged application, it cannot directly access the virtual runtime environment that the managed AD FS code is executed within. The loader overcomes this limitation and loads the backdoor alongside the AD FS code by leveraging the CLR hosting interfaces and APIs to access the virtual runtime environment within which the AD FS code is executed.

The loader performs the following high-level actions:

- Enumerate all CLR's loaded in the AD FS process
Microsoft.IdentityServer.ServiceHost.exe
- For each CLR, enumerate all running application domains and perform the following actions for each domain:
 - Read the contents of the following encrypted FoggyWeb backdoor file into memory:
C:\Windows\SystemResources\Windows.Data.TimeZones\pris\Windows.Data.TimeZones.zh-PH.pri
 - Decrypt the encrypted FoggyWeb backdoor file using the Lightweight Encryption Algorithm (LEA). The LEA-128 key schedule uses the following hardcoded master key to generate the round keys:

After decrypting each 16-byte cipher block, the loader uses the following XOR key to decode each individual decrypted/plaintext block:

This is equivalent to first LEA decrypting the entire file and then XOR decoding the decrypted data (instead of decrypting and XOR decoding each individual 16-byte block).

- Create a Safe Array and copy the decrypted FoggyWeb backdoor bytes to the array. It then calls the *Load()* function for the current application domain to load the FoggyWeb DLL into the application domain. After the FoggyWeb DLL is loaded into the current application domain, the loader invokes the following method from the DLL:
Microsoft.IdentityServer.WebExtension.WebHost.

At this point in the execution cycle, the FoggyWeb DLL is loaded into one or more application domains where the legitimate AD FS code is running. This means the backdoor code runs alongside the AD FS code with the same access and permissions as the AD FS application. Because the backdoor is loaded in the same application domain as the AD FS code, it gains programmatical access to the legitimate classes, methods, properties, fields, objects, and components used by various AD FS modules to carry out their legitimate functionality. Such access allows the FoggyWeb backdoor to directly interact with the AD FS codebase (that is, not an external disk-resident tool) and selectively invoke native AD FS methods needed to facilitate its malicious operations.

FoggyWeb backdoor

This malicious memory-resident DLL (originally named *Microsoft.IdentityServer.WebExtension.dll* by its developer) functions as a backdoor targeting AD FS. It is loaded by the main AD FS service process *Microsoft.IdentityServer.ServiceHost.exe* through a malicious loader component.

When loaded, the backdoor starts an HTTP listener that listens for HTTP GET and POST requests containing the following URI patterns:

- HTTP GET URI pattern: */adfs/portal/images/theme/light01/*
- HTTP POST URI pattern: */adfs/services/trust/2005/samlmixed/upload*

As shown below, the URI patterns are hardcoded in the backdoor and mimic the structure of the legitimate URIs used by the target’s AD FS deployment.

Once the backdoor receives an HTTP request that contains one of the URI patterns above, the listener proceeds to handle the request using either an HTTP GET or HTTP POST callback/handler method (*ProcessGetRequest()* and *ProcessPostRequest()*, respectively).

HTTP GET handler

The incoming HTTP GET requests that contain the URI pattern */adfs/portal/images/theme/light01/* are handled by backdoor's *ProcessGetRequest()* method.

If an incoming HTTP GET request is issued for a file/resource with the file extension of *.webp*, the *ProcessGetRequest()* method proceeds to handle the request. Otherwise, the request is ignored by the backdoor. Also, if the requested file name matches one of the three hardcoded names below, the backdoor treats the request as a C2 command issued by the attacker.

The following URL patterns are treated as C2 commands:

- */adfs/portal/images/theme/light01/profile.webp*
- */adfs/portal/images/theme/light01/background.webp*
- */adfs/portal/images/theme/light01/logo.webp*

The first two C2 commands, *profile.webp* and *background.webp* (*UrlGetFileNames[0]* and *UrlGetFileNames[1]* in the screenshot above), are handled by calling the backdoor's *Service.GetCertificate()* method.

As the name suggests, this method is responsible for retrieving an AD FS certificate (either the token- signing or the token encryption certificate, depending on the value of the *certificateType* parameter passed to the method) from the AD FS service configuration database.

Analyst note: Refer to the Appendix for an in-depth analysis of the *Service.GetCertificate()* method and how it obtains and decrypts either the token signing or encryption certificate.

As shown in the screenshot above, when the C2 command *profile.webp* (*UrlGetFileNames[0]*) is issued to the backdoor (by issuing an HTTP GET request for the URI */adfs/portal/images/theme/light01/profile.webp*), the backdoor retrieves the ***token-signing certificate*** of the compromised AD FS server. Similarly, when the C2

command *background.webp* (*UrlGetFileNames[1]*) is issued to the backdoor (by issuing an HTTP GET request for the URI */ads/portal/images/theme/light01/background.webp*), the backdoor retrieves the ***token encryption certificate*** of the compromised AD FS server.

The third C2 command, *logo.webp* (*UrlGetFileNames[2]*), is triggered by sending an HTTP GET request to the following URI: */ads/portal/images/theme/light01/logo.webp*. The C2 command is handled by calling the backdoor's *GetInfo()* method.

The *GetInfo()* method is responsible for dumping the AD FS service configuration data of the compromised server.

As shown above, the AD FS service configuration data is obtained via the *ServiceSettingsData* property, which retrieves the data from the AD FS service configuration database, Windows Internal Database (WID).

Before returning the output of the C2 commands (that is, the token-signing certificate, the token encryption certificate, or the AD FS service configuration data) to the C2 in an HTTP 200 response, the backdoor first obfuscates the output by calling its method named *GetWebpImage()*.

The *GetWebpImage()* method is in charge of masquerading the output of the C2 commands as a legitimate WebP file (by adding appropriate RIFF/WebP file header magic/fields) and encoding the resulting WebP file.

GetWebpImage() uses the following helper methods to create and encode the fake WebP file that contains the C2 command output:

- *GetWebpImage()* first invokes the *Webp.GetFrame()* method, which is responsible for compressing the output of the C2 command and copying the compressed version to a new array (0 padded to a multiple of 32 bytes). The length of the compressed data is added as the first four bytes of the new array.

To compress the data, *GetFrame()* invokes the *Common.Compress()* method, which is used to compress the data by leveraging the C# GZipStream compression class.

For demonstration purposes, assume the C2 command yields the following data (a 256-byte pseudo-randomly generated byte array).

Given the data above (that is, sample C2 command output), *GetFrame()* returns the following byte array.

- Next, *GetWebpImage()* invokes the *Webp.GetWebpHeader()* method, passing in the size of the byte array returned by *GetFrame()* in the step above. *GetWebpHeader()* is responsible for creating and returning an array containing custom RIFF WebP file magic/header bytes.

The array variable above contains the following 32-byte hardcoded RIFF/WebP header bytes.

If the size of the array passed to *GetWebpHeader()* (returned by *GetFrame()*) exceeds 8,192 bytes, the bytes at index 26 and 28 of the header bytes (initially set to 0x00) are replaced with 0x80. Otherwise, the bytes at index 26 and 28 are replaced with 0x40, as shown below.

GetWebpHeader() then returns the custom RIFF/WebP header above to *GetWebpImage()*.

- Next, *GetWebpImage()* creates a new array by appending the custom RIFF/WebP header bytes returned by *GetWebpHeader()* to the array returned by *GetFrame()* (the array containing the compressed version of the C2 command output).

GetWebpImage() calls the *Common.ProtectData()* method of the backdoor to encode the portion of the new array that contains the compressed bytes (that is, it does not encode the custom RIFF/WebP header). As the second argument, *GetWebpImage()* passes the offset of the first compressed byte to *ProtectData()* (as shown in the table above, 0x20 or 32 is the offset of the first compressed byte in this case). *ProtectData()* uses a *dynamic* XOR key and a custom XOR methodology to XOR encode the compressed data.

Initially, the 12-byte hardcoded XOR key array contains the following (seed) bytes.

As shown in the screenshot above, each byte of compressed data is XOR'd with a byte from the XOR key array. The first byte of the compressed data (0x17) is XOR'd with the XOR key byte located at offset 8 of the key array (0x77).

After XOR'ing the first byte of the compressed data with the XOR key byte located at offset 8 of the key array, the XOR key byte itself gets overwritten with a new value.

For example, the XOR key byte located at offset 8 of the XOR key array (0x77) gets overwritten with 0xEE via the following operations.

The second byte of the compressed data (0x01) is XOR'd with the XOR key byte located at offset 9 of the key array ($33 \% 12 = 9$) and so on until the key rolls to the first byte of the XOR array (as mentioned above, the XOR key bytes get overwritten after each encoding operation). Below is the XOR encoded version of the sample compressed array.

After the steps outlined above, *GetWebpImage()* returns the following sample data to the method that invokes it to obfuscate and conceal the output of each C2 command (*ProcessGetRequest()*).

As previously mentioned, *ProcessGetRequest()* returns the fake RIFF/WebP file generated above (containing stolen token-signing certificate, token encryption certificate, or the AD FS service configuration data) to the C2 in an HTTP 200 response.

If the backdoor cannot execute a C2 command successfully, it returns an HTTP 404 response to the C2 instead.

HTTP POST handler

Incoming HTTP POST requests that match the URI pattern */ads/services/trust/2005/samlmixed/upload* are handled by the *ProcessPostRequest()* method.

This method ensures that the *ContentType* value of an incoming HTTP POST request ends with "xml" (case-insensitive), and the HTTP POST data contains two XML elements named *X509Certificate* and *SignatureValue* (for example, a blob that starts with the string "<X509Certificate>" and ends with the string "</X509Certificate>").

If the XML data contains the two elements, the backdoor performs the following actions:

- Decode the values of the *SignatureValue* and *X509Certificate* elements by first decoding the values using Base64 and then calling the *Common.UprotectData()* method on each decoded value.

The *UprotectData()* method treats the first two bytes of the Base64 decoded value as a two-byte XOR key. It invokes the *Common.ProtectData()* method (covered in the previous section) on the rest of the data (that is, third byte on) and then uses the two-byte XOR key to XOR decode the data returned by *Common.ProtectData()*. In other words, *UprotectData()* leverages *Common.ProtectData()* to remove the first layer of XOR encoding and then another XOR routine to remove the second layer of XOR encoding applied to the data.

- Invoke the *Service.ExecuteAssembly()* method to handle the decoded *SignatureValue* and *X509Certificate* values. As shown below, the decoded *X509Certificate* value is the first GZip decompressed/inflated by calling the *Common.Decompress()* method.

In a new thread, *Service.ExecuteAssembly()* calls *Service.ExecuteAssemblyRoutine()* method to handle the data.

- *ExecuteAssemblyRoutine()* checks if the decoded *X509Certificate* value starts with "MZ" (or the bytes *0x4D 0x5A*, the hexadecimal representation of the decimal numbers 77 and 90, as seen in the screenshot below).

- If the decoded *X509Certificate* value starts with "MZ," the backdoor treats the decoded data as a .NET-based assembly/payload and proceeds to call its *Service.ExecuteBinary()* method to load and execute the DLL payload in memory. After loading the DLL in memory, *ExecuteBinary()* proceeds to invoke a specific method from the loaded DLL. The method name and parameters needed to invoke the method are supplied to the backdoor within the decoded *SignatureValue* data.

If the decoded *X509Certificate* value *does not* start with MZ, the backdoor treats the decoded *X509Certificate* value as source code for a C#-based payload and calls its *Service.ExecuteSource()* method to dynamically compile and execute the payload in memory.

After handling the HTTP POST request containing the XML elements *X509Certificate* and *SignatureValue*, the backdoor responds to the request with an HTTP 204 response code. If the HTTP POST does not have the elements mentioned above, the backdoor responds to the request with an HTTP 404 response code.

Appendix: Obtaining and decrypting AD FS tokens

As the name suggests, the *Service.GetCertificate()* method is responsible for retrieving an AD FS certificate (either the token- signing or the token encryption certificate, depending on the value of the *certificateType* parameter passed to the method) from the AD FS service configuration database.

The method performs the following actions to retrieve the desired certificate:

- Invoke another one of its methods named *GetServiceSettingsDataProvider()* to create an instance of type *Microsoft.IdentityServer.PolicyModel.Configuration.ServiceSettingsDataProvider* from the already loaded assembly *Microsoft.IdentityServer*.
- Invoke the *GetServiceSettings()* member/method of the above *ServiceSettingsDataProvider* instance to obtain the AD FS service configuration settings.
- Obtain the value of the AD FS service settings (from the *SecurityTokenService* property), extract the value of the *EncryptedPfx* blob from the service settings, and decode the blob using Base64.

- Invoke another method named *GetAssemblyByName()* to enumerate all loaded assemblies by name and locate the already loaded assembly *Microsoft.IdentityServer.Service*. This method retrieves the value of two fields named *_state* and *_certificateProtector* from an object of type *Microsoft.IdentityServer.Service.Configuration.AdministrationServiceState* (from the *Microsoft.IdentityServer.Service* assembly).

The *AdministrationServiceState* class/object contains configuration information necessary for the execution and handling of client requests. The field *_state* is used to maintain the current state of the *AdministrationServiceState* class/object (screenshot from *Microsoft.IdentityServer.Service.dll*).

The *AdministrationServiceState* object (stored in the *_state* field) contains another field named *_certificateProtector*.

The field *_certificateProtector* stores an instance of the Data Protector class *DkmDataProtector* for Distributed Key Management (DKM). The *DkmDataProtector* class implements a method named *Unprotect()*, which ultimately calls the *Unprotect()* method of DKM/IDKM (screenshot from *Microsoft.IdentityServer.dll*).

The DKM *Unprotect()* method inherits a method named *Unprotect()* from *Microsoft.IdentityServer.Dkm.DKMBase* (screenshot from *Microsoft.IdentityServer.Dkm.dll*).

The *Unprotect()* method from *Microsoft.IdentityServer.Dkm.DKMBase* (shown above) provides the functionality to decrypt the encrypted certificate (a PKCS12 object) stored in the *EncryptedPfx* blob.

Armed with the knowledge about the availability of the *Unprotect()* method accessible via the *_certificateProtector* field, the backdoor invokes the *Unprotect()* method to decrypt the encrypted certificate stored in the *EncryptedPfx* blob of the desired certificate type (either the AD FS token signing or encryption certificate).

A variant of the technique described in this Appendix was publicly presented by Douglas Bienstock and Austin Baker at the TROOPERS conference in 2019 ([I am AD FS and so can you: Attacking Active Directory Federated Services](#)). However, the method used by FoggyWeb differs from the publicly presented method, in that FoggyWeb leverages the *_state* and *_certificateProtector* fields from the *AdministrationServiceState* class/object to facilitate access to the Data Protector class *DkmDataProtector* (used to gain access to and invoke the *Unprotect()* method).

Indicators of compromise (IOCs)

Type	Threat Name	Threat Type	Indicator
MD5	FoggyWeb	Loader	5d5a1b4fafaf0451151d552d8eeb73ec
SHA-1	FoggyWeb	Loader	c896ece073dd01191cbc1d462bc2f47161828a83
SHA-256	FoggyWeb	Loader	231b5517b583de102cde59630c3bf938155d17037162f663874e4662af2481b1
		Backdoor	
MD5	FoggyWeb	(encrypt d)	9ff9401315d0f7258a9fcde0cfdef02b
		Backdoor	
SHA-1	FoggyWeb	(encrypt d)	4597431f26424cb814c917168fa8d74d01ab7cd1
		Backdoor	
SHA-256	FoggyWeb	(encrypt d)	da0be762bb785085d36aec80ef1697e25fb15414514768b3bcaf798dd9c9b169
		Backdoor	
MD5	FoggyWeb	(decrypt d)	e9671d294ce41fe6dbb9637dc0157a88

		Backdoor	
SHA-1	FoggyWeb	(decrypte d)	85cfecbb48fd9f498d24711c66e458e0a80cc90
SHA-256	FoggyWeb	(decrypte d)	568392bd815de9b677788addfc4fa4b0a5847464b9208d2093a8623bbecd81e6

Mitigations

Customers should review their AD FS Server configuration and implement changes to secure these systems from attacks:

- [Best Practices for securing AD FS and Web Application Proxy](#)

We strongly recommend for organizations to harden and secure AD FS deployments through the following best practices:

- Ensure only Active Directory Admins and AD FS Admins have admin rights to the AD FS system.
- Reduce local Administrators’ group membership on all AD FS servers.
- Require all cloud admins to use multi-factor authentication (MFA).
- Ensure minimal administration capability via agents.
- Limit on-network access via host firewall.
- Ensure AD FS Admins use Admin Workstations to protect their credentials.
- Place AD FS server computer objects in a top-level OU that doesn’t also host other servers.
- Ensure that all GPOs that apply to AD FS servers apply only to them and not to any other servers. This limits potential privilege escalation through GPO modification.
- Ensure that the installed certificates are protected against theft. Don’t store these on a share on the network and set a calendar reminder to ensure they get renewed before expiring (expired certificate breaks federation auth). Additionally, we recommend protecting signing keys or certificates in a [hardware security module \(HSM\)](#) attached to AD FS.
- Set logging to the highest level and send the AD FS (and security) logs to a SIEM to correlate with AD authentication as well as Azure AD (or similar).
- Remove unnecessary protocols and Windows features.
- Use a long (>25 characters) and complex password for the AD FS service account. We recommend using a [Group Managed Service Account \(gMSA\)](#) as the service account, as it removes the need for managing the service account password over time by managing it automatically.
- Update to the latest AD FS version for security and logging improvements (as always, test first).
- When federated with Azure AD follow the best practices for [securing](#) and [monitoring](#) the AD FS trust with Azure AD.

Detections

Protecting AD FS servers is key to mitigating NOBELIUM attacks. Detecting and blocking malware, attacker activity, and other malicious artifacts on AD FS servers can break critical steps in known NOBELIUM attack chains. Microsoft Defender Antivirus detects the new NOBELIUM components discussed in this blog as the following malware:

- **Loader:** *Trojan:Win32/FoggyWeb.A!dha*
- **Backdoor:** *Trojan:MSIL/FoggyWeb.A!dha*

Microsoft 365 Defender

Endpoint detection and response (EDR) capabilities in Microsoft Defender for Endpoint detect malicious behavior related to this malware which is surfaced as alerts

with the following titles:

- A suspicious DLL was loaded by the ADFS service
- Suspicious service launched
- Suspicious file dropped

Azure AD Identity Protection

This kind of attack can also be detected in the cloud using Azure AD Identity Protection. It is recommended that you monitor the [Azure AD Identity Protection](#) Risk detections report for the [“Token Issuer Anomaly” detection](#). This detection looks for anomalies in the SAML token presented to the Azure AD tenant.

Advanced hunting queries

Microsoft Defender for Endpoint

To locate related activity, run the following advanced hunting queries in Microsoft 365 Defender:

```
DeviceImageLoadEvents
| where FolderPath has @"C:\Windows\ADFS"
| where FileName has @"version.dll"
```

Azure Sentinel

Azure Sentinel customers can use the following detection queries to look for this activity:

Detection query: https://github.com/Azure/Azure-Sentinel/tree/master/Detections/MultipleDataSources/Nobelium_FoggyWeb.yaml

Indicator file: <https://github.com/Azure/Azure-Sentinel/tree/master/Sample%20Data/Feeds/FoggyWebIOC.csv>

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