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# Family Matters: Abusing Family Refresh Tokens to Gain Unauthorised Access to Microsoft Cloud Services

## Exploratory Study of Azure Active Directory Family of Client IDs

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**Keywords:** Azure Active Directory, Azure AD, OAuth, OIDC, Authentication, Authorisation, Security, FRT, Privilege Escalation.

**Abstract:** Azure Active Directory (Azure AD) is an identity and access management service used by Microsoft 365 and Azure services and thousands of third-party service providers. Azure AD uses OAuth and OpenID Connect (OIDC) protocols for authentication and authorisation, respectively. OAuth authorisation involves four parties: client, resource owner, resource server, and authorisation server. The resource owner can access the resource server using the specific client after the authorisation server has authorised the access. The authorisation is presented using a cryptographically signed Access Token, which includes the identity of the resource owner, client, and resource. During the authorisation, Azure AD assigns Access and Id Tokens that are valid for one hour and a Refresh Token that is valid for 90 days. Refresh Tokens are used for requesting new Access and Id token after their expiration. By OAuth 2.0 standard, Refresh Tokens should only be able to be used to request Access Tokens for the same resource owner, client, and resource. In this paper, we will present findings of a study related to undocumented feature used by Azure AD, the Family of Client ID (FOCI). After studying 600 first-party clients, we found 16 FOCI clients which supports a special type of Refresh Tokens, called Family Refresh Tokens (FRTs). These FRTs can be used to obtain Access Tokens for any FOCI client. This non-standard behaviour makes FRTs primary targets for a token theft and privilege escalation attacks.


## 1 INTRODUCTION


### 1.1 Azure Active Directory


Azure Active Directory (Azure AD) is an identity and access management service (IAM) provided by Microsoft (Microsoft, 2021f). It is used as IAM by Microsoft's own services, such as Microsoft 365 and Azure, and thousands of third-party service providers (Microsoft, 2022a). At least 88 per cent of fortune 500 companies and 95 per cent of top 2000 universities are using Azure AD (Syynimaa, 2022). This makes Azure AD one of the most critical IAM services globally.

### 1.2 OAuth 2.0 and OIDC

Azure AD uses OpenID Connect (OIDC) and OAuth protocols for authentication and authorisation, respectively. OAuth 2.0 authorisation framework allows third-party applications to access HTTP based services either directly or on-behalf-of users (IETF, 2012). OIDC is an identity layer on top of OAuth 2.0 protocol (OpenID Foundation, 2022). Both protocols have four parties: *OAuth Client* (OC), *Resource Owner* (RO), *Resource Server* (RS), and *Authorisation Server* (AS). Moreover, both protocols use *bearer tokens* to grant access to a *bearer*, which typically refers to the RO. A simple authorisation flow, where RO uses OC to request access from AS to RS is illustrated in Figure 1.

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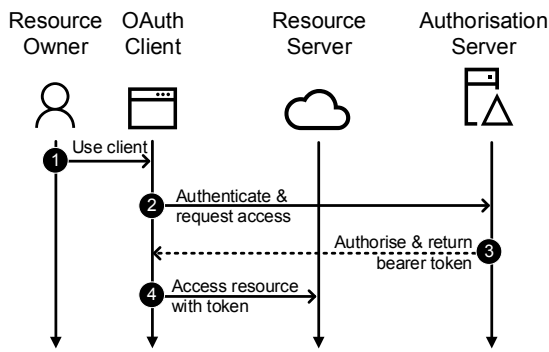


Figure 1: OAuth 2.0 authorisation flow.

Before authorisation can be requested, the used OC needs to have a *consent*. This process and the granularity of the consent depends on the used AS and RS. Microsoft OAs are generally referred as *first-party clients*. Some of these, such as Exchange Online, are pre-authorised in all Azure AD environments.

### 1.3 Tokens

A standard representation of a bearer token is JSON Web Token, or JWT (IETF, 2015). There are two flavours of JWT: JSON Web Signature (JWS) and JSON Web Encrypt (JWE). The former is used to represent bearer tokens and is also generally used as a synonym for JWT. JWS consists of three Base64 URL encoded parts: Javascript Object Signing and Encrypt (JOSE) header, JWS payload, and JWS signature. The JOSE header contains the information about the key used to sign the JWS, the payload contains a set of JWS claims, and the signature contains the cryptographic signature of the header and the payload.

Azure AD uses three types of tokens: *access tokens*, *Id tokens*, and *refresh tokens* (Microsoft, 2021c). Different token types and their properties are listed in Table 1.

Table 1: Azure AD token types.

| Type          | Standard | Lifetime |
|---------------|----------|----------|
| Id Token      | OIDC     | 1 hour   |
| Access Token  | OAuth2   | 1 hour   |
| Refresh Token | OAuth2   | 90 days  |

The *Id token* contains the user's (*i.e.*, the bearers) identity information. A sample id token can be seen in Figure 2. As we can see, it contains different information about the user, like *unique\_name* on line 18. It also includes information about the issuer (*i.e.*, Authorisation Server) on line 2.

```

1 {
2   "aud": "1b730954-1685-4b74-9bfd-dac224a7b894",
3   "iss": "https://sts.windows.net/5e5bce06-2dc3-4374-b377-3399711d6623",
4   "iat": 1641970106,
5   "nbf": 1641970106,
6   "exp": 1641974006,
7   "amr": ["pwd"],
8   "family_name": "Sample",
9   "given_name": "User",
10  "ipaddr": "[redacted]",
11  "name": "User Sample",
12  "oid": "20e6d481-6393-42a8-accb-bd670fba36dd",
13  "puid": "10032001148ECAf9",
14  "rh": "0.AXkAnZT_xZYmaEueEwVfGe0tUVQJcxuFFnRLm_3awiSnu",
15  "sub": "KB0M861sBjxLD7GRFpB0JqqxA47rUZFvqC3rT-2R_5I",
16  "tenant_region_scope": "EU",
17  "tid": "5e5bce06-2dc3-4374-b377-3399711d6623",
18  "unique_name": "UserS@contoso.com",
19  "upn": "UserS@contoso.com",
20  "ver": "1.0"
21 }

```

Figure 2: A sample id token.

The *access token* contains the same information as the identity token, but also information about the resource the user has been authorised to access. A sample access token can be seen in Figure 3. As we can see, the audience (*i.e.*, Resource Server) is included on line 2. Moreover, the *scope* is included on line 19. The scope is used in Azure AD to further limit access to the resource server by listing different Application Programming Interface (API) scopes. The *user\_impersonation* and *.default* scopes mean that the user can access all APIs on the RS but can perform only actions they have permissions on the RS in question.

```

1 {
2   "aud": "https://management.core.windows.net/",
3   "iss": "https://sts.windows.net/5e5bce06-2dc3-4374-b377-3399711d6623",
4   "iat": 1641970153,
5   "nbf": 1641970153,
6   "exp": 1641979237,
7   "acr": "1",
8   "aio": "E22gYU1b/udCi2UBh15qhFOW8SaLp7V3Nymdn6pR8qm/Sn",
9   "amr": ["pwd"],
10  "appid": "d3590ed6-52b3-4102-aeff-aad2292ab01c",
11  "appidaacr": "0",
12  "family_name": "Sample",
13  "given_name": "User",
14  "ipaddr": "[redacted]",
15  "name": "User Sample",
16  "oid": "20e6d481-6393-42a8-accb-bd670fba36dd",
17  "puid": "10032001148ECAf9",
18  "rh": "0.AXkAnZT_xZYmaEueEwVfGe0tUVQJcxuFFnRLm_3awiSnu",
19  "scp": "user_impersonation",
20  "sub": "1tbnuCM6tMLN_04-JlVnJ821r2eJLAW_m_GMCej_A",
21  "tid": "5e5bce06-2dc3-4374-b377-3399711d6623",
22  "unique_name": "UserS@contoso.com",
23  "upn": "UserS@contoso.com",
24  "uti": "XzC_CEIVNE1LkWRIVzEqAA",
25  "ver": "1.0"
26 }

```

Figure 3: A sample access token.

*Refresh token* is used to obtain a new set of tokens when access or Id tokens expires (IETF, 2012). In Azure AD, refresh token is an opaque binary large object (blob) encrypted with a key known only by Microsoft (Microsoft, 2021a), delivered as JWE. As such, its actual content is unknown. A sample refresh token can be seen in Figure 4.

```

1 0.AXkAnZT_xZYmaEueEwVfGe0tUdYOWdOzUgJBrv-q0ikqsBx5AOW.AgABAAA
9F-qaYcgg9LKg7p0AbdYuvT16Hc7pHg7j5IGGqFSNBryzeIubQxHd4SRcKi.
pLVExrsOXjzd9QCTp1T0C1KPKQYjXRbBHVZ1NkGGRhOSdaiPEX3zPg4SPPzDUa
aJ9z29vE_bTV1eK92CLxVenT9G9Ru_h5be0o5SEUoCBBjuWlqPE87sCyBG1z4Z
4B6ThKZx29zNlGHQeevqING7E2atKEPAL4acZAYIqKLEvD8wDR4ViSFCJttO_J
9xWRlHDo7q3BvxjC2QSFfMcip084TdhmVxSt0b6WYwfbKwn5cmVX9ts7VhMu
34xKAjK7wo151PSf0Y7Fcllvmk7ODGFSP5jriis9ar0vKmIk3MbgathG7aR8k
kLZk-IQUdrbxSgtvXDLzk7_7J6f9HhzeTyMHRIHU81PeBcm4gH9a-5DoF83teI
WVjxmsGEUBtuudDZ2AncX81Tku8xwt_G-4mDv1QKt7AdrdLiXpEaDN45sdurI
Vvx1T21Rr1WP5fcAbd1R78X2w1wrmKgI0RZJBtw6rKZExc0If4iHuXhcx0al
-6h0gOy4FK4elyBhuQJb-md7vOKqSm99rnWCkwFpHep_CBIbewoqEx4RvbYbh
QFVYez8PAvoIUEJA206p7F2txCNTM7eP73iR

```

Figure 4: A sample refresh token.

## 1.4 OAuth 2.0 Authentication Flows

OAuth 2.0 standard (IETF, 2012) defines several different flows for acquiring authorisation: *Authorization Code Grant*, *Implicit Grant*, *Resource Owner Password Credentials Grant*, and *Client Credentials Grant*.

The Authorization Code Grant is commonly used to obtain the initial set of tokens (id token, access token, and refresh token). The Authorization Code Grant allows the RO to use more secure authentication mechanisms, such as multi-factor authentication (MFA), and without the need to share their credentials with the OC. In contrast, the Resource Owner Password Credential (ROPC) flow allows the OC to authenticate using the RO's credentials. A sample ROPC request made to Azure AD's */token* endpoint can be seen in Figure 5 (line breaks added for readability).

```

1 POST https://login.microsoftonline.com/common/oauth2/token
2 User-Agent: Mozilla/4.0 (compatible; MSIE 7.0; Windows NT
3 Content-Type: application/x-www-form-urlencoded
4 Host: login.microsoftonline.com
5 Content-Length: 184
6
7 grant_type=password&
8 password=xxxxxxxx&
9 client_id=ecd6b820-32c2-49b6-98a6-444530e5a77a&
10 username=user%40contoso.com&
11 resource=https%3A%2F%2Fgraph.windows.net&
12 scope=openid

```

Figure 5: Sample ROPC authorisation request.

After the access and id tokens have expired, a new set of access tokens can be obtained using the refresh token. A sample request using refresh token can be seen in Figure 6 (line breaks added for readability).

```

1 POST https://login.microsoftonline.com/common/oauth2/token
2 User-Agent: Mozilla/4.0 (compatible; MSIE 7.0; Windows NT
3 Content-Type: application/x-www-form-urlencoded
4 Host: login.microsoftonline.com
5 Content-Length: 1217
6
7 grant_type=refresh_token&
8 refresh_token=0.AXkAnZT_xZYmaEueEwVfGe0tUdYOWdOzUgJBrv-q0i
9 client_id=ecd6b820-32c2-49b6-98a6-444530e5a77a&
10 resource=https%3A%2F%2Fgraph.windows.net&
11 scope=openid

```

Figure 6: Sample refresh token authorisation request.

The OAuth 2.0 standard (IETF, 2012, section 6) and *OAuth 2.0 Threat Model and Security*

*Considerations* (IETF, 2013, section 5.2.2.2.) specifies that refresh tokens should be bound to the client id it was issued. Moreover, OAuth 2.0 standard specifies that refresh tokens can be used to obtain access tokens “..with identical or narrower scope..” (IETF, 2012, section 1.5).

The OAuth implementation in Azure AD deviates from the standard regarding refresh tokens. Azure AD does not enforce the requirement that newly issued access tokens must have the same or narrower scope as the original authorisation. Microsoft (2021a) documentation states that:

*“Refresh tokens are bound to a combination of user and client, but aren't tied to a resource or tenant. As such, a client can use a refresh token to acquire access tokens across any combination of resource and tenant where it has permission to do so.”*

A recent research article (Syynimaa, 2020) revealed, however, that the refresh tokens issued to certain Microsoft first-party clients (later to be known as FOCI clients) are redeemable for new access tokens authorised to a different client. This behaviour, or feature, was unexpected given the Microsoft documentation and OAuth specifications.

## 1.5 Research Questions

Our research sought to answer the following research questions:

1. Which first-party clients are supported by this feature?
2. What is the purpose of granting access tokens for other first-party clients using refresh tokens?

## 1.6 Structure of the Paper

The rest of the paper is structured as follows. In Section 2, we describe the research methodology used in the study. In Section 3, the results of the study are presented. Finally, in Section 4, implications of the findings and a conclusion are presented.

## 2 METHODOLOGY

The research had two distinct research lines, one for each research question.

To answer the first research question, a list of 450 first-party clients (Seb8iaan, 2020) was acquired and supplemented with the client ids (~150) harvested from Azure AD sign-in logs. After that, the initial set of tokens for each first-party client using various

scopes was obtained, and a new set of tokens was tried to be received with the refresh token. The details of the experiment are as follows:

1. A new Azure AD tenant with two users (one admin, one regular user) was provisioned. Both users were assigned Microsoft E5 license.
2. The initial set of tokens were obtained for each client using a *Jupyter Notebook* and the *Microsoft Authentication Library (MSAL) for Python*.
3. ROPC flow was used to authorise each client for *.default*, *openid*, *profile*, and *offline\_access* scopes on 40 different resources including: *Microsoft Graph*, Microsoft 365 APIs (*Exchange Online*, *Sharepoint*, and *Teams*), Azure Resource Manager APIs (*Azure Storage*, *Vault*, *Database*), and the client itself. The *offline\_access* scope instructs AS to issue a refresh token in addition to Id and access tokens.
4. The results of each authorisation attempt was logged, including the issued tokens in JSON format.
5. The refresh tokens obtained in previous steps were used to request new authorisation via *refresh grant* flow for the same combination of clients, scopes, and resources.
6. The issued access tokens were compared to the initial set of tokens for each successful refresh attempt.

To answer the second research question, the public Microsoft documentation and Github were studied, and the various Google searches were conducted. Microsoft was also contacted during the research, including the findings and comments regarding the first research question.

### 3 RESULTS

A subset of the research is available at Github (see Cobb & Gore, 2022) with interactive demo in form of a Jupyter Notebook. This allows other researchers to reproduce and expand upon findings described in the following sections.

#### 3.1 Family of Client IDs (FOCI) and Family Refresh Tokens (FRTs)

After running an experiment with ~600 first-party clients, only 13 clients were found to be supported by the feature. Later, three additional clients were found

by scraping client ids from various Github sites. All 16 clients are listed in Table 2.

Table 2: List of Azure AD FOCI clients.

| Client                                   | Client Id                             |
|--|---------------------------------------|
| Office 365 Management (mobile app)       | 00b41c95-dab0-4487-9791-b9d2c32c80f2  |
| Azure CLI                                | 04b07795-8ddb-461a-bbee-02f9e1bf7b46  |
| AZ PowerShell Module                     | 1950a258-227b-4e31-a9cf-717495945fc2  |
| Teams                                    | 1fec8e78-bce4-4aaf-ab1b-5451cc387264  |
| Windows Search                           | 26a7ee05-5602-4d76-a7ba-eae8b7b67941  |
| MS MAM Service API                       | 27922004-5251-4030-b22d-91ecd9a37ea4  |
| Microsoft Bing Search for Microsoft Edge | 2d7f3606-b07d-41d1-b9d2-0d0c9296a6e8  |
| Authenticator App                        | 4813382a-8fa7-425e-ab75-3b753aab3abb  |
| Microsoft Stream Mobile Native           | 844cca35-0656-46ce-b636-13f48b0eeecbd |
| Microsoft Teams – Device Admin Agent     | 87749df4-7ccf-48f8-aa87-704bad0e0e16  |
| OneDrive                                 | ab9b8c07-8f02-4f72-87fa-80105867a763  |
| Microsoft Bing Search                    | cf36b471-5b44-428c-9ce7-313bf84528de  |
| Office Desktop client                    | d3590ed6-52b3-4102-aeff-aad2292ab01c  |
| Visual Studio                            | 872cd9fa-d31f-45e0-9eab-6e460a02d1f1  |
| OneDrive iOS App                         | af124e86-4e96-495a-b70a-90f90ab96707  |
| Edge                                     | ecd6b820-32c2-49b6-98a6-444530e5a77a  |

When obtaining the initial set of tokens for the aforementioned clients, the received JSON responses had a *foci* attribute with a value set to “1” (see line 11 in Figure 7). These clients are later referred as *FOCI clients*. The *foci* attribute did not exist for other clients. The list of known FOCI clients is maintained in the Github repository associated with this research (see Cobb & Gore, 2022).

All FOCI clients were so-called *public clients* (Microsoft, 2021d) which can only access APIs on behalf of the user. FOCI clients could exchange their refresh token for new tokens for any other FOCI client. The scopes in the newly issued access tokens were based on the new client and its *.default* scopes,



### 4.1.2 Token Theft

Refresh tokens can be considered long-term credentials and, thus, are subject to theft (IETF, 2013). The level of access afforded to an attacker from a stolen refresh token is determined by the resources and scopes authorised to the access tokens obtained using the stolen refresh token. FRTs can be used to acquire access tokens for any FOCI client, resource, and scope, and thus, are much more powerful than ordinary refresh tokens.

Some commonly used attack paths the malicious actors can use to obtain refresh tokens are (IETF, 2013):

- Steal a previously and legitimately issued refresh token.
- Obtain refresh token through malicious authorisation.

These attack paths also apply to FRTs. It is possible to steal FRTs that were previously issued to FOCI client. For example, if the attacker compromises the cache where the tokens are stored (such as the Windows Web Account Manager), eavesdrops on network traffic during a grant flow, or finds them serialised on disk in files (like `~/Azure/accessTokens.json`). We focused our

attention, however, on how an attacker could obtain FRTs by maliciously authorising a FOCI client.

*Device Code Phishing* is an attack method where a malicious actor can lure the victim to authorise access to a resource using *device authorisation grant flow* (see IETF, 2013). If the attacker is using a FOCI client, the user consent is not required, and the attacker can use whatever FOCI client is most likely to socially engineer the victim. After successful authorisation, the attacker can redeem the returned FRT for a new access token for a different FOCI client for the desired scopes.

### 4.1.3 Single Sign-on

Another likely attack path to family refresh tokens is to abuse SSO on Azure AD joined devices. The OAuth 2.0 threat model describes a scenario where an attacker might obtain a refresh token through exploiting some mechanism that automatically authorises client applications without knowledge or intent from the resource owner (IETF, 2013, section 4.4.1.10). This is trivially possible on Azure AD joined devices. Processes that execute in the context of a logged-in Azure AD user on an Azure AD-joined Windows device can request a pre-signed cookie from a COM service (Christensen, 2020). This cookie

|                                 |                                      |                                      |
|---------------------------------|--------------------------------------|--------------------------------------|
| ActivityFeed-Internal.ReadWrite | https://substrate.office.com         | d3590ed6-52b3-4102-aeff-aad2292ab01c |
| Addins.ReadWrite                | https://outlook.office.com           | 27922004-5251-4030-b22d-91ecd9a37ea4 |
|                                 | https://outlook.office365.com        | 27922004-5251-4030-b22d-91ecd9a37ea4 |
|                                 | https://substrate.office.com         | 27922004-5251-4030-b22d-91ecd9a37ea4 |
| AdminApi.AccessAsUser.All       | https://outlook.office.com           | 00b41c95-dab0-4487-9791-b9d2c32c80f2 |
|                                 | https://outlook.office365.com        | 00b41c95-dab0-4487-9791-b9d2c32c80f2 |
| Apps.ReadWrite                  | https://api.spaces.skype.com         | 27922004-5251-4030-b22d-91ecd9a37ea4 |
|                                 | https://api.spaces.skype.com         | d3590ed6-52b3-4102-aeff-aad2292ab01c |
| AuditLog.Read.All               | 04b07795-8ddb-461a-bbee-02f9e1bf7b46 | 04b07795-8ddb-461a-bbee-02f9e1bf7b46 |
|                                 | d3590ed6-52b3-4102-aeff-aad2292ab01c | d3590ed6-52b3-4102-aeff-aad2292ab01c |
|                                 | https://graph.microsoft.com          | 04b07795-8ddb-461a-bbee-02f9e1bf7b46 |
|                                 | https://graph.microsoft.com          | d3590ed6-52b3-4102-aeff-aad2292ab01c |
| Avery-Internal.Read             | https://outlook.office.com           | 27922004-5251-4030-b22d-91ecd9a37ea4 |
|                                 | https://outlook.office365.com        | 27922004-5251-4030-b22d-91ecd9a37ea4 |
| Avery-Internal.ReadWrite        | https://outlook.office.com           | 27922004-5251-4030-b22d-91ecd9a37ea4 |
|                                 | https://outlook.office365.com        | 27922004-5251-4030-b22d-91ecd9a37ea4 |
| BingCortana-Internal.ReadWrite  | https://outlook.office.com           | 27922004-5251-4030-b22d-91ecd9a37ea4 |
|                                 | https://outlook.office365.com        | 27922004-5251-4030-b22d-91ecd9a37ea4 |
|                                 | https://substrate.office.com         | 27922004-5251-4030-b22d-91ecd9a37ea4 |
| Branford-Internal.ReadWrite     | https://outlook.office.com           | d3590ed6-52b3-4102-aeff-aad2292ab01c |
|                                 | https://outlook.office365.com        | d3590ed6-52b3-4102-aeff-aad2292ab01c |
| Calendar.ReadWrite              | d3590ed6-52b3-4102-aeff-aad2292ab01c | d3590ed6-52b3-4102-aeff-aad2292ab01c |
|                                 | https://graph.microsoft.com          | d3590ed6-52b3-4102-aeff-aad2292ab01c |
| Calendars.Read.Shared           | d3590ed6-52b3-4102-aeff-aad2292ab01c | d3590ed6-52b3-4102-aeff-aad2292ab01c |
|                                 | https://graph.microsoft.com          | d3590ed6-52b3-4102-aeff-aad2292ab01c |
| Calendars.ReadWrite             | d3590ed6-52b3-4102-aeff-aad2292ab01c | d3590ed6-52b3-4102-aeff-aad2292ab01c |
|                                 | https://graph.microsoft.com          | d3590ed6-52b3-4102-aeff-aad2292ab01c |
|                                 | https://outlook.office.com           | 1fec8e78-bce4-4aaf-ab1b-5451cc387264 |
|                                 | https://outlook.office365.com        | 27922004-5251-4030-b22d-91ecd9a37ea4 |
|                                 | https://outlook.office365.com        | d3590ed6-52b3-4102-aeff-aad2292ab01c |
|                                 | https://outlook.office365.com        | 1fec8e78-bce4-4aaf-ab1b-5451cc387264 |
|                                 | https://outlook.office365.com        | 27922004-5251-4030-b22d-91ecd9a37ea4 |
|                                 | https://substrate.office.com         | d3590ed6-52b3-4102-aeff-aad2292ab01c |
|                                 | https://substrate.office.com         | 26a7ee05-5602-4d76-a7ba-eae8b7b67941 |
|                                 | https://substrate.office.com         | 27922004-5251-4030-b22d-91ecd9a37ea4 |
|                                 | https://substrate.office.com         | d3590ed6-52b3-4102-aeff-aad2292ab01c |

Figure 8: Excerpt from Scope Lookup Table.

can then be used to complete an authorisation grant flow for arbitrary client applications, including FOCI clients.

Typically, the disadvantage of abusing SSO is that each time the attacker wants access to some scope that was not authorised for some stolen access token, the attacker needs to request a new signed cookie or otherwise complete an authorisation grant flow again to obtain a new access token with the desired scopes. In the case of FRTs, even if the attacker only had the opportunity to generate a single pre-signed cookie, the attacker can silently exchange the FRT multiple times for new access tokens for other FOCI clients and benefit from their authorised scopes.

#### 4.1.4 Zero Trust

FOCI predates the adoption of the *Zero Trust* security model at Microsoft. The guiding principals of Zero Trust require that client authentication and authorization are based on all available information, client access is limited to least privilege for the shortest duration, and that the client is assumed to be breached, so the blast radius must be minimized (Microsoft, 2022c). The current implementation of FOCI is incompatible with the Zero Trust model. FRTs allow long-term persistent access and privilege escalation relative to the client application. As there is only one “family” of Microsoft first-party client applications means that the level of access afforded by FRTs is not segmented according to the needs of legitimate software that require FOCI to function.

#### 4.1.5 Conditional Access Policies

Conditional access policies still apply to FOCI clients and FRTs. Conditional access policies that require multi-factor authentication, however, do not impede attackers from abusing the legitimately issued FRTs since refresh token grants are always non-interactive, and usually inherit the authentication method claims from the original authorisation grant. Furthermore, conditional access policies based on trusting the device are ineffective when a FOCI client is maliciously authorised by abusing SSO because the request “originates” from the trusted device.

Any conditional access policies (or other controls) based purely on the FOCI client identifiers are trivial to bypass if another FOCI client has consent for the desired scopes.

Refresh token grants are logged in Azure AD non-interactive user sign-ins log. Currently, the non-interactive sign-in log events do not contain details about the client application to which the refresh token

was originally issued. This prevents detecting exploitation of FRTs.

#### 4.1.6 Anticompetitive Practices

According to United States Federal Trade Commission (FTC), antitrust laws “prohibit conduct by a single firm that unreasonably restrains competition by creating or maintaining monopoly position” (FTC, 2022). FTC uses a previous Microsoft case as an example for monopolisation (FTC, 2022):

*Microsoft was able to use its dominant position in the operating systems market to exclude other software developers and prevent computer makers from installing non-Microsoft browser software to run with Microsoft's operating system software.*

FOCI establishes a “family” of first-party Microsoft client applications that are given special treatment compared to third-party client applications in Azure AD. Microsoft does not allow third-party developers to benefit from the FOCI functionality, *i.e.*, designate their own “family” of client. As such, it may have provided Microsoft software with a competitive advantage over third-party software even if the third-party used Azure AD as the identity provider.

## 4.2 Conclusion

In this paper, we reported our findings related to the non-standard behaviour of certain Azure AD’s first-party clients’ refresh tokens.

We found answers to both research questions. First, we found 16 first-party clients supporting these special type of refresh tokens, called Family Refresh Tokens (FRTs). Second, we found out that the clients supporting FRTs were called Family of Client ID (FOCI) clients, and that the purpose of FRTs is to provide single-sign-on experience without a separate authentication broker for mobile platforms.

Based on our findings, we recommend Microsoft to publish the list of FOCI clients, so that Azure AD customers can protect their environments accordingly. Further, as FOCI is created for mobile platforms, its usage should be limited to those platforms.

## 4.3 Limitations

The used data set of ~600 first-party applications is not exhaustive, so the study may not have revealed all FOCI clients. Also, Microsoft is creating new and removing old FOCI applications (MSRC, 2021).



When building the scope lookup table, only a limited number of scopes were used when obtaining tokens. As such, only the scopes that Azure AD automatically adds were returned. Therefore, the list of scopes may not be exhaustive.

#### 4.4 Directions for Future Research

As new the FOCI clients are introduced, the list of known FOCI clients needs to be updated.

The security implications of FOCI clients and FRTs requires more research, especially in the mobile platforms. For instance, studying how FRTs are stored and accessible in mobile devices would be an interesting research target.

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