SPECTEROPS

Less Praying More Relaying

Detecting NTLM relay mitigations for ~~MSSQL~~ multiple protocols

Intros

- **Nick Powers**
  - Service Architect, Adversary Simulation
  - Interested in NTLM relay tradecraft, initial access techniques, and payload development
  - **@zyn3rgy**

- **Matt Creel**
  - Senior Consultant, Adversary Simulation
  - Interested in post-exploitation tradecraft and tool development
  - **@Tw1sm**

The “What” and “Why”

What are we covering?

- Extended Protection for Authentication (EPA) is an increasingly common integrity protection that can mitigate popular authentication relay attack primitives

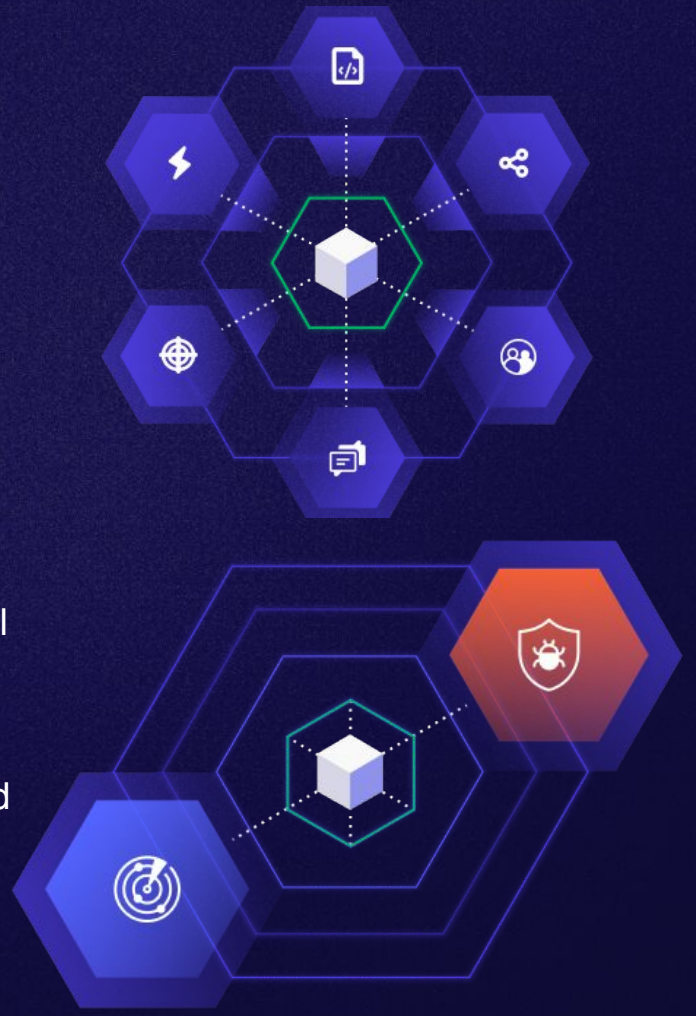
- We will demonstrate new ways to determine the enforcement state of this integrity protection for arbitrary target services, from the attacker’s perspective

The “What” and “Why”

Why are we covering it?

- Mature orgs have had SMB signing enforced for years
- Popular relays targeting LDAP have thrust LDAP protections into the spotlight
  - *KrbRelayUp* style local privilege escalation
  - Targeted, remote WebClient abuse
- Many orgs have addressed ADCS ESC8
  - Web enrollment service removal
  - EPA
- Misconfiguration Manager TAKEOVER-1 (MSSQL) is still often successful
  - Microsoft added EPA support to SCCM in Dec 2024
- Significant overhead for relay attacks through C2
  - Can we determine the protections in place before lab simulation and attack setup?

This content and subsequent tool release will address that by better informing your relay decisions



https://learn.microsoft.com/en-us/intune/configmgr/core/plan-design/changes/whats-new-in-version-2409#

Agenda

- EPA Background and Fundamentals
- Server EPA Implementation Nuances
- Client Error-Based Enumeration Strategy
- Tool Releases
- Conclusion and Key Takeaways

EPA Background and Fundamentals

EPA Background and Fundamentals

Introduction and Basics

- Extended Protection for Authentication (EPA)
  - Security feature to protect the integrity of authentication mechanisms such as NTLM and Kerberos
    - Does this by **binding** the authentication to the intended **channel** and/or **service**
    - Focus for this presentation will be NTLM
  - Configured in one of three enforcement levels
    - Disabled
    - Allowed / Accepted / When Supported
    - Required
- Focus for this talk will be specific to NTLM(v2) implementation
  - And “interesting” server implementation design decisions (more on this later)

EPA Background and Fundamentals

Introduction and Basics

- EPA consists of *channel binding* **and** *service binding*
  - Common confusion that EPA = channel binding (not the case)
  - Determined by the server's implementation exactly when to check what
- Where do these "bindings" exist?
  - NTLM negotiation consists of three messages, and the values that are validated for EPA are sent in the third message from client → server
  - Server validates based on AV pair contents within NTLM Type 3 / NTLM_AUTH
    - Channel binding - **MsvAvChannelBindings**
    - Service binding - **MsvAvTargetName**

EPA Background and Fundamentals

Enforcement Settings (Server Expectations)

Disabled

Server ignores presence, or lack thereof, the **MsvAvTargetName** and **MsvAvChannelBindings** AV pairs

Allowed / Accepted / When Supported

Server accepts auth where the relevant AV pair is not present

Server treats the mere presence of the relevant AV pair as proof the client is aware of EPA and will enforce validity

Windows NTLM SSP will always include these AV pairs

Required

Server requires the relevant channel binding or service binding AV pair to be present and valid

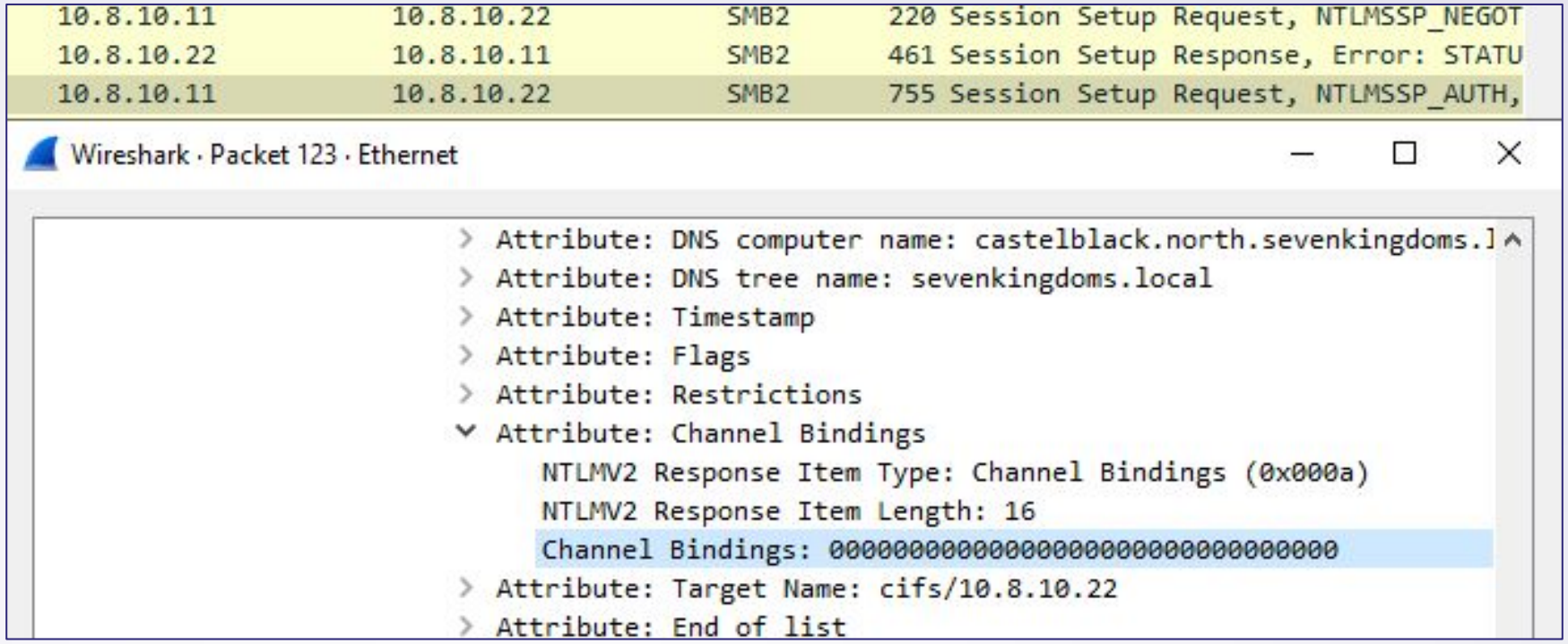
EPA Background and Fundamentals

Enforcement Settings (Common Client Behavior)

- Common NTLM relays begin poisoning or coercing traffic
  - broadcast / multicast poisoning (LLMNR, mDNS, DHCPv6, etc)
  - authentication coercion (MS-EFSR [petitpotam], [MS-RPRN] printerbug, etc)
- Modern Windows SSPI (NTLM SSP) includes both relevant av pairs by default
  - Both options above mostly commonly result in the Windows constructing the NTLMv2 client blob
  - Makes sense for **MsvAvTargetName**, target name often appears in NTLMv2 clients
  - Importantly though, **MsvAvChannelBindings** will **always appear** regardless of the target protocol's support for channel binding

EPA Background and Fundamentals

Enforcement Settings (Common Client Behavior)



SMB(v2) / HTTP (WebDav)

Server EPA Implementation Nuances

Server EPA Implementation Nuances

What We Would Expect

- EPA can protect both encrypted and unencrypted connections
  - Encrypted connection
    - Channel binding - calculated by some aspect of TLS negotiation
      - tls-server-end-point (IIS), tls-unique (MSSQL), tls-unique-for-telnet, tls-exporter
  - Unencrypted connection
    - Service binding - included by majority of NTLMv2 clients and determined by the client
- When this feature is enabled, there should be coverage for both by default… right?

Wrong

Server EPA Implementation Nuances

MSSQL

MSSQL - Encrypted

When EPA is set to *allowed* or *required* the channel bindings AV pair value is validated and the target name AV pair is ignored

```
Attribute: Channel Bindings
    NTLMV2 Response Item Type: Channel Bindings (0x000a)
    NTLMV2 Response Item Length: 16
    Channel Bindings: 996fc2637144aeacd4435b09bc1619db
```

MSSQL - Unencrypted

When EPA is set to *allowed* or *required* the target name AV pair value is validated and the channel bindings AV pair is ignored

```
Attribute: Target Name: MSSQLSvc/castelblack.north.sevenkingdoms.local:1433
    NTLMV2 Response Item Type: Target Name (0x0009)
    NTLMV2 Response Item Length: 102
    Target Name: MSSQLSvc/castelblack.north.sevenkingdoms.local:1433
```

Server EPA Implementation Nuances

Visual

	MSSQL	
	EPA On	EPA Off
Encrypted	CB	None
Unencrypted	SB	None

CB = Channel Binding SB = Service Binding

Server EPA Implementation Nuances

IIS

IIS - Encrypted / HTTPS

EPA set to *accept* or *required* through the IIS GUI will enable channel binding for HTTPS

IIS - Unencrypted / HTTP

EPA set through the IIS GUI *DOES NOT* enable any protections for unencrypted connections

Service binding can be configured (instead of channel binding) manually in the server's *applicationHost.config* file

"A Study on Windows HTTP Authentication" by Pierre Milioni & Geoffrey Bertoli from Synacktiv

Server EPA Implementation Nuances

Visual

	MSSQL		IIS HTTP	
	EPA On	EPA Off	EPA On	EPA Off
Encrypted	CB	None	CB	None
Unencrypted	SB	None	None	None

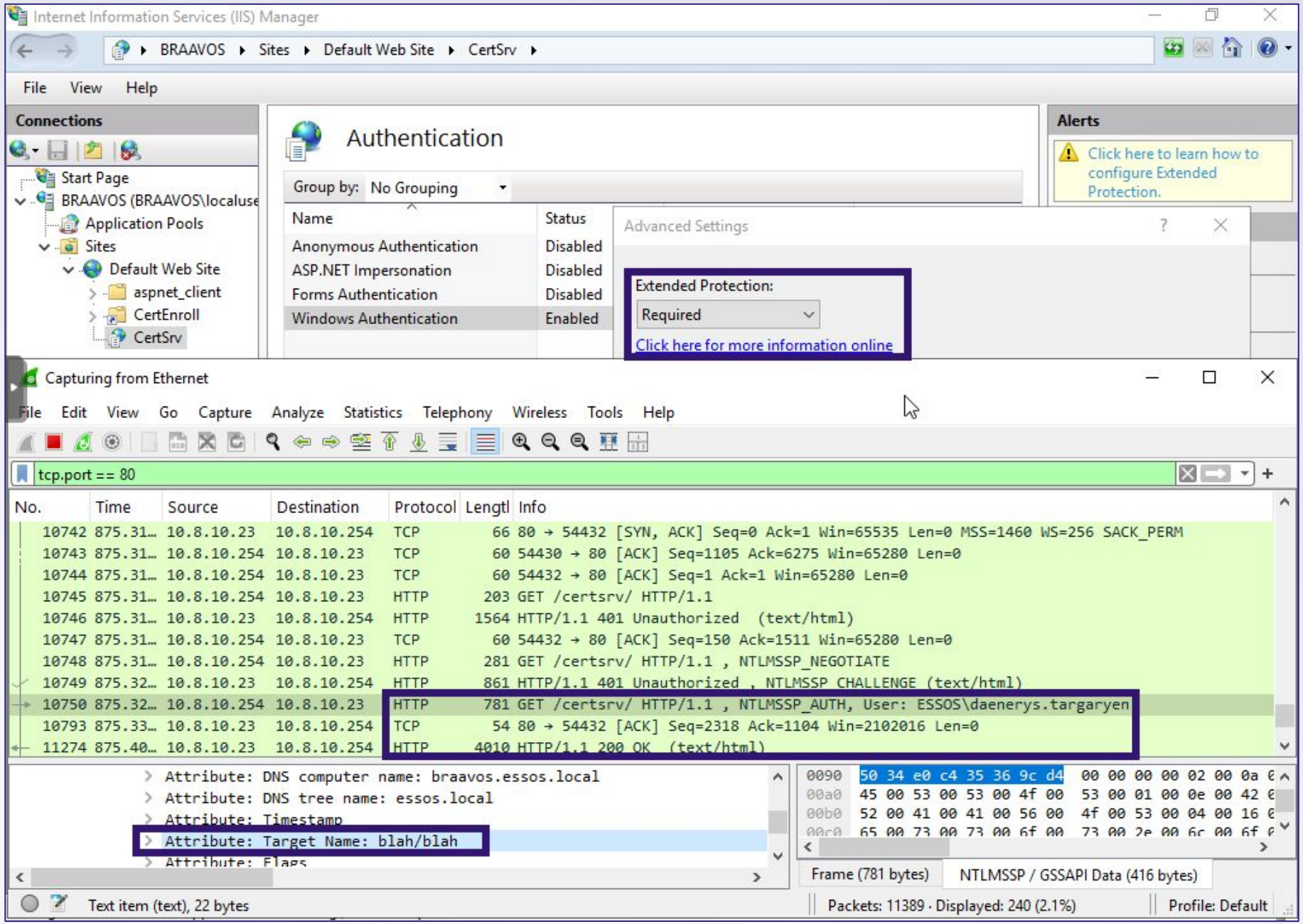
CB = Channel Binding SB = Service Binding

Server EPA Implementation Nuances

Visual

	MSSQL		IIS HTTP		IIS HTTP (Manual SB Config)	
	EPA On	EPA Off	EPA On	EPA Off	EPA On	EPA Off
Encrypted	CB	None	CB	None	SB	None
Unencrypted	SB	None	None	None	SB	None

CB = Channel Binding SB = Service Binding



https://www.synacktiv.com/en/publications/a-study-on-windows-http-authentication-part-ii

Server EPA Implementation Nuances

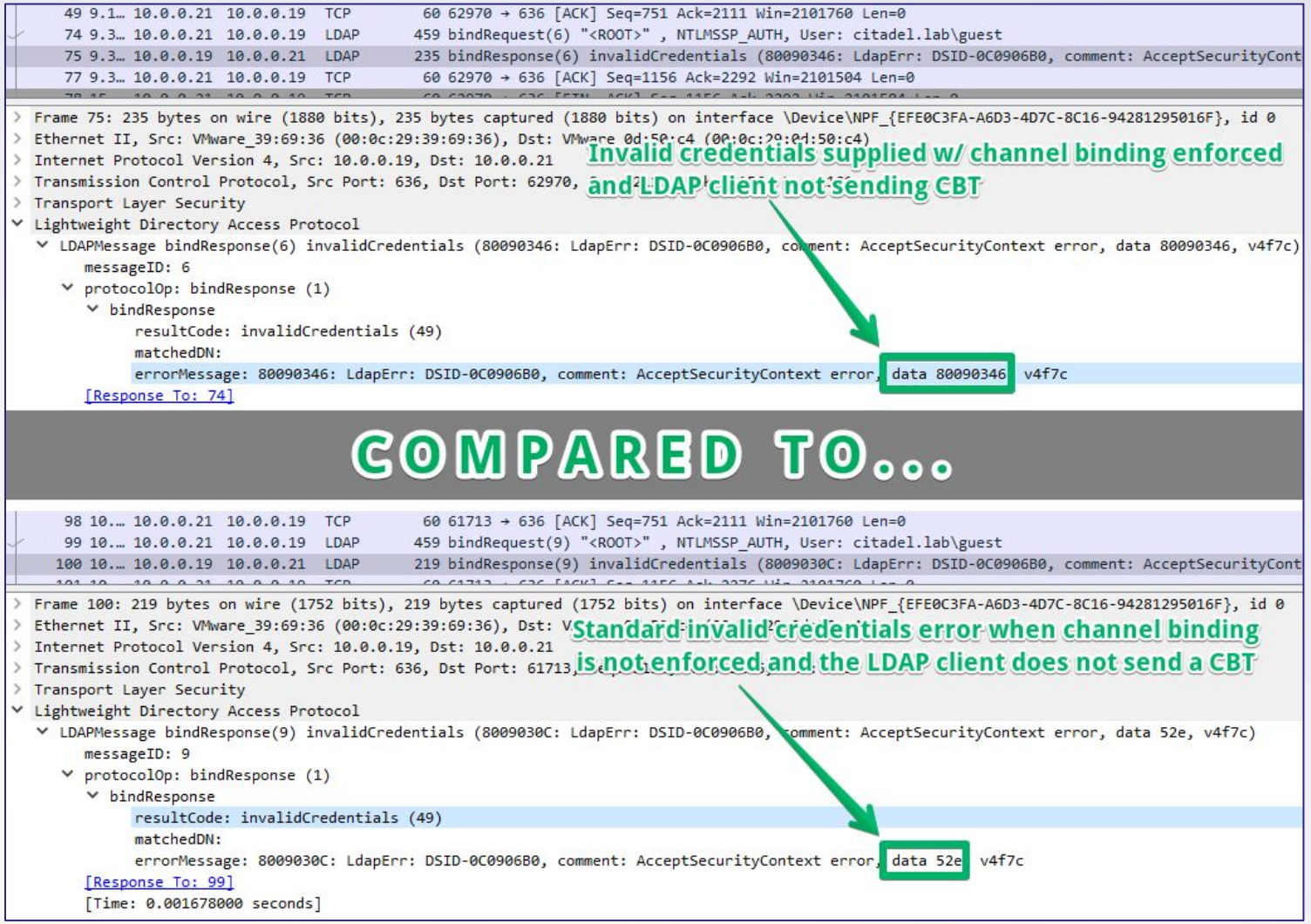
Implementation Takeaways

- Servers can take unexpected liberties with how they implement EPA
- Understanding how a server implements this protection is important
  - What to manipulate when enumerating EPA enforcement
  - What is possible regarding NTLM relays
- Server implementations often result in unique responses for EPA validation failure
  - Manipulating the relevant values during authentication can help us enumerate enforcement and identify potential gaps

Client Error-Based Enumeration Strategy

Client Error-Based Enumeration

Where It Started



Client Error-Based Enumeration

Same Problem, New Protocols

- Control of the client gives us many variables to manipulate in search of unique responses
  - Manipulation of EPA relevant AV pair
  - In some cases, removal of AV pairs entirely
- Any difference in a response, specific to EPA enforcement, will suffice
  - Data in response
  - Error codes
  - Response codes
  - Timing of responses

Client Error-Based Enumeration

MSSQL Analysis

- MSSQL servers can support unencrypted and encrypted authentication
  - **Force Encryption** can be configured to only allow encrypted connections
- Encryption will determine what type of EPA is validated
  - Unencrypted (if allowed) = service binding
  - Encrypted = channel binding
- How do we ensure this is the case?

Client Error-Based Enumeration

MSSQL Analysis

```
33 9.907751    10.5.10.22    10.5.10.31    TDS    361 Response, NTLMSSP_CHALLENGE
34 9.908259    10.5.10.31    10.5.10.22    TDS    718 SSPI message, NTLMSSP_AUTH, User: SEVENKINGDOMS\ja
37 9.931696    10.5.10.22    10.5.10.31    TCP     54 1433 → 50429 [ACK] Seq=1440 Ack=1558 Win=2102272 L
55 10.128964   10.5.10.22    10.5.10.31    TDS    238 Response

Token - Error
   Token length: 164
   SQL Error Number: 18456
   State: 1
   Class (Severity): 14
   Error message length: 54 characters
   Error message: Login failed for user 'SEVENKINGDOMS\jaime.lannister'.
   Server name length: 22 characters
   Server name: CASTELBLACK\SQLEXPRESS
   Process name length: 0 characters
   Line number: 1
Token - Done
```

Response to invalid target name / CBT when EPA is off
(valid domain credentials)

```
0000  bc 24 11 52 85 5a b
0010  00 e0 76 21 40 00 8
0020  0a 1f 05 99 c4 fd 7
0030  20 14 29 11 00 00 0
0040  00 18 48 00 00 01 0
0050  00 6e 00 20 00 66 0
0060  00 20 00 66 00 6f 0
0070  00 72 00 20 00 27 0
0080  00 4b 00 49 00 4e 0
```

```
709 205.335096    10.5.10.22    10.5.10.31    TDS    361 Response, NTLMSSP_CHALLENGE
710 205.335578    10.5.10.31    10.5.10.22    TDS    662 SSPI message, NTLMSSP_AUTH, User: SEVENKINGDOMS\
725 205.340382    10.5.10.22    10.5.10.31    TDS    334 Response

Token - Error
   Token length: 260
   SQL Error Number: 18452
   State: 1
   Class (Severity): 14
   Error message length: 102 characters
   Error message: Login failed. The login is from an untrusted domain and cannot be used with Integrated authentication.
   Server name length: 22 characters
   Server name: CASTELBLACK\SQLEXPRESS
   Process name length: 0 characters
   Line number: 1
Token - Done
```

Response to invalid target name / CBT when EPA is enabled
(valid domain credentials)

Client Error-Based Enumeration

MSSQL Analysis

- MSSQL EPA enumeration requirements
  - Any valid NTLM authentication for the domain
- MSSQL EPA enumeration logic
  - (Optionally) Validate credentials
  - Send TDS pre-login message to determine encryption requirement
  - If encryption is required
    - Send authentication with an invalid channel bindings AV pair value
    - Send authentication without a channel bindings AV pair
  - If encryption is not required
    - Send authentication with an invalid target name AV pair value
    - Send authentication without a target name AV pair

Client Error-Based Enumeration

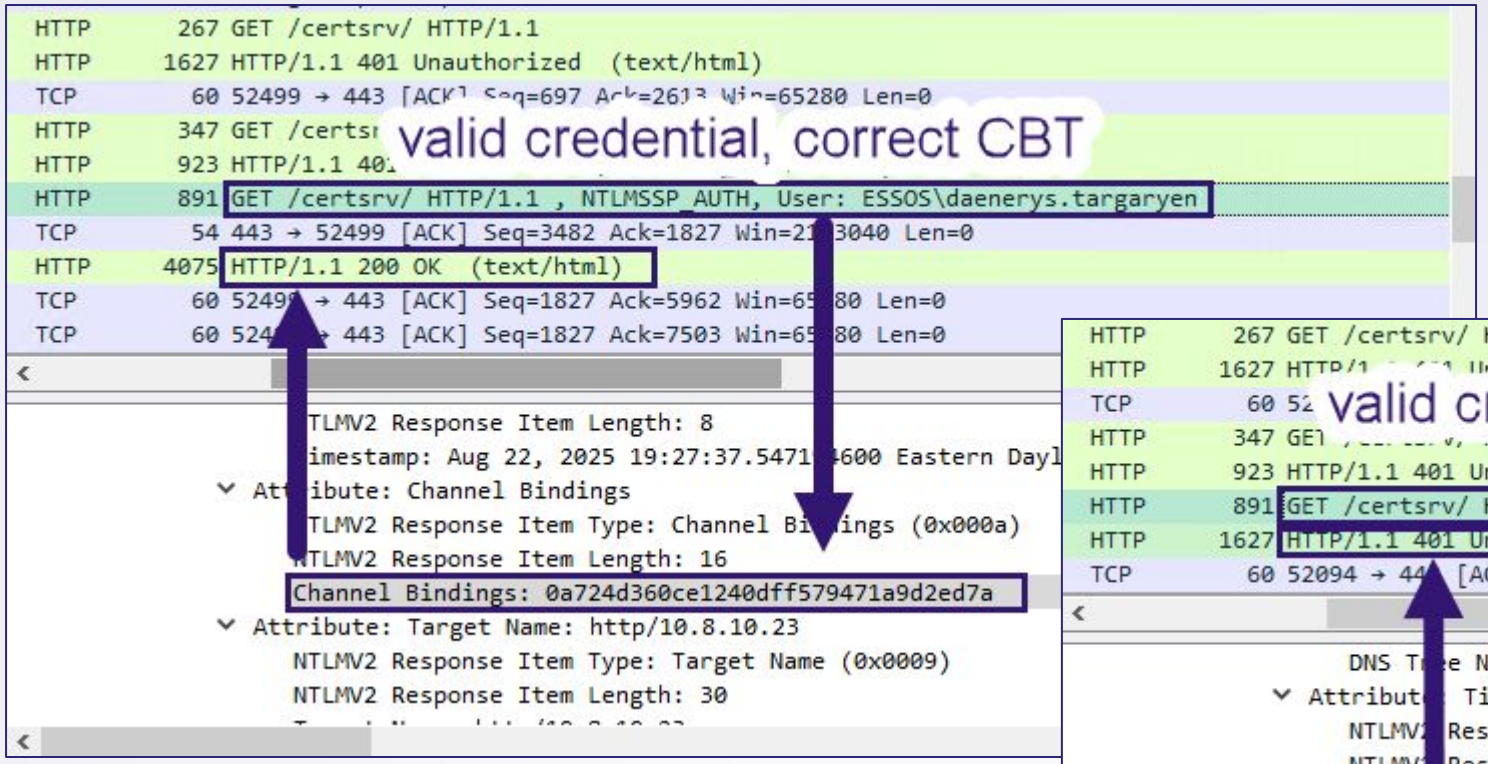
HTTP Analysis

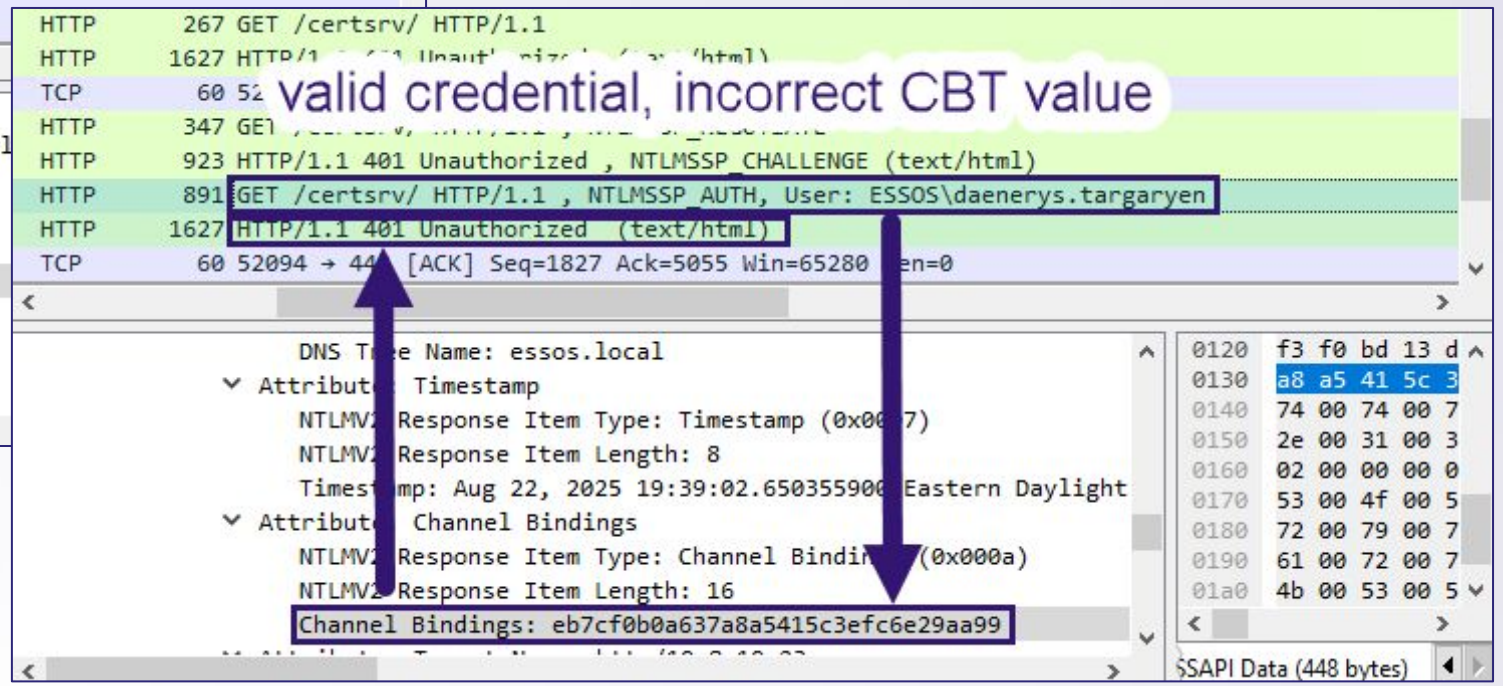
- HTTP/S EPA enumeration requirements
  - Valid NTLM authentication *that results in 200 response code*
- HTTP/S EPA enumeration logic
  - Prerequisite check with valid channel binding and service binding where applicable
    - Validate a 200 response code is received
  - If HTTPS, authenticate with:
    - **invalid channel binding** value (and valid target name)
    - **stripped channel binding** AV pair (and valid target name)
    - **stripped target name** AV pair(and correct channel binding)
    - **invalid target name** (and correct channel binding)
  - If HTTP, authenticate with:
    - **stripped target name** AV pair(and correct channel binding)
    - **invalid target name** (and correct channel binding)
- Counterintuitive logic for HTTPS used
  - IIS observations
  - Coverage across multiple server implementations

https://www.synacktiv.com/en/publications/a-study-on-windows-http-authentication-part-ii

Client Error-Based Enumeration

HTTPS Analysis

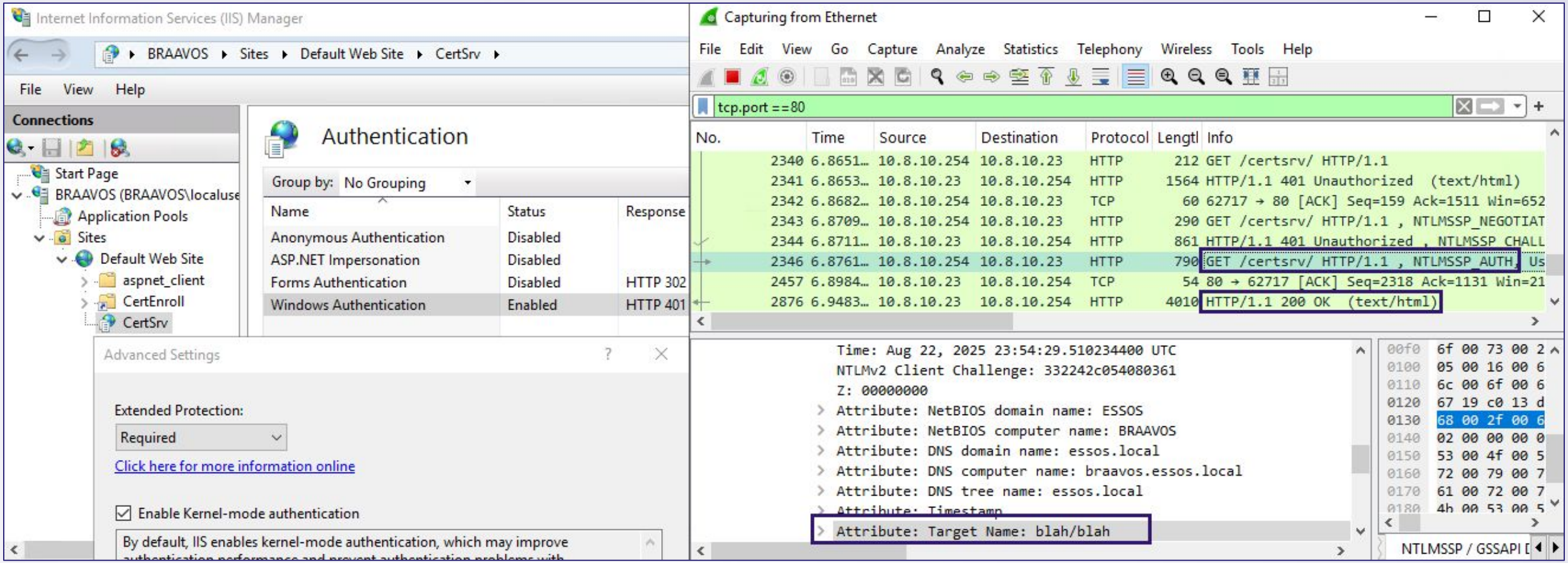




** EPA allowed / required

Client Error-Based Enumeration

IIS Analysis (EPA configured using GUI only)



Client Error-Based Enumeration

Key Takeaways

- Understanding *what* and *when* a server validates is important
  - Informed by manipulating **MsvAvChannelBindings** and **MsvAvTargetName** on client-side
  - Any difference in response can help identify EPA enforcement

- **More unauthenticated opportunity for edge cases**
  - MSSQL
    - configured to allow GUEST login → unauthenticated EPA enumeration (error-based)
  - IIS
    - default EPA configuration → unauthenticated EPA enumeration (timing-based)

Tool Releases

~Python and BOF Implementations~

RelayInformer

Python Implementation (MSSQL)

```
┌─[2025-08-23 03:55:35] defaultuser ~/dev/relayinformer
└─$ uv run relayinformer mssql --target 10.8.10.23 --user 'ESSOS/daenerys.targaryen' --password 'BurnThemAll!'
[03:56:02] INFO     Testing EPA enforcement level for MSSQL service at 10.8.10.23 on port 1433 as ESSOS/daenerys.targaryen
[03:56:02] INFO     Server supports but does not require encryption (TDS_ENCRYPT_OFF)
[03:56:03] INFO     Successfully connected to MSSQL server
[03:56:03] INFO     Prereq check passed with an expected response, continuing
[03:56:03] INFO     Conducting logins while manipulating target service av pair over unencrypted connection
[03:56:03] INFO     --------------------------------
[03:56:03] INFO          EPA setting - Required
[03:56:03] INFO     --------------------------------
┌─[2025-08-23 03:56:03] defaultuser ~/dev/relayinformer
└─$ uv run relayinformer mssql --target 10.8.10.23 --user 'ESSOS/daenerys.targaryen' --hashes :34534854d33b398b66684072224bb47a
[03:56:37] INFO     Testing EPA enforcement level for MSSQL service at 10.8.10.23 on port 1433 as ESSOS/daenerys.targaryen
[03:56:37] INFO     Server requires encryption (TDS_ENCRYPT_REQ)
[03:56:37] INFO     Successfully connected to MSSQL server
[03:56:37] INFO     Prereq check passed with an expected response, continuing
[03:56:37] INFO     Conducting logins while manipulating channel binding av pair over encrypted connection
[03:56:37] INFO     Successfully connected to MSSQL server
[03:56:37] INFO     --------------------------------
[03:56:37] INFO          EPA setting - Allowed
[03:56:37] INFO     --------------------------------
```

RelayInformer

Python Implementation (HTTP)

```
┌─[2025-08-23 03:26:10] defaultuser ~/dev/relayinformer
└─$ uv run relayinformer --debug http --url https://10.8.10.23/certsrv/ --user 'ESSOS\daenerys.targaryen' --password 'BurnThemAll!'
[03:26:14] INFO     Testing EPA enforcement level for HTTPS service at https://10.8.10.23/certsrv/ as ESSOS\daenerys.targaryen
[03:26:14] DEBUG    Running prerequisite check with correct parameters
[03:26:14] DEBUG    Successfully authenticated to https://10.8.10.23/certsrv
[03:26:14] INFO     Prereq check passed with correct av pair values
[03:26:14] DEBUG    EPA checks will manipulate channel binding AV pair over encrypted (HTTPS) connection
[03:26:14] DEBUG    Checking with NO CBT and correct target name
[03:26:14] DEBUG    Authentication failed with 401 Unauthorized
[03:26:14] INFO     EPA (channel binding) is REQUIRED
[03:26:14] DEBUG    Checking with CORRECT CBT and STRIPPED target name (service binding)
[03:26:15] DEBUG    Successfully authenticated to https://10.8.10.23/certsrv
[03:26:15] DEBUG    Service binding not required when target name stripped (200). Proceeding to fake target service check
[03:26:15] DEBUG    Checking with CORRECT CBT and FAKE target service name
[03:26:15] DEBUG    Successfully authenticated to https://10.8.10.23/certsrv
[03:26:15] INFO     EPA (service binding) is DISABLED
┌─[2025-08-23 03:26:15] defaultuser ~/dev/relayinformer
└─$ uv run relayinformer --debug http --url http://10.8.10.23/certsrv/ --user 'ESSOS\daenerys.targaryen' --password 'BurnThemAll!'
[03:26:48] INFO     Testing EPA enforcement level for HTTP service at http://10.8.10.23/certsrv/ as ESSOS\daenerys.targaryen
[03:26:48] DEBUG    Running prerequisite check with correct parameters
[03:26:48] DEBUG    Successfully authenticated to http://10.8.10.23/certsrv
[03:26:48] INFO     Prereq check passed with correct av pair values
[03:26:48] DEBUG    EPA checks will manipulate "target service" AV pair over unencrypted (HTTP) connection
[03:26:48] DEBUG    HTTP check: STRIPPED target name
[03:26:48] DEBUG    Successfully authenticated to http://10.8.10.23/certsrv
[03:26:48] DEBUG    HTTP check: FAKE target service name
[03:26:49] DEBUG    Successfully authenticated to http://10.8.10.23/certsrv
[03:26:49] INFO     EPA (service binding) is DISABLED
```

RelayInformer

Python Implementation (HTTP)

```
┌─[2025-08-23 03:29:27] defaultuser ~/dev/relayinformer
└─$ uv run relayinformer http --url https://10.8.10.23/certsrv/ --user 'ESSOS\daenerys.targaryen' --password 'BurnThemAll!'
[03:29:39] INFO     Testing EPA enforcement level for HTTPS service at https://10.8.10.23/certsrv/ as ESSOS\daenerys.targaryen
[03:29:39] INFO     Prereq check passed with correct av pair values
[03:29:39] INFO     EPA (channel binding) is REQUIRED
[03:29:39] INFO     EPA (service binding) is DISABLED
┌─[2025-08-23 03:29:39] defaultuser ~/dev/relayinformer
└─$ uv run relayinformer http --url http://10.8.10.23/certsrv/ --user 'ESSOS\daenerys.targaryen' --password 'BurnThemAll!'
[03:29:46] INFO     Testing EPA enforcement level for HTTP service at http://10.8.10.23/certsrv/ as ESSOS\daenerys.targaryen
[03:29:46] INFO     Prereq check passed with correct av pair values
[03:29:47] INFO     EPA (service binding) is DISABLED
```

RelayInformer

Python Implementation (LDAP)

```
┌─[2025-08-23 03:49:13] defaultuser ~/dev/relayinformer
└─$ uv run relayinformer ldap --method LDAPS --dc-ip 10.8.10.12
[03:49:21] INFO     Identified Domain Controllers

   -> meereen.essos.local

[03:49:21] INFO     Checking DCs for LDAP NTLM relay protections
[03:49:21] INFO     [meereen.essos.local] (LDAPS) CHANNEL BINDING SET TO NEVER! PARTY TIME!
┌─[2025-08-23 03:49:21] defaultuser ~/dev/relayinformer
└─$ uv run relayinformer ldap --method BOTH --dc-ip 10.8.10.12 --user drogon --password Dracarys
[03:49:29] INFO     Identified Domain Controllers

   -> meereen.essos.local

[03:49:29] INFO     Checking DCs for LDAP NTLM relay protections
[03:49:29] INFO     [meereen.essos.local] (LDAP) SERVER SIGNING REQUIREMENTS NOT ENFORCED!
[03:49:29] INFO     [meereen.essos.local] (LDAPS) CHANNEL BINDING SET TO NEVER! PARTY TIME!
```

RelayInformer

BOF Design Considerations

- Existing approaches
  - **LdapSignCheck** - Manually calls AcquireCredentialsHandle/InitializeSecurityContext and feed a credential/context handle to protocol-specific APIs
  - **SharpLdapRelayScan** - Manually builds NTLM messages
    - Requires cleartext password to be supplied
- Our design requirements
  - Needs to work with multiple protocols
    - Ex: SSPI context handle can’t be passed directly into a SQLDriverConnect call
  - Needs to be capable of leveraging the current logon session

RelayInformer

BOF Implementation

- Trap *sspicli.dll* function calls using hardware breakpoints
  - *AcquireCredentialsHandle*
  - *InitializeSecurityContext*

Syntax

C++ Copy

```
SECURITY_STATUS SEC_Entry AcquireCredentialsHandle(
  _In_  SEC_CHAR       *pszPrincipal,
  _In_  SEC_CHAR       *pszPackage,
  _In_  ULONG          fCredentialUse,
  _In_  PLUID          pvLogonID,
  _In_  PVOID          pAuthData,
  _In_  SEC_GET_KEY_FN pGetKeyFn,
  _In_  PVOID          pvGetKeyArgument,
  _Out_ PCredHandle    phCredential,
  _Out_ PTimeStamp     ptsExpiry
);
```

Syntax

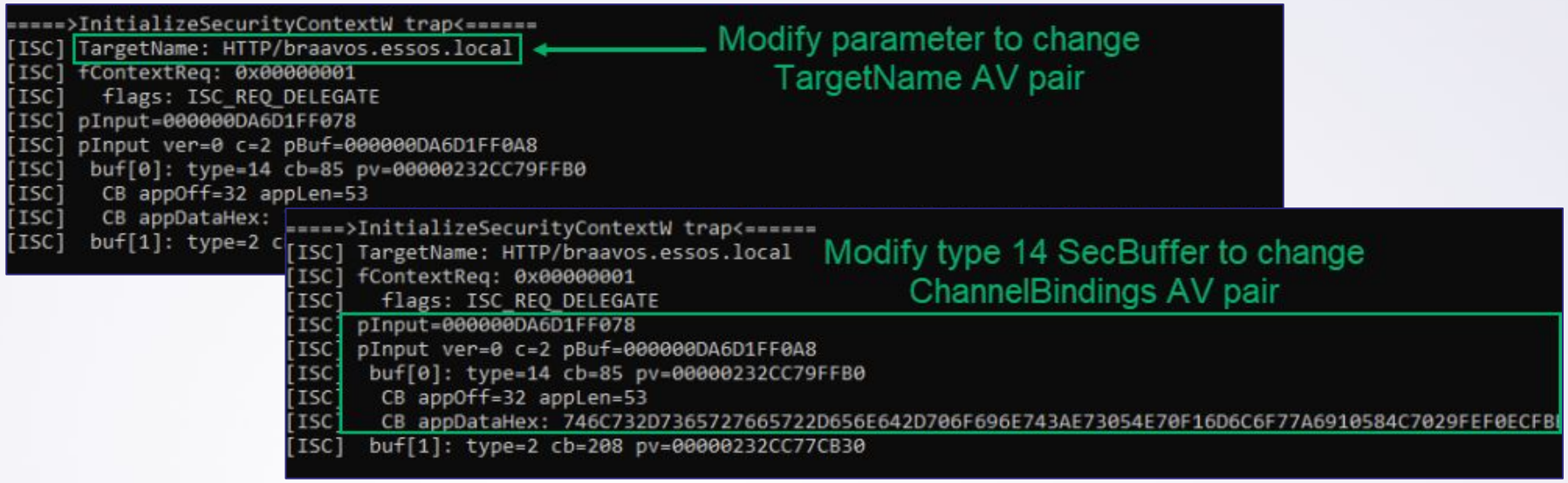
C++ Copy

```
KSECDDDECLSPEC SECURITY_STATUS SEC_ENTRY InitializeSecurityContextW(
  [in, optional]      PCredHandle      phCredential,
  [in, optional]      PCtxtHandle      phContext,
  [in, optional]      PSECURITY_STRING pTargetName,
  [in]                unsigned long    fContextReq,
  [in]                unsigned long    Reserved1,
  [in]                unsigned long    TargetDataRep,
  [in, optional]      PSecBufferDesc   pInput,
  [in]                unsigned long    Reserved2,
  [in, out, optional] PCtxtHandle      phNewContext,
  [in, out, optional] PSecBufferDesc   pOutput,
  [out]               unsigned long    *pfContextAttr,
  [out, optional]     PTimeStamp       ptsExpiry
);
```

RelayInformer

BOF Implementation

- Traps work as a drop-in approach across MSSQL, HTTP/S and LDAPS
  - *WLDAP32!ldap_bind_s*, *ODBC32!SQLDriverConnect*, *WINHTTP!WinHttpSendRequest* all filter down to ACH/ISC API calls



RelayInformer

BOF Implementation Nuances

- ODBC32 calls funnel to ANSI versions of ACH/ISC
- Default ODBC “SQL Driver” does not support channel binding
  - Newer ODBC 17/18 drivers support channel binding, but require installation
- WinHTTP uses threading under the hood
  - At least when using the low security autologon policy
  - Requires arming hardware breakpoints on all threads to catch SSPI calls
- Checking LDAP signing requires stripping certain context flags from ISC calls
  - *WLDAP32!ldap_bind_s* allows auth method specification (can force NTLM without trapping ACH)

RelayInformer

BOF Implementation

- BOFs can detect EPA disabled vs enabled
  - Windows SSP always sends the relevant AV pairs!
- Support for EPA/signing across multiple protocols
  - MSSQL
  - HTTP/S
  - LDAP/S
  - SMB

```
[08/22 15:05:43] beacon> http-relay-informer https://braavos.essos.local/certsrv/
[08/22 15:05:43] [*] Tasked beacon to inform on HTTP/S protections
[08/22 15:05:47] [+] host called home, sent: 14615 bytes
[08/22 15:05:48] [+] received output:
[*] Targeting URL: https://braavos.essos.local/certsrv/
[*] Zeroed out channel binding token rejected!
[*] EPA is ACCEPT or REQUIRED (Channel Binding)

[08/22 15:05:49] beacon> http-relay-informer http://braavos.essos.local/certsrv/
[08/22 15:05:49] [*] Tasked beacon to inform on HTTP/S protections
[08/22 15:05:57] [+] host called home, sent: 14613 bytes
[08/22 15:05:57] [+] received output:
[*] Targeting URL: http://braavos.essos.local/certsrv/
[*] EPA is OFF
```

```
[08/22 15:34:10] beacon> mssql-relay-informer castelblack.north.sevenkingdoms.local 1433 master
[08/22 15:34:10] [*] Tasked beacon to inform on MSSQL protections
[08/22 15:34:18] [+] host called home, sent: 14290 bytes
[08/22 15:34:18] [+] received output:
[*] Target: mssql://castelblack.north.sevenkingdoms.local:1433
[*] ForceEncryption is ON, checking channel binding...
[*] EPA is ALLOWED or REQUIRED
```

Conclusion

Conclusion

Key Takeaways

- EPA can now be enumerated for MSSQL and HTTPS, in addition to LDAPS
  - LDAPS - still does not require authentication
  - MSSQL - require any valid credential, no need for DB access (BOF)
  - HTTP - requires credentials that can authenticate (BOF)
- Understanding server implementation of EPA can lead to identifying gaps
  - IIS configuration of EPA in GUI vs config file

Conclusion

Credit & References

- **Alex DeMine** - initial effort in MSSQL EPA research
- **@Defte_** - “A journey implementation Channel Binding on MSSQLClient.py”
  - https://sensepost.com/blog/2025/a-journey-implementing-channel-binding-on-mssqlclient.py/
- **@lowercase_drm** - early open source implementation of LDAP channel binding in LDAP3 library
- **Pierre Milioni** and **Geoggrey Bertoli** - “A Study on Windows HTTP Authentication (Part 2)”
  - https://sensepost.com/blog/2025/a-journey-implementing-channel-binding-on-mssqlclient.py/
- **Adam Crosser** - “Relaying to ADFS Attacks”
  - https://www.praetorian.com/blog/relaying-to-adfs-attacks/
- Many open-source developers contributing to libraries such as **Impacket**, **msldap, LdapSignCheck**, and more

SPECTEROPS

Questions

Nick Powers | npowers@specterops.io

Matt Creel | mcreel@specterops.io