Call & Register

Relay attack on WinReg RPC client

Agenda

- MS-RPC introduction and overview
- RPC Authentication and NTLM (relay)
- Windows Remote Registry
- Downgrade attack -> relay

whoami

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@kupsul  

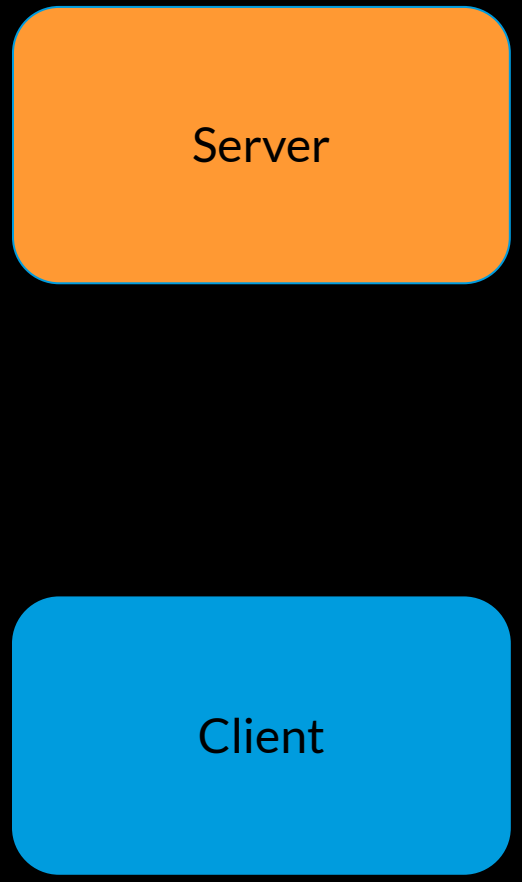
Background in DFIR and Windows internals

MS-RPC Overview

Terminology

- Interface
- {M}IDL
- Transport
- Endpoint
- Binding

The RPC Client-Server Model



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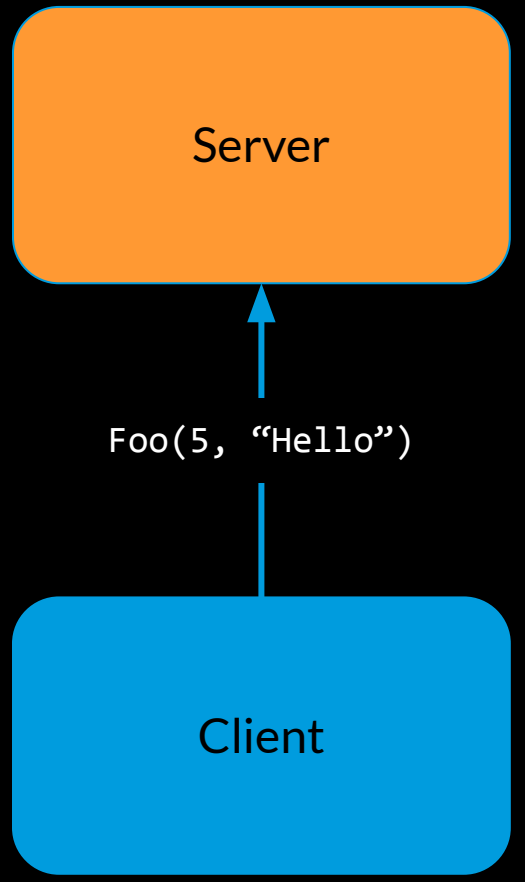
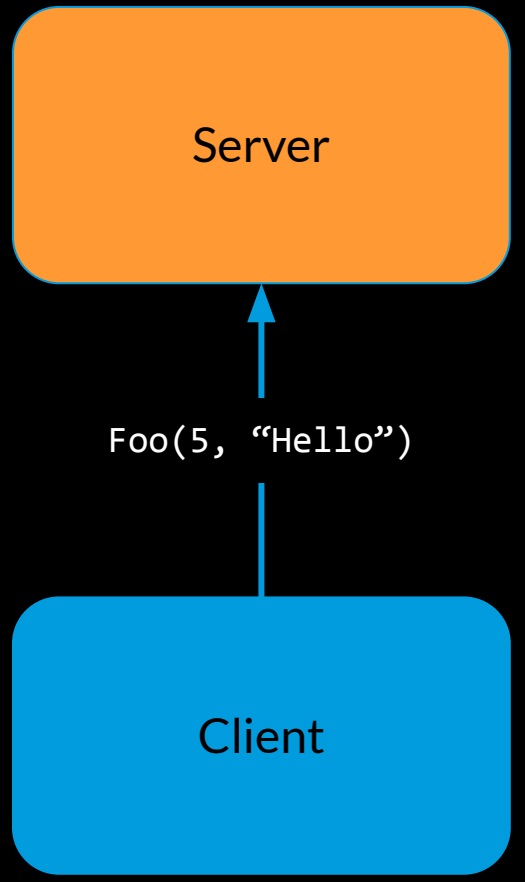


The RPC Client-Server Model

```
[
uuid(12345678-4000-2006-0000-2
0000000001a)
]

interface Test
{
void Foo([in] int number,
[in] char *message);
void Bar([out] int * result);
}
```



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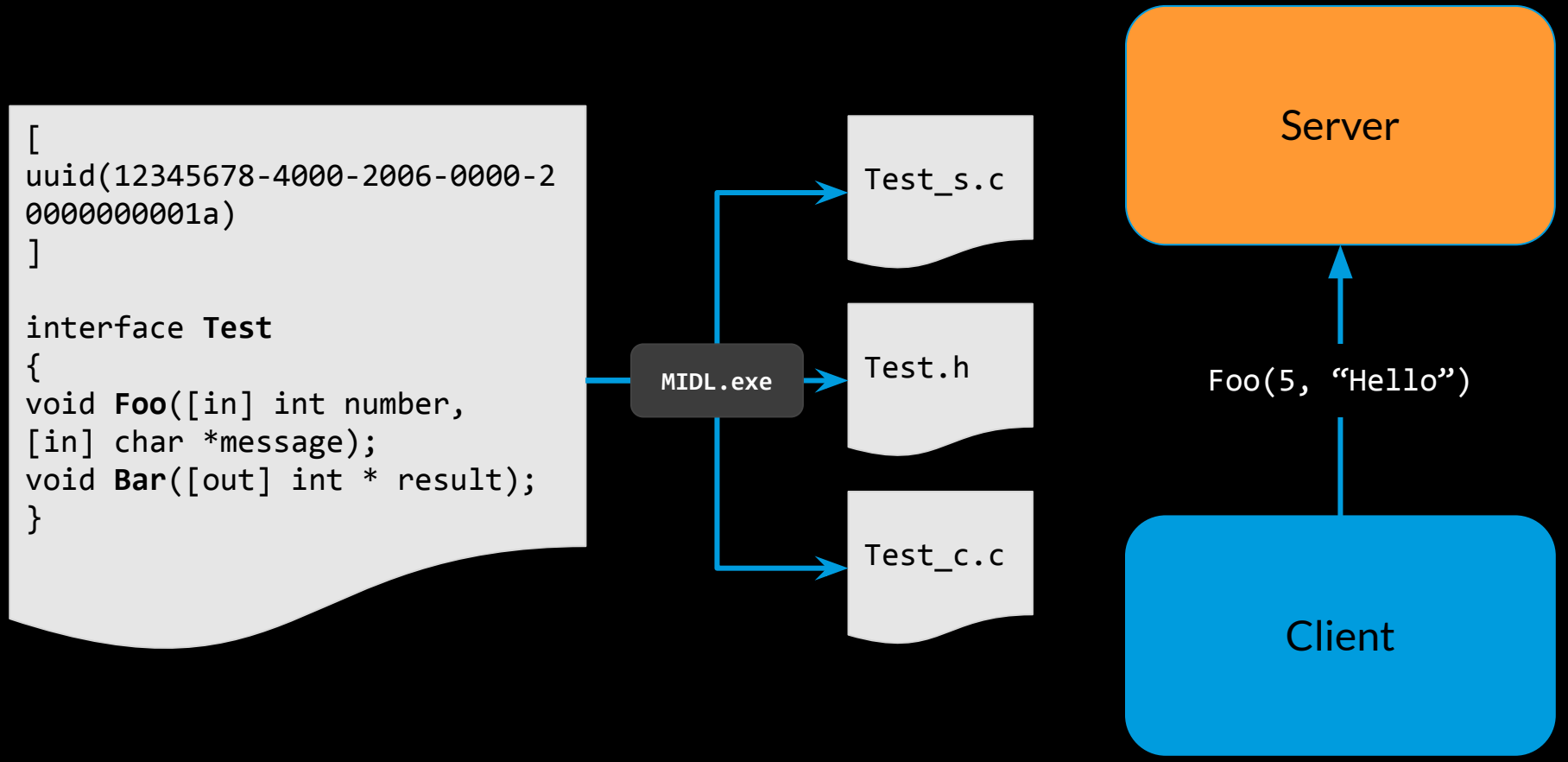

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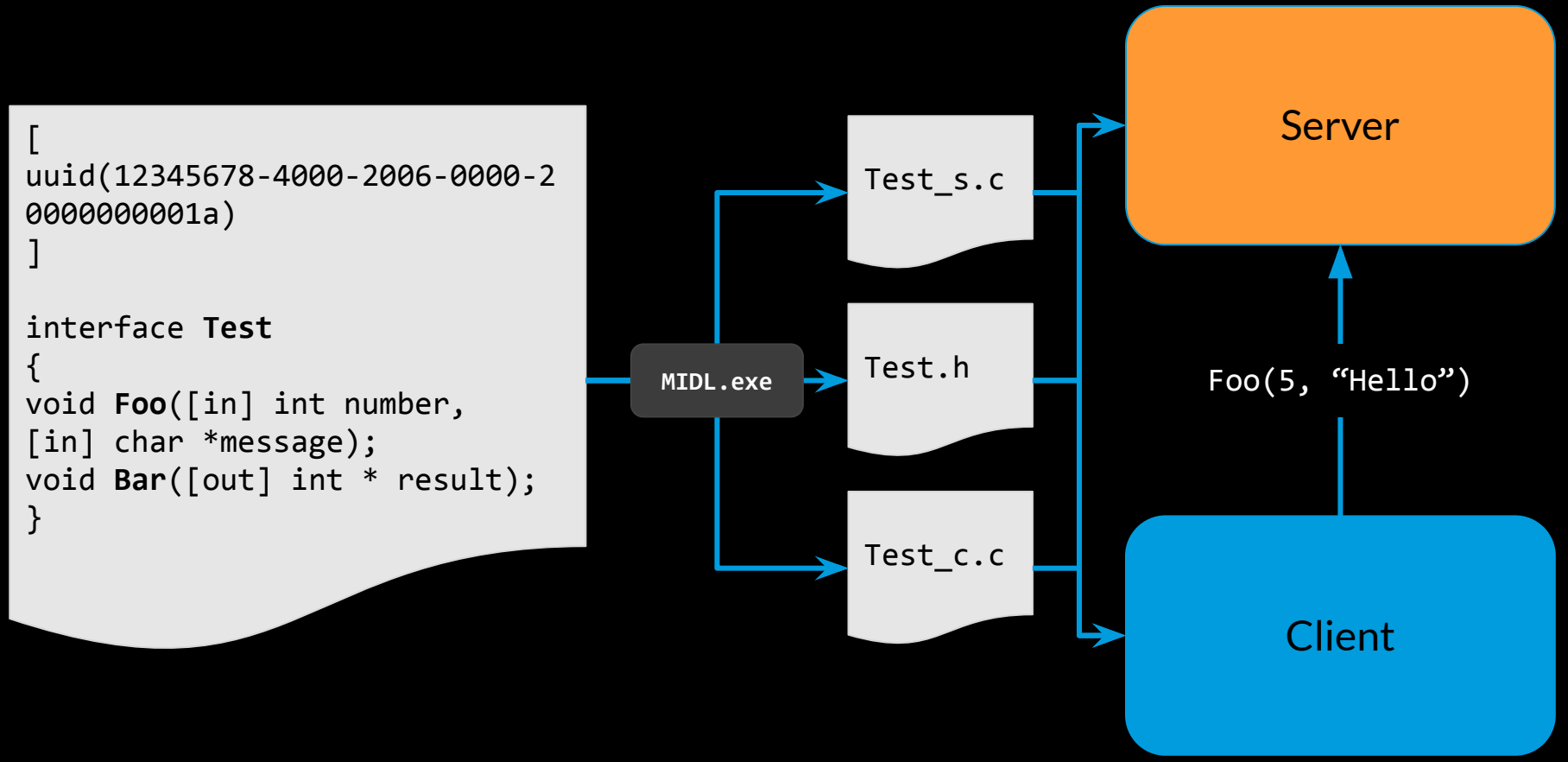


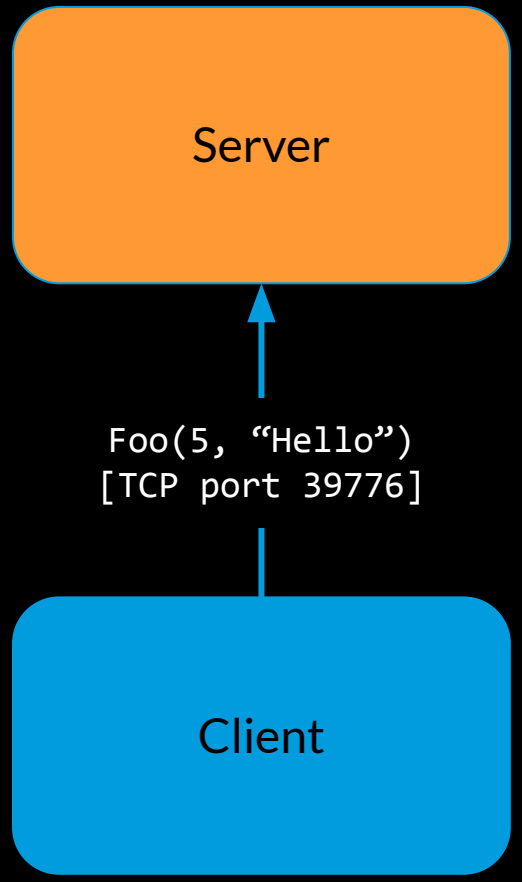
Endpoints

The server registers an *endpoint* using a certain *transport*

Transports	Protocol Sequence	Endpoints
TCP	`ncacn_ip_tcp`	<port number>
Named pipe	`ncacn_np`	<pipe name>
UDP	`ncadg_ip_udp`	<port number>
ALPC	`ncalrpc`	<ALPC port>
HTTP	`ncacn_http`	<hostname>
Hyper-V socket	`ncacn_hvsocket`	<UUID>

Well-Known Endpoints

Dynamic Endpoints



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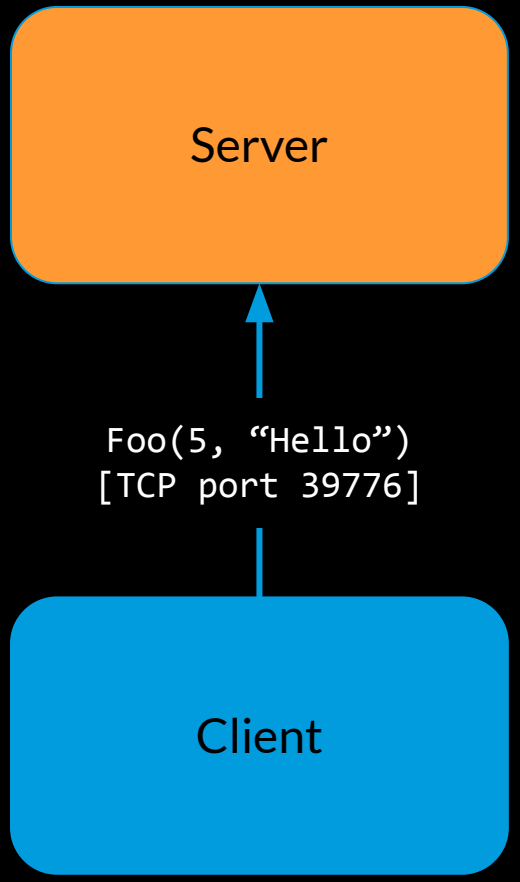

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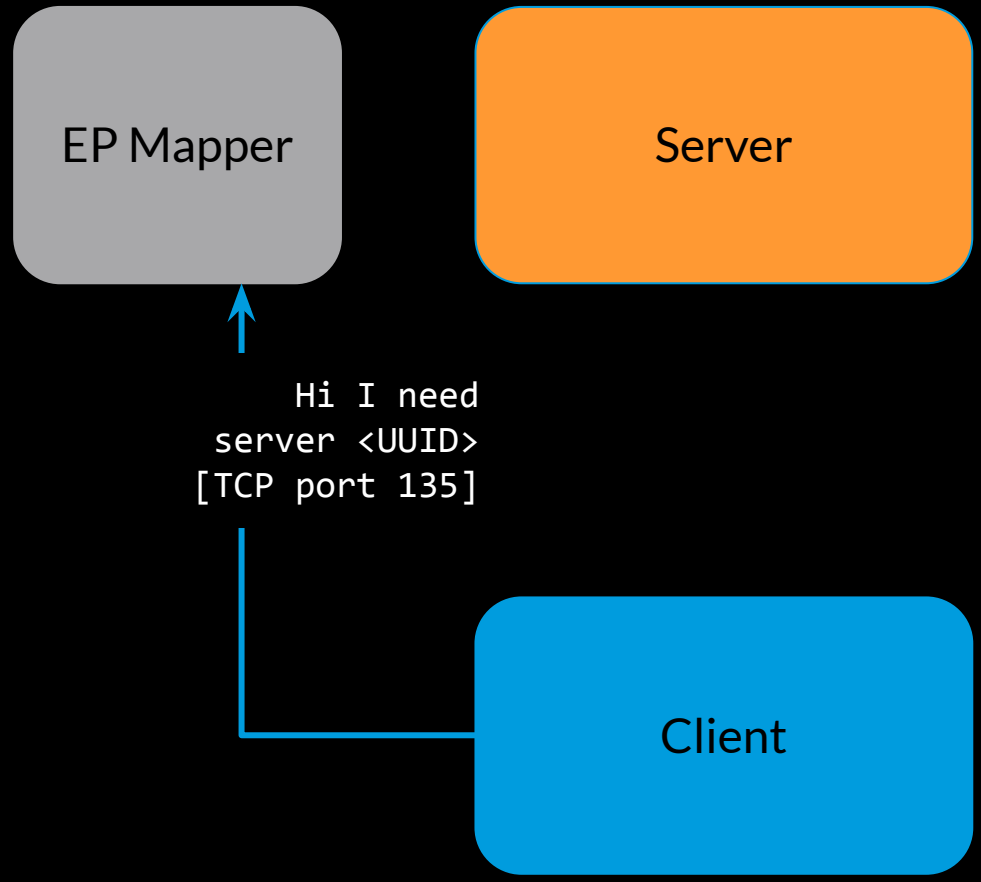

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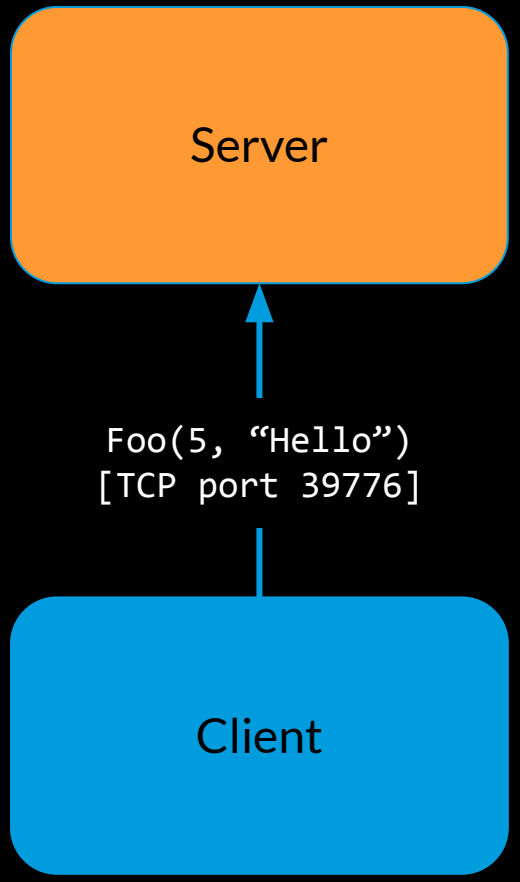

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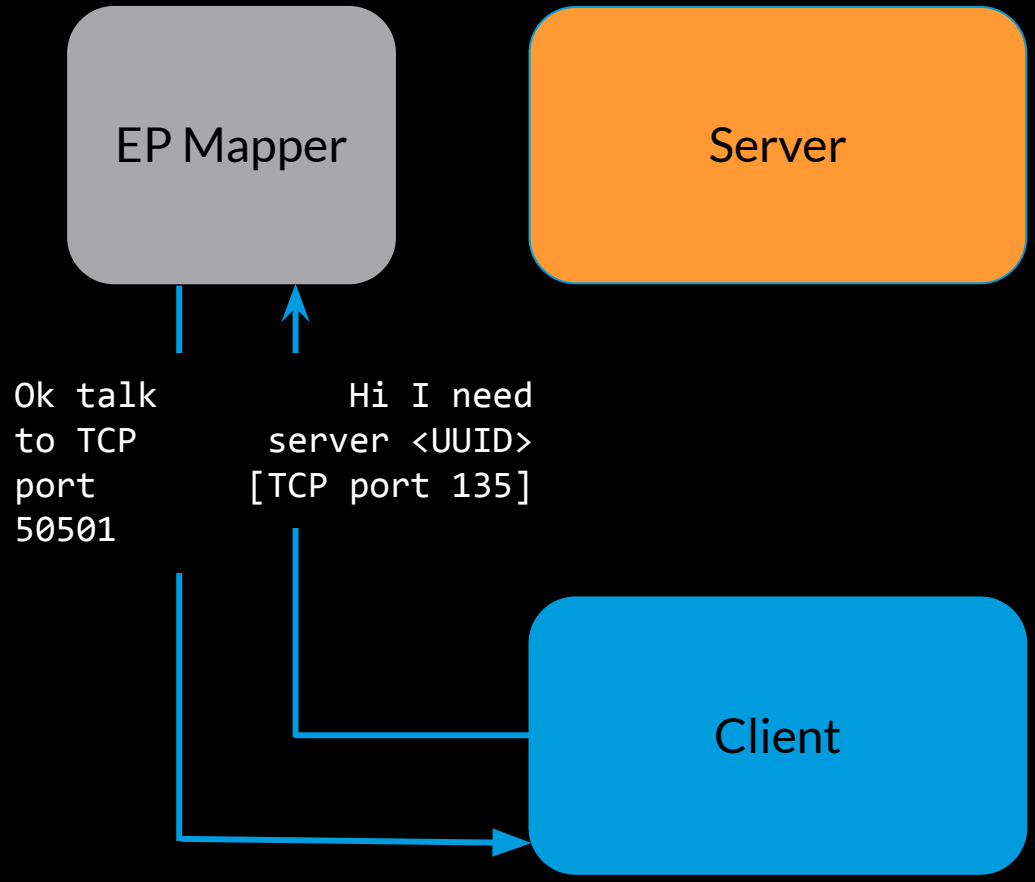

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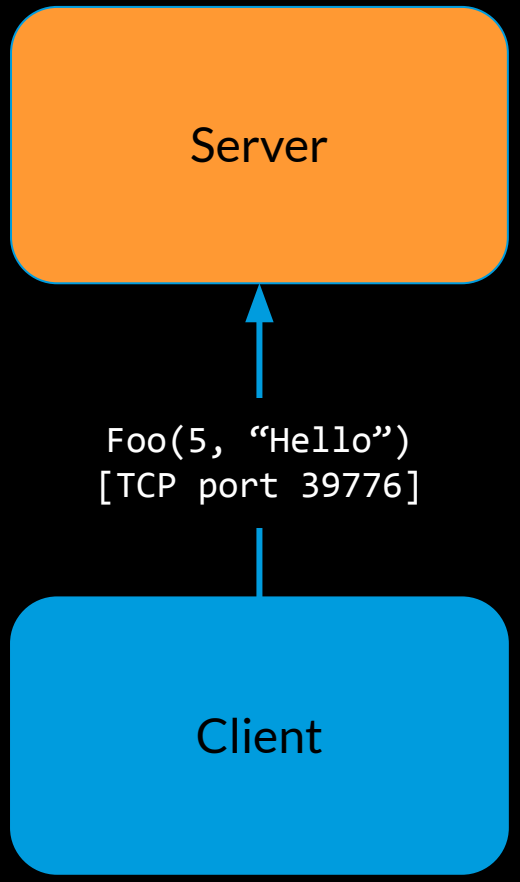

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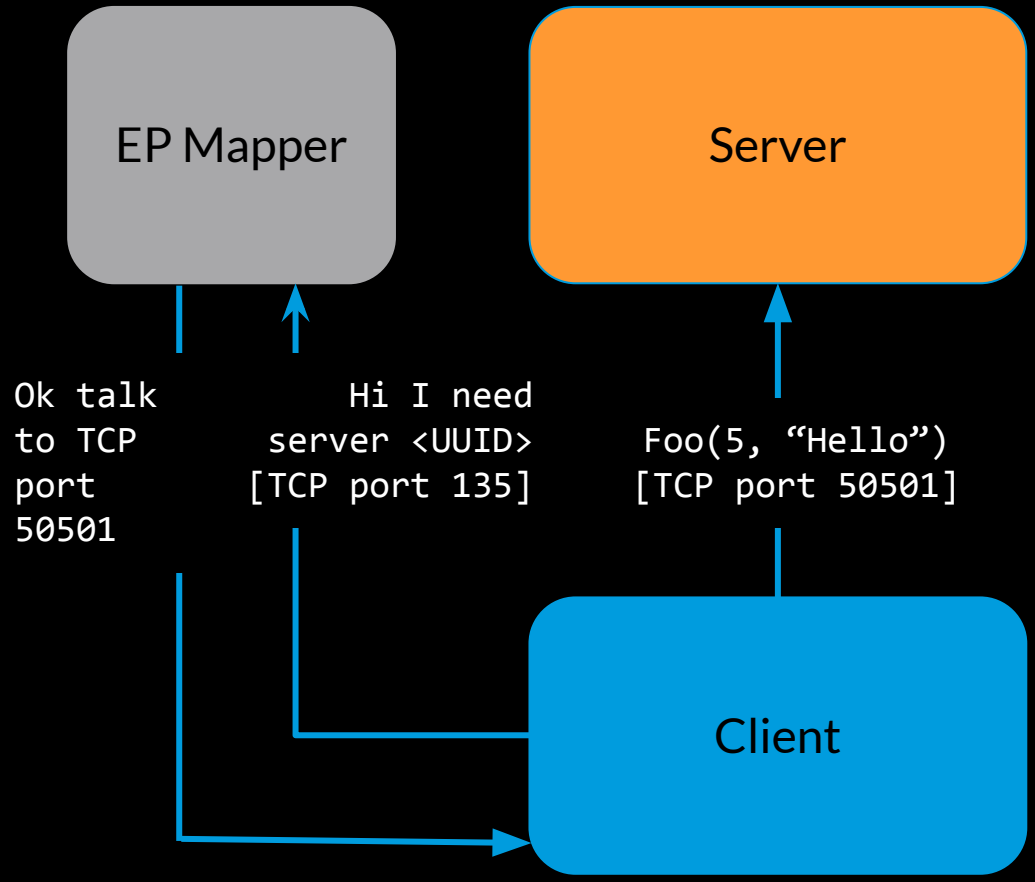

Name	Value	Purpose
GUID_ATSvc	1FF70682-0A51-30E8-076D-740BE8CEE98B	ATSvc UUID version 1.0
GUID_SASec	378E52B0-C0A9-11CF-822D-00AA0051E40F	SASec UUID version 1.0
GUID_ITaskSchedulerService	86D35949-83C9-4044-B424-DB363231FD0C	ITaskSchedulerService UUID version 1.0

Task Scheduler Service Remoting Protocol

Parameter	Value
RPC interface UUID	{367ABB81-9844-35F1-AD32-98F038001003}
Named pipe	\PIPE\svcctl

Service control manager remote protocol

Parameter	Value
RPC Well-Known Endpoint	\pipe\lsarpc<3>
RPC Interface UUID	{c681d488-d850-11d0-8c52-00c04fd90f7e}
RPC Well-Known Endpoint	\pipe\efsrpc
RPC Interface UUID	{df1941c5-fe89-4e79-bf10-463657acf44d}

Encrypting File System Remote (EFSRPC) Protocol

Endpoint Resolution

```
192.168.0.4 192.168.0.5 TCP      66 52803 → 135 [SYN, ECE, CWR] Seq=0 Win=64240 Len=0 MSS=1
192.168.0.5 192.168.0.4 TCP      66 135 → 52803 [SYN, ACK, ECE] Seq=0 Ack=1 Win=65535 Len=0
192.168.0.4 192.168.0.5 TCP      54 52803 → 135 [ACK] Seq=1 Ack=1 Win=2102272 Len=0
192.168.0.4 192.168.0.5 DCERPC  214 Bind: call_id: 2, Fragment: Single, 3 context items: EP
192.168.0.5 192.168.0.4 DCERPC  162 Bind_ack: call_id: 2, Fragment: Single, max_xmit: 5840
192.168.0.4 192.168.0.5 EPM     222 Map request, SVCCTL, 32bit NDR
192.168.0.5 192.168.0.4 EPM     226 Map response, SVCCTL, 32bit NDR
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192.168.0.4 192.168.0.5 DCERPC  644 AUTH3: call_id: 2, Fragment: Single, NTLMSSP_AUTH, User
192.168.0.4 192.168.0.5 SVCCTL  214 OpenSCManagerW request
```

Endpoint Resolution

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                                   anagerW request
```

```
▾ Tower pointer:
    Referent ID: 0x0000000000000003
    Length: 75
    Length: 75
    Number of floors: 5
  ▸ Floor 1 UUID: SVCCTL
  ▸ Floor 2 UUID: 32bit NDR
  ▸ Floor 3 RPC connection-oriented protocol
  ▸ Floor 4 TCP Port:49704
  ▸ Floor 5 IP:192.168.0.5
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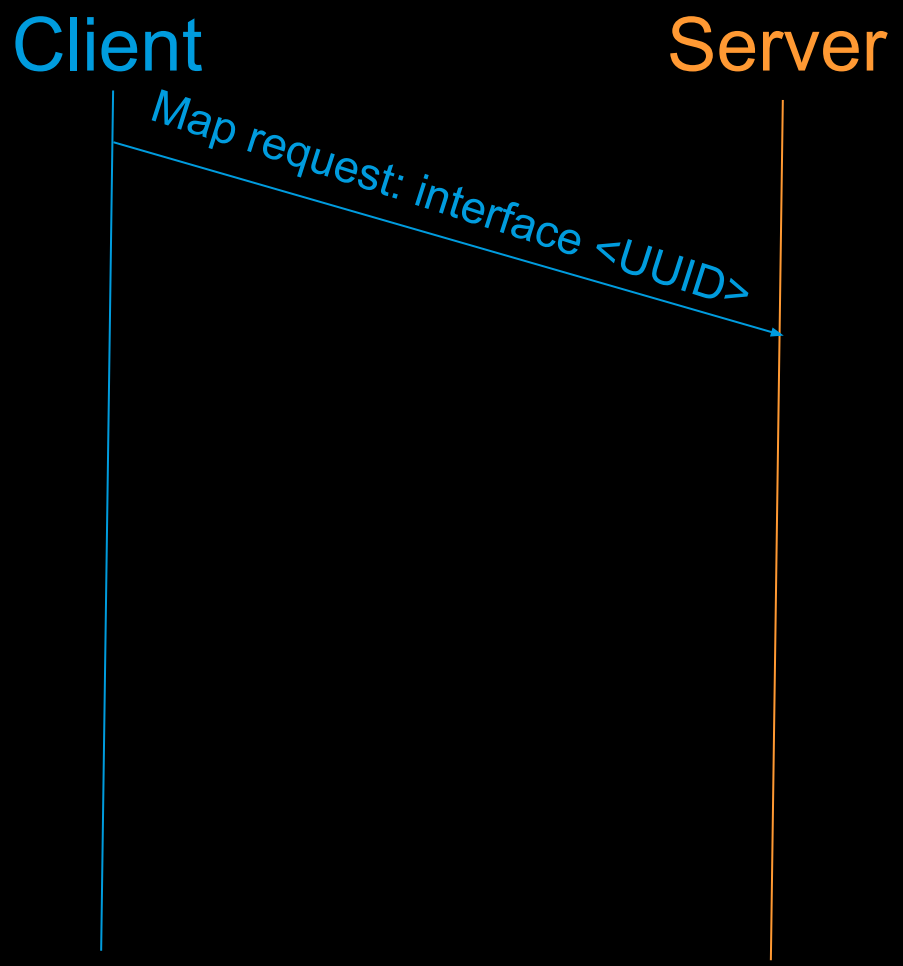
Binding

- Establishing a context session between a client and a server
- Carries details about the connection
  - Context
  - Security
  - Authentication

Message Flow



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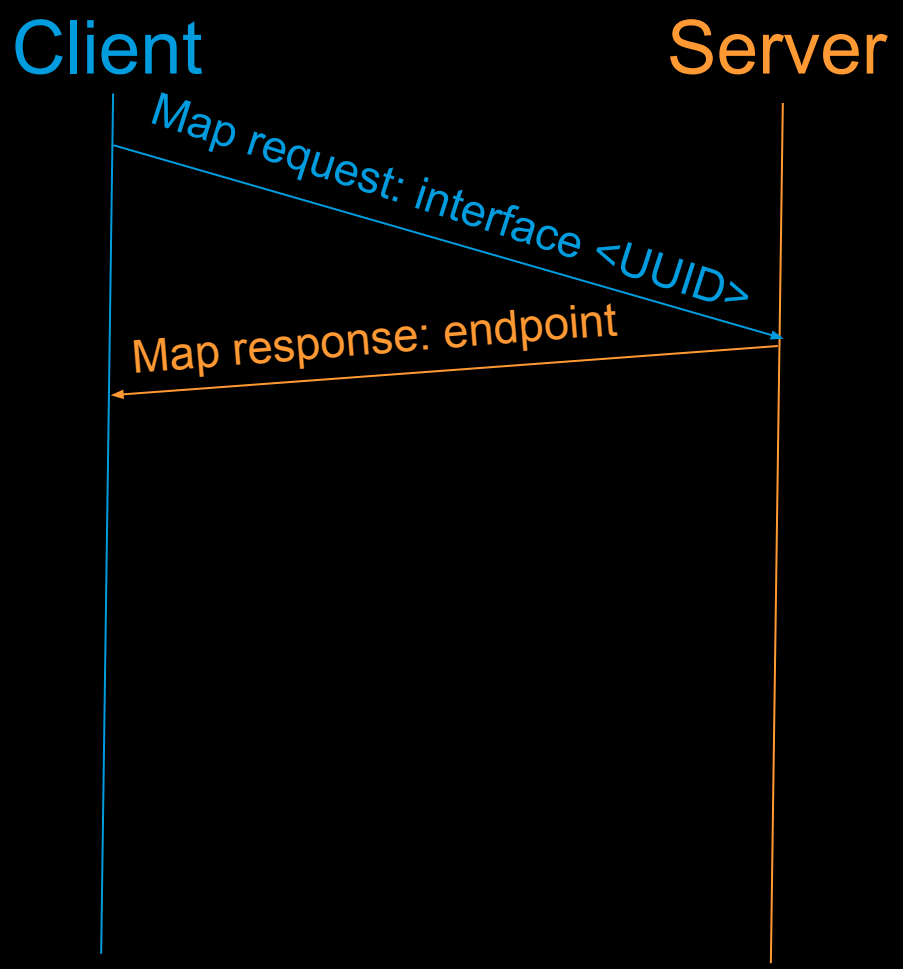

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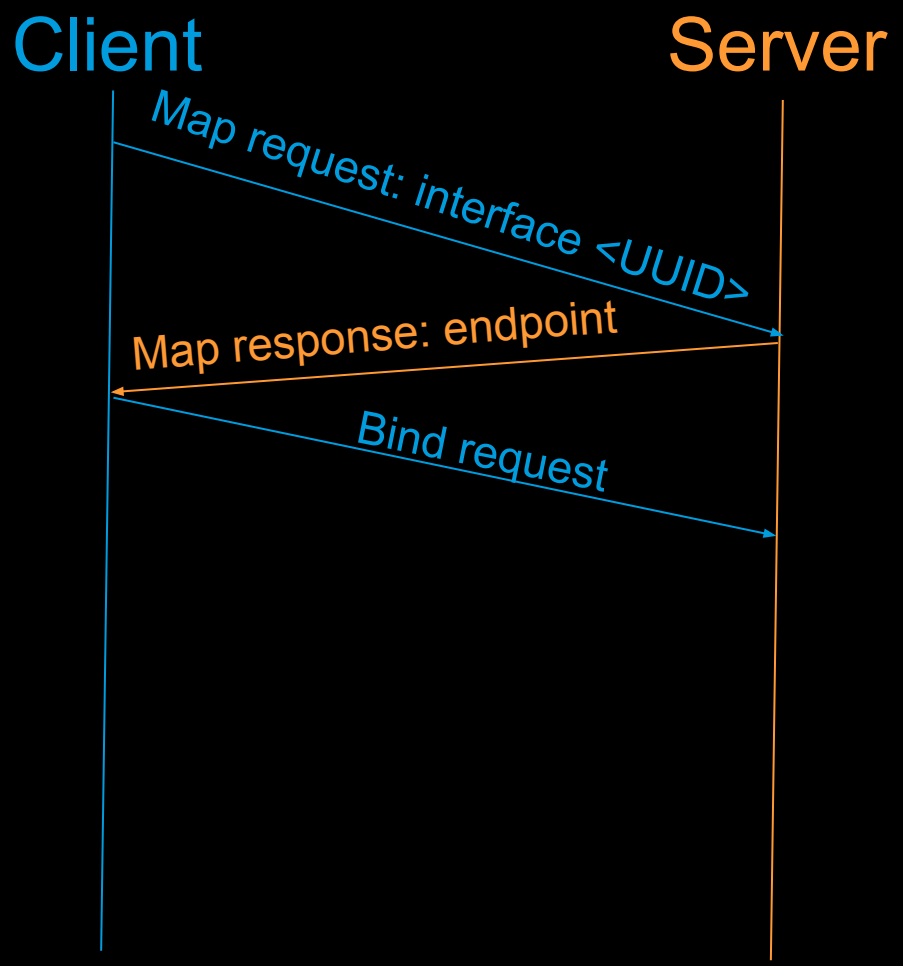

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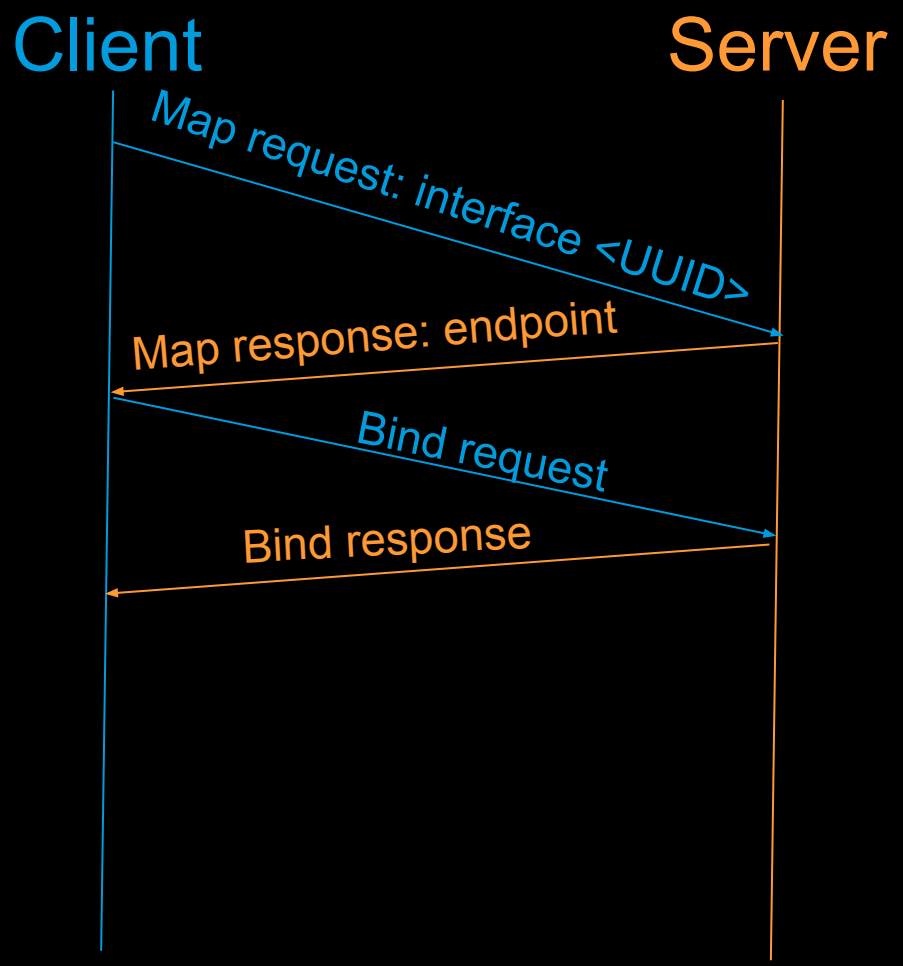

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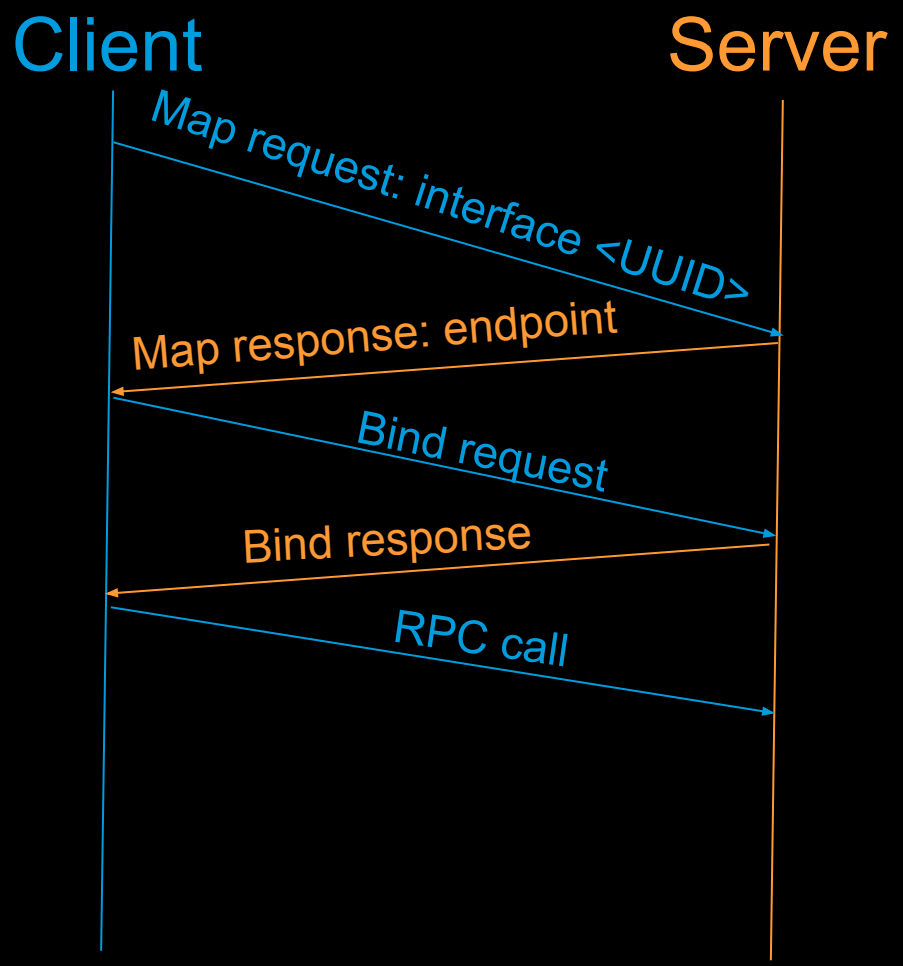

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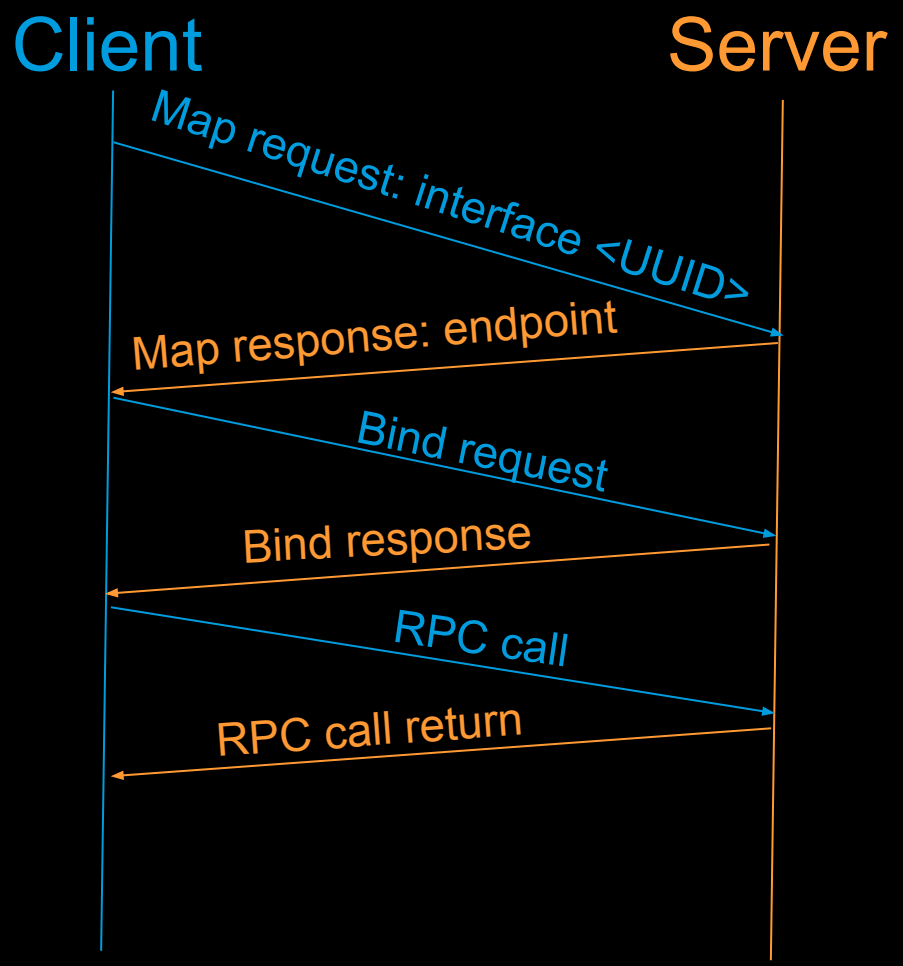
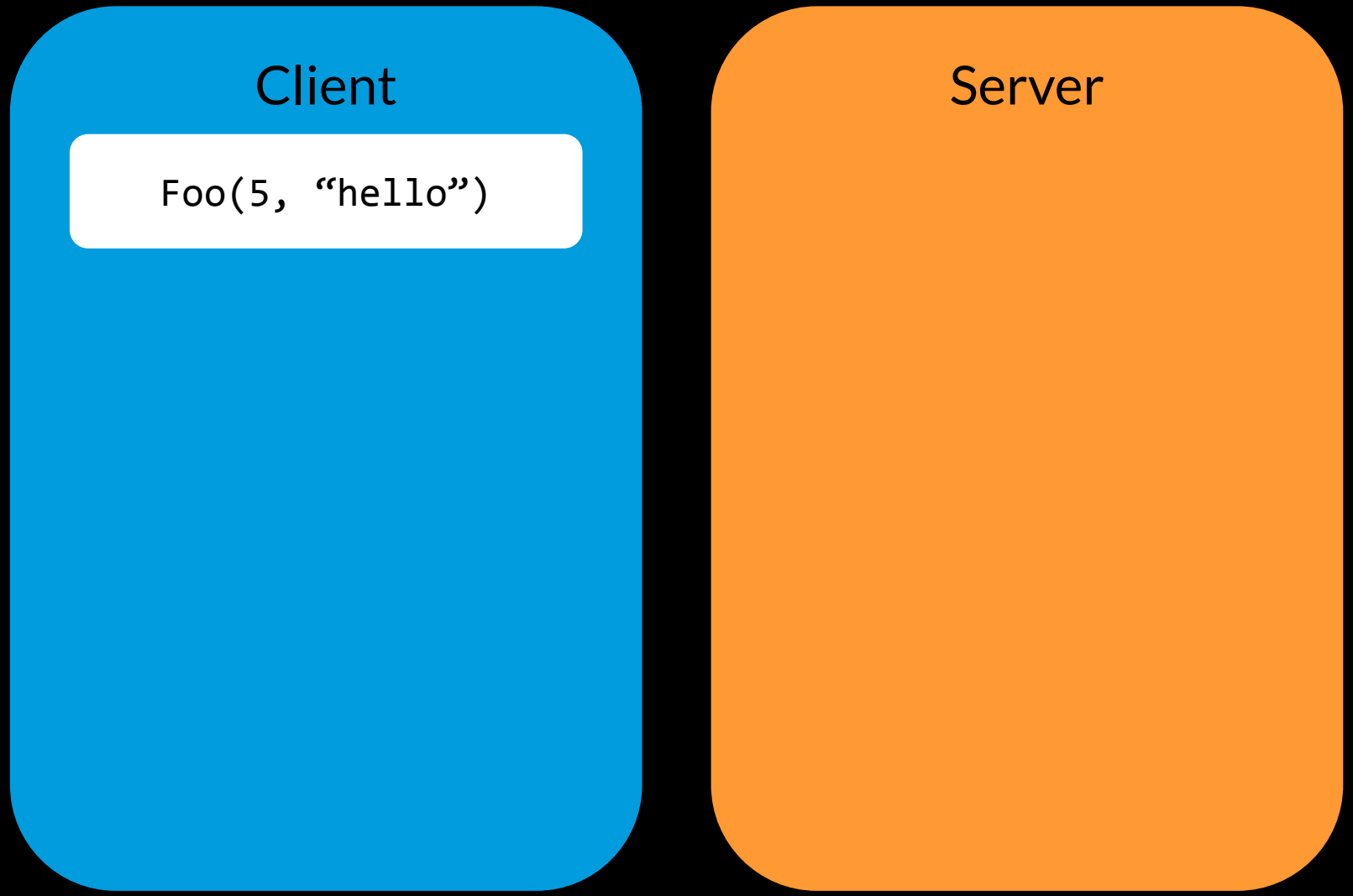


An RPC Call's Flow



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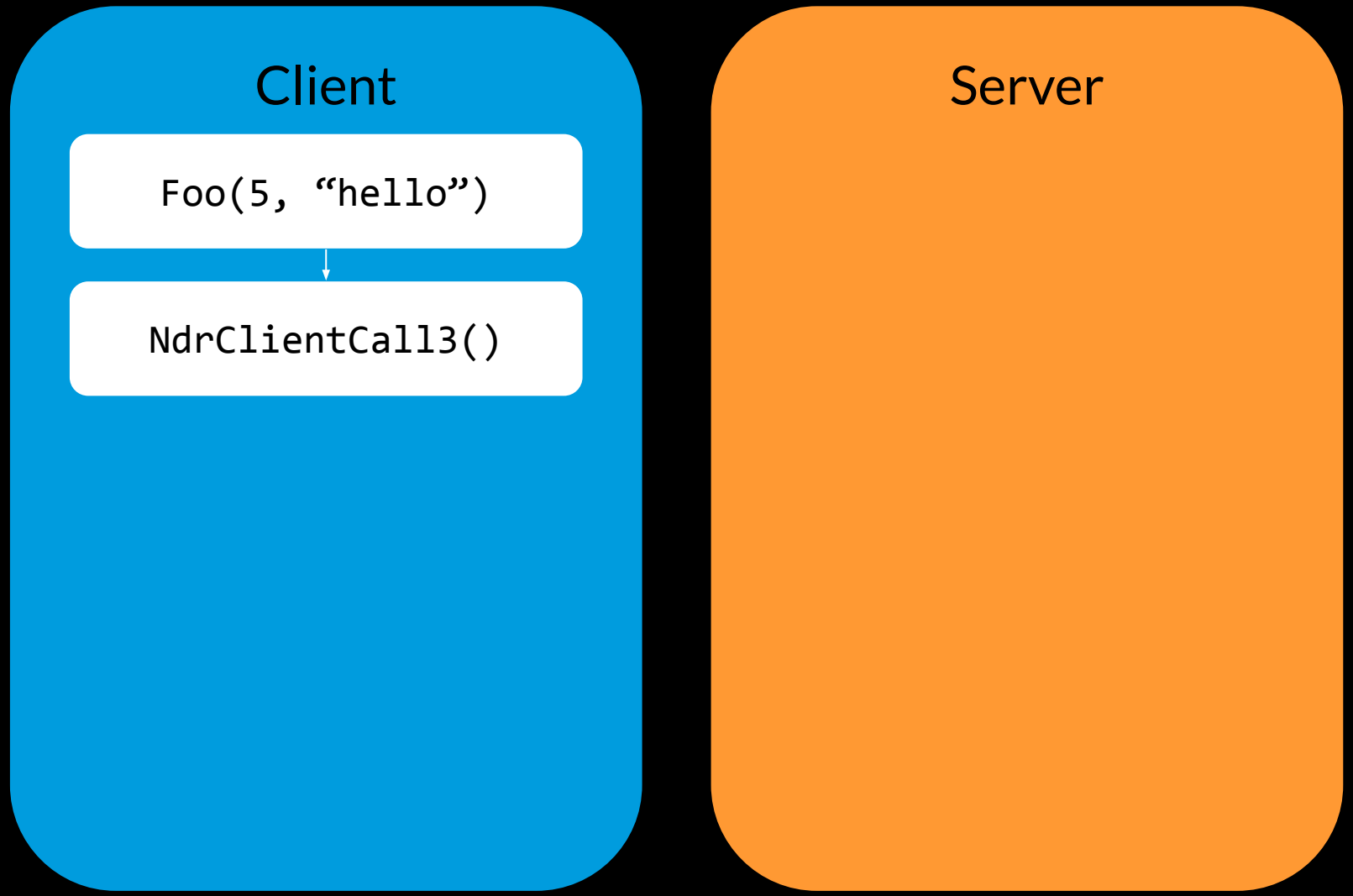

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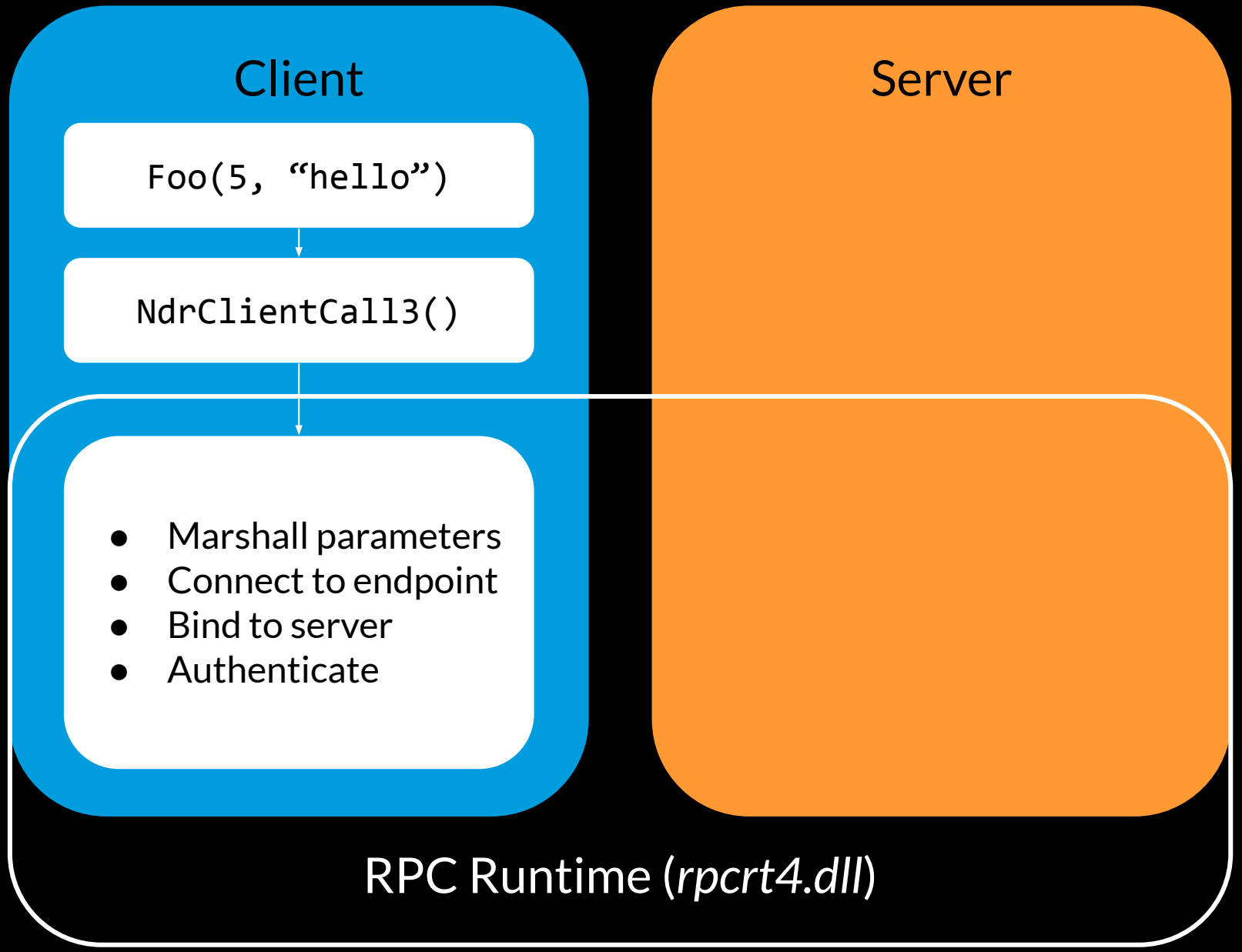

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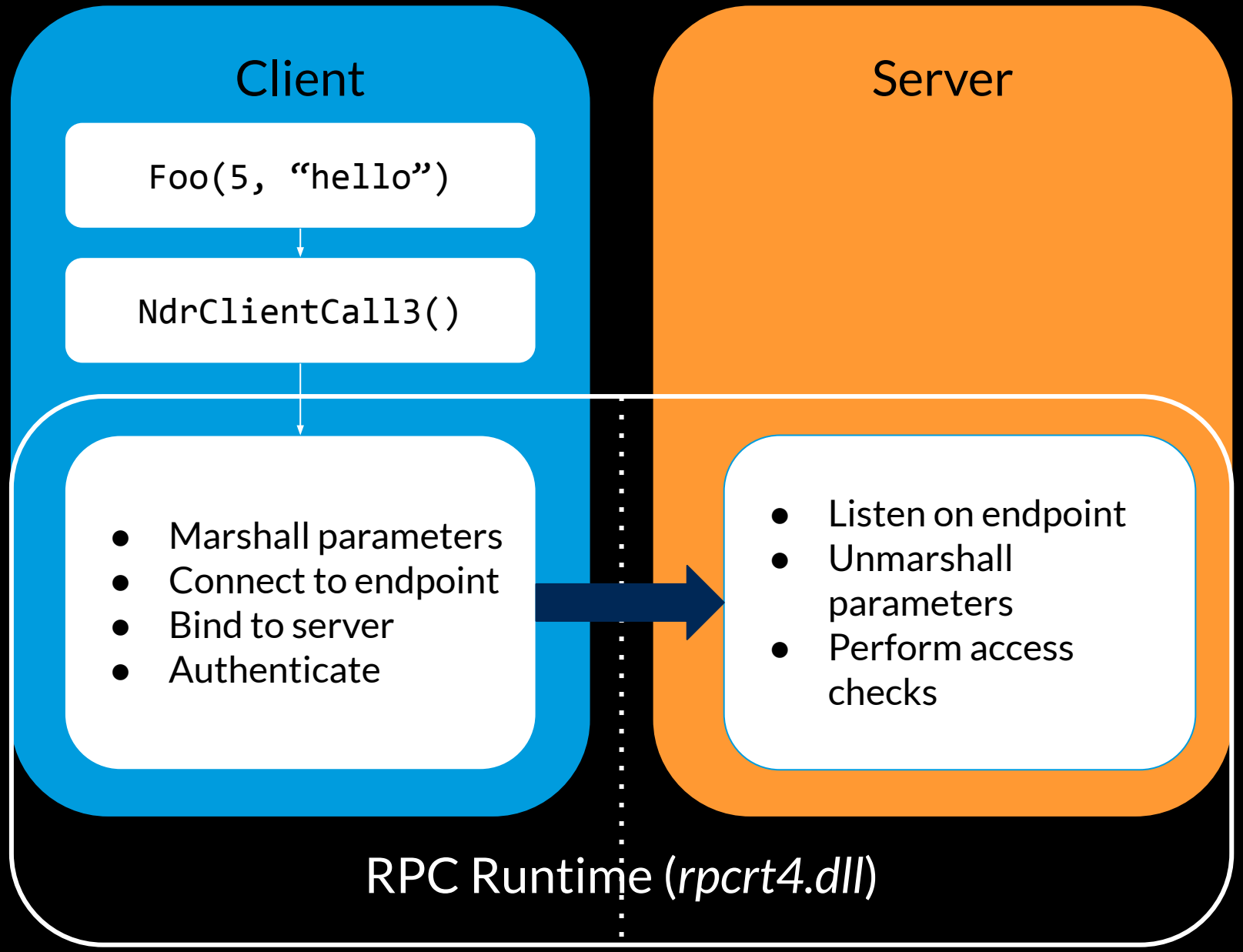

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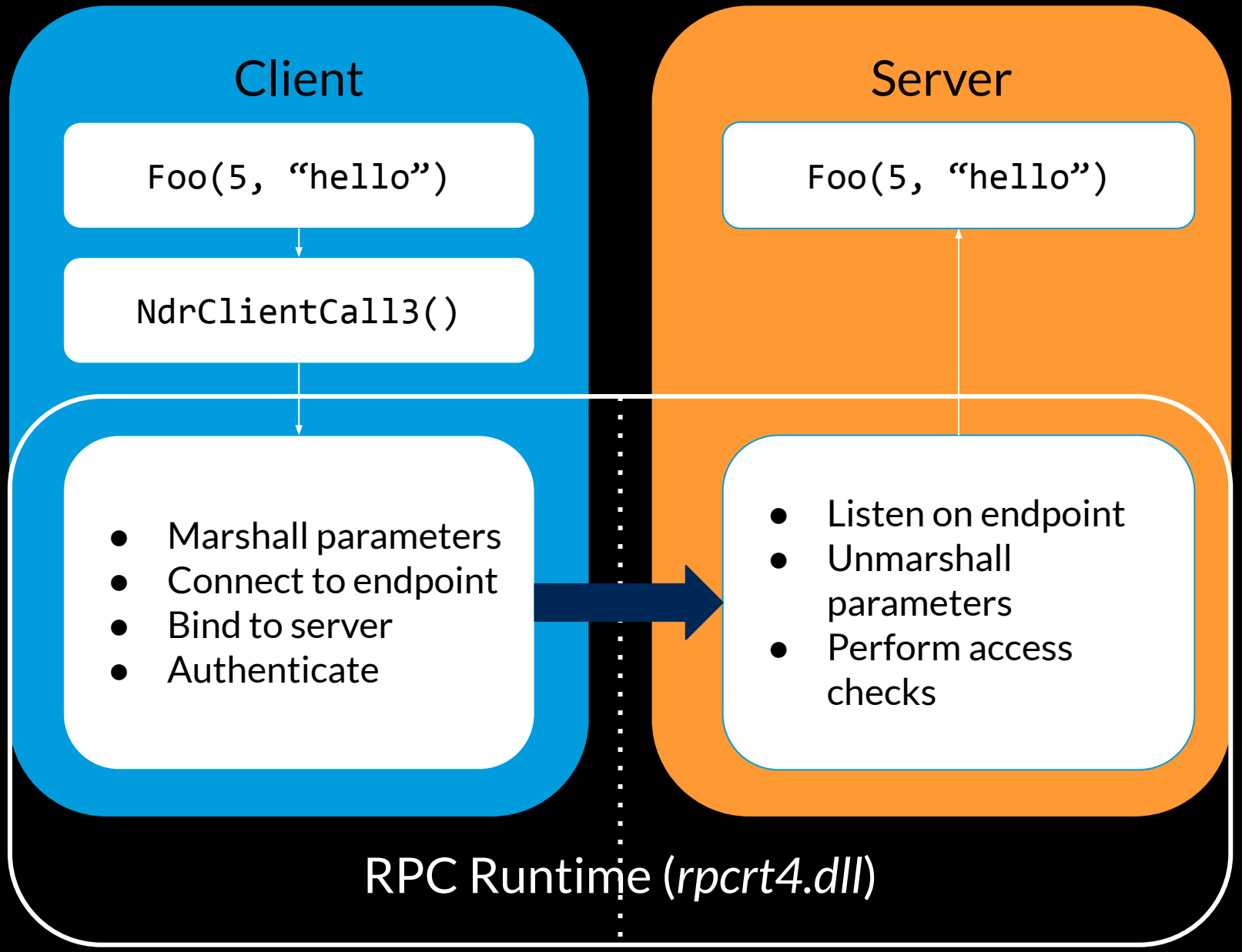
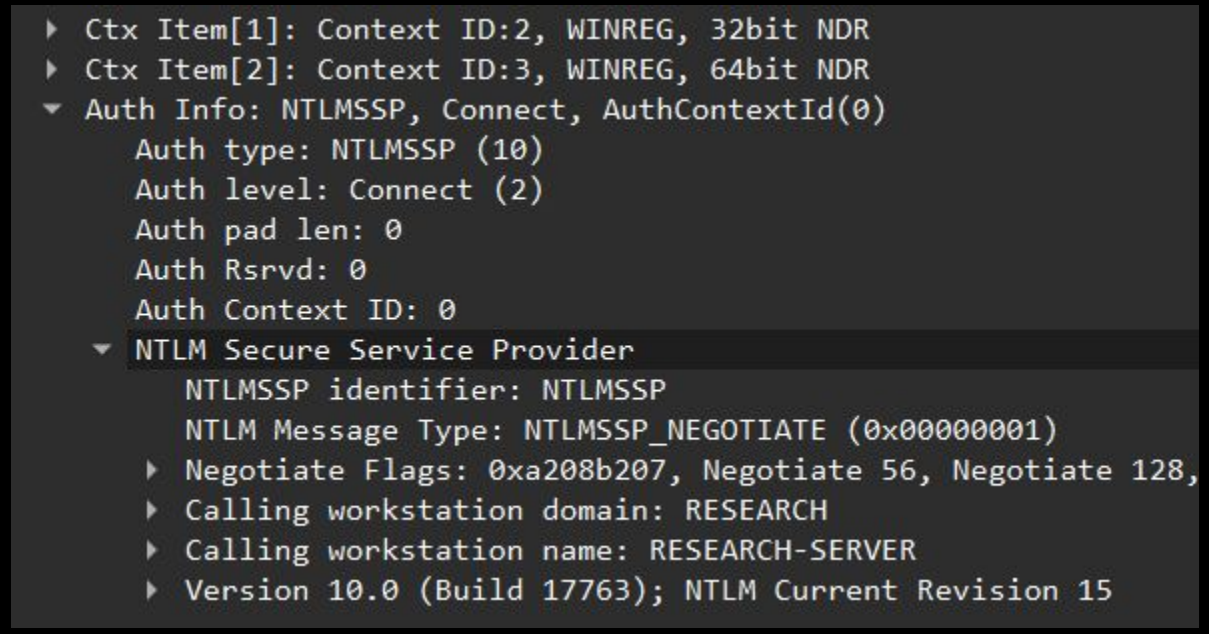


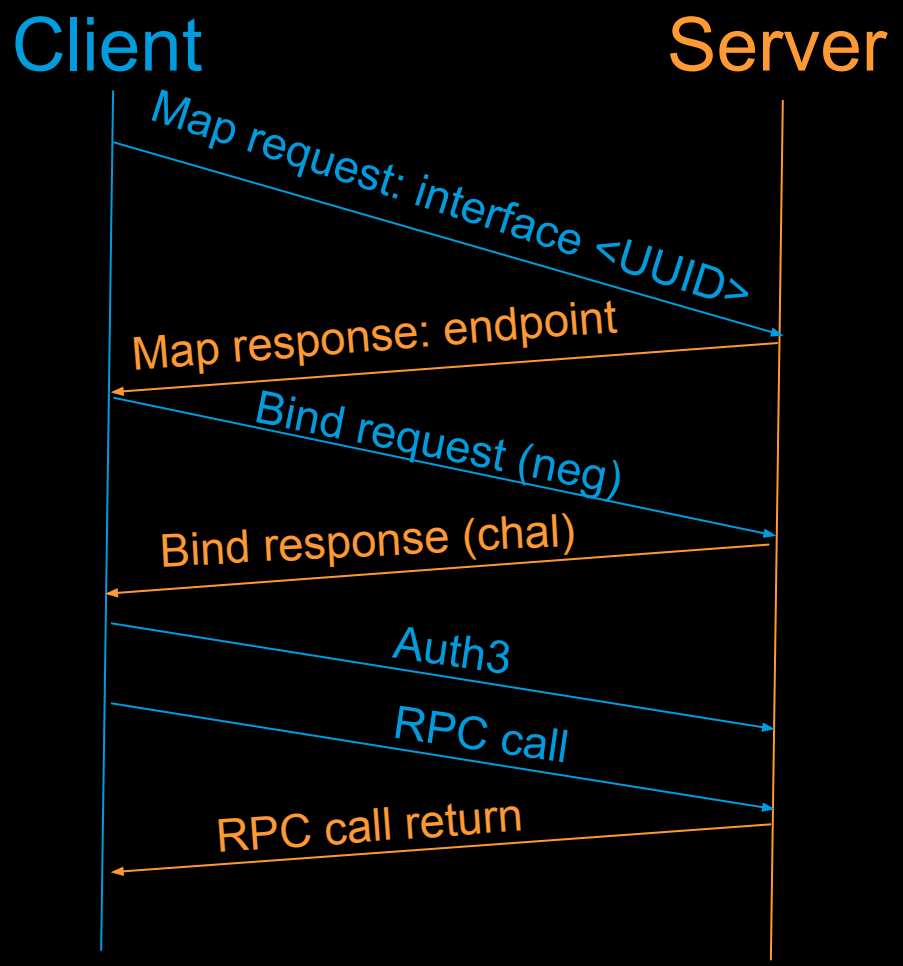
RPC → Auth → NTLM

Binding & Authentication

```
Bind: call_id: 66, Fragment: Single, 2 context items: WINREG V1.0 (32bit NDR), WINREG V1.0 (64bit NDR), NTLMSSP_NEGOTIATE
135 → 53743 [ACK] Seq=1 Ack=188 Win=64128 Len=0
Bind_ack: call_id: 66, Fragment: Single, max_xmit: 5840 max_recv: 5840, 2 results: Acceptance, Provider rejection, NTLMSSP_CHALLENGE
AUTH3: call_id: 66, Fragment: Single, NTLMSSP_AUTH, User: RESEARCH\Administrator
```



Message Flow (NTLM)



RPC Authentication

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- RPC servers must tell the runtime they want authentication support
  - RpcServerRegisterAuthInfo
- Clients aren’t forced to authenticate
  - Unless server specify RPC_IF_ALLOW_SECURE_ONLY during registration

Server (side of) Authentication

- Authentication in RPC is implemented with the Security Support Provider Interface (SSPI)

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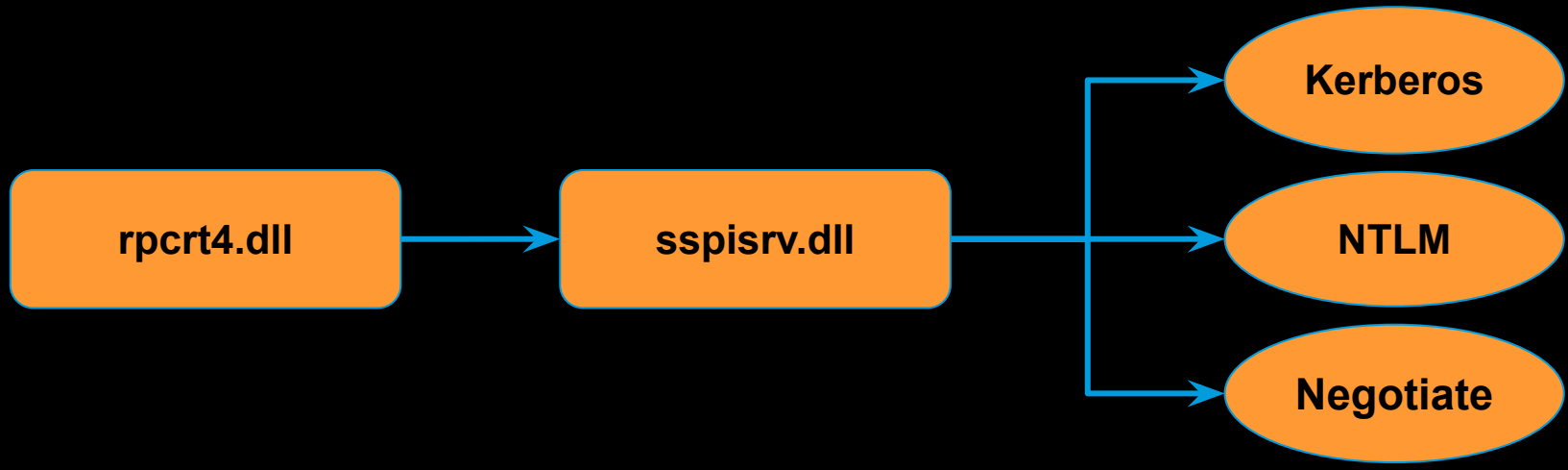

Client (side of) Authentication

```
RPC_STATUS RpcBindingSetAuthInfo(
  RPC_BINDING_HANDLE        Binding,
  RPC_CSTR                  ServerPrincName,
  unsigned long             AuthnLevel,
  unsigned long             AuthnSvc,
  RPC_AUTH_IDENTITY_HANDLE  AuthIdentity,
  unsigned long             AuthzSvc
);
```

Client (side of) Authentication

RPC session

Protocol

Credentials

```
RPC_STATUS RpcBindingSetAuthInfo(
  RPC_BINDING_HANDLE        Binding,
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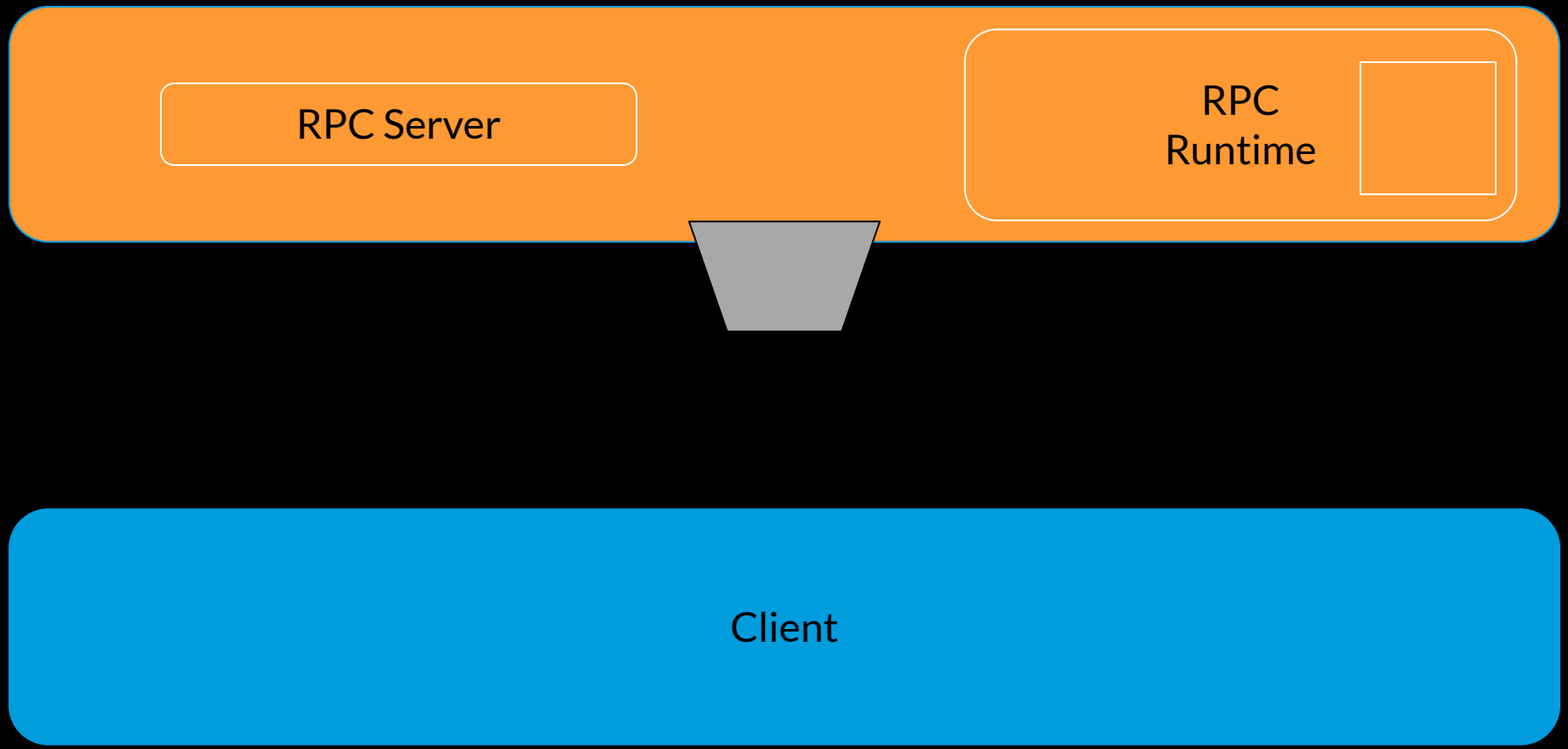
Server Authentication



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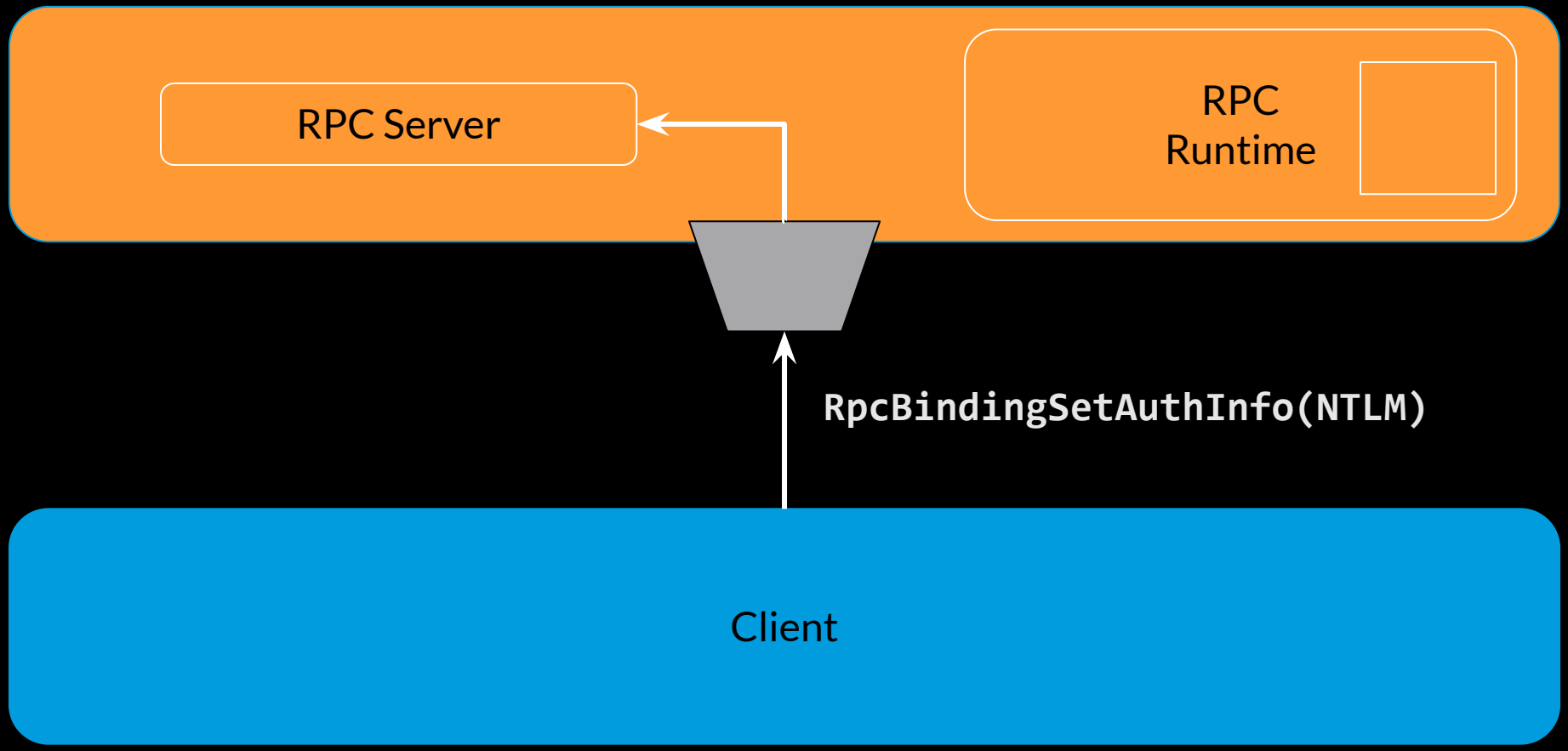
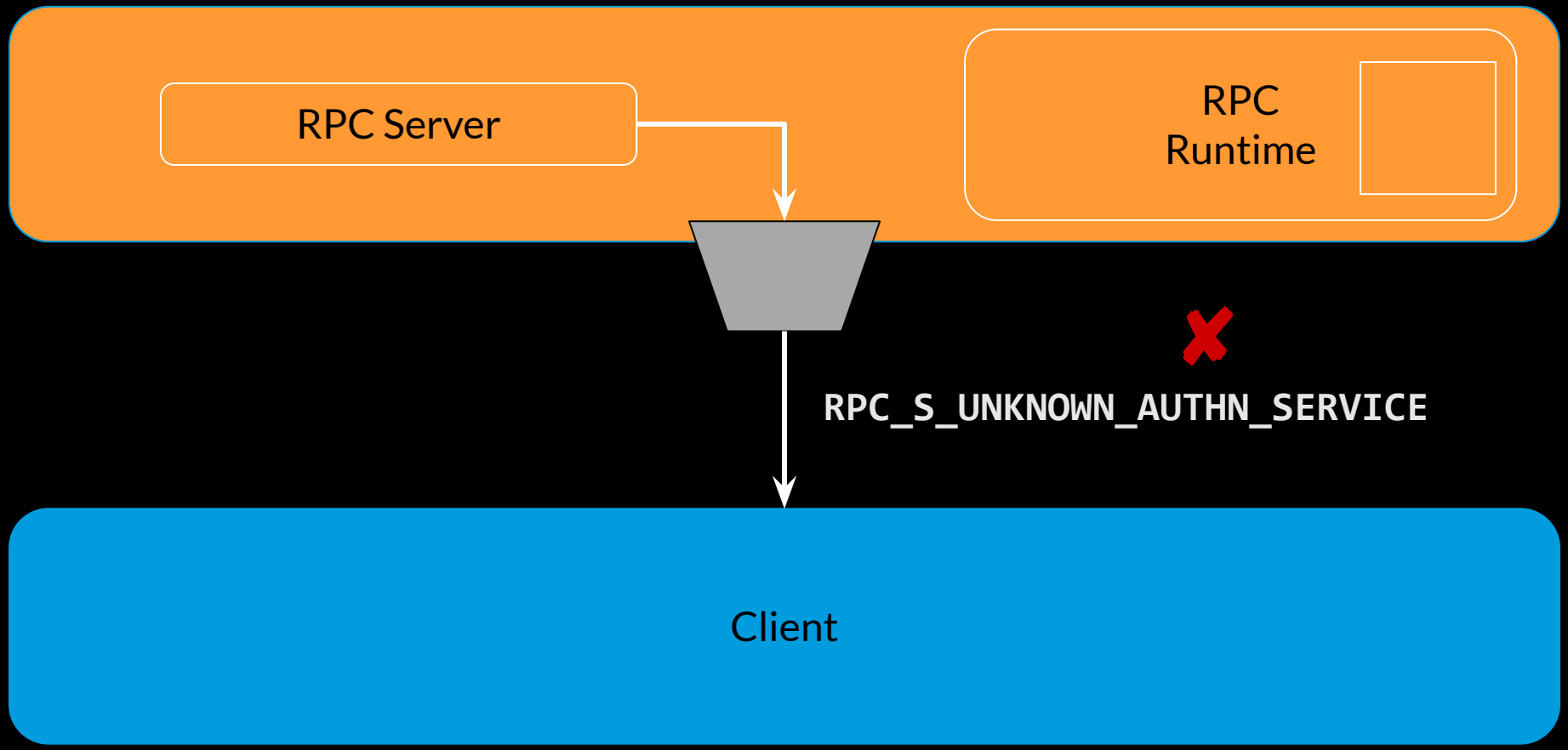
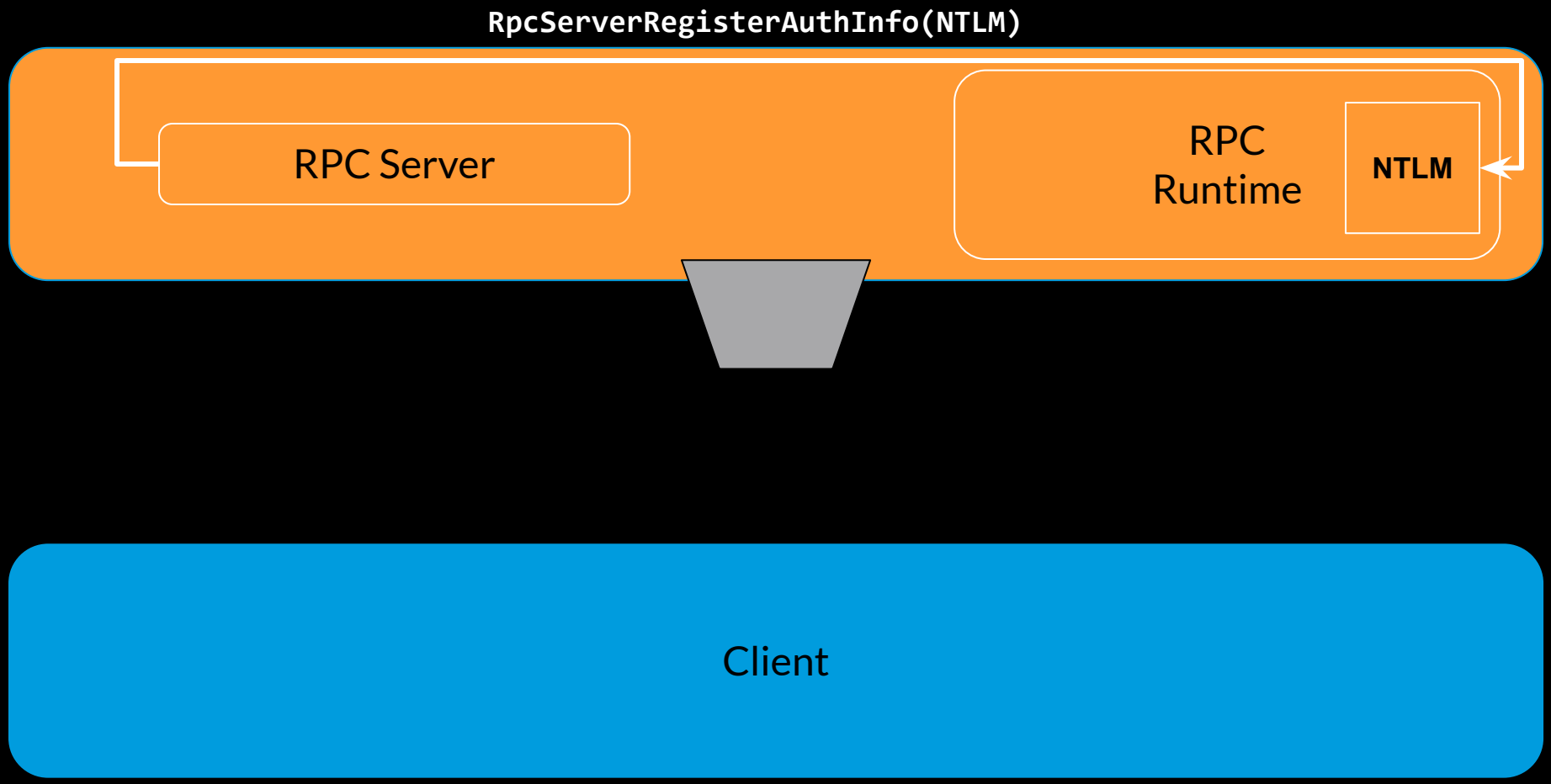


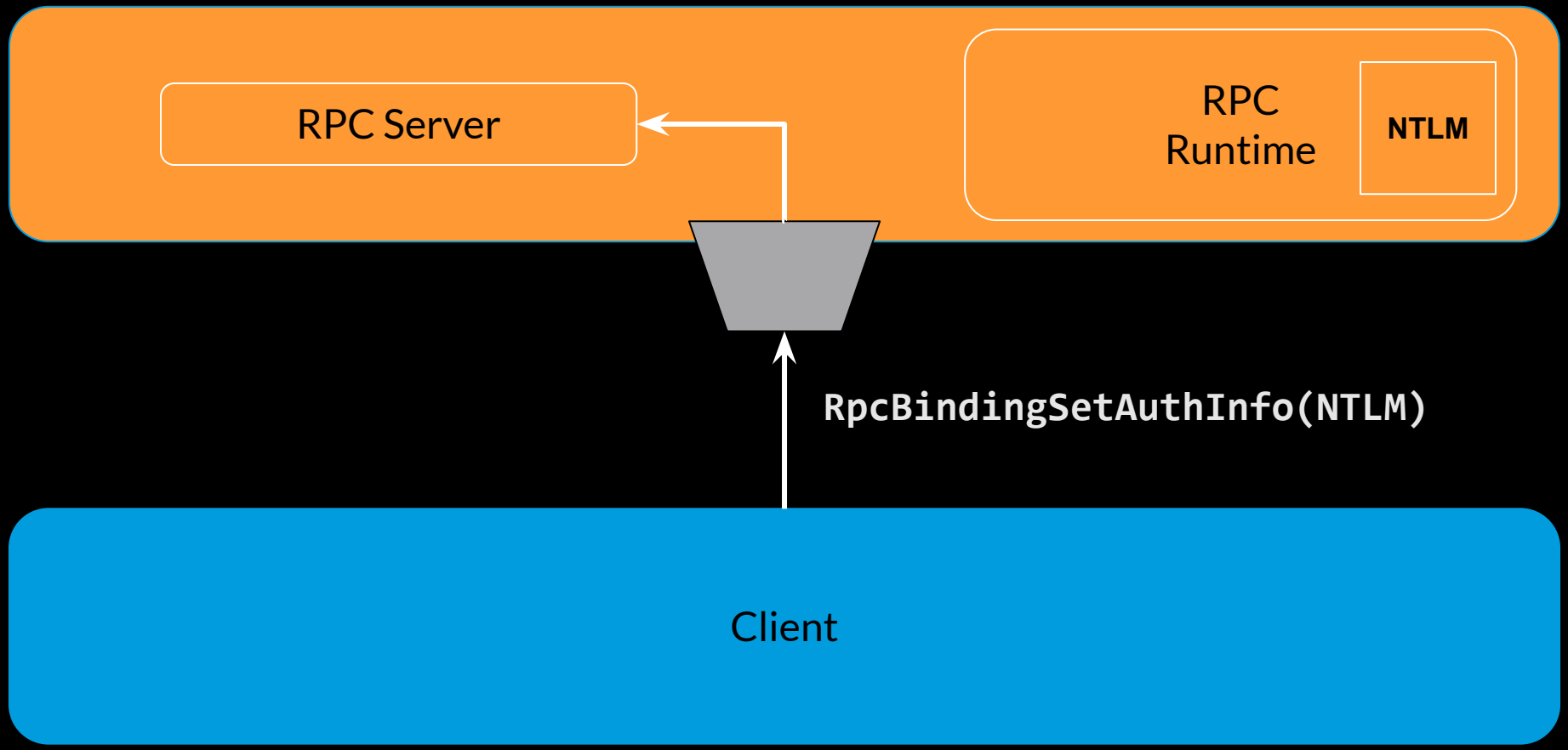
Server Authentication



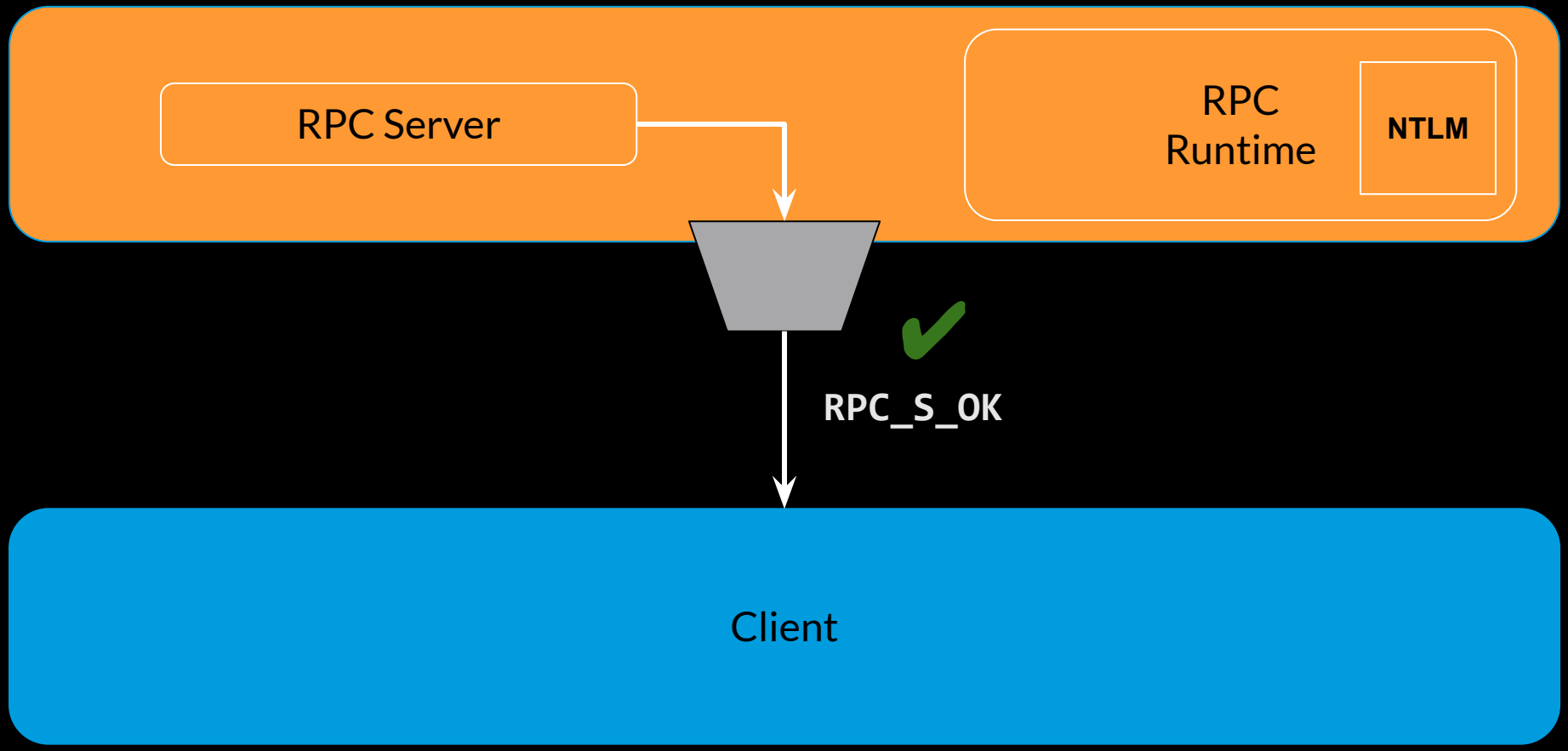
Server Authentication



Server Authentication



Server Authentication



Security

```
RPC_STATUS RpcBindingSetAuthInfo(
  RPC_BINDING_HANDLE        Binding,
  RPC_CSTR                  ServerPrincName,
  unsigned long             AuthnLevel,
  unsigned long             AuthnSvc,
  RPC_AUTH_IDENTITY_HANDLE  AuthIdentity,
  unsigned long             AuthzSvc
);
```

Authentication Levels

RPC_C_AUTHN_LEVEL_NONE	No authentication
RPC_C_AUTHN_LEVEL_CONNECT	Authenticate when establishing a binding
RPC_C_AUTHN_LEVEL_CALL	Authenticate on each call
RPC_C_AUTHN_LEVEL_PKT	Authenticate on each packet and verify that all the data was received
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Let’s Find Some Victims

Find RPC PEs

Imports rpcrt4.dll

RpcServerRegisterAuthInfoW /
RpcBindingSetAuthInfoA

Let’s Find Some Victims

Find RPC PEs

Parse authentication info

Imports rpcrt4.dll

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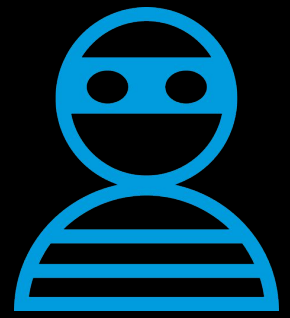
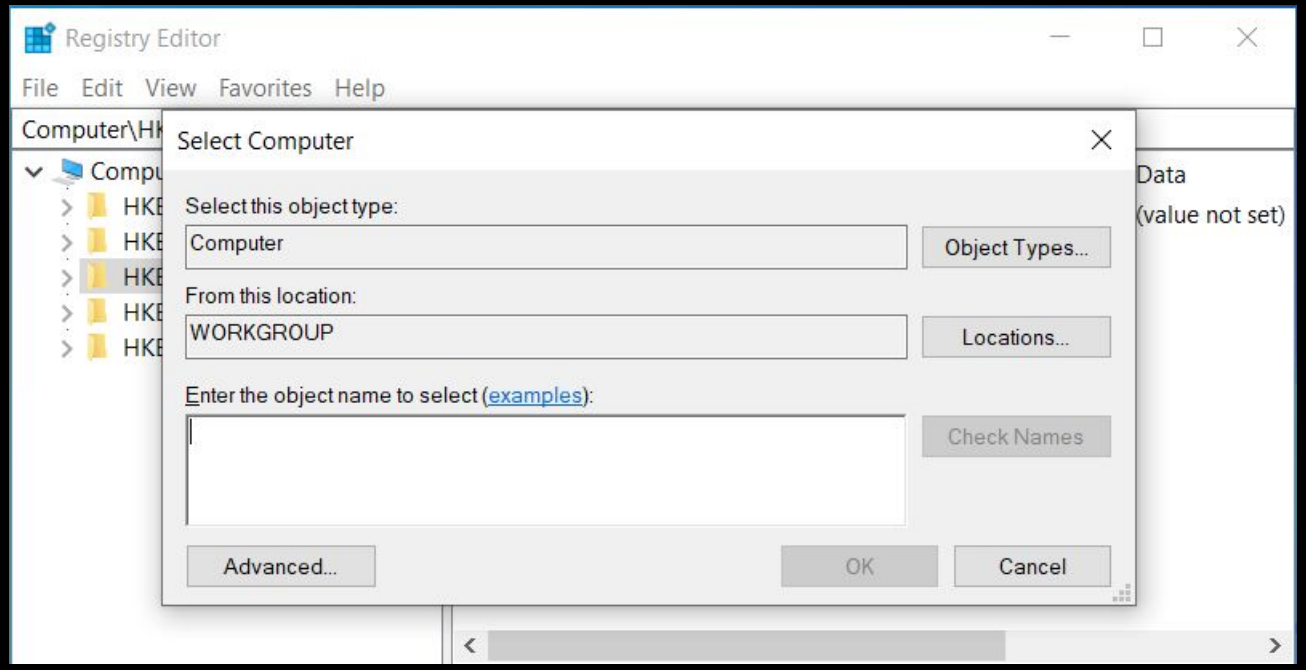
Profit?



Windows Remote Registry

RPC Interface: MS-RRP

- Interface UUID: {338CD001-2244-31F1-AAAA-900038001003}
- Well known endpoint: \PIPE\winreg
- RPC server implemented in regsvc.dll
- RPC client implemented in advapi32.dll



https://learn.microsoft.com/en-us/openspecs/windows_protocols/ms-rrp/0fa3191d-bb79-490a-81bd-54c2601b7a78

Why Is It Special?

```
v12 = RpcBindingSetAuthInfoA(Binding, (RPC_CSTR)&ServerPrincName, 2u, 0xAu, 0i64, 0);
```

```
v12 = RpcBindingSetAuthInfoW(Binding, v19, 6u, 9u, AuthzSvc, (unsigned int)AuthzSvc);
```

Why Is It Special?

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```

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v12 = RpcBindingSetAuthInfoW(Binding, v19, 6u, 9u, AuthzSvc, (unsigned int)AuthzSvc);
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```

RPC_C_AUTHN_LEVEL_CONNECT

```
v12 = RpcBindingSetAuthInfoW(Binding, v19, 6u, 9u, AuthzSvc, (unsigned int)AuthzSvc);
```

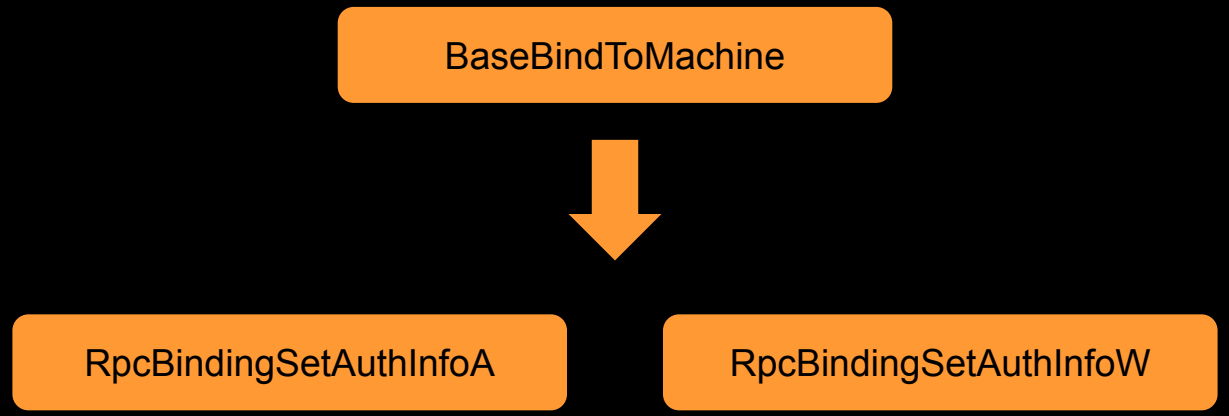
RPC_C_AUTHN_LEVEL_PKT_PRIVACY

Callstack

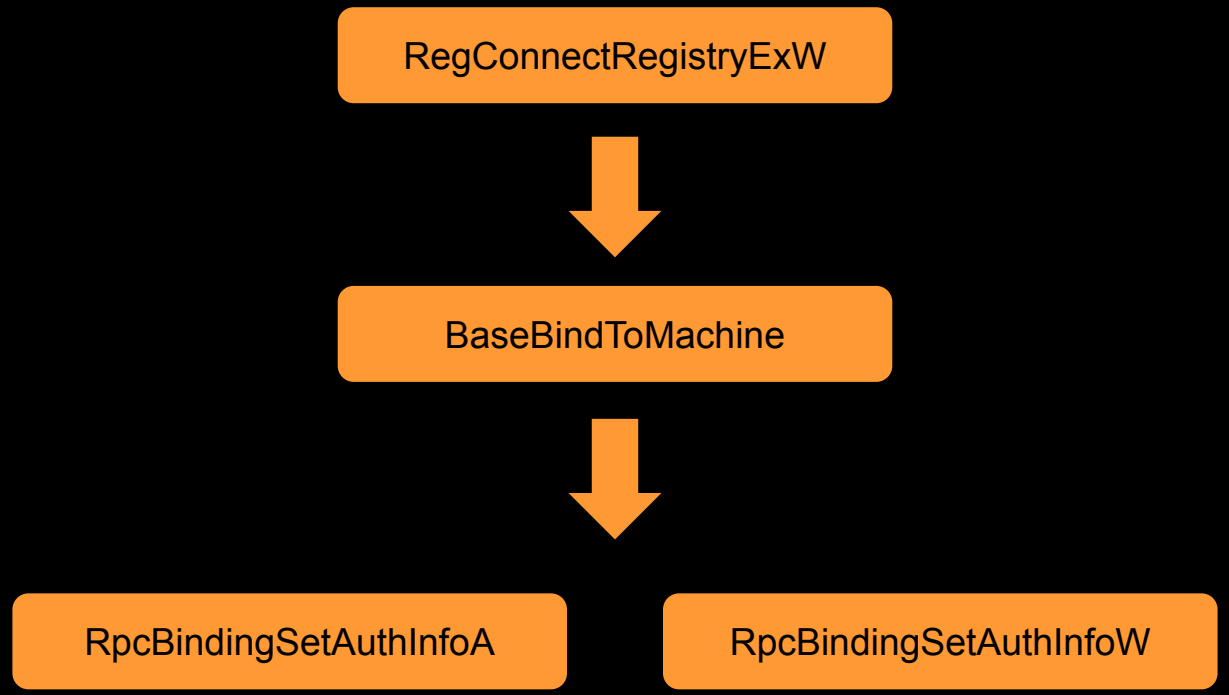
RpcBindingSetAuthInfoA

RpcBindingSetAuthInfoW

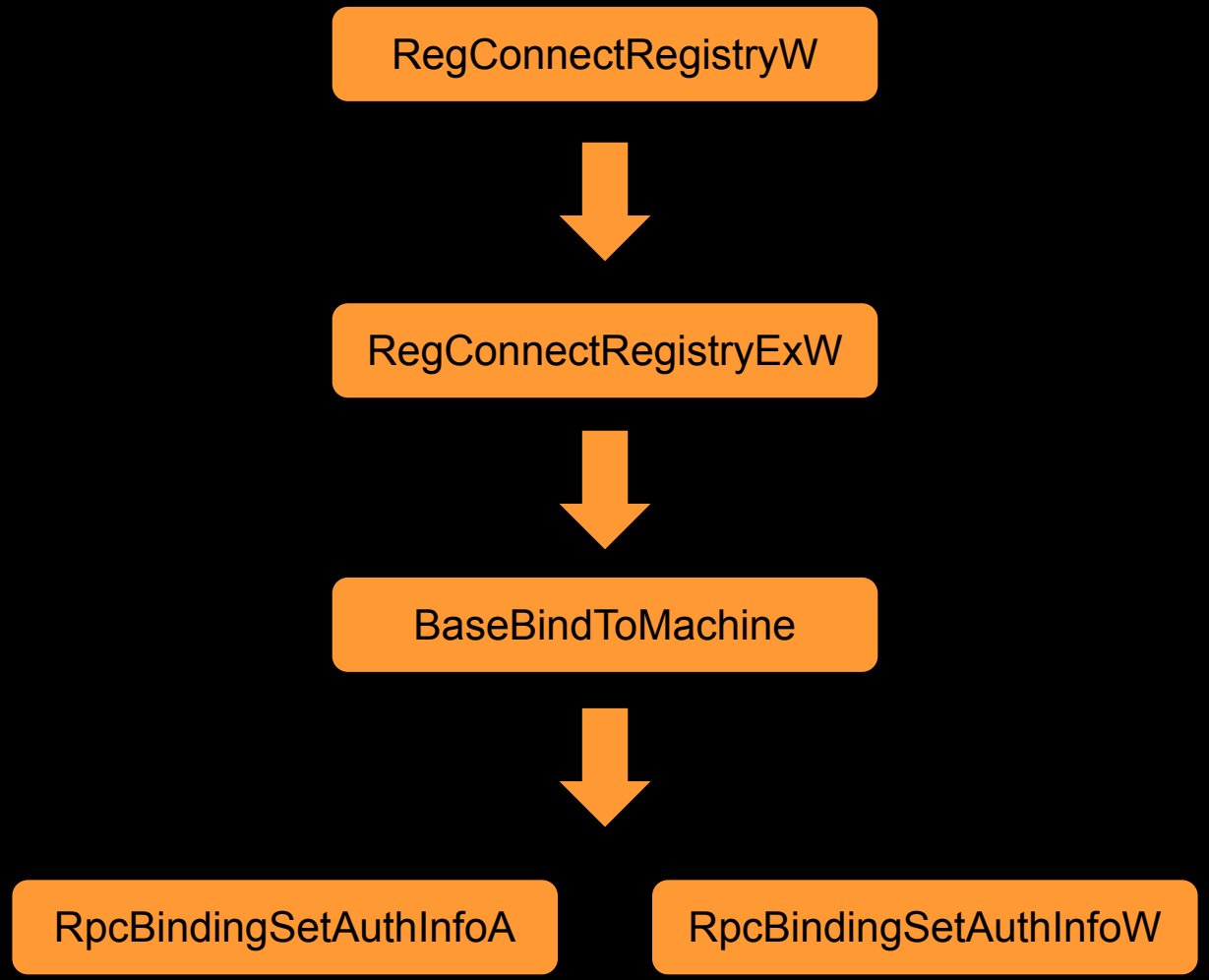
Callstack


BaseBindToMachine
RpcBindingSetAuthInfoA
RpcBindingSetAuthInfoW

Callstack


RegConnectRegistryExW
BaseBindToMachine
RpcBindingSetAuthInfoA
RpcBindingSetAuthInfoW

Callstack


RegConnectRegistryW
RegConnectRegistryExW
BaseBindToMachine
RpcBindingSetAuthInfoA
RpcBindingSetAuthInfoW

Transport Fallback

```
BindingBuilder = RegConn_np;
v5 = function_array;
v6 = 1;
v7 = a4;
v8 = (a3 & 1) == 0;
do
{
  while ( 1 )
  {
    while ( 1 )
    {
      if ( ((unsigned int (__fastcall *)(STRSAFE_PCNZWCH, RPC_BINDING_HANDLE *))BindingBuilder)(pszSrc, &Binding) )
        goto LABEL_49;
      if ( BindingBuilder == RegConn_np )
        break;
      if ( RpcEpResolveBinding(Binding, &unk_180070560) )
        goto LABEL_44;
      v12 = RpcBindingSetAuthInfoA(Binding, (RPC_CSTR)&ServerPrincName, 2u, 0xAu, 0i64, 0);
```

Transport Fallback

- Tries to connect via RPC over SMB (ncacn_np) — \PIPE\winreg
- On failure, tries to use other transport protocols:
  - SPX — ncacn_spx
  - TCP — ncacn_ip_tcp
  - NetBEUI — ncacn_nb_nb
  - NetBIOS — ncacn_nb_tcp
  - IPX — ncacn_nb_ipx

Transport Fallback

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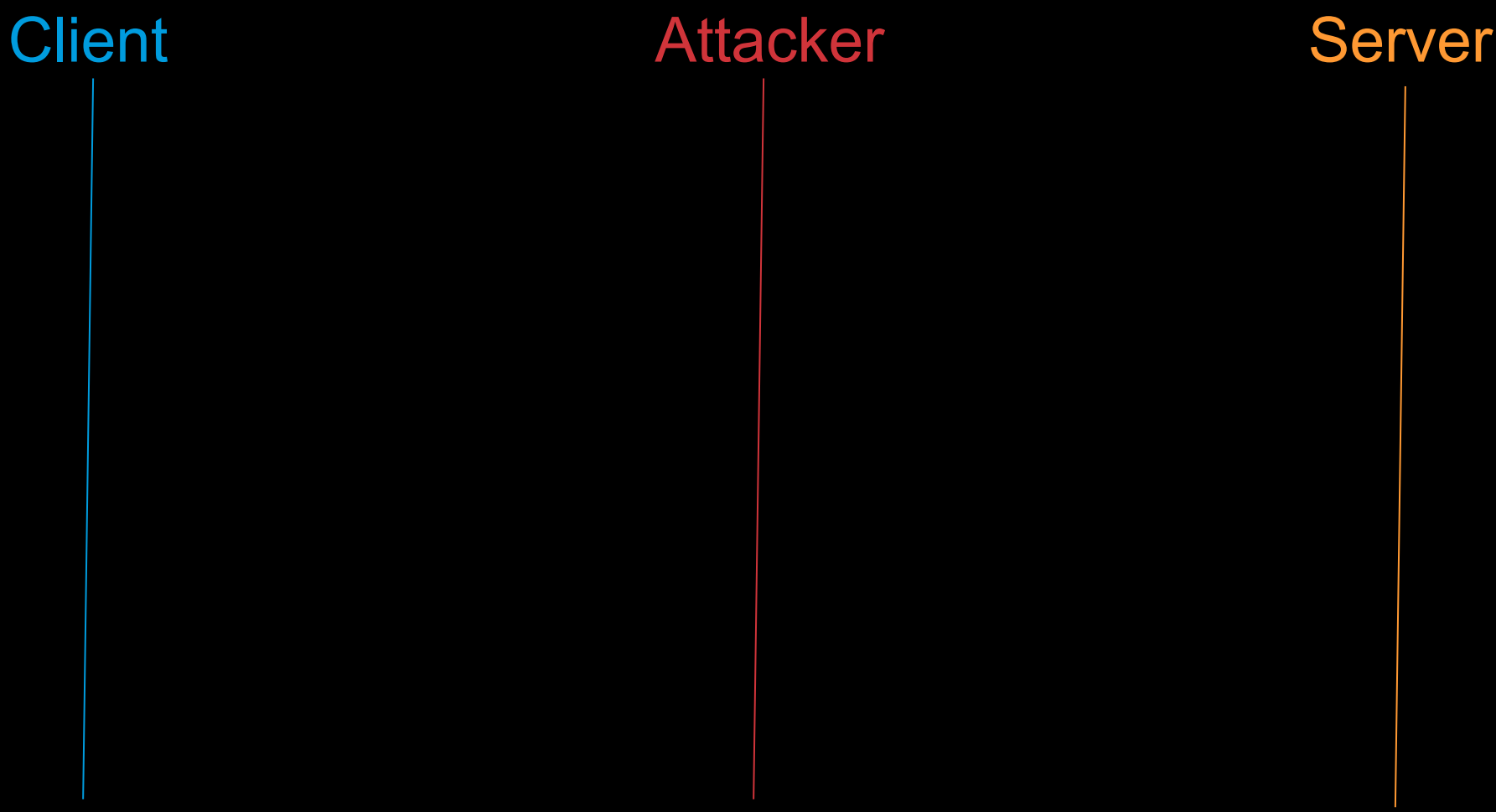
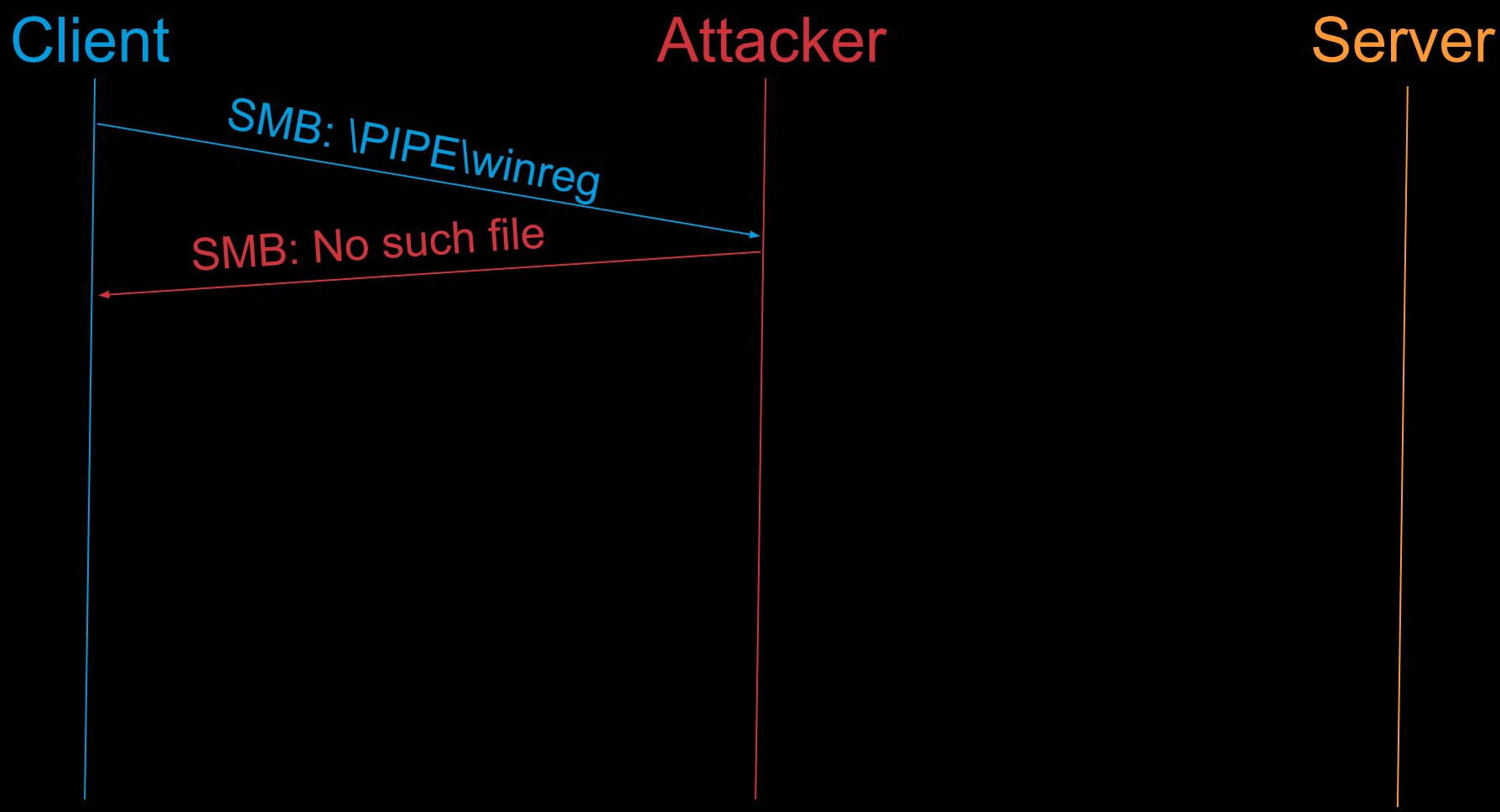
SMB transport is PKT_PRIVACY, fallbacks are CONNECT

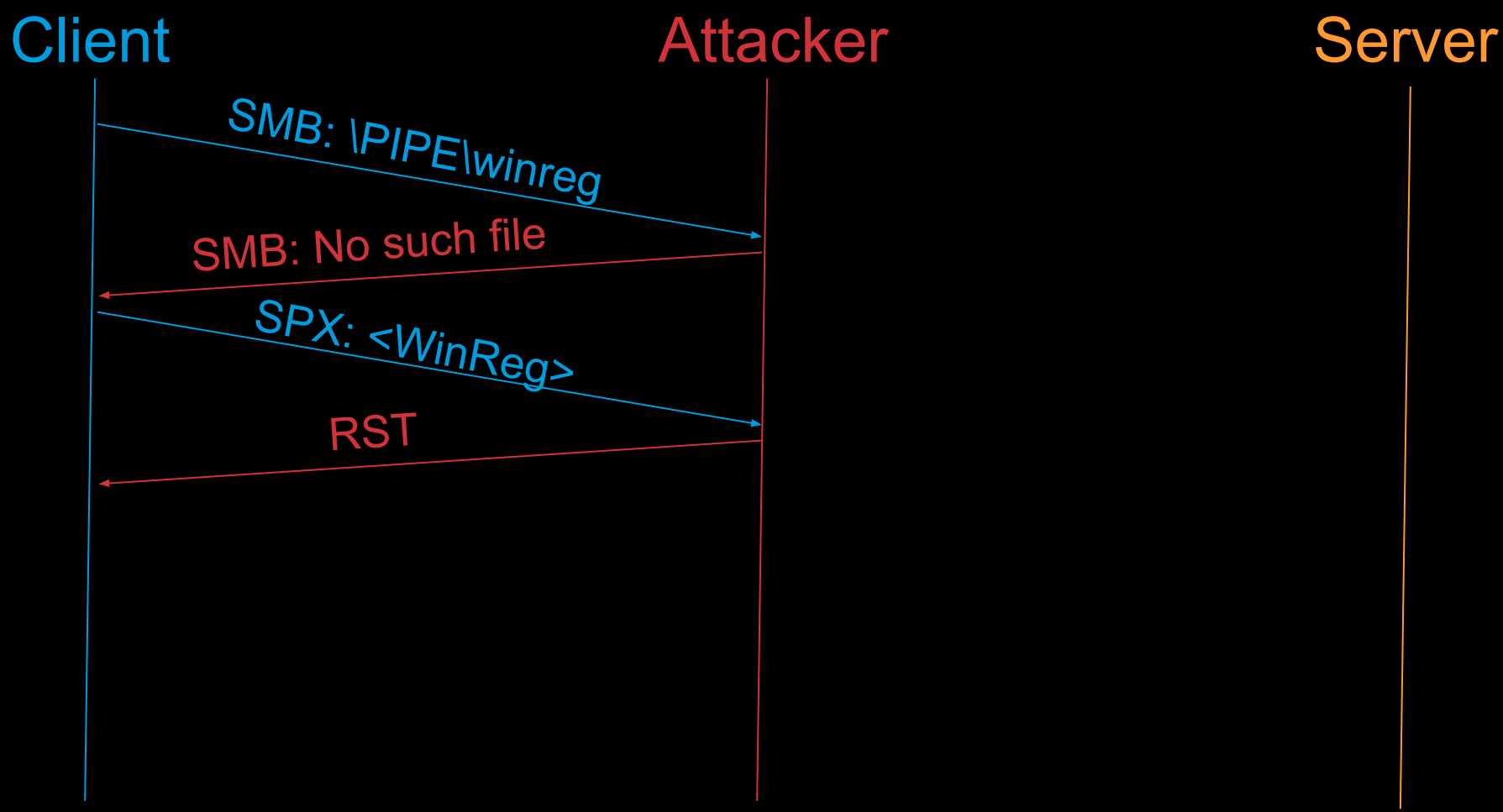
Attack Chain



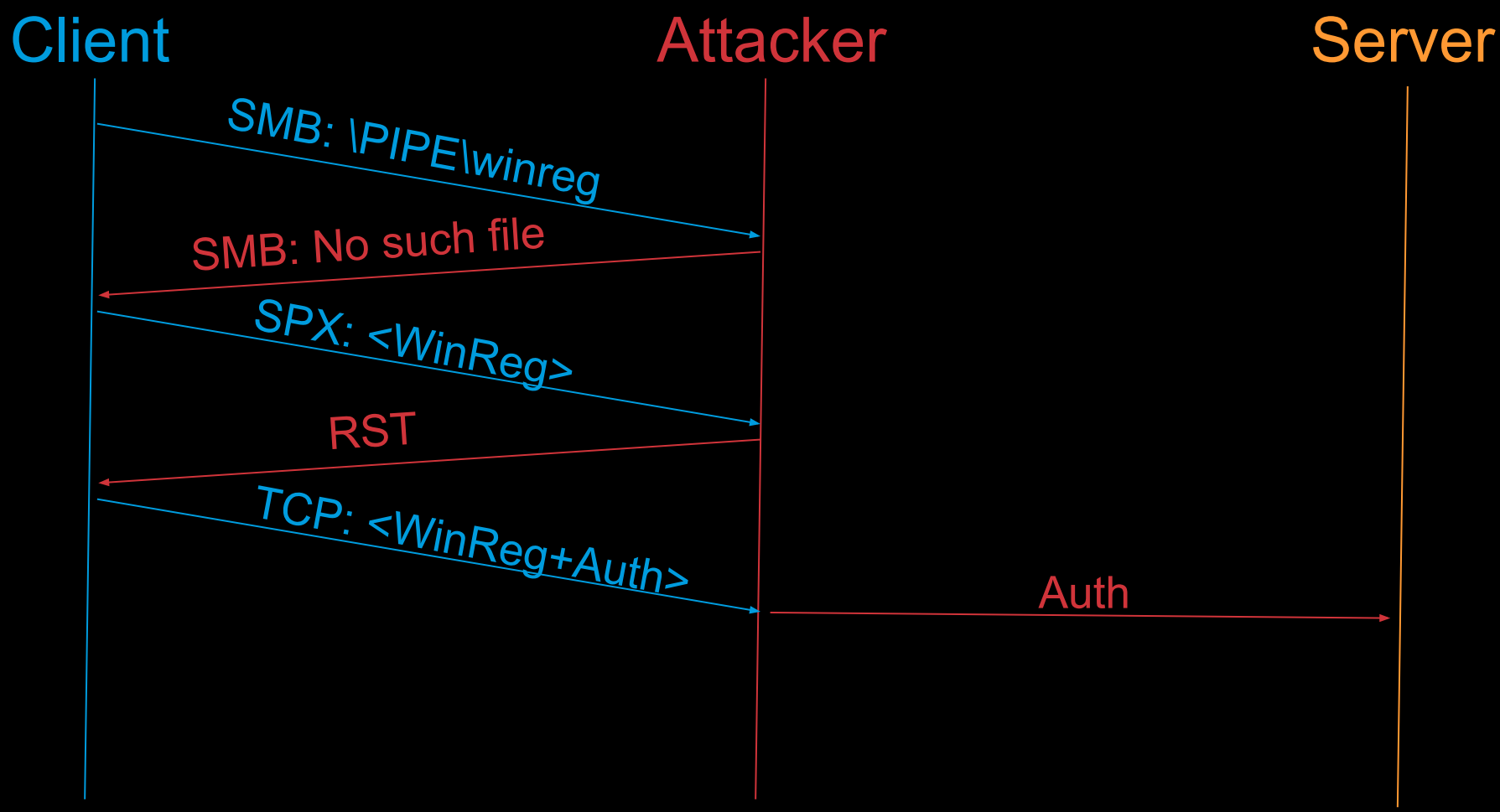
Attack Chain



Attack Chain



Attack Chain



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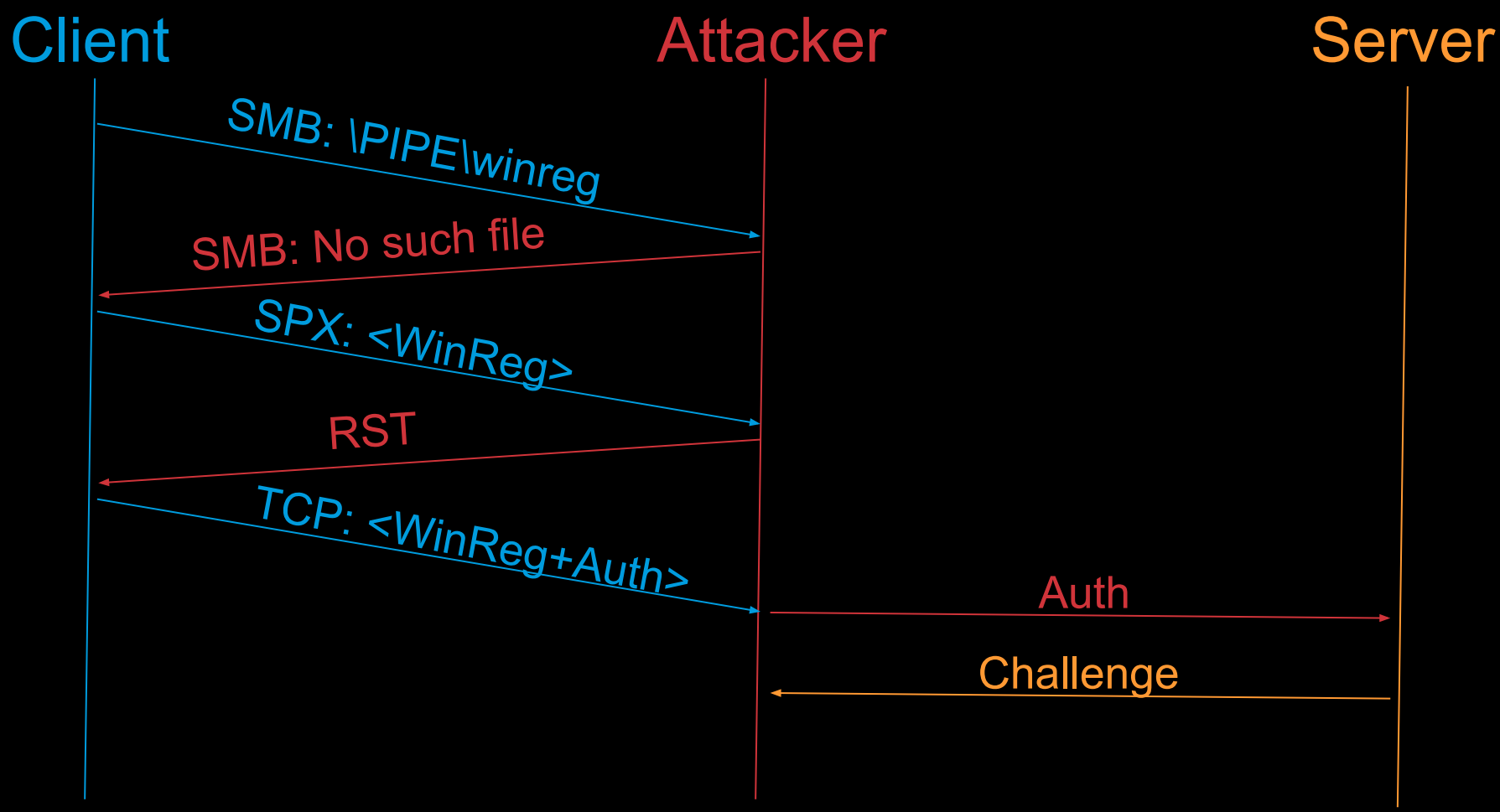

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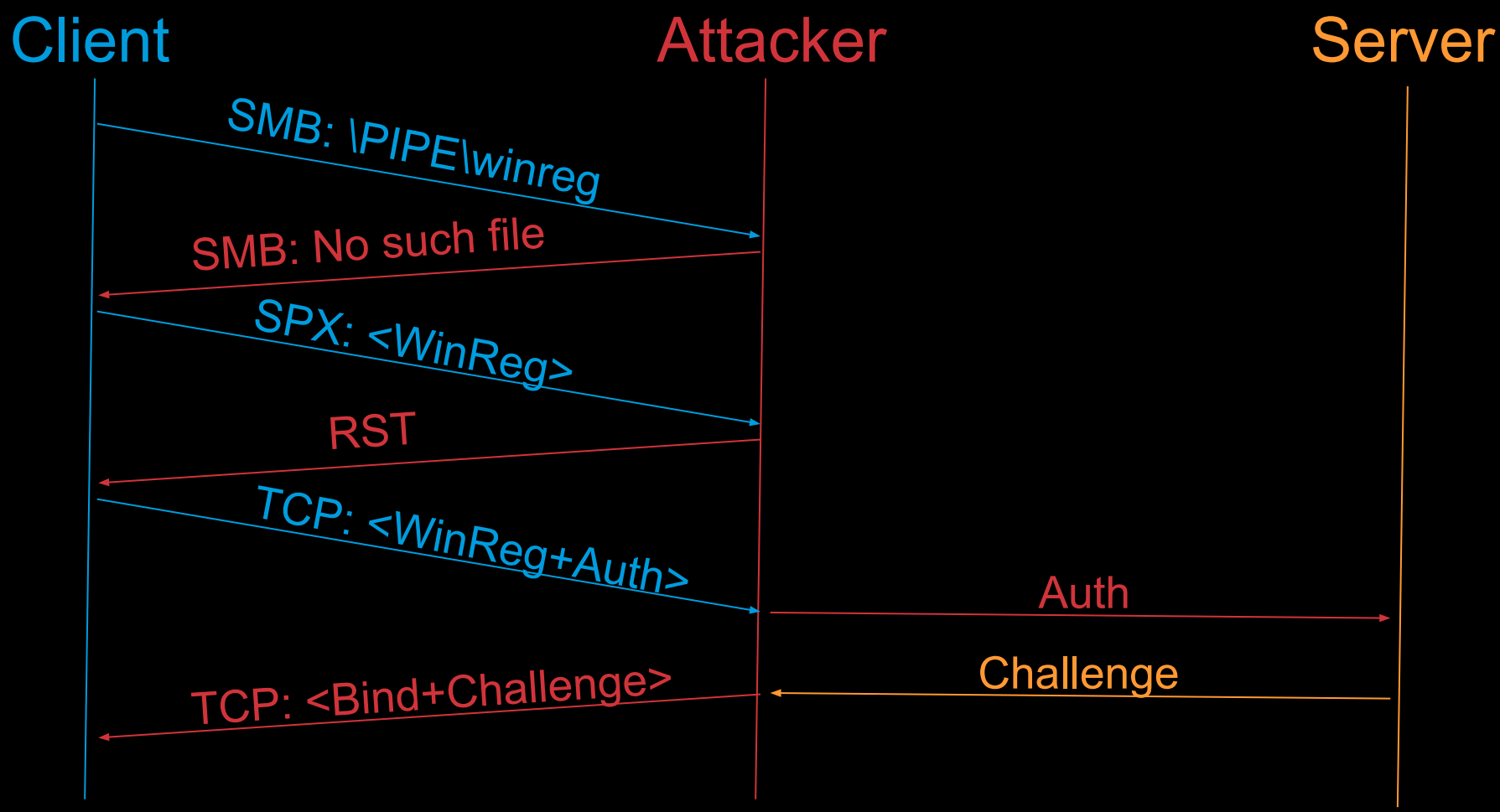

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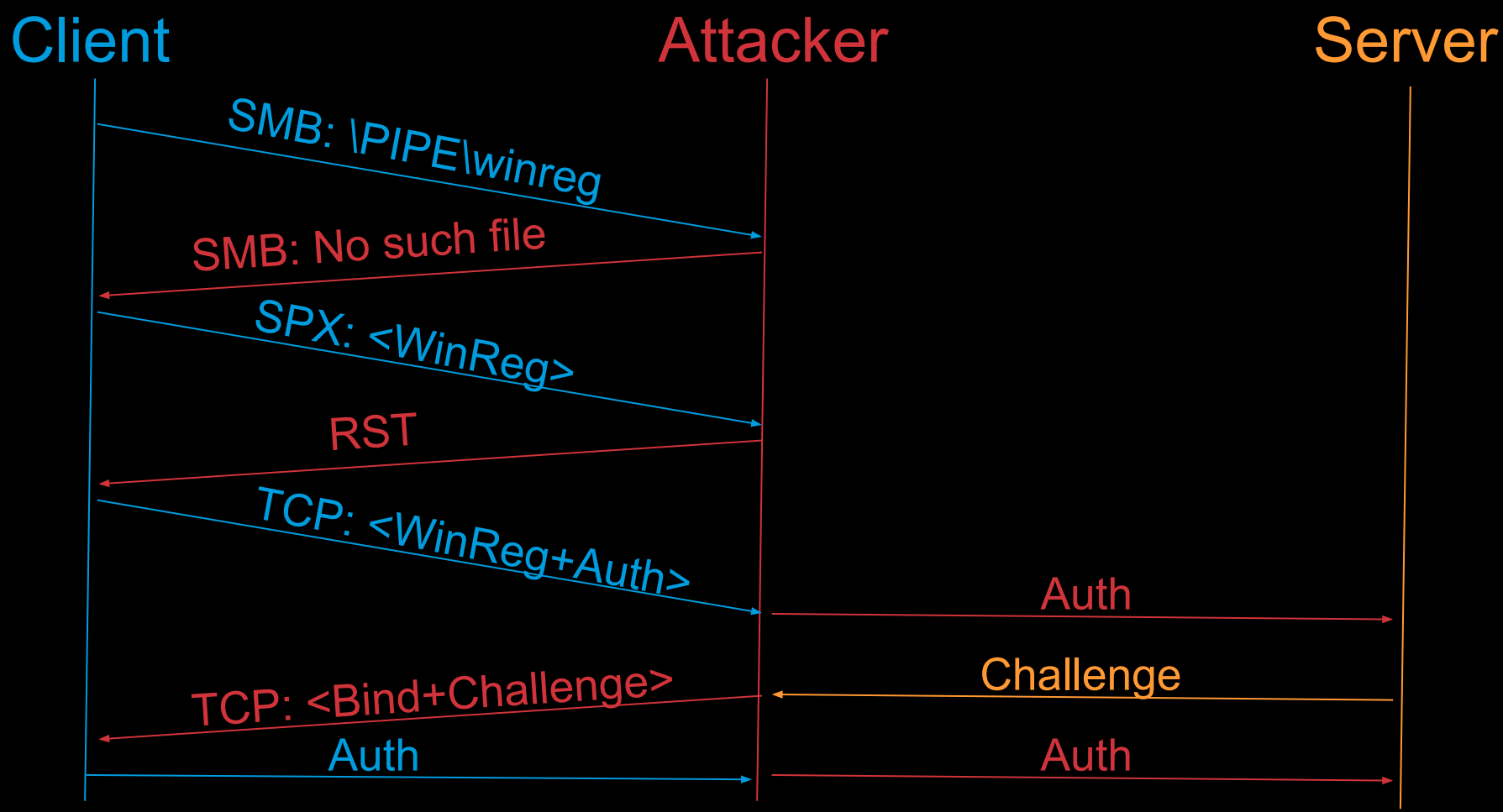

Relay Targets

Can’t relay to RPC servers that require PKT_PRIVACY

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- SCM, Task scheduler

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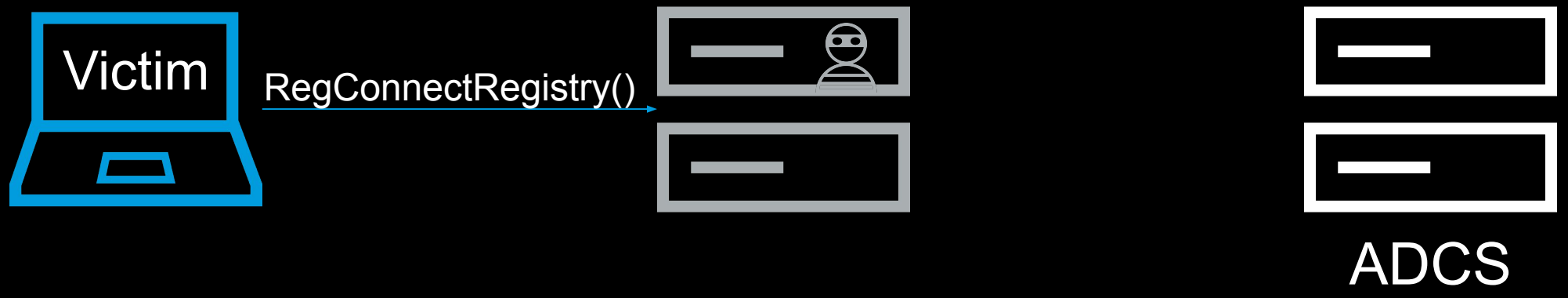
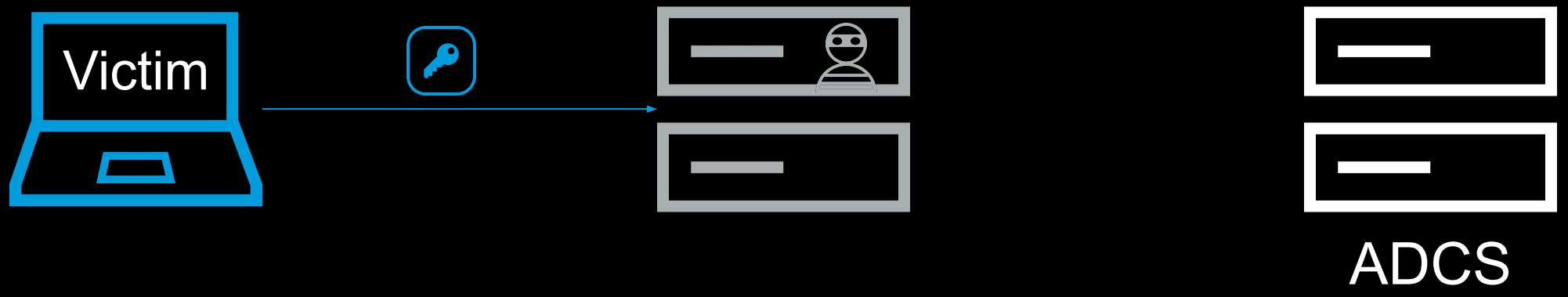
- Encryption is derived from shared secret — the password
- SCM, Task scheduler
- Winreg server as well, surprisingly

```
v5 = RpcServerInqCallAttributesW(0i64, &RpcCallAttributes);
if ( v5 != 1746 )                               // RPC_S_BINDING_HAS_NO_AUTH
{
  if ( v5 )
    RpcRaiseException(v5);
  if ( RpcCallAttributes.AuthenticationLevel < 6 )// RPC_C_AUTHN_LEVEL_PKT_PRIVACY
    RpcRaiseException(5);
}
```

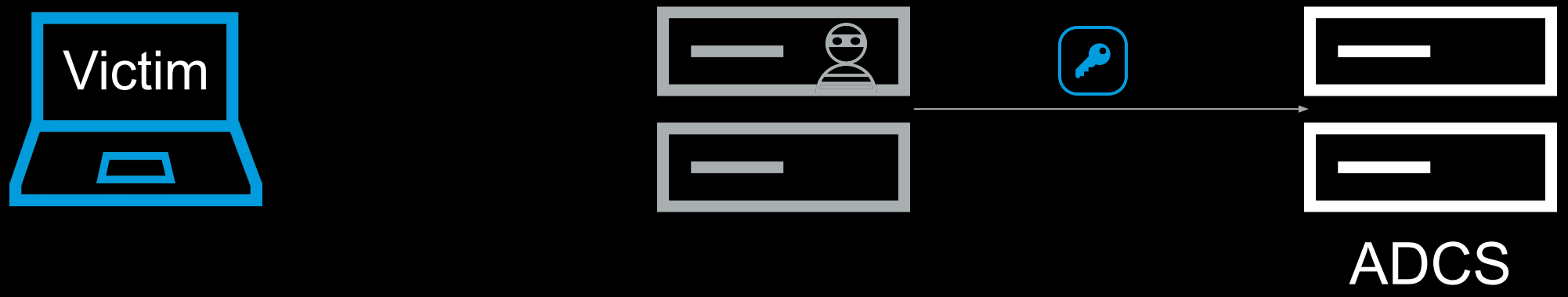
ADCS Relay



ADCS Relay



ADCS Relay



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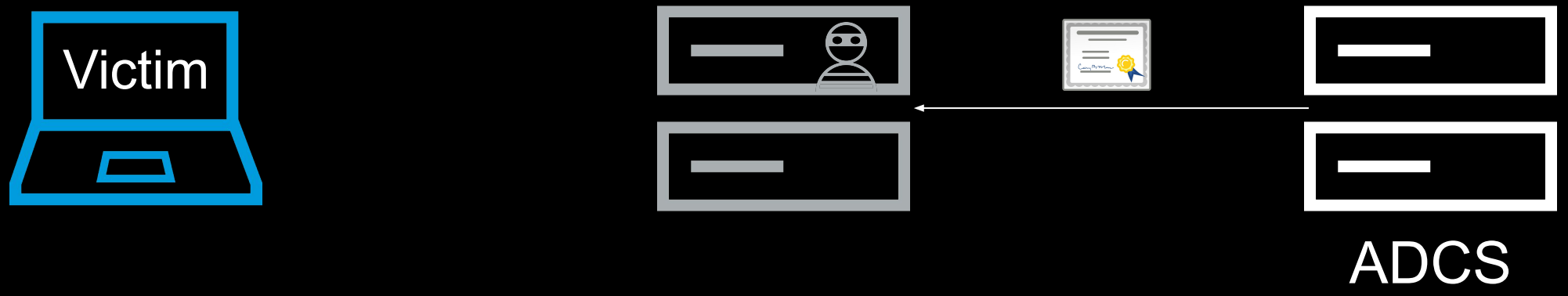

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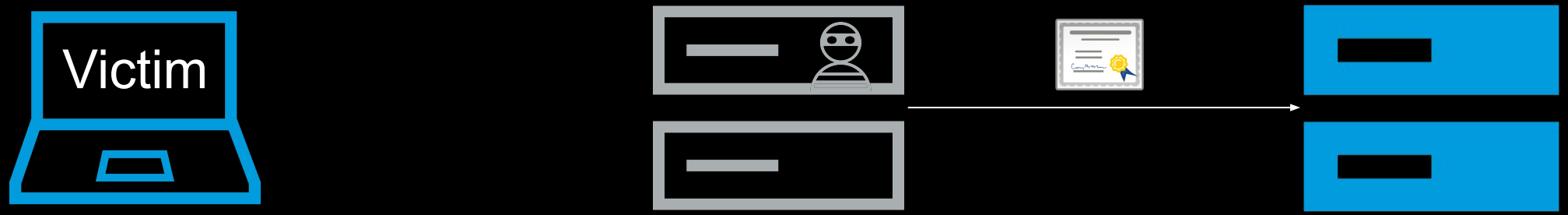


Demo

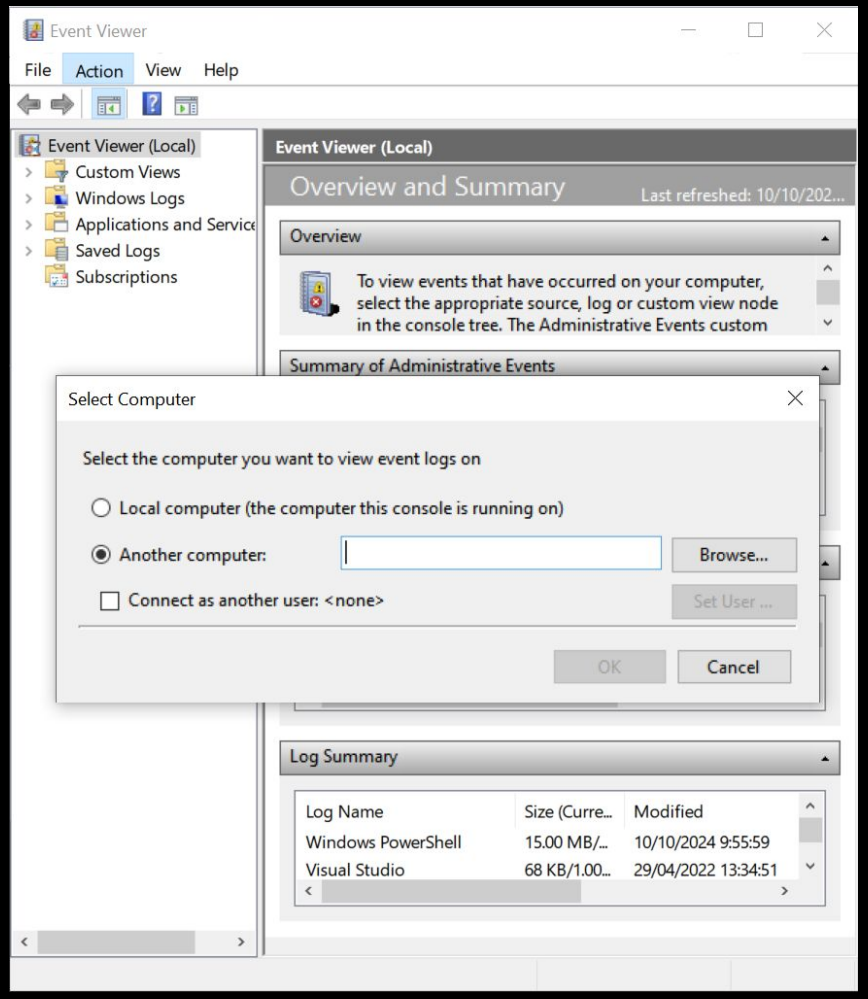
Potential Impact

Vulnerability is in Windows API — who the hell calls it?

- regedit
- ADCS
- Certutil
- DFS Namespaces
- taskview/taskkill
- Windows Event Viewer

Event Viewer?

- Can query logs remotely via RPC MS-EVEN[6]
  - Quick Google search shows people actually use it to view logs remotely
- Implemented as an .msc for mmc.exe
- Most logic is in els.dll

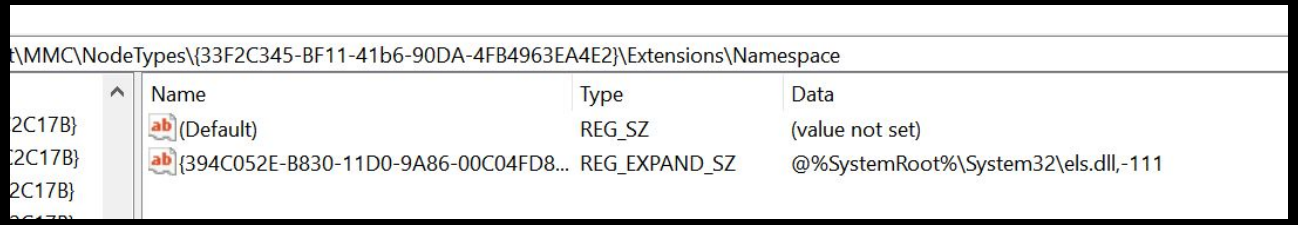


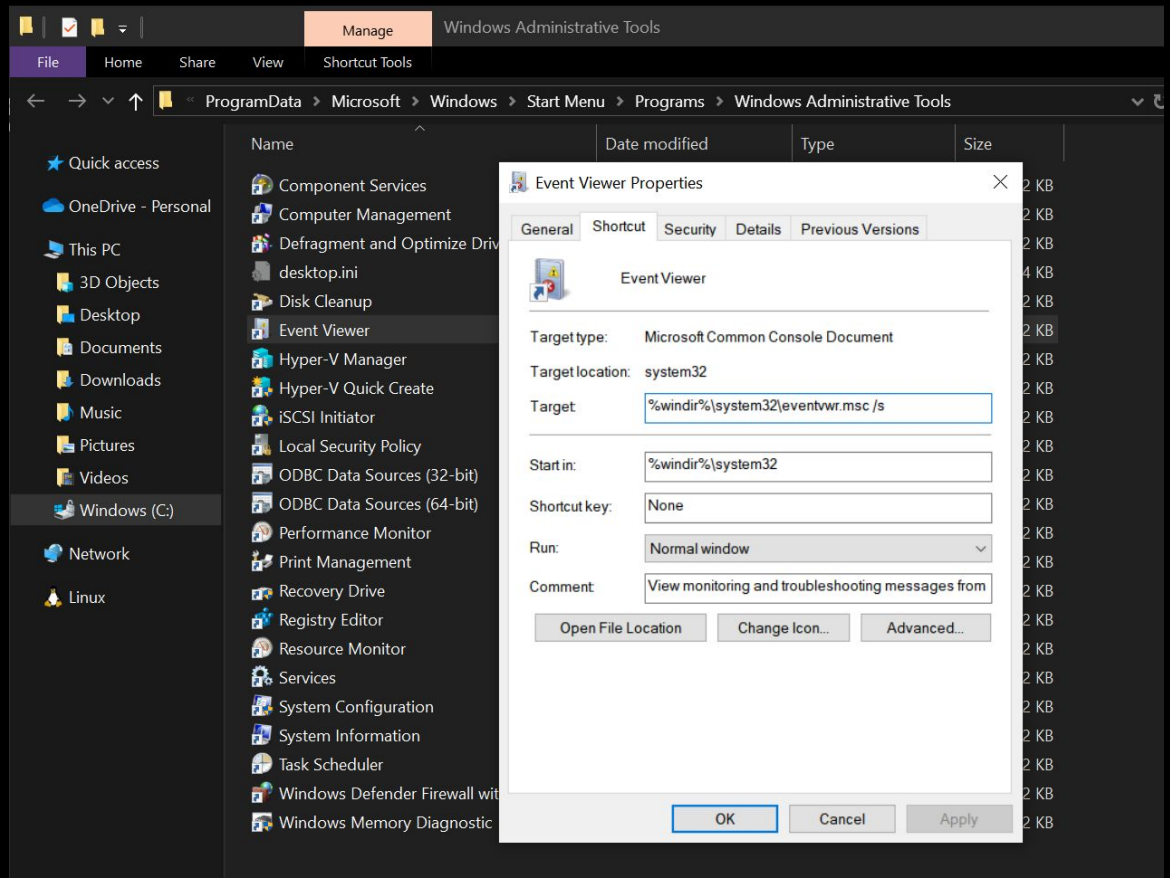
Event Viewer - Exploitation

- Classic MitM for NTLM relay

Event Viewer - Exploitation

- Classic MitM for NTLM relay
- Modify the Event Viewer shortcut for persistent pseudo coercion
- Modify the registry to load a modified els.dll





Event Viewer - Exploitation

- Classic MitM for NTLM relay
- Modify the Event Viewer shortcut for persistent pseudo coercion
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  els.dll

Requires administrative privileges

Event Viewer - Exploitation Benefits

- CVE patch uses new internal function - RegpCalculateConnectionFlags
  - Function checks new registry values for verdict

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Software\Microsoft\RemoteRegistryClient\TransportFallbackPolicy

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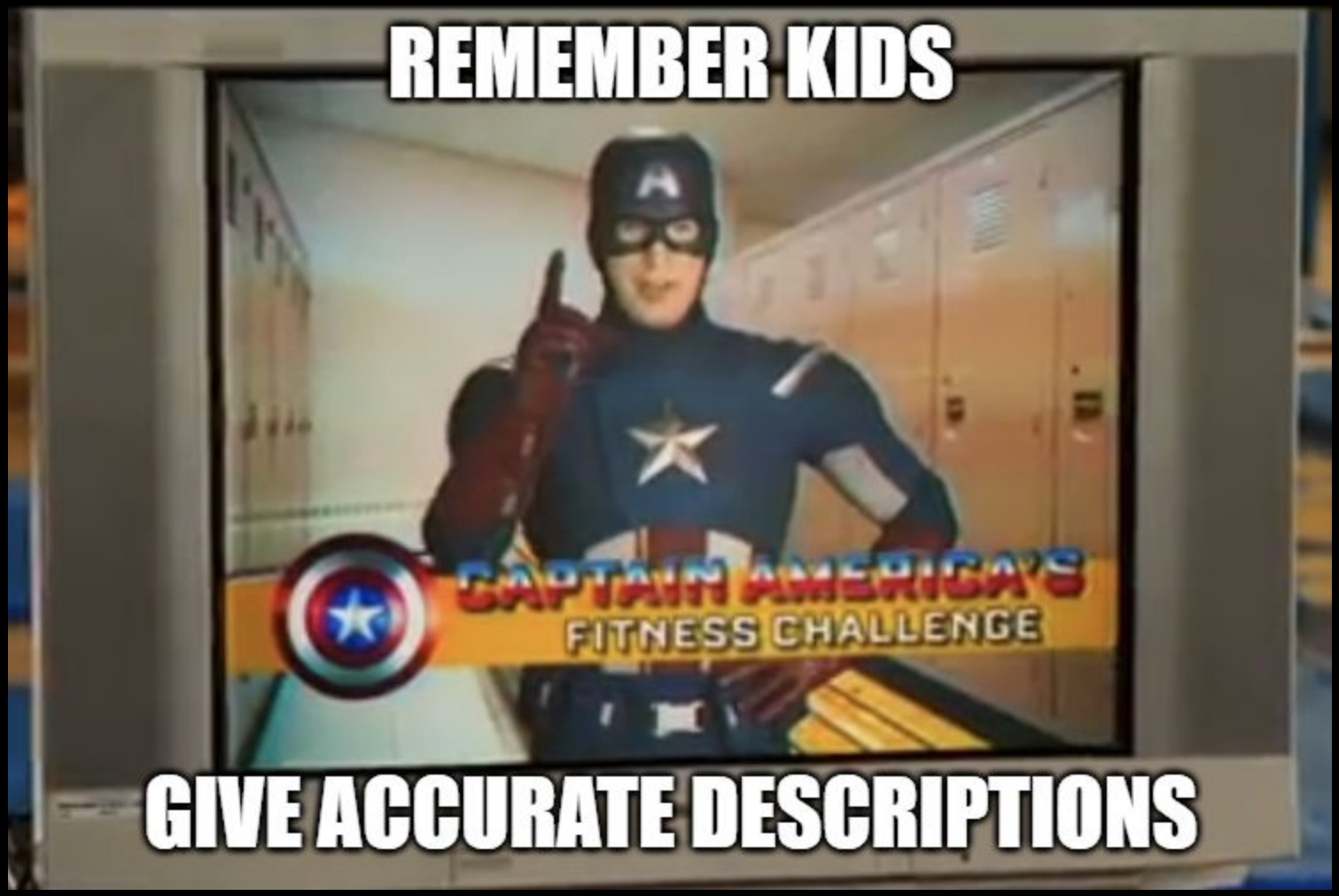
Software\Microsoft\RemoteRegistryClient\TransportFallbackPolicy

Attacker can set Event Viewer “backdoor” == Attacker can set transport policy


REMEMBER KIDS
CAPTAIN AMERICA'S
FITNESS CHALLENGE
GIVE ACCURATE DESCRIPTIONS

The Disclosure Process

Open vulnerability disclosure

Report on *RegConnectRegistryExW* with half working PoC — no actual relay

Reopen vulnerability disclosure

Report on *RegConnectRegistryW* with better PoC — adcs relay

Vulnerability patched

CVE-2024-43532 - EoP 8.8 CVSS

Report closed

Marked as documentation issue as *RegConnectRegistryExW* contains a flag to prevent fallback

Vulnerability confirmed

Further Research

- Look for more relay-able RPC clients
  - They seem more overlooked compared to RPC servers
- Coerce outbound Winreg on components that use RegConnectRegistryW

Thanks for listening

Questions?