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Pass-The-Hash Toolkit for Windows
Implementation & use

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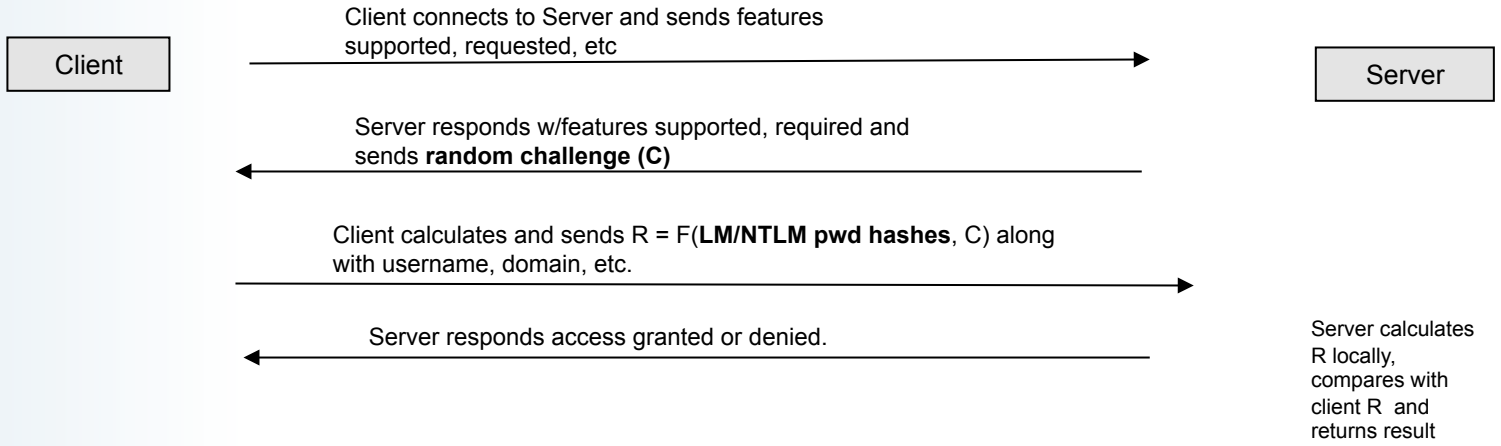
- **I'm going to talk about..**
  - What is the 'Pass-the-hash' technique?
    - » Brief history and explanation of the technique
      - Current (previous) Implementations and limitations
  - What is the Pass-the-hash Toolkit for Windows?
    - » Brief history
    - » Description of included tools and advantages
    - » Implementation (technical details)
    - » A 'new' post-exploitation 'attack/technique/thing to do'
    - » How to use the tools
      - Demos
    - » If someone is still in the room… Q/A.

What is the ‘Pass-the-hash’ technique?

- **What is Pass-the-hash?**
  - Windows stores, generally, two **hashes** of a user's passwords in its 'users database' (e.g.:SAM)
    - LM hash, NTLM hash
  - "Pass-the-hash" allows an attacker to use LM & NTLM hashes to authenticate to a remote host (using NTLM auth) without having to decrypt those hashes to obtain the cleartext password
  - First published (theory & exploit code) in 1997 by Paul Ashton (http://www.securityfocus.com/bid/233/discuss)

How/Why does 'Pass-the-hash' work?

(over)simplified diagram of NTLM challenge-response authentication protocol



- How hashes are used (F) varies (ntlmv1,ntlmv2,etc)
- Having LM/NTLM Hashes == having the cleartext password for remote NTLM auth

- **How do you obtain the LM&NTLM hashes to ‘Pass-the-hash’?**
  - Post-Exploitation
  - Dump SAM database using pwdump3/3e/4/5/6/7, fgdump, etc.
    - » Administrator: 500:01020304050607080 90A0B0C0D0E0F10:01020304050607080 90A0B0C0D0E0F10:::

- **How do you obtain the LM&NTLM hashes to 'Pass-the-hash'?, cont. (2)**
  - From c:\windows\repair\sam
  - From c:\windows\system32\config\SAM
  - Sniff SMB challenge-response over the network
    - Simplifying: capture the nonce and encrypted nonce
      - » Need to brute-force to obtain a hash to 'pass-the-hash' (e.g.: use l0phtcrack, cain&abel)
      - » Common misconception is to believe the 'encrypted nonce' is a hash we can work with, but it is not.
  - Cachedump to obtain 'hashed' hashes ☺ and then brute-forcing..
  - Etc...

- **Available 'Pass-the-hash' implementations**
  - Paul Ashton's original 'exploit code': modified SAMBA client
    - With cleartext-password (not actual smbclient params):
      - smbclient //192.168.1.20/diskC –U Administrator –p mypwd
        - Analog to 'net use z: \\192.168.1.20\diskC /u:Administrator mypwd'
    - The patch allows the following (not actual smbclient params):
      - smbclient //192.168.1.20/disckC –U Administrator –p 4ECC0E7568976B7EAAD3B435B51404EE:551E3B3215FFD87F5E037B3E3523D5F6

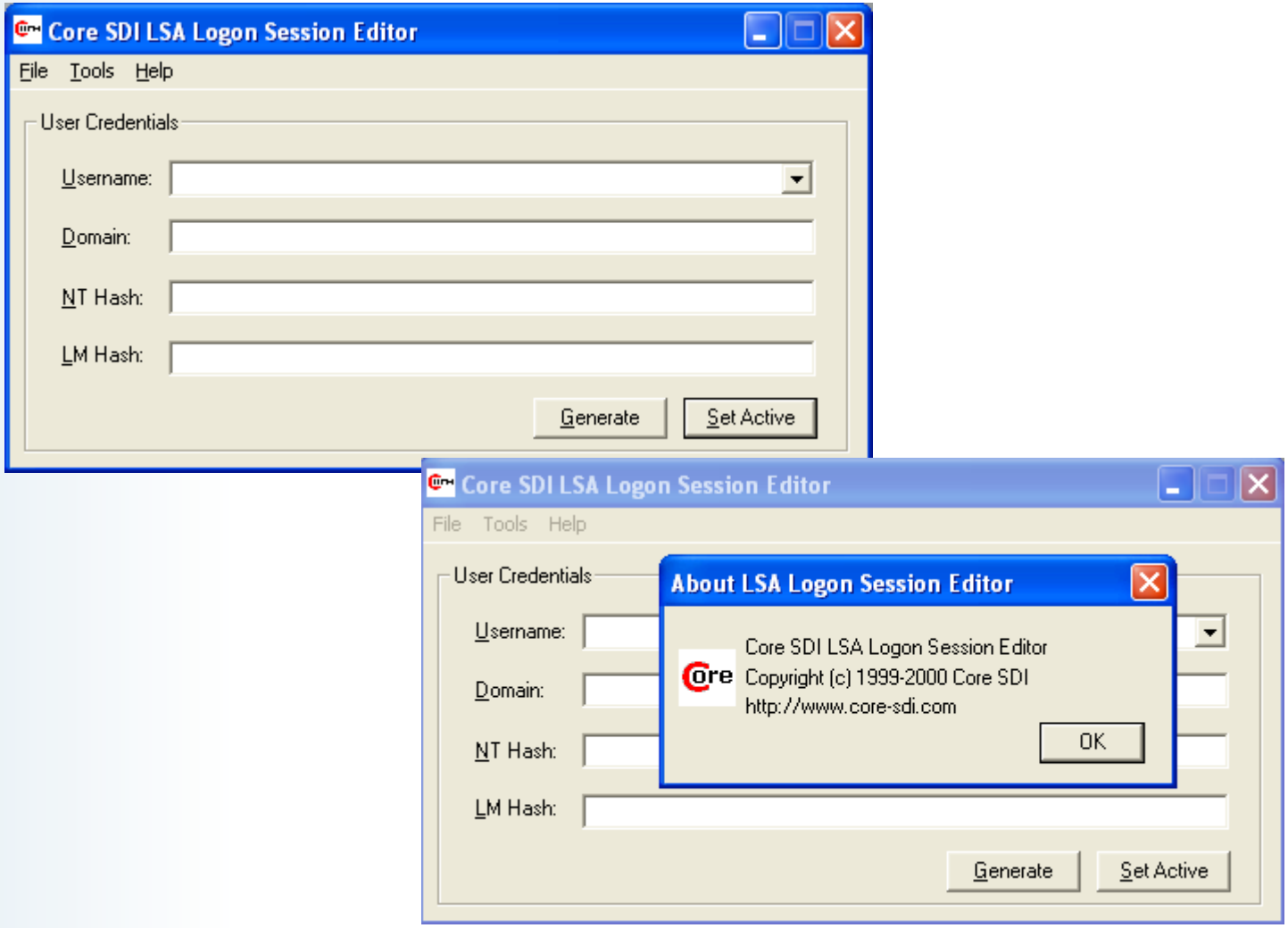
- **Available 'Pass-the-hash' implementations, cont. (2)**
  - Lots of impl. with the same approach since then:
    - » Samba-TNG provides built-in functionality for 'passing-the-hash'
    - » Lots of third-party implementations of the NTLM authentication mechanism allow performing the 'pass-the-hash' technique
      - In python, ruby, java, you name it..
      - Including metasploit, CORE IMPACT, impacket, etc.

- **Pass-the-hash previous implementations “limitations”**
  - Mostly, limited functionality:
    - Samba & Samba-TNG: enormous amount of functionality but still not everything is implemented
    - Other third-party libraries/programs implement even LESS functionality than Samba & Samba-TNG
    - Functionality is scattered among different libraries/programs
    - Some protocols and functionality is ‘partially implemented’
  - » Third-party implementations are always running behind:
    - » Implementation is done by reverse-engineering and it takes a considerable amount of effort/time
  - » You can’t use native Windows tools

- **What is Pass-the-hash Toolkit for Windows?**
  - A set of tools that brings pass-the-hash to the Windows platform (and more)
  - Published in 2007, is Free and Open Source (written in C, by me ☺)
  - Currently, it works on Windows XP, Windows Server 2003 and Vista

- **What is Pass-the-hash Toolkit for Windows?, cont.(2)**
  - I first developed a fully-working version of this technique for Windows NT4 (and later for Win2000) in 2000:
    - » I couldn't publish the code back then (it was sold to a 'company')
    - » But I wrote a paper: "Modifying Windows NT Logon Credentials"
      - Check out http://www.coresecurity.com/content/modifying-windows-nt-logon-credential
  - In 2007, I wrote a completely new implementation of the technique from scratch and the PSH/PTH Toolkit was born

- **Pass-the-hash Toolkit for Windows memorabilia**



- **PSH/PTH Toolkit for Windows Advantages**

  - Mainly, available functionality is “unlimited”
    - » It run on Windows! So…
    - » You can use any tool that uses NTLM authentication
      - – from Microsoft or any other third-party tool (think admin interfaces, DCOM, etc)
    - » You can use the same tools you’d use if you had the cleartext password
    - » You have access to all available functionality and not partial implementations
    - » You can use it on compromised remote Windows boxes during pentests and then use windows native tools

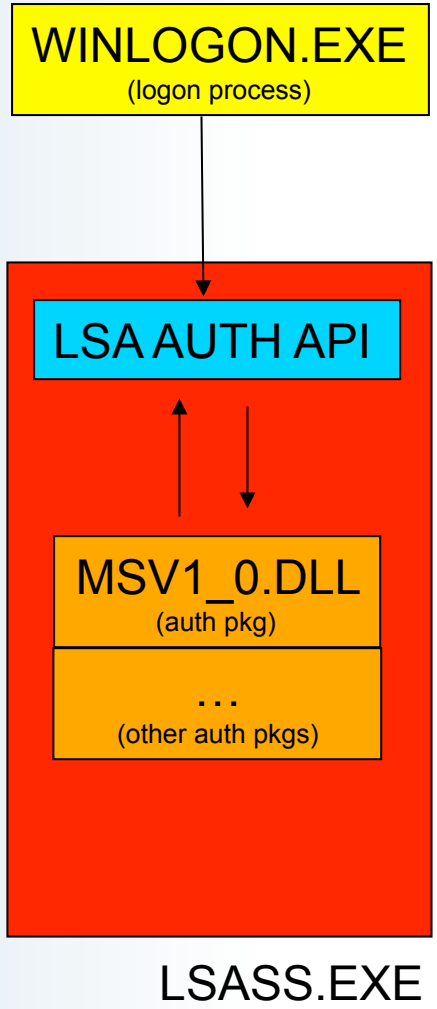
- **PSH/PTH Toolkit for Windows Advantages, cont. (2)**
  - PSH/PTH also provides a post-exploitation ‘technique/attack/tool’
    - ‘Steals’ credentials stored in memory
    - Using this, you may be able to own a windows domain more easily, more on this later..

Implementing ‘Pass-the-hash’ on Windows

- **What do we want to achieve?**
  - Analog functionality to 'smbclient //<server>/<share> -U Administrator –p 4ECC0E7568976B7EAAD3B435B51404EE:551E3B3215FFD87F5E037B3E3523D5F6'
    - » Net use z: \\<server>/<share> -U Administrator 4ECC0E7568976B7EAAD3B435B51404EE:551E3B3215FFD87F5E037B3E3523D5F6
    - » But for ALL tools that use Windows native support (API) for NTLM auth
  - We want to be able to do it as many times as we want without logging in and out
  - We want to do it without having to reboot the 'attacking machine'

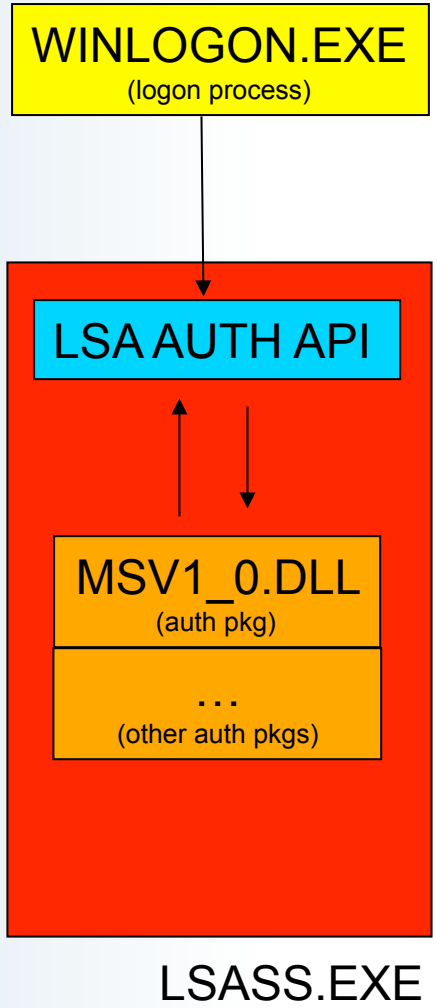
- **So, how do we do all that?**
  - Let's take a look at the Windows NT Logon and Authentication model…

- **Three basic components take part**
  - **Logon processes**: a component trusted by the OS to monitor I/O devices for logon attempts
  - **The LSA (Local Security Authority) Server Process**: user-mode process (lsass.exe) responsible basically for the local system security policy and user auth.
  - **Authentication packages**: component (DLL) responsible for performing actual user's credentials auth
    - » Each auth pkg registers to the LSA at startup (authpkg id)
    - » **Create new LSA Logon Sessions**
    - » Return info for inclusion in Token object
      - The token represents security context for access
      - **The auth packages associate credentials with the user's logon session**



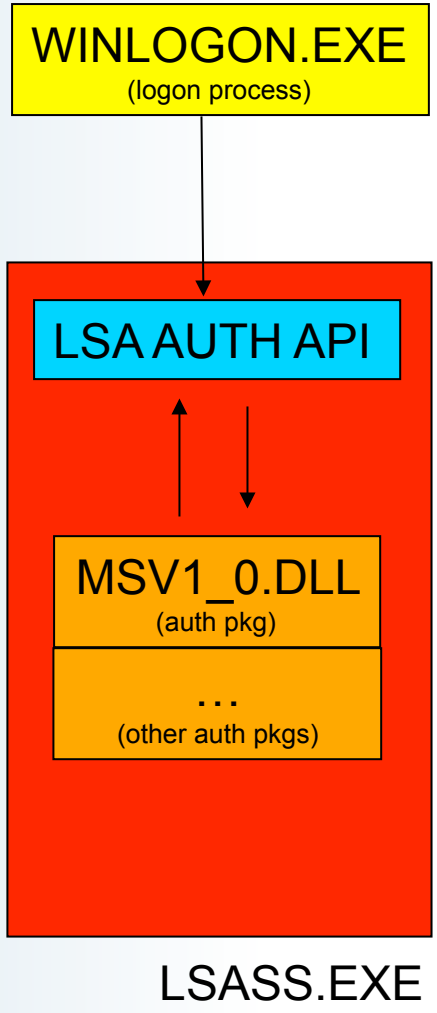
NTLM AUTH

- **Winlogon.exe:** default logon process for interactive logons
- **MSV1_0.DLL:** NTLM auth package
- **LSASS.EXE:** keeps track of logon sessions



- **Winlogon**
  - Intercepts logon attempts from the keyboard
  - calls *LsaLogonUser()* with msv1_0's id
    - » This ends up in MSV1_0.DLL

Winlogon.exe and msv1_0.dll, cont. (4)



- **Msv1_0**
  - Authenticates user using local sam or AD etc
    - Creates logon session (LUID)
  - Msv1_0 **adds credentials to logon session** by calling *LsaAddCredential()*
    - The username, the domain name, and the LM&NTLM hashes
    - These are the credentials used by windows when you try to access remote resources (e.g.: *net use \\server \c$*)

- **Msv1_0 communicates with *LSA* using the LSA AUTH API:**
  - » Auth packages export the function

    – NTSTATUS *LsaApInitializePackage*(
    __in ULONG AuthenticationPackageId,
    __in PLSA_DISPATCH_TABLE *LsaDispatchTable*,
    __in_opt PLSA_STRING *Database*,
    __in_opt PLSA_STRING *Confidentiality*,
    __out PLSA_STRING **AuthenticationPackageName*
    );

  - » LSA calls this function at startup and passes the *LsaDispatchTable* structure

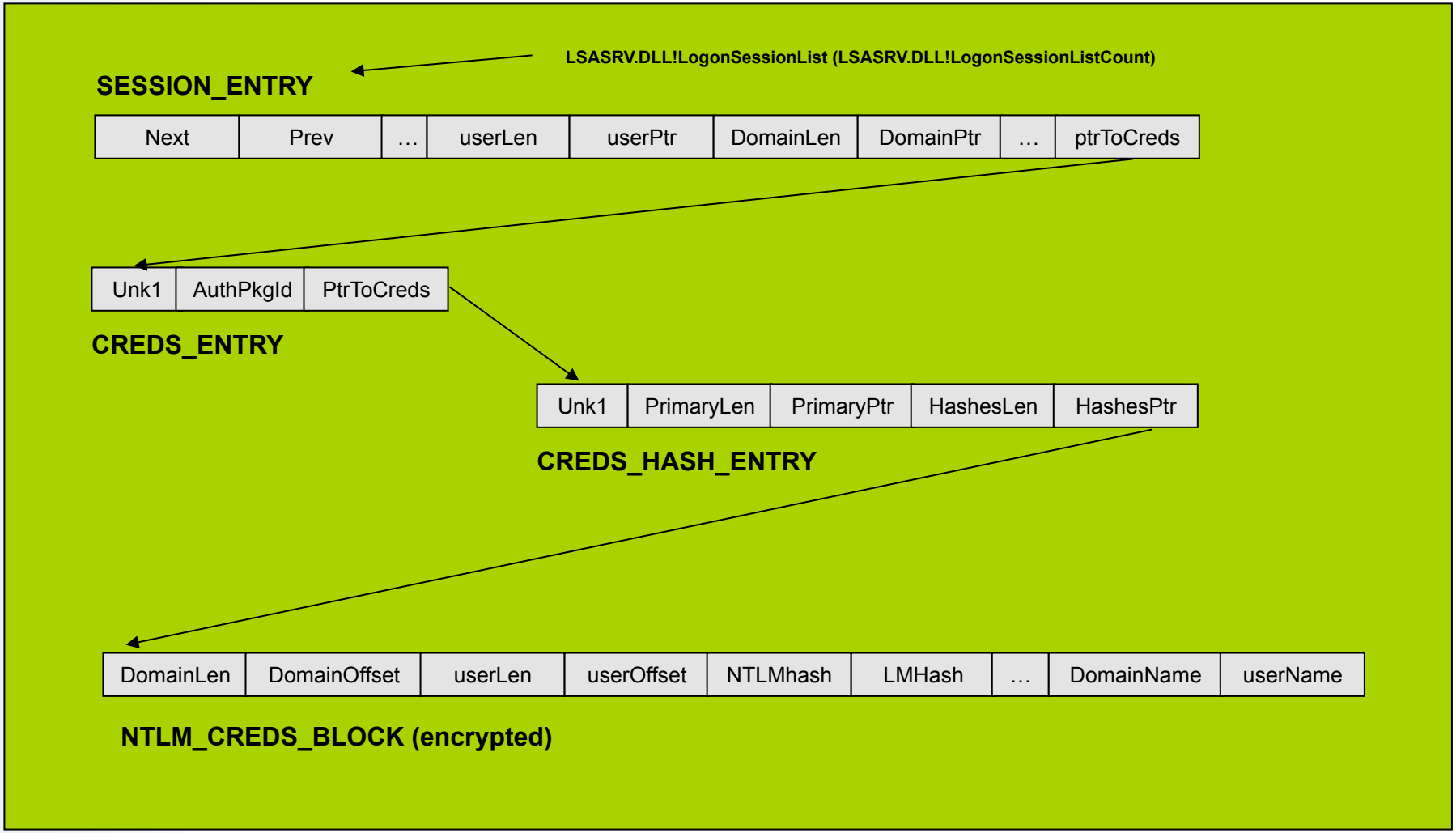
- **LSA_DISPATCH_TABLE**
  - Structure that contains the addresses of LSA functions that can be called by auth packages.

```
typedef struct LSA_DISPATCH_TABLE {

    PLSA_CREATE_LOGON_SESSION CreateLogonSession;
    PLSA_DELETE_LOGON_SESSION DeleteLogonSession;
    PLSA_ADD_CREDENTIAL AddCredential;
    PLSA_GET_CREDENTIALS GetCredentials;
    PLSA_DELETE_CREDENTIAL DeleteCredential;
    PLSA_ALLOCATE_LSA_HEAP AllocateLsaHeap;
    PLSA_FREE_LSA_HEAP FreeLsaHeap;
    PLSA_ALLOCATE_CLIENT_BUFFER AllocateClientBuffer;
    PLSA_FREE_CLIENT_BUFFER FreeClientBuffer;
    PLSA_COPY_TO_CLIENT_BUFFER CopyToClientBuffer;
    PLSA_COPY_FROM_CLIENT_BUFFER CopyFromClientBuffer;

} LSA_DISPATCH_TABLE,PLSA_DISPATCH_TABLE;
```

- **So, how can we implement ‘Pass-the-hash’ on Windows ALREADY!?**
  - » We play around with the logon sessions and their associated credentials…
    - – Remember…
      - » Credentials associated with logon sessions are the credentials used when you want to access a remote resource using NTLM auth
      - » So if we change these credentials (e.g.: modify the password hashes), we modify credentials used for over the network auth and we will accomplish our goal



LSASS.EXE maintains a double-linked list of logon sessions LSASS.EXE

- **Each logon session may have associated NTLM credentials (or others)**
  - NTLM creds. encrypted w/random key using either desX-cbc or rc4
    - » If modulo(size/8)==0 use desX-cbc, otherwise use rc4
    - » **DES-X** (or **DESX**) is a variant of DES intended to increase the complexity of a brute-force attack using a technique called *key whitening*.
      - DES-X augments DES by XORing an extra 64 bits of key (K1) to the plaintext *before* applying DES, and then XORing another 64 bits of key (K2) *after* the encryption

- I've never seen credentials encrypted with rc4
- desX key appears to be lost but IV, whitening keys and scheduled key are available
  - » LSASS itself uses this info to encrypt/decrypt
    - it uses the *LSASRV.DLL!LsaEncryptMemory()* function

- **LSASRV.DLL!LsaInitializeProtectedMemory generates the keys used to encrypt credentials in memory**

```
// global_vars
uchar *g_pRandomKey;                    // ?g_pRandomKey@@3PAEA
ulong g_cbRandomKey;                    // ?g_cbRandomKey@@3KA
ulong CredLockedMemorySize;             // ?CredLockedMemorySize@@3KA
void* CredLockedMemory;                 // ?CredLockedMemory@@3PAXA
_desxtable *g_pDESXKey;                 // ?g_pDESXKey@@3PAU_desxtable@@
                                        //typedef struct _desxtable {
                                        //      unsigned char inWhitening[8];
                                        //      unsigned char outWhitening[8];
                                        //      DESTable desTable;
                                        //} DESXTable;
unsigned __int64 g_Feedback;            // ?g_Feedback@@3_KA

LsaInitializeProtectedMemory
{

g_cbRandomKey = 0x100 (256) ;
CredLockedMemorySize  = 0x190 (400);

CredLockedMemory = VirtualAlloc(0, 190h, MEM_COMMIT(1000h), PAGE_READWRITE(4))
VirtualLock( CredLockedMemory, CredLockedMemoriSize );


// _desxtable *g_pDESXKey
g_pDESXKey = CredLockedMemory;

g_pRandomKey = g_pDESXKey + 0x90 (144);

SystemFunction036@8( g_pRandomKey, 0x18 (24) );
SystemFunction036@8( &g_Feedback, 8);
desxkey( g_pDESXKey, g_pRandomKey);
SystemFunction036@8( g_pRandomKey, g_cbRandomKey );



}
```

- **LSASRV.DLL!LsaEncryptMemory is used to encrypt/decrypt credentials**

```
void LsaEncryptMemory(unsigned _int8 *buffer, unsigned __int32 len, unsigned int mode)
{
char *pbuffer;
??? outRC4key;
unsigned int feedback1;
unsigned int feedback2;

        if( buffer == NULL) return;

        pbuffer = buffer;

        if( len == 0 ) return;

        if( !(len&7) ) {

                rc4_key( &outRC4key,  g_cbRandomKey, g_pRandomKey);
                rc4( outRC4Key, len, buffer);
                return;

        }

        feedback1, feedback2 = g_Feedback;
        _CBC@28( &_function_desx@16,
                                8,
                                buffer,
                                buffer,
                                g_pDESXKey,
                                mode,
                                &feedback1);

}
```

Pass-the-hash Toolkit for Windows included tools & implementation

- **PSH/PTH Toolkit for Windows – included tools**
  - *IAM.exe* and *IAM-ALT.exe*: performs 'pass-the-hash'
  - *WHOSTHERE.exe* and *WHOSTHERE-ALT.exe*: obtain credentials stored in memory (domain, username, NT&NTLM hashes)
  - *PASSTHEHASH.IDC*: *IDA Pro* .IDC script; obtain addresses *IAM.exe* and *WHOSTHERE.exe* need to function
  - *GENHASH.exe*: helper tool. Mainly for testing purposes:
    - » Generates NT&NTLM hashes from a cleartext password

- **GENHASH.EXE**
  - Generates LM & NTLM hashes
  - Uses 'undocumented' functions
    - *Advapi32.dll!SystemFunction006(strupr(char* pwd), out uchar* hash)*
      - Generates LM hash
    - *Advapi32.dll!SystemFunction007*(unicode* pwd, out uchar* hash)
      - Generates NTLM hash

The “hard” way
(iam.exe / whosthere.exe)

- **IAM.EXE and IAMDLL.DLL**
  - *Findfuncs() in LSASRV.DLL*
    - » *LsaAddCredential, LsaEncryptMemory, Feedback, DesXKey, LogonSessionList, LogonSessionCount*
  - Gets current LogonID
    - » If –r, creates new logon session and process (advapi32.dll!CreateProcessWithLogonW)
  - Creates 'NTLM_CREDS_BLOCK'

DomainLen	DomainOff	userLen	userOffset	NTLMhash	LMHash	…	Domain	User

NTLM_CREDS_BLOCK

  - Injects *iamdll.dll* into *LSASS.EXE*
    - *Encrypts credentials manually and*

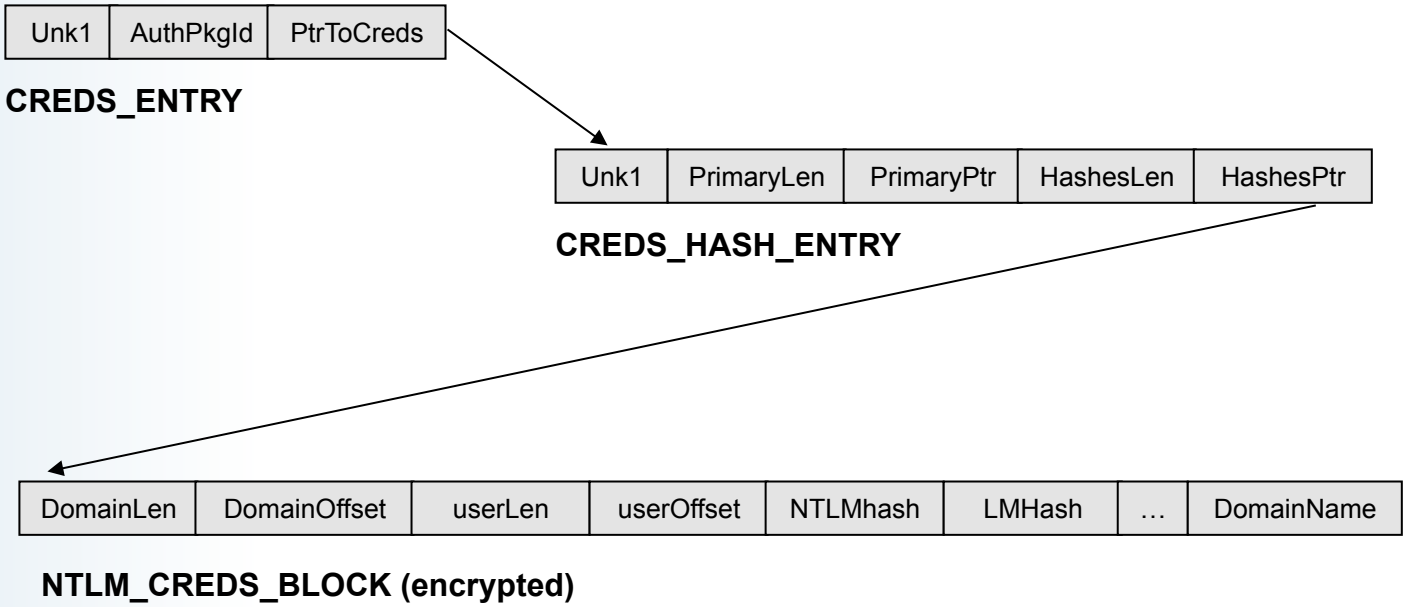
calls LSASRV.DLL!LsaAddCredential(LogonID,&primaryKey,&MSV_CREDS)

- **WHOSTHERE.EXE**
  - *Findfuncs()* inside *LSASRV.DLL*
    - » *LsaAddCredential, LsaEncryptMemory, Feedback, DesXKey, LogonSessionList, LogonSessionCount*
  - From *LSASS.EXE*
    - » Reads value of *g_Feedback,DesXKey, LogonSessionlist, LogonSessionListCount*
  - Iterates thru items in double-linked list of sessions

SESSION_ENTRY

Next	Prev	…	userLen	userPtr	DomainLen	DomainPtr	…	ptrToCreds

- **Gets to encrypted credentials per each logon session**



Findfuncs()

- **Address group**
  - LSASRV.DLL!?LsaEncryptMemory@@YGXPAEKH@Z
  - LSASRV.DLL!_LsapAddCredential@16
  - LSASRV.DLL!?g_Feedback@@3_KA
  - LSASRV.DLL!?g_pDESXKey@@3PAU_desxtable@@A
  - LSASRV.DLL!?LogonSessionCount@@3KA / LSASRV.DLL!?LogonSessionListCount@@3KA (in W2003)
  - LSASRV.DLL!?LogonSessionList@@3U_LIST_ENTRY@@A / LSASRV.DLL!?LogonSessionList@@3PAU_LIST_ENTRY@@A (in W2003)

- **Address Group Example**

```
#define V2976_XPSP2_ADDCREDENTIAL_FRENCH                (PBYTE)0x756C7A24
#define V2976_XPSP2_ENCRYPTMEMORY_FRENCH                (PBYTE)0x756C5449
#define V2976_XPSP2_FEEDBACK_ADDR_FRENCH                (PBYTE)0x75750BD8
#define V2976_XPSP2_DESKEY_PTR_ADDR_FRENCH
        (PBYTE)0x75750BE0
#define V2976_XPSP2_LOGON_SESSION_LIST_ADDR_FRENCH
        (PBYTE)0x7574FCB8
#define V2976_XPSP2_LOGON_SESSION_LIST_COUNT_FRENCH
        (PBYTE)0x7574FE54
```

- **'Database' of 'addresses groups' for different *LSASRV.DLL* versions**
  - addresses change based on
    - » DLL version of auth components
    - » Service pack
    - » Windows version (XP,2003, etc)
    - » Language (French,German,etc)

The “easy” way

(iam-alt.exe / whosthere-alt.exe)

- ***IAM-ALT.EXE* and *PTH.DLL***
  - Gets *LogonID*
    - » If –r, create new logon session and process (*advapi32.dll! CreateProcessWithLogonW*)
      - Obtain LogonID
  - Injects *PTH.DLL* into *LSASS.EXE*
    - » Finds *msv1_0.dll!NlpAddPrimaryCredential*
      - *Not exported*
      - Searches for signatures (series of fixed opcodes)
    - » Calls *msv_10.dll!NlpAddPrimaryCredential*
      - No need to encrypt credentials

- ***WHOSTHERE-ALT.EXE* and *PTH.DLL***
  - Calls *secur32.dll!LsaEnumerateLogonSessions()*
  - Iterates thru sessions (LUIDs)
    - » Gets username, domain, authpkg name
  - Injects *pth.dll* into *LSASS.EXE*
    - » Finds *msv1_0.dll!NlpGetPrimaryCredential()*
      - Not exported
      - Searches for signatures (series of fixed opcodes)
    - » Calls *msv1_0.dll!NlpGetPrimaryCredential()*
      - No need to decrypt

Implementation Summary

- ***IAM.EXE* and *IAM-ALT.EXE***
  - Perform ‘pass-the-hash’
  - Replace current and new logon session credentials
  - Two different implementations of the same ‘technique’
  - IAM-ALT uses a more ‘generic’ and ‘easy’ approach and should work on more systems
  - IAM uses a more ‘specialized’ approach meant to be more ‘stealthy’ (sthg like that..does not completely accomplishes this right now..)

- ***WHOSTHERE.EXE* and *WHOSTHERE-ALT.EXE***
  - List credentials of current logon sessions
  - Two different implementations of the same ‘technique’
  - WHOSTHERE-ALT uses a more ‘generic’ and ‘easy’ approach and should work on more systems
  - WHOSTHERE just reads memory
    - » Very safe
    - » Specially to use on pentests

DEMO

Using whosthere/whosthere-alt to help you “own the domain”

- **Compromise a Windows machine**
  - Dump SAM to obtain NT&NTLM hashes (e.g.:pwdump)
    - » Obtains password hashes of, **ONLY**, users on LOCAL SAM database

- **How do you move from owning a single machine to owning a domain?**
  - » Use whosthere/whosthere-alt to dump LM&NTLM credentials stored in memory
    - – New logon sessions
    - – Logon sessions created pre-exploitation
  - » You might get lucky and get accounts with **domain admin privileges**
  - » I've seen this many times.. (I'm not that lucky, so you should see the same thing ☺)
  - » **Sometimes… logon sessions and NTLM credentials remain in memory after users log off…**

DEMO

CONCLUSIONS

- **PSH Toolkit brings pass-the-hash to Windows (iam/iam-alt)**
- **The 'technique' is no longer limited to certain functionality**
  - You can use any microsoft and third-party tool that uses NTLM auth
  - ALL functionality of such tools is available to you
  - You can use this in a pentest (pivoting)

- **Whosthere/whosthere-alt grabs hashes of (active?) logon sessions**
  - Dump credentials stored in memory
  - Leave whosthere/whosthere-alt running and grab hashes of new logon sessions when they are created
  - **You can obtain credentials of users not local to the workstation you are on**
  - Sometimes credentials are in memory **even when users are not currently logged on**
  - helps you own the domain after compromising only one server/ workstation

QUESTIONS?

Thanks!

- **Blog: hexale.blogspot.com**
- **My web site: www.hexale.org**
- **Forums: www.hexale.org/forums**
- **PSH/PTH toolkit available at http://oss.coresecurity.com/projects/pshtoolkit.htm**
- **More info available at http://oss.coresecurity.com/pshtoolkit/doc/index.html and at my web site.**

- **PASSTHEHASH.IDC Script**
  - » Finds the following Symbols
    - – ?LsaEncryptMemory@@YGXPAEKH@Z
    - – _LsapAddCredential@16
    - – ?g_Feedback@@3_KA
    - – ?g_pDESXKey@@3PAU_desxtable@@A
    - – ?LogonSessionCount@@3KA / ?LogonSessionListCount@@3KA (in W2003)
    - – ?LogonSessionList@@3U_LIST_ENTRY@@A / ? LogonSessionList@@3PAU_LIST_ENTRY@@A (in W2003)

  – If WHOSTHERE/IAM don't work on your system, you can make them work yourself
    - » You don't need to recompile the tools