Windows Kernel Internals
Lightweight Procedure Calls

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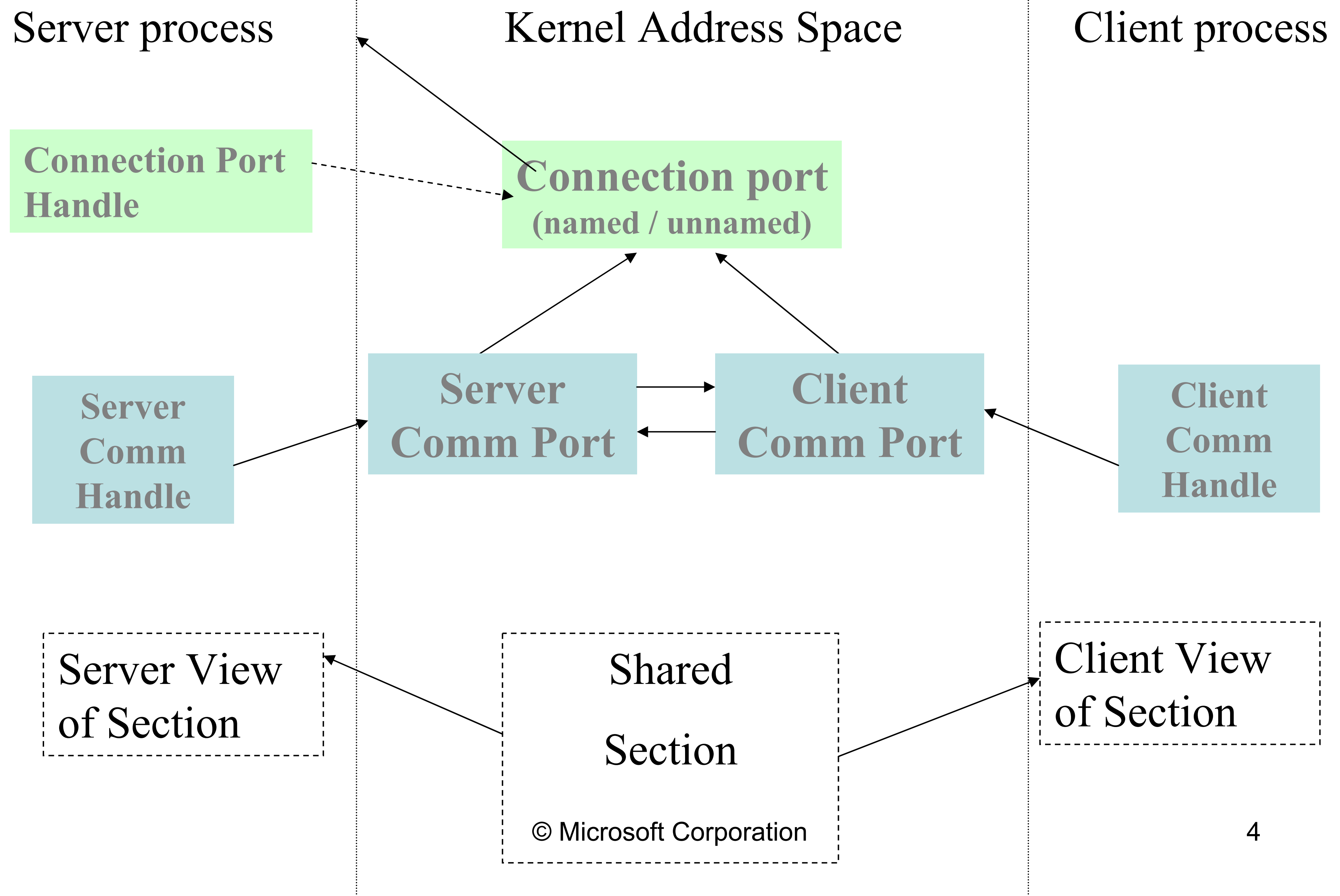
Topics

- LPC overview
- !lpc debugger extension
- Investigation checklist
- Debugging samples

LPC usage

- LPC is an internal interface for NT components.
- Communications between two user mode components (csrss and win32, winlogon and lsass)
- Communications between a user-mode process and a kernel-mode component (lsass and Security Reference Monitor)
- Local RPC

LPC Architecture



LPC ports

- Connection port (named / unnamed)
  - Created by the server side.
  - Used to accept connections, receive requests and to reply to messages
- Server communication port
  - The server receives a handle to server port each time a new connection is created.
  - Used to terminate a connection, to impersonate the client or to reply.
- Client communication port
  - The client receives a handle to a client port if the connection was successfully accepted.
  - Used to request/receive messages

LPC Data Transfer

- The message is temporary copied to kernel (< 256 bytes*)
- Using shared sections, mapped in both client and server address spaces
- The server can directly read from or write to a client address space

Creating an LPC server

- 1. Create a named connection port (NtCreatePort)
- 2. Create one or more working threads listening to requests on that LPC connection port (NtReplyWaitReceivePort)

Creating an LPC server – cont

```
{   …
    If ( NtCreatePort(&SrvConnHandle, “LPCPortName”) ) {
            CreateThread ( ProcessLPCRequestProc)
    }
    …
}
ProcessLPCRequestProc ()
{
    ReplyMsg = NULL;
    while ( forever_or_so ){
            NtReplyWaitReceivePort( SrvConnHandle, ReplyMsg, ReceiveMsg )
            DoStuffWithTheReceivedMessage()
             ReplyMsg = PrepareTheReply ( IfAny )*
    }
}
```

* Some servers launch an worker thread to process the request and reply to the client

Establishing an LPC connection

- The Client initiates a connection (NtConnectPort)
- The server receives a connection request message
- The server decides to accept/reject the connection and calls NtAcceptConnectPort
- The server wakes up the client (NtCompleteConnectPort)

Common issues

- Servers cannot send messages to clients that are not waiting for an LPC message
- If a server dies, the client is not notified unless it has threads waiting for a reply
- No timeout for the LPC wait APIs

LPC data structures

- LPC Port (paged)
  - Port type, connection & connected port, owning process, server process, port context
- LPC Message (paged)
  - MessageID, message type, ClientID
- Thread LPC fields (non-paged)
  - Wait state, request messageID, LCP port, received message id, port rundown queue
- Global data
  - LpcpNextMessageId, LpcpLock

LPC port object

- Object fields (name, ref count, type)
- Port type (connection, server comm, client comm)
- Connection and connected port
- Creator CID
- Message queue
- Port context
- Thread rundown queue

LPCP_PORT_OBJECT

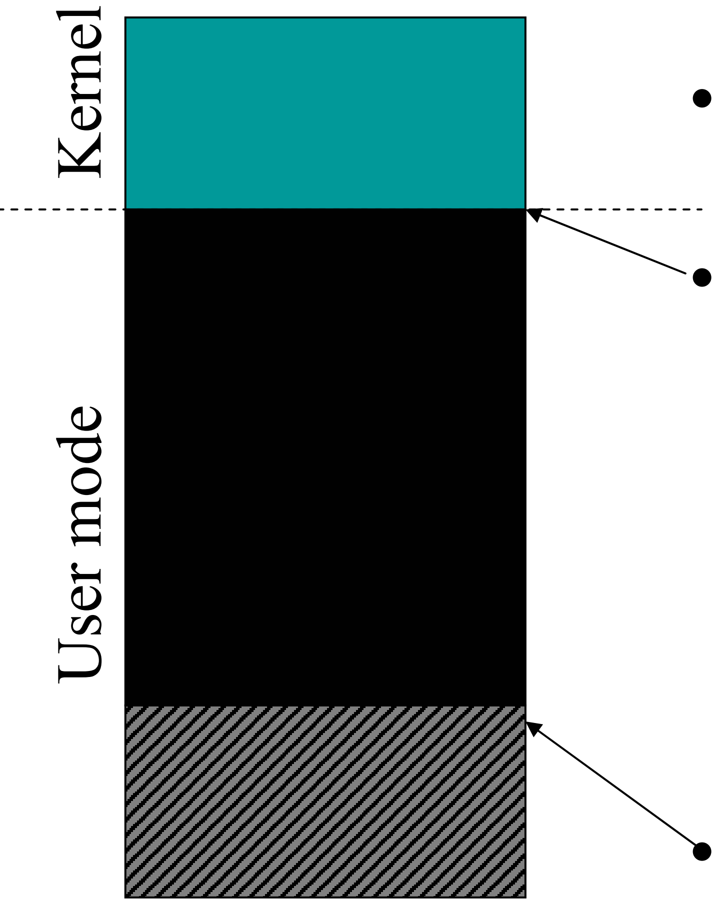
```
typedef struct _LPCP_PORT_OBJECT {
    ULONG Flags;
    struct _LPCP_PORT_OBJECT *ConnectionPort;
    struct _LPCP_PORT_OBJECT *ConnectedPort;
    LPCP_PORT_QUEUE MsgQueue;
    CLIENT_ID Creator;
    PVOID PortContext;
    ULONG MaxMessageLength;
    LIST_ENTRY LpcReplyChainHead;
    LIST_ENTRY LpcDataInfoChainHead;

     …
}
```

LPC ports in EPROCESS

- DebugPort
  - Used to send debugger messages
- ExceptionPort
  - CsrCreateProcess assigns it to a win32 process
- SecurityPort
  - Used by lsass

LPC message format



- Kernel side (Port context, messages list)
- User side (PORT_MESSAGE)
  - Message type (request, reply, connection request, client died, port closed)
  - Message length, data offset
  - Client ID
  - Message ID
- Private data

LPCP_MESSAGE

```
typedef struct _LPCP_MESSAGE {
    union {
        LIST_ENTRY Entry;
    };
    PETHREAD RepliedToThread;
    PVOID PortContext;

    …
    PORT_MESSAGE Request;
} LPCP_MESSAGE, *PLPCP_MESSAGE;
```

PORT_MESSAGE

```
typedef struct _PORT_MESSAGE {
  CSHORT DataLength;
  CSHORT TotalLength;
  CSHORT Type;
  CSHORT DataInfoOffset;
  LPC_CLIENT_ID ClientId;
  ULONG MessageId;
  ULONG CallbackId;

  …
//  UCHAR Data[];
} PORT_MESSAGE, *PPORT_MESSAGE;
```

More about LPC messages

- Where are messages to be found?
  - On the caller stack
  - In the port queue
  - In the thread pending the reply
- Can you tell how old a message is?
- Validating fields to detect corruptions
  - MessageID
  - Message type
  - Client ID

Typical message

```
Waiting for reply to LPC MessageId 000016df:

Pending LPC Reply Message:

    e1a9d378: [e190e620,e1bd3008]


      kd> dd e1a9d378
      e1a9d378  e1bd3008 e190e620 00000000 00000000
      e1a9d388  00000000 00000033 00cc009c 0000000a
      e1a9d398  000007cc 00000784 000056df 00000000
      e1a9d3a8  00000000 00000000 00000000 00000000
      e1a9d3b8  00000000 00000000 e18e8ce0 00000000


1: kd> dc NT!LpcpNextMessageId l1

8025bafc  000027d8
```

The LPC fields in ETHREAD

- LpcReplyChain
  - To wake up a client if a server port goes away
- LpcReplySemaphore
  - It gets signaled when the reply message is ready
- LpcReplyMessageId
  - The message ID at which the client is waiting a reply
- LpcReplyMessage
  - The reply message received
- LpcWaitingOnPort
  - The port object currently used for a LPC request
- LpcReceivedMessageId
  - The last message ID that a server received

!lpc KD debugger extension

- !lpc message [MessageId]
- !lpc port [PortAddress]
- !lpc scan PortAddress
- !lpc thread [ThreadAddr]
- !lpc PoolSearch

Analyzing the LPC connection

- Get the information from the client thread
  - Use !thread to get the messageId and the communication port
- Find the server process
  - Use !lpc message to find the server thread/process working on this message
  - Use !lpc port to identify the connection port
- Check the server connection state
  - Semaphore state, message queue
- Look at what is doing the server thread

Client waiting for reply

- Recognizing the state
  - !thread will display:
    - WAIT state WrLpcReply
    - "Waiting for reply to LPC MessageId x"
    - "Current LPC port y"
- What's next
  - Use !lpc to find the server thread / process / port
  - See if the server:
    - Didn't receive the request
    - The server received but it didn't reply

Common server problems

- The server is not servicing the port
  - All server threads are busy with some other requests (or deadlocked)
  - The server is suspended by the debugger
- The server replied to a wrong client
- The reply failed, and the server didn’t managed the result
- The server replied/impersonated using a wrong port

Discussion