INSIDE THE ULTIMA ONLINE GOLD DEMO
- THE PACKET COMMUNICATION – PART 2

GOAL

It's our goal to get a deep understanding of how the Ultima Online Gold Demo works. This demo is a representation of the rule set from the Ultima Online Second Age Era.

There is proof that some people have already reversed this demo partially or as a whole, however so far no tools or knowledge has been published. This project is to overcome does shortcomings.

URL's with some proof for this:
http://www.runuo.com/forums/general-discussion/94767-help-m-files.html
http://azaroth.org/2008/12/31/your-topic/ (posting by Faust)

If we understand the demo there is a big chance we can alter the demo and even create our own demo. By default mounting horses is not possible in the demo, but what if we can alter the demo and unlock horses; can we then see how horses behaved during T2A?

This demo is 10 years old and I do not understand no one published his/her work. Maybe that DMCA thing is in the way?

UTILITIES USED

IDA Pro, a very professional utility, definitely worth buying, Standard version is affordable.
HxD, a very neat hex editor and above all, it's free
Explorer Suite, it did the job for this project but the tool can be improved

ABOUT ME

I'm just a guy who loves the Ultima universe and knows a bit assembler. Why not combine the two? ☺ I learned programming in BASIC, and then I switched to C and from there to assembler. I think that's the most logical order and I believe every one should learn to program like that. BASIC because it's easy, C because it's a language where other languages are based upon (C++, Java, C#, …) and at the same time you have to stay focused to avoid buffer overruns (which I consider to be an important skill). Assembler will teach you how a program works and it doesn't open a door or a window, it opens a **gate** to the inner workings of your computer.

SMALL RECAPULATION

In part 1 of The Packet Communication we learned where and how the sending and receiving of the packets is done (at the transfer level, not at the game level). Today's goal is to insert code to enable logging of these packets.

It's my decision to use the log format of the Razor application. Razor is a macro utility for free shards. This log format is clear text so files will become big quickly. I could have chosen to create my own binary format which will be easier to implement but this means that yet another log format would have been born. That my dear reader I wanted to avoid!

WHERE TO START THE PATCH

My first idea was to modify the constructor of the MemoryTransfer0C object, however; this object is initialized before the critical section is entered. If we have two log files, one for client to server and one for server to client, this wouldn't be much of a problem. That is however a silly idea.

Remember, we have to keep thread-safety into mind so it's better to insert our code between the EnterCriticalSection and LeaveCriticalSection calls.

```
004E72B5 mov     ecx, [ebp+THIS_MemoryTransfer20]
004E72B8 push    ecx                             ; lpCriticalSection
004E72B9 call    ds:EnterCriticalSection
004E72BF mov     edx, [ebp+THIS_MemoryTransfer20]
004E72C2 cmp     [edx+struct_MemoryTransfer20.MemoryTransfer0C_LinkedList], 0
004E72C6 jnz     short loc_4E72DC
004E72C8 mov     eax, [ebp+THIS_MemoryTransfer20]
004E72CB mov     ecx, [ebp+VAR_MemoryTransfer0C_2]
004E72CE mov     [eax+struct_MemoryTransfer20.MemoryTransfer0C_LinkedList], ecx
004E72D1 mov     edx, [ebp+THIS_MemoryTransfer20]
004E72D4 mov     eax, [ebp+VAR_MemoryTransfer0C_2]
004E72D7 mov     [edx+struct_MemoryTransfer20.MemoryTransfer0C_FirstInLinkedList], eax
004E72DA jmp     short loc_4E72F1
004E72DC ; ---------------------------------------------------------------------------
004E72DC
004E72DC loc_4E72DC:                             ; CODE XREF: FUNC_MemoryTransfer_Write+85↑j
004E72DC mov     ecx, [ebp+THIS_MemoryTransfer20]
004E72DF mov     edx, [ecx+struct_MemoryTransfer20.MemoryTransfer0C_LinkedList]
004E72E2 mov     eax, [ebp+VAR_MemoryTransfer0C_2]
004E72E5 mov     [edx+struct_MemoryTransfer0C.NextMemoryTransfer0C], eax
004E72E8 mov     ecx, [ebp+THIS_MemoryTransfer20]
004E72EB mov     edx, [ebp+VAR_MemoryTransfer0C_2]
004E72EE mov     [ecx+struct_MemoryTransfer20.MemoryTransfer0C_LinkedList], edx
004E72F1
004E72F1 loc_4E72F1:                             ; CODE XREF: FUNC_MemoryTransfer_Write+99↑j
004E72F1 mov     eax, [ebp+THIS_MemoryTransfer20]
004E72F4 push    eax                             ; lpCriticalSection
004E72F5 call    ds:LeaveCriticalSection
004E72FB mov     eax, [ebp+ARG_BytesToSend]
```

Do you see place to insert code? I didn't.

We can redesign the whole function and optimize it correctly to gain space. However, I took a different approach. I replaced the call to LeaveCriticalSection with a call to inserted code plus I added code to make sure we can use the fastcall.

WHAT IS FASTCALL

Fastcall is a calling convention like any other ☺. When using fastcall you are passing variables through registers and not through the stack (which is faster, hence fastcall). Extra reading: http://en.wikipedia.org/wiki/X86_calling_conventions#fastcall.

WHAT TO INSERT

The code we are adding in this patch is really big compared with previous patches so I decided to code and test this in C. Remember, modern C compilers support 64-bit time_t values, but due to its age the uodemo is limited to 32-bit. Luckily you can tell modern C compilers to use the old-style time_t standard.

WARNING! With this patch I could be introducing the Year 2038 bug in the demo because of using 32-bit time_t!

The actual C code is attached at the end of this document!

THE PATCH ENTRY

The screenshot below shows the modified FUNC_MemoryTransfer_Write function, notice the added “XCHG EAX, EDX”:

```
004E72C2 83 7A 1C 00      cmp     [edx+struct_MemoryTransfer20.MemoryTransfer0C_LinkedList], 0
004E72C6 75 14            jnz     short loc_4E72DC
004E72C8 8B 45 E4         mov     eax, [ebp+THIS_MemoryTransfer20]
004E72CB 8B 4D F0         mov     ecx, [ebp+VAR_MemoryTransfer0C_2]
004E72CE 89 48 1C         mov     [eax+struct_MemoryTransfer20.MemoryTransfer0C_LinkedList], ecx
004E72D1 8B 55 E4         mov     edx, [ebp+THIS_MemoryTransfer20]
004E72D4 8B 45 F0         mov     eax, [ebp+VAR_MemoryTransfer0C_2]
004E72D7 89 42 18         mov     [edx+struct_MemoryTransfer20.MemoryTransfer0C_FirstInLinkedList], eax
004E72DA EB 16            jmp     short loc_4E72F2
004E72DC                  ; ---------------------------------------------------------------------------
004E72DC
004E72DC                  loc_4E72DC:                             ; CODE XREF: FUNC_MemoryTransfer_Write+85↑j
004E72DC 8B 4D E4         mov     ecx, [ebp+THIS_MemoryTransfer20]
004E72DF 8B 51 1C         mov     edx, [ecx+struct_MemoryTransfer20.MemoryTransfer0C_LinkedList]
004E72E2 8B 45 F0         mov     eax, [ebp+VAR_MemoryTransfer0C_2]
004E72E5 89 42 08         mov     [edx+struct_MemoryTransfer0C.NextMemoryTransfer0C], eax
004E72E8 8B 4D E4         mov     ecx, [ebp+THIS_MemoryTransfer20]
004E72EB 8B 55 F0         mov     edx, [ebp+VAR_MemoryTransfer0C_2]
004E72EE 89 51 1C         mov     [ecx+struct_MemoryTransfer20.MemoryTransfer0C_LinkedList], edx
004E72F1 92               xchg    eax, edx
004E72F2
004E72F2                  loc_4E72F2:                             ; CODE XREF: FUNC_MemoryTransfer_Write+99↑j
004E72F2 8B 55 E4         mov     edx, [ebp+THIS_MemoryTransfer20]
004E72F5 52               push    edx
004E72F6 E8 27 5D 10 00   call    FUNC_LoggerEntry__Patch
004E72FB 8B 45 0C         mov     eax, [ebp+ARG_BytesToSend]
```

The EAX will contain a pointer to the MemoryTransfer0C object, remember, that object contains the pointer to the packet data and contains the packet size.

This is the called FUNC_LoggerEntry function (I added __Patch so I know during the debugging sessions that it's a patch that is being called):

```
005ED022                    FUNC_LoggerEntry__Patch proc near      ; CODE XREF: FUNC_MemoryTransfer_Write+B5↑p
005ED022
005ED022                    ARG_EIPofCaller_FarAway= dword ptr  2Ch
005ED022
005ED022 8B 48 04           mov     ecx, [eax+struct_MemoryTransfer0C.MemorySize]
005ED025 8B 10              mov     edx, [eax+struct_MemoryTransfer0C.MemoryBlock]
005ED027 8B 44 24 2C        mov     eax, [esp+ARG_EIPofCaller_FarAway]
005ED02B FF 15 60 AC 9A 00  call    ds:GLOBAL_LogFunction
005ED031 FF 25 E0 55 9A 00  jmp     ds:LeaveCriticalSection
005ED031                    FUNC_LoggerEntry__Patch endp
```

I will clarify that function a bit; it looks odd if you don't know assembler that well.

We know from the previous screenshot that EAX is used to pass the pointer to the MemoryTransfer0C object, so the memory size and memory block (packet) is placed into respectively ECX and EDX (fastcall at work again).

Then ARG_EIPofCaller_FarAway is put into EAX. This EIP is **not** the address of the FUNC_MemoryTransfer_Write. It is the EIP of where FUNC_MemoryTransfer will return to. That EIP will tell us whether it is the server code that is calling the write function or whether it is the client code that is calling. This is important so the logger knows it should record Server->Client or Client->Server. You cannot code ARG_EIPofCaller_FarAway in C without the help of extra variables or assembler. This is the power of assembler at its best because we have direct access to the stack.

GLOBAL_LogFunction is a pointer to the log function (stored in memory). The idea is: the first time the function is called "LOGFILE" is looked up in the environment strings, if not found we will replace GLOBAL_LogFunction with a call to a "nullsub". If found we will replace GLOBAL_LogFunction with a call to the log function. That way we don't have to check every time whether or not the log file has been opened. It's a simply but effective speed optimization technique.

THE LOG FILE INITIALIZATION

By default, GLOBAL_LogFunction points to FUNC_LoggerInit__Patch:

```
UVA_DATA:009AAC60 37 D0 5E 00          GLOBAL_LogFunction dd offset FUNC_LoggerInit__Patch
UVA_DATA:009AAC60                                                    ; DATA XREF: FUNC_LoggerEntry__Patch+9↑r
UVA_DATA:009AAC60                                                    ; FUNC_LoggerInit__Patch:LOCAL_Return↑w
UVA_DATA:009AAC64                      ; FILE *GLOBAL_LogHandle
UVA_DATA:009AAC64 00 00 00 00          GLOBAL_LogHandle dd 0         ; DATA XREF: FUNC_LoggerInit__Patch+20↑w
UVA_DATA:009AAC64                                                    ; FUNC_LoggerLogPacket__Patch:LOCAL_LogDirectionOK↑r
UVA_DATA:009AAC68 20 20 20 20 20 20 20+a__LogText1 db '      0  1  2  3  4  5  6  7   8  9  A  B  C  D  E  F',0
UVA_DATA:009AAC68 20 30 20 20 31 20 20+                              ; DATA XREF: FUNC_LoggerLogPacket__Patch+60↑o
UVA_DATA:009AACA0 20 20 20 20 20 20 20+a__LogText2 db '     -- -- -- -- -- -- -- --  -- -- -- -- -- -- -- --',0
UVA_DATA:009AACA0 2D 2D 20 2D 2D 20 2D+                              ; DATA XREF: FUNC_LoggerLogPacket__Patch+6C↑o
```

This is the actual function:

```
005ED037                      FUNC_LoggerInit__Patch proc near     ; CODE XREF: FUNC_LoggerEntry__Patch+9↑p
005ED037                                                           ; DATA XREF: UVA_DATA:GLOBAL_LogFunction↓o
005ED037
005ED037                      EIP_Caller= dword ptr  20h
005ED037
005ED037 60                   pusha
005ED038 89 E5                mov     ebp, esp
005ED03A 68 38 E2 4E 00       push    offset a__LOGFILE            ; "LOGFILE"
005ED03F BB 00 7A 4E 00       mov     ebx, offset nullsub_1
005ED044 E8 07 D4 EF FF       call    _getenv
005ED049 6A 61                push    'a'
005ED04B 91                   xchg    eax, ecx
005ED04C 54                   push    esp                          ; Mode
005ED04D E3 5D                jecxz   short LOCAL_Return
005ED04F 51                   push    ecx                          ; Filename
005ED050 E8 4B CB EF FF       call    _fopen
005ED055 09 C0                or      eax, eax
005ED057 A3 64 AC 9A 00       mov     ds:GLOBAL_LogHandle, eax
005ED05C 74 4E                jz      short LOCAL_Return
005ED05E 83 EC 20             sub     esp, 20h
005ED061 97                   xchg    eax, edi
005ED062 89 E3                mov     ebx, esp
005ED064 6A 00                push    0
005ED066 54                   push    esp
005ED067 6A 05                push    5
005ED069 E8 62 28 F0 FF       call    _setlocale
005ED06E 6A 00                push    0                            ; Time
005ED070 E8 1B DD FE FF       call    _time
005ED075 50                   push    eax
005ED076 54                   push    esp                          ; Time
005ED077 E8 B4 EB EF FF       call    _localtime
005ED07C 68 25 63 00 00       push    'c%'
005ED081 89 E1                mov     ecx, esp
005ED083 50                   push    eax                          ; Tm
005ED084 51                   push    ecx                          ; Format
005ED085 6A 20                push    20h ; ' '                    ; SizeInBytes
005ED087 53                   push    ebx                          ; Buf
005ED088 E8 03 E0 EF FF       call    _strftime
005ED08D 53                   push    ebx
005ED08E 68 68 5F 60 00       push    offset a_LoggingStartedAt    ; "\r\n\r\n\r\n>>>>>>>>>> Logging started at %s "...
005ED093 57                   push    edi                          ; File
005ED094 E8 07 CD EF FF       call    _fprintf
005ED099 6A 43                push    67
005ED09B 54                   push    esp
005ED09C 6A 05                push    5
005ED09E E8 2D 28 F0 FF       call    _setlocale
005ED0A3 BB B6 D0 5E 00       mov     ebx, offset FUNC_LoggerLogPacket__Patch
005ED0A8 83 6D 20 06          sub     [ebp+EIP_Caller], 6
005ED0AC
005ED0AC                      LOCAL_Return:                        ; CODE XREF: FUNC_LoggerInit__Patch+16↑j
005ED0AC                                                           ; FUNC_LoggerInit__Patch+25↑j
005ED0AC 89 1D 60 AC 9A 00    mov     ds:GLOBAL_LogFunction, ebx
005ED0B2 89 EC                mov     esp, ebp
005ED0B4 61                   popa
005ED0B5 C3                   retn
005ED0B5                      FUNC_LoggerInit__Patch endp
005ED0B5
```

Notable things going on are:

1) EBX points to either “nullsub” or “FUNC_LoggerPacket_Patch” and is placed into GLOBAL_LogFunction at the end
2) setlocale(LC_TIME, “”) is called, this makes the C API us your computers time settings
3) strftime is used to convert the current time to a string
4) setlocale(LC_TIME, “C”) is called to restore the default C API settings (to minimize interference with the uodemo (if time functions are used that is))
5) “SUB [ebp+EIP_Caller], 6” will re-execute “CALL GLOBAL_LogFunction”

THE LOGGING

This is the first part of the actual log function. Remember GLOBAL_LogHandle is not checked against NULL because this function can only be called when it has been set.

```
005ED0B6                      FUNC_LoggerLogPacket__Patch proc near   ; DATA XREF: FUNC_LoggerInit__Patch+6C↑o
005ED0B6
005ED0B6                      var_E4= dword ptr -0E4h
005ED0B6                      var_DA= dword ptr -0DAh
005ED0B6                      var_78= byte ptr -78h
005ED0B6                      Dest= byte ptr -38h
005ED0B6                      SystemTime= _SYSTEMTIME ptr -32h
005ED0B6                      var_1C= byte ptr -1Ch
005ED0B6                      arg_8= dword ptr  0Ch
005ED0B6                      arg_10= dword ptr  14h
005ED0B6                      arg_14= dword ptr  18h
005ED0B6                      arg_18= dword ptr  1Ch
005ED0B6
005ED0B6 09 C9                or      ecx, ecx
005ED0B8 75 01                jnz     short LOCAL_Continue
005ED0BA C3                   retn
005ED0BB                      ; ---------------------------------------------------------------------------
005ED0BB
005ED0BB                      LOCAL_Continue:                         ; CODE XREF: FUNC_LoggerLogPacket__Patch+2↑j
005ED0BB 60                   pusha
005ED0BC 89 E5                mov     ebp, esp
005ED0BE 83 EC 78             sub     esp, 78h
005ED0C1 BF F9 5F 60 00       mov     edi, offset a__Server           ; "Server"
005ED0C6 81 7D 1C E3 3F 51 00 cmp     [ebp+arg_18], offset loc_513FE3
005ED0CD BE F2 5F 60 00       mov     esi, offset a__Client           ; "Client"
005ED0D2 75 02                jnz     short LOCAL_LogDirectionOK
005ED0D4 87 F7                xchg    esi, edi
005ED0D6
005ED0D6                      LOCAL_LogDirectionOK:                   ; CODE XREF: FUNC_LoggerLogPacket__Patch+1C↑j
005ED0D6 A1 64 AC 9A 00       mov     eax, ds:GLOBAL_LogHandle
005ED0DB 8D 4D CE             lea     ecx, [ebp+SystemTime]
005ED0DE 93                   xchg    eax, ebx
005ED0DF 51                   push    ecx                             ; lpSystemTime
005ED0E0 FF 15 A8 55 9A 00    call    ds:GetLocalTime
005ED0E6 8B 45 14             mov     eax, [ebp+arg_10]
005ED0E9 FF 75 18             push    [ebp+arg_14]
005ED0EC 0F B6 10             movzx   edx, byte ptr [eax]
005ED0EF 93                   xchg    eax, ebx
005ED0F0 52                   push    edx
005ED0F1 0F B7 4D DC          movzx   ecx, [ebp+SystemTime.wMilliseconds]
005ED0F5 56                   push    esi
005ED0F6 57                   push    edi
005ED0F7 51                   push    ecx
005ED0F8 97                   xchg    eax, edi
005ED0F9 0F B7 4D DA          movzx   ecx, [ebp+SystemTime.wSecond]
005ED0FD 0F B7 55 D6          movzx   edx, [ebp+SystemTime.wHour]
005ED101 51                   push    ecx
005ED102 FF 75 D8             push    dword ptr [ebp+SystemTime.wMinute]
005ED105 52                   push    edx
005ED106 68 A0 5F 60 00       push    offset a__LogPacketHeader       ; Format
005ED10B 57                   push    edi                             ; File
005ED10C E8 8F CC EF FF       call    _fprintf
005ED111 BE D5 5F 60 00       mov     esi, offset a__S__              ; Format
005ED116 68 68 AC 9A 00       push    offset a__LogText1              ; "      0   1   2   3   4   5   6   7    8   9  "...
005ED11B 56                   push    esi                             ; Format
005ED11C 57                   push    edi                             ; File
005ED11D E8 7E CC EF FF       call    _fprintf                        ; Format
005ED122 68 A0 AC 9A 00       push    offset a__LogText2              ; "     -- -- -- -- -- -- -- --  -- -- -"...
005ED127 56                   push    esi                             ; Format
005ED128 57                   push    edi                             ; File
005ED129 E8 72 CC EF FF       call    _fprintf
005ED12E 31 C0                xor     eax, eax
005ED130 89 45 0C             mov     [ebp+arg_8], eax
005ED133
005ED133                      LOCAL_MainLoop:                         ; CODE XREF: FUNC_LoggerLogPacket__Patch+12F↓j
```

In the first stage, EDI and ESI are used to point a string either “Server” or “Client”. Depending on the EAX register (ARG_EIPofCaller_FarAway) they are swapped or not.

Instead of the C API “time(NULL)”, this time the Windows API “GetLocalTime” is used to obtain the current time. Why? Because GetLocalTime returns the current millisecond whereas the C API doesn’t return this value at all. In a later stage, EDI is used to contain the log file handle (GLOBAL_LogHandle) and ESI points to a__S__ (which is “%s\r\n”).

This big screenshot shows the second part of the logger function:

```
005ED133                          LOCAL_MainLoop:                  ; CODE XREF: FUNC_LoggerLogPacket__Patch+12F↓j
005ED133 56                       push    esi
005ED134 57                       push    edi
005ED135 6A 08                    push    8                        ; Dest
005ED137 8B 7D 18                 mov     edi, [ebp+arg_14]
005ED13A 58                       pop     eax
005ED13B 50                       push    eax
005ED13C 39 C7                    cmp     edi, eax
005ED13E 8D 75 C8                 lea     esi, [ebp+Dest]
005ED141 76 01                    jbe     short LOCAL_Ready1
005ED143 97                       xchg    eax, edi
005ED144
005ED144                          LOCAL_Ready1:                    ; CODE XREF: FUNC_LoggerLogPacket__Patch+8B↑j
005ED144 53                       push    ebx
005ED145
005ED145                          LOCAL_Loop1:                     ; CODE XREF: FUNC_LoggerLogPacket__Patch+A6↓j
005ED145 0F B6 03                 movzx   eax, byte ptr [ebx]
005ED148 50                       push    eax
005ED149 68 EC 5F 60 00           push    offset a__X__            ; "%02X "
005ED14E 56                       push    esi                      ; Dest
005ED14F E8 2C B6 EF FF           call    _sprintf
005ED154 83 C4 0C                 add     esp, 0Ch
005ED157 43                       inc     ebx
005ED158 83 C6 03                 add     esi, 3
005ED15B 4F                       dec     edi
005ED15C 75 E7                    jnz     short LOCAL_Loop1
005ED15E 5B                       pop     ebx
005ED15F 59                       pop     ecx
005ED160 8D 75 E4                 lea     esi, [ebp+var_1C]
005ED163 8D 04 09                 lea     eax, [ecx+ecx]
005ED166 8B 7D 18                 mov     edi, [ebp+arg_14]
005ED169 50                       push    eax
005ED16A 39 C7                    cmp     edi, eax
005ED16C 88 26                    mov     [esi], ah
005ED16E 76 01                    jbe     short LOCAL_Ready2
005ED170 97                       xchg    eax, edi
005ED171
005ED171                          LOCAL_Ready2:                    ; CODE XREF: FUNC_LoggerLogPacket__Patch+B8↑j
005ED171 29 CF                    sub     edi, ecx
005ED173 76 1D                    jbe     short LOCAL_SkipLoop2
005ED175 53                       push    ebx
005ED176 01 CB                    add     ebx, ecx
005ED178
005ED178                          LOCAL_Loop2:                     ; CODE XREF: FUNC_LoggerLogPacket__Patch+D9↓j
005ED178 0F B6 03                 movzx   eax, byte ptr [ebx]
005ED17B 50                       push    eax
005ED17C 68 EC 5F 60 00           push    offset a__X__            ; "%02X "
005ED181 56                       push    esi                      ; Dest
005ED182 E8 F9 B5 EF FF           call    _sprintf
005ED187 83 C4 0C                 add     esp, 0Ch
005ED18A 43                       inc     ebx
005ED18B 83 C6 03                 add     esi, 3
005ED18E 4F                       dec     edi
005ED18F 75 E7                    jnz     short LOCAL_Loop2
005ED191 5B                       pop     ebx
005ED192
005ED192                          LOCAL_SkipLoop2:                 ; CODE XREF: FUNC_LoggerLogPacket__Patch+BD↑j
005ED192 5E                       pop     esi
005ED193 5F                       pop     edi
005ED194 8D 45 E4                 lea     eax, [ebp+var_1C]
005ED197 8D 4D C8                 lea     ecx, [ebp+Dest]
005ED19A 50                       push    eax
005ED19B 51                       push    ecx
005ED19C 8D 45 88                 lea     eax, [ebp+var_78]
005ED19F FF 75 0C                 push    [ebp+arg_8]
005ED1A2 68 DA 5F 60 00           push    offset a__LogPacketData  ; "%04X   %-25s%-26s"
005ED1A7 50                       push    eax                      ; Dest
005ED1A8 E8 D3 B5 EF FF           call    _sprintf
005ED1AD 83 C4 14                 add     esp, 14h
005ED1B0 8D 54 05 88              lea     edx, [ebp+eax+var_78]
005ED1B4 8B 4D 18                 mov     ecx, [ebp+arg_14]
005ED1B7 39 F1                    cmp     ecx, esi
005ED1B9 76 02                    jbe     short LOCAL_Ready3andLoop3
005ED1BB 89 F1                    mov     ecx, esi
005ED1BD
005ED1BD                          LOCAL_Ready3andLoop3:            ; CODE XREF: FUNC_LoggerLogPacket__Patch+103↑j
005ED1BD                                                           ; FUNC_LoggerLogPacket__Patch+112↓j
005ED1BD 8A 03                    mov     al, [ebx]
005ED1BF E8 31 01 F0 FF           call    FUNC_LoggerFixCharacter__Patch
005ED1C4 88 02                    mov     [edx], al
005ED1C6 43                       inc     ebx
005ED1C7 42                       inc     edx                      ; File
005ED1C8 E2 F3                    loop    LOCAL_Ready3andLoop3
005ED1CA 88 0A                    mov     [edx], cl
005ED1CC 8D 45 88                 lea     eax, [ebp+var_78]
005ED1CF 50                       push    eax
005ED1D0 68 D5 5F 60 00           push    offset a__S__            ; "%s\r\n"
005ED1D5 57                       push    edi                      ; File
005ED1D6 E8 C5 CB EF FF           call    _fprintf
005ED1DB 83 C4 0C                 add     esp, 0Ch
005ED1DE 01 75 0C                 add     [ebp+arg_8], esi
005ED1E1 29 75 18                 sub     [ebp+arg_14], esi
005ED1E4 5E                       pop     esi
005ED1E5 0F 87 48 FF FF FF        ja      LOCAL_MainLoop           ; Format
```

I will not explain the function completely as it is based on the C code which you can see later in this document.

Finally, the third and final part of the logger function:

```
005ED1EB 8D 46 02          lea     eax, [esi+2]          ; Format
005ED1EE 50                push    eax
005ED1EF 56                push    esi                   ; Format
005ED1F0 57                push    edi                   ; File
005ED1F1 E8 AA CB EF FF    call    _fprintf
005ED1F6 57                push    edi                   ; File
005ED1F7 E8 54 AD EF FF    call    _fflush
005ED1FC 89 EC             mov     esp, ebp
005ED1FE 61                popa
005ED1FF C3                retn
005ED1FF                   FUNC_LoggerLogPacket__Patch endp
```

Nothing much here, it will write a double “\r\n” and flush the file.

At this stage ESI points to a__S__ (which is “%s\r\n”), thus EAX = ESI + 2 = “\r\n“. This is equal to “printf(LogHandle, “%s\r\n”, “\r\n”);”.

THE STRINGS

Some of the strings I needed to add for this project were really long and I had to look really well where to add them. Later I will tell you how I did this.

For now, I’ll just show you the strings added:

```
00605F68                         ; char a__LoggingStartedAt[]
00605F68 0D 0A 0D 0A 0D 0A 3E+a__LoggingStartedAt db 0Dh,0Ah        ; DATA XREF: FUNC_LoggerInit__Patch+57↑o
00605F68 3E 3E 3E 3E 3E 3E 3E+db 0Dh,0Ah
00605F68 3E 3E 20 4C 6F 67 67+db 0Dh,0Ah
00605F68 69 6E 67 20 73 74 61+db '>>>>>>>>>> Logging started at %s <<<<<<<<<<',0Dh,0Ah
00605F68 72 74 65 64 20 61 74+db 0Dh,0Ah
00605F68 20 25 73 20 3C 3C 3C+db 0Dh,0Ah,0
00605FA0                         ; char a__LogPacketHeader[]
00605FA0 25 30 32 75 3A 25 30+a__LogPacketHeader db '%02u:%02hu:%02u.%04u: %s -> %s 0x%02X (Length: %u)',0Dh,0Ah
00605FA0 32 68 75 3A 25 30 32+                                      ; DATA XREF: FUNC_LoggerLogPacket__Patch+50↑o
00605FD4 00                      a__Unused__QuestionMark db    0
00605FD5                         ; char a__S__[]
00605FD5 25 73 0D 0A 00          a__S__  db '%s',0Dh,0Ah,0          ; DATA XREF: FUNC_LoggerLogPacket__Patch+5B↑o
00605FD5                                                            ; FUNC_LoggerLogPacket__Patch+11A↑o
00605FDA                         ; char a__LogPacketData[]
00605FDA 25 30 34 58 20 20 20+a__LogPacketData db '%04X   %-25s%-26s',0
00605FDA 25 2D 32 35 73 25 2D+                                      ; DATA XREF: FUNC_LoggerLogPacket__Patch+EC↑o
00605FEC                         ; char a__X__[]
00605FEC 25 30 32 58 20 00       a__X__  db '%02X ',0               ; DATA XREF: FUNC_LoggerLogPacket__Patch+93↑o
00605FEC                                                            ; FUNC_LoggerLogPacket__Patch+C6↑o
00605FF2 43 6C 69 65 6E 74 00 a__Client db 'Client',0               ; DATA XREF: FUNC_LoggerLogPacket__Patch+17↑o
00605FF9 53 65 72 76 65 72 00 a__Server db 'Server',0               ; DATA XREF: FUNC_LoggerLogPacket__Patch+B↑o
```

FUNC_LoggerFixCharacter__Patch

The main loop contained code to replace non-standard ASCII strings with a dot, same as Razor is doing. However, I needed more bytes so I had to place that code elsewhere and I replaced it with a single call.

Before:

```
89 F1                 mov     ecx, esi

                      loc_5ED1AA:                     ; CODE XREF: .text:005ED1BA↓j
8A 03                 mov     al, [ebx]

                      loc_5ED1AC:                     ; CODE XREF: .text:005ED1A6↑j
3C 20                 cmp     al, 20h ; ' '
72 04                 jb      short loc_5ED1B4
3C 80                 cmp     al, 80h ; 'Ç'
72 02                 jb      short loc_5ED1B6

                      loc_5ED1B4:                     ; CODE XREF: .text:005ED1AE↑j
B0 2E                 mov     al, 2Eh ; '.'

                      loc_5ED1B6:                     ; CODE XREF: .text:005ED1B2↑j
43                    inc     ebx
88 02                 mov     [edx], al
42                    inc     edx
E2 EE                 loop    loc_5ED1AA
88 0A                 mov     [edx], cl
```

After:

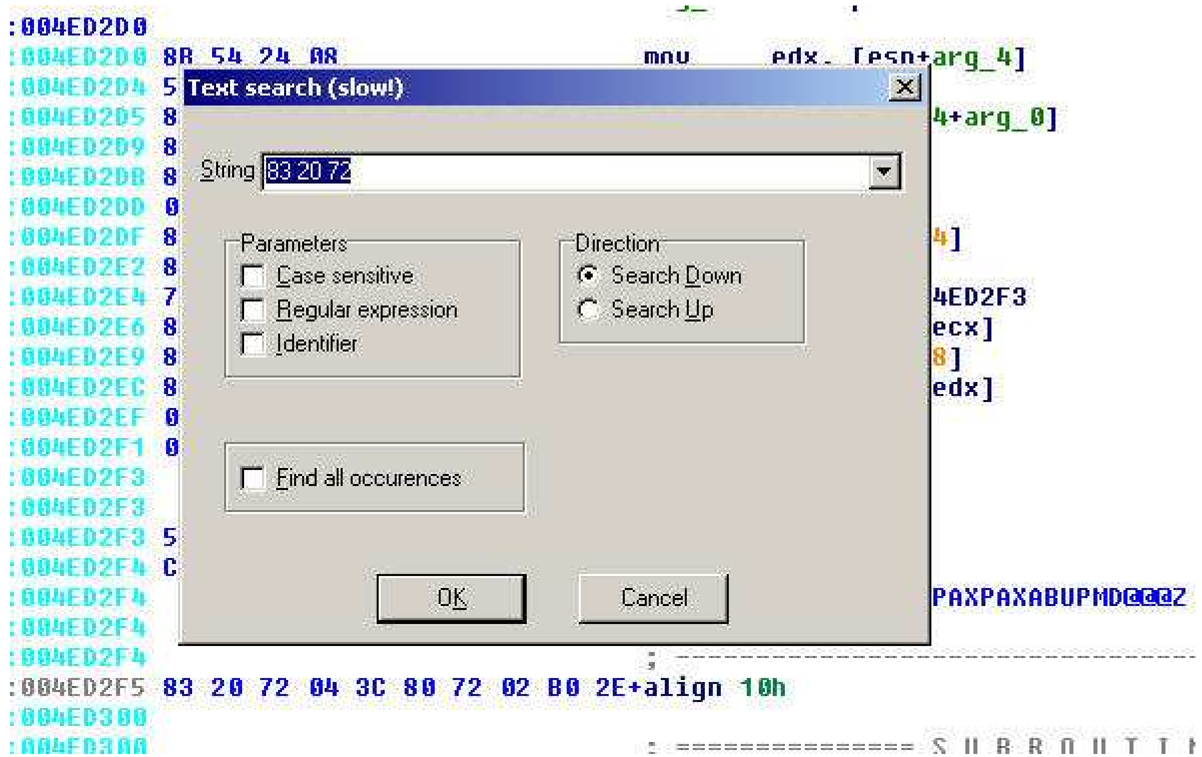
```
89 F1                 mov     ecx, esi

                      LOCAL_Ready3andLoop3:

8A 03                 mov     al, [ebx]
E8 31 01 F0 FF        call    FUNC_LoggerFixCharacter__Patch
88 02                 mov     [edx], al
43                    inc     ebx
42                    inc     edx
E2 F3                 loop    LOCAL_Ready3andLoop3
88 0A                 mov     [edx], cl
```

I searched the EXE for empty space to place the code sequence “3c 20 72 04 3c 80 72 02 b0 2e c3”. I used the search string “c3 90 90 90 90 90 90 90 90 90 90 90 55”. This is a long NOP sequence (alignment) between a RET and a PUSH.

After editing the EXE I used IDA Pro’s text search function to locate the modified code (I had no clue where exactly I placed the function):



After removing the alignment directive and documenting:

```
004ED2F5                   FUNC_LoggerFixCharacter proc near
004ED2F5 3C 20             cmp     al, 20h ; ' '
004ED2F7 72 04             jb      short LOCAL_Change
004ED2F9 3C 80             cmp     al, 80h ; 'Ç'
004ED2FB 72 02             jb      short LOCAL_ChangeDone
004ED2FD
004ED2FD                   LOCAL_Change:
004ED2FD B0 2E             mov     al, 2Eh ; '.'
004ED2FF
004ED2FF                   LOCAL_ChangeDone:
004ED2FF C3                retn
004ED2FF                   FUNC_LoggerFixCharacter endp
004ED2FF
```

Looks better, right?

THE C TEST CODE

```
#define _USE_32BIT_TIME_T
#include <windows.h>
#include <stdio.h>
#include <locale.h>
#include <time.h>

#pragma warning( disable : 4996 )

static FILE *logfile = NULL;

enum DIRECTION
{
  RazorToServer, ClientToServer, ServerToClient
};

void LogPacket(DIRECTION PacketDirection, size_t PacketLength, const BYTE *PacketData)
{
  const char *LogText1 = "        0  1  2  3  4  5  6  7   8  9  A  B  C  D  E  F";
  const char *LogText2 = "       -- -- -- -- -- -- -- --  -- -- -- -- -- -- -- --";

  char LogLine[100];
  char Log8_1[8 * 3 + 1], Log8_2[8 * 3 + 1];

  // We must have an open logfile
  if(logfile == NULL)
    return;

  // Do not log empty packets
  if(PacketLength == 0)
    return;

  // Part 1
  {
    // Get the current time as string
    time_t t = time(NULL);
    GetLocalTime((LPSYSTEMTIME) LogLine); // (use LogLine also for SYSTEMTIME)

    strftime(LogLine, sizeof(LogLine), "%X", localtime(&t));

    // Verify the packet direction
    char *LogDirection1, *LogDirection2;
    switch(PacketDirection)
    {
      case ClientToServer: LogDirection1 = "Client";
                           LogDirection2 = "Server";
                           break;
      case ServerToClient: LogDirection1 = "Server";
                           LogDirection2 = "Client";
                           break;
      default: return;
    }

    fprintf(logfile, "%s.%04u: %s -> %s 0x%02X (Length: %u)\n%s\n%s\n", LogLine,
((LPSYSTEMTIME) LogLine)->wMilliseconds, LogDirection1, LogDirection2, PacketData[0],
PacketLength, LogText1, LogText2);
  }

  // Part 2
  unsigned int per16counter = 0;
  do
  {
    register unsigned int Log8len, MaxCounter;

    Log8len = 0;
    MaxCounter = PacketLength < 8 ? PacketLength : 8;
    for(register unsigned int Counter = 0; Counter < MaxCounter; Counter ++)
    {
      sprintf(Log8_1 + Log8len, "%02X ", PacketData[Counter]); // TEST
      Log8len += 3;
    }
```

```
    if(PacketLength > 8)
    {
      Log8len = 0;
      MaxCounter = PacketLength < 16 ? PacketLength - 8 : 8;
      for(register unsigned int Counter = 0; Counter < MaxCounter; Counter ++)
      {
        sprintf(Log8_2 + Log8len, "%02X ", PacketData[Counter + 8]); // TEST
        Log8len += 3;
      }
    }
    else
      Log8_2[0] = '\0';

    // sprintf returns the number of characters printed
    // KNOW YOUR API's AND RULE THE BINARY WORLD
    rnsigned int len = sprintf(LogLine, "%04X   %-25s%-26s", per16counter, Log8_1, Log8_2);

    MaxCounter = PacketLength < 16 ? PacketLength : 16;
    for(Log8len = 0; Log8len < MaxCounter; Log8len ++)
      if(PacketData[Log8len] < 0x20 || PacketData[Log8len] >= 0x80)
        LogLine[len + Log8len] = '.';
      else
        LogLine[len + Log8len] = PacketData[Log8len];
    LogLine[len + Log8len] = '\0';

    fprintf(logfile, "%s\n", LogLine);

    per16counter += 16;
    PacketData += 16;
    PacketLength -= 16;
  }
  while((int) PacketLength > 0);

  // Part 3
  {
    fprintf(logfile, "\n\n");
    fflush(logfile);
  }
}

void OpenLog(void)
{
  // Open the log file
  register char *envstring = getenv("LOGFILE");
  if(envstring != NULL)
    logfile = fopen(envstring, "a");

  // Write log text
  if(logfile != NULL)
  {
    char LogTime[25];

    // Get the current time as string
    time_t t = time(NULL);
    struct tm *tm = localtime(&t);

    setlocale(LC_TIME, "");
    strftime(LogTime, sizeof(LogTime), "%c", tm);
    setlocale(LC_TIME, "C");

    fprintf(logfile, "\n\n\n>>>>>>>>>> Logging started %s <<<<<<<<<<\n\n\n", LogTime);
  }
}
```

ABOUT OPTIMAZATION TECHNIQUES

I had lot of problems with fitting the code inside the binary. So I had to relook how I implemented to log function and I rewrote it a few times before all the bytes I needed fitted in.

Remember, I optimized for size, not for speed!

Let's take a look at some techniques I used:

1) Replacing "MOV reg32, 0xXXXXXXXX" with "PUSH 0xXX / POP reg32"

   For example, "MOV EAX, 8" is assembled to "B8 08 00 00 00" (5 bytes)
   Now, "PUSH 8 / POP EAX" becomes "6A 08 58" (3 bytes) (but slower!)

2) Not cleaning up the stack after every call

   This is actually a technique also used by modern compilers, because it's faster and uses less code bytes. I only clean-up the stack inside the MainLoop because inside there the stack is actually important and used with care.

3) locale(LC_TIME, "C")

   By default, this becomes:

```
…
PUSH offset a__C          68 XX XX XX XX
PUSH 5 ; LC_TIME          6A 05
CALL locale               E8 XX XX XX XX
ADD ESP, 4                83 C4 04
…
a__C DB 'C', 0            43 00
→ 5+2+5+3+2 = 17 bytes
```

   I implemented this with:

```
…
PUSH 'C'                  6A 43
PUSH ESP                  54
PUSH 5 ; LC_TIME          6A 05
CALL locale               E8 XX XX XX XX
…
→ 2+1+2+5 = 10 bytes
```

   The trick is that "C" is a string consisting of 1 byte and 1 0-terminator. If you push 'C' (43 hex) on the stack then the value is zero extended on the stack and the stack will actually contain "43 00 00 00". Then ESP is pushed because ESP points to the freshly created string on the stack.

The same trick is applied when calling “localtime(&t)”. Instead of placing the return-value of time(NULL) into a variable and then calling localtime with a reference to that variable, localtime is called directly after pushing EAX and pushing ESP (which points to the pushed EAX). I hope I could explain?

4) I also replaced comparisons against a constant with a comparison against a register, this takes one byte less in memory but you have to make sure the register contains the right constant (without adding extra code to put a constant into the register!).

5) CMP equals SUB

   This is something you should know, the CMP instruction is actually a SUB instruction but with that difference the target register isn’t changed. That’s why you are seeing Jxx instructions right after a SUB instruction.

```
mainloop: …
          CMP EAX, 16
          JBE endloop      ; Jump if Below or Equal
          SUB EAX, 16
          JMP mainloop
endloop:  …
```

   becomes:

```
mainloop: …
          SUB EAX, 16
          JA mainloop      ; Jump if Above (=JNBE) (Jump if Not Below or Equal)
endloop:  …
```

   NOTE: also the TEST instruction is actually an AND instruction (not used here)

6) Remember that the C API and Windows API preserve the EBX, EDI, ESI and EBP registers. Make use of that fact! Never ever trust the contents of ECX or EDX after calling an API. Know that most functions put their return values into EAX and sometimes into the EDX:EAX pair.

Let's take a closer look at the following code inside the main loop:

```
005ED15F 59                    pop     ecx
005ED160 8D 75 E4              lea     esi, [ebp+var_1C]
005ED163 8D 04 09              lea     eax, [ecx+ecx]
005ED166 8B 7D 18              mov     edi, [ebp+arg_14]
005ED169 50                    push    eax
005ED16A 39 C7                 cmp     edi, eax
005ED16C 88 26                 mov     [esi], ah
005ED16E 76 01                 jbe     short LOCAL_Ready2
005ED170 97                    xchg    eax, edi
005ED171
005ED171                       LOCAL_Ready2:
005ED171 29 CF                 sub     edi, ecx
005ED173 76 1D                 jbe     short LOCAL_SkipLoop2
005ED175 53                    push    ebx
005ED176 01 CB                 add     ebx, ecx
005ED178
005ED178                       LOCAL_Loop2:
```

If you are looking at that code to understand it, I think you're in hell.

I will help you.

"POP ECX" will put 8 into ECX. It is a constant I pushed on the stack earlier, at address 005ED13B to be exact. ESI points to a string on the stack (Log8_2 in the C Version). EAX is then calculated by adding ECX to itself. EAX = ECX + ECX = 8 + 8 = 16. I could use "MOV EAX, 16" (5 bytes) or the "PUSH / POP" trick (also 3 bytes), but I decided to use the LEA version. Then EAX (16) is pushed on the stack for later use, it will be popped into ESI at address 005ED192.

So, we know that ECX is 8 and EAX is 16. Then EDI ([EBP+ arg_14] aka PacketSize) is compared against EAX (16). We know that EAX is 16, so AL is 16 and AH is 00. Thus "MOV [ESI], AH" equals "MOV BYTE PTR [ESI], 0" thus meaning "*Log8_2 = 0;" or "Log8_2[0] = 0;". The "XCHG EAX, EDI" will put the value of 16 into EDI. After this function, when we reach LOCAL_Ready2, the EAX register is no longer used. "SUB EDI, ECX" equals "SUB EDI, 8", the loop will be skipped if EDI was below or equal to 8.

By the way, EBX is pointing to the packet data.

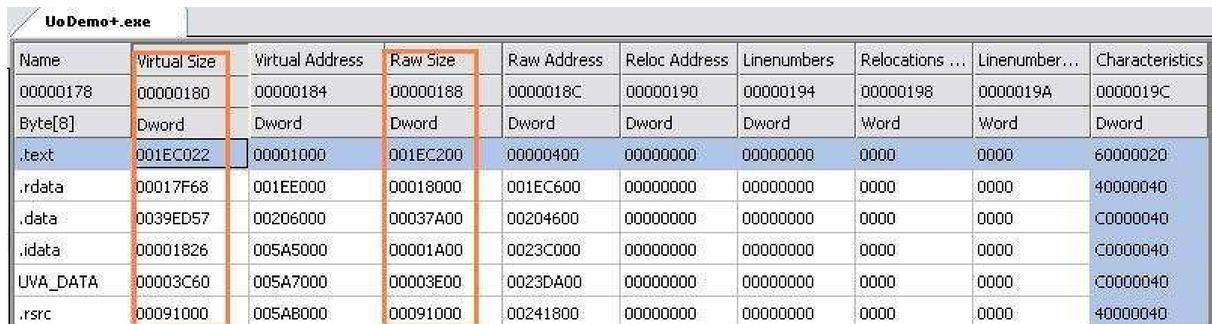
The readable (but binary longer) version of the code above is:

```
        MOV ESI, offset Log8_2
        MOV EDI, PacketSize
        CMP EDI, 16
        MOV BYTE PTR [ESI], 0
        JBE LOCAL_Ready2
        MOV EDI, 16
LOCAL_Ready2:
        CMP EDI, 8
        JBE LOCAL_SkipLoop2
        SUB EDI, 8
        PUSH EBX
        ADD EBX, 8
```

WHERE TO ADD THE CODE AND TEXT

Looking for empty space in an executable can be difficult but can also be easy if the executable is compiled by following the rules.

You have to open the EXE with the Explorer Suite and view the section headers.



UoDemo+.exe

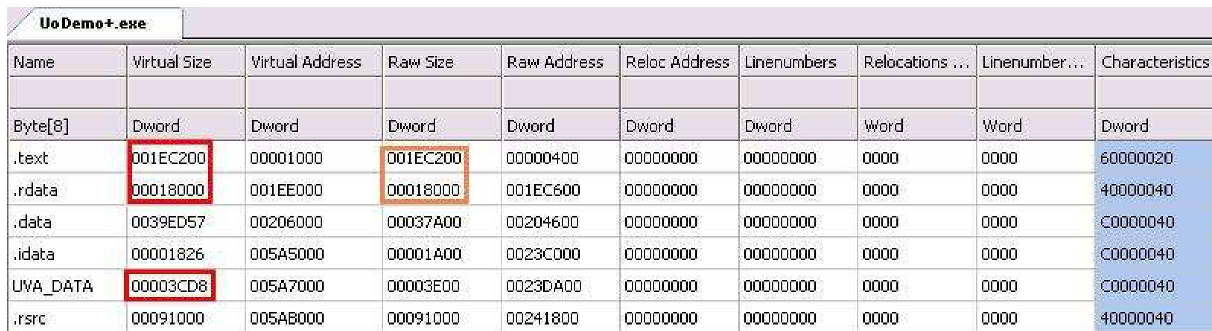
Name	Virtual Size	Virtual Address	Raw Size	Raw Address	Reloc Address	Linenumbers	Relocations ...	Linenumber...	Characteristics
00000178	00000180	00000184	00000188	0000018C	00000190	00000194	00000198	0000019A	0000019C
Byte[8]	Dword	Dword	Dword	Dword	Dword	Dword	Word	Word	Dword
.text	001EC022	00001000	001EC200	00000400	00000000	00000000	0000	0000	60000020
.rdata	00017F68	001EE000	00018000	001EC600	00000000	00000000	0000	0000	40000040
.data	0039ED57	00206000	00037A00	00204600	00000000	00000000	0000	0000	C0000040
.idata	00001826	005A5000	00001A00	0023C000	00000000	00000000	0000	0000	C0000040
UVA_DATA	00003C60	005A7000	00003E00	0023DA00	00000000	00000000	0000	0000	C0000040
.rsrc	00091000	005AB000	00091000	00241800	00000000	00000000	0000	0000	40000040

The Raw Size is the number of bytes a certain section takes inside the file. The Virtual Size is the number of bytes in memory. If the Virtual Size is lower than the Raw Size, then it means there is unused space (if the compiler is following the rules!).

So actually, you can see that have quite some unused space inside the UoDemo executable!

After inserting your code inside that space, do not forget to edit the section headers so it will contain accurate values, which is important if you want to add code later again.

This is a screenshot of the modified section headers:



UoDemo+.exe

Name	Virtual Size	Virtual Address	Raw Size	Raw Address	Reloc Address	Linenumbers	Relocations ...	Linenumber...	Characteristics
Byte[8]	Dword	Dword	Dword	Dword	Dword	Dword	Word	Word	Dword
.text	001EC200	00001000	001EC200	00000400	00000000	00000000	0000	0000	60000020
.rdata	00018000	001EE000	00018000	001EC600	00000000	00000000	0000	0000	40000040
.data	0039ED57	00206000	00037A00	00204600	00000000	00000000	0000	0000	C0000040
.idata	00001826	005A5000	00001A00	0023C000	00000000	00000000	0000	0000	C0000040
UVA_DATA	00003CD8	005A7000	00003E00	0023DA00	00000000	00000000	0000	0000	C0000040
.rsrc	00091000	005AB000	00091000	00241800	00000000	00000000	0000	0000	40000040

The red squares show the modified virtual sizes.

Note that the ".text" and ".rdata" are now completely full and can no longer grow! If we want to add code in a future patch we either have to either remove code or insert an extra section!

BUG FOUND

Later when testing this code I discovered that I missed something in relation with thread-safety. The bug itself (not deadly but annoying) is explained and solved in Part 3 of "The Packet Communication" series.