Exploring the NFC Attack Surface

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Introduction

Near Field Communication (NFC) has been used in mobile devices in some countries for a while, and is now emerging on mobile devices in use in the United States. This technology allows NFC-enabled devices to communicate with each other within close range, typically a few centimeters. NFC is being deployed and adopted as a way to make payments, using a mobile device to communicate credit card information to an NFC enabled terminal. It is a new, cool, technology, but as with the introduction of any new technology, the question that must be asked is what kind of impact the inclusion of this new functionality will have on the attack surface of mobile devices.

In this paper we explore this question by introducing NFC and its associated protocols. Next, we describe how to fuzz the NFC protocol stack for two devices as well as provide the results of our testing. Then we see for these devices what software is built on top of the NFC stack. It turns out that through NFC, using technologies like Android Beam or NDEF content sharing, one can force some phones to parse images, videos, contacts, office documents, and even open up web pages in the browser, all without user interaction.

In some cases, it is even possible to completely take control of the phone via NFC, including stealing photos, contacts, even sending text messages and making phone calls. The next time you present your phone to pay for your cab, be aware you might have just gotten owned.

NFC protocols

Understanding the NFC attack surface first requires some understanding of NFC and the underlying protocols on which it is based. Figure 1, below, shows a diagram of most of the associated protocols used for NFC transactions.

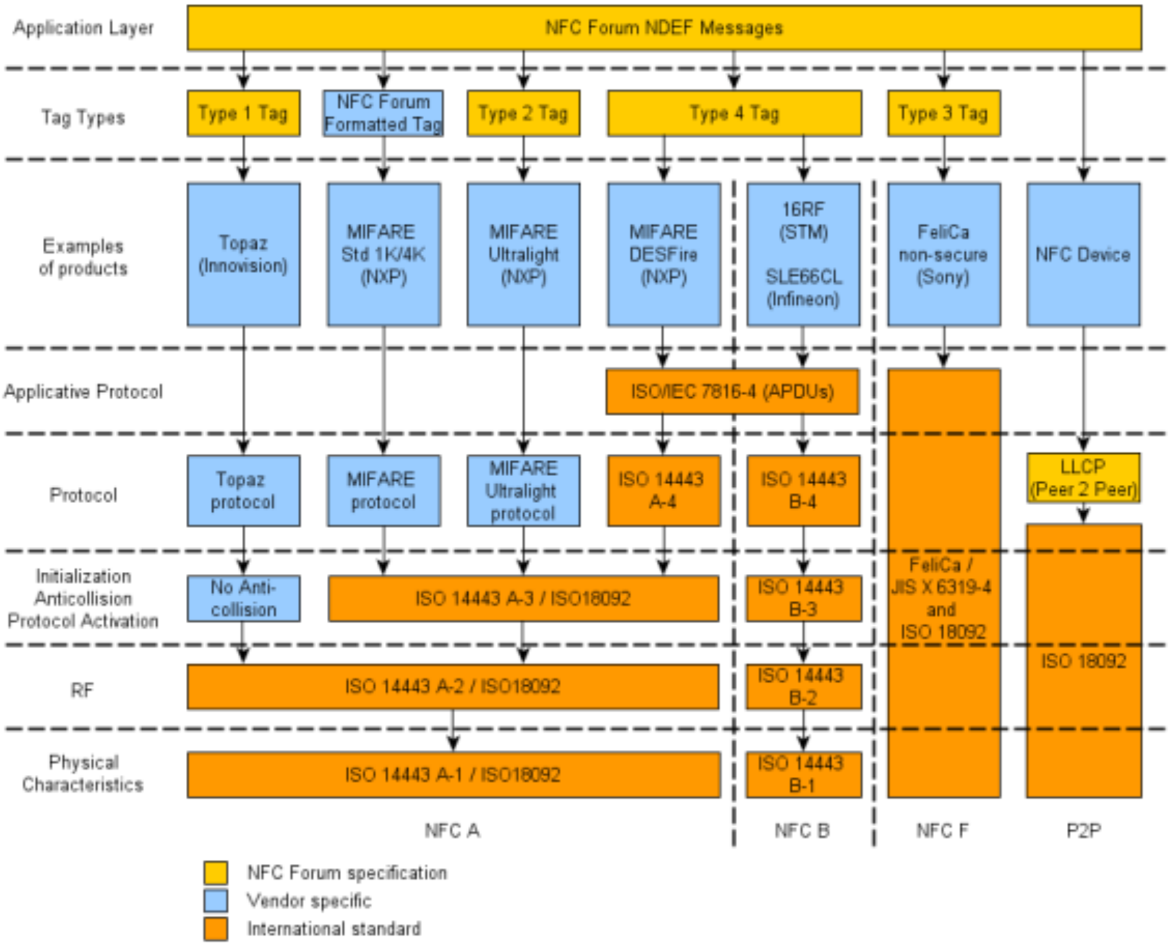


Figure 1: Relevant specifications for NFC

At its most basic level, NFC is a set of communication protocols based on radio-frequency identification (RFID) standards, including ISO 14443. NFC uses the frequency 13.56 MHz and its operating range is said to be between 3-10 centimeters, although in practice it is typically near the lower end of that range. We've observed the range of 2-3 centimeters in real world scenarios. NFC operates at low data rates, ranging from 106kbit/s to 424kbits/s.

There are two general ways NFC communication takes place: in the first, there is an initiator and a target. The initiator, for example a mobile device, actively generates a radio frequency (RF) field that can power the passive target, such as an NFC tag. The target tag answers by modulating the existing field provided by the initiator. This enables the tag to be constructed very simply, without a need for power or batteries. In this situation the initiator can read or sometimes write data to and from the tag. There are many types of tags and many protocols that can be used to interact with different types of tags, again, please see Figure 1.

The other mode of NFC communication is peer-to-peer (P2P). In order to do P2P, both devices need to be powered and generate their own RF fields.

Physical and RF layer

At the lowest level, communication takes place according to ISO 14443 A-2. There are different codings to transfer data. At 106 kbits/s, a modified Miller coding with 100% modulation is used. In other cases, Manchester coding is used with a modulation ratio of 10%. Figure 2 shows an FFT plot of captured NFC traffic using GNU Radio.

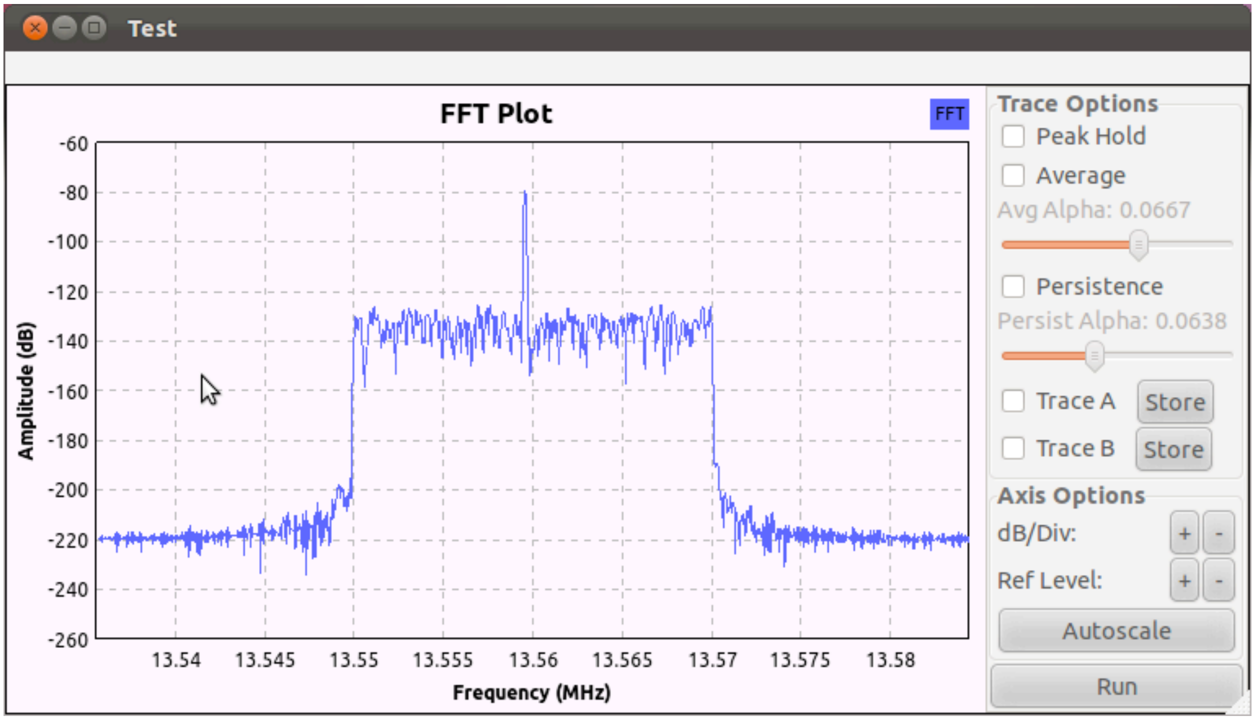


Figure 2: NFC traffic captured at 195k samples/second, decimated by 4, with low pass filter at 10k

The next Figure shows the waveform of some low-level data.

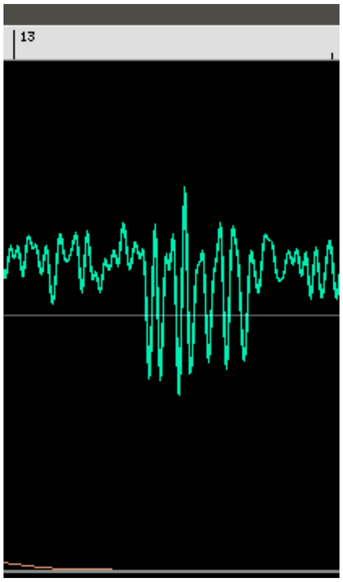


Figure 3: A waveform of the value "26"

From looking at the signal in Figure 3, above, which was taken between a Nexus S Android device and an NFC tag, one can deduce that the Nexus S transmits data at a rate of 106kbps using 100% ASK with Manchester encoding. With some effort, you can find the signal in Figure 3 corresponds to the byte "0x26" which is a SENS_REQ according to ISO 14443-3.

This layer is really too low for our purposes, for more information on this protocol layer, consult [1-3].

Initialization, Anti-Collision, and Protocol Activation layer

For some types of NFC communication, there is a phase whereas two NFC enabled devices become aware of each other and initialize their communications. There is very little data exchanged here, and for reasons discussed in the next section, we cannot easily fuzz this part of the protocol, so we skip any further details. For more information, please see [4].

Protocol layer

Lower levels are focused on physical aspects and starting communication. The protocol layer is the layer for actually transmitting the data intended to be sent or received with the communication. In general, the data can be anything, but a typical data payload will be described in the next section.

There are a variety of protocol layer protocols supported in most NFC devices. We'll briefly describe each of them.

Type 1 (Topaz)

Type 1 tags use a format sometimes called the Topaz protocol, see [5]. It uses a simple memory model which is either static for tags with memory size less than 120 bytes or dynamic for tags with larger memory. Bytes are read/written to the tag using commands such as RALL, READ, WRITE-E, WRITE-NE, RSEG, READ8, WRITE-E8, WRITE-N8.

MIFARE Classic

MIFARE classic tags are storage devices with simple security mechanisms for access control. They use an NXP proprietary security protocol for authentication and ciphering. This encryption was reverse engineered and broken in 2007 [6].

Type 2 (MIFARE UltraLight)

Type 2 tags [7] are similar to Type 1 tags. They have a static memory layout when they have less than 64 bytes available and a dynamic layout otherwise. The first 16 bytes of memory contain metadata like a serial number, access rights, and capability container. The rest is for the actual data. Data is accessed using READ and WRITE commands, see the section “Example data capture” for an example of a Type 2 transaction.

Type 3

As far as I can tell, there aren’t any tags that use Type 3 transactions, but if you care, check out [8].

Type 4 (DESFire)

Type 4 tags contain a simple file system composed of at least 2 files, the Capability Container (CC) file and the NDEF file. The commands include Select, ReadBinary, and UpdateBinary. At the most basic level, the device must read the CC file, which tells it information about the NDEF file which it can then select and read. The CC file is typically 15 bytes in size. See [9] for more details.

LLCP (P2P)

The previous protocol layer protocols have all had initiators and targets and the protocols are designed around the initiator being able to read/write to the target. Logical Link Control Protocol (LLCP) is different because it establishes communication between two peer devices. LLCP allow connections to be established and deactivated, data to be transferred at any time when the link is established, do multiplexing, and provide connectionless or connection-oriented transport. Each PDU contains a source and destination address, a type, a sequence field and the LLCP payload. The different types include things like SYMM to keep connections alive when there are no other PDU’s available, CONNECT to establish a connection-oriented connection, and I for the actual high level data payload. There are other types of PDU’s as well, see [10] for details.

Application layer

While NFC can transport arbitrarily formatted data, typically it transports data in the NFC Data Exchange Format (NDEF). It is a simple binary message format that can be used to encapsulate one or more application-defined payloads of arbitrary type and size into a single payload. NDEF data contains different type identifiers to describe the type of data to expect, such as URI’s, MIME types, or NFC-specific types. There are specifications for NDEF [11] as well as for each of the well known types, see [12-13] for example. One example NDEF is given in the next section. For clarity, and because the NDEF format is so important for NFC, we provide another couple of examples here. We start with a “smart poster” which is basically a URL.

```
0000: D1 02 18 53 70 91 01 05 54 02 65 6E 68 69 51 01  Ñ..Sp<91>..T.enhiQ.
0010: 0B 55 01 67 6F 6F 67 6C 65 2E 63 6F 6D           .U.google.com
```

```
d1 - MB, ME, SR, TNF=”NFC Forum well-known type”
        02 Type length
        18 Payload length
        53 70 Type - “Sp”
                91 - MB, SR
                        01 Type length
                        05 Payload length
                        54 Type - “T”
                                02 Status byte - Length of IANA lang code
                                65 6E language code = “en”
                                68 69 “hi” text
                51 - ME, SR
                        01 Type length
                        0b Payload length
                        55 Type - “U”
                                01 identifier code “http://www.”
                                67 6F 6F 67 6C 65 2E 63 6F 6D = “google.com” - text
```

The previous NDEF example had a single byte devoted to the length of the payload. To support payloads longer than 255 bytes, a longer form of NDEF is used. (You can tell which variant to expect by whether the SR bit is set in the first byte of the NDEF record or not). Below is the beginning of a longer NDEF record.

```
0000: C1 01 00 00 01 2F 54 02 65 6E 61 61 61 61 61 61....
```

```
c1 - MB, ME, TNF=”NFC Forum well-known type”
        01 Type length
        00 00 01 2f Payload length
        54 Type - “T”
                02 - Status byte - Length of IANA lang code
                65 63 - language code = “en”
                61  61  61  61  61  61= “aaaaa...” - text
```

Example data capture

Data can be captured in various ways. Perhaps the simplest way (when it works) is to use a Proxmark3 device [14], see Figure 4, below.

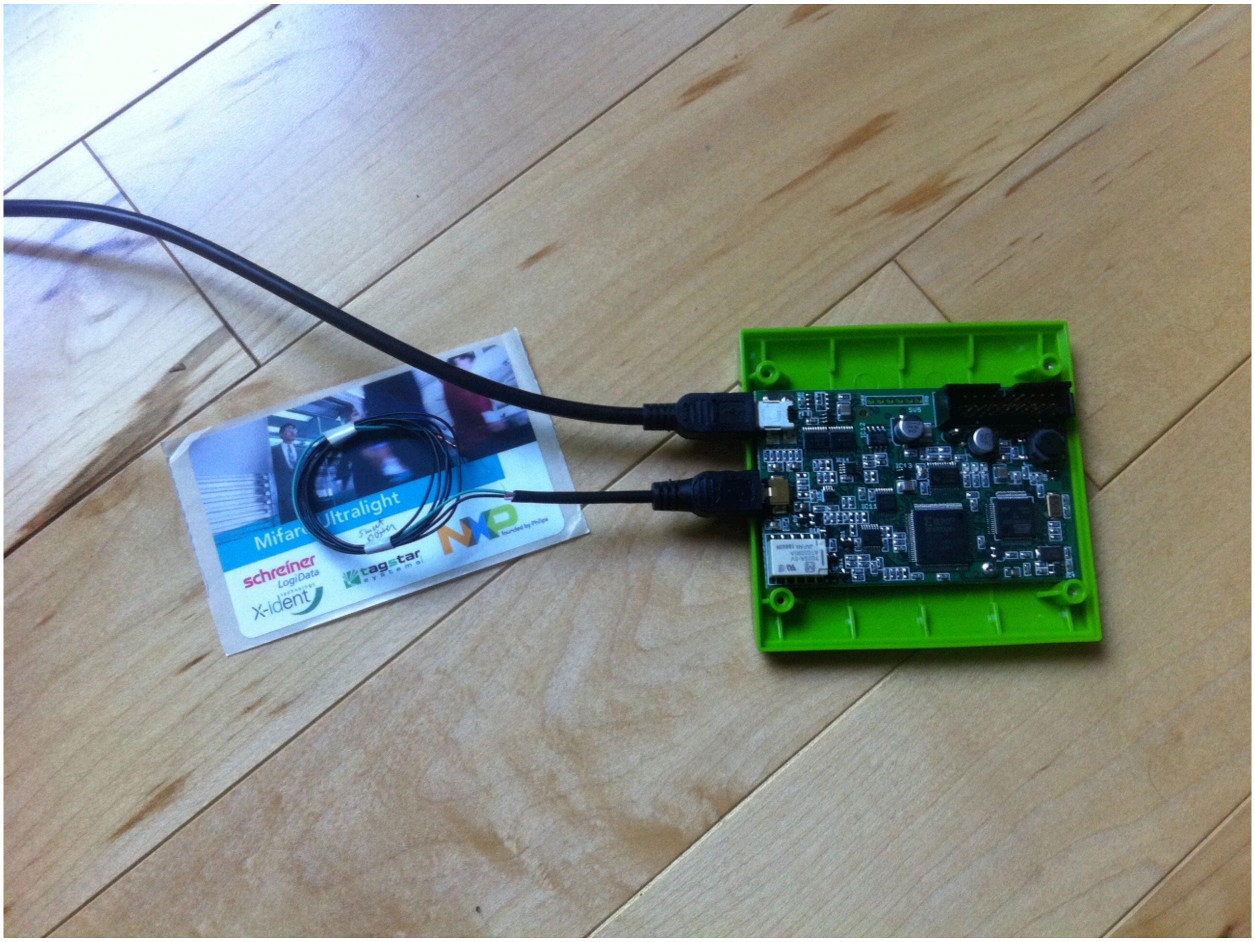


Figure 4: Proxmark homemade antenna waiting for a Type 2 transaction from a SCL3711

Below, you can see a trace obtained from an SCL 3711 NFC card reader reading from a Mifare Ultralight tag. I added brackets to indicates bytes used for checksum purposes. I also indicate the specification used to interpret the bytes.

<Broken out from [15]>

SENS_REQ

```
       26
```

SENS_RES (NFCID1 size: double (7 bytes), Bit frame SDD)

```
TAG    44  00
```

SDD_REQ CL1

```
       93  20
```

SDD_RES (CT? 04-e3-ef BCC)

```
TAG    88  04  e3  ef  <80>
```

SEL_REQ CL1

```
93     70  88  04  e3  ef  80  <99  73>
```

SEL_RES - Not complete, type 2

```
TAG    04  <da  17>
```

SDD_REQ CL2

```
       95  20
```

SDD_RES (a2-ef-20-80 BCC)

```
TAG    a2  ef  20  80  <ed>
```

SEL_REQ CL2

```
       95  70  a2  ef  20  80  ed  <72  c8>
```

SEL_RES - complete, type 2

```
TAG    00  <fe  51>
```

<Broken out from [7]>

READ - 08

```
       30  08  <4a  24>
```

READ Response

```
TAG    74  72  61  6c  69  67  68  74  3f  fe  00  00  e4  f2  e3  01  <06  d5>
```

READ - 03

```
       30  03  <99  9a>
```

READ Response

```
TAG    e1  10  06  00  03  17  d1  01  13  54  02  65  6e  73  75  70  <b1  62>
```

READ - 04

```
       30  04  <26  ee>
```

READ Response

```
TAG    03  17  d1  01  13  54  02  65  6e  73  75  70  2c  20  75  6c  <2a  00>
```

READ - 05

```
       30  05  <af  ff>
```

READ - Response

```
TAG    13  54  02  65  6e  73  75  70  2c  20  75  6c  74  72  61  6c  <16  f6>
```

READ - 06

```
       30  06  <34  cd>
```

READ - Response

```
TAG    6e  73  75  70  2c  20  75  6c  74  72  61  6c  69  67  68  74  <65  db>
```

READ - 04

```
       30  04  <26  ee>
```

READ - Response

```
TAG    03  17  d1  01  13  54  02  65  6e  73  75  70  2c  20  75  6c  <2a  00>
```

READ - 05

```
       30  05  <af  ff>
```

READ - Response

```
TAG    13  54  02  65  6e  73  75  70  2c  20  75  6c  74  72  61  6c  <16  f6>
```

READ - 06

```
       30  06  <34  cd>
```

READ - Response

```
TAG    6e  73  75  70  2c  20  75  6c  74  72  61  6c  69  67  68  74  <65  db>
```

READ - 07

```
       30  07  <bd  dc>
```

READ - Response

```
TAG    2c  20  75  6c  74  72  61  6c  69  67  68  74  3f  fe  00  00  <8b  9e>
```

READ - 08

```
        30  08  <4a  24>
```

READ - Response

```
TAG     74  72  61  6c  69  67  68  74  3f  fe  00  00  e4  f2  e3  01  <06  d5>
```

READ - 09

```
        30  09  <c3  35>
```

READ - Response

```
TAG     69  67  68  74  3f  fe  00  00  e4  f2  e3  01  e4  f2  e3  01  <15  ca>
```

READ - 0a

```
        30  0a  <58  07>
```

READ - Response

```
TAG     3f  fe  00  00  e4  f2  e3  01  e4  f2  e3  01  30  00  00  00  <6a  52>
```

READ - 0b

```
        30  0b  <d1  16>
```

READ - Response

```
TAG     e4  f2  e3  01  e4  f2  e3  01  30  00  00  00  45  34  20  46  <ef  07>
```

READ - 0c

```
        30  0c  <6e  62>
```

READ - Respnose

```
TAG     e4  f2  e3  01  30  00  00  00  45  34  20  46  32  20  45  33  <17  e2>
```

READ - 0d

```
        30  0d  <e7  73>
```

READ - Response

```
TAG     30  00  00  00  45  34  20  46  32  20  45  33  04  e3  ef  80  <f1  77>
```

READ - 0e

```
        30  0e  <7c  41>
```

READ - Response

```
TAG     45  34  20  46  32  20  45  33  04  e3  ef  80  a2  ef  20  80  <01  7e>
```

READ - 0f

```
        30  0f  <f5  50>
```

READ - Response

```
TAG     32  20  45  33  04  e3  ef  80  a2  ef  20  80  ed  48  00  00  <1a  18>
```

SLP_REQ

```
50  00  <57  cd>
```

Pulling out the NDEF data read we find:

```
03  17  d1  01  13  54  02  65  6e  73  75  70  2c  20  75  6c  74  72  61  6c  69  67
68  74  3f  fe  00  00  e4  f2  e3  01  30  00  00  00  45  34  20  46  32  20  45  33
04  e3  ef  80  a2  ef  20  80  ed  48  00  00
```

Examining this NDEF data we can see the contents:

```
<Breaking out from [11]>
03 NDEF Message
17 length
        Record 1
                d1 - MB, ME, SR, TNF="NFC Forum well-known type"
                01 Type length
                13 Payload length
<From [12]>
                        54 Type - "T"
<From [13]>
                                02 - Status byte - Length of IANA lang code
                                65 6e - language code = "en"
                                73  75  70  2c  20  75  6c  74  72  61  6c  69  67  68  74
3f = "sup, ultralight?" - text
        Record 2
                fe Terminator NDEF
```

Fuzzing the NFC stack

When considering the attack surface that the introduction of NFC to a device adds, the most obvious place to start is the NFC software stack itself, the code responsible for parsing the NFC protocols mentioned in the last section. Typically, this code will consist of a driver for the NFC chip, a library used to communicate with the driver, and then the OS code to deal with incoming NFC payloads including dealing with different types of NDEF messages that might arrive. In Android, we see something like Figure 5, below.

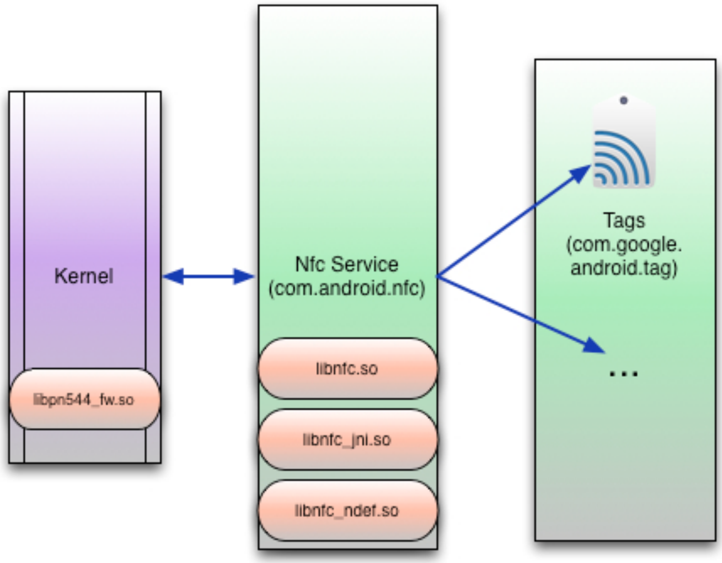


Figure 5: NFC handling code in Android.

In MeeGo it is similar, as in Figure 6, below.

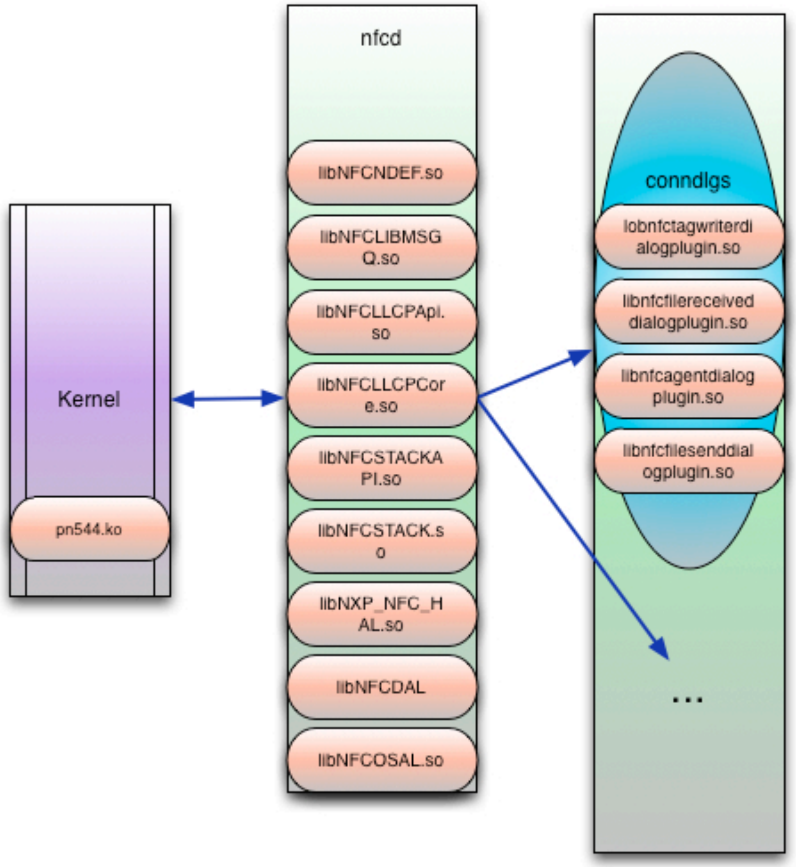


Figure 6: NFC handling code in MeeGo

In such a complex stack, there certainly could be bugs lurking in any of this code that could allow remote compromise of NFC enabled devices. Please note that in Android, some of the components are Java apps and so memory corruption is not a possibility, but this will vary from platform to platform. There will always be some native code involved at the lowest levels, though.

There are various approaches to trying to find vulnerabilities in the NFC stack. A driver that is proprietary could still be reverse engineered and analyzed. The library for the chip on Android, libnfc.so, is open source, and so could be audited. However, one very effective way to get started is to set up a fuzzing environment and fuzz the NFC protocol stack.

Depending on exactly how this is to be carried out, different levels of the protocol stack can be attacked. We considered various approaches such as doing it at the RF level (see [2-3]) or library injection (as was done for SMS in [16]). After many trials and errors, we settled on using card emulation with a collection of off-the-shelf NFC hardware.

For the tag types which had working card emulation functionality, we could fuzz the protocol level and application level. We could potentially fuzz the Initialization, Anti-Collision, and Protocol Activation layer but there isn't much data there so it was determined not to be a good use of time. We could not fuzz the RF layer without a fully working software defined radio (SDR) NFC stack. Figure 7, below, shows which protocols could be tested with this approach.

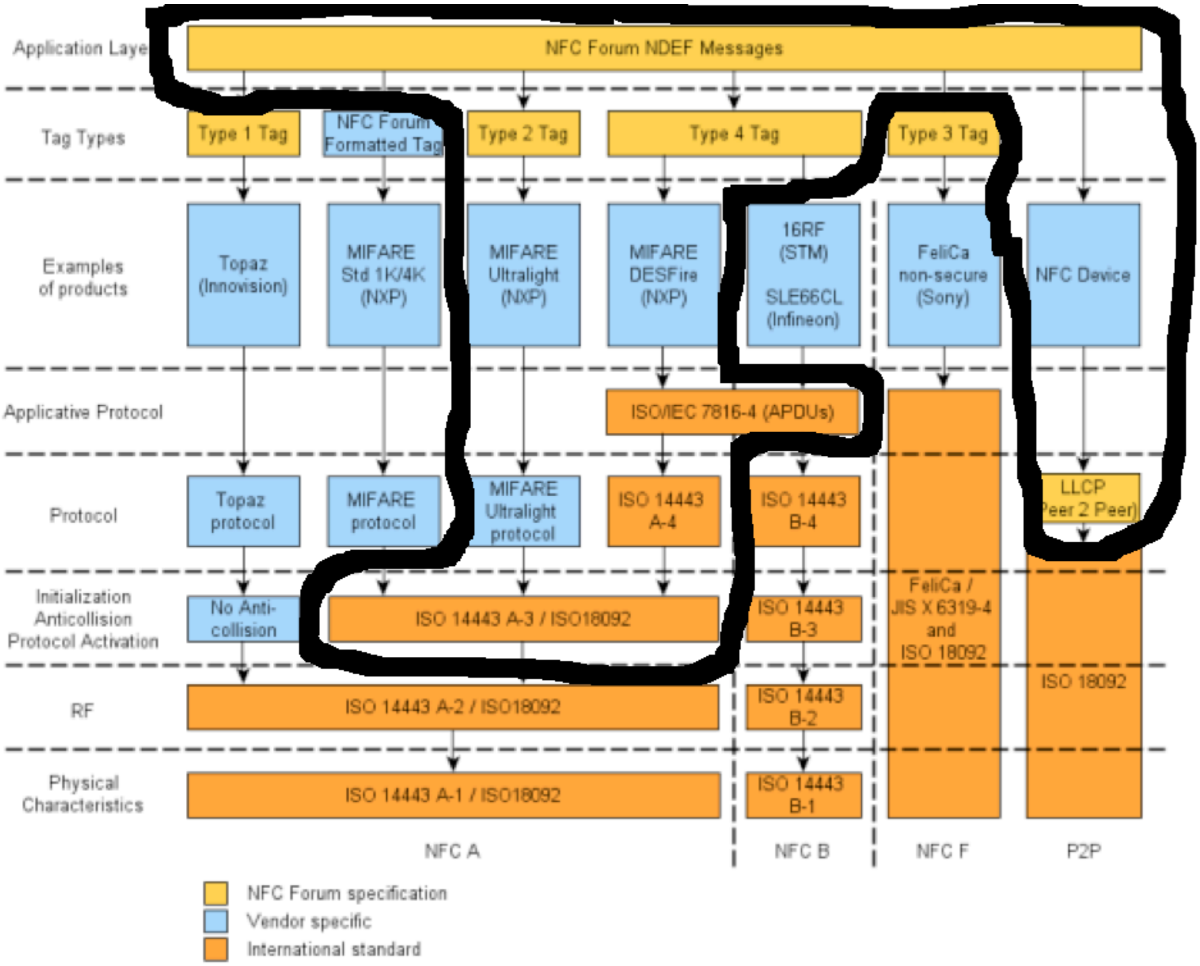


Figure 7: Fuzzing using this setup can fuzz any of the areas indicated above

Fuzzing setup

If you want to simulate various NFC tags, you need to do what is called card emulation. This is where an NFC device acts like a passive tag. We were able to find a couple of pieces of hardware that could perform card emulation in some circumstances. Namely, an SCL 3711 Contactless Mobile Reader could be used with libnfc to do card emulation of a Type 2 Mifare UltraLight tag. An ACS ACR122U can do card emulation using libnfc of a Type 4 Mifare DESFire. Additionally, an SCL3711 can do LLCP transactions using nfcpy. Unfortunately, there is no support for other types of tags using libnfc or nfcpy. It would be interesting to add other tag types into libnfc for testing.

Sometimes the hardware devices would hang and need to be restarted. This cannot be accomplished in software and has to be done in hardware. In order to simulate unplugging and replugging the USB card reader into the computer, we use a USB hub that implements port power control. In particular, we used a DLink DUB-H7 7-Port USB Hub. Therefore, the hardware set-up looks something like that in Figure 8, below.

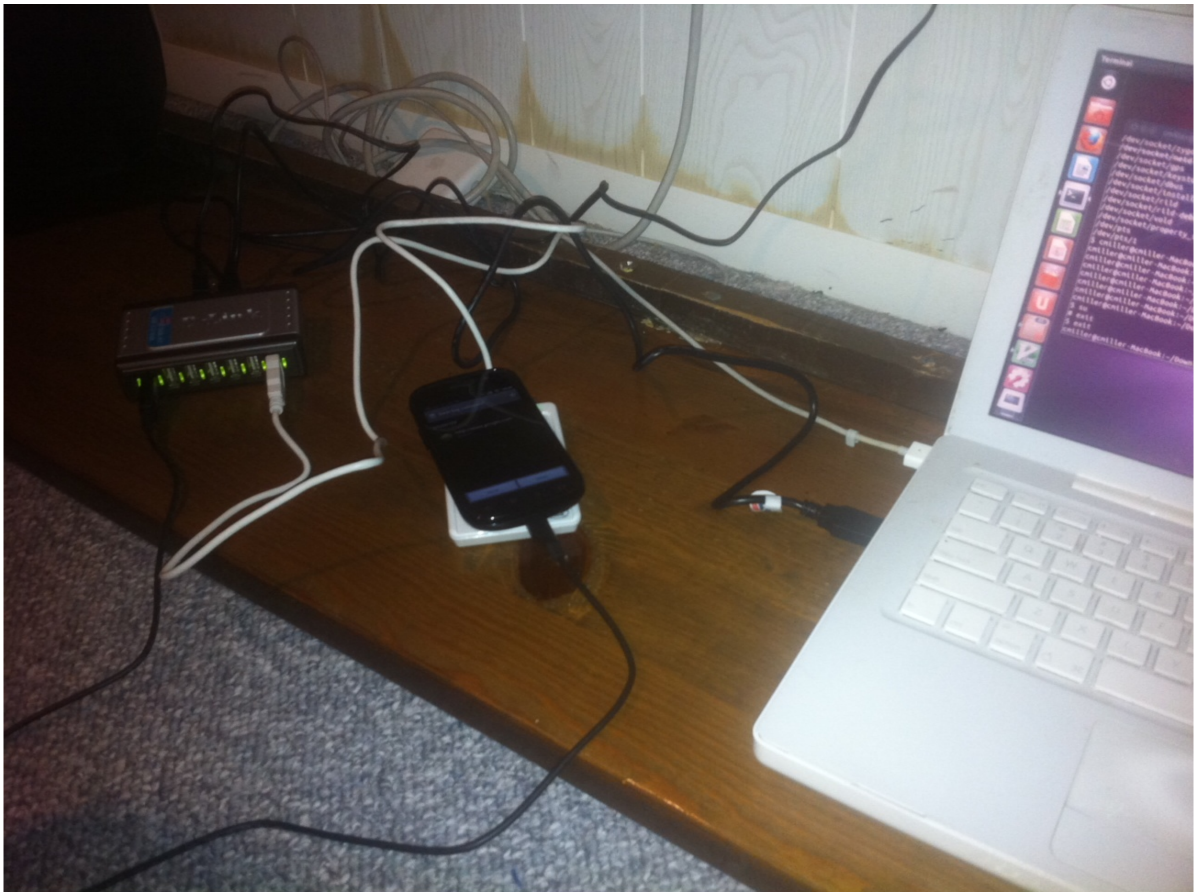


Figure 8: Fuzzing hardware setup

The final step in fuzzing is to simulate someone placing the device onto the emulated tag. In some cases, you cannot just emulate the tag with a device already in the RF field of an NFC initiator. In order to simulate a device entering the field, a couple of options are available. The first is to kill the NFC process and restart it when the tag is being emulated. A slightly nicer way is to issue the SIGSTOP and SIGCONT signals, respectively, to simulate removing/placing the Nexus S NFC reader. A final way was to enable and disable the NFC service,in the same way the Settings application does it in Android.

Fuzzing test cases

In general, there are two ways to generate fuzzing test cases, generation based and mutation based. For generation based, we create test cases from “scratch”, using the specification as a guide. For mutation based fuzzing, we take existing valid data and inject faults into it. One of the interesting things about fuzzing is that it turns out using multiple fuzzers is often superior to using a single fuzzer. Therefore, we use an approach to try to use both mutation and generation based fuzzers as well as incorporate a couple of different types of mutations to add to the valid data.

Protocol layer fuzzing

On the protocol level, we used only a mutation-based approach since the fields being fuzzed were so simple. We are constrained by the hardware and software which can do device emulation. We only have the ability to emulate Type 2 and Type 4 tags as well as perform basic LLCP connections. For these three types, we can fuzz at a low level, just after the anti-collision. For other types of cards or transactions, we cannot fuzz at a low level. In particular we cannot fuzz Type 1 (Topaz) or Type 3 (FeliCa) protocols at this time.

For this low level fuzzing for tags, we used the nfc-emulate-forum-tag2 and nfc-emulate-forum-tag4 programs which come with libnfc, modified to present different data before a valid NDEF was presented. For fuzzing low level Type 2 tags, we fuzz the non-NDEF bytes in the MiFare Ultralight's memory. Namely, this includes the first 16 bytes of the static memory structure (see section 2.1 in [7]).

For type 4 tags, we fuzz the Capability Container file, see section 5.1 of [9].

For LLCP, we use modified versions of the nfcpy software suite. In particular, we fuzz the CONNECT packet and the I (Information) packet (see 4.3.10 in [10]) of the connection. For Android we used the nfcpy script npp-test-client and for for the Nokia N9, we used the snep-test-client. NPP is the NDEF Push Protocol which is used by Android [17]. SNEP is the Simple NDEF Exchange Protocol used by Nokia and other devices [18].

Application layer fuzzing

Application layer fuzzing involves creating fuzzed NDEF messages and getting them to the device using one of the available low level protocols. As in the low level protocols, we start with a mutation-based approach. We took many different types of NDEF messages and added mutations to them.

Additionally, we utilized a generation-based approach to create more specialized NDEF fuzzing test cases.

For this, we utilize the Sulley Fuzzing Framework. We created 11 different test case generation scripts (ndef_*.py) based on a modified version of Sulley. Each will generate many thousands of NDEF test cases to STDOUT. For example,

```
$ ./ndef_short_uri.py | grep -v "^\["
D1010B550036333633393934373931
D1010B550136333633393934373931
D1010B550236333633393934373931
D1010B550336333633393934373931
```

```
D1010B550436333633393934373931
D1010B550536333633393934373931
D1010B550636333633393934373931
D1010B550736333633393934373931
D1010B550836333633393934373931
D1010B550936333633393934373931
...
```

In the above output, the fifth byte is being mutated.

```
$ ./ndef_short_uri.py | grep "total cases"
[10:08.08] fuzzed 0 of 1419 total cases
```

Sulley is designed to do everything from test case generation to sending and monitoring during fuzzing. Since we tend to fuzz esoteric devices, it is not well suited for this, and so my modifications to Sulley are mostly to allow it to print out test cases in a way which are easily read by another program which will be responsible for sending the test cases and monitoring the test device.

Results - Nexus S

We fuzzed the NFC stack on a Nexus S phone running Android 2.3.3 with the above approaches. This was the most current version when we started fuzzing and I believe is the most up to date version for an AT&T Nexus S using default methods of upgrade.

Protocol Layer

A total of 12,000 test cases were developed and tested against the low level NFC protocols, see below for details.

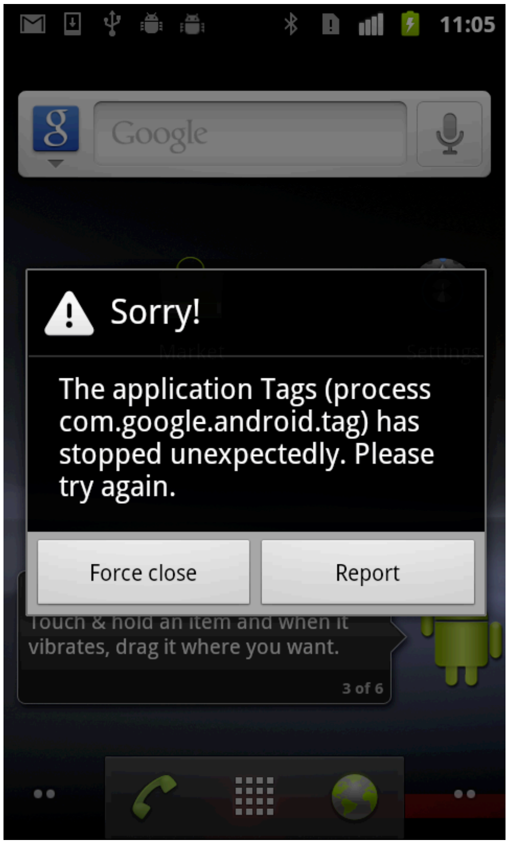
Device	**Type**	Test cases	Results/notes
Nexus S	Type 2 (UL)	4000	18 bytes of MiFare UL memory
	MiFare 1k/4k		Cannot emulate at this time
	Type 4 (DESFire)	4000	15 bytes of Capacity Container
	ISO 14443 A-4 (PDU)		Nothing interesting to fuzz
	Type 1 (Topaz)		Cannot emulate at this time
	Type 3 (FelCa)		Cannot emulate at this time
	LLCP - Connect	2000	19 bytes of information, some crashes

Device	**Type**	Test cases	Results/notes
	LLCP - I	2000	13 bytes of header information, some crashes

Application Layer
A total of 52362 test cases were performed against the Nexus S. See below for details.

Device	**Type**	**Test cases**	**Results/notes**
Nexus S	NDEF - bitflip	9000	Mutation-based
	NDEF - short text	1626	Generation-based
	NDEF - short URI	538	Generation-based
	NDEF - short SMS	1265	Generation-based
	NDEF - short SP	3675	Generation-based
	NDEF - short BT	1246	Generation-based
	NDEF - long text	2440	Generation-based
	NDEF - long vcard	32572	Generation-based

Android - Crashes
The most common crash found was of the Tags application, which is the default Android NFC tag reader application. This application is written in Java and so crashes correspond to Java exceptions and not, for example, memory corruption. See Figure 9, below, for an example of what a crash looks like on the phone.



Sorry!

The application Tags (process com.google.android.tag) has stopped unexpectedly. Please try again.

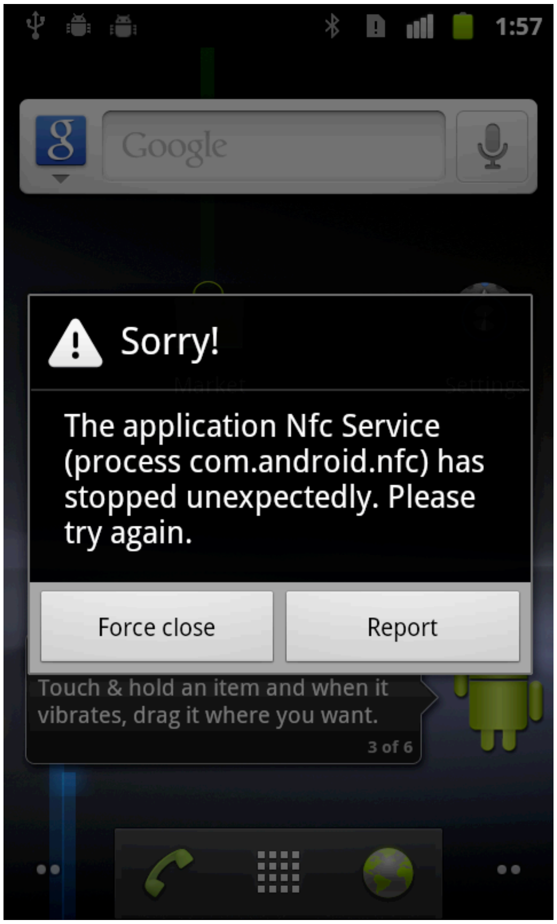
Touch & hold an item and when it vibrates, drag it where you want.

Figure 9: Tags application dying

The log reveals

```
E/NfcService(17875): failed to parse record
E/NfcService(17875): java.lang.ArrayIndexOutOfBoundsException
E/NfcService(17875):     at com.android.nfc.NfcService
$NfcServiceHandler.parseWellKnownUriRecord(NfcService.java:2570)
E/NfcService(17875):     at com.android.nfc.NfcService
$NfcServiceHandler.setTypeOrDataFromNdef(NfcService.java:2616)
E/NfcService(17875):     at com.android.nfc.NfcService
$NfcServiceHandler.dispatchTagInternal(NfcService.java:2713)
```

During low level fuzzing, a different (Java) application, the NFC Service, was also seen to crash, shown in Figure 10, below. The NFC Service is the default Android NFC processing service. .



Sorry!

The application Nfc Service (process com.android.nfc) has stopped unexpectedly. Please try again.

Google
Force close
Report
Touch & hold an item and when it vibrates, drag it where you want.
3 of 6
1:57

Figure 10: The NFC service is prone to Java exceptions

The log corresponds to something like the series of exceptions below:

```
D/NdefPushServer( 3130): java.io.IOException
D/NdefPushServer( 3130):      at
com.android.internal.nfc.LlcpSocket.receive(LlcpSocket.java:193)
D/NdefPushServer( 3130):      at
com.android.nfc.ndefpush.NdefPushServer
$ConnectionThread.run(NdefPushServer.java:70)
D/NdefPushServer( 3130): about to close
W/dalvikvm( 3130): threadid=8: thread exiting with uncaught
exception (group=0x40015560)
E/AndroidRuntime( 3130): FATAL EXCEPTION: NdefPushServer
E/AndroidRuntime( 3130): java.lang.NegativeArraySizeException
E/AndroidRuntime( 3130):      at
com.android.nfc.ndefpush.NdefPushProtocol.<init>(NdefPushProtoco
l.java:97)
E/AndroidRuntime( 3130):      at
com.android.nfc.ndefpush.NdefPushServer
$ConnectionThread.run(NdefPushServer.java:86)
```

Java exceptions are generally pretty boring from a security perspective. However, we did find a few native code crashes in the handling of LLCP packets. One appears to be a null pointer dereference caused by sending a CC (Connection Complete) packet before a CONNECT packet. Other crashes may be more interesting and occur in libc.

One frequent crash address found corresponds to a call to abort() in libc. Normally, this isn’t very interesting because programs may call abort when they see something has gone wrong, which in fuzzing, is all the time! However, there is a chance it is significant because the exception may indicate memory corruption.

One crash log from an interesting Java exception is:

```
D/NdefPushServer(13178): starting new server thread
D/NdefPushServer(13178): about create LLCP service socket
D/NdefPushServer(13178): created LLCP service socket
D/NdefPushServer(13178): about to accept
D/NFC JNI (13178): Discovered P2P Target
D/NfcService(13178): LLCP Activation message
E/NFC JNI (13178): phLibNfc_Llcp_CheckLlcp() returned
0x00ff[NFCSTATUS_FAILED]
I/DEBUG   (   73): *** *** *** *** *** *** *** *** *** *** *** *** *** ***
*** ***
I/DEBUG   (   73): Build fingerprint: 'google/sojua/crespo:2.3.3/
GRI54/105536:user/release-keys'
I/DEBUG   (   73): pid: 13178, tid: 13178  >>> com.android.nfc <<<
I/DEBUG   (   73): signal 11 (SIGSEGV), code 1 (SEGV_MAPERR), fault addr
0000000c
I/DEBUG   (   73):  r0 afd46494  r1 00000004  r2 00000000  r3 afd46450
I/DEBUG   (   73):  r4 00295530  r5 afd46450  r6 00000000  r7 40002410
I/DEBUG   (   73):  r8 00000001  r9 0000008a  10 00000002  fp bed9725c
I/DEBUG   (   73):  ip afd46474  sp bed97220  lr afd10e60  pc afd13d06  cpsr
00000030
I/DEBUG   (   73):  d0  bed9734806293705  d1  0000000080542286
I/DEBUG   (   73):  d2  000000060000008a  d3  0000001500000075
I/DEBUG   (   73):  d4  8040a46f0000001d  d5  8040a48f00000013
I/DEBUG   (   73):  d6  8040a4b600000014  d7  8040a4cc00000015
I/DEBUG   (   73):  d8  0000000000000000  d9  0000000000000000
I/DEBUG   (   73):  d10 0000000000000000  d11 0000000000000000
I/DEBUG   (   73):  d12 0000000000000000  d13 0000000000000000
I/DEBUG   (   73):  d14 0000000000000000  d15 0000000000000000
I/DEBUG   (   73):  d16 0000000740af0af0  d17 3fe999999999999a
I/DEBUG   (   73):  d18 42eccefa43de3400  d19 3fbc71c71c71c71c
I/DEBUG   (   73):  d20 4008000000000000  d21 3fd99a27ad32ddf5
I/DEBUG   (   73):  d22 3fd24998d6307188  d23 3fcc7288e957b53b
I/DEBUG   (   73):  d24 3fc74721cad6b0ed  d25 3fc39a09d078c69f
I/DEBUG   (   73):  d26 0000000000000000  d27 0000000000000000
I/DEBUG   (   73):  d28 0000000000000000  d29 0000000000000000
I/DEBUG   (   73):  d30 0000000000000000  d31 0000000000000000
I/DEBUG   (   73):  scr 60000012
I/DEBUG   (   73):
I/DEBUG   (   73):          #00  pc 00013d06  /system/lib/libc.so
I/DEBUG   (   73):          #01  pc 000144be  /system/lib/libc.so
I/DEBUG   (   73):          #02  pc 0004375c  /system/lib/libnfc.so
I/DEBUG   (   73):          #03  pc 00042b84  /system/lib/libnfc.so
```

```
I/DEBUG   (   73):          #04  pc 000433f4  /system/lib/libnfc.so
```

With some investigation you can see that the source code, found in com_android_nfc_NativeNfcManager.cpp, reveals a classic double-free.

```
/* Llcp methods */


static jboolean com_android_nfc_NfcManager_doCheckLlcp(JNIEnv *e, jobject o)
{
   NFCSTATUS ret;
   jboolean result = JNI_FALSE;
   struct nfc_jni_native_data *nat;
   struct nfc_jni_callback_data  *cb_data;


   CONCURRENCY_LOCK();

   /* Memory allocation for cb_data */

cb_data = (struct nfc_jni_callback_data*) malloc (sizeof(nfc_jni_callback_data));
...
   if(ret != NFCSTATUS_PENDING && ret != NFCSTATUS_SUCCESS)
   {
      LOGE("phLibNfc_Llcp_CheckLlcp() returned 0x%04x[%s]", ret, nfc_jni_get_status_name(ret));
      free(cb_data);
      goto clean_and_return;
   }
...
clean_and_return:
   nfc_cb_data_deinit(cb_data);
   CONCURRENCY_UNLOCK();
   return result;
}
```

The problem is that nfc_cb_data_deinit also calls free() on the buffer cb_data. This vulnerability was fixed in ICS (4.0.1) by Google without my help. You can see by the logging statement bolded in the crash log, this crash really is from this double free.

The fix can be seen in the git here:

http://218.211.38.204/?p=android/platform/packages/apps/Nfc.git;a=commitdiff;h=0ce29d75b2e19075f9f287a6bdfd92a7c7e91c13;hp=4467dca5650a170af5020c10a8ccb25f86f1007f

Even though the issue was fixed in ICS, it can still be problematic. For example, all Gingerbread devices with NFC would still have this vulnerability. In fact, over 92% of Android devices still run Gingerbread [19].

Some other crashes were found during our testing as well which seem likely to be memory corruption vulnerabilities. Due to the fact that logging messages are different than those seen in the last crash we know they are different than the last crash but we could not reliably reproduce them enough to actually find the root cause of these bugs. Some of the backtraces are given below where we've added function names in braces to illustrate more clearly the nature of the crashes.

The first one is a call to abort() from dlmalloc. It is typical to call abort from dlmalloc if the heap is corrupted in some manner.

```
I/DEBUG   (   73):          #00  pc 00015ca4  /system/lib/libc.so <libc_android_abort>
I/DEBUG   (   73):          #01  pc 00013e08  /system/lib/libc.so <dlmalloc>
I/DEBUG   (   73):          #02  pc 0001423e  /system/lib/libc.so <???>
I/DEBUG   (   73):          #03  pc 000142ac  /system/lib/libc.so <dlrealloc>
I/DEBUG   (   73):          #04  pc 0001451a  /system/lib/libc.so <realloc>
I/DEBUG   (   73):          #05  pc 0001abf0  /system/lib/libbinder.so
<android::Parcel::continueWrite>
I/DEBUG   (   73):          #06  pc 0001ad0c  /system/lib/libbinder.so
<android::Parcel::growData>
I/DEBUG   (   73):          #07  pc 0001ae68  /system/lib/libbinder.so
<android::Parcel::writeInplace>
DEBUG   (   73):          #08  pc 0001aea8  /system/lib/libbinder.so
<android::Parcel::writeString16>
DEBUG   (   73):          #09  pc 0001aed4  /system/lib/libbinder.so
<android::Parcel::writeString16>
DEBUG   (   73):          #10  pc 0001aef8  /system/lib/libbinder.so
<android::Parcel::writeInterfaceToken>
...
```

Another crash seen was from a call to abort from dlfree(). This usually occurs due to heap corruption.

```
D/NFC JNI (27180): phLibNfc_Mgt_UnConfigureDriver() returned
0x0000[NFCSTATUS_SUCCESS]^M^M
I/DEBUG   (   73):          #00  pc 00015ca4  /system/lib/libc.so <libc_android_abort>
I/DEBUG   (   73):          #01  pc 00013614  /system/lib/libc.so <dlfree>
I/DEBUG   (   73):          #02  pc 000144da  /system/lib/libc.so <free>
I/DEBUG   (   73):          #03  pc 0004996e  /system/lib/libdvm.so <dvmDestroyJNI>
I/DEBUG   (   73):          #04  pc 00053fda  /system/lib/libdvm.so
<dvmDetachCurrentThread>
I/DEBUG   (   73):          #05  pc 000494da  /system/lib/libdvm.so <???>
I/DEBUG   (   73):          #06  pc 00005310  /system/lib/libnfc_jni.so
<nfc_jni_client_thread>
I/DEBUG   (   73):          #07  pc 000118e4  /system/lib/libc.so
<_thread_entry>
```

An almost identical backtrace was observed except instead of abort being called, it actually crashed in dlfree:

```
D/NFC JNI (27180): phLibNfc_Mgt_UnConfigureDriver() returned
0x0000[NFCSTATUS_SUCCESS]^M^M
I/DEBUG   (   73):          #00  pc 00013256  /system/lib/libc.so <dlfree>
I/DEBUG   (   73):          #01  pc 000144da  /system/lib/libc.so <free>
I/DEBUG   (   73):          #02  pc 0004996e  /system/lib/libdvm.so <dvmDestroyJNI>
```

This crash occurs in unlink_large_chunk inside dlfree() when dereferencing p->bk.

A final call to abort from dlmalloc was seen during initialization,

```
I/DEBUG   (   73):          #00  pc 00015ca4  /system/lib/libc.so <libc_android_abort>
I/DEBUG   (   73):          #01  pc 00013e08  /system/lib/libc.so <dlmalloc>
I/DEBUG   (   73):          #02  pc 000144be  /system/lib/libc.so <calloc>
I/DEBUG   (   73):          #03  pc 000509c8  /system/lib/libdvm.so 
<dvmInitReferenceTable>
I/DEBUG   (   73):          #04  pc 000533f8  /system/lib/libdvm.so  <???>
I/DEBUG   (   73):          #05  pc 00053454  /system/lib/libdvm.so 
<dvmAttachCurrentThread>
```

Since these crashes are not reliably reproducible, it is hard to say if they are all separate or a single bug, or even if they are fixed or not, without further testing and analysis.

Results - Nokia N9

We also fuzzed the NFC stack on a Nokia N9 running MeeGo 1.2 Harmattan PR1.2 with the same approaches described above.

Protocol Layer

A total of 12,000 test cases were developed and tested against the low level NFC protocols, as described below.

Device	**Type**	Test cases	Results/notes
Nokia N9	Type 2 (UL)	4000	18 bytes of MiFare UL memory
	MiFare 1k/4k		Cannot emulate at this time
	Type 4 (DESFire)	4000	15 bytes of Capacity Container
	ISO 14443 A-4 (PDU)		Nothing interesting to fuzz
	Type 1 (Topaz)		Cannot emulate at this time
	Type 3 (FelCa)		Cannot emulate at this time
	LLCP - Connect	2000	19 bytes of information
	LLCP - I	2000	13 bytes of header information

Application Layer

A total of 34852 test cases were performed against the Nokia N9. See below for details.

Device	Type	Test cases	Results/notes
Nokia N9	NDEF - bitflip	9000	Mutation-based
	NDEF - short text	1626	Generation-based
	NDEF - short URI	538	Generation-based
	NDEF - short SMS	1265	Generation-based
	NDEF - short SP	3675	Generation-based
	NDEF - short BT	1246	Generation-based
	NDEF - long text	2440	Generation-based
	NDEF - long vcard	15062	Generation-based

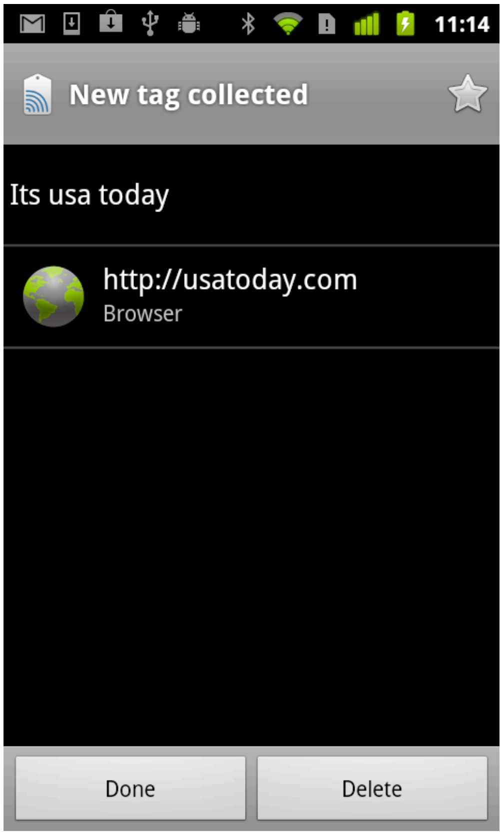
Crashes
No crashes were detected. Nokia N9 stack FTW, or more likely, my method is flawed in some manner.

NFC higher level code

So far we have considered the NFC stack responsible for communicating and obtaining NDEF messages from the outside world. Clearly, this is an important part of the attack surface, but it is really just the first piece of the puzzle. What remains to be seen is what the mobile device does with the NDEF data when it receives it. This section answers that question and sees what other components of the device are related to NFC and can be activated and used without user interaction.

Nexus S - Android 2.3.3
The first device we reviewed was a Nexus S running Android 2.3.3. As of now, there is no supported way to update a Nexus S with AT&T baseband to Android 4. This device's support of NFC is pretty basic. Out of the box, NFC is enabled but doesn't do a whole lot. The device will process NFC data presented to it anytime the screen is on (even if the device is locked).

NFC intents are handled by the Tags application, see Figure 11, below.

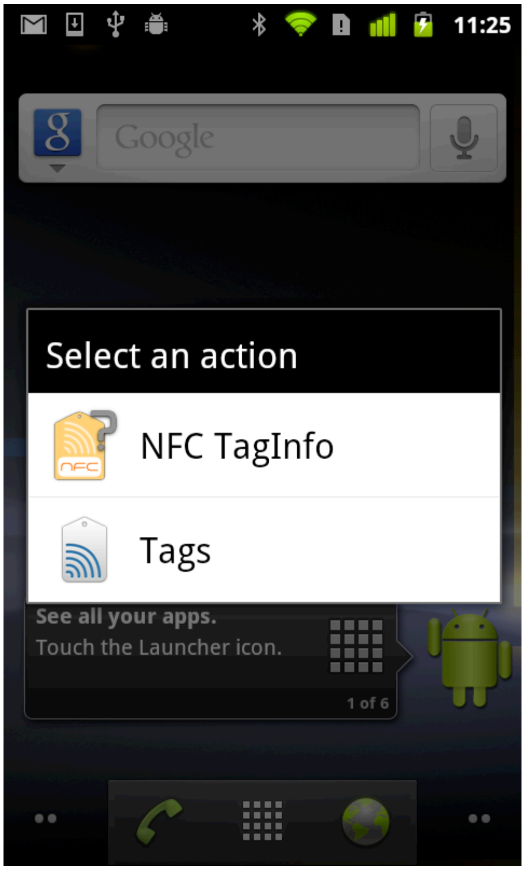

New tag collected

Its usa today

http://usatoday.com
Browser

Figure 11: Tags processing an NFC Smart Poster

This Java application just displays the contents but takes no real action. If you tap on the URL, it will open up the application indicated (in this case Browser) with the included data, in this case a URL. By default, the Tags application handles NFC data, but other applications can register for that intent as well. When this happens, depending on the configuration of the app, the new app either handles the NFC data instead of Tags or allows the user to choose which app to handle NFC data, as in Figure 12, below.



See all your apps.
Touch the Launcher icon.

Figure 12: The user may choose which app to handle the NFC tag

The Tags application can display data from the following categories defined in src/com/android/apps/tag/message/NdefMessageParser.java in the Android source code:

- Text
- SMS
- Smart Poster
- Phone call
- Vtag
- URL
- Image

In general, outside of the NFC stack, there is not much on the attack surface of this Android phone. Large portions of the NFC code are written in Java, only a small amount of the codebase is actually native code.

Galaxy Nexus - Android 4.0.1

The Galaxy Nexus is an Android phone running Ice Cream Sandwich. It still has some of the same features as the Nexus S, but ICS introduced Android Beam, which greatly increases the attack surface visible through NFC. Out of the box, the device has NFC enabled. It will process NFC data any time the screen is on and the device is unlocked.

For some types of NDEF data, it is exactly the same as the the Nexus S running Gingerbread, using com.android.nfc to hand data off to com.google.android.tag to display to the user. These types of data include:

- Text
- SMS
- Phone
- Image

However, some types of data that used to be handled by Tags are now handled by Android Beam.

Android Beam is a way for two NFC-enabled Android devices to quickly share data such as contacts, web pages, You Tube videos, directions, and apps, see [20]. One can determine which apps are enabled with Android Beam by searching the AndroidManifest.xml files to see which apps handle NFC intents.

For example, looking at the Android Browser, we see:

```
<!-- Accept inbound NFC URLs at a low priority -->
  <intent-filter android:priority="-101">
    <action android:name="android.nfc.action.NDEF_DISCOVERED" />
    <category android:name="android.intent.category.DEFAULT" />
    <data android:scheme="http" />
    <data android:scheme="https" />
  </intent-filter>
```

The only apps that register for these types of intents are Browser, Contacts, and Tags.

When two devices are placed close to each other, if one of them is currently showing something that is “beamable”, the device will prompt the user if they want to send it, as seen in Figure 13, below.

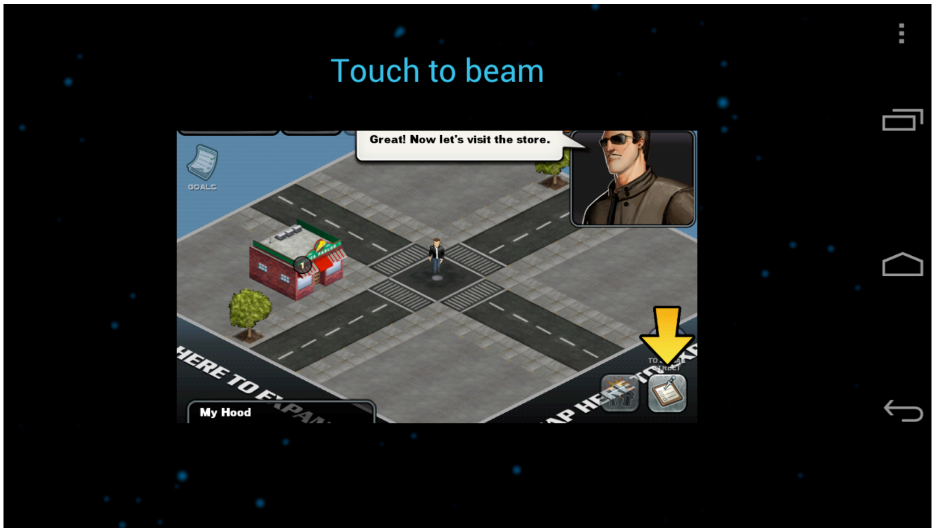


Figure 13: Android asking a user to share the app they're using, in this case Crime City

If the user chooses to beam it, the devices establish an LLCP connection and a simple NDEF message is passed from the device beaming to the other device. The data is sent via Simple NDEF Exchange Protocol (SNEP) with a fallback to NDEF Push Protocol (NPP), see [17,18,21].

In the end, however, the device does not act any differently whether a particular NDEF message is received via LLCP/NPP or simply read from a tag. In other words, the magic of Android Beam has nothing to do with establishing NFC connections between devices but rather relies entirely on how the device is configured to handle different NDEF messages when they arrive. What this means is that now instead of vtags and smart posters being processed by the Tags application, this data is now directly passed to the Contacts or Browser applications.

Just to reiterate, this means that on ICS devices, *if an attacker can get the device to process an NFC tag, they can get it to visit a web site of their choosing in the Browser with no user interaction.* Obviously, the Browser represents an extremely large attack surface, and in ICS, that attack surface is now available through NFC!

The Android Browser will parse at least the following formats, if not more:

Type	File format
Web related	html
	css
	js
	xml

Type	File format
Image	bmp
	gif
	ico
	jpg
	wbmp
	svg
	png
Audio	mp3
	aac
	amr
	ogg
	wav
Video	mp4
	3pg
Font	ttf
	eot

The way that Android beam works for the other advertised services is simply through URL handlers. In Android you can bring up Google Play (aka Android MarketPlace), the Maps application, YouTube, etc. through special URLs passed to the browser. In other words, instead of the attack surface looking like Figure 1, it really looks like Figure 14, below.

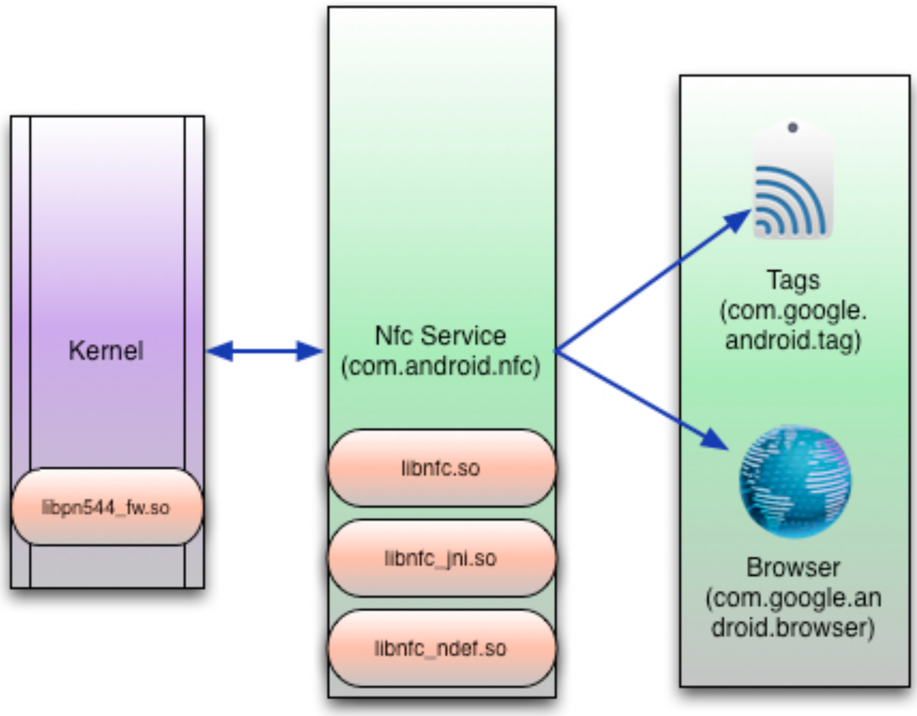
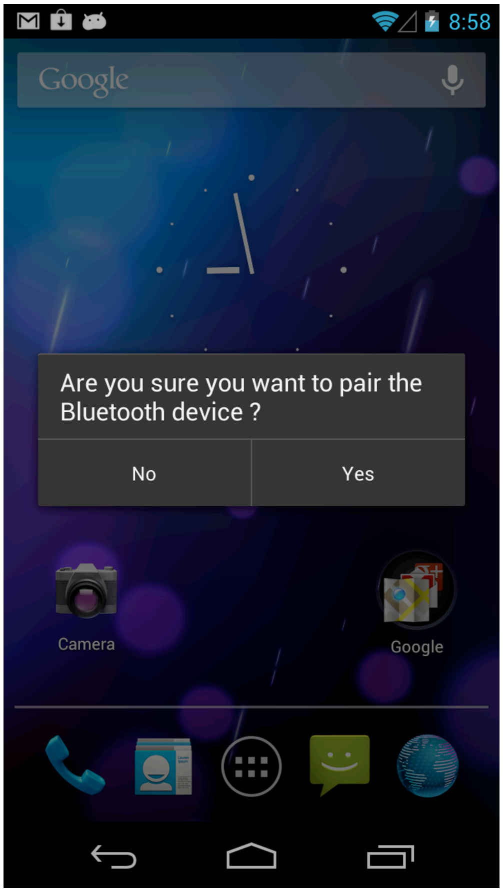


Figure 14: Actual NFC attack surface if NFC can communicate with the browser

Galaxy Nexus - Android 4.1.1
We briefly looked at a Galaxy Nexus running Jelly Bean. It is mostly the same as an ICS device. There are two small changes. One is that it supports NFC simple Bluetooth pairing, like the Nokia N9. However, it always prompts before allowing Bluetooth pairing over NFC. Figure 15 shows an example of the prompt.



Are you sure you want to pair the Bluetooth device ?

Figure 15: Android displays a prompt before establishing a Bluetooth Pairing via NFC

The other way Jelly Bean NFC differs is in regards to Android Beam. A few more applications are configured to accept NFC intents. The list is below.

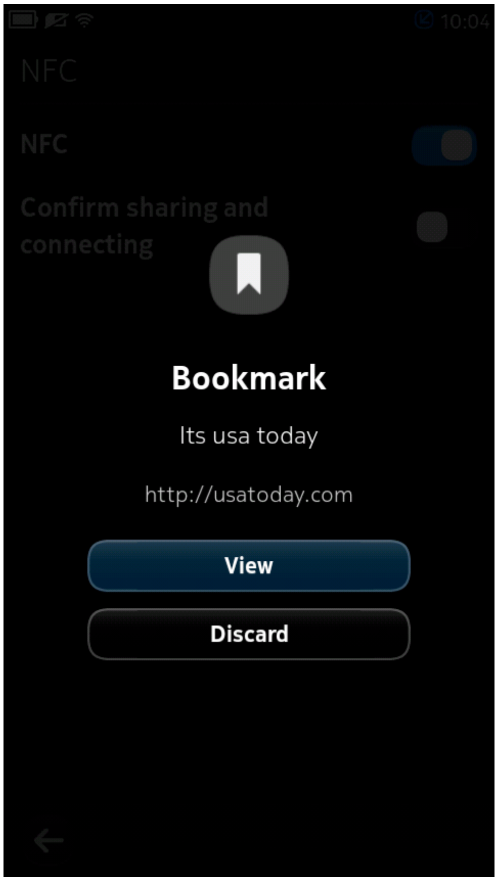
- BrowserGoogle
- Contacts
- Gmail
- GoogleEarth
- Maps
- Phonesky
- TagGoogle
- YouTube

Otherwise, the Jelly Bean build performs identically as an ICS build with regards to NFC.

Nokia N9 - MeeGo 1.2 Harmattan PR1.3

The Nokia N9 is a phone running the MeeGo operating system. Out of the box it does not have NFC enabled. Once enabled, It will process NFC data anytime the screen is on. If the device is locked, it will process low level NFC data, but handles high level data differently. None of the attacks outlined later work if the N9 has the screen locked.

Typically, when an NFC message is read, a process called conndlgs (Connectivity Dialogues) displays it to the screen, see Figure 16, below.



NFC

NFC

Confirm sharing and connecting

Bookmark

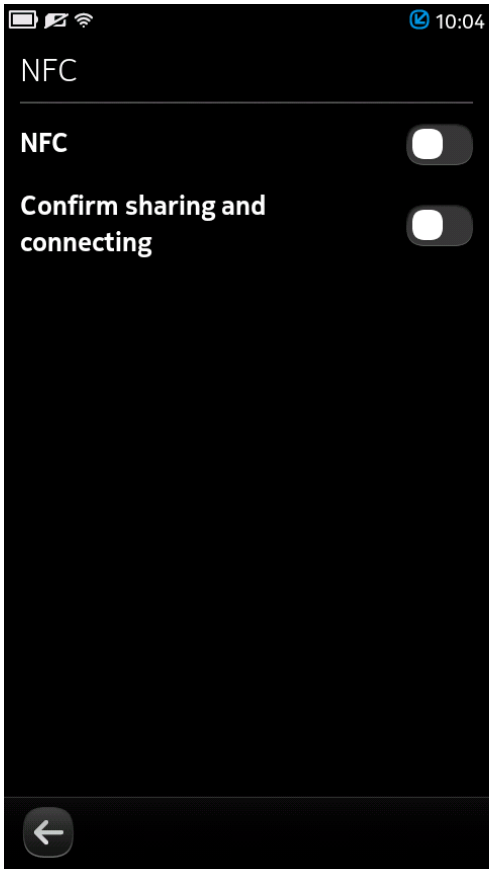
Its usa today

http://usatoday.com

Figure 16: conndlgs and its simple interface

The conndlgs process will display options to “view” or “send” which will open up the appropriate corresponding application or cancel. For example, hitting view for text NDEFs opens up the notes application while hitting view for smart poster NDEFs opens up the web browser, called QTWebProcess.

One exception to this rule is Bluetooth pairing. When the device receives an NDEF Pairing request, it automatically attempts to pair to the requesting device. Depending on user settings, this may or may not require user interaction, see Figure 17, below. By default, pairing does not require user interaction. Furthermore, if Bluetooth is disabled, when an NDEF Pairing request arrives, the device will enable Bluetooth for the user.


10:04

NFC

NFC ○

Confirm sharing and connecting ○

Figure 17: If the “Confirm sharing and connecting option” is enabled, it forces a prompt before Bluetooth sharing is performed

Nokia N9’s also have a similar mechanism to Android’s Beam called Content Sharing. It is possible for one N9 to share data with another N9 over NFC (for small payloads) or over Bluetooth automatically set up via NFC. Using this mechanism one can force a Nokia N9 to display images in Gallery, contacts in Contacts, videos in Videos, and documents such as .txt, .doc, .xls, .pdf, and so forth in Documents. It does not seem to be possible to force it to open the browser but just about everything else is possible. It does not require user interaction, even if the setting “Confirm sharing and connecting” is set to on. The thought of forcing the device to parse arbitrary PDF and MS Office formats is almost as frightening as having it open up web pages!

One interesting thing is it doesn’t seem to be possible by default to share audio files via the Music app. However, if you want to, you can share audio files by sharing them through the Videos app. Just set a breakpoint at open64 in the obex-client process, call

```
print strcpy($r0, "/home/user/MyDocs/Movies/mv.mp3")
```

hit continue and the audio file will be shared.

The following is a list of the file formats which can be shared though content sharing.

App	File type	Library used (if known)
Contacts	vCard	
Gallery	png	libpng 1.2.42 - Jan 2010
	jpg	libjpg 6n - 1998
	gif	libgif 4.1.6 - 2007
	bmp	
	tiff	libtiff 3.9.4 - Jul 2010
Videos (video-suite)	mp4	
	wmv	
	3gp	
	mp3	
	aac	
	flac	
	wma	
	amr	
	wav	
	ogg	
Documents (office-suite)	pdf	poppler 16.6 - May 2011
	txt	
	doc(x)	docximport.so - KDE 4.74 - Dec 2011
	xls(x)	xlsximport.so - KDE 4.74
	ppt(x)	powerpointimport.so - KDE 4.74

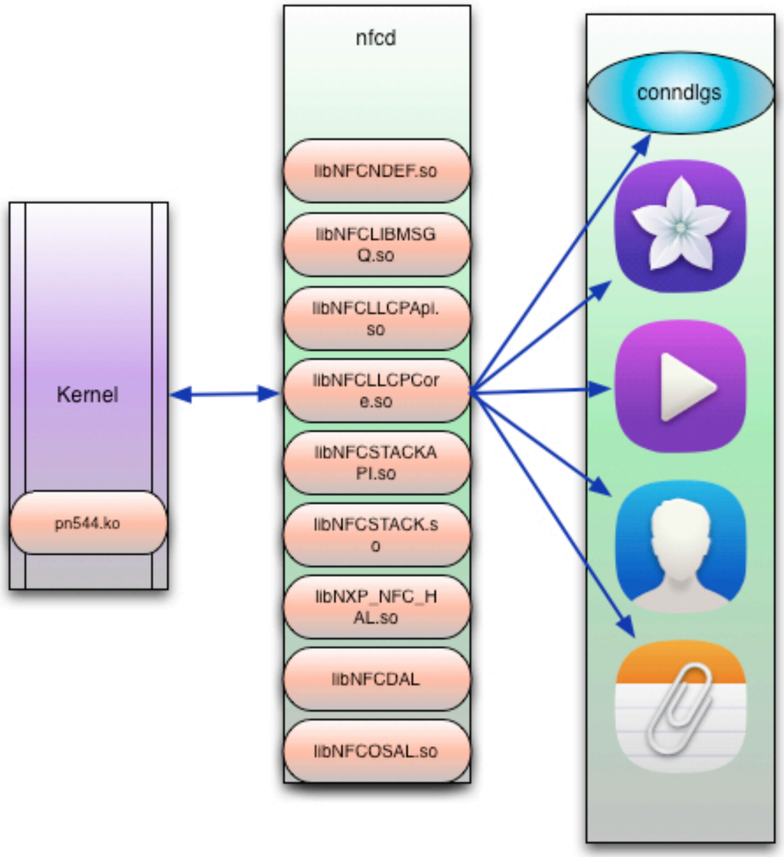


Figure 18: Actual Nokia N9 attack surface

Possible attacks

Looking at the above discussion, there are a few avenues of attack. We'll discuss a few in detail. In each of them we assume an attacker can get close enough to an active phone to cause an NFC transaction to occur. We also assume that the screen is on and, when necessary, the device is not locked. This might be getting very close to someone using their phone, putting a device next to a legitimate NFC payment terminal, or using some kind of antenna setup to do it across the room, see [22].

From [23], active reads have been made of NFC from a distance of up to 1.5 meters.

Android NFC Stack bug

If one were to exploit one of the NFC stack bugs shown earlier in Android, you could imagine exploiting it and getting control of the NFC Service. This isn't necessarily the best process for an attacker to control. If you look at the AndroidManfiest.xml file for com.android.nfc, you see it does not contain Internet permissions. It will be difficult for an attacker to exfiltrate data over the Internet without this permission, although it is possible, see [24]. However, the NFC Service does have BLUETOOTH and BLUETOOTH_ADMIN, so it is probably possible to establish a Bluetooth connection with the attacker. As we'll see for the N9 below, if an attacker can bluetooth pair with the device, it is possible to take complete control of the device.

Android Browser

Since an attacker can force an active device to display an arbitrary web page, armed with an Android browser exploit, an attacker can compromise an active device with an NFC tag. In this case, the attacker will be running code in the browser itself and not in the NFC service.

N9 Bluetooth pairing

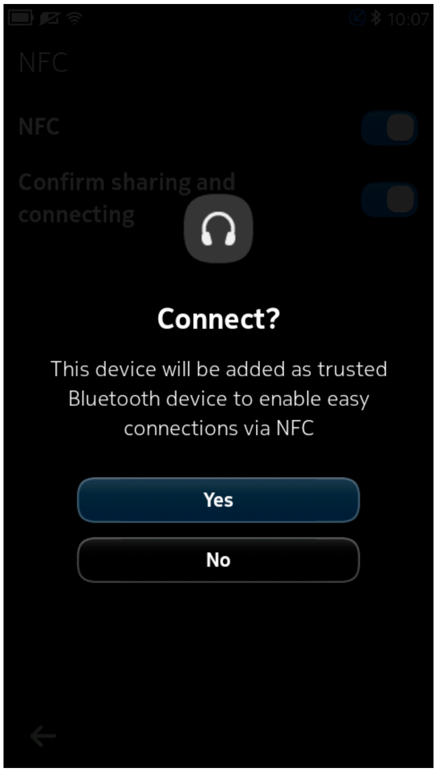
If the N9 has NFC enabled and does not have "Confirm sharing and connecting" enabled (see Figure 17), if you present it a Bluetooth Pairing message, it will automatically pair with the device in the message without user confirmation, even if Bluetooth is disabled.

An example of such an NDEF message is

```
[0000] d4 0c 27 6e 6f 6b 69 61 2e 63 6f 6d 3a 62 74 01  ..'nokia.com:bt.
[0010] 00 1d 4f 92 90 e2 20 04 18 31 32 33 34 00 00 00  ..O... ..1234...
[0020] 00 00 00 00 00 00 00 00 00 0c 54 65 73 74 20 6d  ..........Test m
[0030] 61 63 62 6f 6f 6b                                acbook
```

In this message, a PIN is given as "1234", a Bluetooth address, and a name of the device are also provided. Once paired, it is possible to use tools such as obexfs, gsmsendsms, or xgnokii to perform actions with the device. Basically, if a user just enables NFC and makes no other changes to the device, it can be completely controlled by an attacker if the attacker can get it read an NFC tag.

On the other hand, If you have "Confirm sharing and connecting" enabled, a prompt appears that looks like that seen in Figure 19, below.



Connect?

This device will be added as trusted Bluetooth device to enable easy connections via NFC

Figure 19: The prompt raised if notification is required

A similar attack against a Nokia 6212 was outlined in [25] except the authors didn't know how to make the device complete the pairing process and so tried additional ways to try to activate the Bluetooth. Also, due to the fact they never succeeded in pairing, they uploaded an app instead of trying to control the device. Finally, on the 6212, by default, the device prompted before pairing where by default the N9 does not.

N9 bugs

If the victim has the Confirm sharing and connecting feature enabled, then the attacker will have to resort to Content Sharing as an attack vector. Recall that without user interaction, it is possible to force the Nokia N9 to parse and display a variety of file formats, oftentimes in outdated libraries.

If one were to try to use PNG files, for example, the version of PNG shipped on the latest N9 firmwares is 1.2.42. There are at least two critical vulnerabilities that have been found and patched since that release, as shown in [26].

If one wanted to find their own vulnerabilities, they would just have to spend some time fuzzing. To demonstrate this, we briefly fuzzed the Documents application on the Nokia N9. Here are a couple of interesting crashes that we found, as seen in valgrind.

First a crash for PPT rendering,

```
==3572== Thread 2:
==3572== Invalid free() / delete / delete[] / realloc()
==3572==    at 0x48347B4: free (vg_replace_malloc.c:366)
==3572==    by 0x5DE780F: free_mem (in /lib/libc-2.10.1.so)
==3572==    by 0x5DE71F7: __libc_freeres (in /lib/libc-2.10.1.so)
==3572==    by 0x48285B7: _vgnU_freeres (vg_preloaded.c:61)
==3572==    by 0x5DB5AC3: __libc_enable_asynccancel (libc-cancellation.c:66)
==3572==    by 0x6826CAF: ??? (in /lib/libglib-2.0.so.0.2800.4)
==3572==  Address 0x7491f30 is not stack'd, malloc'd or (recently) free'd
```

Here is one for PDF rendering.

```
==4002== Invalid write of size 1
==4002==    at 0x7290FB4: SplashXPathScanner::clipAALine(SplashBitmap*, int*,
int*, int) (in /usr/lib/libpoppler.so.13.0.0)
==4002==  Address 0xf8dc5090 is not stack'd, malloc'd or (recently) free'd
```

Finally, here is one in DOC rendering. (Note, this is a 0-day not only for Nokia N9 via NFC, but also for Koffice, which utilizes the same libraries). The following excerpt comes from the file koffice-2.3.3/filters/kword/msword-odf/wv2/src/styles.cpp.

```
bool STD::read( U16 baseSize, U16 totalSize, OLEStreamReader* stream, bool
preservePos )
...
    grupxLen = totalSize - ( stream->tell() - startOffset );
    grupx = new U8[ grupxLen ];
    int offset = 0;
    for ( U8 i = 0; i < cupx; ++i) {
        U16 cbUPX = stream->readU16();  // size of the next UPX
        stream->seek( -2, G_SEEK_CUR ); // rewind the "lookahead"
        cbUPX += 2;                     // ...and correct the size

        for ( U16 j = 0; j < cbUPX; ++j ) {
            grupx[ offset + j ] = stream->readU8();  // read the whole UPX
        }
...
```

In this function, it allocates a buffer for the array grupx based on a parameter passed to this function. It then fills in this array based on an unsigned short read in directly from the file, stored in the variable cbUPX. In this case, the length of a copy and the data being copied is read directly from the supplied file, which leads to an ideal heap overflow. Depending on the way memory is manipulated, it is possible to get control of the process using this vulnerability. Below demonstrates one such trial.

```
Program received signal SIGSEGV, Segmentation fault.
0x18ebffaa in ?? ()
(gdb) bt
#0  0x18ebffaa in ?? ()
#1  0x41f61f64 in wvWare::Parser::~Parser() () from /usr/lib/libkowv2.so.9
#2  0x41f6537c in ?? () from /usr/lib/libkowv2.so.9
#3  0x41f6537c in ?? () from /usr/lib/libkowv2.so.9
(gdb) x/2i 0x41f61f5c
```

```
   0x41f61f5c <_ZN6wvWare6ParserD2Ev+232>:      ldr   r12, [r3, #4]
   0x41f61f60 <_ZN6wvWare6ParserD2Ev+236>:      blx   r12
(gdb) print /x $r3
$3 = 0x41414141
```

In this case, a value read from the file is used as a pointer. This data where this pointer points is then read and used as a function pointer. With minimal work, this would lead to control of program flow and ultimately code execution.

Summary

Any time a new way for data to enter a device is added, it opens up the possibility of remote exploitation by an attacker. In the case of NFC, a user would typically think that the new data would be limited to just a few bytes embedded in an NFC tag. This document shows that the new attack surface introduced by NFC is actually quite large. The code responsible for parsing NFC transmissions begins in kernel drivers, proceeds through services meant to handle NFC data, and eventually ends at applications which act on that data. We provide techniques and tools to carry out fuzzing of the low level protocol stacks associated with NFC.

At a higher level, for both the Android and MeeGo device we examined, it is possible through the NFC interface to make the device, without user interaction, parse web pages, image files, office documents, videos, etc which most users of NFC would probably be surprised to learn.

NFC offers convenience to share files and games as well as make mobile payments. However, since anytime an attacker is in close proximity to a victim, she can force the victim’s device to parse one of over 20 different formats without user interaction, it has to raise security concerns.

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