Mobile Devices Security

On Practical Risks of NFC Payments

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Part ONE

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”)

13,56 MHz

NFC vs. RFID

- 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 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 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.

Part TWO

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 provider as well
  - The smart phone OS is the right place!
  - Apple’s Passbook may serve for an illustration.

Part THREE

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].

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.

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

What Does It Mean Anyway

- Besides obvious 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!

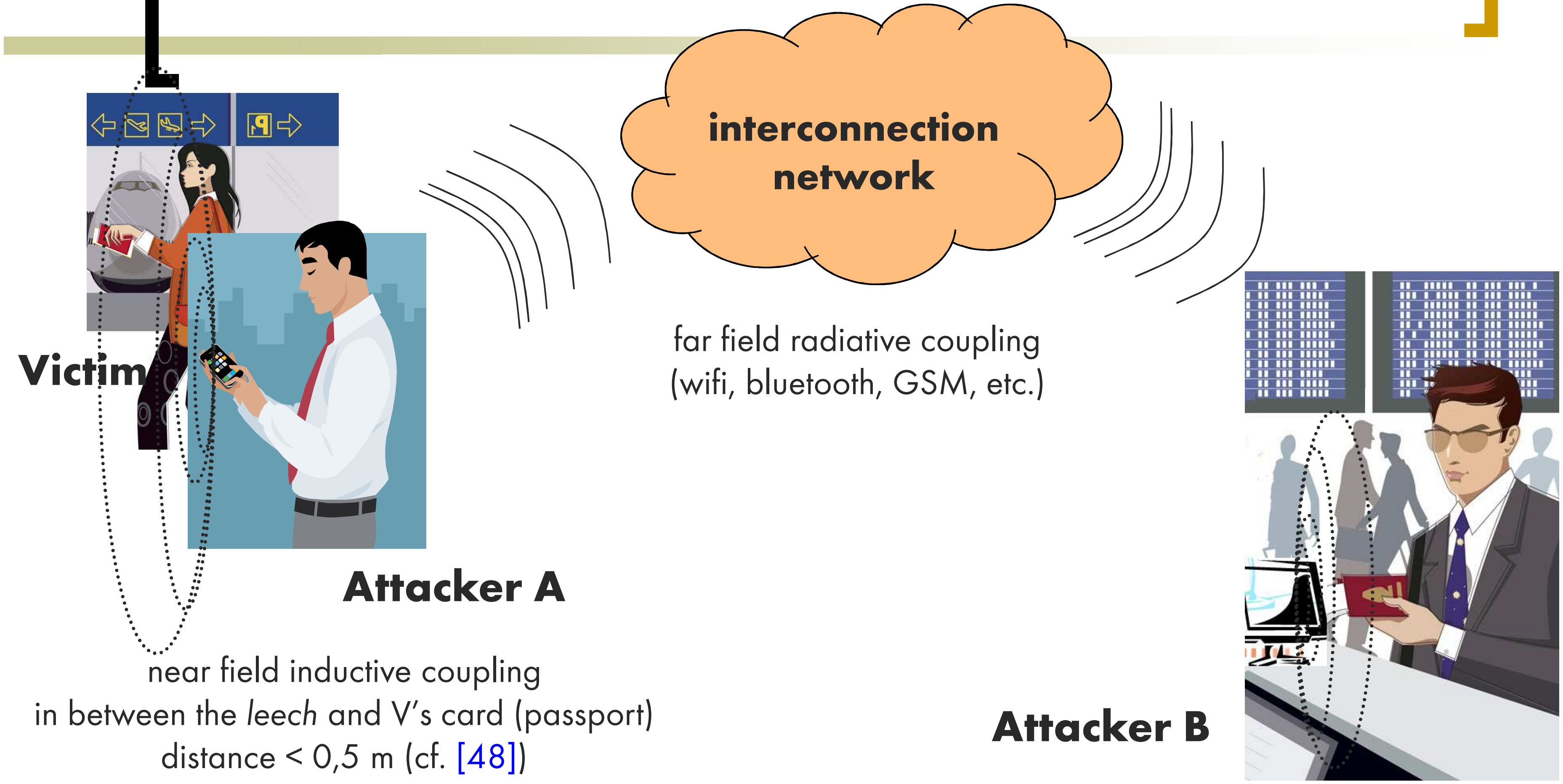
But…

- … 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…

Part FOUR

Attacking Scenarios

Wormhole Attack Illustrated



interconnection network

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

Victim

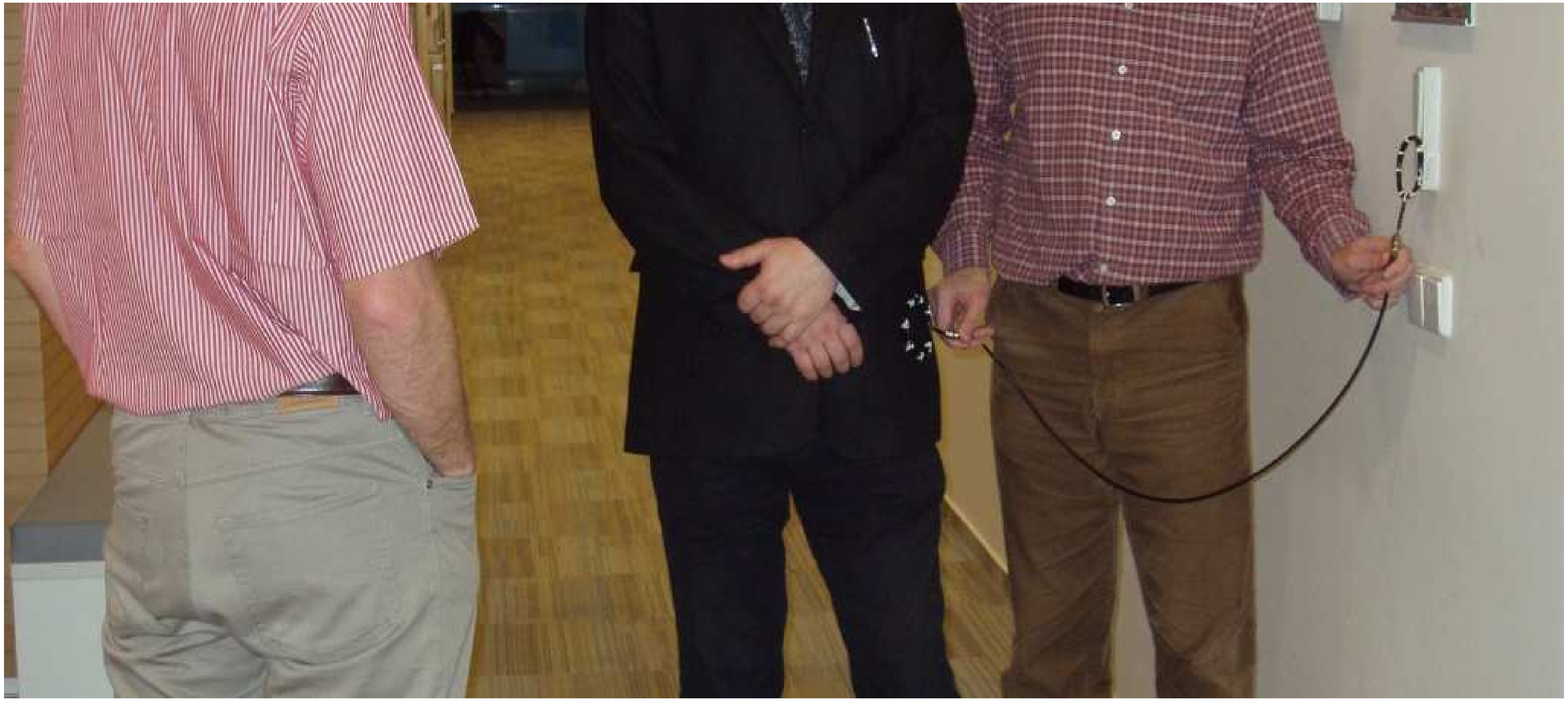
Attacker A

Attacker B

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

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

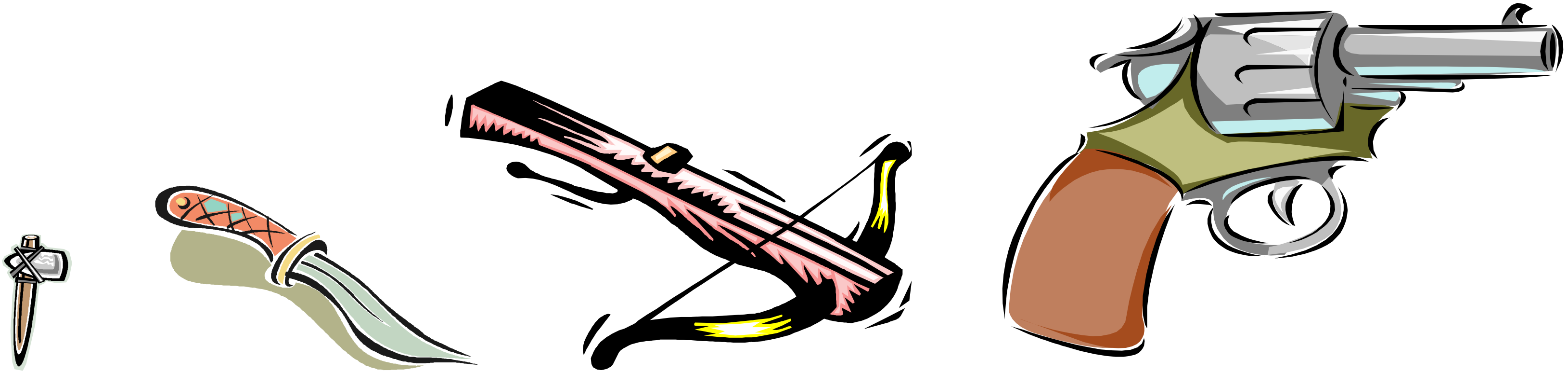
Wormhole In Access Control



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

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 emulated 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

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.

Part FIVE

Tweaking iOS Peripherals

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.

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 ↔ 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 ↔ 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:] (l@:^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:] (l@:^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!..
```

Part SIX

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.

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.

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 agent 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.

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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