Can we redesign mobile payments to deal with poor networks and cut transaction fees?

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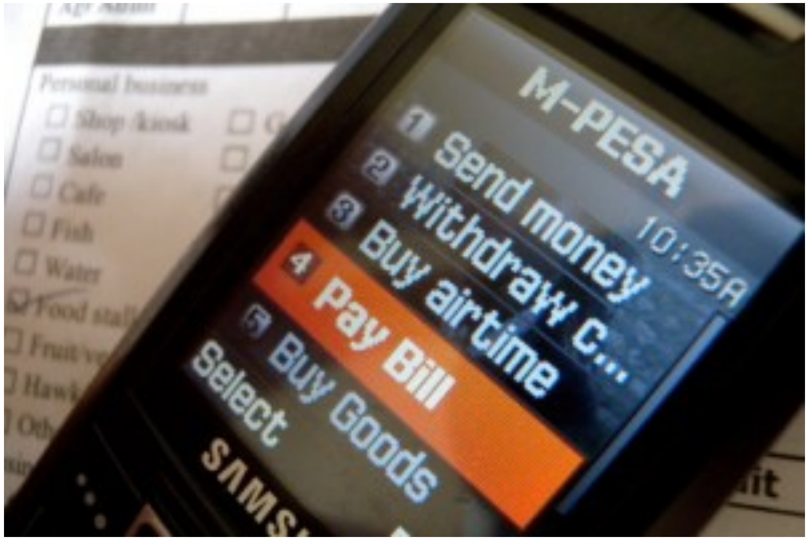
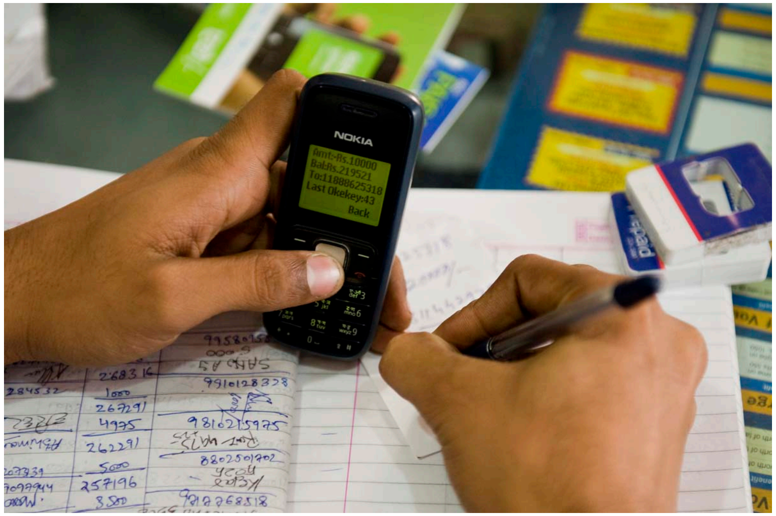
The mobile money revolution





Mobile money achievements

- Helped poorest communities in many ways!
- Brought banking services to hundreds of millions who didn't have them
- Built mechanisms for direct payments and remittances; store of value; personal safety; transaction history; access to credit
- Provided direct channel for government payments and services
- Connected lots of people to the online world

What are the remaining challenges?

- Is our priority to:
- Extend payments to areas with no mobile service (mountains, deserts, islands)?
- Make service still work when network service intermittent (congestion, power cuts)?
- Cut network charges / transaction fees?
- Establish standards and interoperability for international remittances?

Who we are

- Cambridge University Computer Laboratory is interested in payment security and fraud
- The Cambridge Cybercrime Centre now collects data on online scams and abuse
- During the 1990s we studied fraud on ATMs using magnetic-strip cards
- We helped develop the STS prepayment meter systems used to electrify millions of households (South Africa, Brazil … even Kenya!)

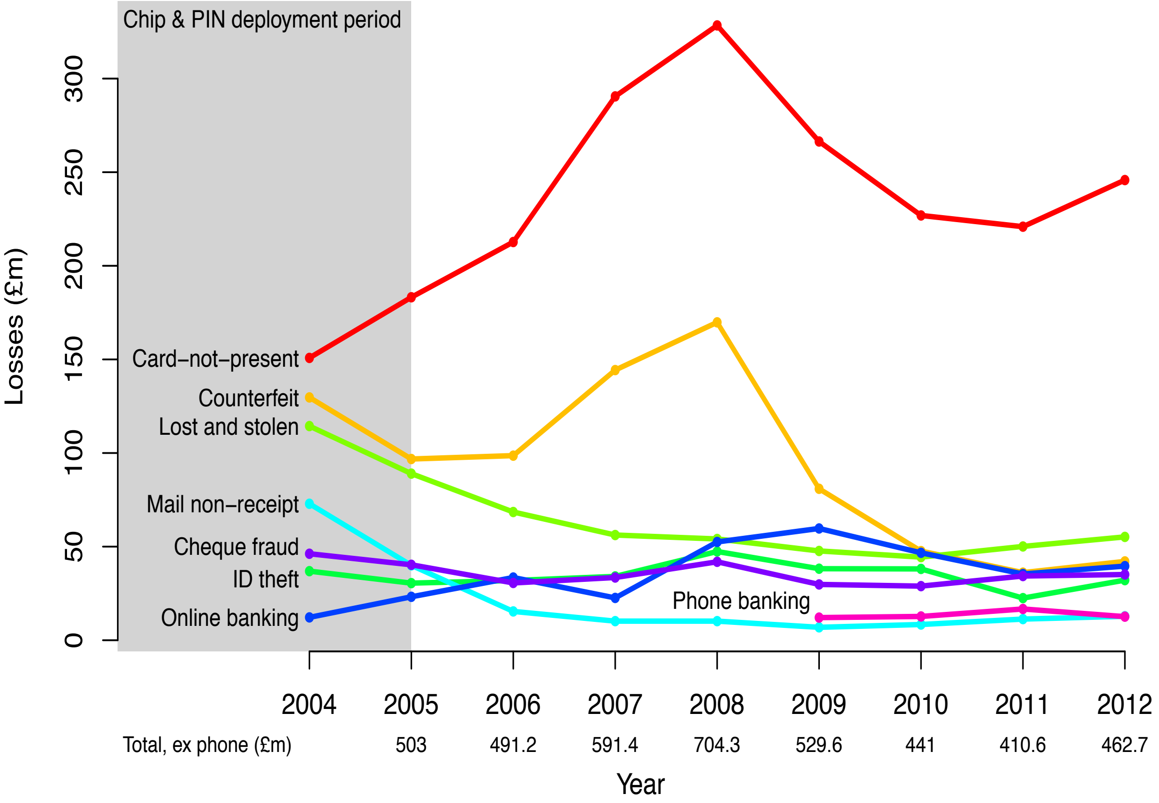
EMV ('Chip and PIN')

Chip and PIN

EMVCo

- Deployed in Europe and elsewhere since 2003–5
- 'Liability shift' – disputes are charged to the card holder if PIN was used, else to the merchant
- Changed many things, not always in the ways banks expected…

Fraud history, UK

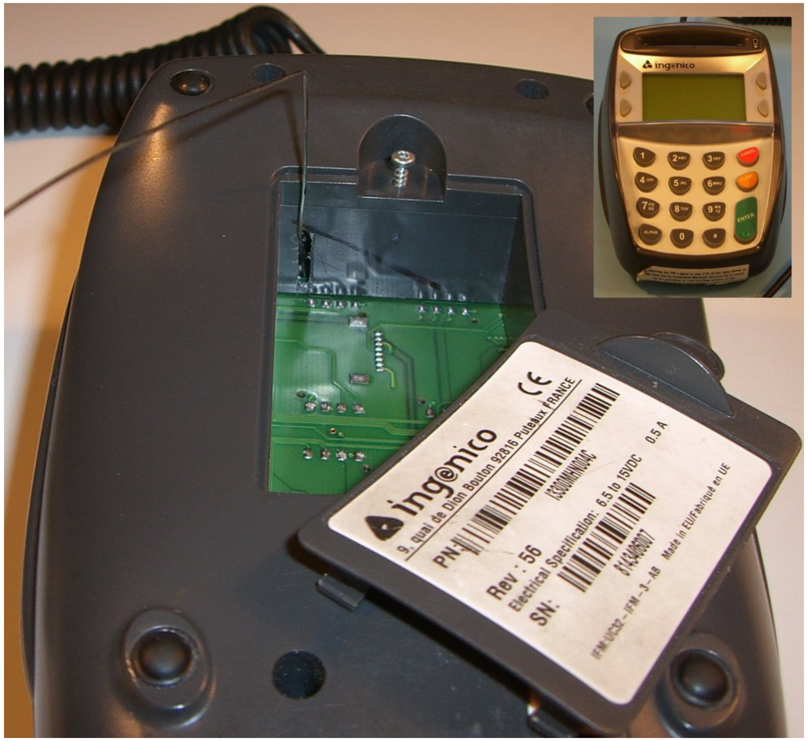


- Cardholder liable if PIN used
- Else merchant pays
- Banks hoped fraud would go down
- It went up …
- Then down, then up again

Attacks on EMV in the real world

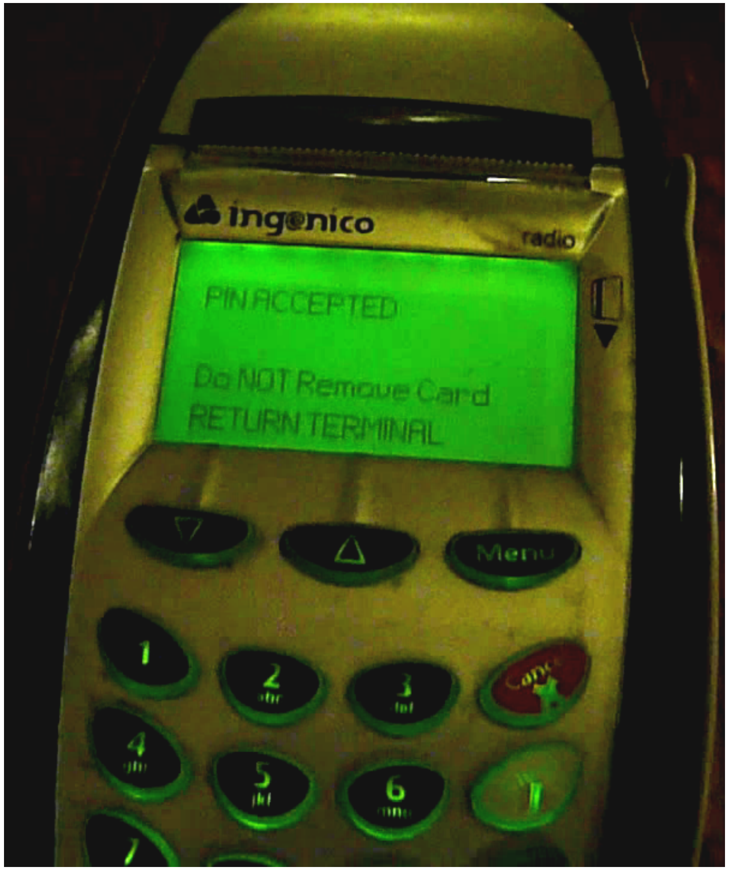
- The first thing the bad guys did was to go for mail order, phone order and Internet fraud
- Then mag-strip fallback fraud ballooned as people were now entering PINs everywhere
- PEDs tampered at Shell garages by ‘service engineers’ (PED supplier was blamed)
- Then ‘Tamil Tigers’
- After fraud at BP Girton: we investigate

TV demo: Feb 26 2008


ingenico
9, quai de Dion Bouton 92816 Puteaux FRANCE
PN:
Rev : 56
Electrical Specification: 6.5 to 15VDC 0.5A
SN:
Made in EU/Fabriqué en UE
ENTER

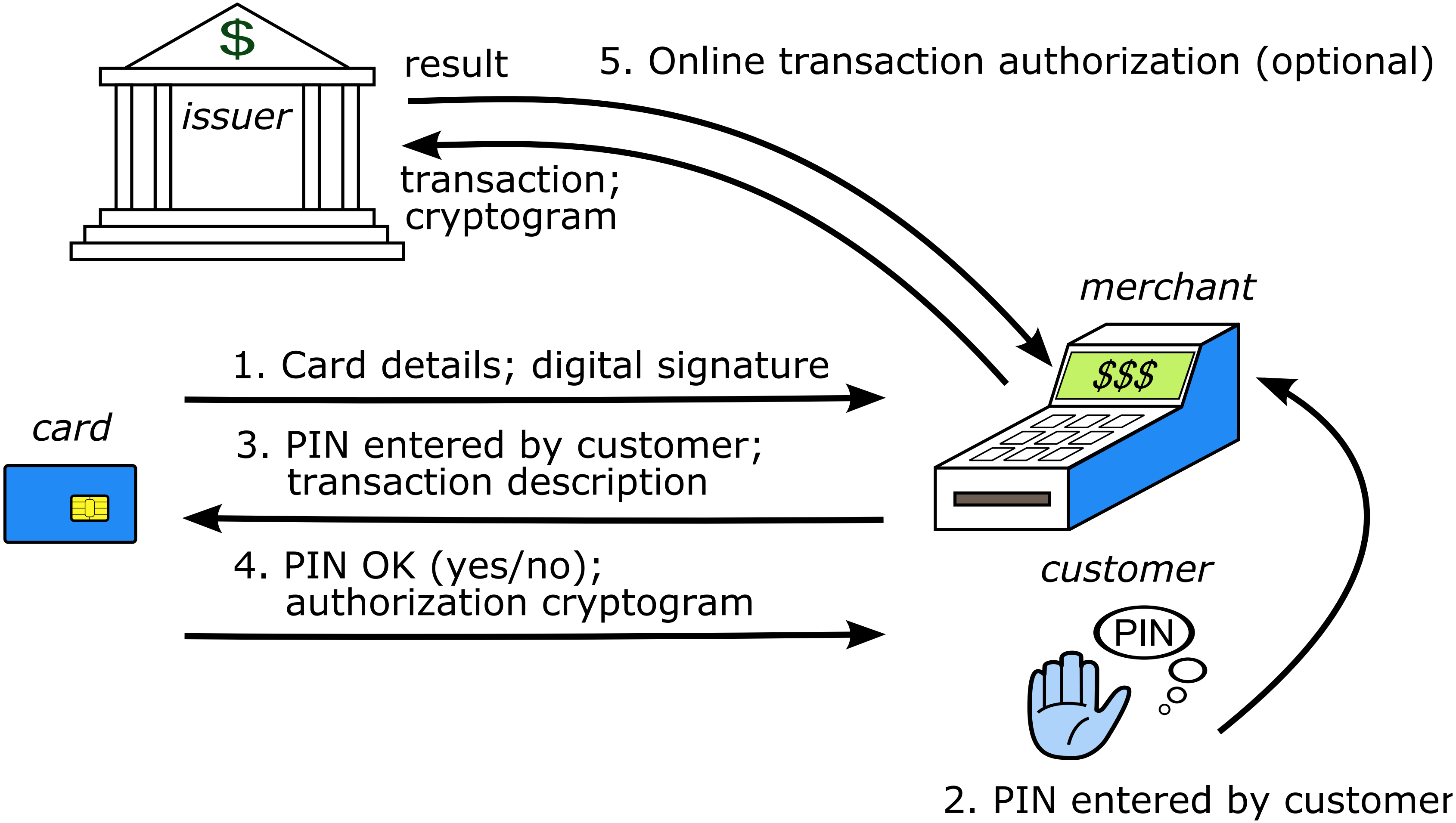
- PEDs ‘evaluated under the Common Criteria’ were trivial to tap
- Acquirers, issuers have different incentives
- Banks said (Feb 08) it wasn’t a problem…
- Khan case (July 2008)
- Trial (Oct 2011): banks offered no evidence…

The ‘No-PIN’ attack



- Victims told us: crooks seem to be able to use a stolen card without knowing the PIN
- How? We found: insert a device between card & terminal
- Card thinks: signature; terminal thinks: pin
- TV: Feb 11 2010

A normal EMV transaction



issuer

result

5. Online transaction authorization (optional)

transaction;
cryptogram

merchant

1. Card details; digital signature

card

3. PIN entered by customer;
transaction description

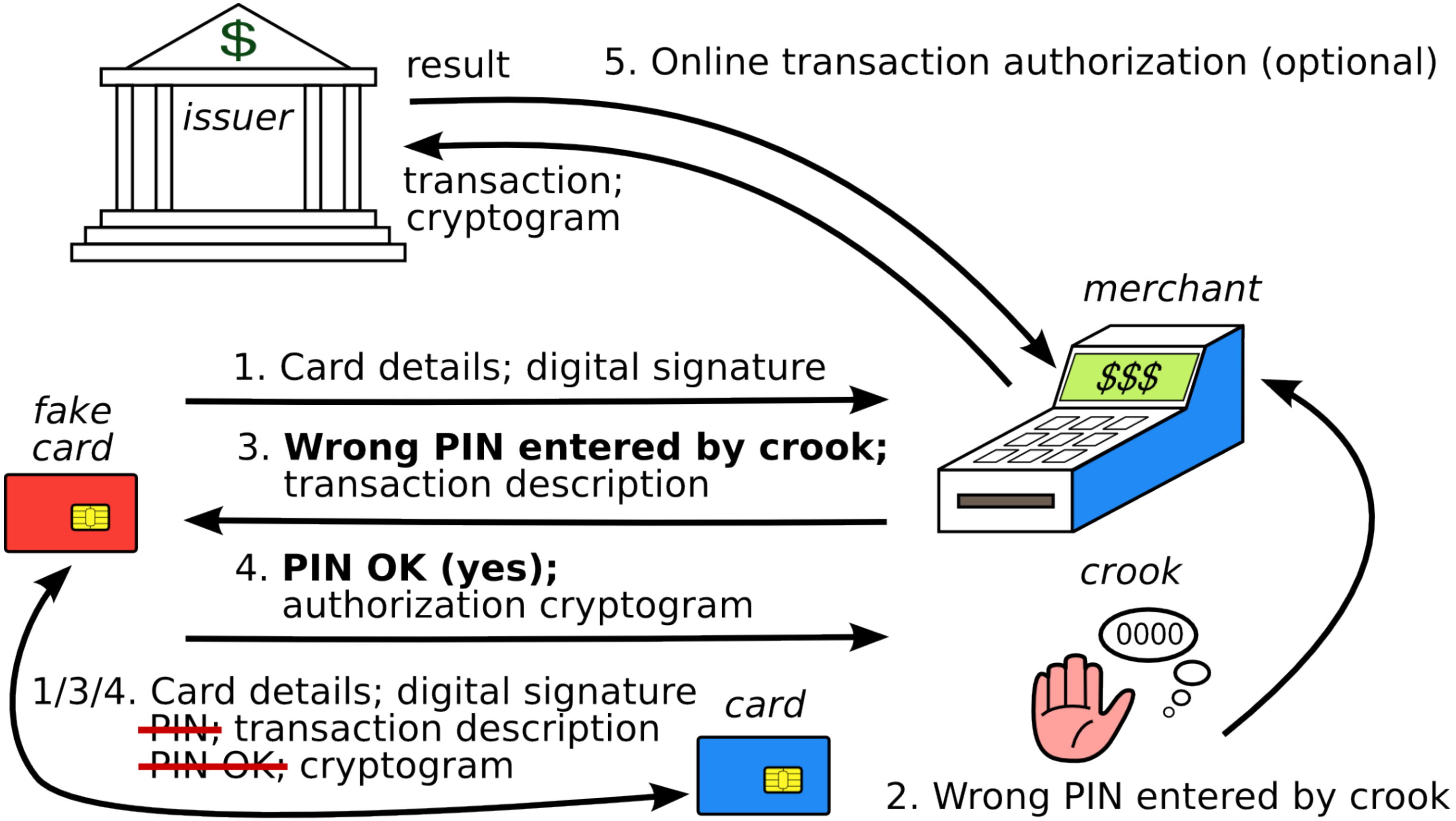
4. PIN OK (yes/no);
authorization cryptogram

customer

PIN

2. PIN entered by customer

A ‘No-PIN’ transaction


issuer
$
result
5. Online transaction authorization (optional)
transaction;
cryptogram
merchant
$$$
1. Card details; digital signature
fake
card
3. **Wrong PIN entered by crook;**
transaction description
4. **PIN OK (yes);**
authorization cryptogram
crook
0000
1/3/4. Card details; digital signature
~~PIN;~~ transaction description
~~PIN OK;~~ cryptogram
card
2. Wrong PIN entered by crook

EMV and Random Numbers

- In EMV, the terminal sends a random number N to the card along with the date d and the amount X
- The card computes an authentication request cryptogram (ARQC) on N, d, X
- What happens if I can predict N for d?
- Answer: if I have access to your card I can precompute an ARQC for amount X, date d

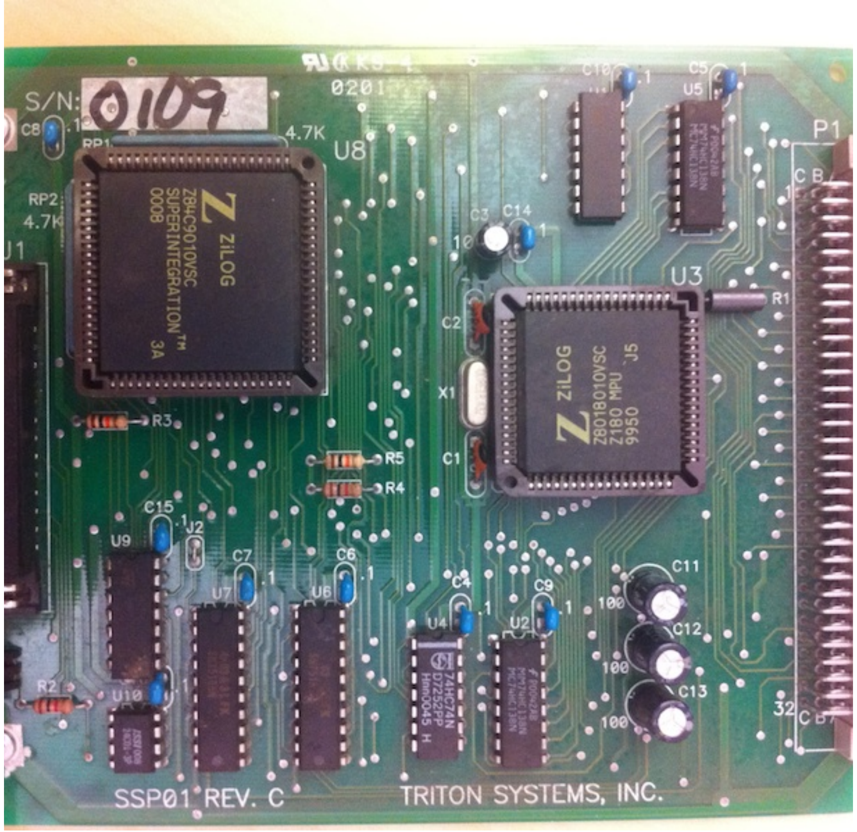
ATMs and Random Numbers (2)

- Log of disputed transactions at Majorca:

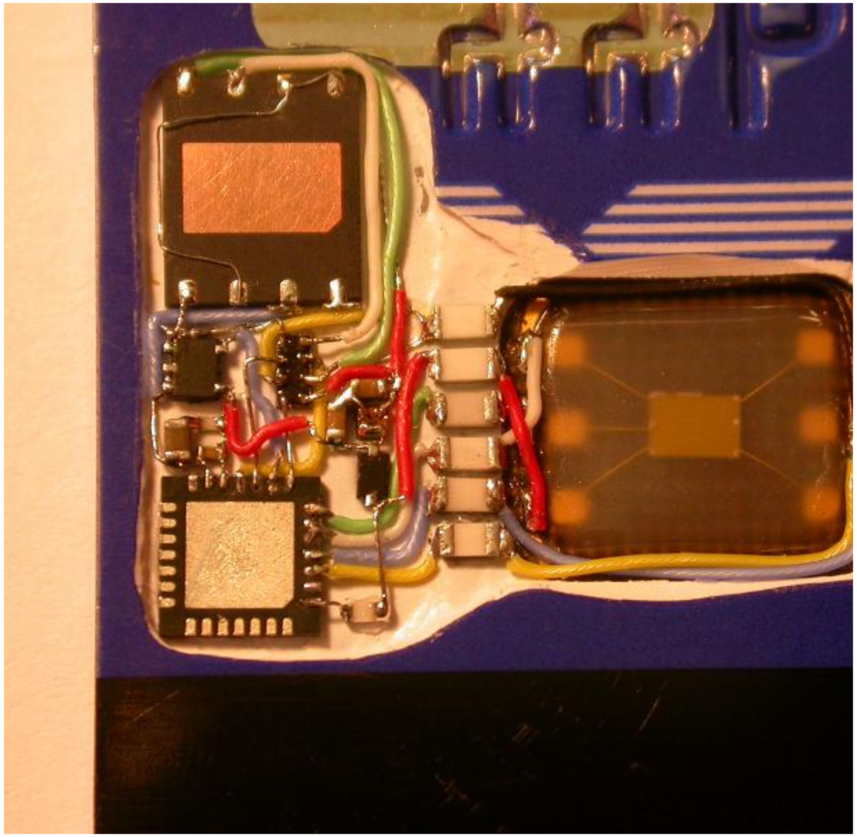
```
2011-06-28          10:37:24          F1246E04
2011-06-28          10:37:59          F1241354
2011-06-28          10:38:34          F1244328
2011-06-28          10:39:08          F1247348
```

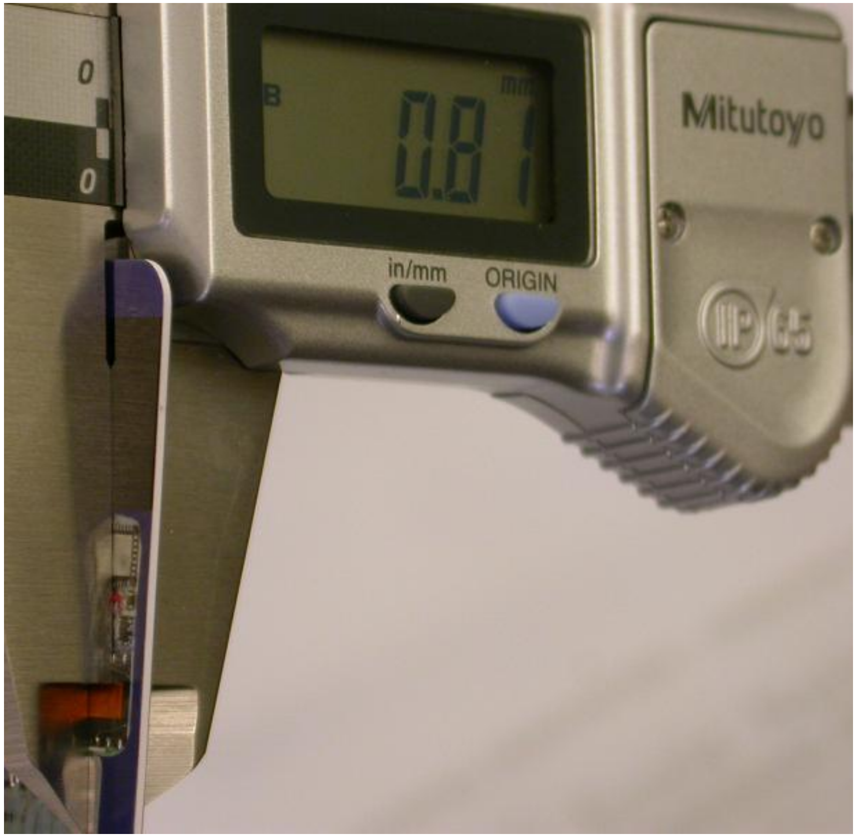
- N is a 17 bit constant followed by a 15 bit counter cycling every 3 minutes
- We test, & find half of ATMs use counters!

ATMs and Random Numbers (3)



ATMs and Random Numbers (4)





The preplay attack

- Collect ARQCs from a target card
- Use them in a wicked terminal at a collusive merchant, which fixes up nonces to match
- We won an interesting test case in 2015…
- Sailor spent €33 on a drink in a Spanish bar. He got hit with ten transactions for €3300, an hour apart, from one terminal, through three different acquirers, with ATC collisions
- So: how can we apply all this to mobile?

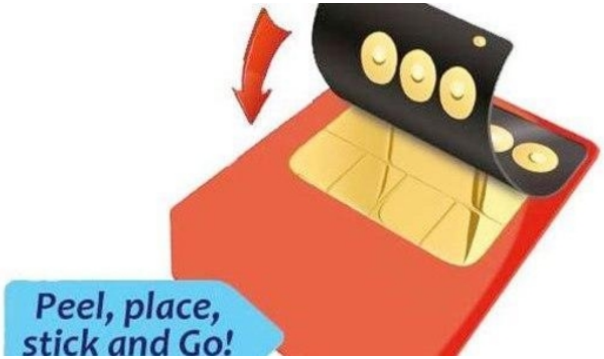
The DigiTally project

- The Gates Foundation asked for ideas to increase merchant use of mobile money
- We talked to operators and users in several countries: issues were network access, costs
- So: how can you do a payment between two phones when there's no GSM signal?
- It's easy with two smartphones, but what about basic handsets?

DigiTally

- DigiTally is a prototype purse system we've built to do research on offline mobile payments
- It works by copying short authentication codes from one phone to another
- Our prototype is implemented in overlay SIMs for use in simple phones
- It can also be implemented in your SIM toolkit or as a smartphone app

Overlay SIMs



- Tamper-resistant SIM
- Sticks on top of the regular SIM
- Bypasses the mobile network operator
- Independent secure device, like SE in NFC
- Can be used to compute authorization codes, just as in EMV

DigiTally payment, step 1

- Alice wants to pay Bob $4 for a taxi ride
- The first step is for each of them to give the other their phone number which they each enter into their DigiTally menus
- This is just like in current systems, where Alice and Bob use the phone system to verify and store each other's phone numbers

DigiTally payment, step 2

- Bob then enters the amount, “$4” on his phone
- It shows an 8-digit authorization request, say ‘4761 0825’ which he reads to Alice
- She taps “$4” and “4761 0825” on her phone
- If they agree on the two phone numbers and the amount, then Alice’s phone proceeds to the next stage

DigiTally payment, step 3

- Alice enters her PIN (just like in a normal phone payment)
- Her phone displays “$4 paid” and an 8-digit authorization response, say “6409 3527”, which she reads to Bob
- He taps in the code
- If it’s correct, his phone displays “$4 received” with a full log of the transaction

Usability lessons learned

- Prepayment meters widely introduced 20 years ago (South Africa, Brazil, Kenya …)
- People have no difficulty copying 20 digits

Operations

- As now, village agent recruits customers, merchants, and installs overlay SIMs in their phones
- And customers pay money to load their purse
- And the payment service operator maintains a system of shadow purse accounts
- All that changes is that whenever a customer or merchant goes into an area with working network service, the overlay SIM uploads transaction history

Security case

- Implementation in tamper-resistant overlay SIMs or other secure products acceptable to the banks
- Cryptography can use AES or 3DES to generate authentication codes
- The payment protocol was formally verified and sent to the Security Protocols Workshop this spring for peer review
- Here is the basic version…

Under the hood

- When Alice agrees to pay Bob X, each of them enters both this amount and the other party's phone number into their phones
- Bob chooses a 4-digit nonce N_B and forms a 4-digit MAC C (using the shared secret key K) of B and X
- He tells Alice the 8 digits

$$(N_B, C) \text{ where } C = MAC_K\{B,A,X,N_B\}$$

Under the Hood II

- Alice types in the digits, verifies the MAC, then authorises the transaction (using her PIN)
- It decrements the value counter by X, creates a 4-digit nonce and computes a 4-digit response which she reads or shows to Bob:

$$(N_A, R) \text{ where } R = MAC_K\{A, N_A, X, N_B, B\}$$

- Bob enters the 8 digits (N_A, R) into his phone, and checks that it increments by X

DigiTally benefits

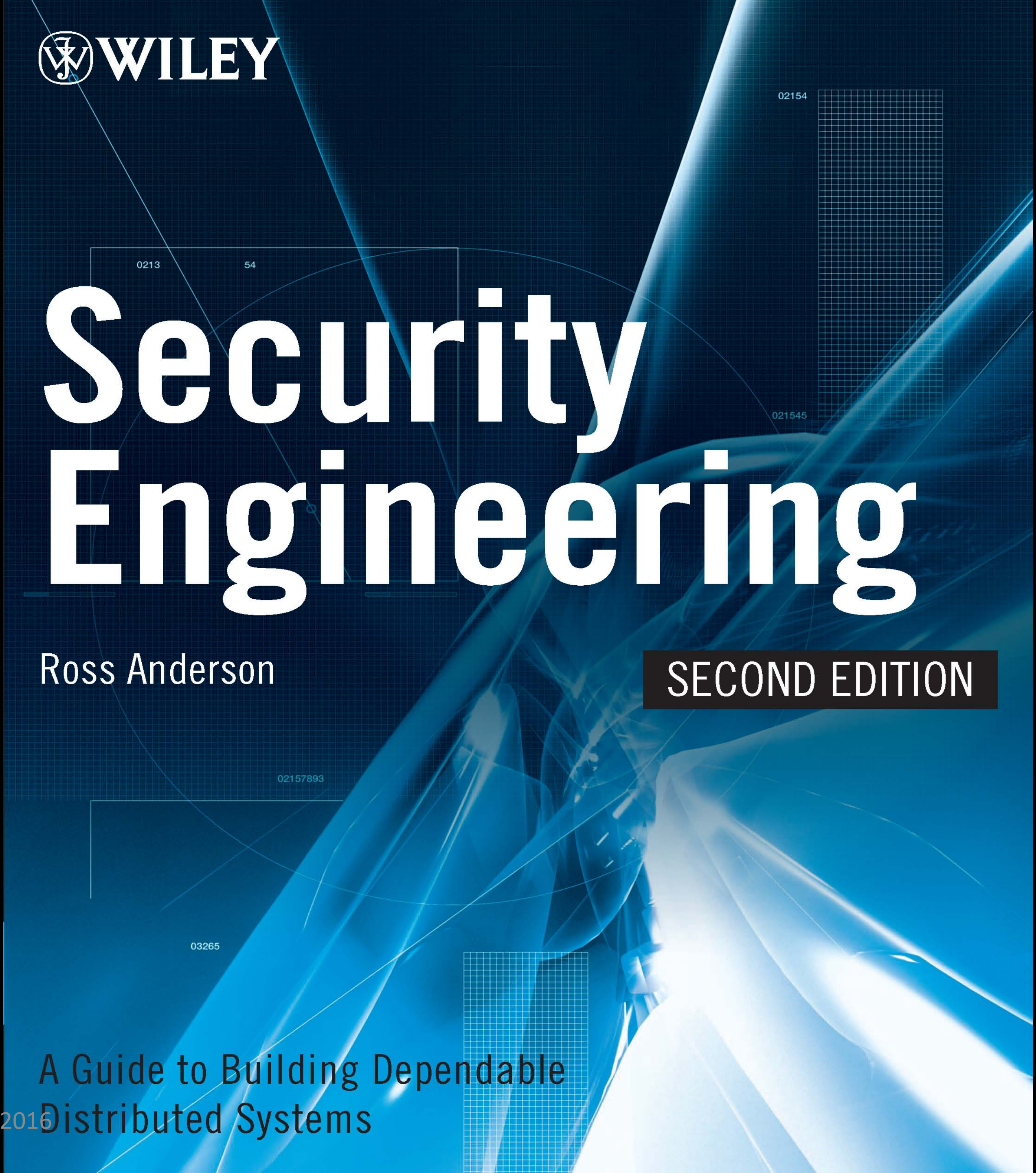
- Serve customers in villages with no network
- Serve customers when the network is congested or down
- Cut network costs for repeated transactions between the same customer and merchant
- Works for customers who don’t have smartphones (as well as those who do!)
- And perhaps in many other applications…

Next steps

- We have built a prototype offline payment system using an overlay SIM toolkit
- We'll do initial usability study here next week
- Next: incorporate lessons learned in larger-scale field trial
- Goal: free open-source software for all to use!
- What other applications might benefit from offline value transfer?

More

- More on DigiTally at the project web page http://www.cl.cam.ac.uk/~kabhb2/DigiTally/
- More on the security group at http://www.cl.cam.ac.uk/research/security/
- More on bank fraud in our blog http://www.lightbluetouchpaper.org
- And get the book on security engineering from http://www.cl.cam.ac.uk/~rja14/book



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Security Engineering

Ross Anderson

SECOND EDITION

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