TimeTrust

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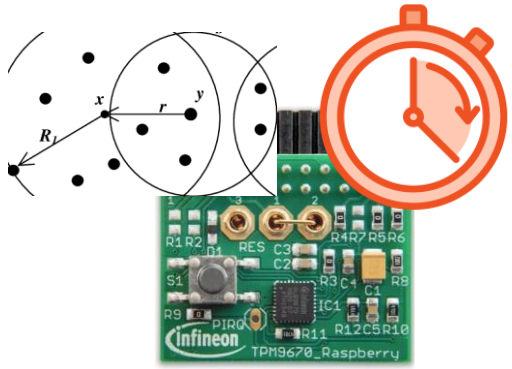
TimeTrust

Robust Timing via Hardware Roots of Trust and Non-standard Hardware
-with Application to EMV Contactless Payments-

Topic: -- using **hardware-roots of trust** to build (~backwards-compatible) counteractions of attacks based on **forging proximity** and/or **forging time checks**

-- focus on **contactless payments** made with bankcards and smart devices (phones)

-- focus on a **formal treatment**, with some practical assessment



Academic Parties

Ioana Boureanu (Lecturer in Secure Systems)

Liqun Chen (Professor in Secure Systems)

Tom Chothia (Senior Lecturer in Cyber Security)

Industry partners/advisors: Main representatives

Mike Ward (Director, Product Development and Innovation, EMV & Digital Devices)

Charles Yuexi Chen (Senior Director - EMV Solutions)

Fraser Dickin (Senior Research Engineer)

Steve Pannifer (Director)

TimeTrust-funded Researchers

Postdoctoral Researcher (Univ. of Birmingham) – Andreea-Ina Radu
-- to start Jan. 2020 until June 2021
-- 18 months

Postdoctoral Research (Univ. of Surrey) -- Dr. Chris Newton
-- to start in March 2020, until October 2021
-- 20 months

TimeTrust Objectives

Objective 1 (via WP2) **--- Security against collusive-relaying** (**CR)**, by using and extending HW-RoT such as **TPMs**

Objective2 (via WP3) -- **Security against CR** for non-standard hardware (ns-HW) such as mobile devices, via **vTPMs and TEEs** and hardware surfaces

Objective 3 (via WP4) **– Privacy in proximity checking**, using HW-RoT and/or vTPMS/ TEEs and/or ns-HW

Objective 4 (via WP5) -- Cryptographic and formal-verification analyses

Objective 5 (via WP6) -- application to **contactless EMV**

- to inform future work into enhancing the security of

EMV against untrustworthy readers

One of TimeTrust's Scopes
-- wireless communication & proximity checking

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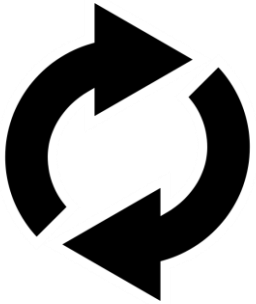
-- relay attacks 
-- proximity checking = the main way to hinder relay
-- present in one EMV contactless payment protocol (Mastercard's RRP)

Would it collude in relaying to take illicit payments ?

!! ALSO, no track in EMV that a reader would do the proximity-checking



time0 ———  ———  ———→

←——— time1

RTT:= time1- time0

? RTT <= bound ?

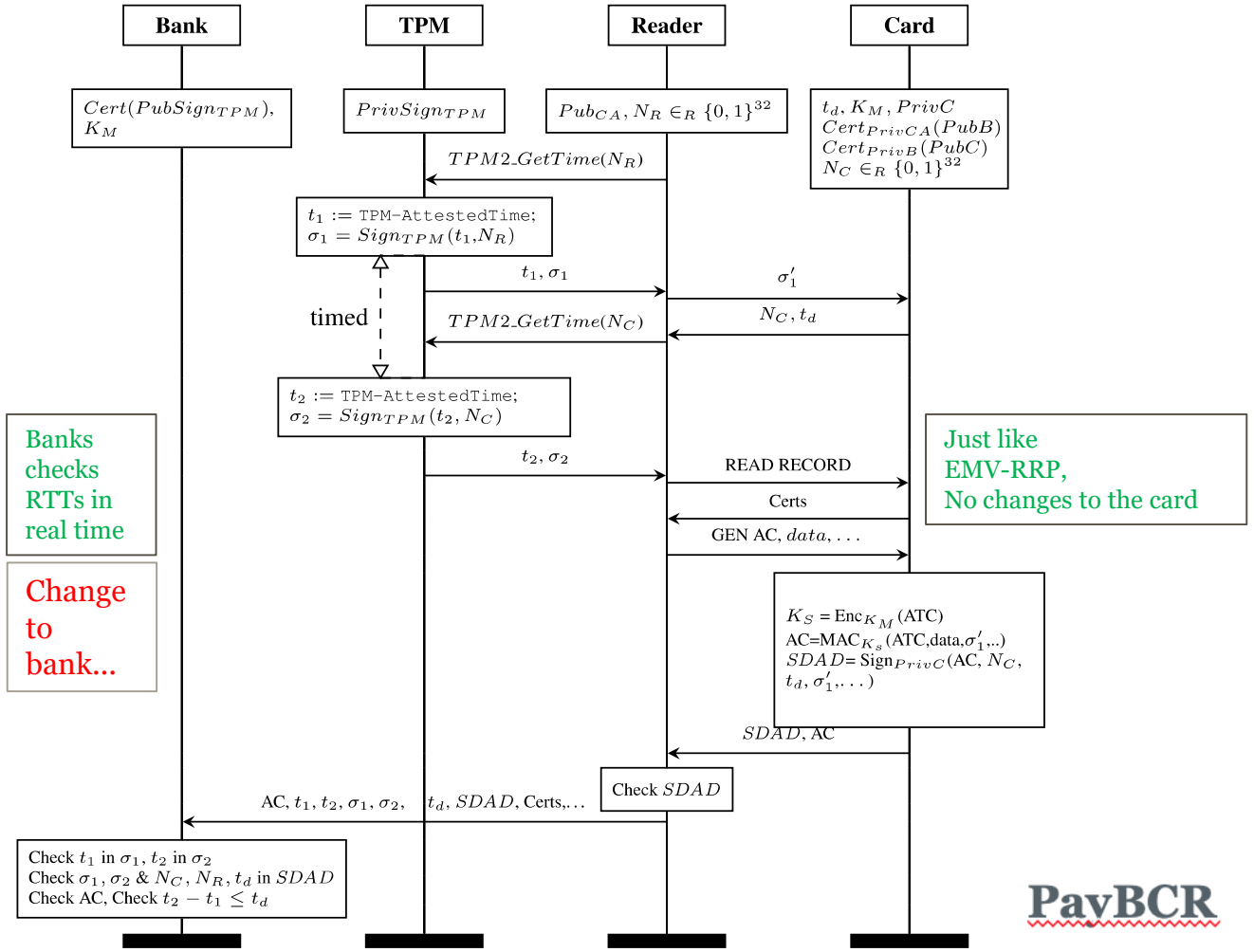
New security notion: **collusive relaying**

FinancialCrypto 19 *[CBC]*

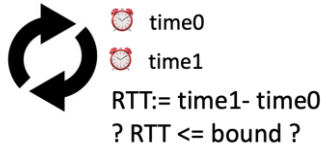
-- introducing PayBCR, PayCCR: ~backwards-compatible RRP + resistance to collusive relaying

Basically, a TPM-based proximity checking mechanism , via two GETTIME() commands.

We do not think we can do efficiently in 1 command, due to TPM being stateless



Our Threat Model for These

- On... distance-bounding 

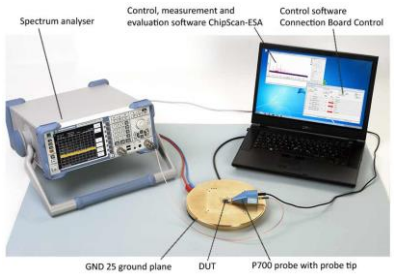
+ EMV  + Trusted computing 



- Attacker can
  1. Corrupt cards, incl. all their key material, use these at any location
  2. Know the readers' key/secret material, control their software, **within the communication model**
  3. **Not** corrupt the TPM in ways unspecified by TCG:
     a. cannot tamper with the initial setup of the TPM's Clock;
     b. cannot mount any physical attack on the TPM's time-reporting TPM-AttestedTime=(Clock, Time)
     c. can deviate the TPM's Clock **only by making it go forward** w.r.t. to the real time **by a negligible fraction.**
- Std. assumptions: cryptographic primitives are secure as per their threat model

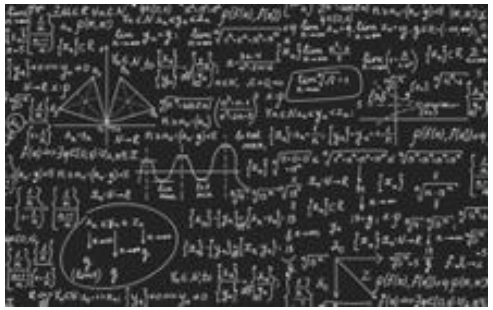
Progress

1. Practice



- Implemented a robust **RRP-relaying app**
- Implemented PayBCR with a TPM 2.0 v1.38, in collaboration with Consult Hyperion
- Tested it against relaying, collusive-relaying and comparing it with RRP

2. Formal



- A first, prototype modelling of RRP in the cryptographic prover (no full TPM specs yet ...) – **EasyCrypt**
- Developed a new symbolic formalism to formally verify PayBCR-like protocols + automatic analysis in **ProVerif**
- ...

Symbolic Verification in Proverif & Cryptographic Proofs in EasyCrypt

```
    new chal:channel;
    out(cP, chal);
    out(SecChal(chal), (tpmID, xnR, sigma1));
    (***)
    out(cP,(time, sigma1));
    0.

et Card(cID:bitstring,tpmID:bitstring) =
    in(cP, CertC:bitstring);
    let Test1 = equals(pubKey(cID), Verify(CertC,pubKey(idBank))) in
    in(cP, CertTPM:bitstring);
    let Test2 = equals(pubKey(tpmID), Verify(CertTPM,pubKey(idBank))) in

    in(cP, xsigma1:bitstring);
    new nC:bitstring;
    event Action(cID, xsigma1, nC);
    out(cP, nC);

    in(cP, (xt2:bitstring, xsigma2:bitstring, xt1:bitstring, xnR:bitstring, xcertTPM:bitstring));
    let Test3 = equals(xcertTPM, CertTPM) in

    out(cP, CertC);
    in(cP, xGen:bitstring);
    let Test4 = equals(xGen, GEN_AC) in
    let (temp:bitstring,a:bitstring) = Verify(xsigma1, pubKey(tpmID)) in
    let (temp:bitstring,b:bitstring) = Verify(xsigma2, pubKey(tpmID)) in
    let TestSigma1 = equals(xnR ,a) in
    let TestSigma2 = equals(nC ,b) in

    event EndC(cID, tpmID, xsigma1, xsigma2);

    let Ks = sEnc(ATC, shk(cID, idBank)) in
    let AC = Mac((ATC, xsigma1, xsigma2), Ks) in
    let SDAD = Sign((AC, xsigma1, xsigma2), secKey(cID)) in
    out(cP, (SDAD, AC));
    0.
```

```
module type Card ={
  proc init(): (pkey*skey)
  proc generateNO(): message
  proc certify(sk: skey,un: message): (message * signature)
  proc send(un: message,sk: skey): (message * signature)
}.

module type Oracle ={

  proc adv_send_as_card (t: ctime, sid:session_id, m: message): unit
  proc hon_card_send (t: ctime, sid: session_id): unit
  proc adv_send_as_reader (t: ctime, sid: session_id, m: message): unit
  proc hon_reader_send (t: ctime, sid: session_id): unit
  proc card_read (t: ctime, sid: session_id): message
  proc reader_read (t: ctime, sid: session_id): message
  proc adv_read(t: ctime, sid: session_id): message
  proc verify_read(sid: session_id): bool option
```

-- main difficulty modelling Euclidean spaces and timing
-- also, modelling the TPM….

Future

- Improve the PayBCR implementation, leveraging at different TPM implementations (... discussions with *Infineon* re GETTIME())

- Look at Visa's L1 solution for relaying

- Look at practical timing-attacks on TPMs/TEEs
- Use TPMs for EMV-aspects other than relays...

- ....

THANK YOU!

For further questions, contact me at
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