The Phish-Market Protocol

Securely Sharing Attack Data Between Competitors

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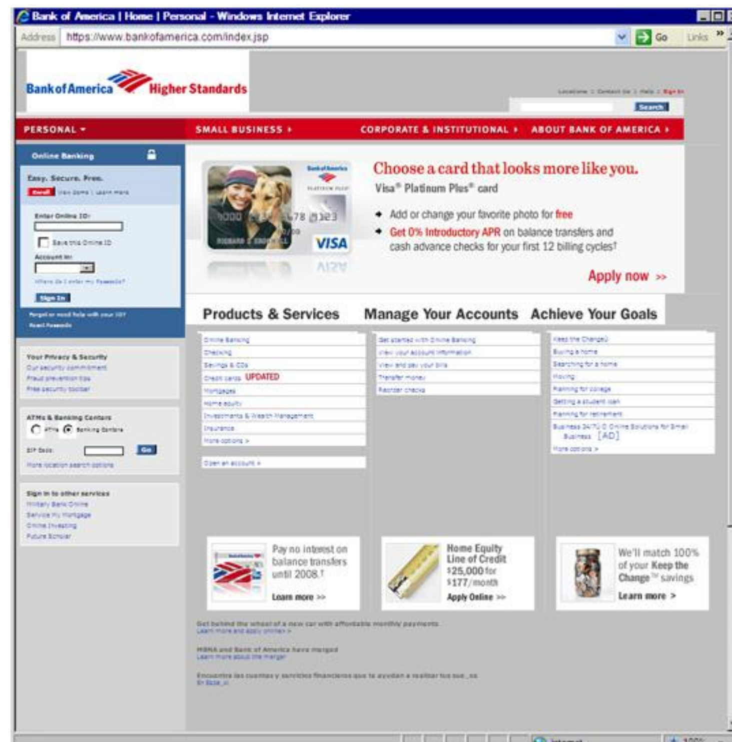
Outline

- Motivation
- Requirements & Challenges
- The Phish-Market Protocol
  - Concepts, not math
- Implementation & performance

Motivation

- Phishing is a serious problem for banks
- Phishers set up fake websites:
  - pretend to be banks
  - link to fake websites in spam
  - scam users into entering passwords



Motivation

- Banks hire `take-down' companies to patrol internet for phishing sites
  - Aggregate multiple URL feeds
  - Read from public sources (e.g., APWG)
  - Proprietary sources (e.g., spam honey traps)
    - Considered competitive advantage
- Take-down companies compete for clients
- Moore and Clayton estimate $330,000,000 cost of refusing to share data

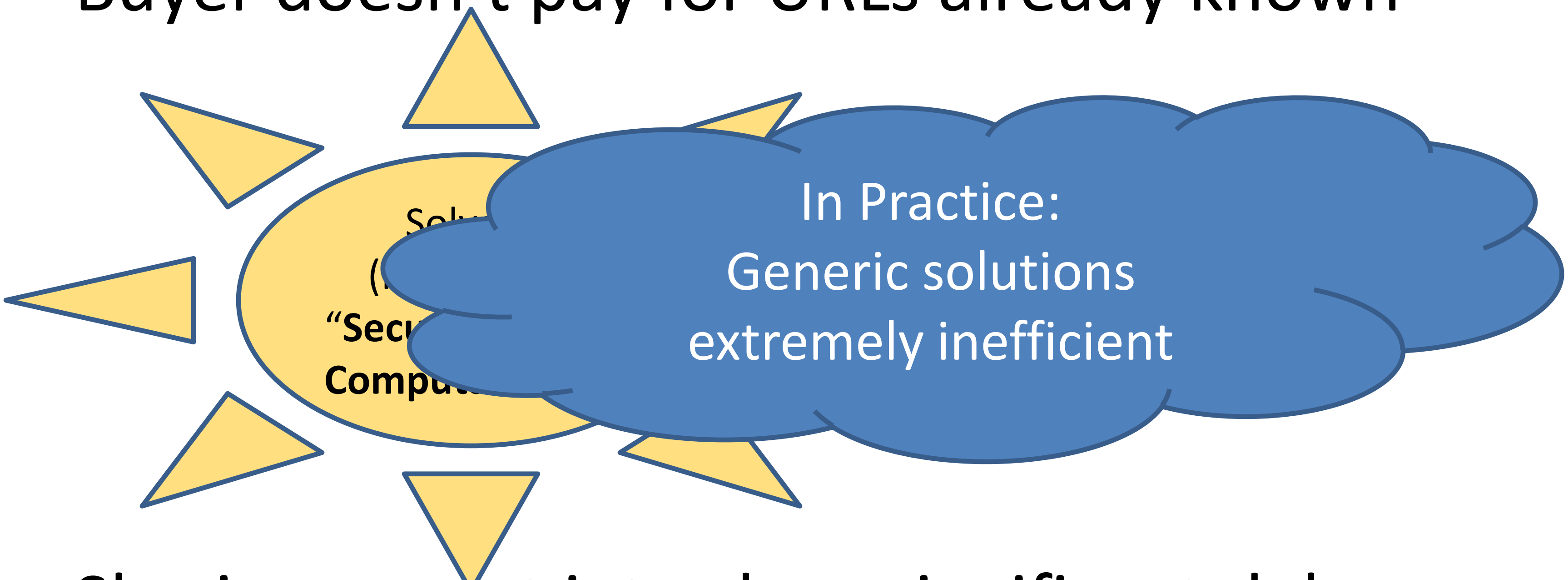
  - For these two companies alone!

The Proposal

- Create a market for phishing data
  - Compensate companies for sharing data
  - Must take competitive interests into account

Requirements & Challenges

- Buyer learns only URLs that phish client banks
- Seller cannot learn who the Buyer's clients are
- Buyer must pay for new each URL learned
- Buyer doesn't pay for URLs already known



- Sharing cannot introduce significant delays

Protocol Ideas

- Idea: “pay” with encrypted “coins”
- Reveal only payment totals
  - Can’t tell which URLs were those “sold”
- Relaxations for efficiency:
  - Buyer learns “tags” (i.e. banks) of *all* Seller URLs
  - Buyer learns which URLs already known to Seller (but does not pay for them)

Transaction Overview

1. Seller offers URL to Buyer
   - Oblivious Transfer

2. Buyer sends encrypted payment
   - Homomorphic Commitment

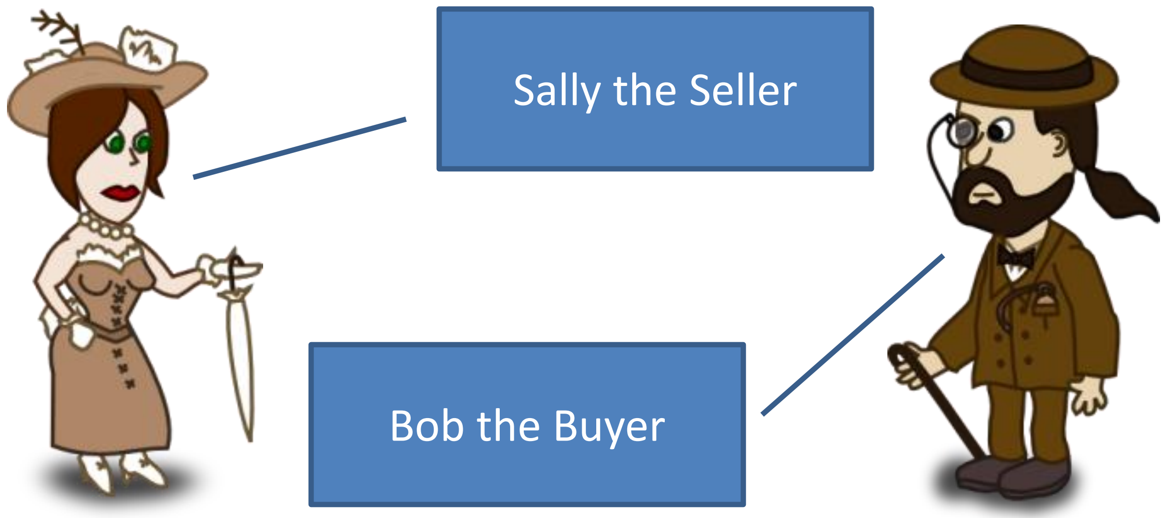
3. Buyer “proves” payment is good
   - Zero-Knowledge Proof

4. Buyer “proves” he knew URL
   - Zero-Knowledge Proof

- Seller’s view is always the same, regardless of whether the payment is real or fake!

The Phish-Market Protocol

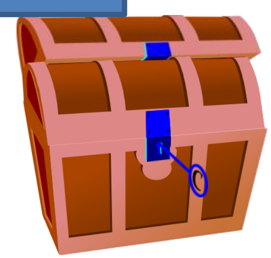
- Meet Sally and Bob:



Commitment Schemes

- Commitment to a value:
  - Commit now
    - “Hiding”: Sally doesn’t learn contents

Think of this as Encryption



  - Reveal later
    - “Binding”: Bob can’t change the contents
  - Bob commits in advance to the URLs he knows

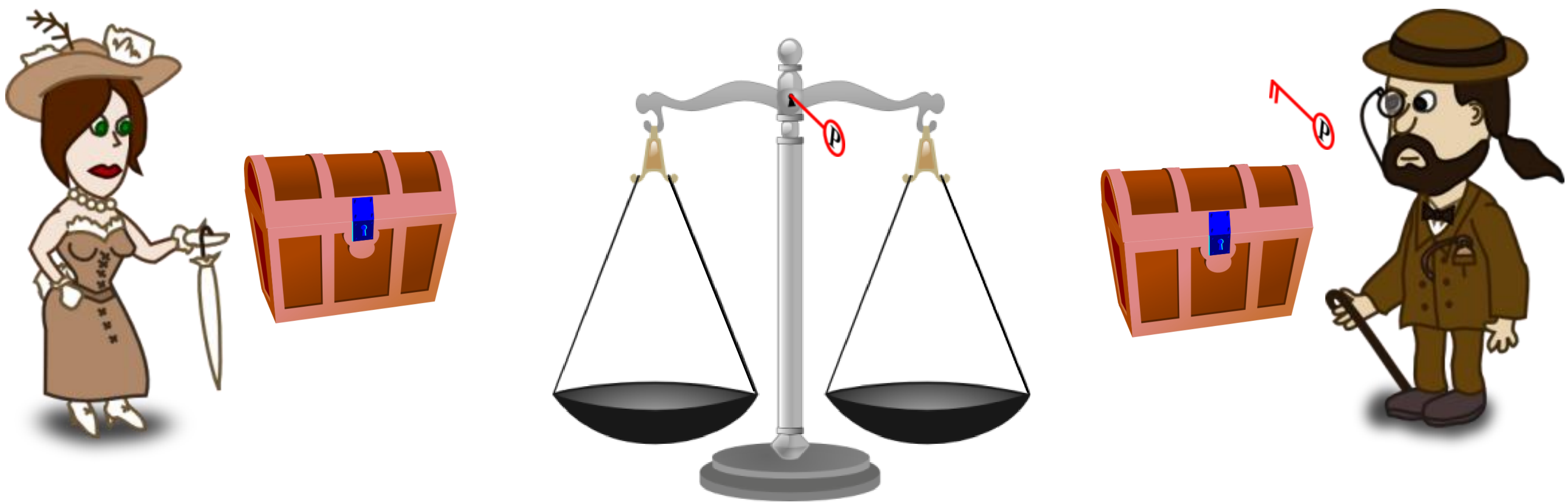
Zero-Knowledge Equivalence Proofs

- Prove two commitments are the same
- Don't reveal anything else

- To prove payment is good: "payment=C(1)"
- To prove Bob already knew URL

Zero-Knowledge Equivalence Proofs *with trapdoor*

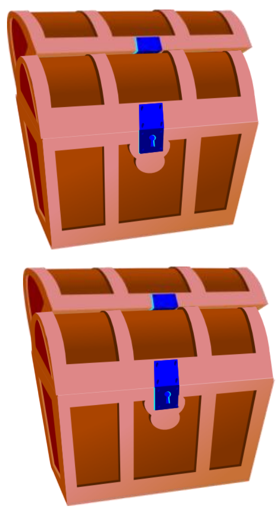
- Sometimes Bob shouldn't pay
- Sometimes Bob didn't know URL beforehand



- Trapdoor lets Bob use secret key to fake proof
- Sally can't tell the difference

Oblivious Transfer (OT)

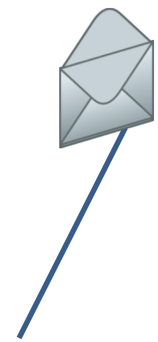
- Sally prepares **two** encrypted items
- Bob gets to choose only **one** encryption key



  - Either learn URL or get extra “proof key”
- Sally doesn’t learn which key Bob chooses
    - assume keys are indistinguishable

Homomorphic Addition

- Special commitment scheme:
  - Can add commitments without opening them

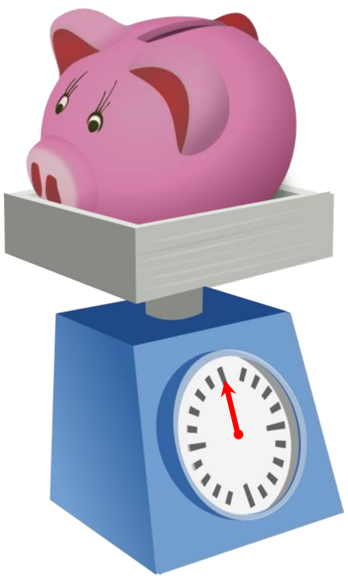


This is a payment commitment

(A chest won't fit in the piggy bank)

Homomorphic Addition

- Special commitment scheme:
  - Can add commitments without opening



  - Can reveal sum without revealing anything else

High-Level Protocol Summary

Commit to previously known URLs

URL Tag, C(URL) and single ZK proof key

URL

2nd proof key

OT

Choice

result

e = Commitment to payment

u = Commitment to URL

ZK Proof 1

e=C(1)

ZK Proof 2

u=C(URL)

Proof 3: u is in committed set

High-Level Protocol Summary

Commit to previously known URLs

URL Tag, C(URL) and single ZK proof key

URL

2nd proof key

OT

Don't want URL

2nd proof key

e = C(0)

u = C(Fake previously known URL)

ZK Proof 1
e=C(1)

ZK Proof 2
u=C(URL)

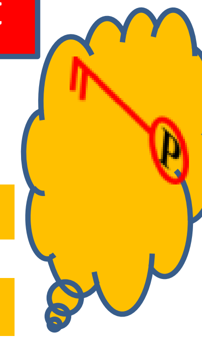
Proof 3: u is in committed set

High-Level Protocol Summary

Not in list

Commit to previously known URLs

URL Tag, C(URL) and single ZK proof key



URL

2nd proof key

OT

Want URL

URL

e = C(1)

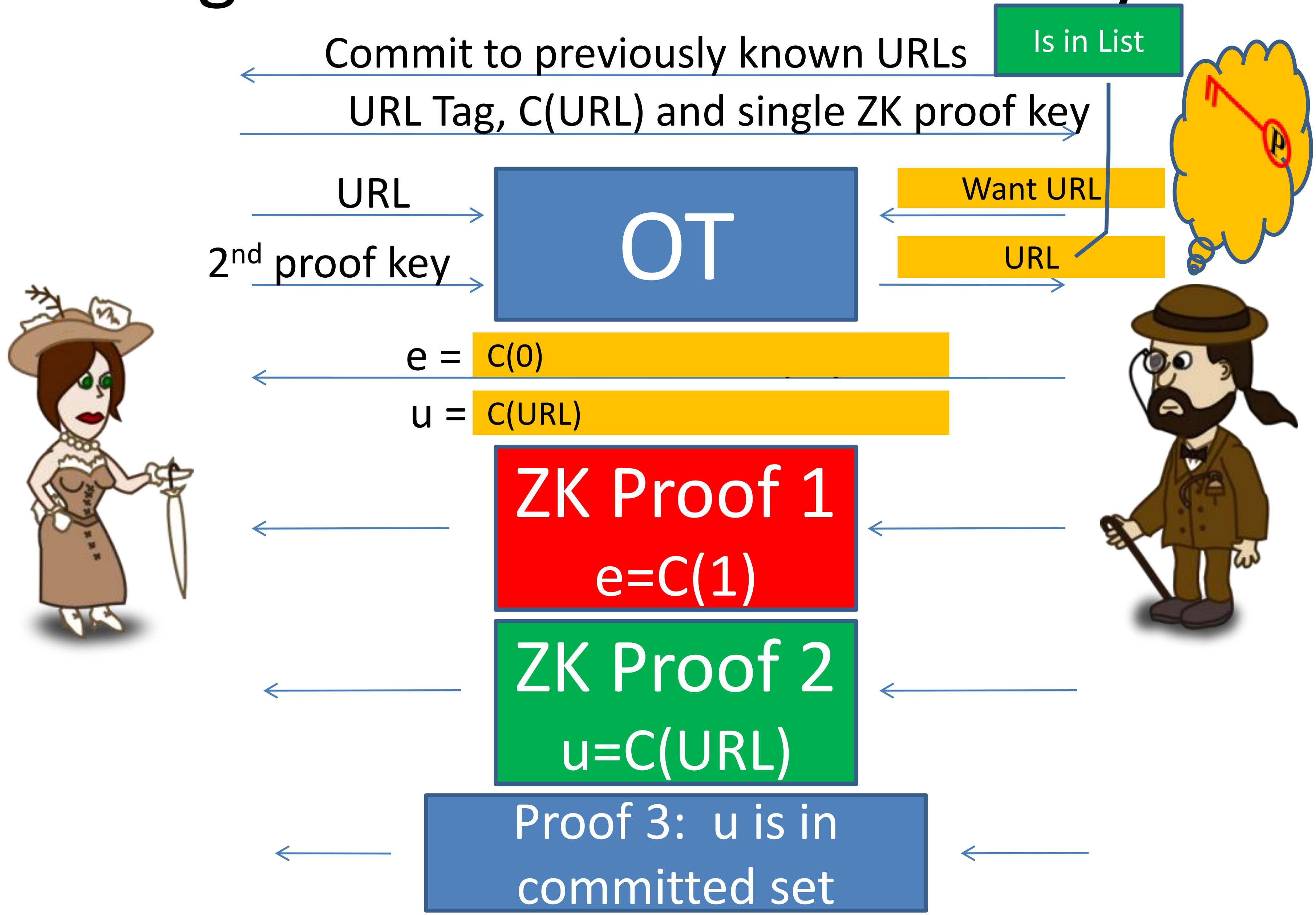
u = C(Fake previously known URL)

ZK Proof 1
e=C(1)

ZK Proof 2
u=C(URL)

Proof 3: u is in committed set

High-Level Protocol Summary



Formal Security Guarantees

- For Seller:
  - Equivalent to an “ideal world” with a trusted third party.
- For Buyer:
  - Seller doesn’t learn anything about Buyer’s secrets except what is revealed by aggregate payment.

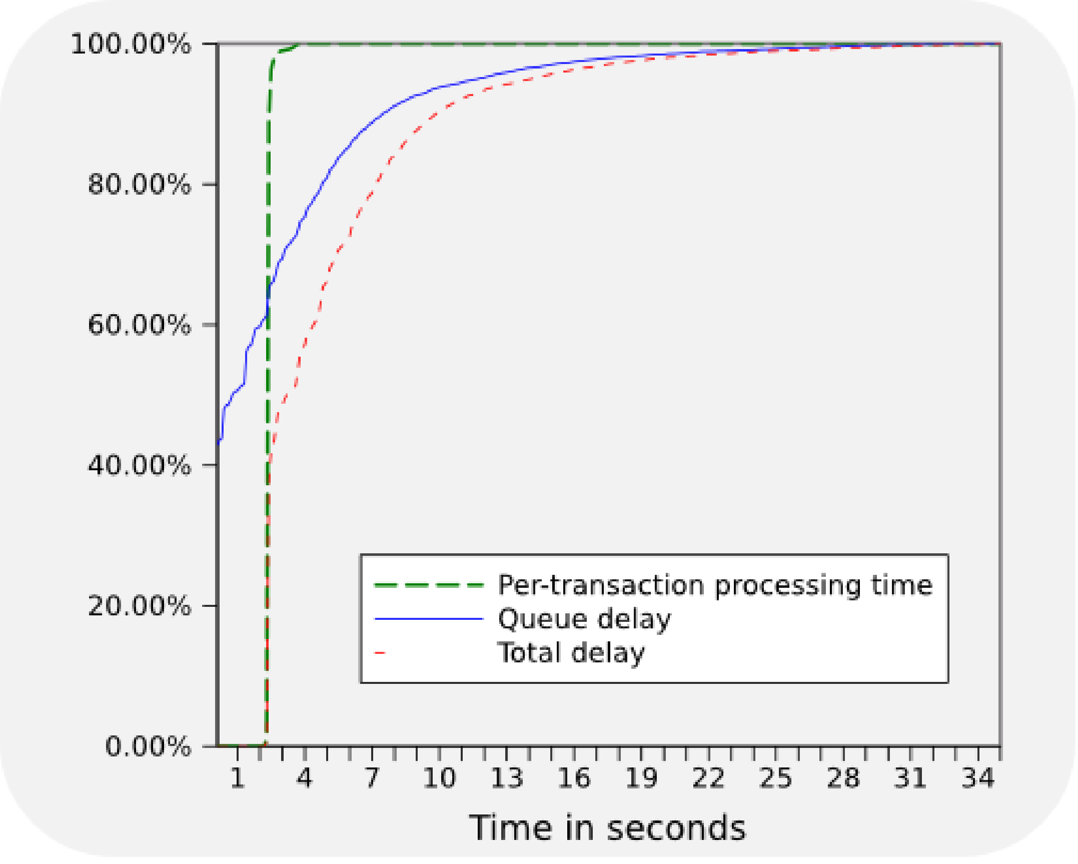
- Theorem: the protocol is secure!

Our Implementation

- Pedersen Commitment
- Naor-Pinkas Oblivious Transfer
  – (uses “Random Oracle”)
- Both based on hardness of discrete log in a generic group
  - can be implemented over Elliptic-Curves or using modular arithmetic

Performance

- Elliptic-Curve based Java implementation
- Ran experiments using real data from 2 take-down companies (2 weeks)
- ~10000 URLs
- Avg. 5 sec delay.
- Max. 35 sec.



The Qilin Crypto SDK

(shameless plug for my absent co-author)

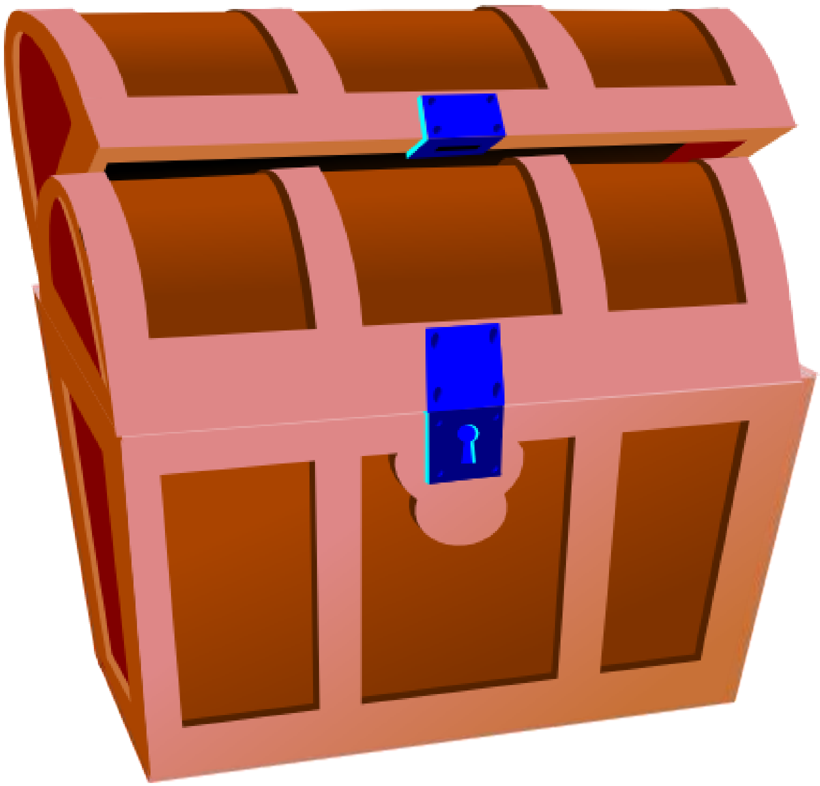
- Java SDK for rapid prototyping of cryptographic protocols
- API follows concepts from theoretical crypto
- Currently implements all building-blocks of Phish-Market Protocol
  - Generic implementation of El-Gamal, Pedersen
  - Instantiations over elliptic curves and over $\mathbf{Z}^*_p$
  - Automatic Fiat-Shamir converter for Σ-Protocols

- Get Qilin: http://qilin.seas.harvard.edu/

Open Questions

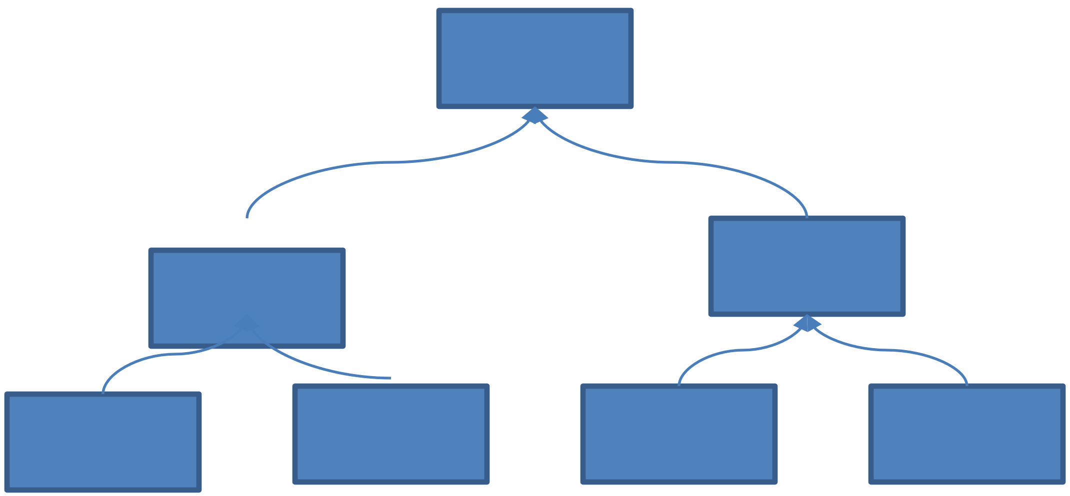
- Solve related data-sharing problems?
  - Much easier if we don't need to handle previously known URLs
- Implement generic secure computation to prevent tag leaks
- Side-channels?
- Will any take-down companies or banks adopt our protocol?

Thank You



Proof 3: Merkle Trees

- Efficient commitment to large sets
  - Send only the root of the tree:



- Proofs are not zero-knowledge
  - We use commitments as leaves
  - Add “chaff” commitments for fake URLs

ZK Equivalence Proof (for homomorphic commitments)

- To prove: $C(x) \approx C(y)$
  - Reduce to "proof of commited value":
  - Prove: $C(x)/C(y)=C(x-y) \approx C(0)$
- Standard protocol to prove $C(x) \approx C(0)$:
  1. Prover commits: $C(b)$, sends b
  2. Verifier sends random challenge: a
  3. Prover opens commitment: $C(ax+b)=C(x)^a C(b)$
     - Value must be: b
- If $x \neq 0$, w.h.p. (over a) we have: $ax+b \neq b$
- If Prover knows a, can cheat by computing $b'=ax+b$ in step 1.

Doesn't open commitment

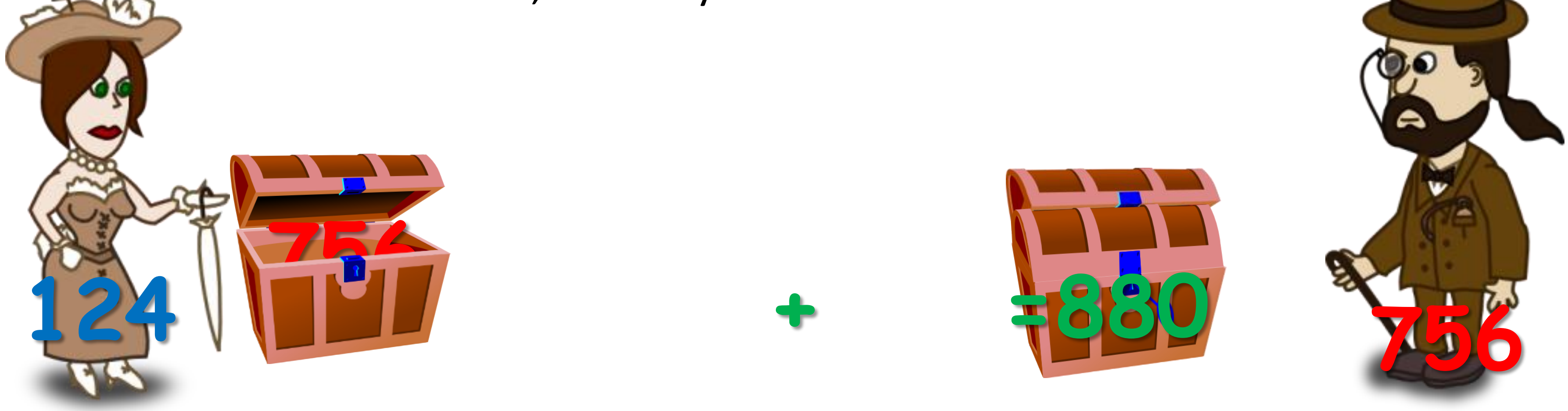
Note: arithmetic is modular!

Trapdoor ZK Proofs

- ZK $\sum$- Protocol:
  1. Prover commits
  2. Verifier sends a random challenge
  3. Prover opens commitment
- Generic transformation to add trapdoor:
  1. Prover commits
  2. Challenge computed using Coin-Flipping protocol
  3. Prover opens commitment
- We use Coin-Flipping protocol with trapdoor.

Blum Coin-Flipping
(with trapdoor)

- Use a commitment to flip a coin:
  - Bob chooses a random value
    - He's committed, but Sally doesn't know the value



  - Sally chooses a random value
  - Bob opens his commitment.
  - The value of the coin is the sum.
- Bob can cheat if he can equivocate on commitment