TrustMe: Anonymous Management of Trust Relationships in Decentralized P2P Systems

Aameek Singh
aameek@cc.gatech.edu

Ling Liu
lingliu@cc.gatech.edu

College of Computing
Georgia Institute of Technology

Outline

- Introduction of concepts
  - Trust based P2P systems
  - Review of existing work
- Anonymity – Why is it essential ?
- TrustMe – Protocol details
- Security Analysis
- Experimental Results
- Conclusions and Future Work

Introduction – Use of Trust

- Open and anonymous nature invites malicious behavior – sharing harmful content, viruses
- Decentralized solutions are required
- Trust based reputation metrics
  - Measure the trustworthiness of a peer
  - Dynamically assign a *trust value* based on peer reviews
- What reputation metrics to use – Trust Model
- How to access and secure their use – Access Protocol

Desired Features

- Security
  - Trust values are securely accessed and transmitted
  - No malicious attacks on peers giving reviews
- Reliability
  - Querying peer gets the correct reply in spite of presence of malicious peers
- Accountability
  - Way to hold a peer accountable for its feedback

Trust Based P2P Systems - Review

- Various trust models are available
- Scarce work on access protocols
- Polling based protocol – Cornelli et al
  - Every peer before interacting with another peer broadcasts a *trust query* for that peer
  - All peers that have interacted with that peer send their votes which are combined locally
  - Public Key Cryptography used to secure

Issues with current approaches

- No persistence
  - Users not currently logged on cannot participate
  - Extremely prone to simple malicious group activity
- Tedious decision making
  - Require to wait for all replies and confirmations
- No anonymity
  - Peers giving reviews cannot remain anonymous
  - Fear of retaliation and external attacks

TrustMe

- Persistent - uses global trust values
  - All peers after interacting, review and file a report
  - All reviews combined to give a single value based on the trust model used
  - The trust values are hosted at another peer
    - Each peer has a Trust Holding Agent (THA) Peer
- Secure and Anonymous
  - Complete anonymity to both the querying peer and THA peer
- Fast decision making
  - A single reply message is enough to make a decision

TrustMe - Phases

- Query
  - Broadcast a *trust query* for another peer (say Peer A)
- Reply
  - Peer A's THA peer replies with its trust value
- Interaction
  - If trustworthy, querying peer interacts with Peer A and collects proof-of-interaction
- Report
  - The querying peer reviews Peer A's performance and files a report

TrustMe – Infrastructure I

- Secure Bootstrap Server (BS)
  - Entry point for peers to enter the network
  - Acts as a *kind* of certification authority – helps only in pseudo-identification of peers
  - Possesses a private-public key pair $<P_{BS} , B_{BS} >$
  - B_{BS} is publicly available to all peers – network parameter
- Each Peer
  - Possesses two pairs of private-public keys $<P_i, B_i>$ and $<P'_i , B'_i >$
  - BS assigned ID: $BID_i = P_{BS}$(“Valid Node”| B'_i)
- BS maintains a list of active peers

TrustMe – Infrastructure II

- Peer Join – When Peer i joins the network
  - Bootstrap server needs to assign a THA peer (say Peer x)
    - Chooses a peer randomly from the list of active peers
    - Creates a new private-public key pair < SP_i, SB_i>
      - Only the THA peer will have the knowledge of SP_i
      - Used for secure transmission of trust values for the reply and the report phase
    - Securely transmits < ID_i, B_i, SP_i, SB_i> to Peer x
      - Broadcast a message of the format

$$BID_x | P_{BS}(BID_x | B'_x(ID_i | \ B_i | \ SP_i | \ SB_i))$$

      - Only BS can generate and only Peer x can read

TrustMe – Query & Reply

- Peer typically will have a list of offering peers
- Message Format:

$$ID_i \mid ID_j \mid ID_k \mid ID_l \mid \ldots$$

- For any peer i being queried, its THA peer should reply with its trust value. Need to ensure
  - Reply can only be sent by the THA peer
  - Reaches destination un-tampered
- Message Format:

$$ID_i \mid B_i \mid SB_i \mid SP_i(TV \mid TS \mid BID_x \mid P'_x(TS))$$

TrustMe – Reply

$$ID_i | B_i | SB_i | SP_i(TV | TS | BID_x | P'_x(TS))$$

- All peers can read it
- Only THA peer can send it (encryption with SP_i)
- Cannot be replayed (use of timestamp TS)
- Use of BID_x ensures accountability
  - Can be used to identify malicious THA peers
- Use of $P'_x(TS)$ ensures nobody can use somebody else's BID_x
- B_i and SB_i are used by querying peer

TrustMe – Interaction

- No peer can file a report without interacting
  - Prevents malicious report-filing
- If Peer i and Peer j interact, they exchange messages
- Peer j gets $P_i(TS|B_j|ID_j)$ and Peer i gets $P_j(TS|B_i|ID_i)$
  - Prevents replay
  - Cannot be generated in a fake manner
  - Ensures only the correct peer can file a report

TrustMe – Report

- Need to make sure that only the THA peer can read the report (*secret ballot*)
- Only a peer that actually interacted with Peer i can file a report for Peer i
- Message Format:

$$ID_i \mid SB_i(\text{“Report”} \mid V \mid B_j \mid P_j(\underbrace{P_i(TS \mid B_j \mid ID_j)}_{\text{Proof-of-interaction}}))$$

- THA peer updates rating by Peer j and updates TV

TrustMe – Analysis I

- Manipulating Reply Messages

  $ID_i | B_i | SB_i | SP_i(TV | TS | BID_x | P'_x(TS))$

  - Malicious THA peer
    - Maintain K THA peers and select based on majority vote
    - Blacklist malicious THA peers based on BID_x
  - Malicious non-THA peers
    - Offering peers include their B_i and SB_i as part of the initial offer
- Manipulating Proof-of-interaction - $P_i(TS | B_j | ID_j)$
  - Using fake keys
    - Easily verifiable

TrustMe – Analysis II

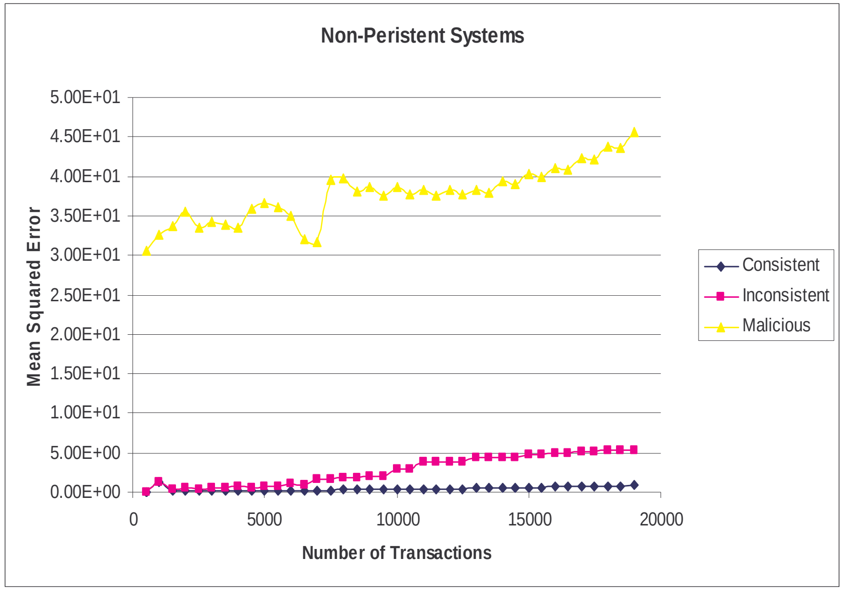
- Why use two pairs $<P_i, B_i>$ and $<P'_i , B'_i >$
  - $<P'_i , B'_i >$ used only while acting as a THA peer
  - Prevents mapping of public key to identifier after prolonged monitoring of the network
- Peer Leave – Whenever Peer i leaves the network
  - Create a new THA peer for peers it was responsible for
  - Its trust information is dumped after it is not accessed for some time

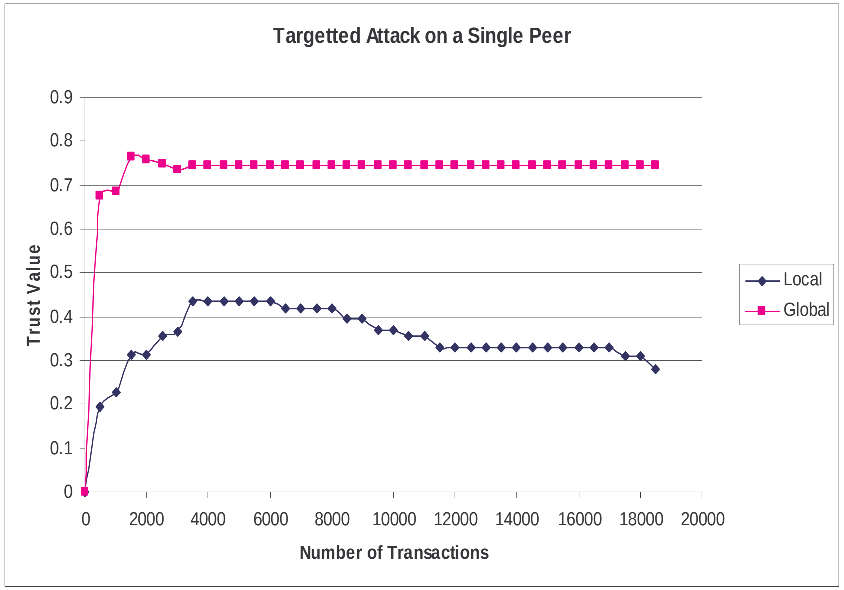
TrustMe – Benefits

- Security and Anonymity
- Reliability
- Accountability
- Persistence
- Fast decision time
- Ease of contribution
  - A single report is required

TrustMe – Experimental Results I

- Effect of Persistence

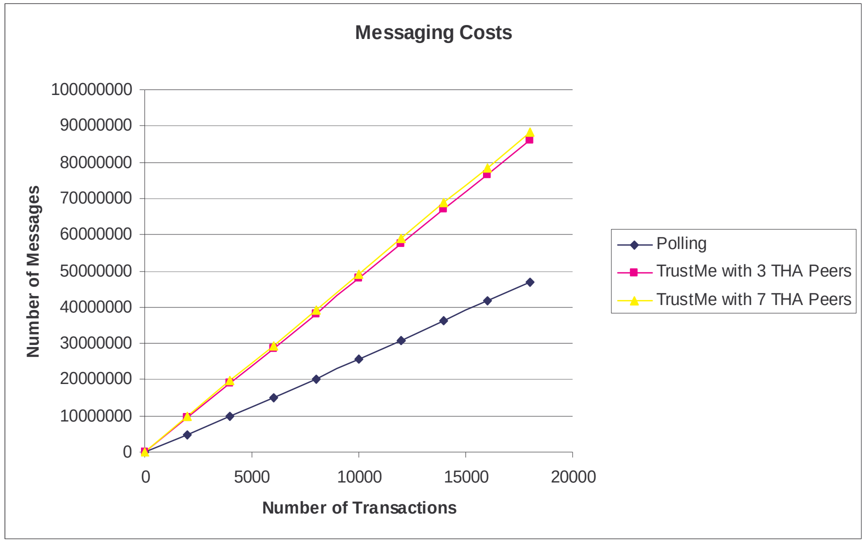


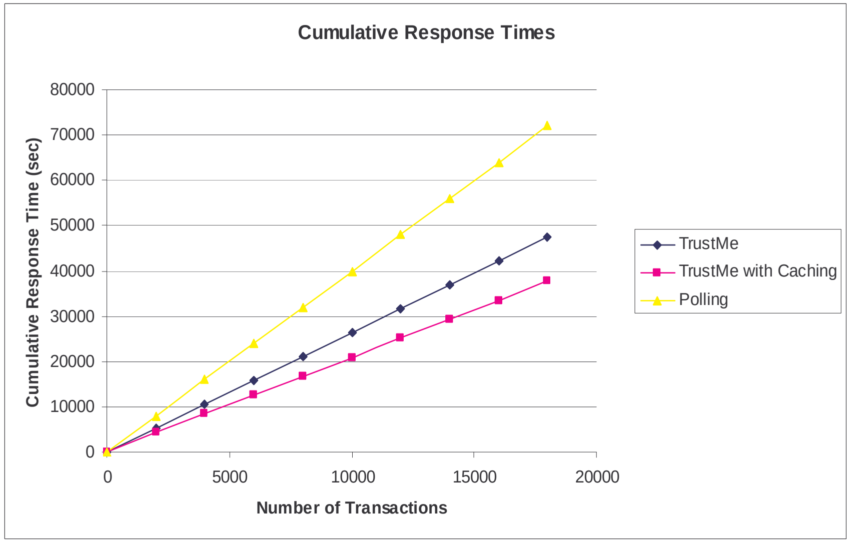


- Non-persistent systems can report highly misleading values
- Having as little as 10 malicious peers acting together can rate the peer being untrustworthy, even when it is not

TrustMe – Experimental Results II

- Cost and Response Times





- TrustMe costs more because of more broadcasts
- Cost varies little with increase in number of THA peers
- Caching improves response times
- Increase in number of THA peers also improves response times

Conclusions and Future Work

- Anonymous trust management possible
- TrustMe provides secure and reliable access to trust values in a decentralized P2P system
- Compatible with existing Gnutella style systems

- Use symmetric key based broadcast authentication protocols like TESLA
- Design variants with different levels of anonymity and security

Thanks