Peer-to-Peer Networks
10 Anonymity

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Motivation

- Society
  - Free speech is only possible if the speaker does not suffer negative consequences
  - Thus, only an anonymous speaker has truly free speech
- Copyright infringement
  - Copying items is the best (and most) a computer can do
  - Copyright laws restrict copying
  - Users of file sharing systems do not want to be penalized for their participation or behavior
- Dictatorships
  - A prerequisite for any oppressing system is the control of information and opinions
  - Authors, journalists, civil rights activists like all citizens should be able to openly publish documents without the fear of penalty
- Democracies
  - In many democratic states certain statements or documents are illegitimate, e.g.
    - (anti-) religious statements
    - insults (against the royalty)
    - certain sexual contents
    - political statements (e.g. for fascism, communism, separation, revolution)
- A anonymizing P2P network should secure the privacy and anonymity of each user without endangering other users

Terms

- From
  - Danezis, Diaz, A Survey of Anonymous Communication Channels
  - Pfitzmann, Hansen, Anonymity, Unobservability and Pseudonymity – A Proposal for Terminology
- Anonymity (Pfitzmann-Hansen 2001)
  - describes the state of being not identifiable within a larger set of subjects (peers), i.e.
    - the anonymity set
  - The anonymity set can be all peers of a peer-to-peer network
    - yet can be another (smaller or larger) set

Terms

- Unlinkability
  - Absolute (ISO15408)
    - „ensures that a user may make multiple uses of resources or services without other being able to link these uses together.“
  - Relative
    - Any attacker cannot find out more about the connections of the uses by observing the system
      - a-priori knowledge = a-posteriori knowledge

Terms

- Unobservability
  - The items of interests are protected
  - The use or non-use of any service cannot be detected by an observer (attacker)
- Pseudonymity
  - is the use of pseudonyms as IDs
  - preserves accountability and trustability while preserving anonymity

Attacks

- Denial-of-Service Attacks (DoS)
  - or distributed denial of service attacks (DDoS)
  - one or many peers ask for a document
  - peers are slowed down or blocked completely
- Sybil Attacks
  - one attacker produces many fake peers under new IP addresses
  - or the attacker controls a bot-net
- Use of protocol weaknesses
- Infiltration by malign peers
  - Byzantine Generals
- Timing attacks
  - messages are slowed down
  - communication line is slowed down
  - a connection between sender and receiver can be established
- Poisoning Attacks
  - provide false information
  - wrong routing tables, wrong index files etc.
- Eclipse Attack
  - attack the environment of a peer
  - disconnect the peer
  - build a fake environment

Cryptography in a Nutshell

- Symmetric Cryptography
  - AES
  - Affine Cryptosystems
- Public-Key Cryptography
  - RSA
  - ElGamal
- Digital Signatures
- Public-Key-Exchange
  - Diffie-Hellman

- Interactive Proof Systems
  - Zero-Knowledge-Proofs
  - Secret Sharing
  - Secure Multi-Party Computation

Blakley‘s Secret Sharing

- Geroge Blakley, 1979
- Task
  - n persons have to share a secret
  - only when k of n persons are present the secret is allowed to be revealed
- Blakley‘s scheme
  - in a k-dimensional space the intersection of k non-parallel k-1-dimensional spaces define a point
  - this point is the information
  - with k-1 sub-spaces one gets only a line
- Construction
  - A third (trusted) instance generate for a point n in R^k k non-parallel k-1-dimensional hyper-spaces

Shamir's Secret Sharing Systems

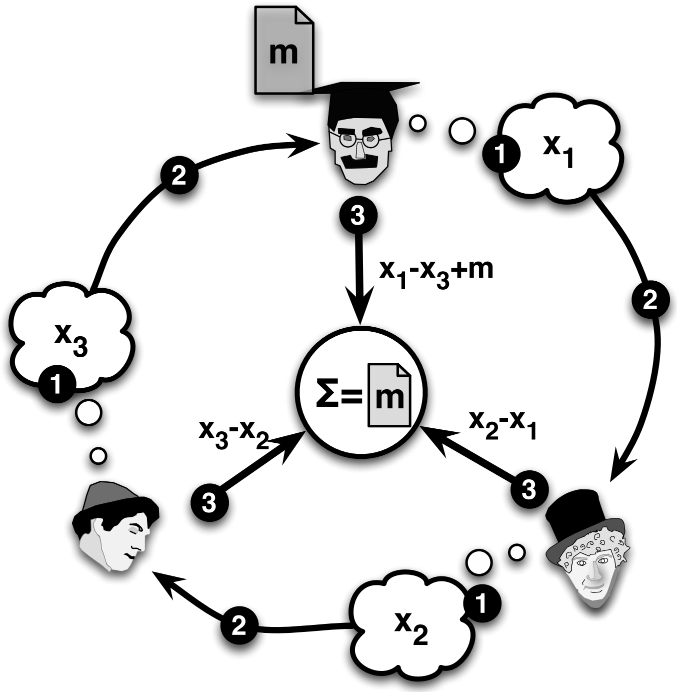
- Adi Shamir, 1979
- Task
  - n persons have to share a secret s
  - only k out of n persons should be able to reveal this secret
- Construction of a trusted third party
  - chooses random numbers $a_1,...,a_{k-1}$
  - defines

$$f(x) = s + a_1 x + a_2 x^2 + \ldots + a_{k-1} x^{k-1}$$

  - chooses random $x_1, x_2, ..., x_n$
  - sends $(x_i, f(x_i))$ to player i
- If k persons meet
  - then they can compute the function f by the fundamental theorem of algebra
    - a polynomial of degree d is determined by d+1 values
  - for this they exchange their values and compute by interpolation
    - (e.g. using Lagrange polynoms)
- If k-1 persons meet
  - they cannot compute the secret at all
  - every value of s remains possible
- Usually, Shamir's and Blakley's scheme are used in finite fields
  - i.e. Galois fields (known from CRC)
  - this simplifies the computation and avoids rounding errors in the context of floating numbers

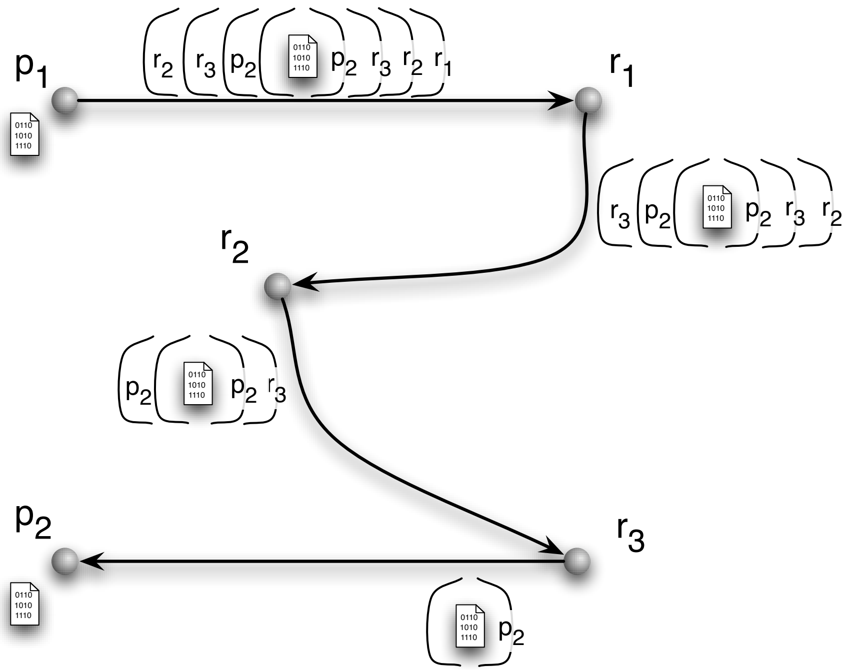
Dining Cryptographers

- Anonymous publications without any tracing possibility
- $n \geq 3$ cryptographers sit at a round table
  - neighbored cryptographers can communicate secretly
- Each peer chooses secret number x_i and communicates it to the right neighbor
- If i wants to send a message m
  - he publishes $s_i = x_i - x_{i-1} + m$
- else
  - he publishes $s_i = x_i - x_{i-1}$
- Now they compute the sum $s=s_1+...+s_n$
  - if s=0 then there is no message
  - else the sum of all messages



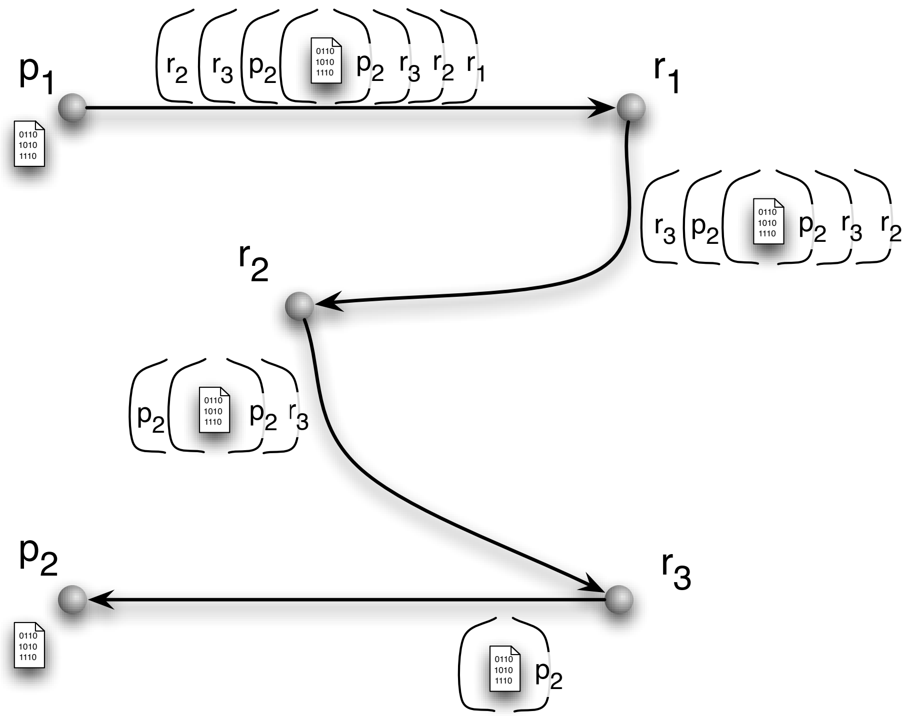
Chaum's Mix-Cascades

- All peers
  - publish the public keys
  - are known in the network
- The sender p_1 now chooses a route
  - p_1, r_1, r_2, r_3, ..., p_2
- The sender encrypts m according to the public keys from
  - p_2, ... r_3, r_2, r_1
  - and sends the message
  - $f(pk_{k1},(r_2, f(pk_{r2} \ldots f(pk_{rk},(p_2,f(pk_{p2},m)))\ldots)))))$
  - to r_1
- r_1 encrypts the code, deciphers the next hop r_2 and sends it to him
- ...
- until p_2 receives the message and deciphers it



Chaum's Mix Cascades

- No peer on the route
  - knows its position on the route
  - can decrypt the message
  - knows the final destination
- The receiver does not know the sender
- In addition peers may voluntarily add detour routes to the message
- Chaum's Mix Cascades
  - aka. Mix Networks or Mixes
  - is safe against all sort of attacks,
  - but not against traffic analysis



TOR - Onion Routers

- David Goldschlag, Michael Reed, and Paul Syverson, 1998
- Goal
  - Preserve private sphere of sender and receiver of a message
  - Safety of the transmitted message
- Prerequisite
  - special infrastructure (Onion Routers)
    - all except some smaller number of exceptions cooperate
- Method
  - Mix Cascades (Chaum)
  - Message is sent from source to the target using proxies (Onion Routers)
  - Onion Routers unpredictably choose other routers as intermediate routers
  - Between sender, Onion Routers, and receiver the message is encrypted using symmetric cryptography
  - Every Onion Router only knows the next station
  - The message is encoded like an onion
- TOR is meant as an infrastructure improvement of the Internet
  - not meant as a peer-to-peer network
  - yet, often used from peer-to-peer networks

Other Work based on Onion Routing

- Crowds
  - Reiter & Rubin 1997
  - anonymous web-surfing based on Onion Routers
- Hordes
  - Shields, Levine 2000
  - uses sub-groups to improve Onion Routing
- Tarzan
  - Freedman, 2002
  - A Peer-to-Peer Anonymizing Network Layer
  - uses UDP messages and Chaum Mixes in group to anonymize Internet traffic
  - adds fake traffic against timing attacks

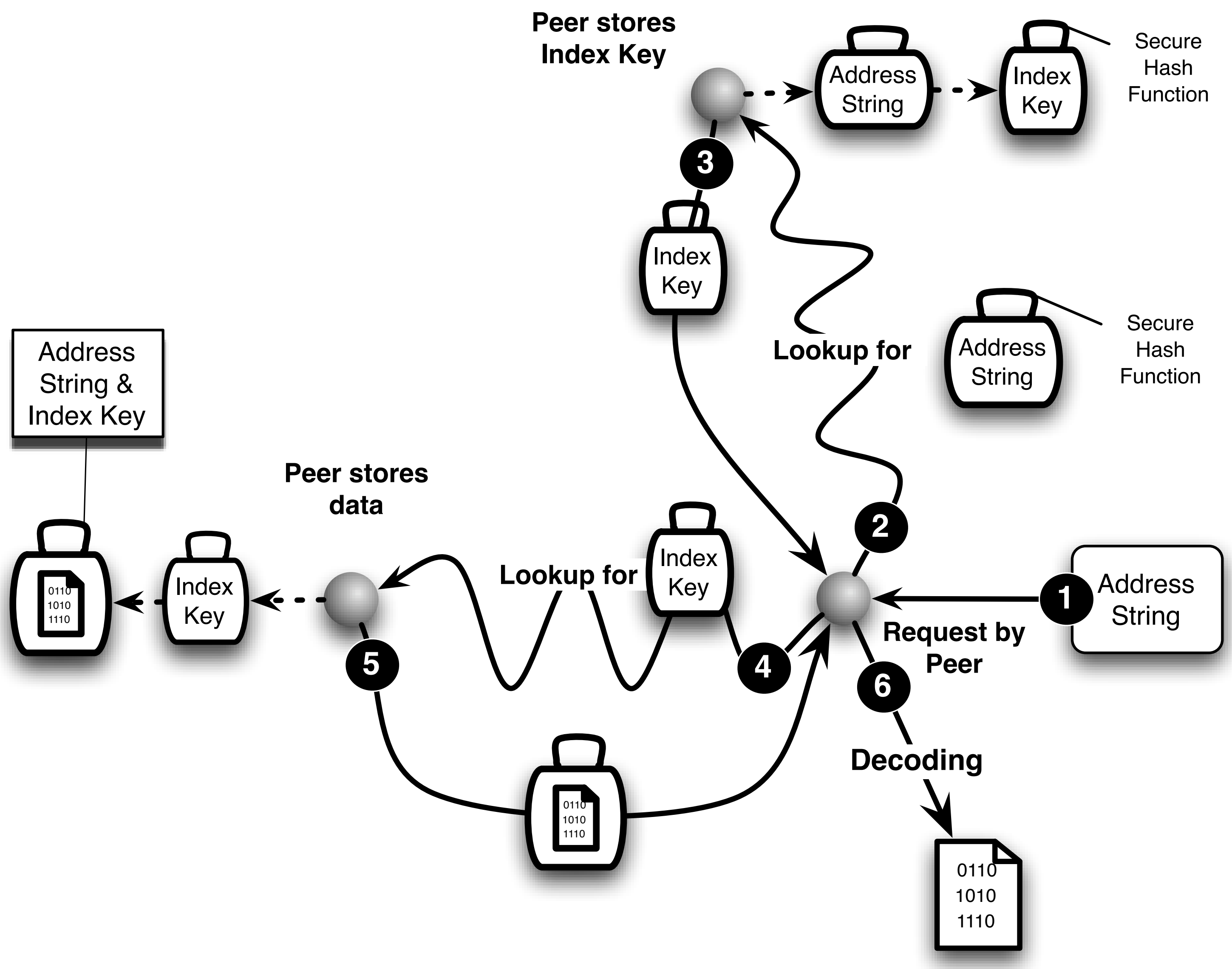
Free-Net

- Ian Clarke, Oskar Sandberg, Brandon Wiley, Theodore Hong, 2000
- Goal
  - peer-to-peer network
  - allows publication, replication, data lookup
  - anonymity of authors and readers
- Files
  - are encoding location independent
    - by encrypted and pseudonymously signed index files
    - author cannot be identified
  - are secured against unauthorized change or deletion
  - are encoded by keys unknown by the storage peer
    - secret keys are stored elsewhere
  - are replicated
    - on the look up path
  - and erased using “Least Recently Used” (LRU) principle

Free-Net

- Network Structure
  - is similar to Gnutella
  - Free-Net is like Gnutella Pareto distributed
- Storing Files
  - Each file can be found, decoded and read using the encoded address string and the signed subspace key
  - Each file is stored together with the information of the index key but without the encoded address string
  - The storage peer cannot read his files
    - unless he tries out all possible keywords (dictionary attack)
- Storing of index files
  - The address string coded by a cryptographic secure hash function leads to the corresponding peer
    - who stores the index data
      - address string
      - and signed subspace key
  - Using this index file the original file can be found

Free-Net



Peer stores
Index Key
Address
String
Index
Key
Secure
Hash
Function
3
Index
Key
Lookup for
Address
String
Secure
Hash
Function
Address
String &
Index Key
Peer stores
data
2
Index
Key
Lookup for
0110
1010
1110
Index
Key
Address
String
1
5
4
Request by
Peer
6
Decoding
0110
1010
1110
0110
1010
1110

Free-Net

- Lookup
  - steepest-ascent hill-climbing
    - lookup is forwarded to the peer whose ID is closest to the search index
  - with TTL field
    - i.e. hop limit
- Files are moved to new peers
  - when the keyword of the file is similar to the neighbor‘s ID
- New links
  - are created if during a lookup close similarities between peer IDs are discovered

Efficiency of Free-Net

- Network structure of Free-Net is similar to Gnutella
- The lookup time is polynomial on the average

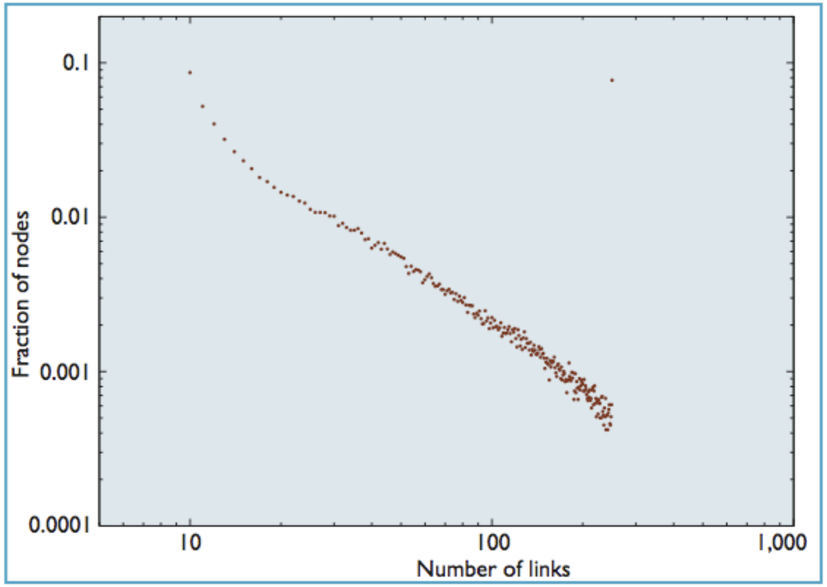


Figure 2. Degree distribution among Freenet nodes. The network shows a close fit to a power-law distribution.

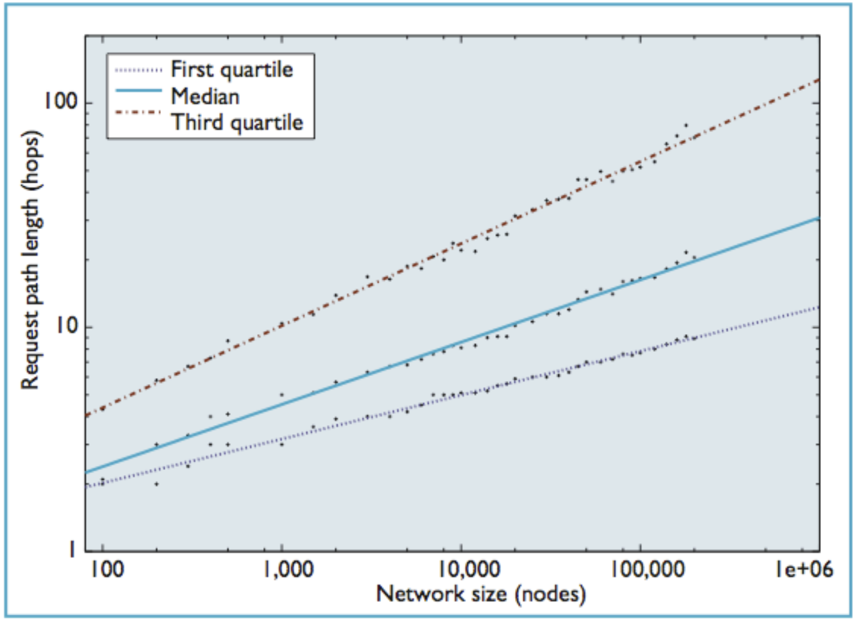


Figure 3. Request path length versus network size. The median path length in the network scales as $N^{0.28}$.

Dark-Net & Friend-to-Friend

- Dark-Net is a private Peer-to-Peer Network
  - Members can trust all other members
  - E.g.
    - friends (in real life)
    - sports club
- Dark-Net control access by
  - secret addresses,
  - secret software,
  - authentication using password, or
  - central authentication
- Example:
  - WASTE
    - P2P-Filesharing up to 50 members
    - by Nullsoft (Gnutella)
  - CSpace
    - using Kademlia

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