Lecture 6

P2P with TomP2P

Advanced Topics

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P2P in the news

- **15.3.2015 - Microsoft to deliver Windows 10 updates using peer-to-peer technology**
  - Windows 10 updates using a peer-to-peer (P2P)
  - Maybe due to Pando Networks (acquired my MS)
    - Managed peer-to-peer media distribution company
    - Based on BitTorrent, but using central management
- **16.3.2015 – First Beta of PeerWasp**
  - Secure P2P Sharing and Synchronization
  - Using TomP2P / Hive2Hive – Windows client
- **Please send us the Scrum login account info**
  - Many tools available (100+ tools)

0. Lecture Overview

1. Advanced Topics in TomP2P

1. Mechanisms based on Hashing in DHTs
   1. And/Or Searches
   2. Similarity Searches
   3. Range Queries
2. Connectivity, Security, and Robustness
   1. NAT (UPNP/NAT-PMP/Hole punching)
   2. Security
   3. Replication
   4. Direct data connection / persistent connection
3. Consistency
   1. Paxos
   2. vDHT
4. Rsync

1. Mechanisms based on Hashing in DHTs

And / or searching

Similarity Search

Range queries

Mechanisms based on Hashing in DHTs

- **Search in DHT**
  - `DHT.get(h(„Communication Systems Group“))`
  - In order to find it: `DHT.put(h(„Communication Systems Group“), value)`
- **Keywords**
  - `DHT.get(h(„Communication“))`
  - Find it: `DHT.put(h(„Communication“), value)`, `DHT.put(h(„Systems“), value)`, `DHT.put(h(„Group“), value)`
  - value points to `h(„Communication Systems Group“)`
- **Keywords drawbacks**
  - Find good keywords → “the”, “a” are not good keywords
  - Exact matches only

Mechanisms based on Hashing in DHTs

- **Find "Communication" - OR Systems**
  - `DHT.get(h(„Communication“))` and `DHT.get(h(„Systems“))`, combine results
- **Find "Communication" - AND Systems**
  - 1. `DHT.get(h(„Communication“))` and `DHT.get(h(„Systems“))`, intersect results
    - Overhead – use Bloom Filters (sequential vs. parallel)
  - 2. `DHT.get(h(„Communication“) xor h(„Systems“))`
    - In order to find it: `DHT.put(h(„Communication“) xor h(„System“), value)`, `DHT.put(h(„Communication“) xor h(„Group“), value)`, `DHT.put(h(„Group“) xor h(„System“), value)`
    - Combination needs to be known in advance

Mechanisms based on Hashing in DHTs

- **Demo**
  - Keywords
  - Performance issue → consistent hashing (aggregation)

- **Aggregation not done in TomP2P**
  - Routing aggregation?

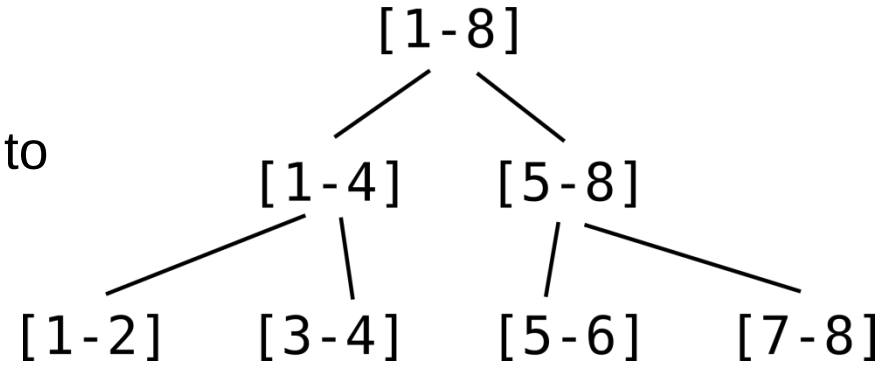
Mechanisms based on Hashing in DHTs

- **Range Queries**
  - Problem: random insert vs. sequence insert
  - Max. nr of items (n), nr of items per peer (m)
  - Sequence → [0..n] [n..2n] [2n..3n] […] → peer responsible for range, hash it, store it, done.
    - But random: worst case: 1 peers has 1 data item, range query for range [0..x] contacts x peers.
- **Over-DHT**
  - **PHT**: trie (prefix tree); **DST**: segment → tree on top of DHT
  - Main idea: hash of tree-node (resp. for range) → DHT
  - PHT: Peer stores n data items, if n reached, splits data (moves data across peers)
  - DST: stores data on each level (redundancy) up to a threshold
    - No data splitting

Mechanisms based on Hashing in DHTs

- **Example:**
  - Set n = 2, m=8
  - `1, "test"; 2, "hallo"; 3, "world"; 5, "sys"`

- **Tree: store value**
  - Translate `putDST(1, "test")` to
    - put(hash([1-8]),"test") → may be stored (only if threshold not reached)
    - put(hash([1-4]),"test") → may be stored
    - put(hash([1-2]),"test") → will be stored
    - Store `put(3, "world"),put(2, "hallo")` and `put(5, "sys")`



Mechanisms based on Hashing in DHTs

- **Query** `getDST(1..5)` **translates to**
  - `get(hash[5-6])` → returns “sys”
  - `get(hash[1-4])` → returns “test”, “world” and tells us that threshold has been reached
  - `get(hash[1-2])` → returns “hallo”, “test”
  - `get(hash[3-4])` → returns “world”
- **Range query as series of** `put()` **and** `get()`
- **Demo**
  - Storage modification

Mechanisms based on Hashing in DHTs

- **Similarity Search in DHT**
  - http://fastss.csg.uzh.ch

- **Project that brings similarity search to HT / DHT**
  - Problem: Search for “netwrk” fails for DHTs
- **Similarity: Edit distance / Levenshtein distance**
  - Min operations to transform one string into another, operations: insert, delete, replace
  - Calculated in matrix size O(m x n)

$$
\begin{aligned}
&d[i,0] = i,\ d[0,j] = j,\\
&d[i,j] = min\,(d[i-1,j]+1,\ d[i,j-1]+1,\\
&\quad d[i-1,j-1] + (if\ s1[i] = s2[j]\ then\ 0\ else\ 1))
\end{aligned}
$$

Mechanisms based on Hashing in DHTs

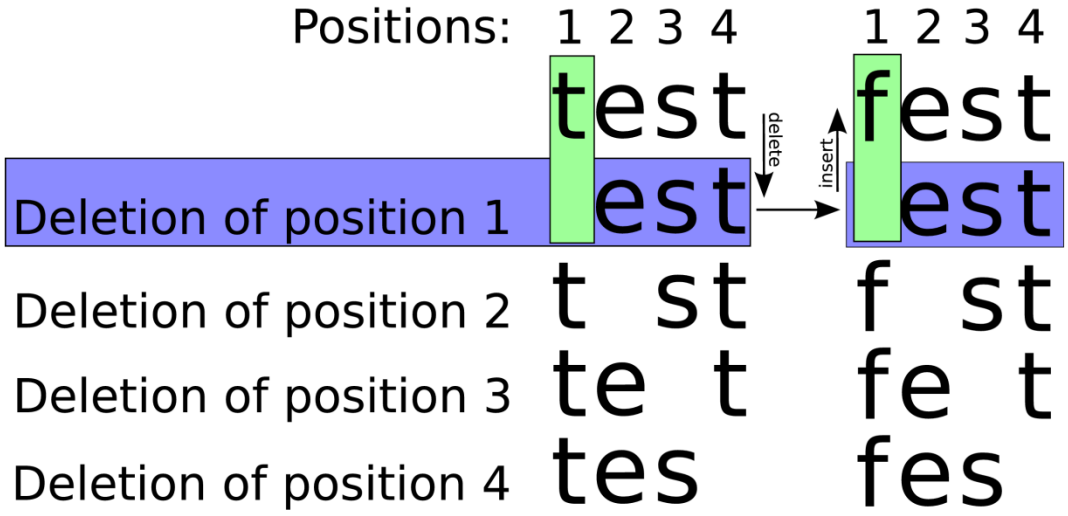
- Example d(test,east) = 2 (remove a, insert t)

		T	E	S	T
	0	1	2	3	4
E	1	1	1	2	3
A	2	2	2	2	3
S	3	3	3	2	3
T	4	3	4	3	2

- Expensive operation if all words need testing
- Main idea: pre-calculate errors
  - All possible errors? Neighbors for test with ed 2: test, testa, testaa, testab, ... , tea, teb, tec, ..., teaa, teab, ... → 23883 more of those!

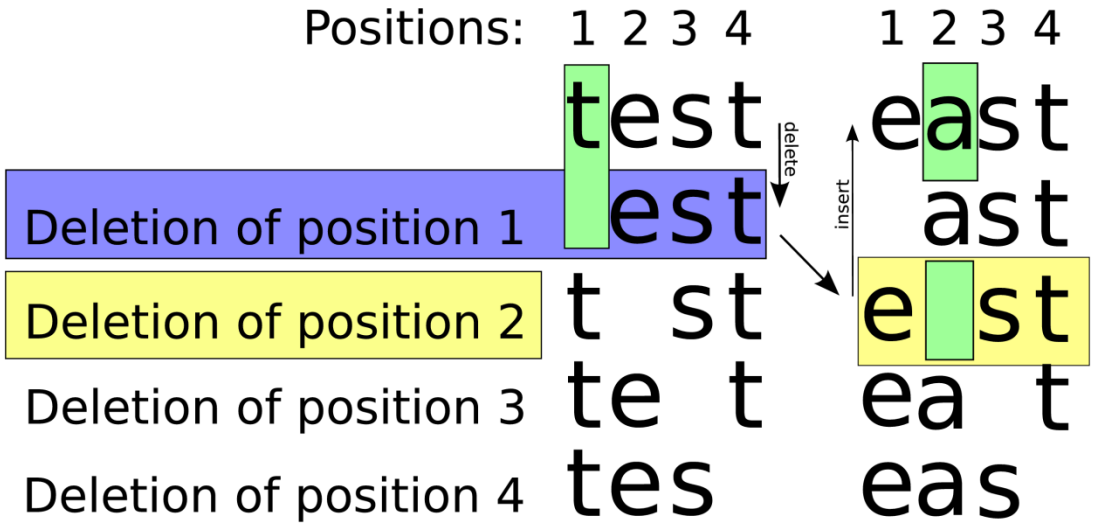
Mechanisms based on Hashing in DHTs

- **FastSS pre-calculates with deletions only**
  - Neighbors for *test* with ed 2: test, est, st, et, es, tst, tt, ts, tet, te, tes
  - Pre-calculation on query **and** index
  - 11 neighbors → 11 more queries, indexed enlarged by 11 entries
- **Example d(test,fest)=1** (query) (index)



Mechanisms based on Hashing in DHTs

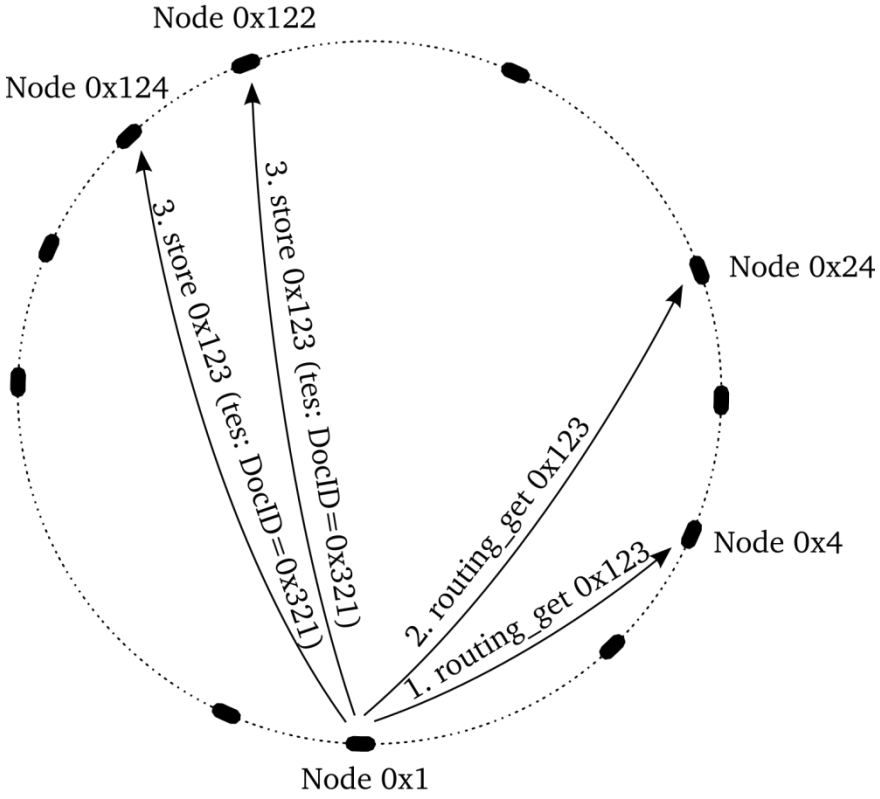
- **Example d(test,east)=2 (query) (index)**



- **P2PFastSS implemented on top of TomP2P (early version) – tests with indexing Wikipedia abstracts**

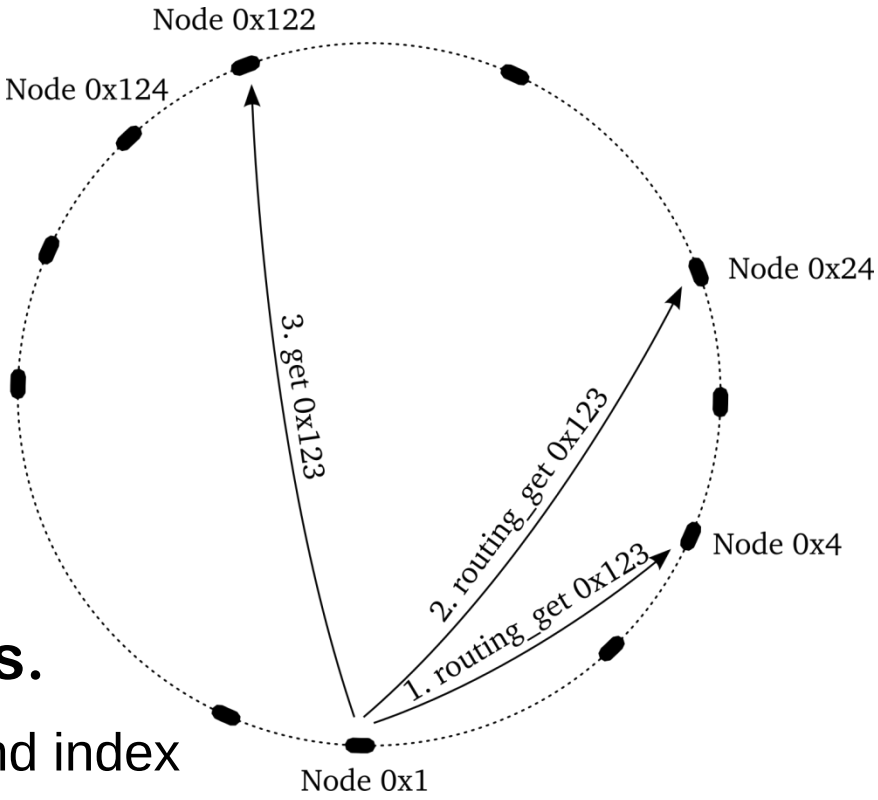
Mechanisms based on Hashing in DHTs

- **Index documents using**
  `put(hash(document), document)`
  - Document (0x321) contains word test
- **Index all neighbors (test, tes, tst, tet, est) using**
  `put(hash(neighbor), point to document)`
  - `hash("tes") = 0x123`



Mechanisms based on Hashing in DHTs

- **User searches for “tesx”**
- **Neighbors are generated (tesx, esx, tsx, tex, tes)**
  - get(hash(neighbor)) → 0x123
  - Find pointer to document (0x321)
  - document = get(0x321)
- **Tests with edit distance 1, partially 2, ignoring delete pos.**
  - Overhead (*n choose k*) for query and index
- **Similarity search as series of `put()` and `get()`**
- **Demo**



Mechanisms based on Hashing in DHTs

- **Direct data and persistent connections (data download)**
  - All connections in TomP2P are RPC and very short-lived
    - Open connection – request – reply – close connection
  - Direct data as seen in the tracker example → keep alive
  - Direct `sendDirect(PeerAddress, …)` / with routing `send(key,…)`
  - Always use `setObjectDataReply()` or `setRawDataReply()`
    - Object serializes object to byte[] (easy)
    - Raw exposes (Netty) buffer to the user for your own protocol (more work)
  - Persistent connections set by the user
    - Only for direct send `send(PeerAddress, …)`
- **Demo with persistent connections (net.tomp2p.examples.ExamplePersistentConnection)**

2. Connectivity, Security, and Robustness

NAT (UPNP/NAT-PMP/Hole punching)

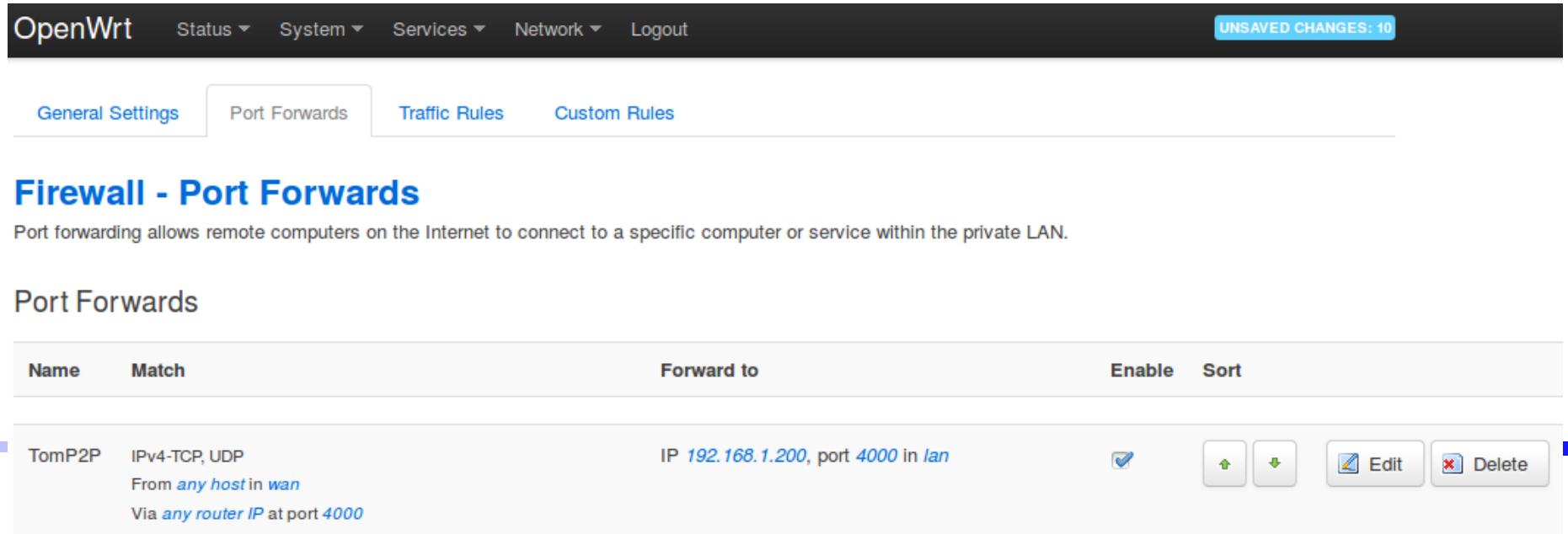
Security

Replication

Direct data connection / persistent connection

Connectivity, Security, and Robustness

- **NAT**
  - Network Address Translation – breaks end-to-end
  - "If nothing else, [NAT] can serve to provide temporarily relief while other, more complex and far-reaching solutions are worked out" (RFC 1631 - The IP Network Address Translator (NAT))
- **Easy solution:**
  - Manual port forwarding: e.g., setup on your router



Connectivity, Security, and Robustness

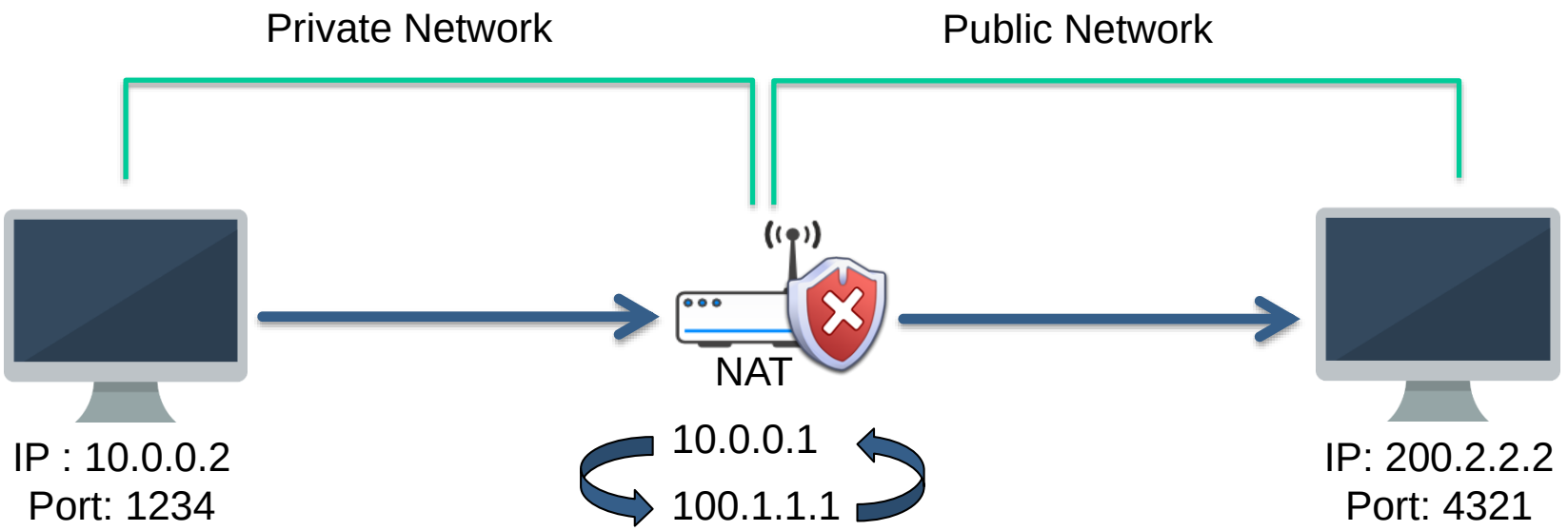
- **Easy solution: UPNP / NAT-PMP**
  - Both configure port forwarding, but UPNP is more: discover devices - uses broadcasting to find router (Simple Service Discovery Protocol)
  - UPNP: configure devices - uses HTTP and XML to configure port forwarding (Internet Gateway Device Protocol)
  - NAT-PMP: protocol made for configuring port-forwarding, but no discover (how to find router?)

Connectivity, Security, and Robustness

- **NAT example in TomP2P, the easy solution**
  - TomP2P supports NAT-PMP and UPNP, holepunching, and relaying
  - Before bootstrap: `peer.discover(PeerAddress);`
  - How it works: (1) send request how others peers sees our IP
    - If other peers sees the same IP as we see, we are fine
    - If not, we are most likely behind a NAT
  - (2) do UPNP, if it fails, do NAT-PMP, if it fails, mark it as firewalled, setup relays / rendez-vous
  - (3) If it works test connection, send request to other peer to contact us using the port we just set up.
  - (4) If we get contacted by this peer within 5 sec, port-forwarding works.
  - Manual setup possible using `Bindings.java`

Connectivity, Security, and Robustness

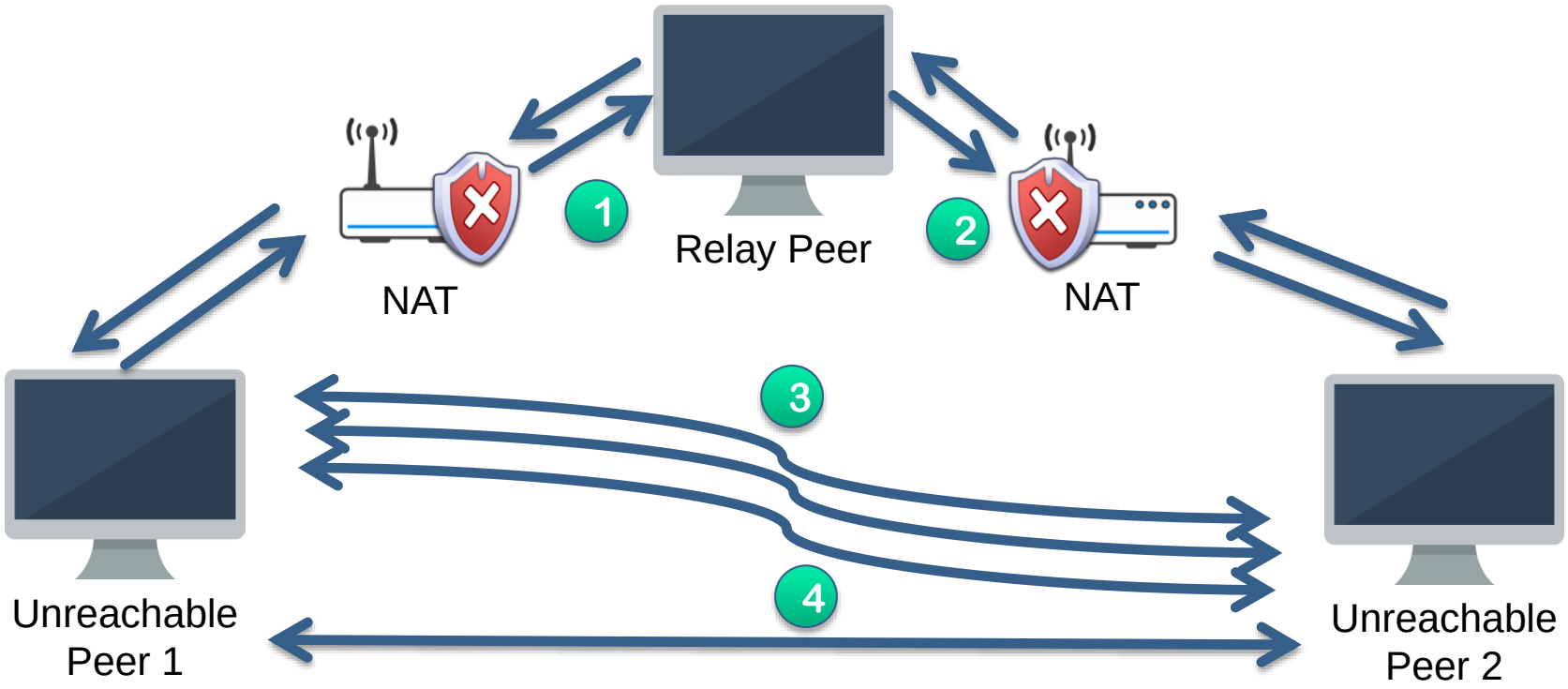
- **Difficult solution: NAT**
  - rendezvous / relay peer which does “hole punching”, in worst case relay traffic.
- **NAT: translation table for private / public network**



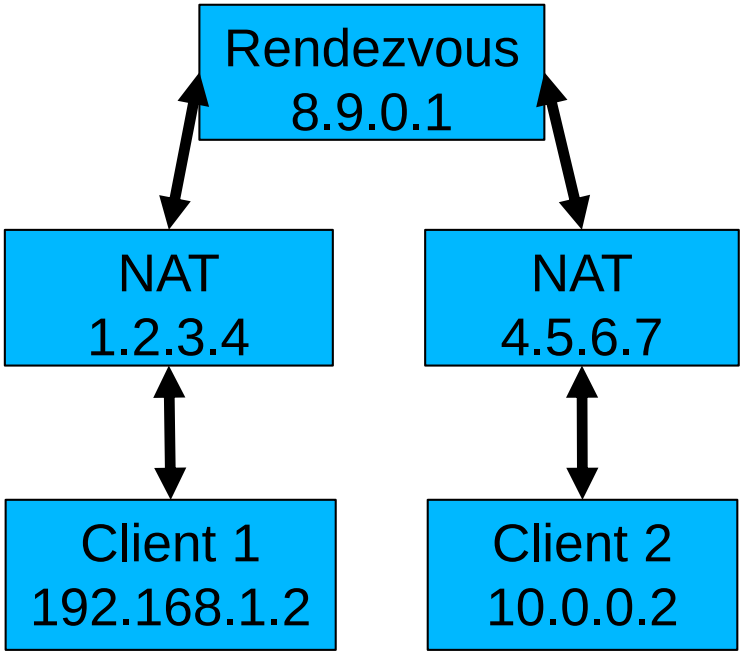
NAT Table Entry: (10.0.0.2:1234, 200.2.2.2:4321; 100.1.1.1:1234, 200.2.2.2:4321)

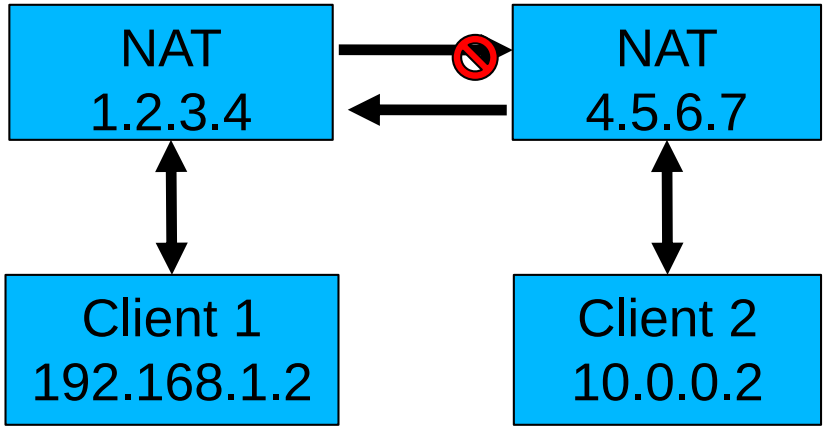
Connectivity, Security, and Robustness: Hole punching

- 1) Peer1 initiates a new connection trial to peer2 via relay and signals its source ports and IP
- 2) Peer2 answers back with its source ports and IP
- 3) Both of the peers punch holes into their firewall/NAT
- 4) Established a connection



- **Hole punching**
  - Client 1 sends request to NAT 4.5.6.7 that will fail – no mapping, however, Client 1 creates a mapping with that request
  - Client 2 send a request to Client 1 (1.2.3.4:Y) – success!



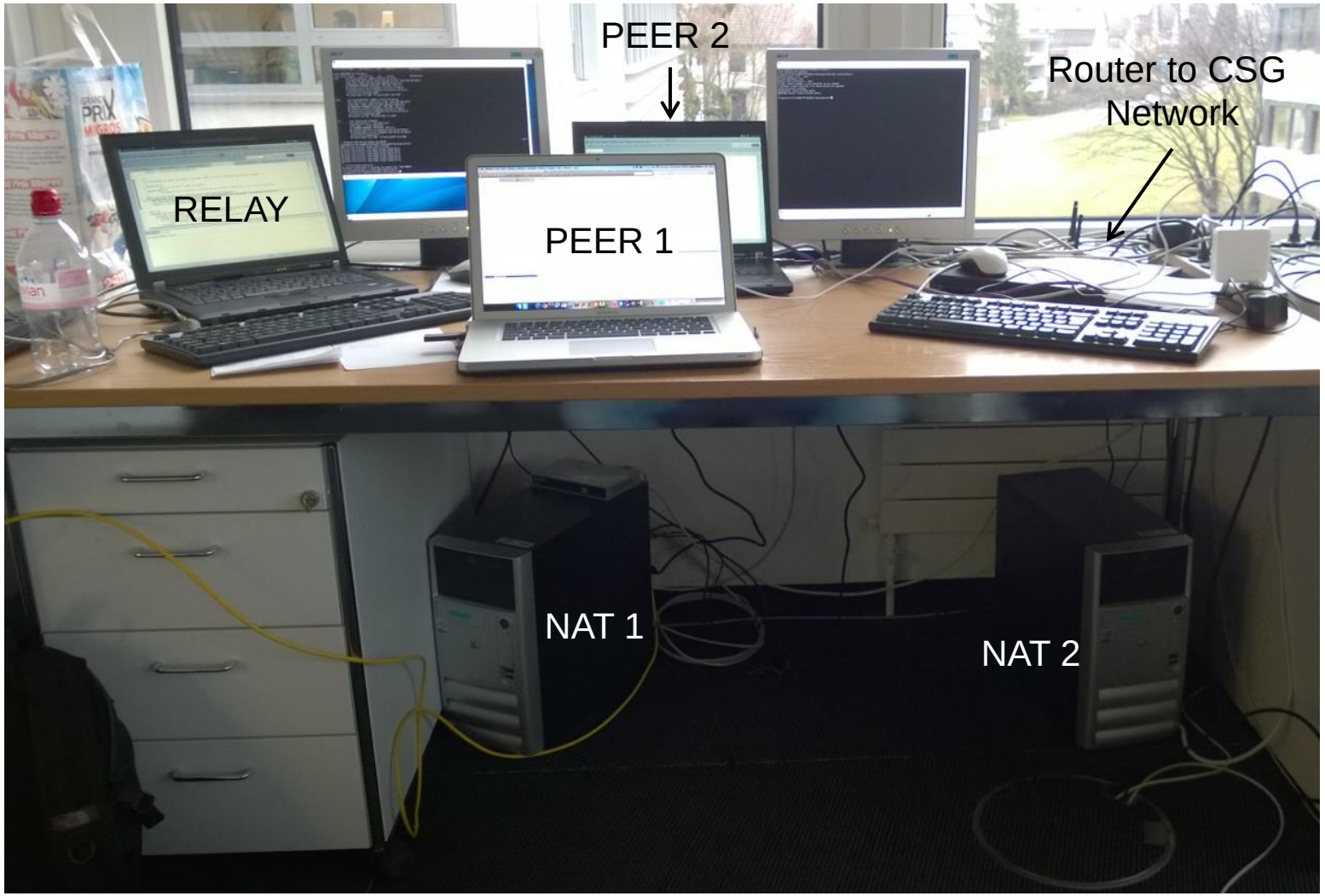


Mapping for NAT 1.2.3.4 (Client 1)			
192.168.1.2:4000	1.2.3.4:X	1.2.3.4:Y	4.5.6.7:Z

Mapping for NAT 4.5.6.7 (Client 2)			
10.0.0.2:5000	4.5.6.7:W	4.5.6.7:Z	1.2.3.4:Y

Connectivity, Security, and Robustness

- **Hole Punching Demo (Jonas Wagner)**



Connectivity, Security, and Robustness

- **If everything fails, use relays**
  - Well connected / reachable peer
  - Forwards the data to and from the unreachable peer
- **Relay candidates are close neighbors**
  - Will be added to your PeerAddress
  - Other peers will see the relay from the peer address, contact them
  - Up to 5 relay peers
- **Relays keep TCP connection open**
  - UDP messages (ping / neighbor) handled by relays itself
  - Unreachable peer must update information for relays to be able to handle request

Connectivity, Security, and Robustness

- **Security in TomP2P (best-effort security)**
  - Signature-based, no data encryption
  - Messages are signed using SHA1 with DSA
  - Sybil attacks!
    - This attack creates large number of identities, may collude
- **How to prevent Data from being overwritten**
  - Domain and entry protection, requires cooperation
  - `StorageGeneric.setProtection(…)`

For domains and entries		
protectionEnabled	ALL	NONE
protectionMode	NO_MASTER	MASTER_PUBLIC_KEY

Connectivity, Security, and Robustness

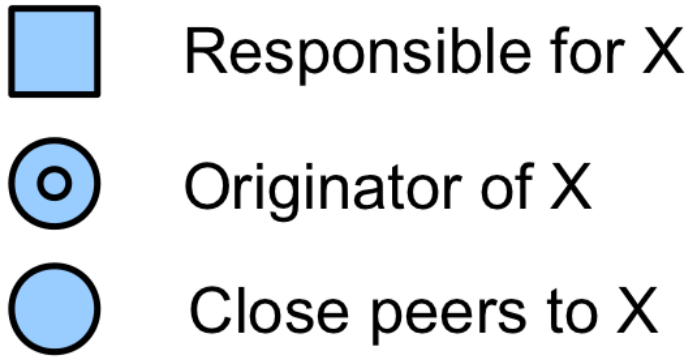
- **Domain protection**
  - Set publick key `new PeerMaker(PublicKey)`
    - Enable=ALL, Mode=NO_MASTER → every peer can protect domains, first come first served
    - Enable=NONE, Mode=NO_MASTER → no peer can protect domains
    - Enable=ALL, Mode=MASTER_PUBLIC_KEY → every peer can protect domains, the owner can claim domain
    - Enable=NONE, Mode=MASTER_PUBLIC_KEY → no peer can protect domains except the owner
  - Owner of domain 0x1234 is peer where 0x1234 == hash(public_key)
  - Same concept for entries
  - Tracker should have no domain protection and entry protection set to Enable=NONE, Mode=MASTER_PUBLIC_KEY → WiP
- **Demo**

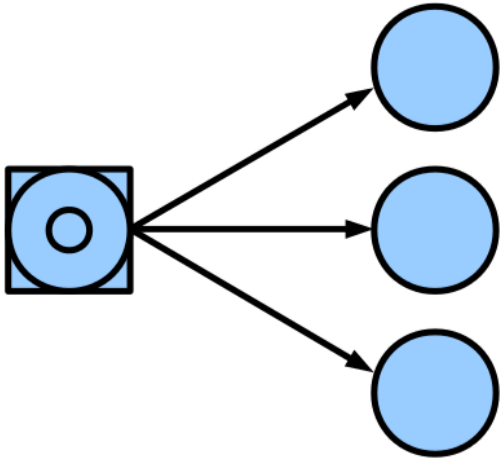
Connectivity, Security, and Robustness

- **Demo 1 (net.tomp2p.examples.ExampleDomainProtection):**
  - 3 peers, all with public keys
  - Setup for domains: Enable=ALL, Mode=MASTER_PUBLIC_KEY
  - (1) peer1 stores data in domain2 → success
  - (2) peer3 wants to store data in domain2 → fail
  - (3) peer2 wants to store data in domain2 → success
- **Demo 2 (net.tomp2p.examples.ExampleDomainProtection):**
  - 3 peers, all with public keys
  - Setup for domains: Enable=NONE, Mode=MASTER_PUBLIC_KEY
  - (1) peer1 stores data in domain2 → success
  - (2) peer3 wants to store data in domain2 → success
  - (3) peer2 wants to store data in domain2 → success
  - (4) peer3 wants to store data in domain2 → fail
- **TomP2P + Bitcoin Blockchain (current master project)**

Connectivity, Security, and Robustness

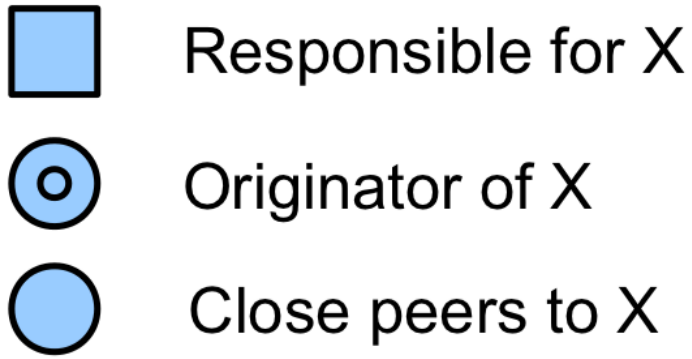
- **Replication**
  - Enough replicas
  - Direct replication
    - Originator peer is responsible
    - Periodically refresh replicas
    - Example: tracker that announces its data

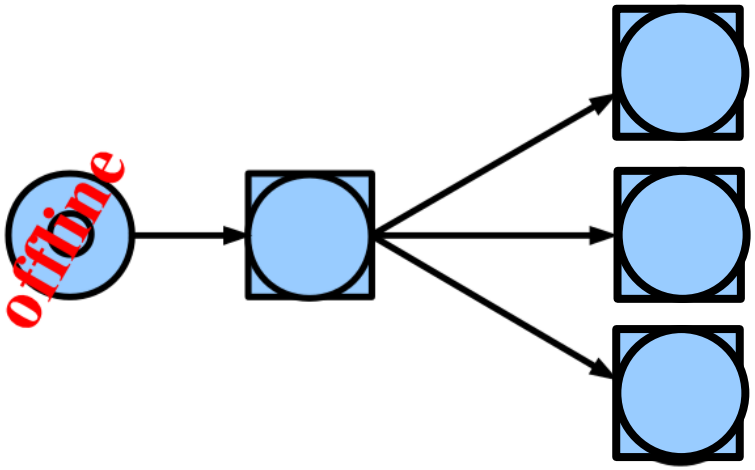




- **Problem**
  - Originator offline → replicas disappear. Content has TTL, e.g.
    `data.ttlSeconds(15)`

- **Indirect Replication**
  - The closest peer is responsible, originator may go offline (0Root)
    - Periodically checks if enough replicas exist
    - Detects if responsibility changes





nRoot (default is 0Root)

- **Problem**
  - Requires cooperation between responsible peer and originator
  - Multiple peers may think they are responsible for different versions → eventually solved
  - **Replication Demo** (net.tomp2p .examples.ExampleDirectReplication)

3. Consistency

Paxos

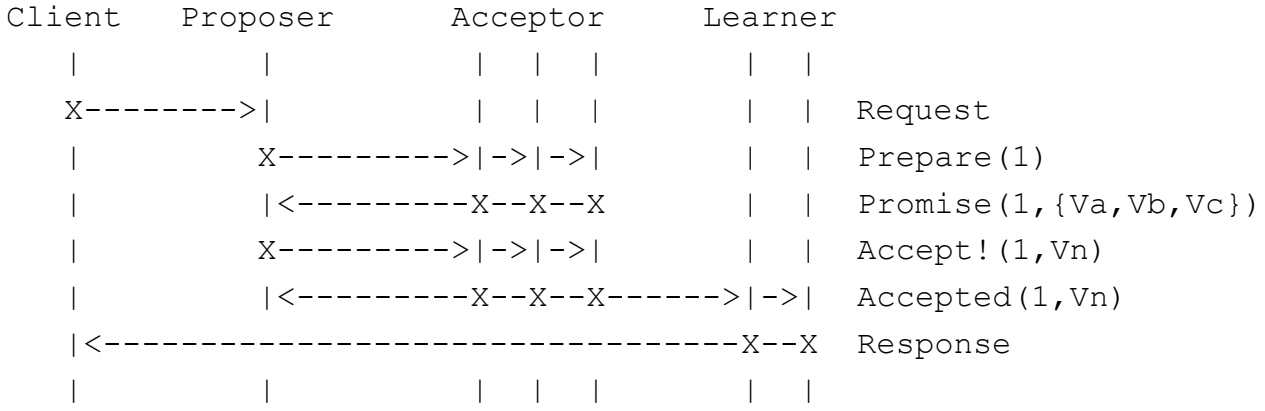
vDHT

Consistency

- **DHTs have weak consistency**
  - Peer A put X.1, Peer B gets X.1 modifies it puts X.2
  - Same time: Peer C gets X.1 modifies it puts X.2
    - Which one is stored X.2 of B or X.2 of C?
- **Consistency generic issue in distributed systems**
  - Coordinator required:
    - easy solution: centralized
    - Interesting solution: decentralized, in case failed peer, pick another peer
- **Coordinator needs to be defined**
  - Election, example Paxos

Consistency

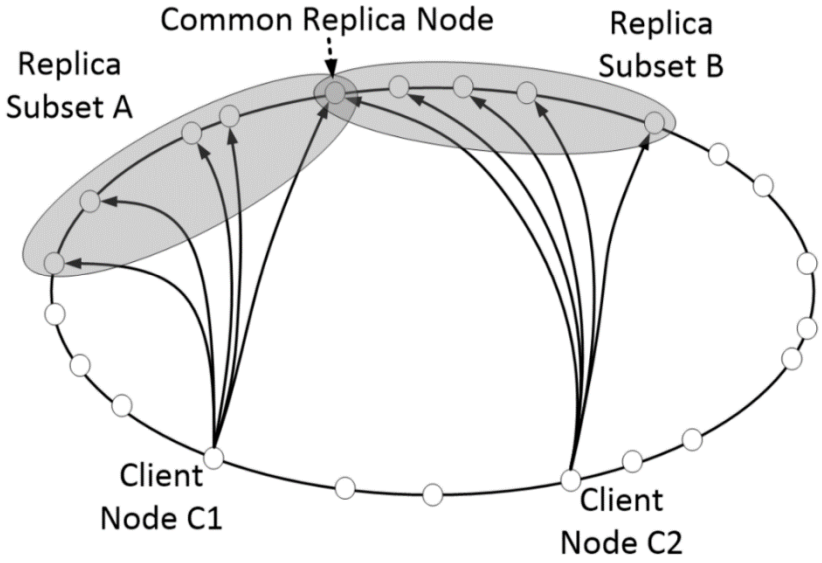
- **Paxos**
  - Protocol family for consensus (multi, cheap, fast, generalized, …)
  - Roles: Client/Proposer (requester), Acceptor (voter), Leader (coordinator), Learner (responder)
    - Client sends requests to a proposer
    - Proposer attempts to convince a majority of acceptors
    - If majority accepts, request is sent to learner
    - Learner sent result to client
- **2 Phases**
  - Phase 1: prepare / promise
  - Phase 2: accept / accepted

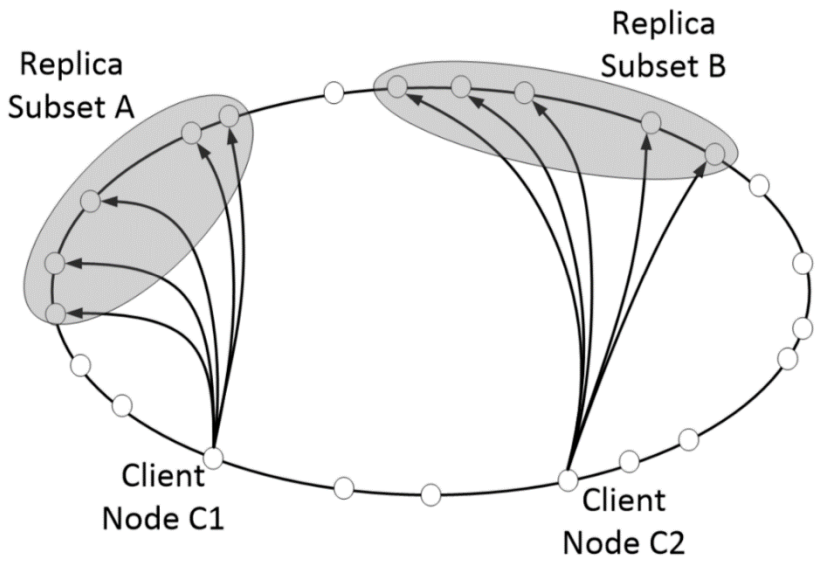


http://en.wikipedia.org/wiki/Paxos_%28computer_science%29

Consistency

- **Raft – Alternative to Paxos (easier), three roles: leader, follower, candidate**
  - Raft, Paxos for partition tolerance
- **Consistency in DHTs – vDHT**
  - CoW and ~2PC and replication → Software transactional memory (STM) → Works for light churn





Consistency

- **vDHT Basics**
  - No locking, no timestamps (replication time may have an influence)
    - 1. get latest version, check if all replica peers have latest version, if not wait and try again
    - 2. put prepared with data and short ttl, if status is OK on all replica peers, go ahead, otherwise, remove the data and go to step 1.
    - 3. put confirmed, don't send the data, just remove the prepared flag
- **In case of heavy churn, API user needs to resolve**
  - In CT: 2 files conflicting, mark files as conflict and let user decide.
- **Demo: net.tomp2p.examples. ExampleVDHT (new)**
  - Example: no consistency – traditional put strategy
  - Example: vDHT - pessimistic put strategy

4. Rsync

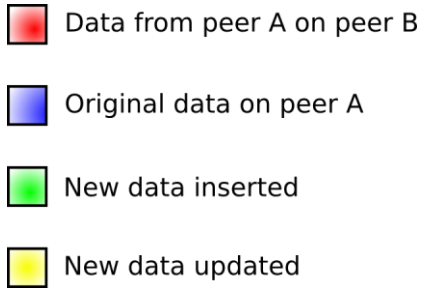
Introduction, Example, and Discussion

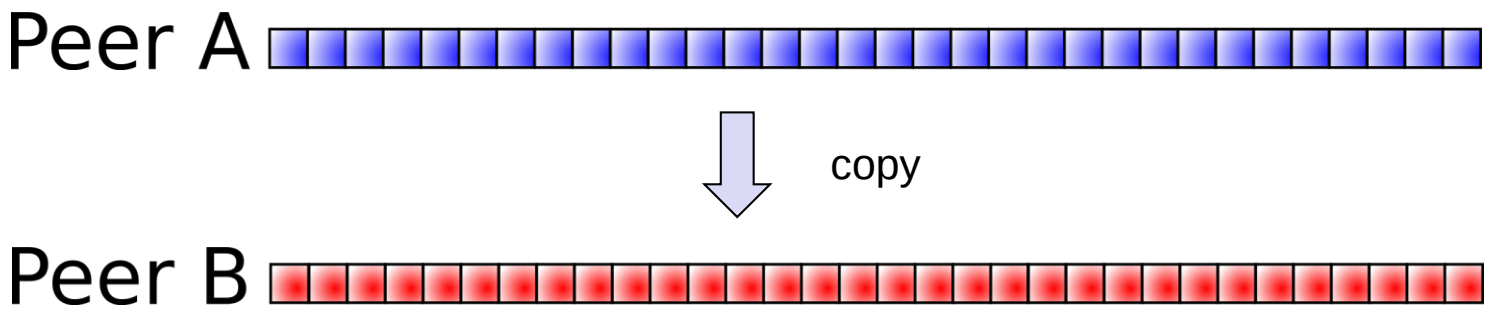
Rsync - Introduction

- **Rsync used to synchronize data over network**
  - Minimizing data transfer (delta)
- **Command line client (standard utility)**
  - E.g. `rsync -aP --link-dest=$HOME/Backups/current /path/to/important_files $HOME/Backups/back-$date`
  - Unchanged files are hard linked (`--link-dest`) → Can be used for incremental backups
- **Main idea**
  - Receiver compute two checksums (strong, weak) → sent to sender
  - Sender computes with weak checksum and checks for known blocks
  - Sender verifies with strong checksum → sends difference to receiver
- **Example with two peers:**

Rsync - Example

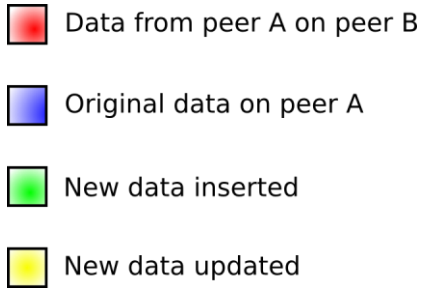
- **Peer B does not have the data → peer A copies it to peer B, no need for rsync**

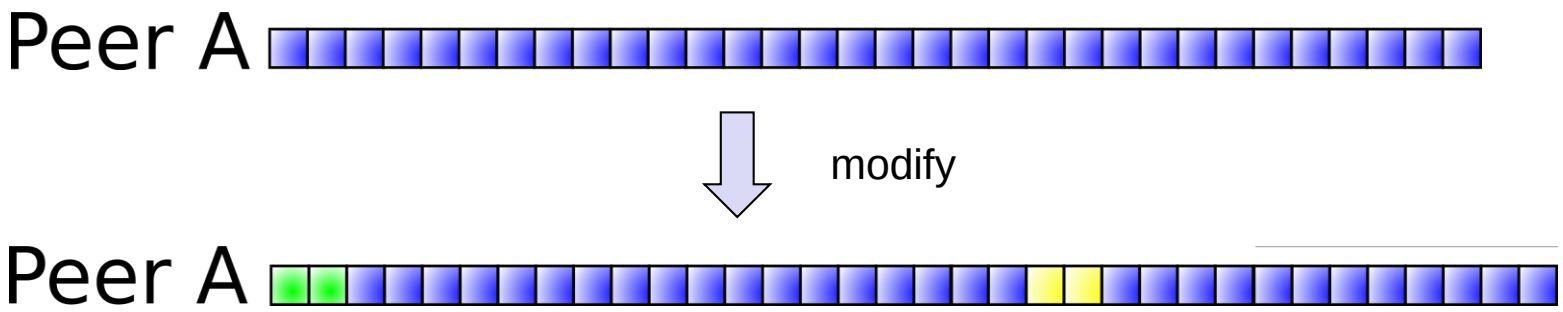




Rsync - Example

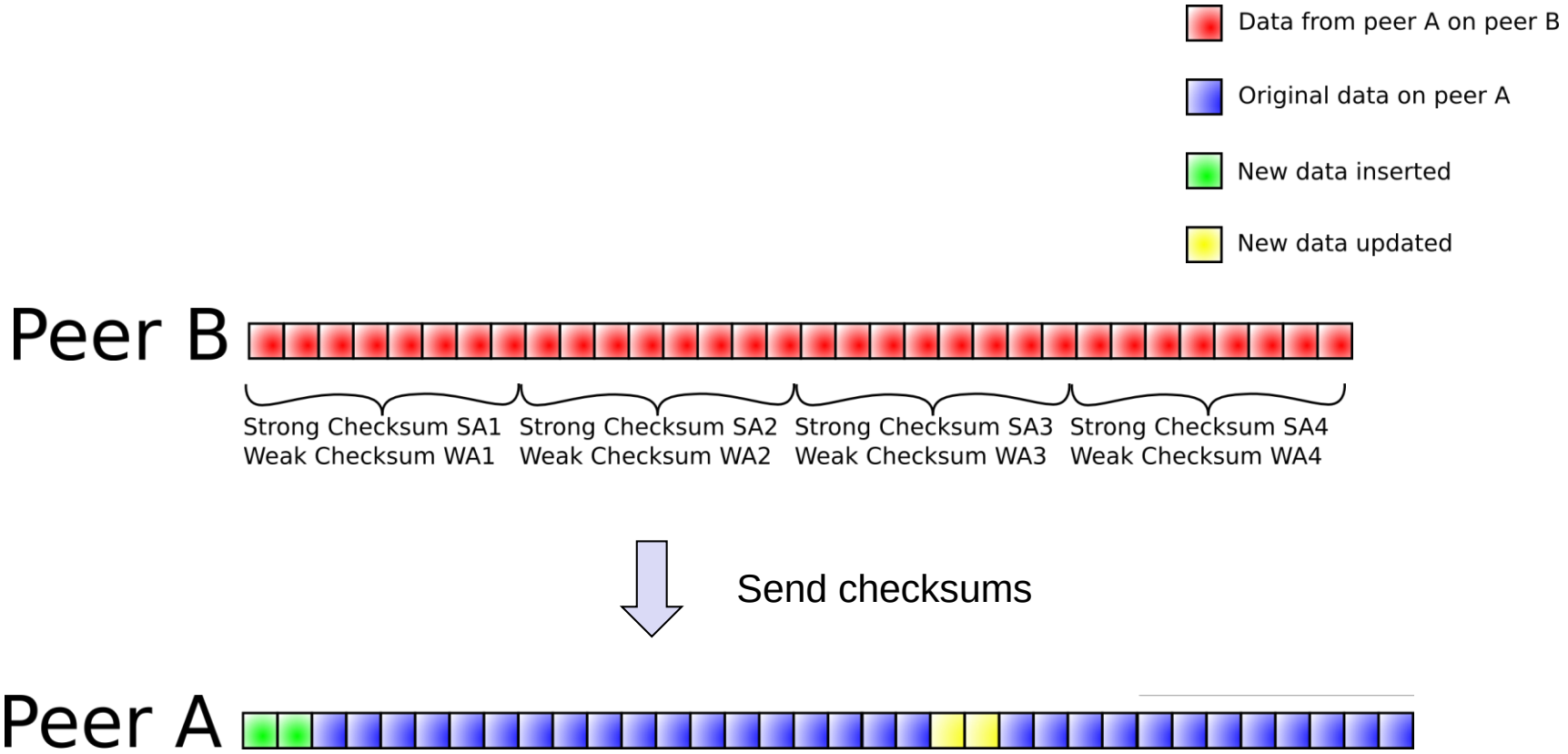
- **Peer A modifies data (insert, update)**
  - Wants to synchronize with peer B



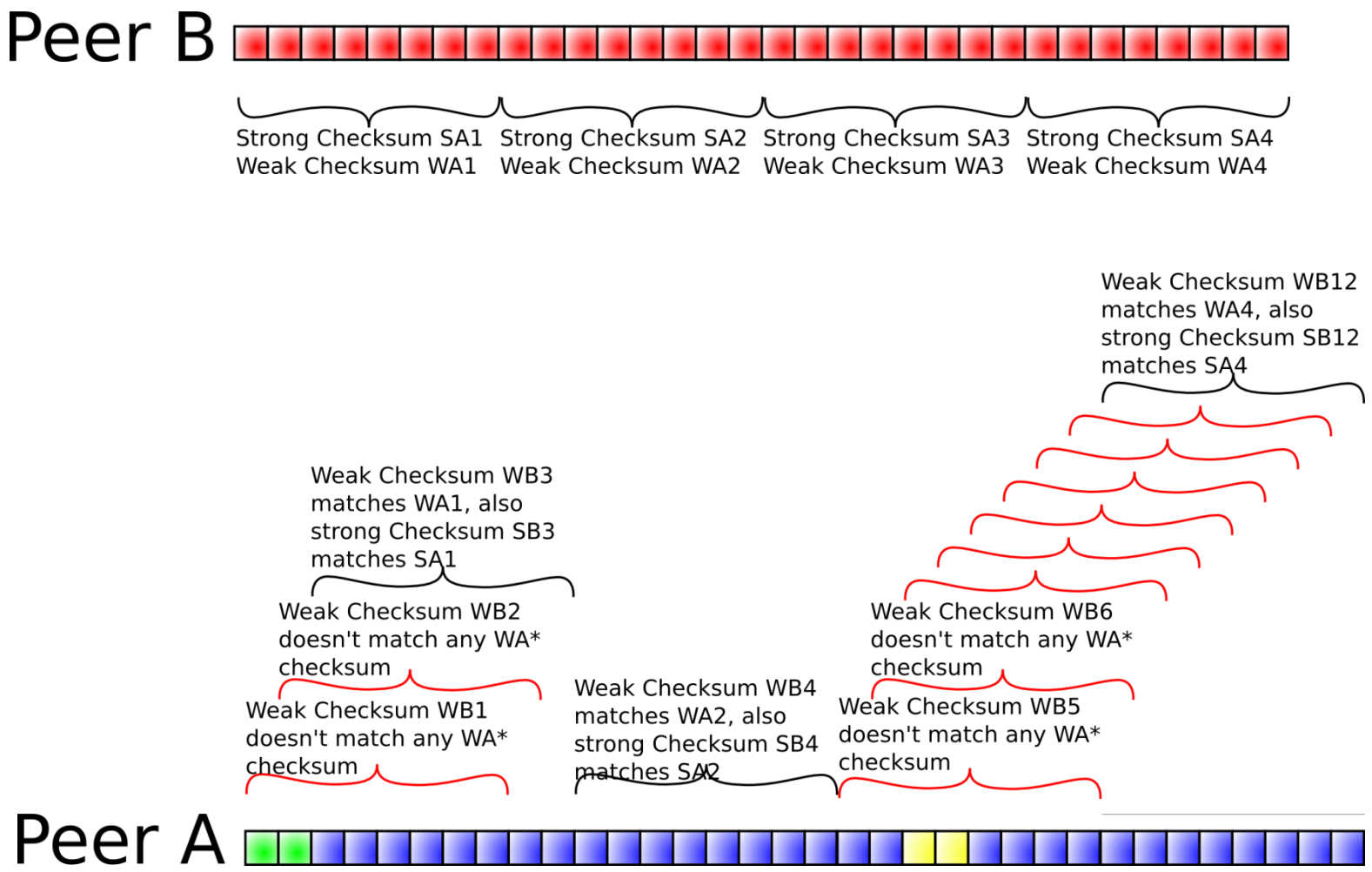


Rsync - Example

- **Peer A modifies data (insert, update)**
  - Wants to synchronize with peer B

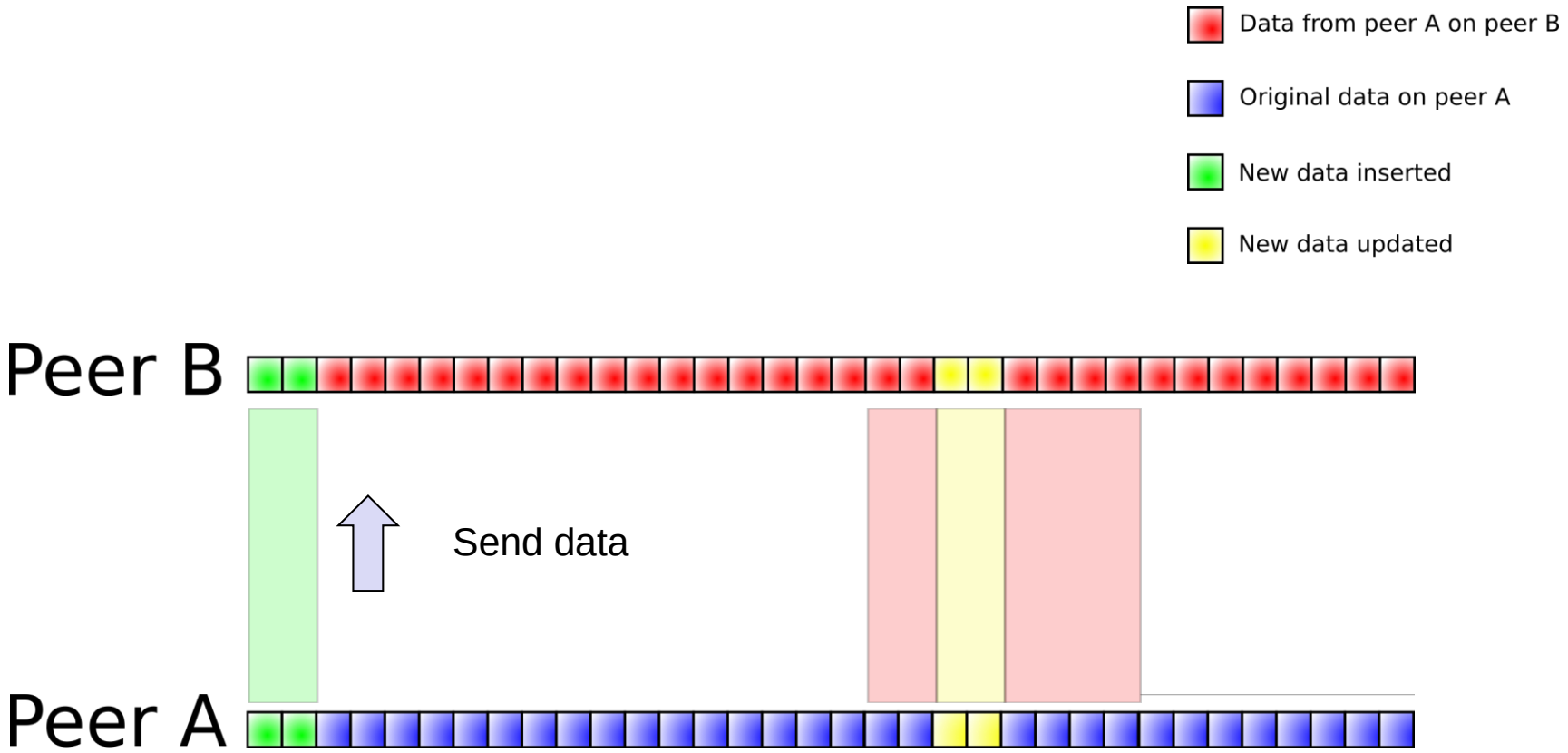


Rsync - Example



Rsync - Example

- **Peer A sends 2 + 8 blocks to peer B**
  - Peer A and peer B have same data



Rsync - Mechanism / Discussion

- **If data does not exist → copy**
  - Use-case: portion of data stays the same
  - Replication
- **Problem if data is compressed**
  - Compressed data changes (adaptive compression)
  - Restart adaption / reset compression algorithm
- **Two checksums for performance (MD5 and Adler-32)**
  - Collisions possible, but unlikely 2^{-160}
- **Rsync in TomP2P (demo)**
  - net.tomp2p.examples.ExampleRsync (new)