CoNe Freiburg

Peer-to-Peer Networks

Chord
3rd Week

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Computer Networks and Telematics
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Summer 2008

Peer-to-Peer Networks

Chord

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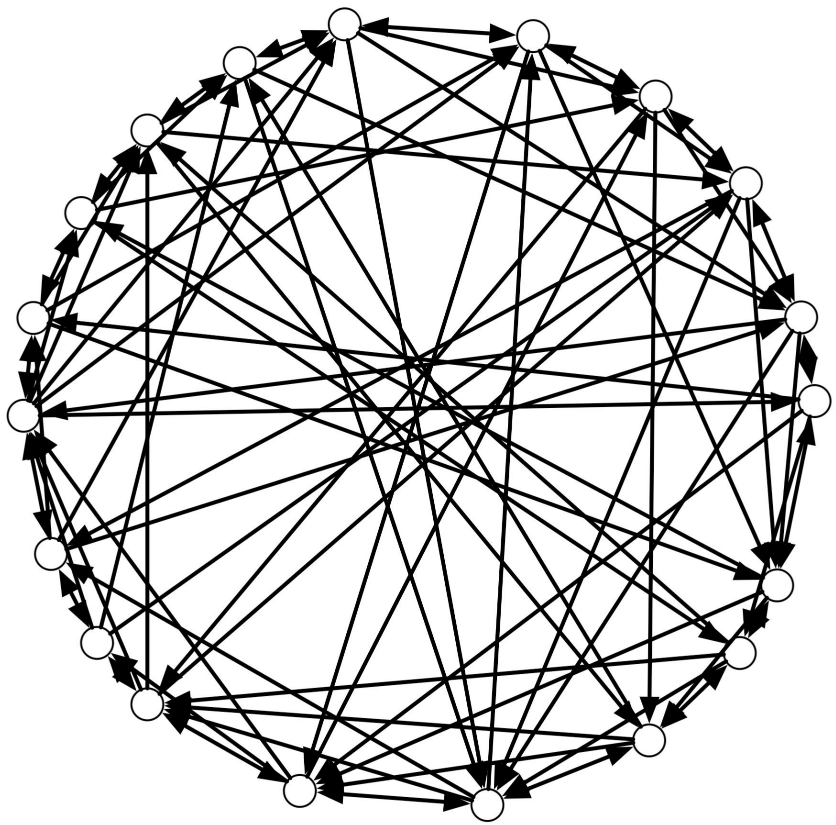
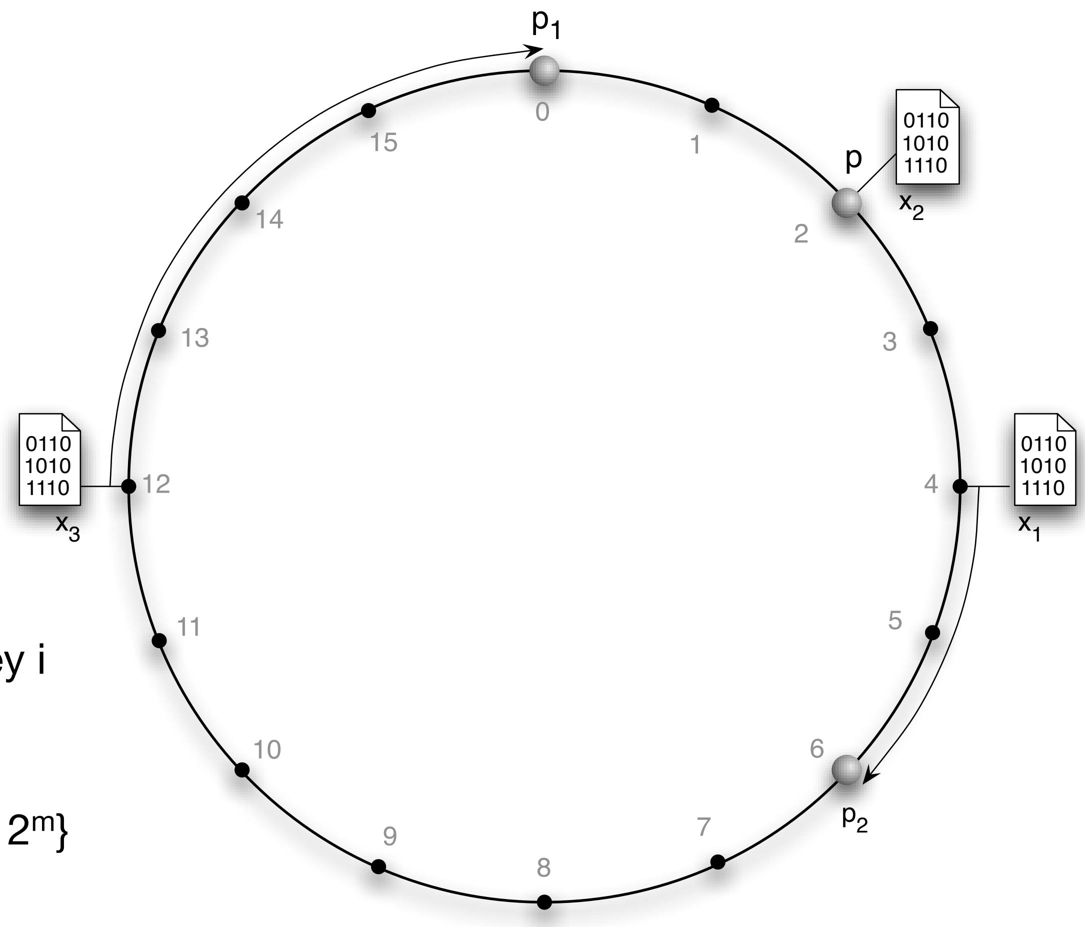
Chord

- **Ion Stoica, Robert Morris, David Karger, M. Frans Kaashoek and Hari Balakrishnan (2001)**
- **Distributed Hash Table**
  - range {0,..,2^m-1}
  - for sufficient large m
- **Network**
  - ring-wise connections
  - shortcuts with exponential increasing distance



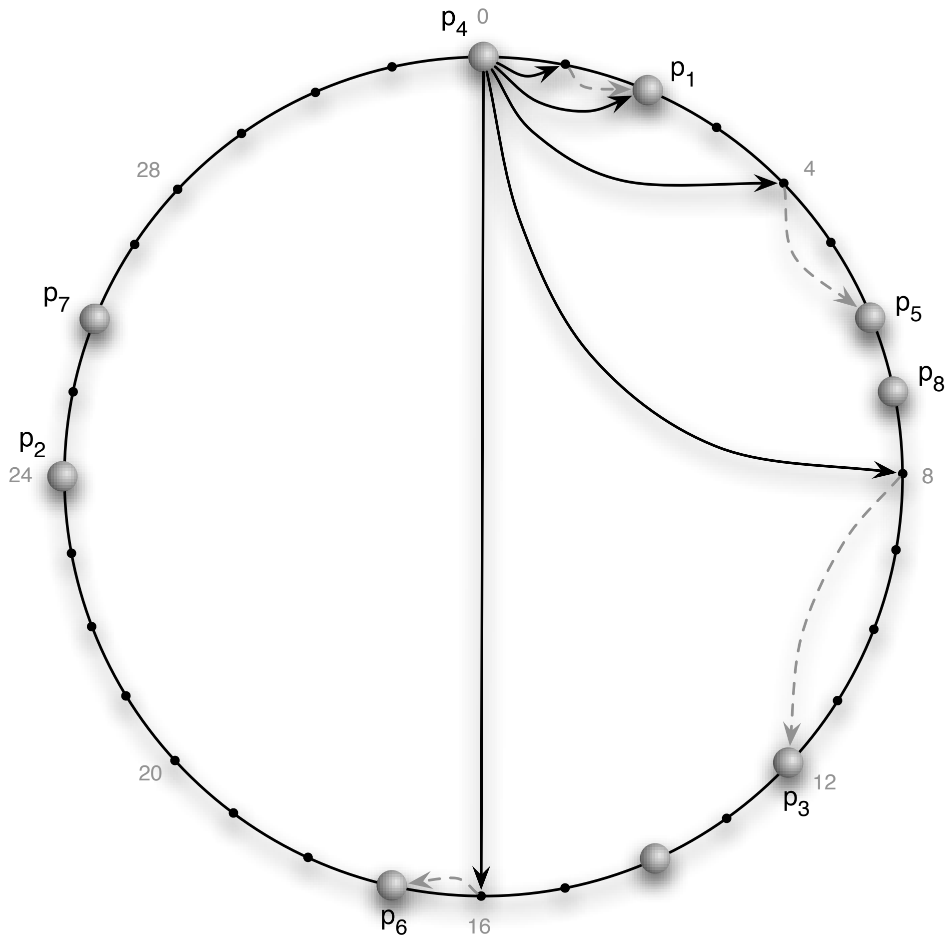
Chord as DHT

- **n number of peers**
- **V set of peers**
- **k number of data stored**
- **K set of stored data**
- **m: hash value length**
  - $m \geq 2 \log \max\{K,N\}$
- **Two hash functions mapping to $\{0,..,2^{m-1}\}$**
  - $r_V(b)$: maps peer to $\{0,..,2^{m-1}\}$
  - $r_K(i)$: maps index according to key i to $\{0,..,2^{m-1}\}$
- **Index i maps to peer $b = f_V(i)$**
  - $f_V(i) := \arg\min_{b \in V}\{(r_V(b)-r_K(i)) \bmod 2^m\}$



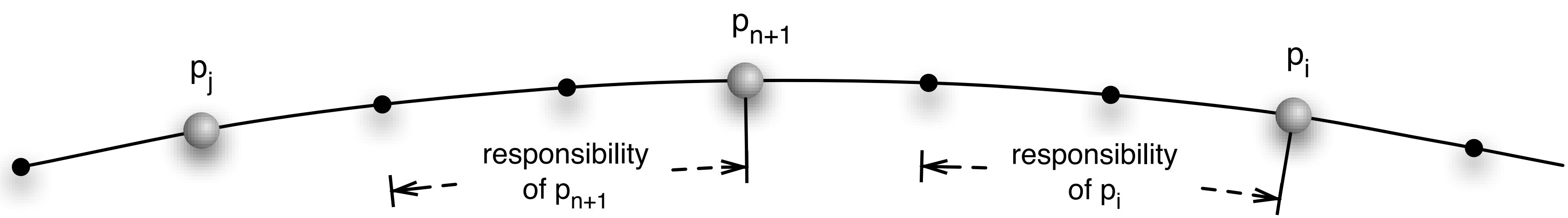
Pointer Structure of Chord

- **For each peer**
  - successor link on the ring
  - predecessor link on the ring
  - for all i ∈ {0,..,m-1}
    - Finger[i] := the peer following the value $r_V(b+2^i)$
- **For small i the finger entries are the same**
  - store only different entries
- **Lemma**
  - The number of different finger entries is O(log n) with high probability, i.e. $1\text{-}n^{-c}$.



Balance in Chord

- **Theorem**
  - We observe in Chord for n peers and k data entries
    - Balance&Load: Every peer stores at most O(k/n log n) entries with high probability
    - Dynamics: If a peer enters the Chord then at most O(k/n log n) data entries need to be moved
- **Proof**
  - …



Properties of the DHT

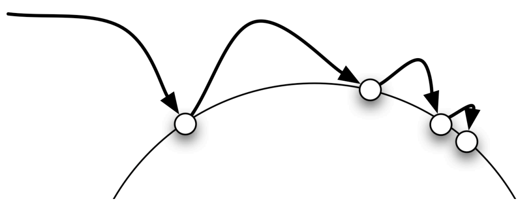
- **Lemma**
  - For all peers b the distance $|r_V(b.succ) - r_V(b)|$ is
    - in the expectation $2^m/n$,
    - $O((2^m/n) \log n)$ with high probability (w.h.p.)
    - $2^m/n^{c+1}$ für a constant $c>0$ with high probability
  - In an interval of length $w\ 2^m/n$ we find
    - $\Theta(w)$ peers, if $w=\Omega(\log n)$, w.h.p.
    - at most $O(w \log n)$ peers, if $w=O(\log n)$, w.h.p.
- **Lemma**
  - The number of nodes who have a pointer to a peer b is $O(\log^2 n)$ w.h.p.

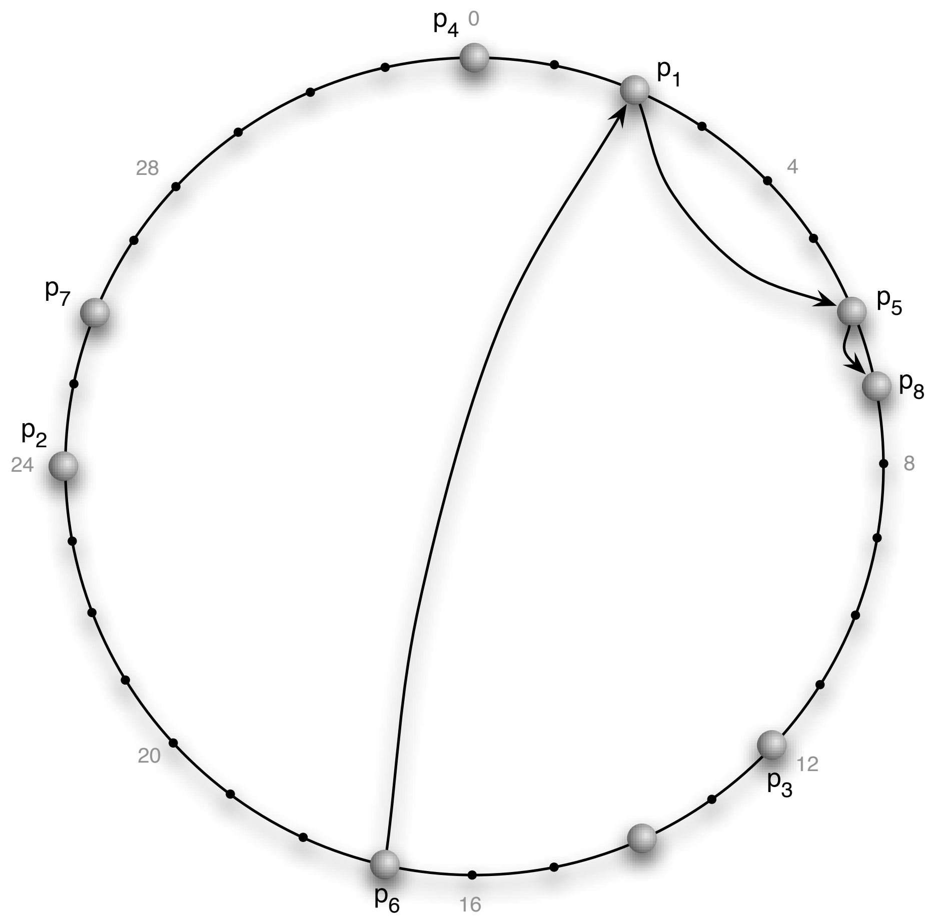
Lookup in Chord

- **Theorem**
  - The Lookup in Chord needs O(log n) steps w.h.p.
- **Lookup for element s**
  - Termination(b,s):
    - if peer b,b'=b.succ is found with $r_K(s) \in [r_V(b),r_V(b')|$
  - **Routing**:
    Start with any peer b
    while not Termination(b,s) do
    for i=m downto 0 do
    if $r_K(s) \in [r_V(b.finger[i]),r_V(finger[i+1])]$ then
    b ← b.finger[i]
    fi
    od

Lookup in Chord

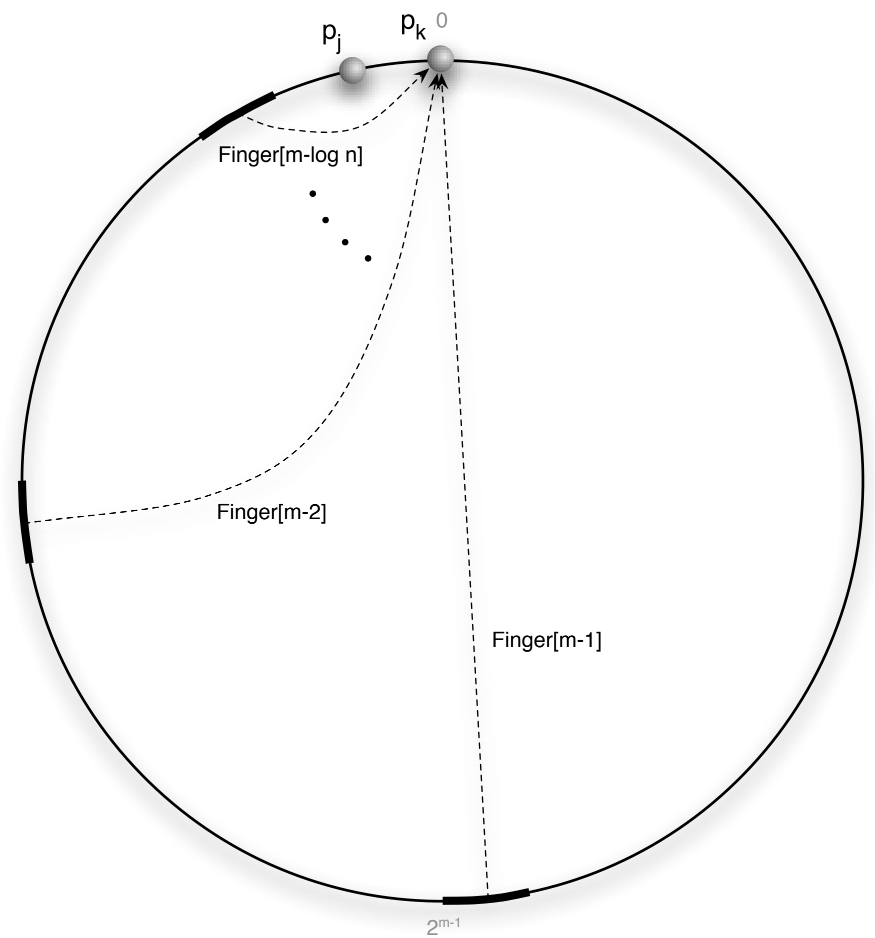
- **Theorem**
  - The Lookup in Chord needs O(log n) steps w.h.p.
- **Proof:**
  - Every hops at least halves the distance to the target
  - At the beginning the distance is at most
  - The minimum distance between is $2^m/n^c$ w.h.p.
  - Hence, the runtime is bounded by c log n w.h.p.





How Many Fingers?

- **Lemma**
  - The out-degree in Chord is O(log n) w.h.p.
  - The in-degree in Chord is $O(\log^2 n)$ w.h.p.
- **Proof**
  - The minimum distance between peers is $2^m/n^c$ w.h.p.
    - this implies that that the out-degree is O(log n) w.h.p.
  - The maximum distance between peers is $O(\log n\ 2^m/n)$ w.h.p.
    - the overall length of all line segments where peers can point to a peer following a maximum distance is $O(\log^2 n\ 2^m/n)$
    - in an area of size $w=O(\log^2 n)$ there are at most $O(\log^2 n)$ w.h.p.



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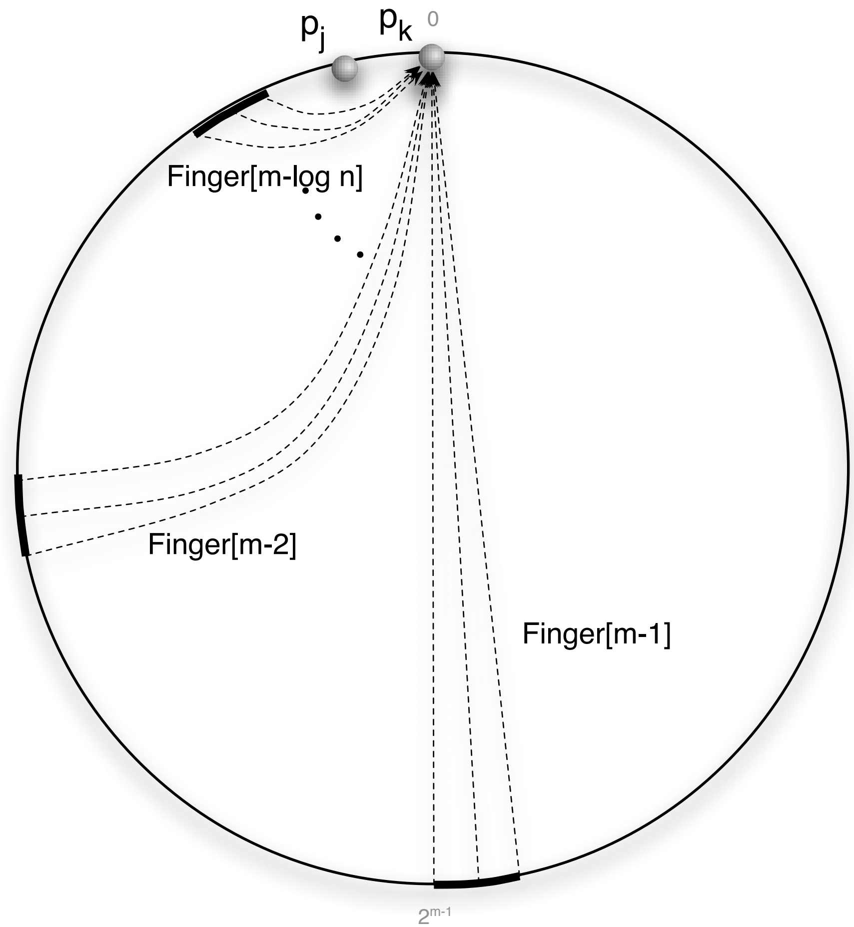
Inserting Peer

- **Theorem**
  - For integrating a new peer into Chord only $O(\log^2 n)$ messages are necessary.

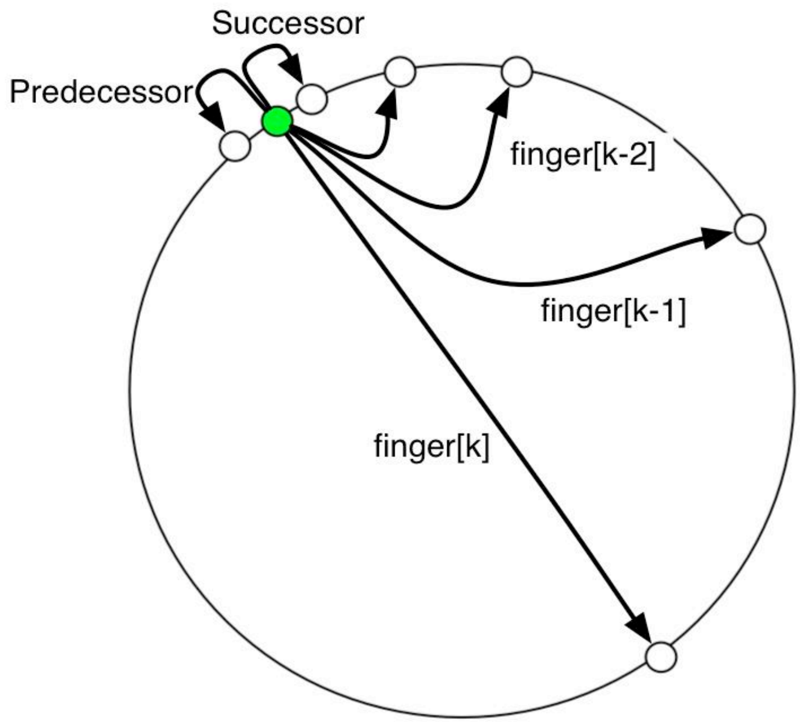
Adding a Peer

- **First find the target area in O(log n) steps**
- **The outgoing pointers are adopted from the predecessor and successor**
  - the pointers of at most O(log n) neighbored peers must be adapted
- **The in-degree of the new peer is O(log²n) w.h.p.**
  - Lookup time for each of them
  - There are O(log n) groups of neighb ored peers
  - Hence, only O(log n) lookup steps with at most costs O(log n) must be used
  - Each update of has constant cost



Data Structure of Chord

- **For each peer**
  - successor link on the ring
  - predecessor link on the ring
  - for all i ∈ {0,..,m-1}
    - Finger[i] := the peer following the value $r_V(b+2^i)$
- **For small i the finger entries are the same**
  - store only different entries
- **Chord**
  - needs O(log n) hops for lookup
  - needs $O(\log^2 n)$ messages for inserting and erasing of peers



Peer-to-Peer Networks

DHash++

Routing-Techniques for CHORD: DHash++

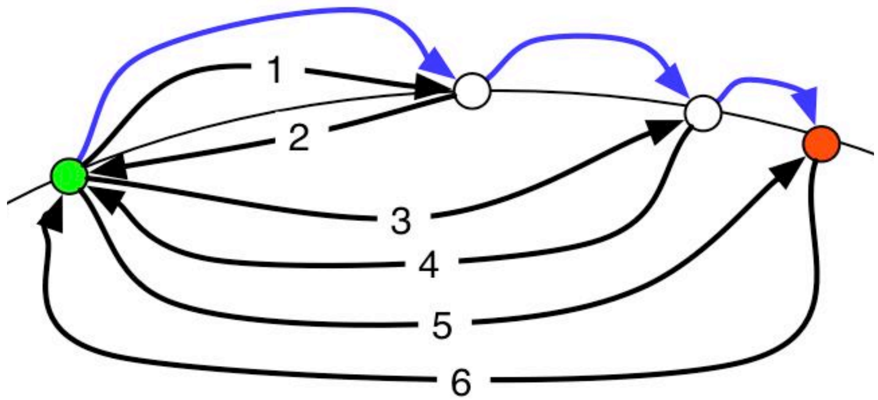
- **Frank Dabek, Jinyang Li, Emil Sit, James Robertson, M. Frans Kaashoek, Robert Morris (MIT)**
  „Designing a DHT for low latency and high throughput“, 2003
- **Idea**
  - Take CHORD
- **Improve Routing using**
  - Datenlayout
  - Recursion (instead of Iteration)
  - Next Neighbor-Election
  - Replication versus Coding of Data
  - Error correcting optimized lookup
- **Modify transport protocol**

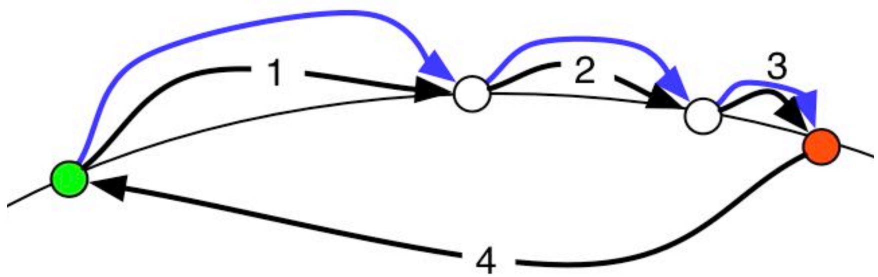
Data Layout

- **Distribute Data?**
- **Alternatives**
  - Key location service
    - store only reference information
  - Distributed data storage
    - distribute files on peers
  - Distributed block-wise storage
    - either caching of data blacks
    - or block-wise storage of all data over the network

Recursive Versus Iterative Lookup

- **Iterative lookup**
  - Lookup peer performs search on his own
- **Recursive lookup**
  - Every peer forwards the lookup request
  - The target peer answers the lookup-initiator directly
- **DHash++ choses recursive lookup**
  - speedup by factor of 2





Recursive Versus Iterative Lookup

- **DHash++ choses recursive lookup**
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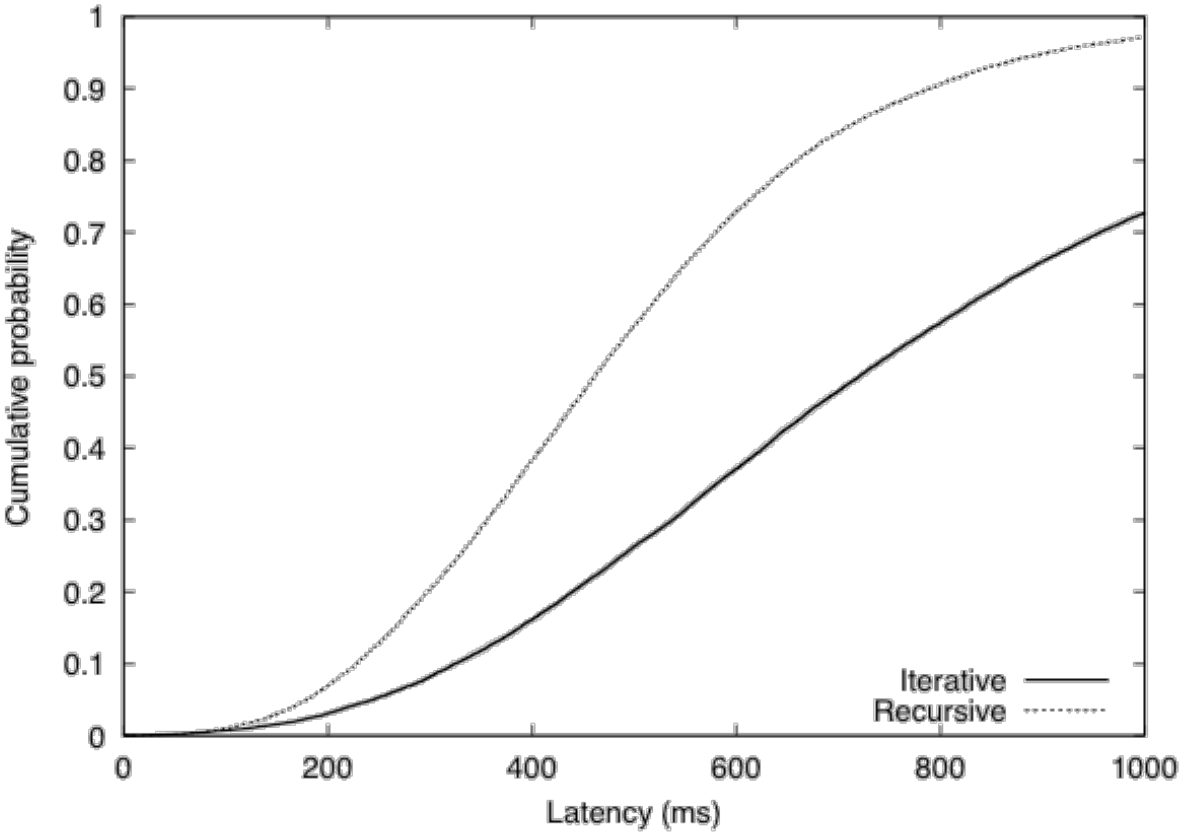
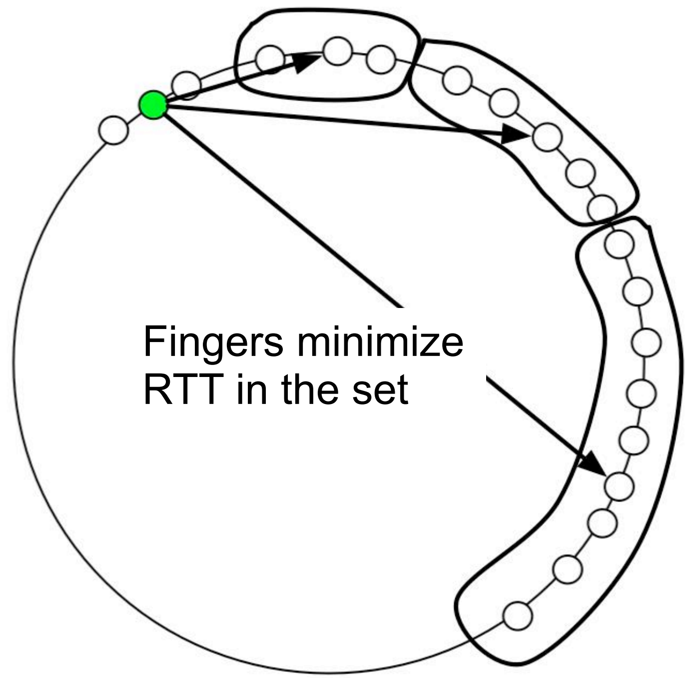


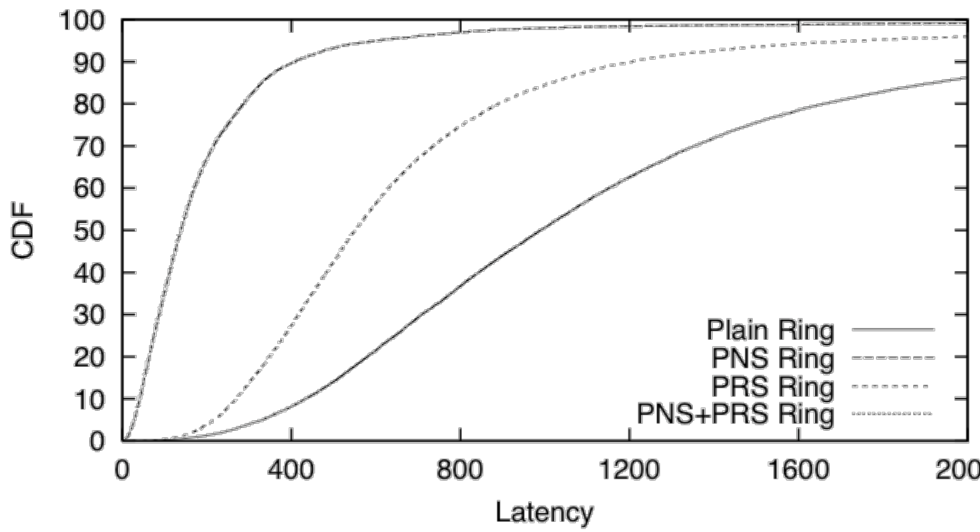
Next Neighbor Selection

- **RTT: Round Trip Time**
  - time to send a message and receive the acknowledgment
- **Method of Gummadi, Gummadi, Grippe, Ratnasamy, Shenker, Stoica, 2003, „The impact of DHT routing geometry on resilience and proximity“**
  - Proximity Neighbor Selection (PNS)
    - Optimize routing table (finger set) with respect to (RTT)
    - method of choice for DHASH++
  - Proximity Route Selection(PRS)
    - Do not optimize routing table choose nearest neighbor from routing table

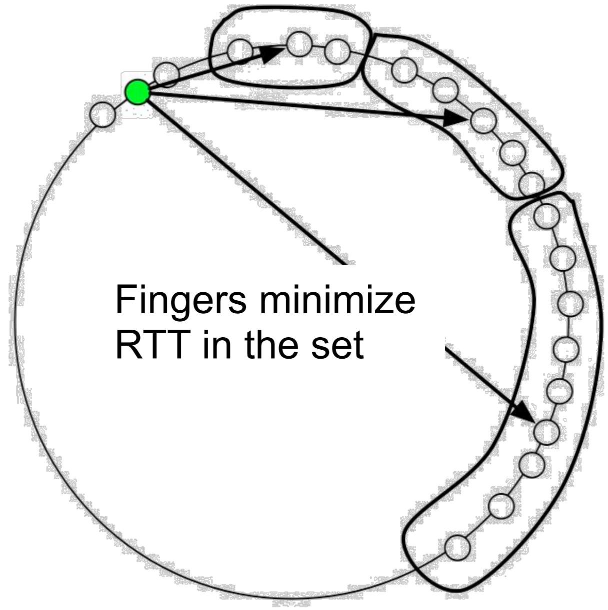


Next Neighbor Selection

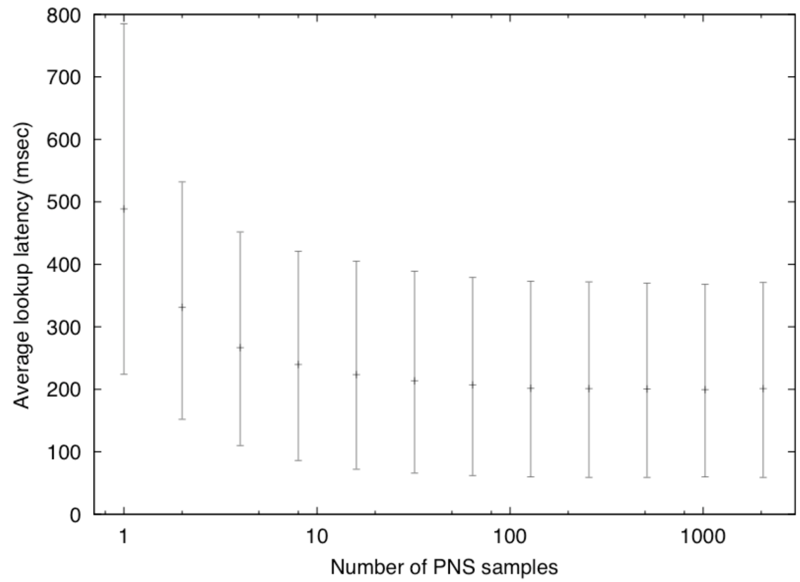
- **Gummadi, Gummadi, Grippe, Ratnasamy, Shenker, Stoica, 2003, „The impact of DHT routing geometry on resilience and proximity“**
  - Proximity Neighbor Selection (PNS)
    - Optimize routing table (finger set) with respect to (RTT)
    - method of choice for DHASH++
  - Proximity Route Selection(PRS)
    - Do not optimize routing table choose nearest neighbor from routing table
- **Simulation of PNS, PRS, and both**
  - PNS as good as PNS+PRS
  - PNS outperforms PRS



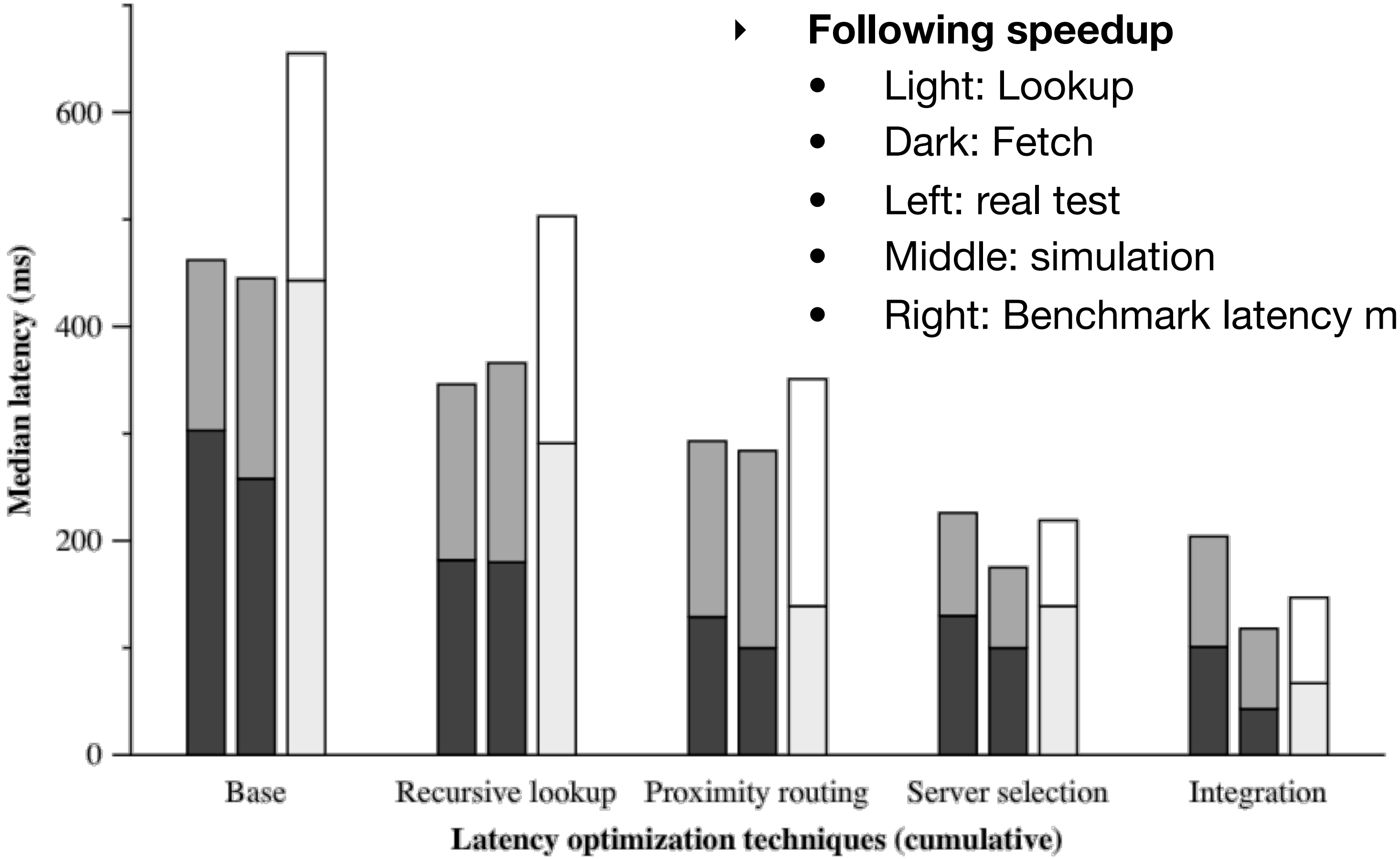
Next Neighbor Selection



- **DHash++ uses (only) PNS**
  - Proximity Neighbor Selection
- **It does not search the whole interval for the best candidate**
  - DHash++ chooses the best of 16 random samples (PNS-Sample)
- **The right figure shoes the (0.1,0.5,0.9)-percentile of such a PNS-Sampling**

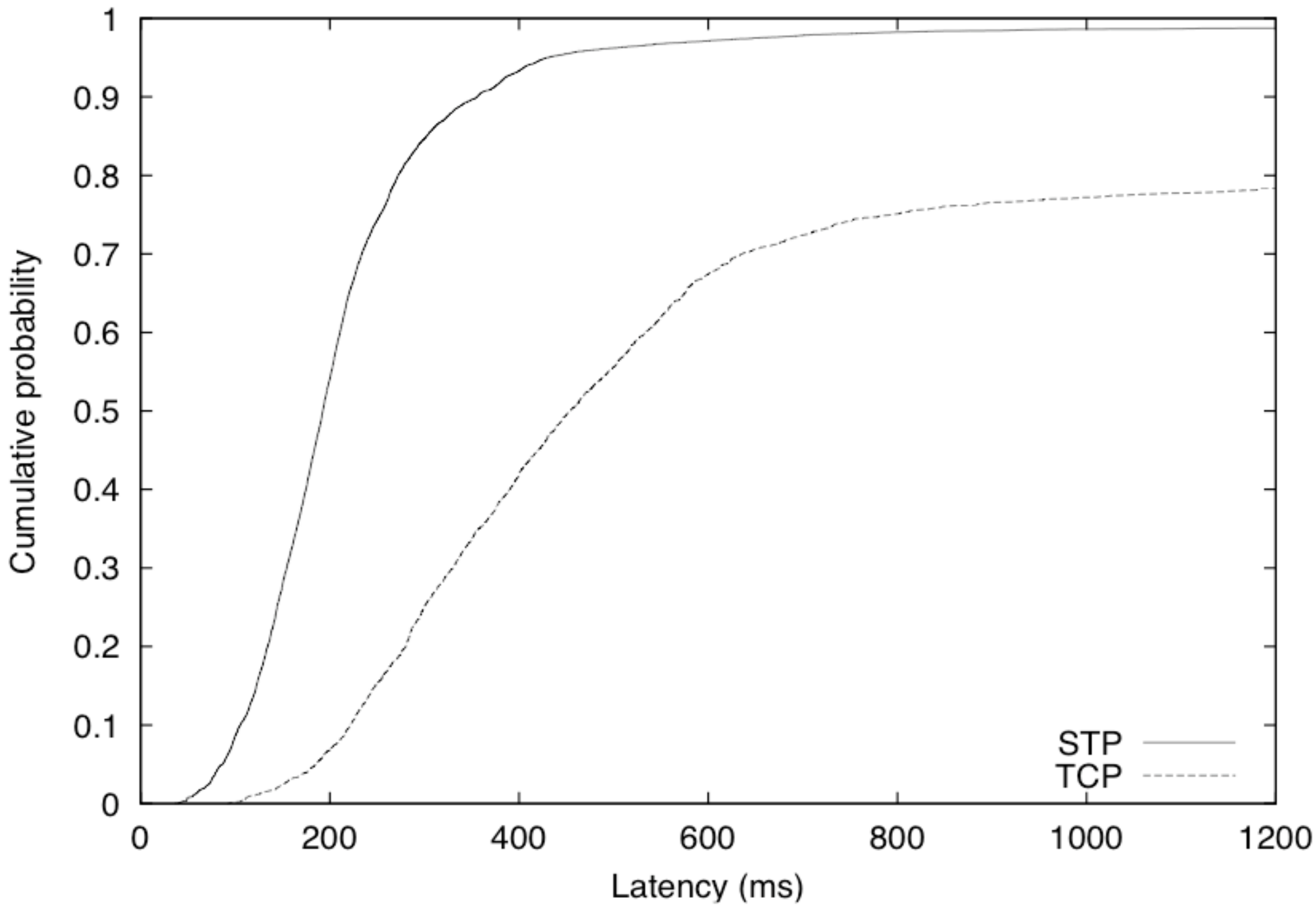


Cumulative Performance Win



- **Following speedup**
  - Light: Lookup
  - Dark: Fetch
  - Left: real test
  - Middle: simulation
  - Right: Benchmark latency matrix

Modified Transport Protocol



Discussion DHash++

- **Combines a large quantity of techniques**
  - for reducing the latecy of routing
  - for improving the reliability of data access
- **Topics**
  - latency optimized routing tables
  - redundant data encoding
  - improved lookup
  - transport layer
  - integration of components
- **All these components can be applied to other networks**
  - some of them were used before in others
  - e.g. data encoding in Oceanstore
- **DHash++ is an example of one of the most advanced peer-to-peer networks**

Peer-to-Peer-Netzwerke

End of 3rd Week

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