Achieving One-Hop DHT Lookup and Strong Stabilization by Passing Tokens

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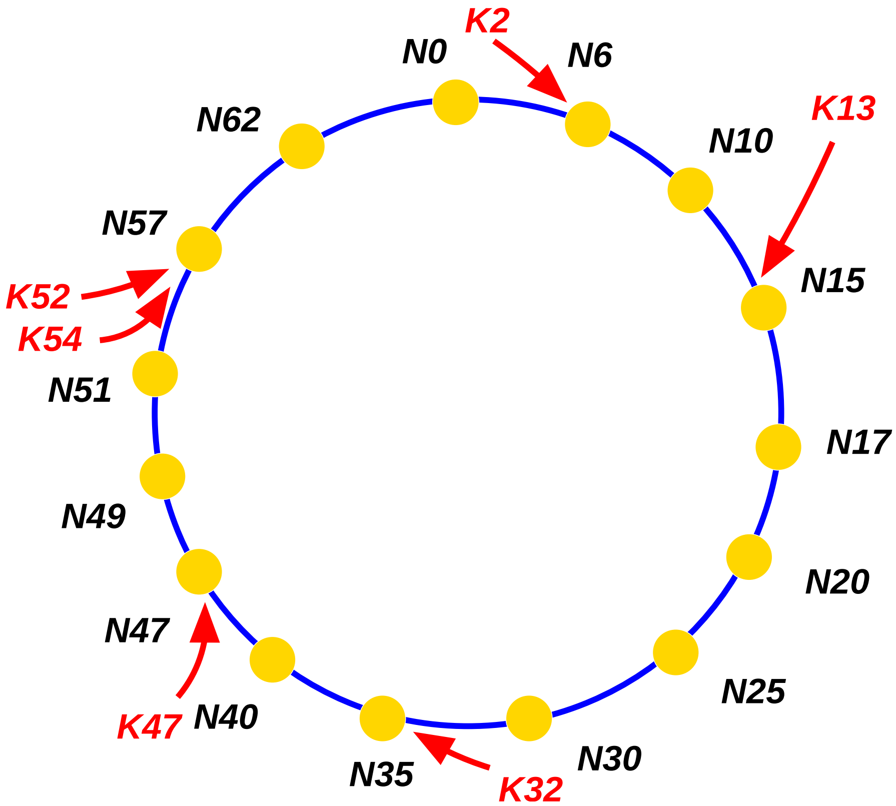
Structured Peer-to-Peer Systems

- Large scale dynamic network
- Overlay infrastructure :
  - Scalable
  - Self configuring
  - Fault tolerant
- Every node responsible for some objects
- Find node having desired object
- Challenge: Efficient Routing at Low Cost

Address Space



- Most common — one-dimensional circular address space

Distributed Hash Tables (DHTs)

- A Distributed Hash Table (DHT) is a distributed data structure that supports a *put/get* interface.
- Store and retrieve {key, value} pairs efficiently over a network of (generally unreliable) nodes
- Early DHTs stored very little state ($O(\log n)$) to cope with network churn (Stoica et al., 2001; Ratnasamy et al., 2001; Zhao et al., 2001; Rowstron and Druschel, 2001).

Distributed Hash Tables (DHTs)

- Keep state stored per node small because of network churn $\Rightarrow$ minimize book-keeping & maintenance traffic
- Storage is cheap, so it is entirely reasonable to store a global lookup table at every node to achieve one-hop lookup (Gupta et al., 2004)
- Problem: Getting the routing information to all nodes and keeping it up-to-date

Anjali’s One-Hop Scheme (NDSI ’04)

- Hierarchical scheme
- Divide ring into slices – node at midpoint is the slice leader
- Slices further divided into units with leaders
- Slice leaders communicate with each other and with unit leaders in slice
- Information progagated along ring on *stay-a-live* messages

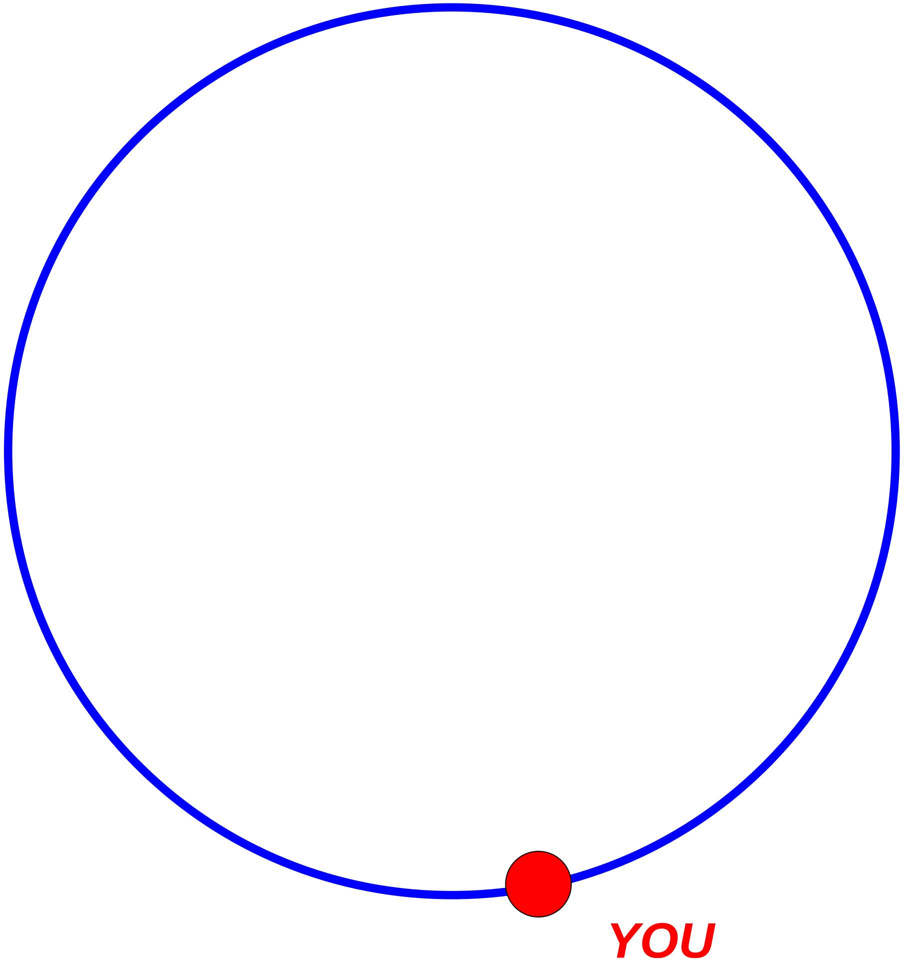
Anjali’s One-Hop Scheme

- Problems:
  - Slice leaders significantly more bandwidth than the other nodes
  - Several parameters — tuning requires knowledge of steady state network size
- Natural question: why don’t we just use per-event ad hoc broadcast trees?

Token Passing Algorithm

- Token – message containing join or leave information (IP address, id).
- Also has a range of propagation, specified by destination n_d.
- When a node receives a token, it can:
  - Pass the token to its predecessor; or
  - Generate q secondary tokens that cover the remaining propagation range.

Token Passing Algorithm



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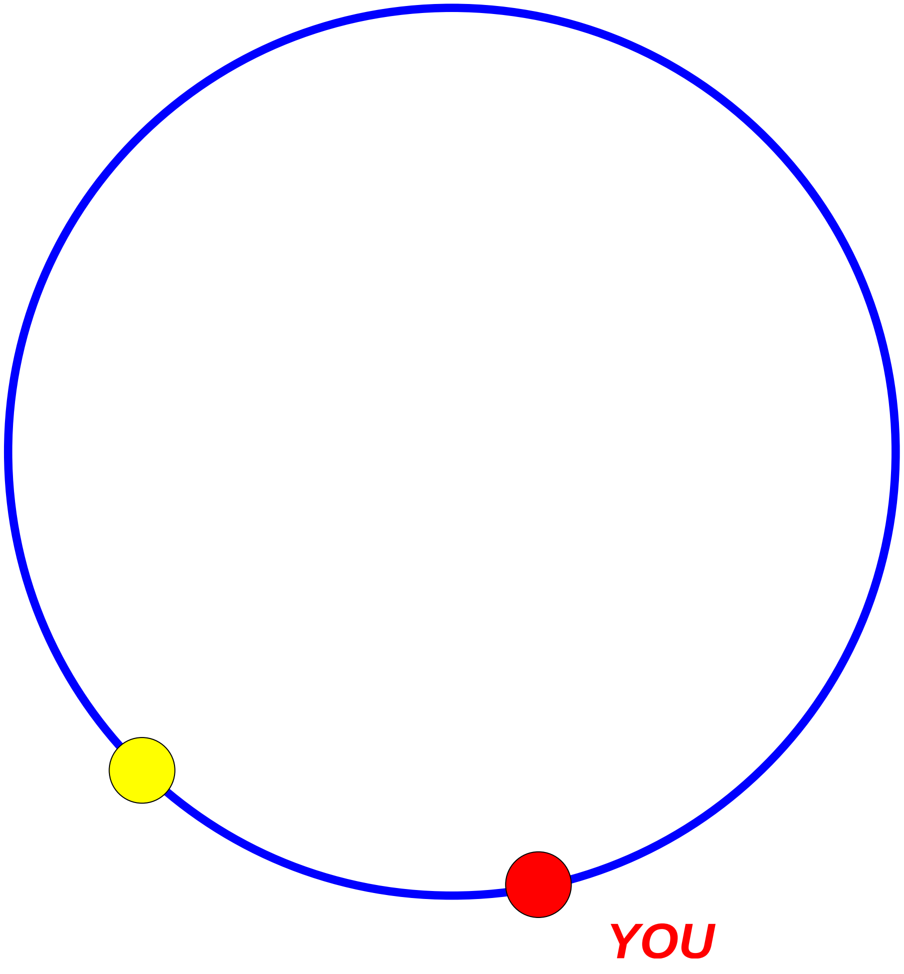

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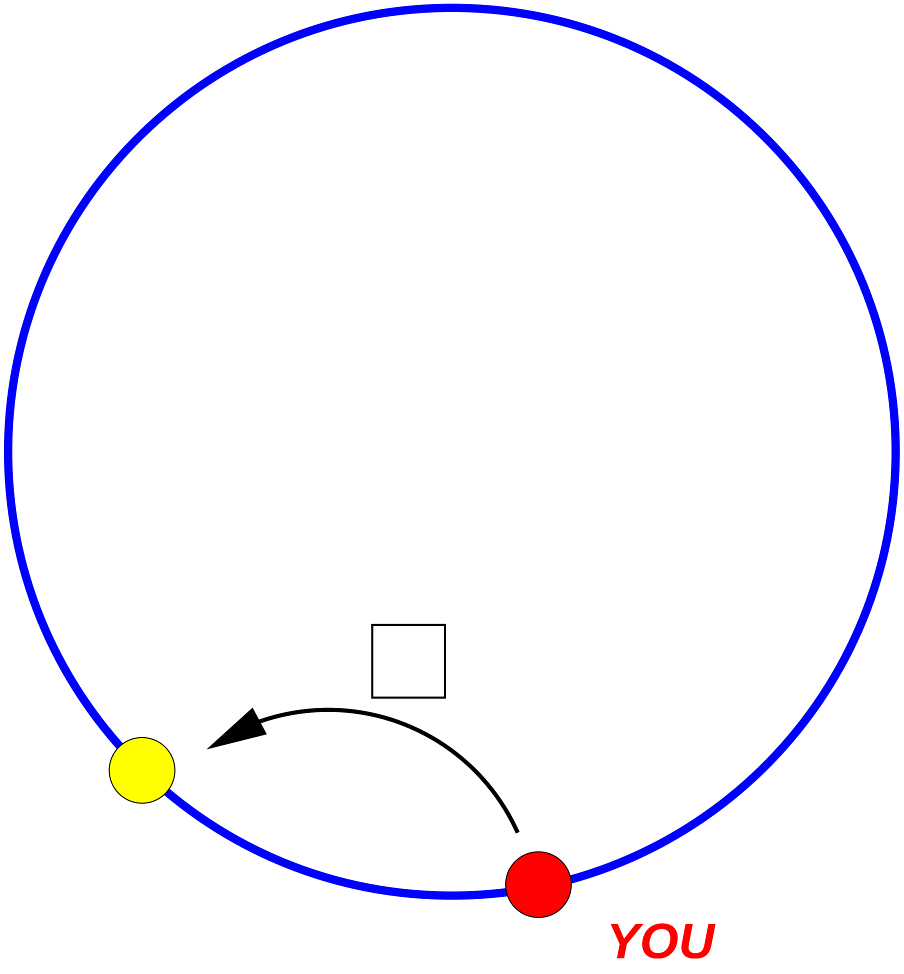

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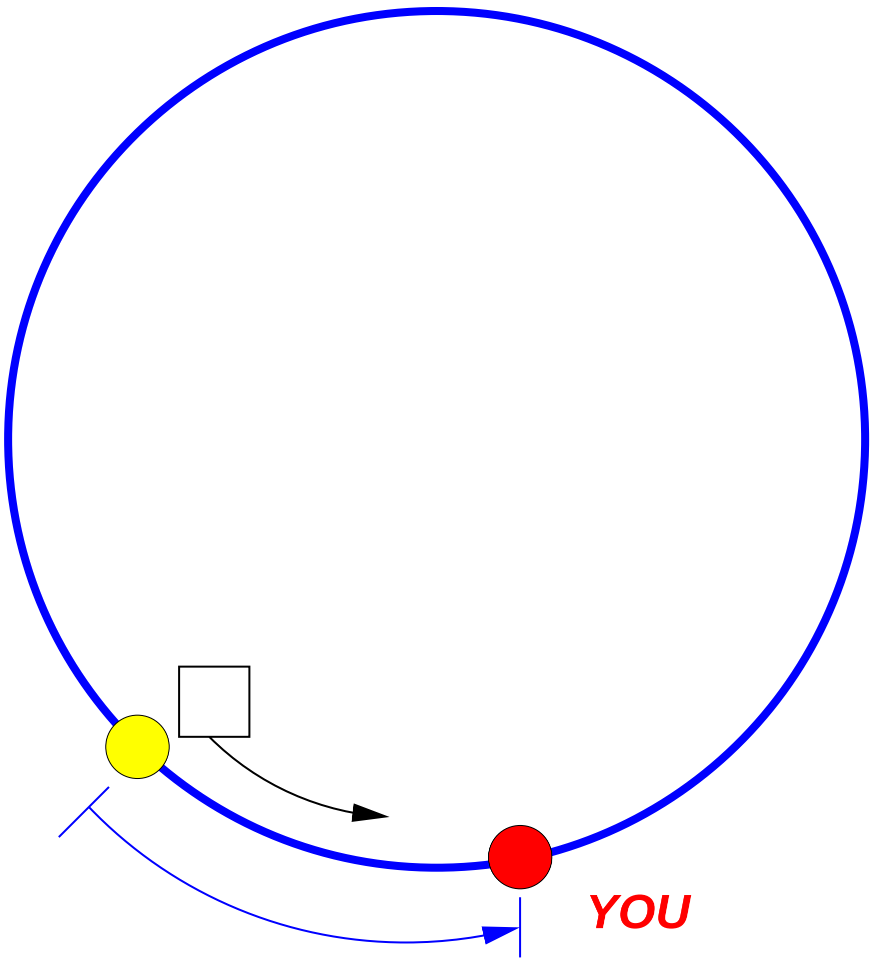

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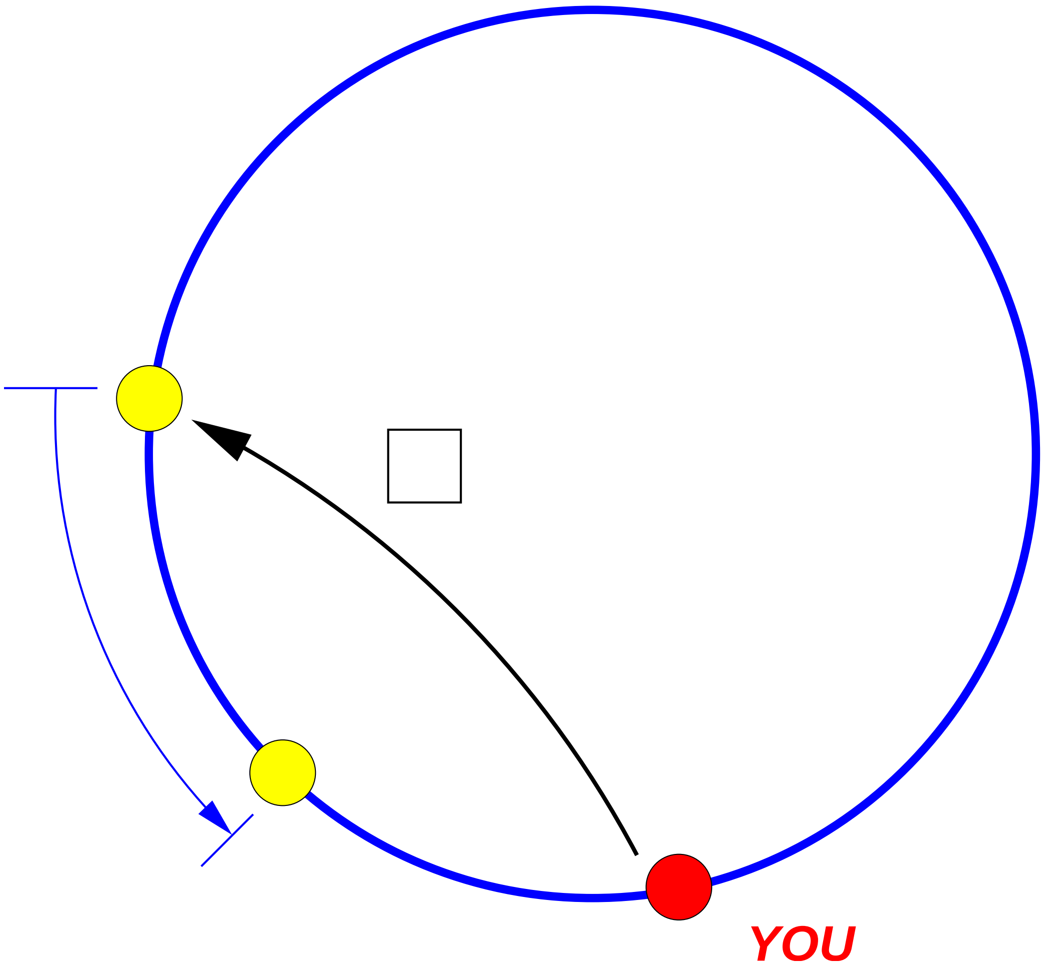

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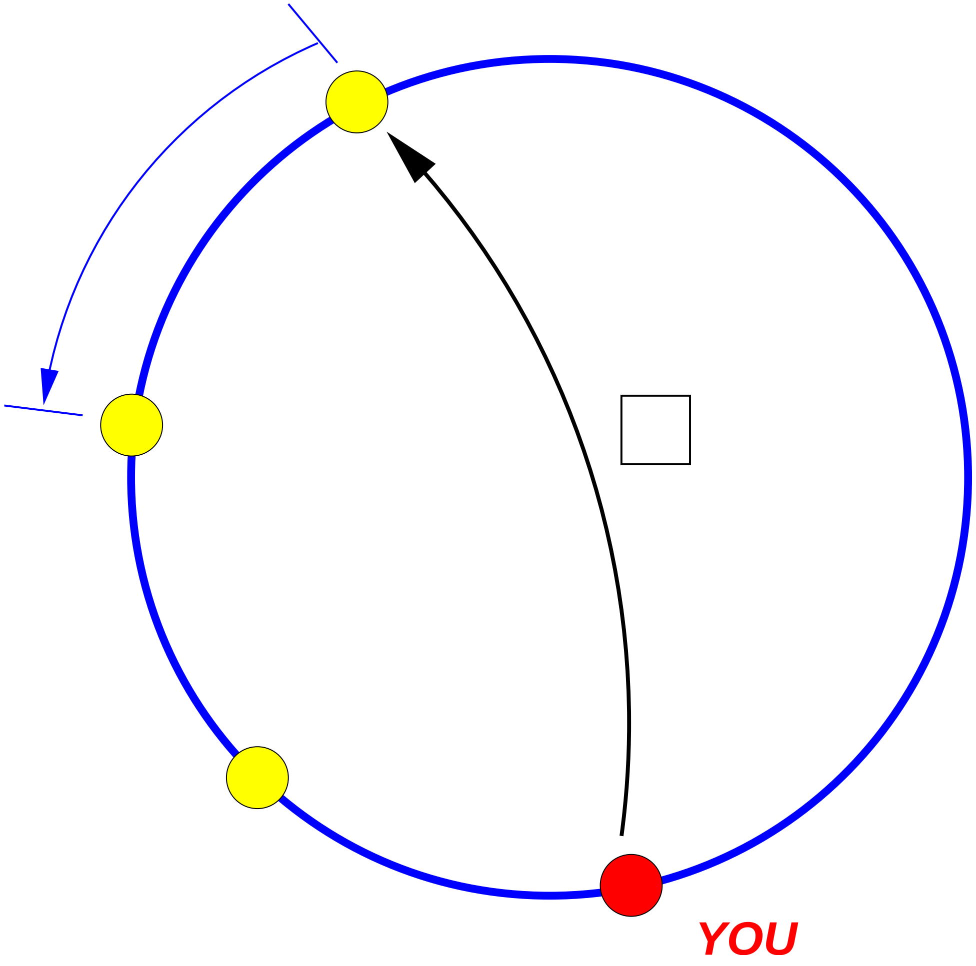

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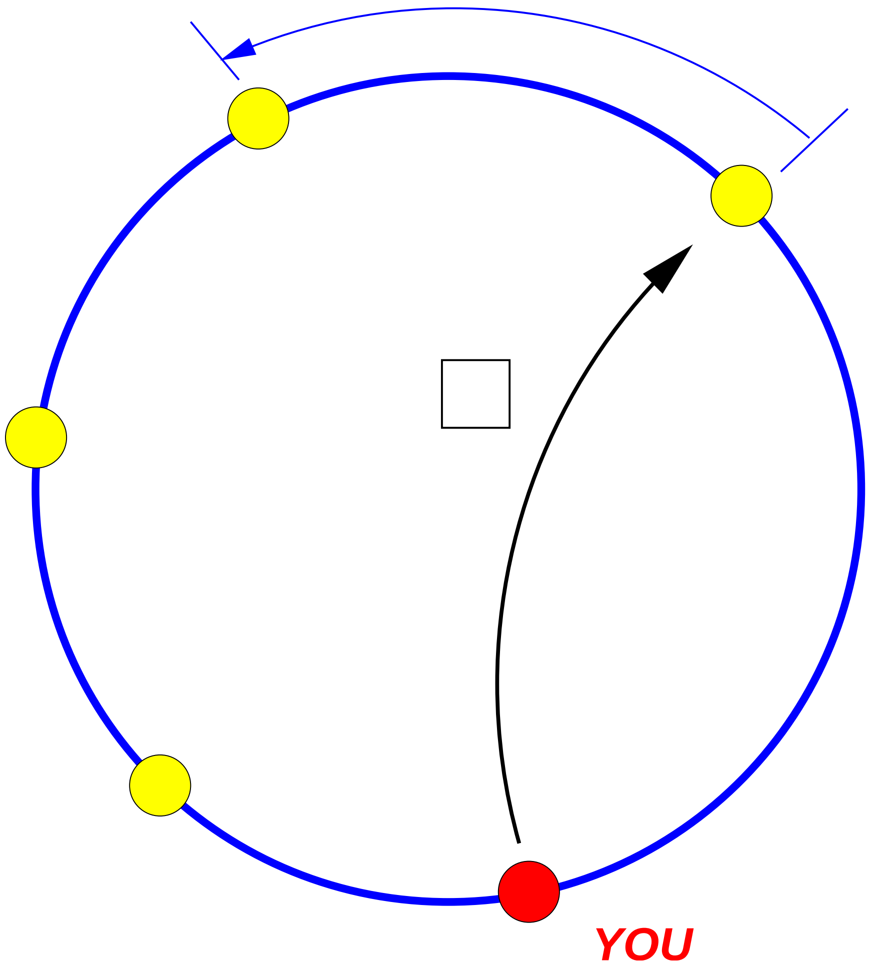

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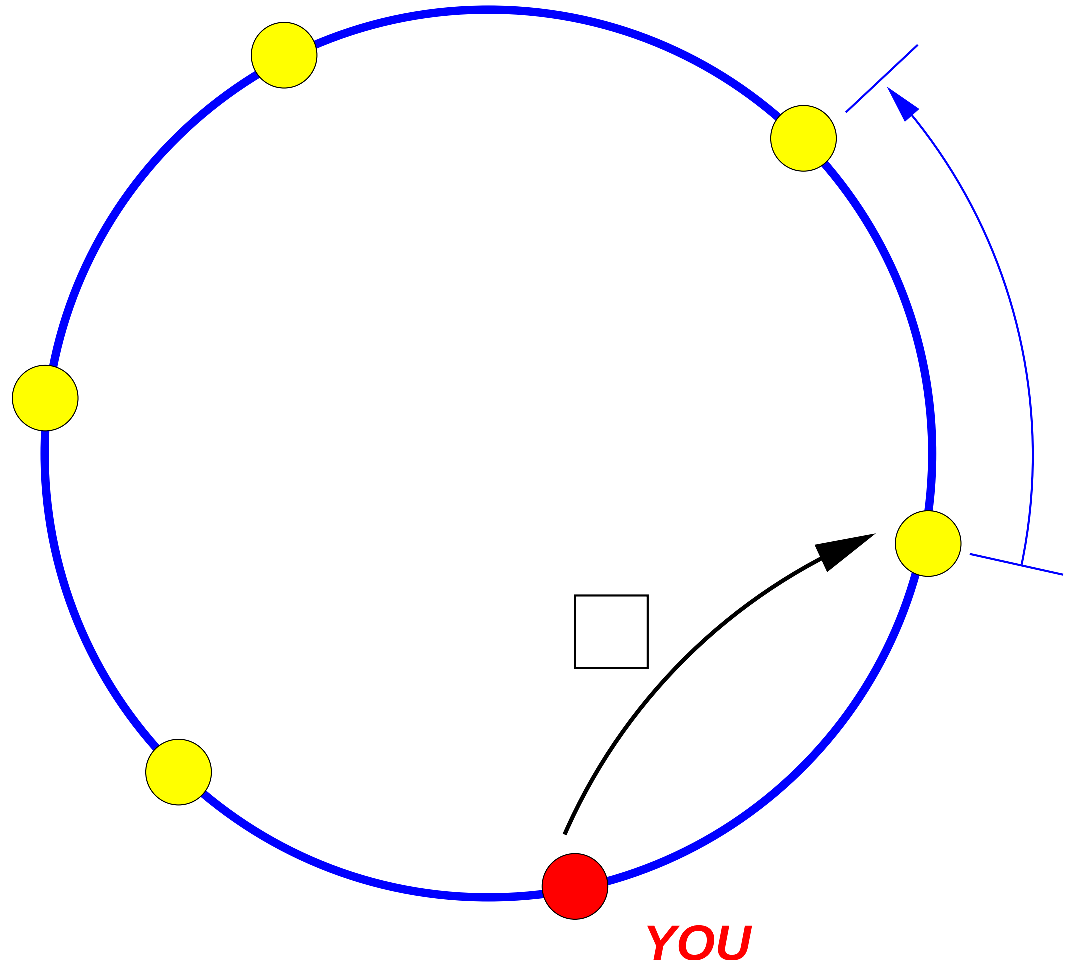
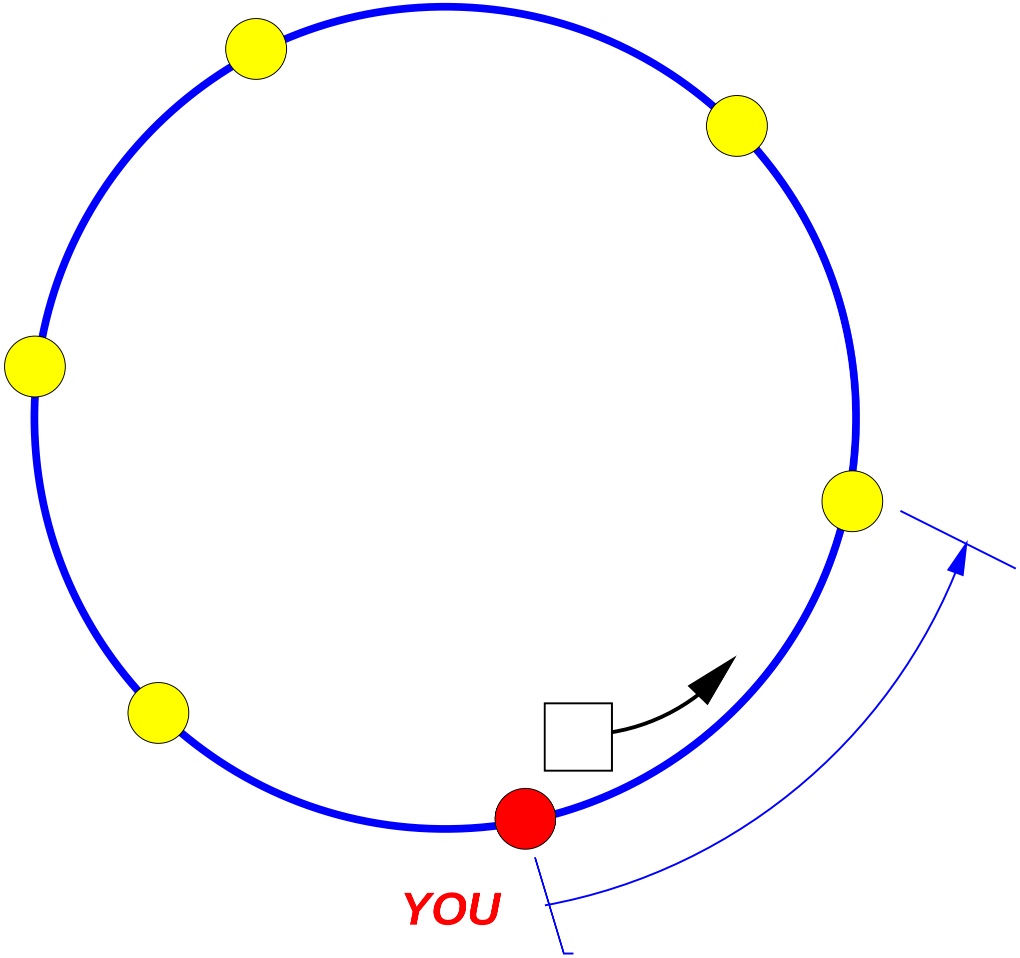


- Pick q nodes in total

Token Passing Algorithm



- Pass last token to predecessor

Token Passing Algorithm

- Address space can be decomposed recursively
- Token is destroyed when it reaches its destination
- Nodes do not necessarily have to use a fixed q
- Tokens can be merged to save on propagation overhead

Lookup Algorithm

- Just contact the best known successor. It's probably the right one; if not, it will tell you where to go.
- Correctness of routing is guaranteed by correctness of successor/predecessor pointers
- In worst case, simply follow a chain of successor pointers – slow but correct.
- Stabilization – process that maintains and repairs successor/predecessor pointers

Definitions

We say that the network is

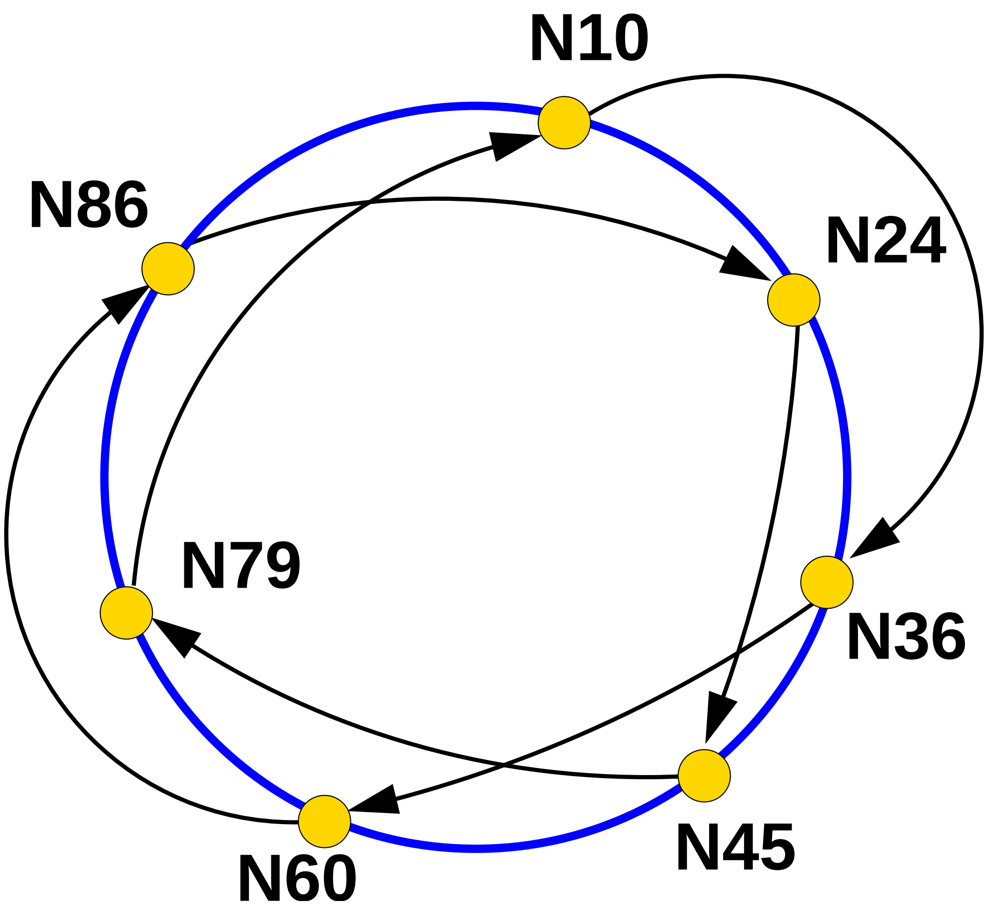
1. *weakly stable* if, for all nodes u, we have $predecessor(successor(u)) = u$;
2. *strongly stable* if, in addition, for each node u, there is no node v such that $u < v < successor(u)$; and
3. *loopy* if it is weakly but not strongly stable (see (Stoica et al., 2002)).

Weak Stabilization

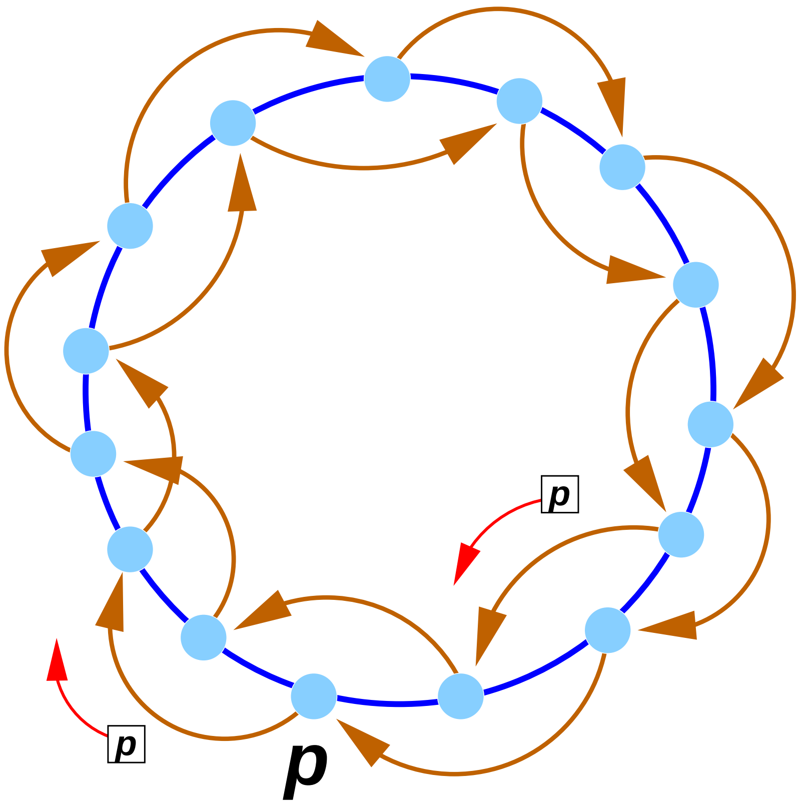
- Nodes periodically probe their immediate neighbors and exchange successor/predecessor lists
- All messages contain IP address, port number and node id

Theorem 1 *The weak stabilization protocol will eventually cause our network to converge to a* weakly stable *state.*

Loopy Example



Strong Stabilization



- Key idea: to detect loops, all we need to do is to traverse the entire ring and make sure that we come back to where we started

Strong Stabilization

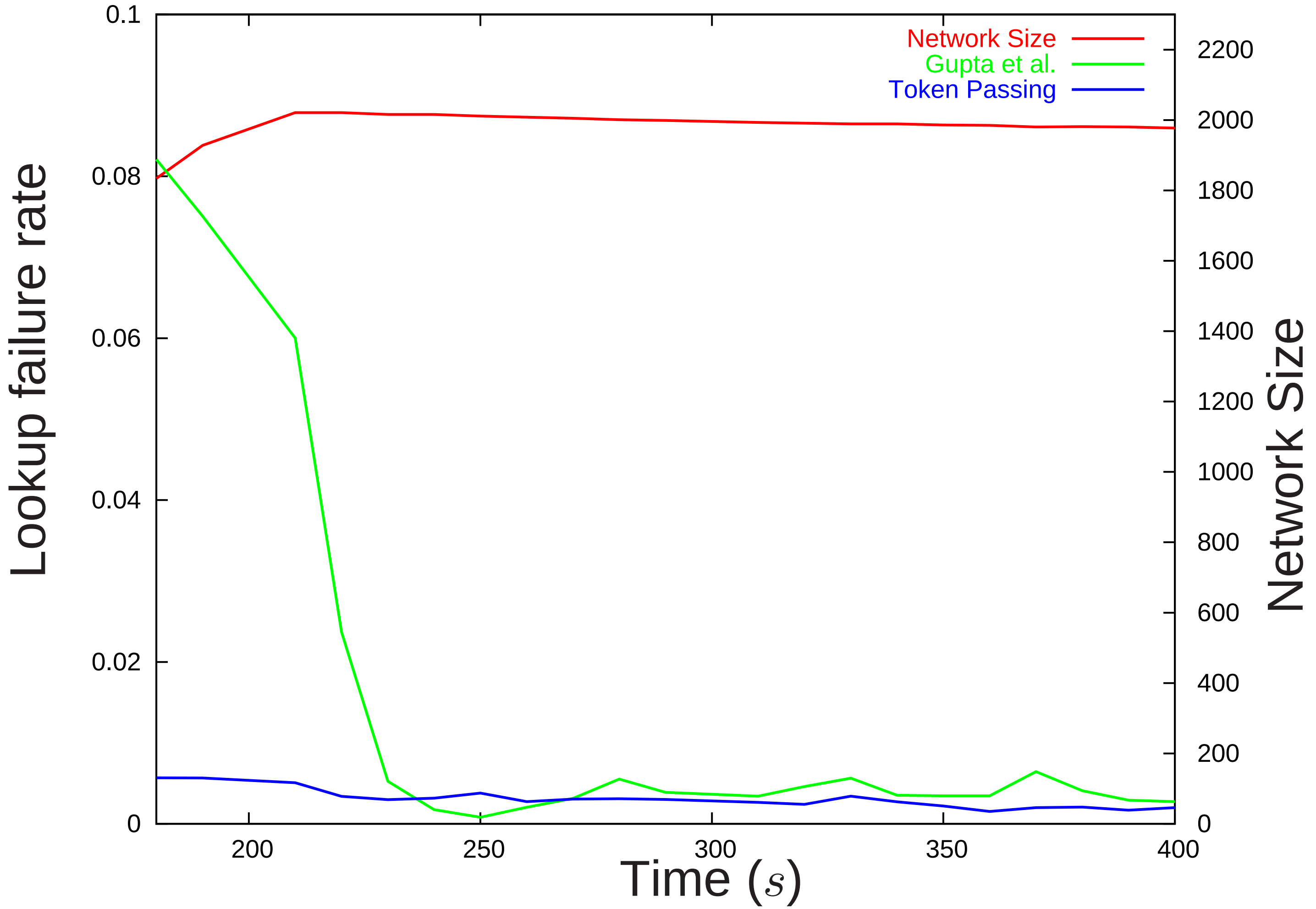
Theorem 2 *The combination of our parallel token-passing algorithm with the weak stabilization protocol will cause our network to converge to a* strongly stable *state within at most $O(n^2)$ rounds of token-passing.*

- Take any set of r nodes and have them send a message to the consecutive node.
- If a loop exists, at least one pair will detect it.
- Key Insight: this property does not change if you choose the r nodes recursively.

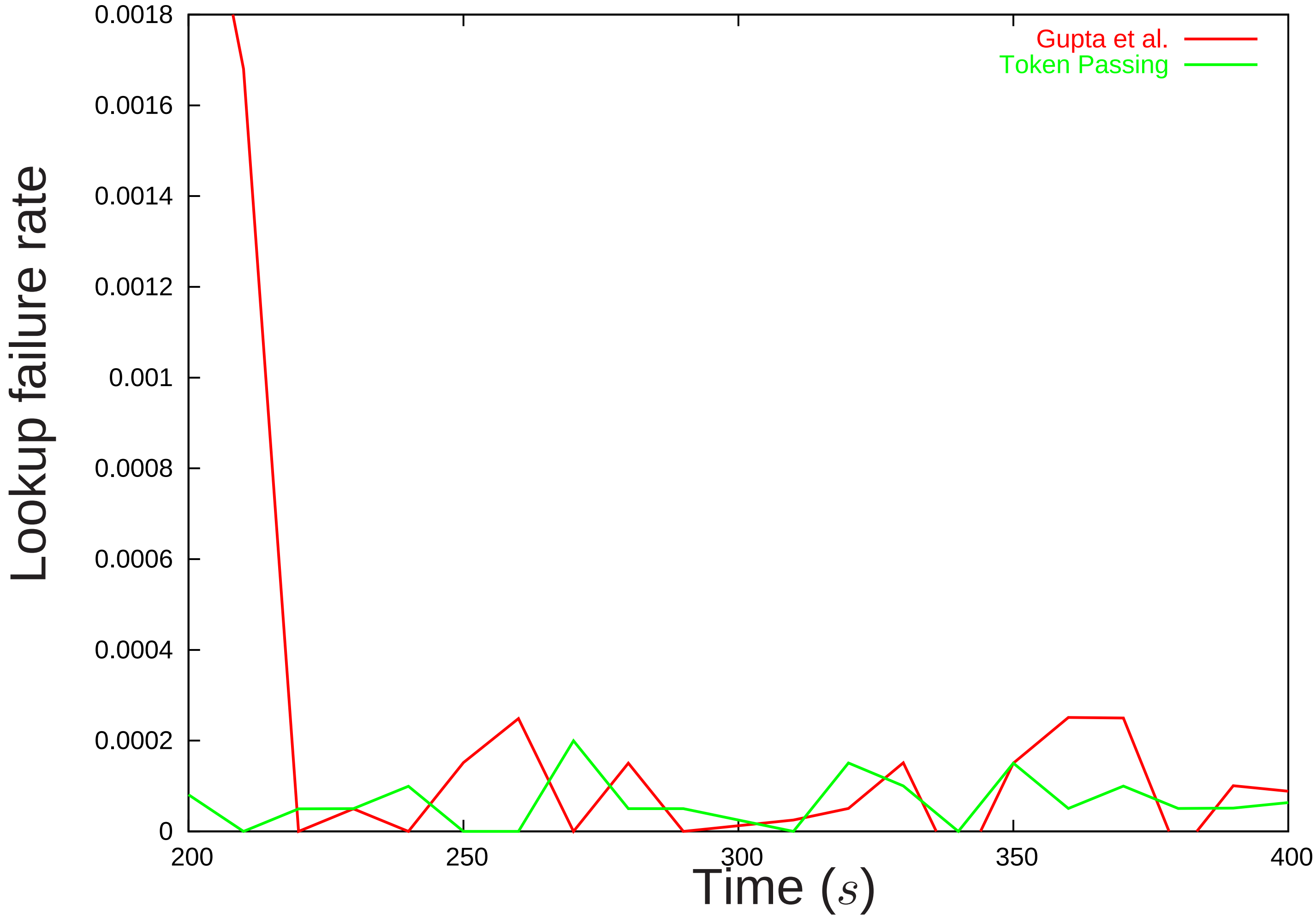
Simulation Results

- Analysis shows that our scheme is feasible in terms of bandwidth consumption under realistic assumptions
- Implemented algorithm in *p2psim* and compared it directly to Anjali's scheme
- Parameters:
  - Node lifetime: 60 mins
  - Avg 10 node joins per second for 200 s.
  - Nodes rejoin after mean interval of 6 mins
  - Query rate — 1 per sec per node

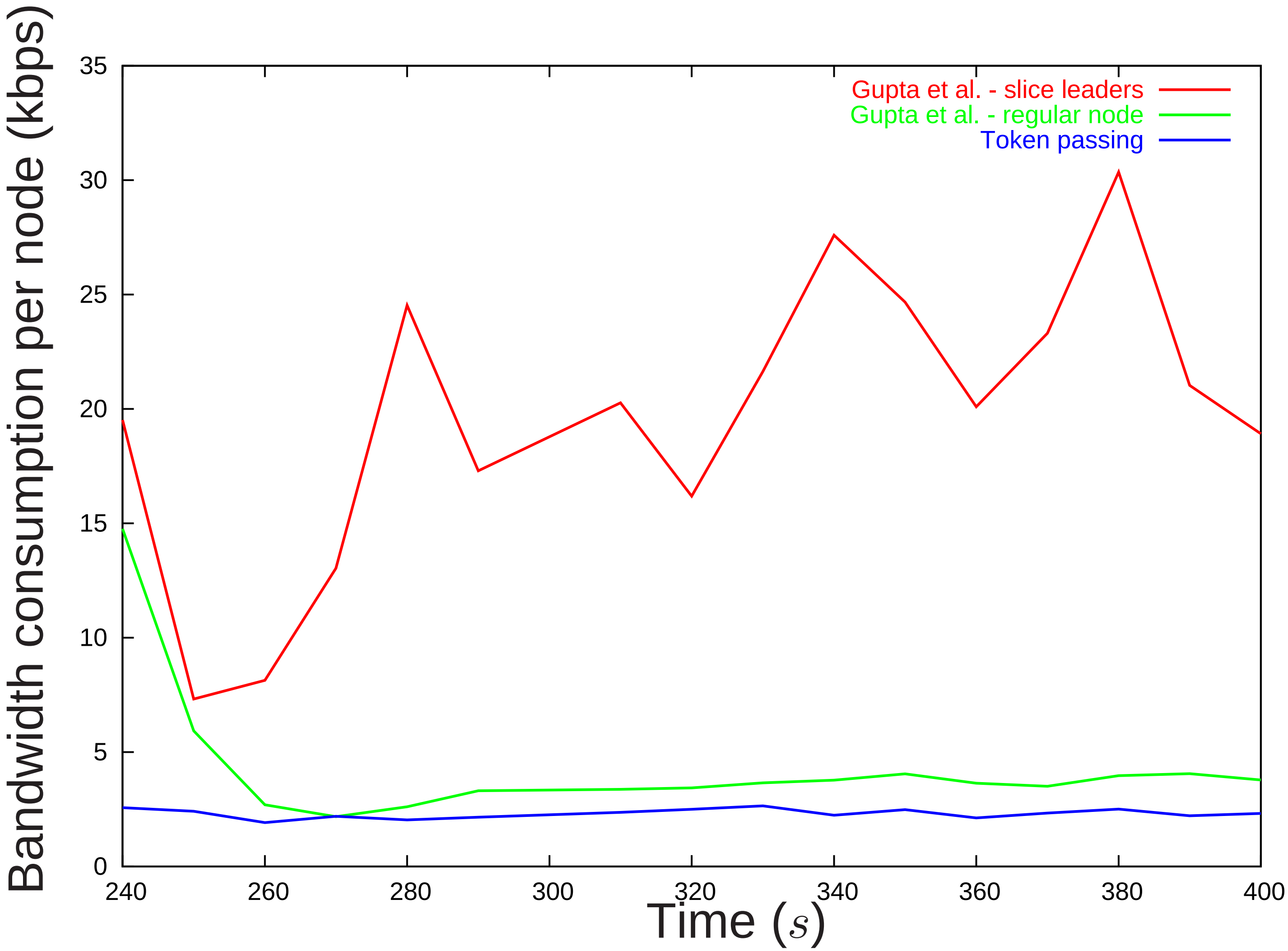
One-Hop Failure Rates



Two-Hop Failure Rates



Bandwidth Consumption



Related Work

- One-Hop (Gupta et al., 2004)
- Superpeers (Mizrak et al., 2003)
- Kelips (Gupta et al., 2003)

Conclusion

- Performs as well as Anjali's scheme
- Simplicity
- Imposes a slightly higher average overhead, but imposes uniform load
- Can vary q to adapt to network heterogeneity
- Have strong stabilization as a side-effect

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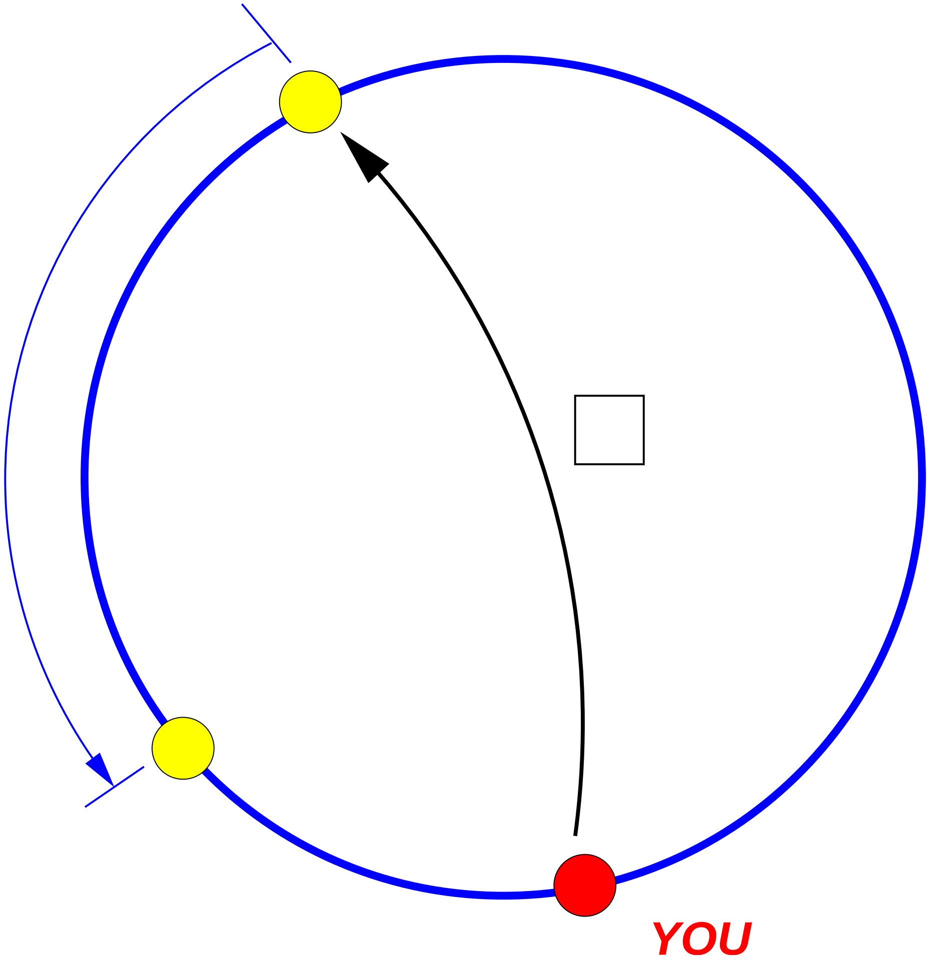
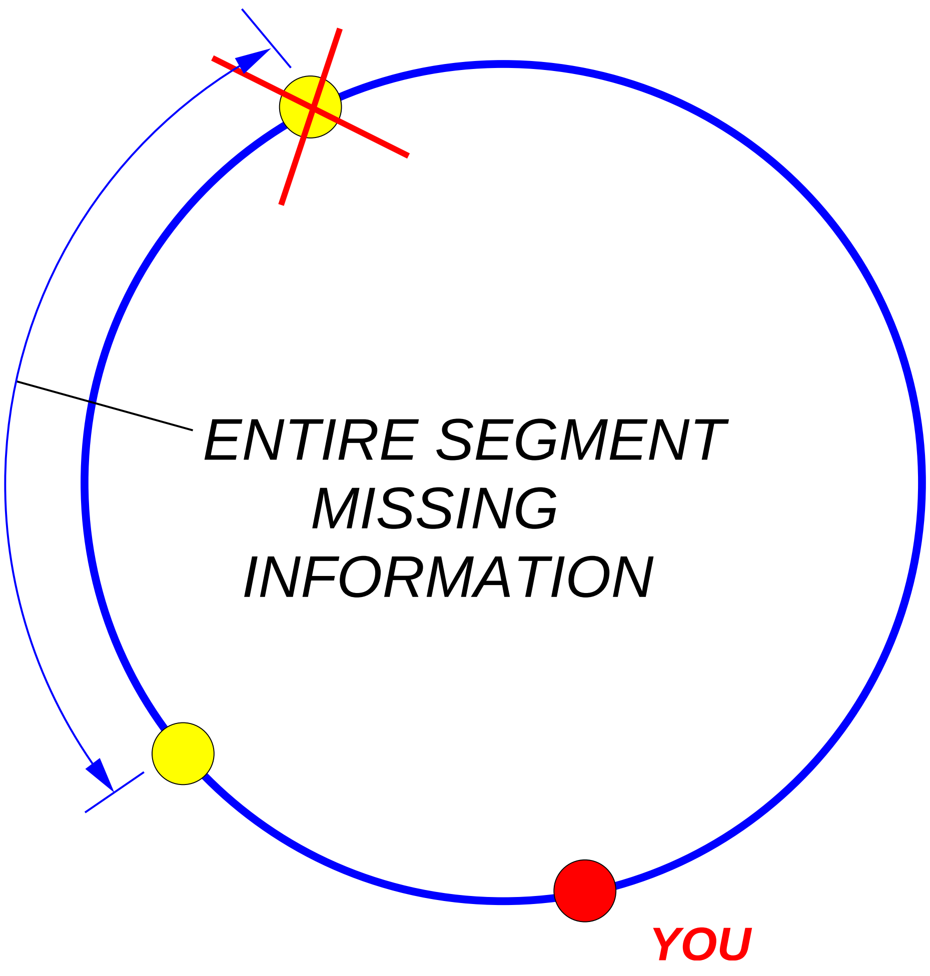
Fault Tolerance

- Sometimes bad things happen and a token is lost.
- Missing information is discovered during lookup process
- Observation: a lost token results in a consecutive segment of the address space missing some piece of information
- Solution: propagate *repair tokens*
  - Passed in both directions
  - Cannot be split

Repair



Repair



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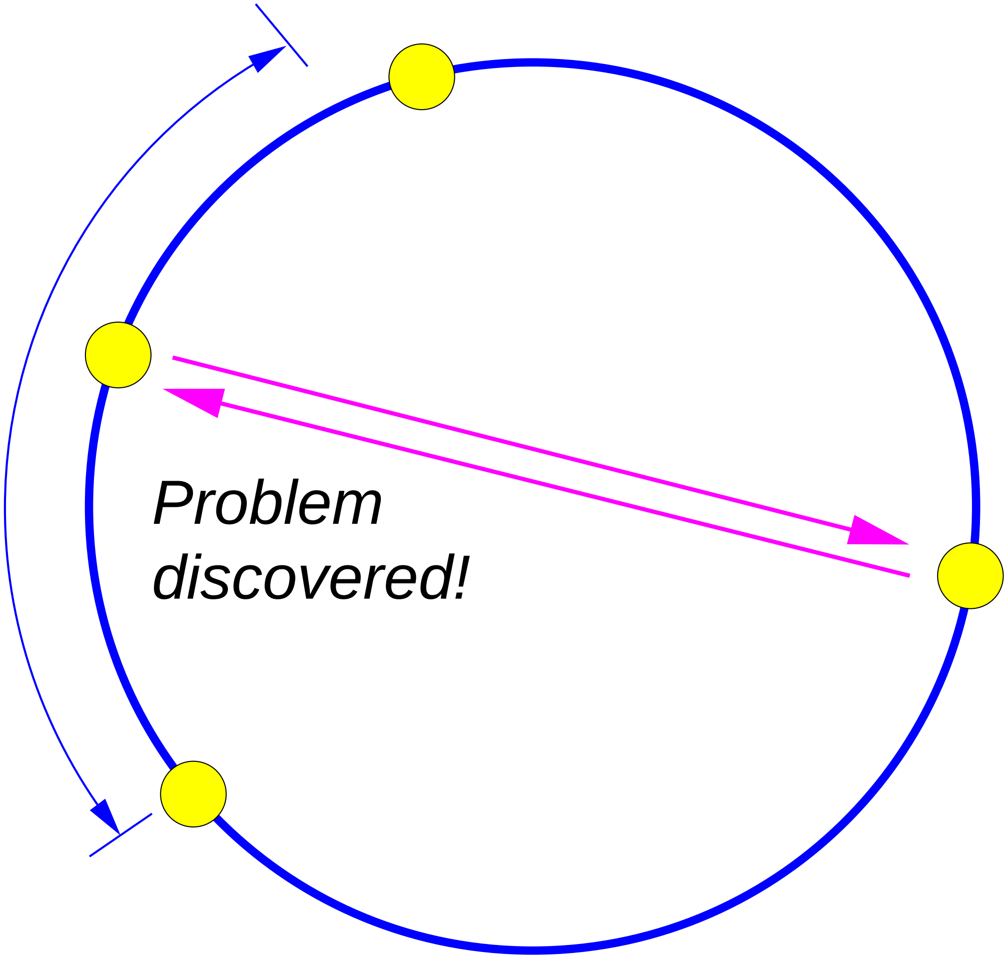

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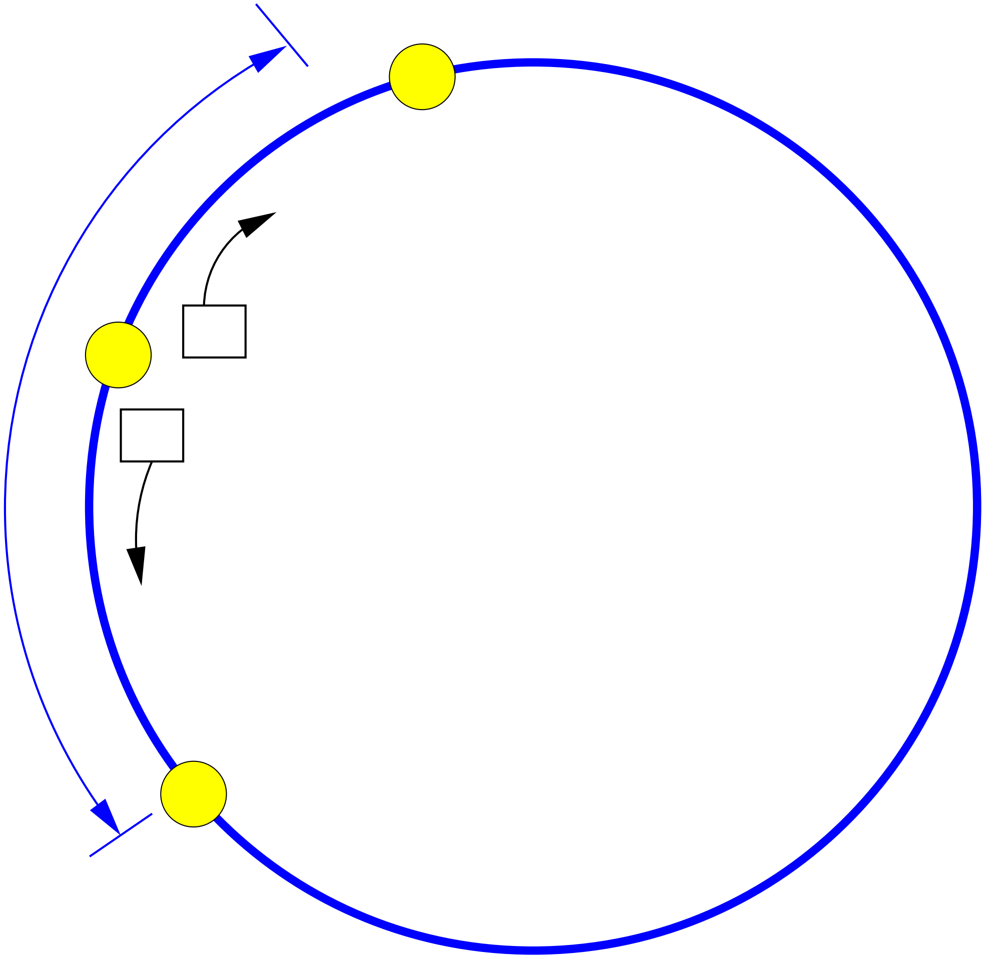

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