Distributed K-Ary System

A seminar presentation

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Outline

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1. Introduction
2. Network Structure
3. Applications
4. Handling Dynamism
5. Conclusion

What can DKS do?

Distributed Hash Table (DHT)

- store and retrieve key/value-pairs

Message Passing

- Broadcast
- Multicast

Fault Tolerance

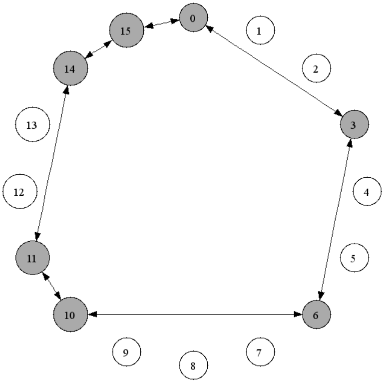
- Protect against failures
- Degree of tolerance is configurable

Why is that interesting?

- DHTs are a research subject
  - First academic papers in 2001
- DKS claims to formalize a class of approaches
  - Chord
  - Pastry
  - Kademlia
- This implies optimization!

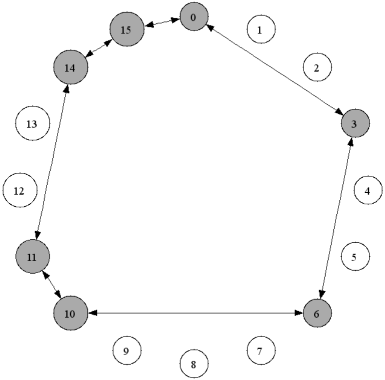
Outline

Basic structure



- Overlay network
- Three parameters: N, k, f
- N= maximum number of nodes
  - Ring structure
- k= search tree arity
  - contact any node in $log_k N$ steps
- f= fault tolerance
  - every key stored f times
  - (f-1) nodes may fail

Definitions



Definition: Modulo arithmetic

- $a \oplus b = (a + b)\ modulo\ N$

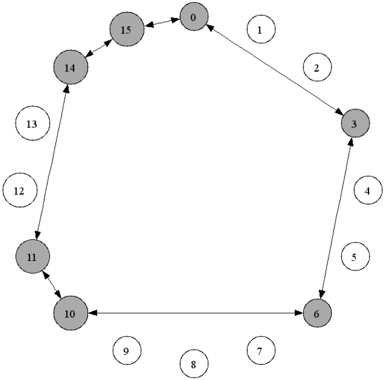
Definition: Distance

- $d(a, b) = b \ominus a$
- Clockwise!

Definition: Successor S(x)

- First node starting at x
- $S(x) = x \oplus min\{d(x, y) \mid y \in \mathcal{P}\}$

Definitions



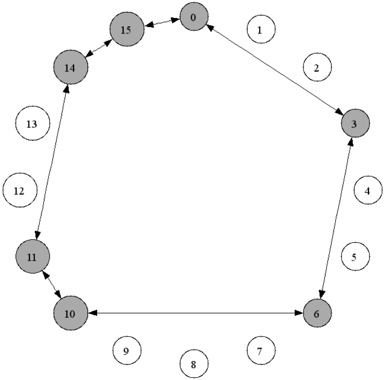
Definition: Next successor succ

- First node after x
- $succ = S(x \oplus 1)$

Definition: Predecessor pred

- First node before x
- $\Leftrightarrow$ Last node after x
- $pred = x \oplus max\{d(x,y) \,|\, y \in \mathcal{P}\}$

Basic Structure



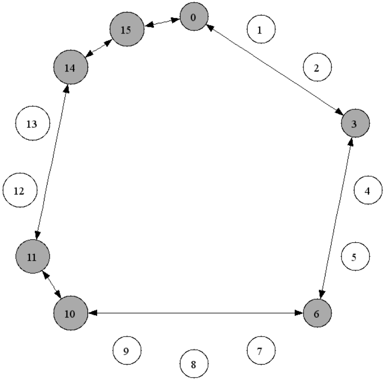
Every node has a route to its

- next successor
- predecessor

A route is

- overlay address (node number)
- underlay address (TCP/IP)

Addressing problem



How can two nodes communicate?

- Does node x exist?
- What is its underlay address?

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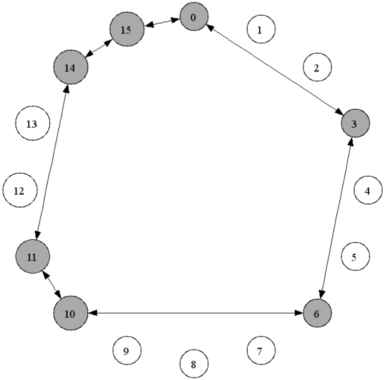

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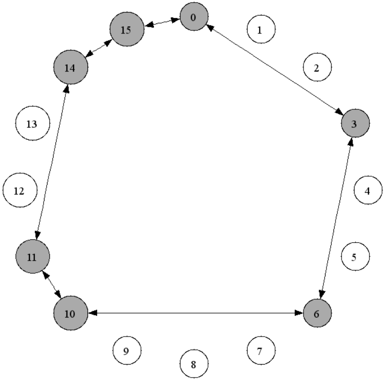

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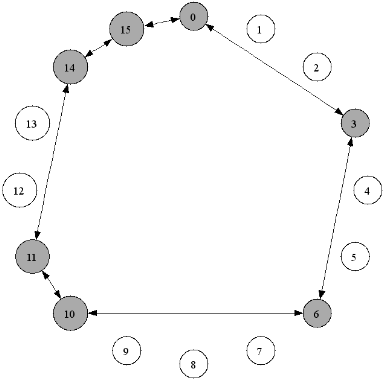
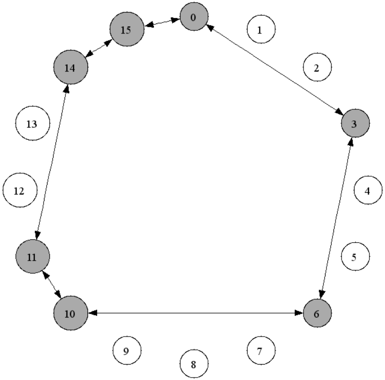


How can two nodes communicate?

- Does node x exist?
  - Talk to successor
- What is its underlay address?
  - His predecessor knows
  - Pass message around
  - Inefficient!
- *We need more routes!*

Addressing problem



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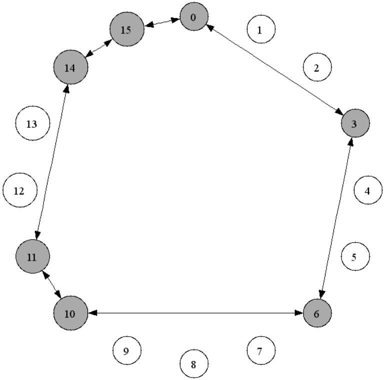

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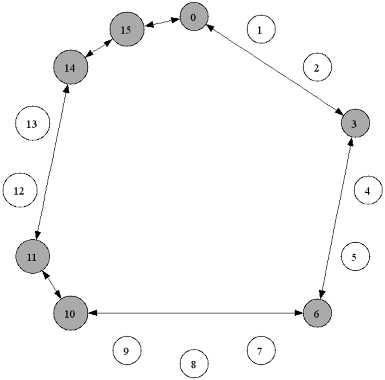

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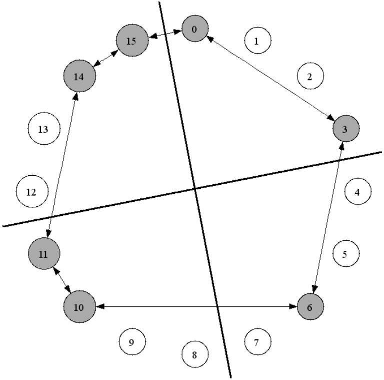
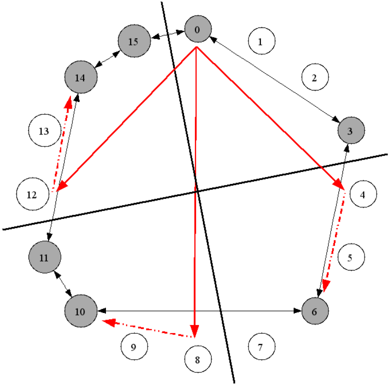
Idea: Add more routes



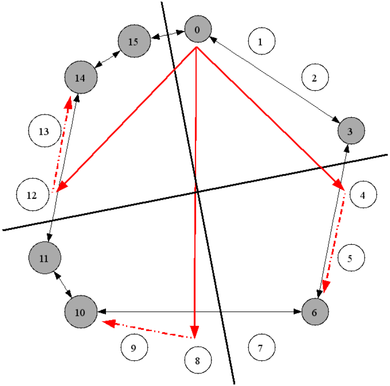
- Idea: Each node divides the network in k intervals

Idea: Add more routes



- Idea: Each node divides the network in k intervals
- Store a pointer to the successor of each interval
  - But any node in the interval is okay, too
- Send to closest node
  - Remember: Distance is clockwise
  - Dont *overshoot*

Idea: Add more routes

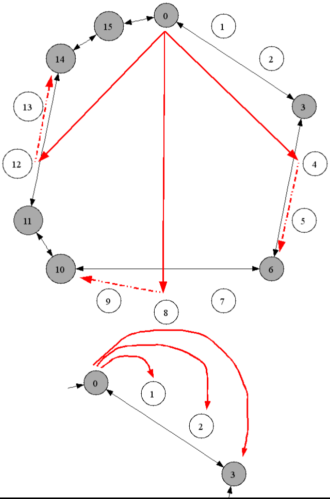


Definition: Successor of an interval

First node in Interval [n, m[:

- if S(n) < m
  - S([n, m[) = S(n)
- else
  - S([n, m[) = nil

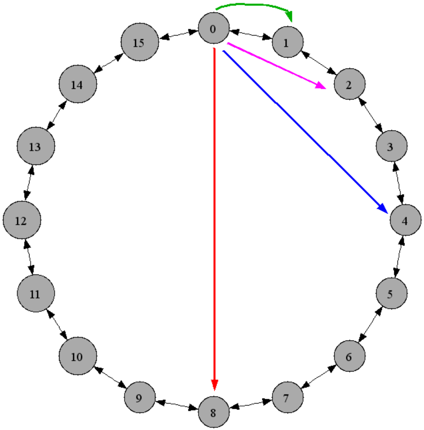
Idea: Add more routes



- So far
  - max. $\frac{N}{k}$ hops instead of N hops
- Apply recursively to first interval
  - each hop divides distance by k
  - $L = log_k N$ levels
  - max. L hops
  - Routing table size $k * L$
- This view is unique for each node (!)

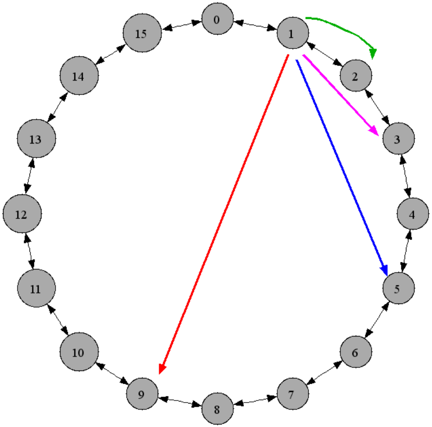
View is unique for each node

N=16, k=2, node 0



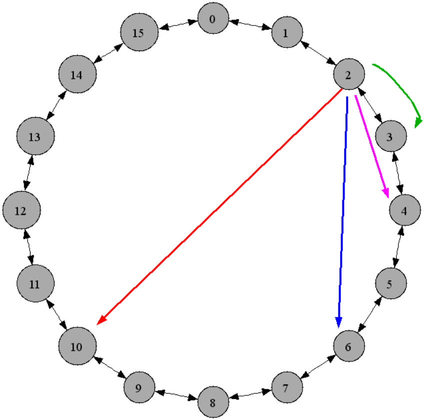
View is unique for each node

N=16, k=2, node 1



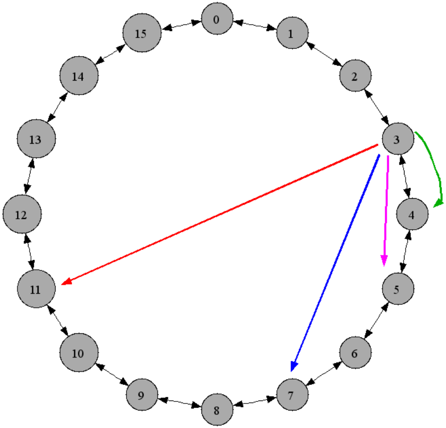
View is unique for each node

N=16, k=2, node 2



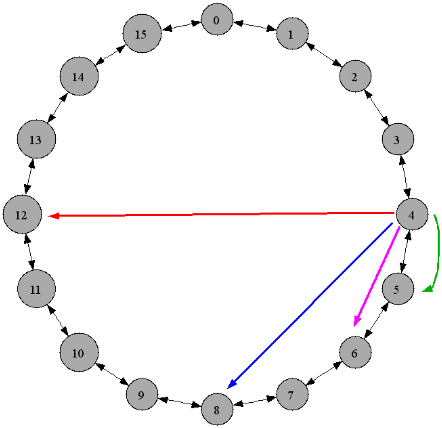
View is unique for each node

N=16, k=2, node 3



View is unique for each node

N=16, k=2, node 4



Idea: Add more routes

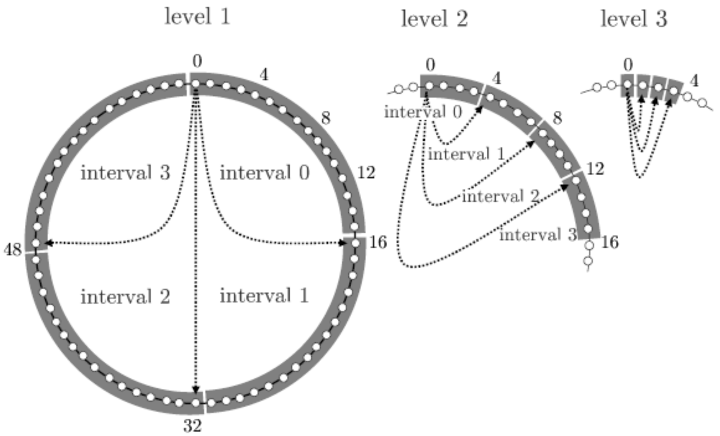
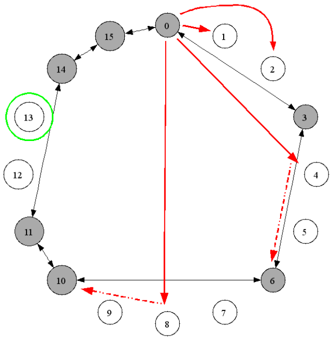


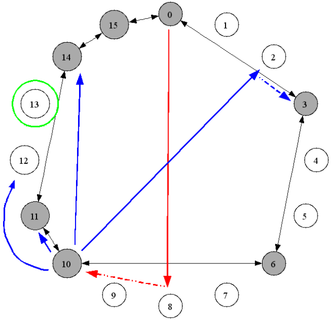
Image from: Ali Ghodsi. Distributed k-ary System: Algorithms for Distributed Hash Tables, PhD dissertation, KTH-Royal Institute of Technology, December 2006.

Example: Send Message from 0 to S(13)



- N=16, k=2
- Send message from 0 to S(13)
- Node 0 does not know wether 13 exists.
- Send message to closest node in routing table:
  - Node 0 sends to node 10

Example: Send Message from 0 to S(13)



- N=16, k=2
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    - Node 0 sends to node 10
    - Node 10 sends to node 11

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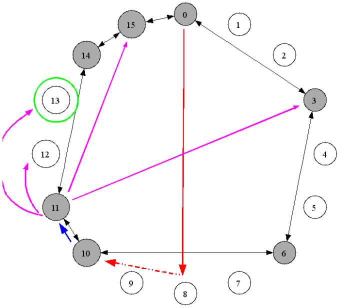
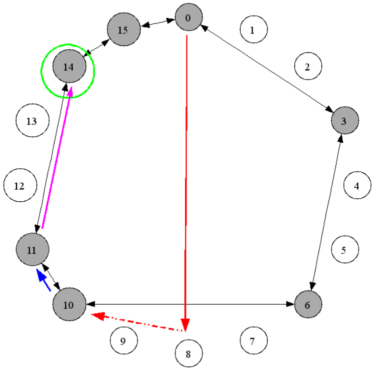


- N=16, k=2
- Send message from 0 to S(13)
- Node 0 does not know wether 13 exists.
- Send message to closest node in routing table:
  - Node 0 sends to node 10
  - Node 10 sends to node 11
  - Node 11 knows node 13 does not exist (as 11.succ = 14)
  - Node 11 sends to S(13) = 14

Example: Send Message from 0 to S(13)



- N=16, k=2
- Send message from 0 to S(13)
- 3 messages (0 to 10, 10 to 11, 11 to 14)
  - $\leq log_k N = 4$

Any questions so far?

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Distributed Hash Table

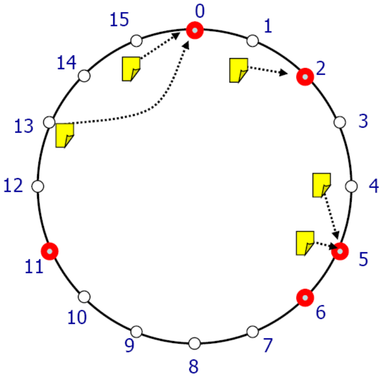
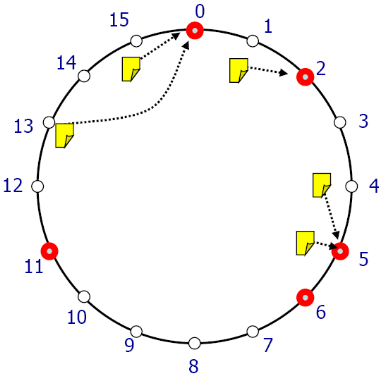


Image taken from DKS presentation by Ali Ghodsi, Seif Haridi, Luc Onana at http://dks.sics.se

- Store and retrieve key/value-pairs
- Known Hash-function maps key to identifier $H(key) \rightarrow [0, N[$
- Store key/value-pair at node S(H(key))
  - "Node n is responsible for key"
- Store/retrieve: send a message to responsible node

Distributed Hash Table



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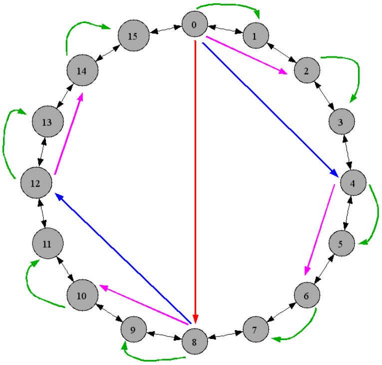
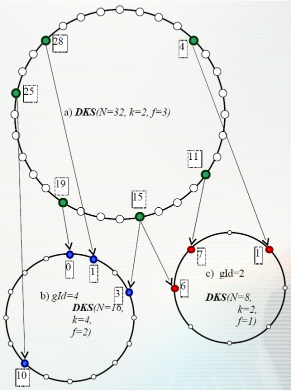
- One DKS can store multiple DHTs
- If a new node joins, it fetches all key/value-pairs it is responsible for from its successor

Broadcast



- Send message to all Level $l = 1$ nodes
- These recursively send to all Level $l + 1$ nodes
- Each node sends max. $log_k N$ messages
- Reaches N nodes with N Messages

Multicast



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- Join multicast group
- Broadcast to group

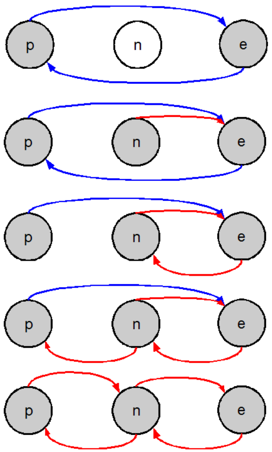
Outline

What about Dynamism?

Nodes can

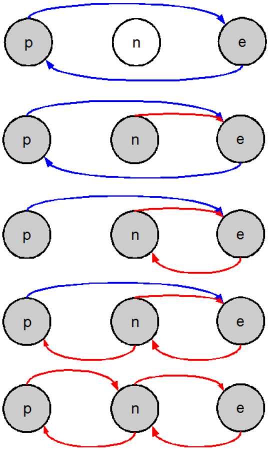
- join
- leave
- fail

Joining



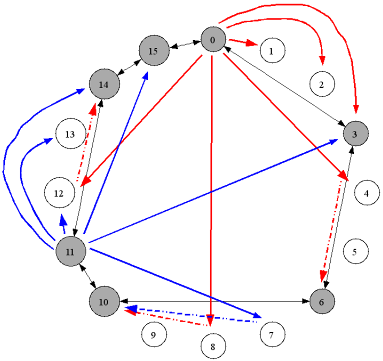
- Joining node must know at least one existing node
- Joining node is assigned identifier n
- Joining node n contacts e = succ(n)
- Insertation like in double-linked list
- Transfer identifiers in]p, n] to n

Joining: forwarding and locking



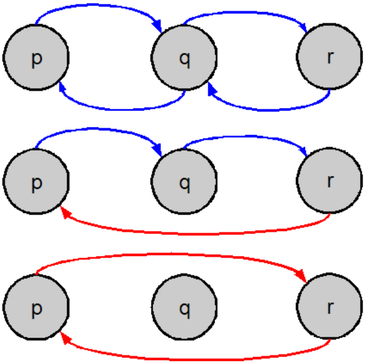
- While n joins, e forwards all messages from p to n (step 4)
    - Lookups stay consistent
    - p tells e when its done
- Locking ensures consistency
    - Each node *hosts* a lock
    - n locks itself in step 1
    - n tries to lock e in step 2
    - in step 5, both locks are released

Joining: populate routing table



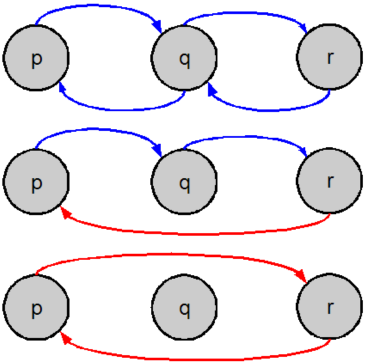
- Next successor e sends approximate routings table to n
  - *Any* node in a given interval is ok
- Node n can lookup better nodes, if it wants to
- Node n tells all nodes in its routing table that it points to them
  - They store node n in their *backlist*

Leaving



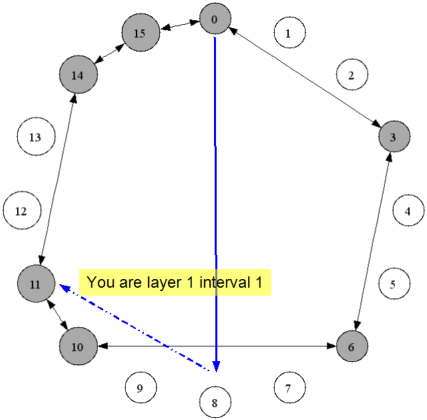
- Node q wants to leave
- Leaving like in double-linked lists
- Node q starts transferring all identifiers to r
- Node q tells all nodes in its routing table and backlist that it is leaving

Leaving: forwarding and locking



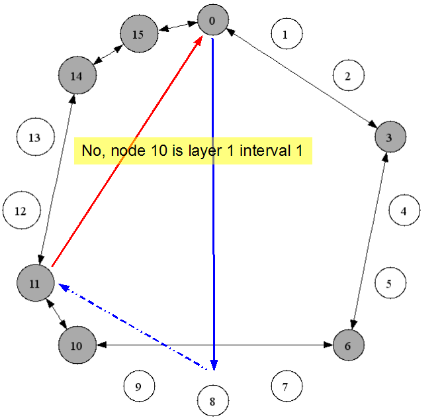
- Node q first locks itself, then its successor
  - If $q > r$: Node q locks its successor, then itself
  - Freedom of Deadlocks, Livelocks
- Node q forwards all messages to its successor
  - Lookup consistency
- Node q releases all locks when done

Correction-on-use



- No periodic stabilization!
- Each time a message is sent, embed *level* and *interval*.
- Receiving node can tell if information is correct
  - If not, tell sender
- Network corrects itself
- Needs enough “user traffic”

Correction-on-use



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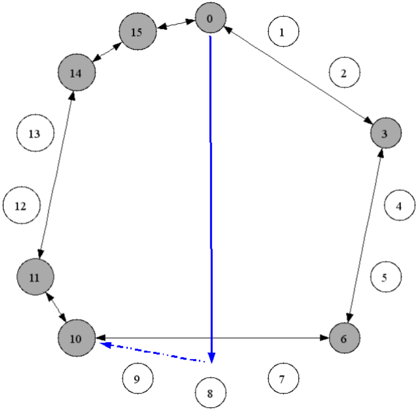

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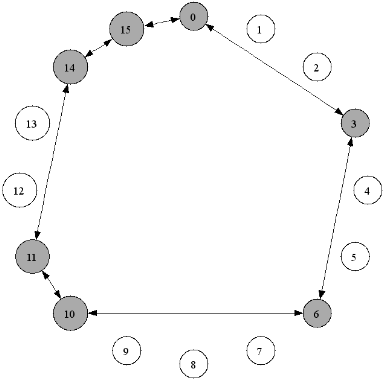
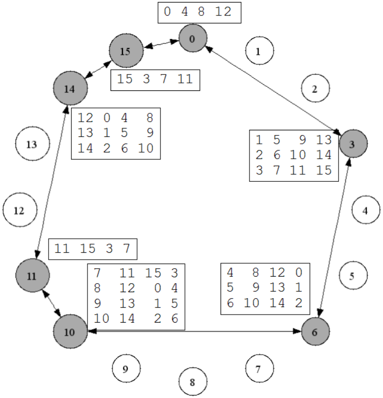
Handling Failures



- Each node maintains *successor list* of length *f*
  - quick replacement when *next successor* fails
- same for *predecessor list*

Symmetric Replication



- Each information is stored f times
  - At nodes $n \oplus i\frac{N}{f}$, $i \in N_0$
- All nodes $n \oplus \frac{N}{f}$ are responsible for the same set of identifiers
- Store in DHT: send f messages
  - Problem of race conditions not mentioned anywhere

Outline

Conclusion

- Routing table size $k * log_k N$
- Lookup node with max. $log_k N$ messages
- Optimal Broadcast with max $log_k N$ messages per node
- Handles concurrency in joins, leaves
- Problems with concurrency in replication

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That's all folks!

Thank you for your attention!

Any questions?