



CLOUD COMPUTING CONCEPTS

with Indranil Gupta (Indy)

P2P SYSTEMS

Lecture E

CHORD

DHT=DISTRIBUTED HASH TABLE

- A hash table allows you to insert, lookup, and delete objects with keys
- A *distributed* hash table allows you to do the same in a distributed setting (objects=files)
- Performance concerns:
 - Load balancing
 - Fault-tolerance
 - Efficiency of lookups and inserts
 - Locality
- Napster, Gnutella, FastTrack are all DHTs (sort of)
- So is Chord, a structured peer-to-peer system that we study next

COMPARATIVE PERFORMANCE

	Memory	Lookup Latency	#Messages for a lookup	
Napster	$O(1)$ ($O(N)$ @server)	$O(1)$	$O(1)$	
Gnutella	$O(N)$	$O(N)$	$O(N)$	

COMPARATIVE PERFORMANCE

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Napster	$O(1)$ ($O(N)$ @server)	$O(1)$	$O(1)$	
Gnutella	$O(N)$	$O(N)$	$O(N)$	
Chord	$O(\log(N))$	$O(\log(N))$	$O(\log(N))$	

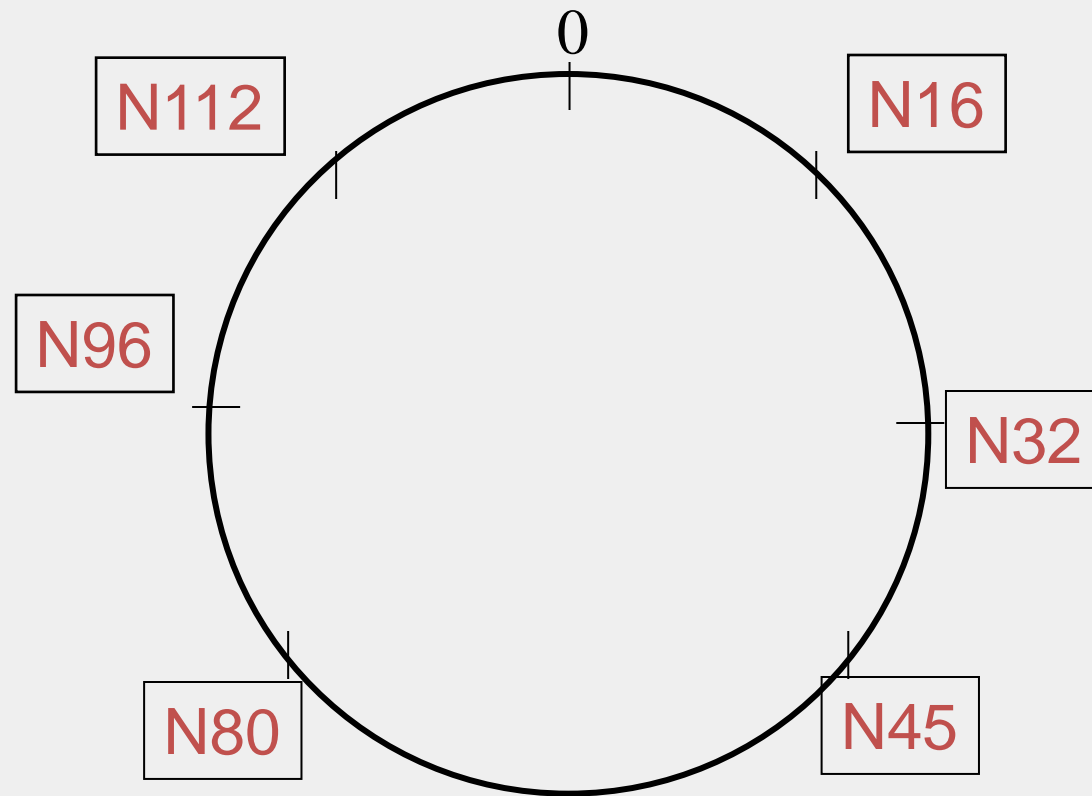
CHORD

- Developers: I. Stoica, D. Karger, F. Kaashoek, H. Balakrishnan, R. Morris, Berkeley, and MIT
- Intelligent choice of neighbors to reduce latency and message cost of routing (lookups/inserts)
- Uses *Consistent Hashing* on node's (peer's) address
 - **SHA-1**(ip_address,port) → 160 bit string
 - Truncated to m bits
 - Called peer *id* (number between 0 and $2^m - 1$)
 - Not unique but id conflicts very unlikely
 - Can then map peers to one of 2^m logical points on a circle

RING OF PEERS

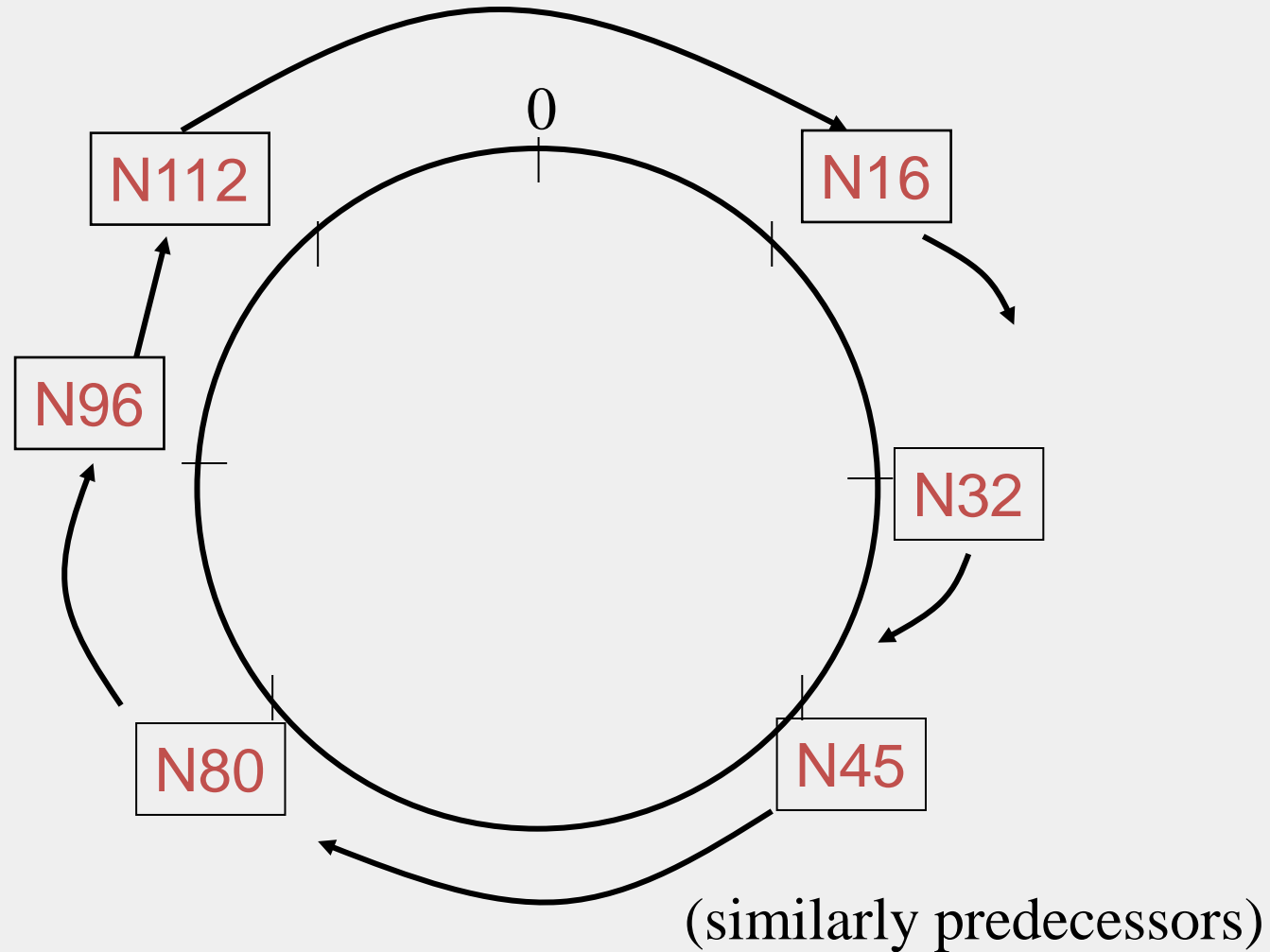
Say $m=7$

6 nodes



PEER POINTERS (1): SUCCESSORS

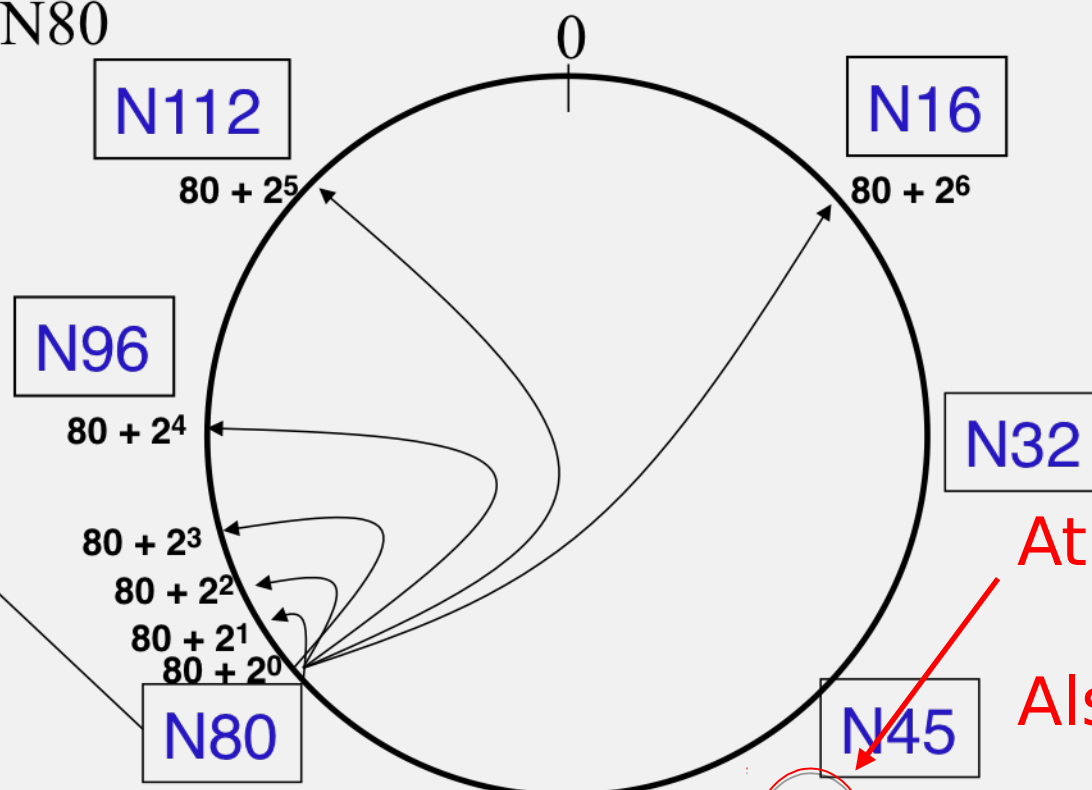
Say $m=7$



Peer pointers (2): finger tables

Finger Table at N80

i	$ft[i]$
0	96
1	96
2	96
3	96
4	96
5	112
6	16



Say $m=7$

At or to the clockwise of.

Also, use $(n + 2^i) \bmod 2^m$.

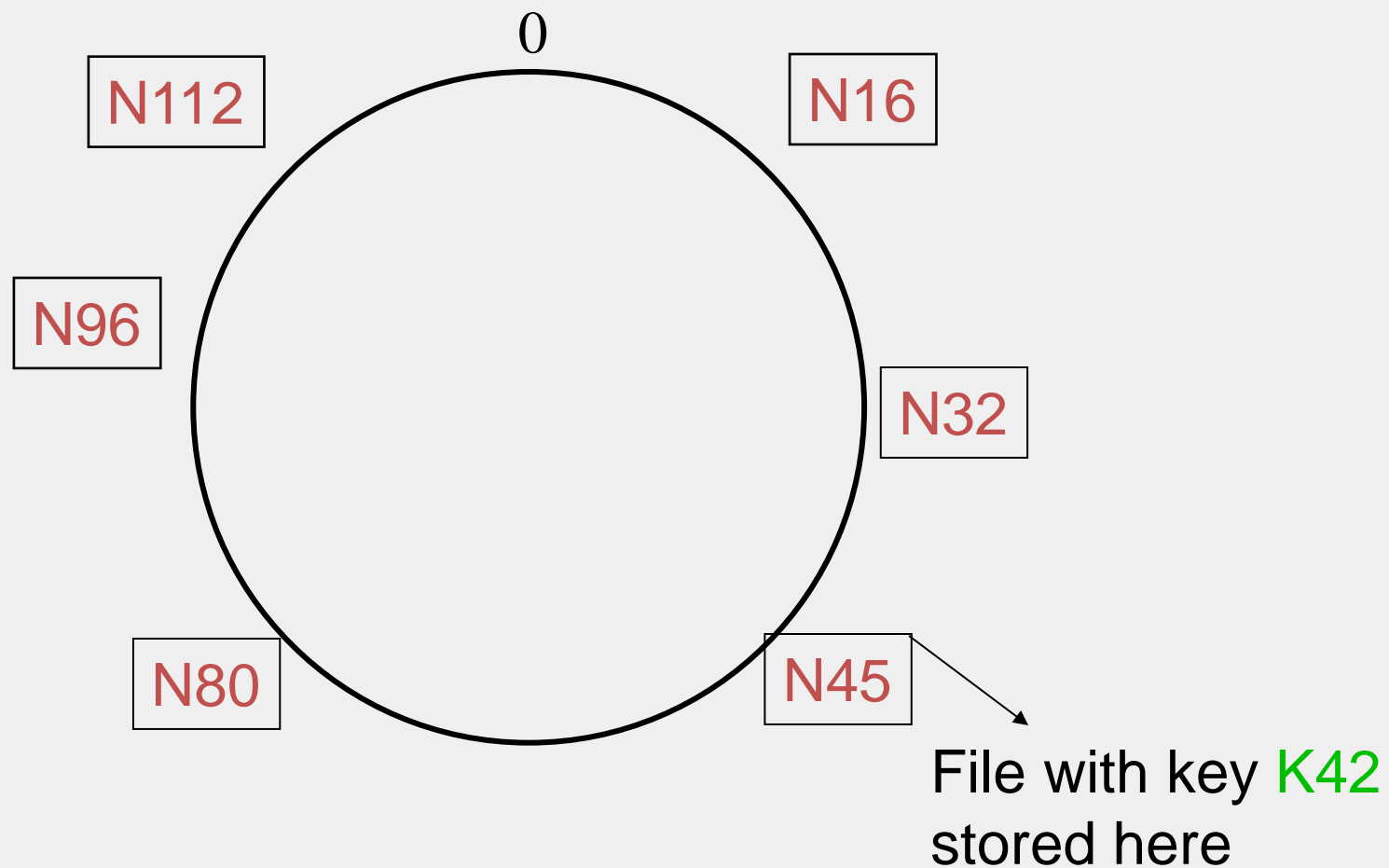
i th entry at peer with id n is first peer with id $\geq \left[n + 2^i \right] (\bmod 2^m)$

WHAT ABOUT THE FILES?

- Filenames also mapped using same consistent hash function
 - $\text{SHA-1}(\text{filename}) \rightarrow 160 \text{ bit string (key)}$
 - File is stored at **first peer with id greater than or equal to its key (mod 2^m)**
- File *cnn.com/index.html* that maps to key K42 is stored at first peer with id at or to the clockwise of 42
 - Note that we are considering a different file-sharing application here : *cooperative web caching*
 - The same discussion applies to any other file sharing application, including that of mp3 files.
- Consistent Hashing \Rightarrow with K keys and N peers, each peer stores $O(K/N)$ keys. (i.e., $< c.K/N$, for some constant c)

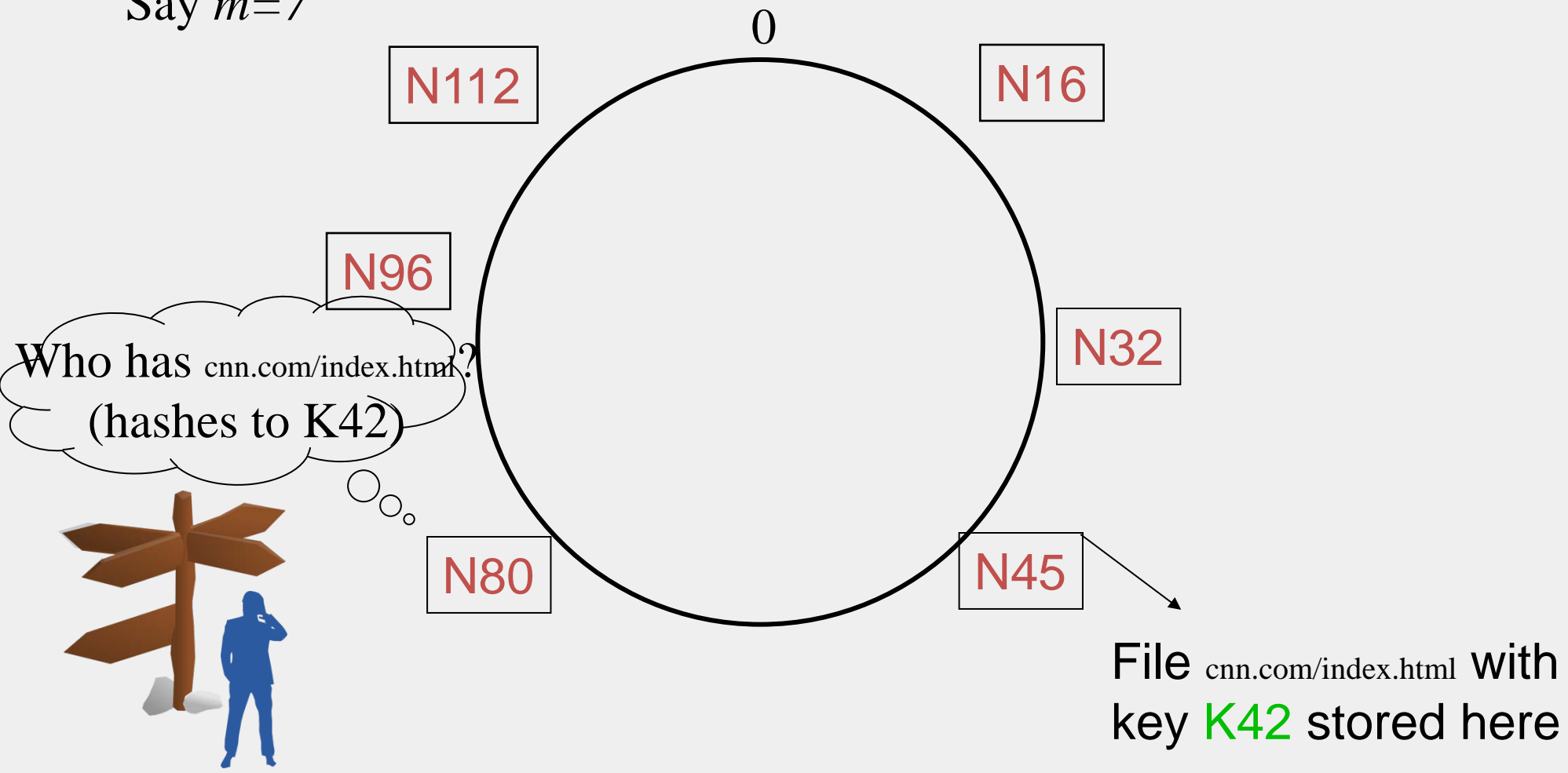
MAPPING FILES

Say $m=7$



SEARCH

Say $m=7$



SEARCH

At node n , send query for key k to largest successor/finger entry $\leq k$
if none exist, send query to $successor(n)$

0

N112

N16

Say $m=7$

N96

N32

Who has `cnn.com/index.html`?
(hashes to K42)

N80

N45

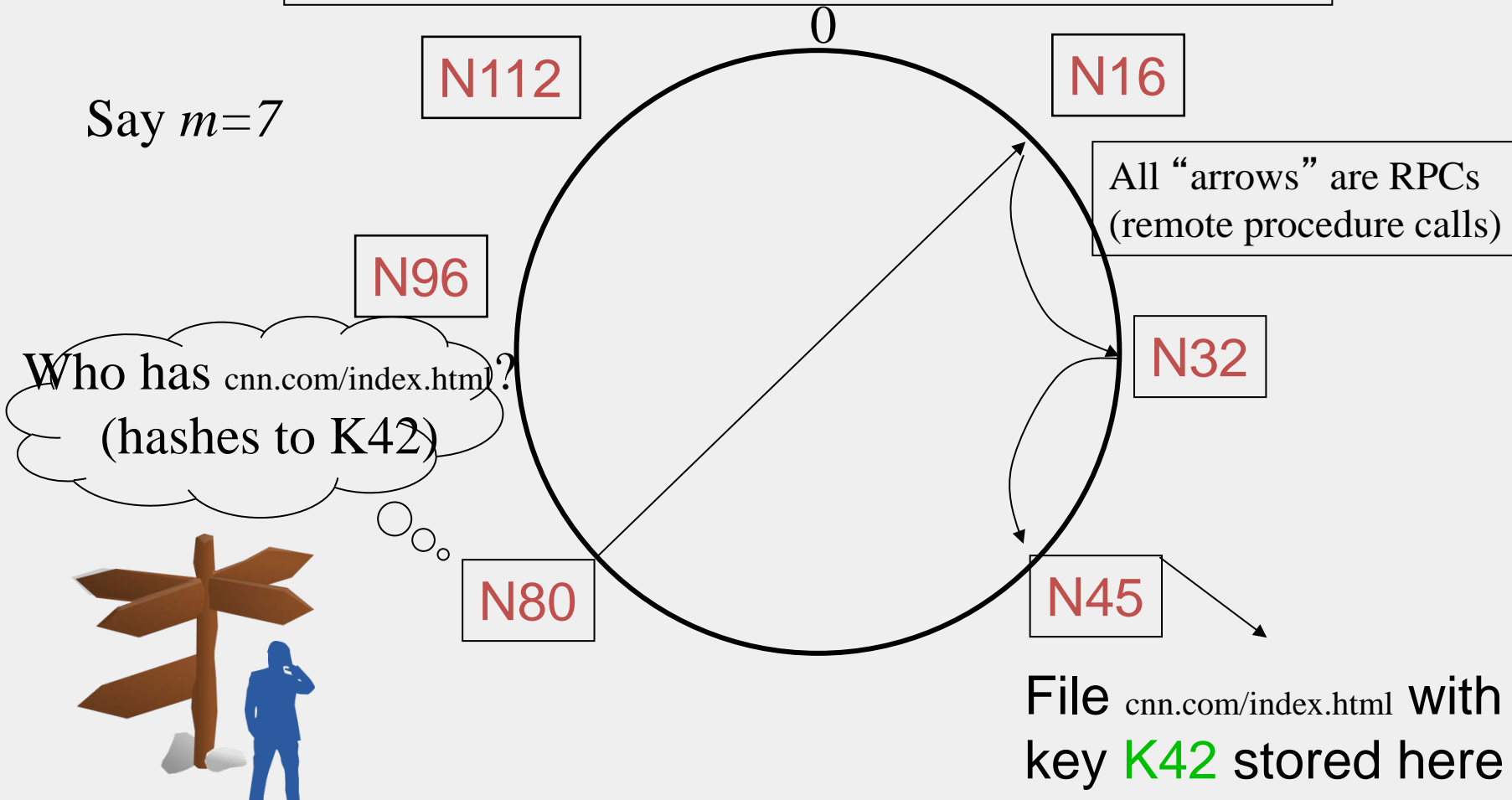
File `cnn.com/index.html` with
key **K42** stored here



SEARCH

At node n , send query for key k to largest successor/finger entry $\leq k$
if none exist, send query to $successor(n)$

Say $m=7$



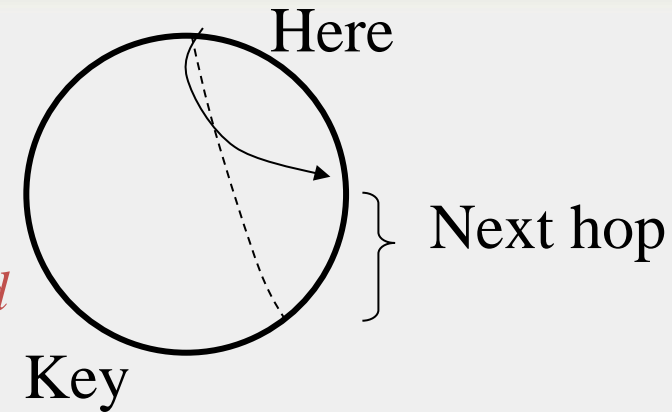
ANALYSIS

Search takes $O(\log(N))$ time

Proof

- (Intuition): *at each step, distance between query and peer-with-file reduces by a factor of at least 2*
- (Intuition): after $\log(N)$ forwardings, distance to key is at most $2^m / 2^{\log(N)} = 2^m / N$
- Number of node identifiers in a range of $2^m / N$ is $O(\log(N))$ with high probability (why? SHA-1! and “Balls and Bins”)

So using *successors* in that range will be ok, using another $O(\log(N))$ hops



ANALYSIS (CONTD.)

- $O(\log(N))$ search time holds for file insertions too (in general for *routing to any key*)
 - “Routing” can thus be used as a **building block** for
 - All operations: insert, lookup, delete
- $O(\log(N))$ time true only if finger and successor entries correct
- When might these entries be wrong?
 - When you have failures