CS 552
Peer 2 Peer Networking

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Credit slides from B. Richardson, I. Stoica, M. Cuenca

Peer to Peer

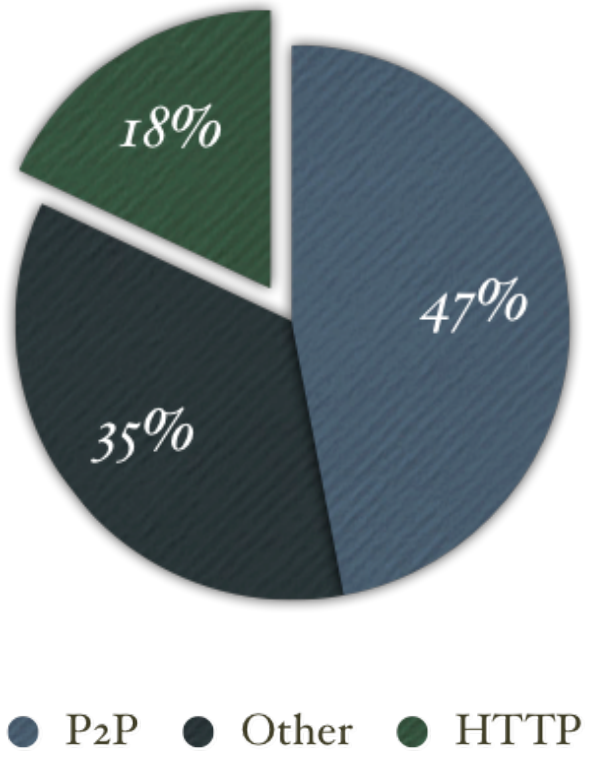
- Outline
- Overview
- Systems:
  - Gnutella
  - Freenet
  - Chord
  - PlanetP

Why Study P2P

- Huge fraction of traffic on networks today
  - >=50%!
- Exciting new applications
- Next level of resource sharing
  - Vs. timesharing, client-server, P2P
  - E.g. Access 10's-100's of TB at low cost.

P2P usage

- CMU network (external to world), 2003
- 47% of all traffic was easily classifiable as P2P
- 18% of traffic was HTTP
- Other traffic: 35%
  - Believe ~28% is port-hopping P2P
- Other sites have a similar distribution



Big Picture

- Gnutella
  - Focus is simple sharing
  - Using simple flooding
- Bit torrent
  - Designed for high bandwidth
- PlanetP
  - Focus on search and retrieval
  - Creates global index on each node via controlled, randomized flooding
- Cord
  - Focus on building a distributed hash table (DHT)
  - Finger tables

Other P2P systems

- Freenet:
  - Focus privacy and anonymity
  - Builds internal routing tables
- KaaZa
- eDonkey
- Napster
  - Success started the whole craze

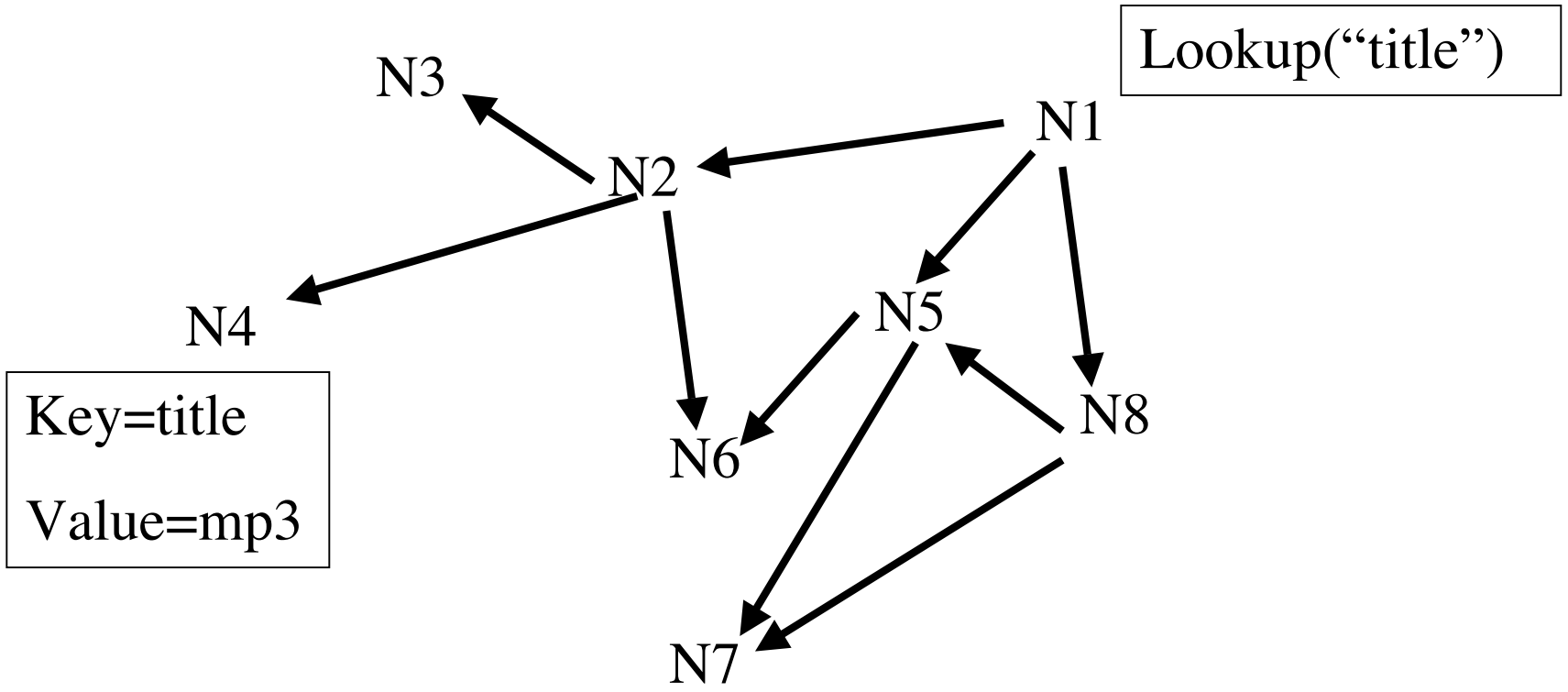
Key issues for P2P systems

- Join/leave
  - How do nodes join/leave? Who is allowed?
- Search and retrieval
  - How to find content?
  - How are metadata indexes built, stored, distributed?
- Content Distribution
  - Where is content stored? How is it downloaded and retrieved?

Search and Retrieval

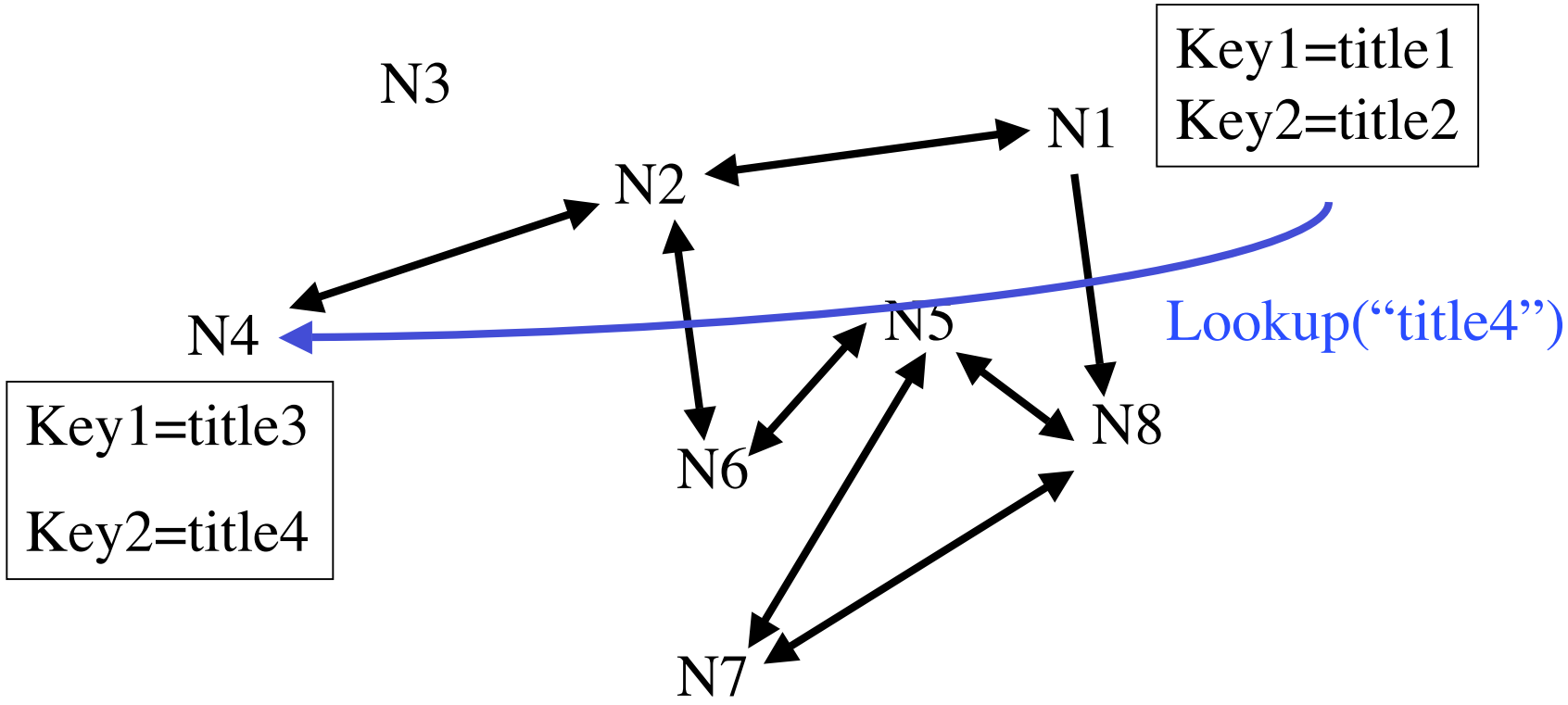
- Basic strategies:
  - Flooding the query
  - Flooding the index
  - Routing the query
- Different tradeoffs depending on application
  - Robustness, scalability, legal issues

Flooding the Query (Gnutella)



Pros: highly robust. Cons: Huge network traffic

Flooding the Index (PlanetP)



Pros: Robust. Cons:Index size

Routing the Query (Chord)

What is Gnutella?

- Gnutella is a protocol for distributed search
- Each node in a Gnutella network acts as both a client and server
- Peer to Peer, decentralized model for file sharing
- Any type of file can be shared
- Nodes are called “Servents”

What do Servents do?

- Servents “know” about other Servents
- Act as interfaces through which users can issue queries and view search results
- Communicate with other Servents by sending “descriptors”

Descriptors

- Each descriptor consists of a header and a body.
- The header includes (among other things)
  - A descriptor ID number
  - A Time-To-Live number
- The body includes:
  - Port information
  - IP addresses
  - Query information
  - Etc… depending on the descriptor

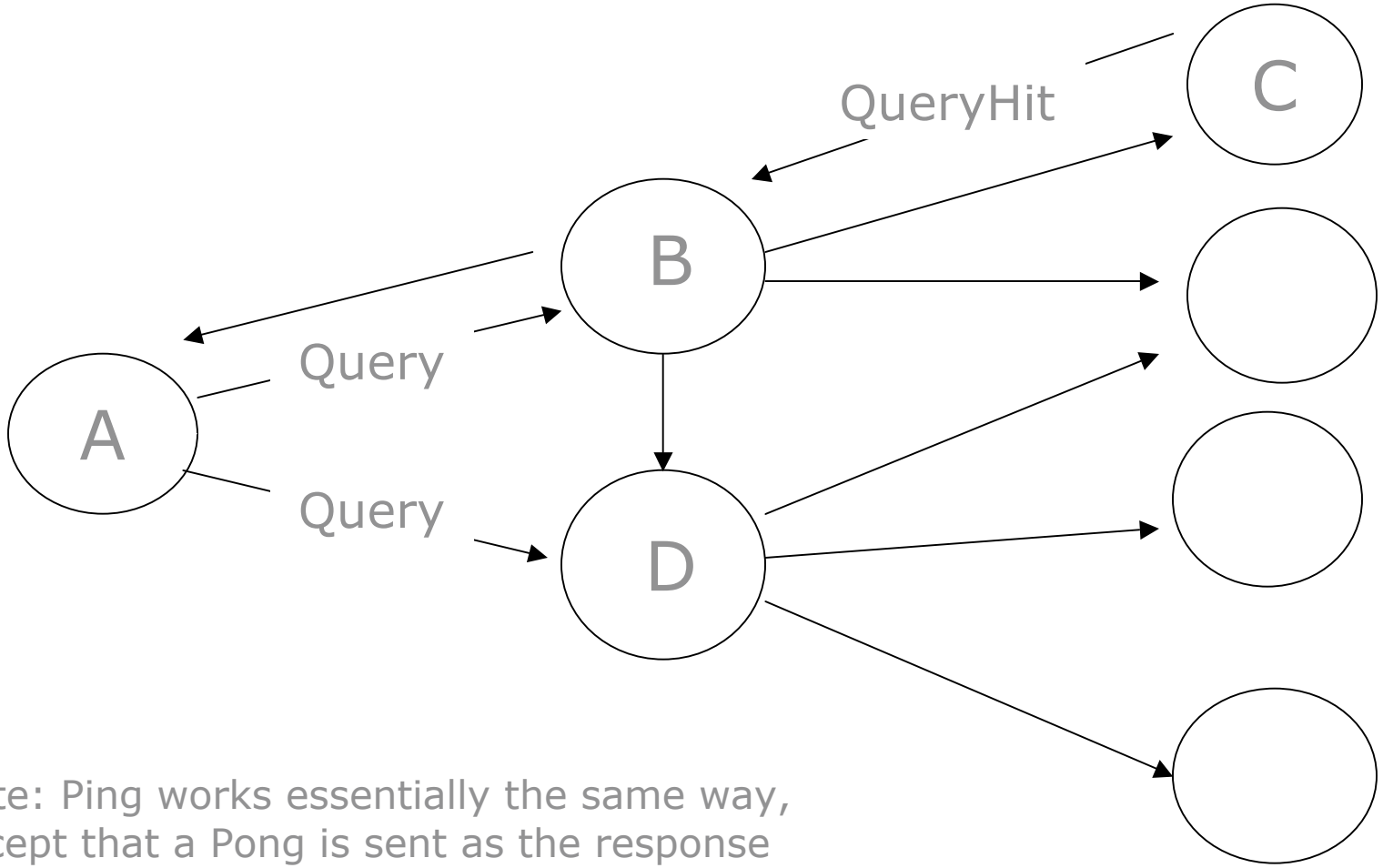
Gnutella Descriptors

- **Ping**: Used to discover hosts on the network.
- **Pong**: Response to a Ping
- **Query**: Search the network for data
- **QueryHit**: Response to a Query. Provides information used to download the file
- **Push**: Special descriptor used for sharing with a firewalled servent

Routing

- Node forwards Ping and Query descriptors to all nodes connected to it
- Except:
  - If descriptor's TTL is decremented to 0
  - Descriptor has already been received before
- Loop detection is done by storing Descriptor ID's
- Pong and QueryHit descriptors retrace the exact path of their respective Ping and Query descriptors

Routing2



Note: Ping works essentially the same way, except that a Pong is sent as the response

Joining a Gnutella Network

- Servent connects to the network using TCP/IP connection to another servent.
- Could connect to a friend or acquaintance, or from a “Host-Cache”.
- Send a **Ping** descriptor to the network
- Hopefully, a number of **Pongs** are received

Querying

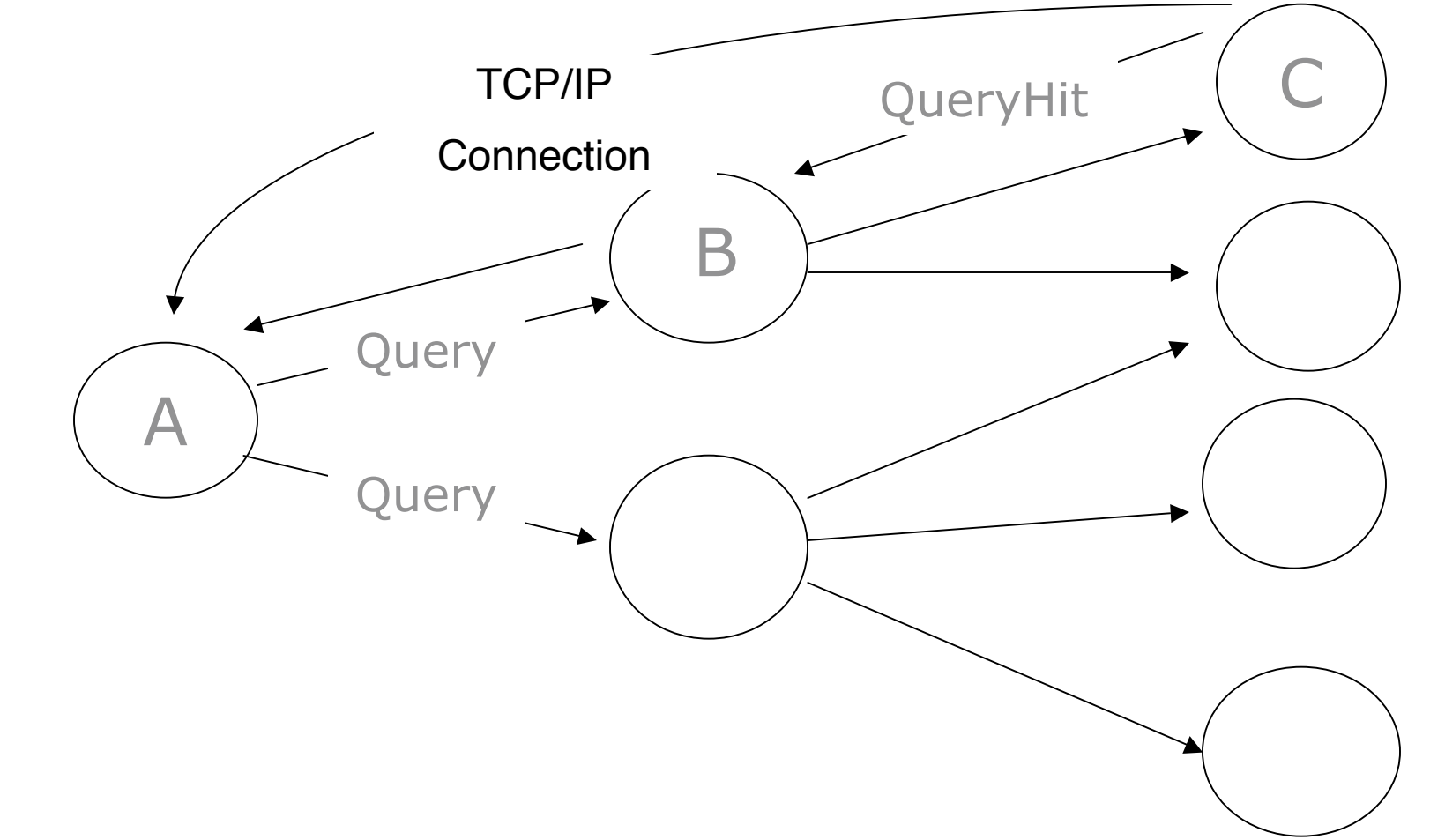
- Servent sends **Query** descriptor to nodes it is connected to.
- Queried Servents check to see if they have the file.
  - If query match is found, a **QueryHit** is sent back to querying node

Downloading a File

- File data is never transferred over the Gnutella network.
- Data transferred by direct connection
- Once a servent receives a QueryHit descriptor, it may initiate the direct download of one of the files described by the descriptor's Result Set.
- The file download protocol is HTTP. Example:

```
GET /get/<File Index>/<File Name>/ HTTP/1.0\r\n
Connection: Keep-Alive\r\n
Range: bytes=0-\r\n
User-Agent: Gnutella\r\n3
```

Direct File Download



Overall:

- Simple Protocol
- Not a lot of overhead for routing
- Robustness?
  - No central point of failure
  - However: A file is only available as long as the file-provider is online.
- Vulnerable to denial-of-service attacks

Overall

- Scales poorly: Querying and Pinging generate a lot of unnecessary traffic
- Example:
  - If TTL = 10 and each site contacts six other sites
  - Up to 10^6 (approximately 1 million) messages could be generated.
  - On a slow day, a GnutellaNet would have to move *2.4 gigabytes per second* in order to support numbers of users comparable to Napster. On a heavy day, *8 gigabytes per second* (Ritter article)
- Heavy messaging can result in poor performance

PlanetP Introduction

- 1st generation of P2P applications based on ad-hoc solutions
  - File sharing (Kazaa, Gnutella, etc), Spare cycles usage (SETI@Home)
- More recently, many projects are focusing on building infrastructure for large scale key-based object location (DHTS)
  - Chord, Tapestry and others
  - Used to build global file systems (Farsite, Oceanstore)
- What about content-based location?

Goals & Challenges

- Provide content addressing and ranking in P2P
  - Similar to Google/ search engines
  - Ranking critical to navigate terabytes of data
- Challenges
  - Resources are divided among large set of heterogeneous peers
  - No central management and administration
  - Uncontrolled peer behavior
  - Gathering accurate global information is too expensive

The PlanetP Infrastructure

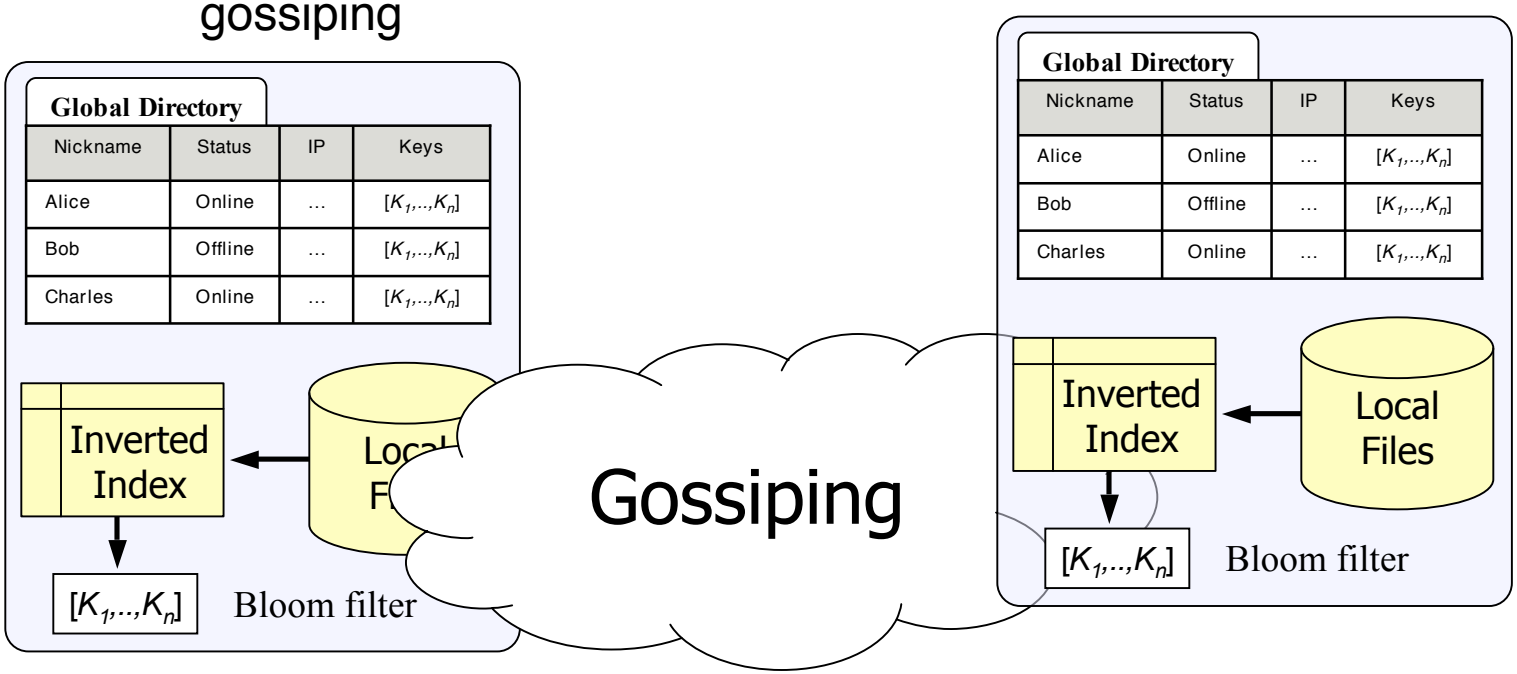
- Compact global index of shared information
  - Supports resource discovery and location
  - Extremely compact to minimize global storage requirement
  - Kept loosely synchronized and globally replicated
- Epidemic based communication layer
  - Provides efficient and reliable communication despite unpredictable peer behaviors
  - Supports peer discovery (membership), group communication, and update propagation
- Distributed information ranking algorithm
  - Locate highly relevant information in large shared document collections
  - Based on TFxIDF, a state-of-the-art ranking technique
  - Adapted to work with only partial information

Using PlanetP

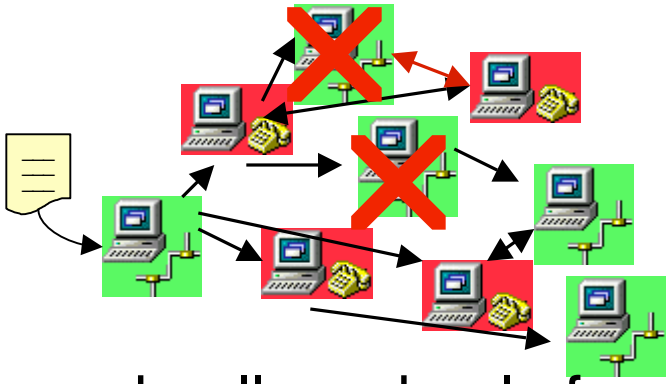
- Services provided by PlanetP:
  - Content addressing and ranking
    - Resource discovery for adaptive applications
  - Group membership management
    - Close collaboration
  - Publish/Subscribe information propagation
    - Decoupled communication and timely propagation
  - Group communication
    - Simplify development of distributed apps.

Global Information Index

- Each node maintains an index of its content
  - Summarize the set of terms in its index using a Bloom filter
- The global index is the set of all summaries
  - Term to peer mappings
  - List of online peers
  - Summaries are propagated and kept synchronized using gossiping

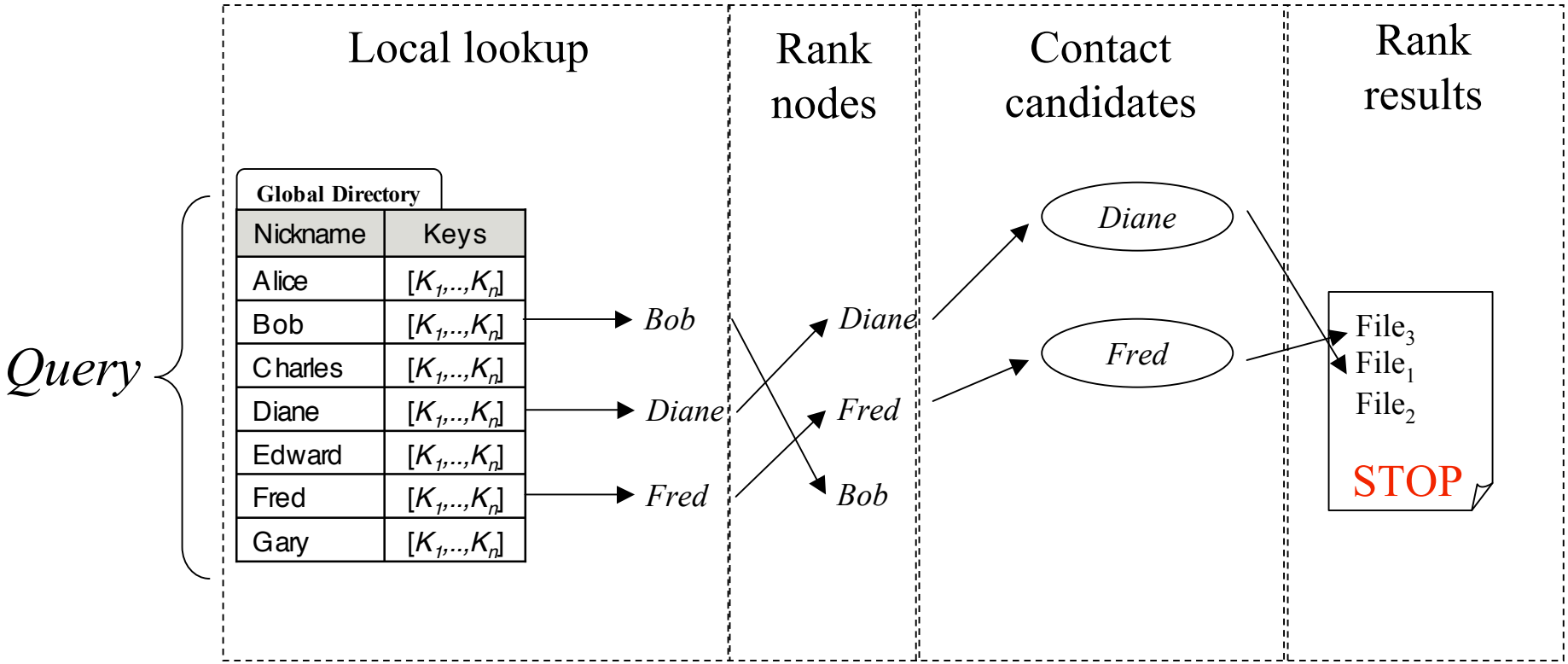


Epidemic Comm. in P2P



- Nodes push and pull randomly from each others
  - Unstructured communication ⇒ resilient to failures
  - Predictable convergence time
- Novel combination of previously known techniques
  - Rumoring, anti-entropy, and partial anti-entropy
    - Introduce partial anti-entropy to reduce variance in propagation time for dynamic communities
  - Batch updates into communication rounds for efficiency
  - Dynamic slow-down in absence of updates to save bandwidth

Content Search in PlanetP



Results Ranking

- The Vector Space model
  - Documents and queries are represented as k-dimensional vectors
    - Each dimension represents the relevance or weight of the word for the document
  - The angle between a query and a document indicates its similarity
  - Does not requires links between documents
- Weight assignment (TFxIDF)
  - Use Term Frequency (TF) to weight terms for documents
  - Use Inverse Document Frequency (IDF) to weight terms for query
  - Intuition
    - TF indicates how relevant a document is to a particular concept
    - IDF gives more weight to terms that are good discriminators between documents

Using TFxIDF in P2P

- Unfortunately IDF is not suited for P2P
  - Requires term to document mappings
  - Requires a frequency count for every term in the shared collection
- Instead, use a two-phase approximation algorithm
- Replace IDF with IPF (Inverse Peer Frequency)
  - IPF(t) = f(No. Peers/Peers with documents containing term t)
  - Individuals can compute a consistent global ranking of peers and documents without knowing the global frequency count of terms
- Node ranking function

$$Rank_i(Q) = \sum_{t \in Q \wedge t \in BF_i} IPF_t$$

Pruning Searches

- Centralized search engines have index for entire collection
  - Can rank entire set of documents for each query
- In a P2P community, we do not want to contact peers that have only marginally relevant documents
  - Use adaptive heuristic to limit forwarding of query in 2nd-phase to only a subset of most highly ranked peers

Evaluation

- Answer the following questions
  - What is the efficacy of our distributed ranking algorithm?
  - What is the storage cost for the globally replicated index?
  - How well does gossiping work in P2P communities?
- Evaluation methodology
  - Use a running prototype to validate and collect micro benchmarks (tested with up to 200 nodes)
  - Use simulation to predict performance on big communities
  - We model peer behavior based on previous work and our own measurements from a local P2P community of 4000 users
- Will show sampling of results from paper

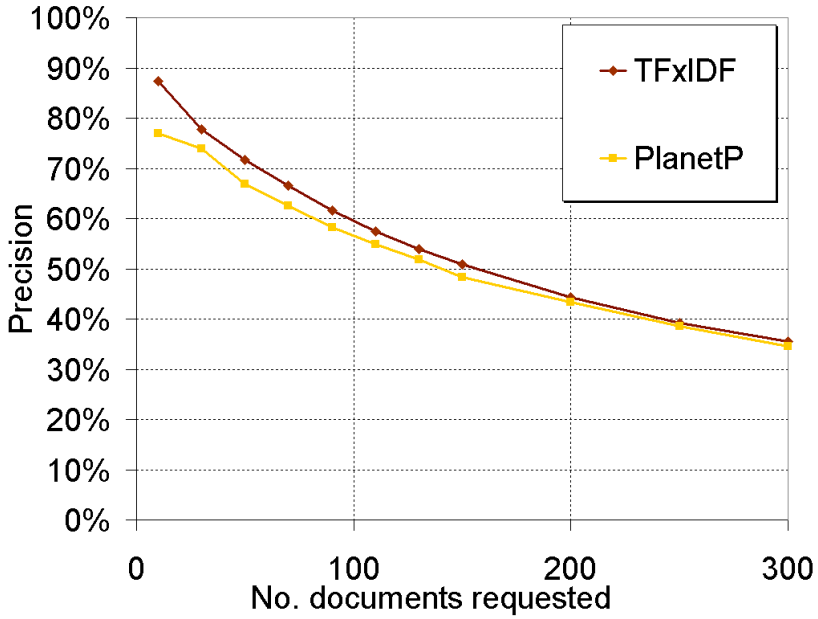
Ranking Evaluation I

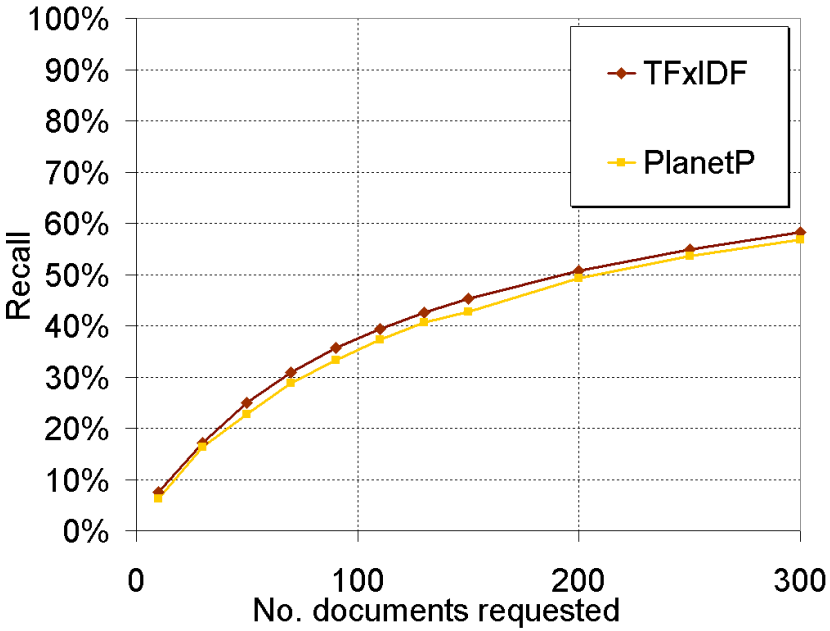
- We use the AP89 collection from TREC
  - 84678 documents, 129603 words, 97 queries, 266MB
  - Each collection comes with a set of queries and relevance judgments
- We measure recall (R) and precision (P)

$$R(Q) = \frac{\text{no. relevant docs. presented to the user}}{\text{total no. relevant docs. in collection}}$$

$$P(Q) = \frac{\text{no. relevant docs. presented to the user}}{\text{total no. docs. presented to the user}}$$

Ranking Evaluation II



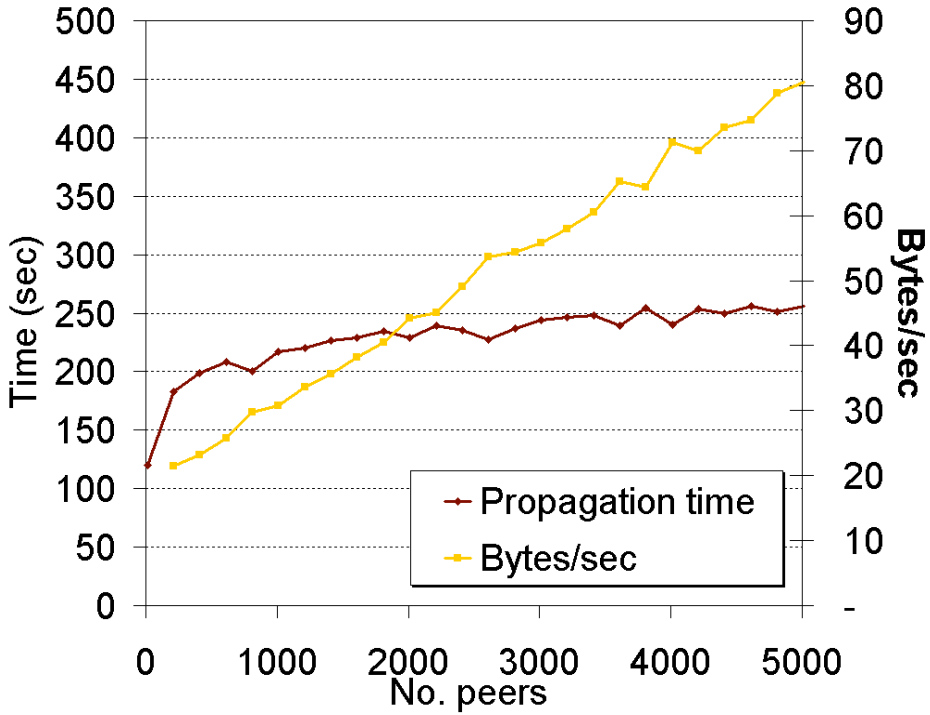


- Results intersection is 70% at low recall and gets to 100% as recall increases
- To get 10 documents, PlanetP contacted 20 peers out of 160 candidates

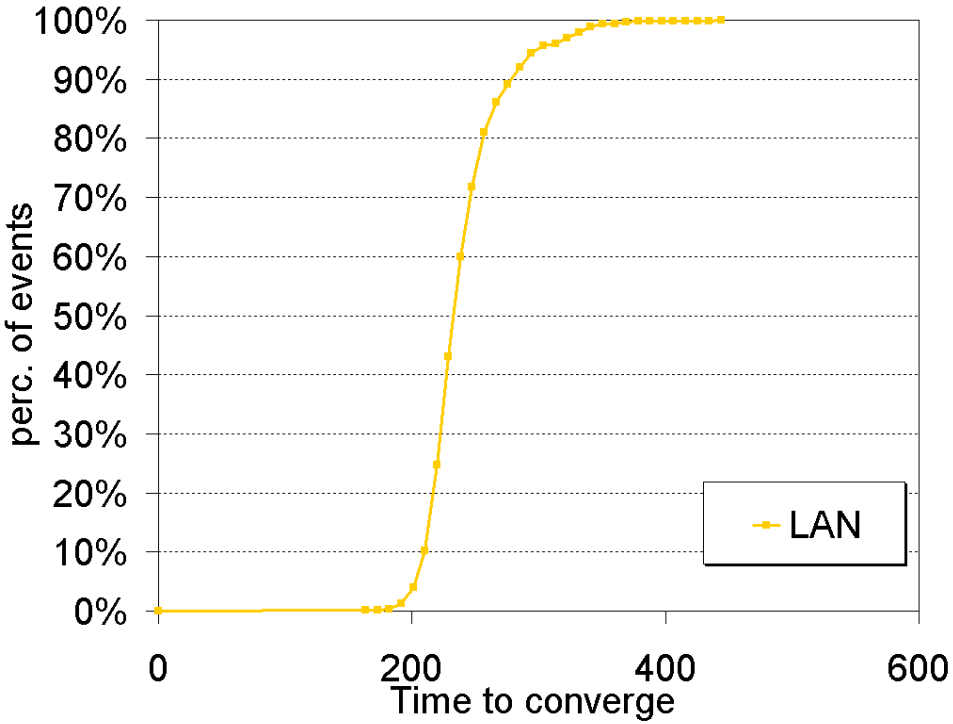
Global Index Space Efficiency

- TREC collection (pure text)
  - Simulate a community of 5000 nodes
    - Distribute documents uniformly
  - 944,651 documents taking up 3GB
  - 36MB of RAM are needed to store the global index
  - This is 1% of the total collection size
- MP3 collection (audio + tags)
  - Using previous result but based on Gnutella measurements
  - 3,000,000 MP3 files taking up 14TB
  - 36MB of RAM are needed to store the global index
  - This is 0.0002% of the total collection size

Data Propagation



Propagation speed experiment (DSL)



Arrival and departure experiment (LAN)

PlanetP Summary

- Explored the design of infrastructural support for a rich set of P2P applications
  - Membership, content addressing and ranking
  - Scale well to thousands of peers
  - Extremely tolerant to unpredictable dynamic peer behaviors
- Gossiping with partial anti-entropy is reliable
  - Information always propagate everywhere
  - Propagation time has small variance
- Distributed approximation of TFxIDF
  - Within 11% of centralized implementation
  - Never collect all needed information in one place
  - Global index on average is only 1% of data collection
  - Synchronization of global index only requires 50 B/sec

BitTorrent: History

- In 2002, Bram Cohen debuted BitTorrent
- Key Motivation:
  - Popularity exhibits temporal locality, Flash Crowds)
  - E.g., Slashdot effect, CNN on 9/11, new release
- Focused on Efficient *Fetching*, not *Searching*:
  - Distribute the *same* file to all peers
  - Single publisher, multiple downloaders
- Has real publishers:
  - Blizzard Entertainment using it to distribute the beta of their new game

BitTorrent: Overview

- Swarming:
  - **Join**: contact centralized “tracker” server, get a list of peers.
  - **Publish**: Run a tracker server.
  - **Search**: Out-of-band. E.g., use Google to find a tracker for the file you want.
  - **Fetch**: Download chunks of the file from your peers. Upload chunks you have to them.

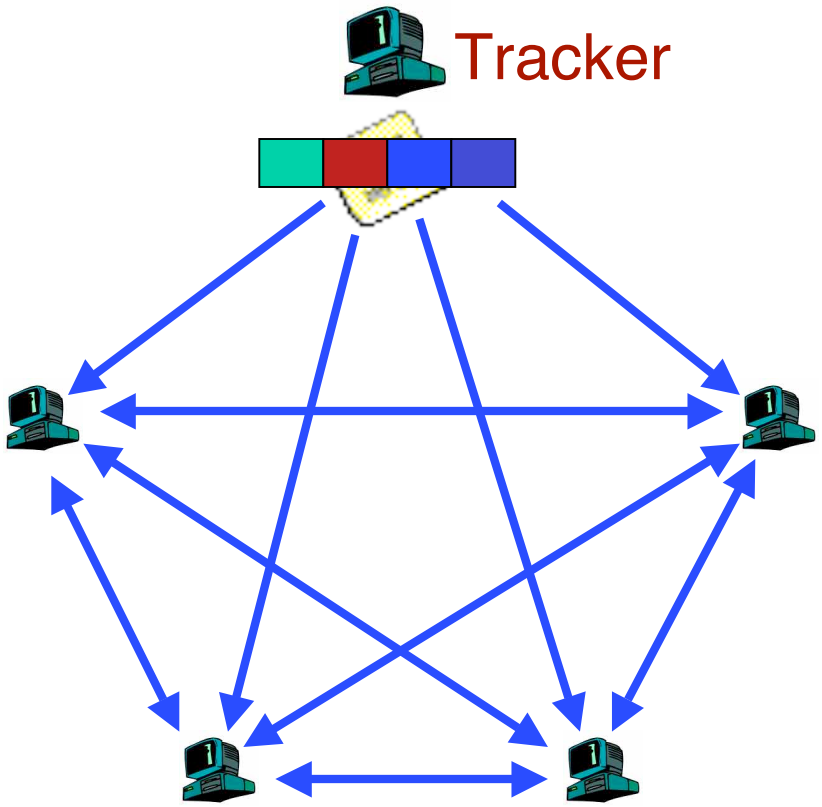
BitTorrent Concepts

- Tracker
  - Lists of peers sharing the file
- .torrent files (.tor)
  - File length, name, hashing info, URL of tracker
- Seed
  - A peer with a copy of the file.
- Peers
  - Downloaders
  - Uploaders

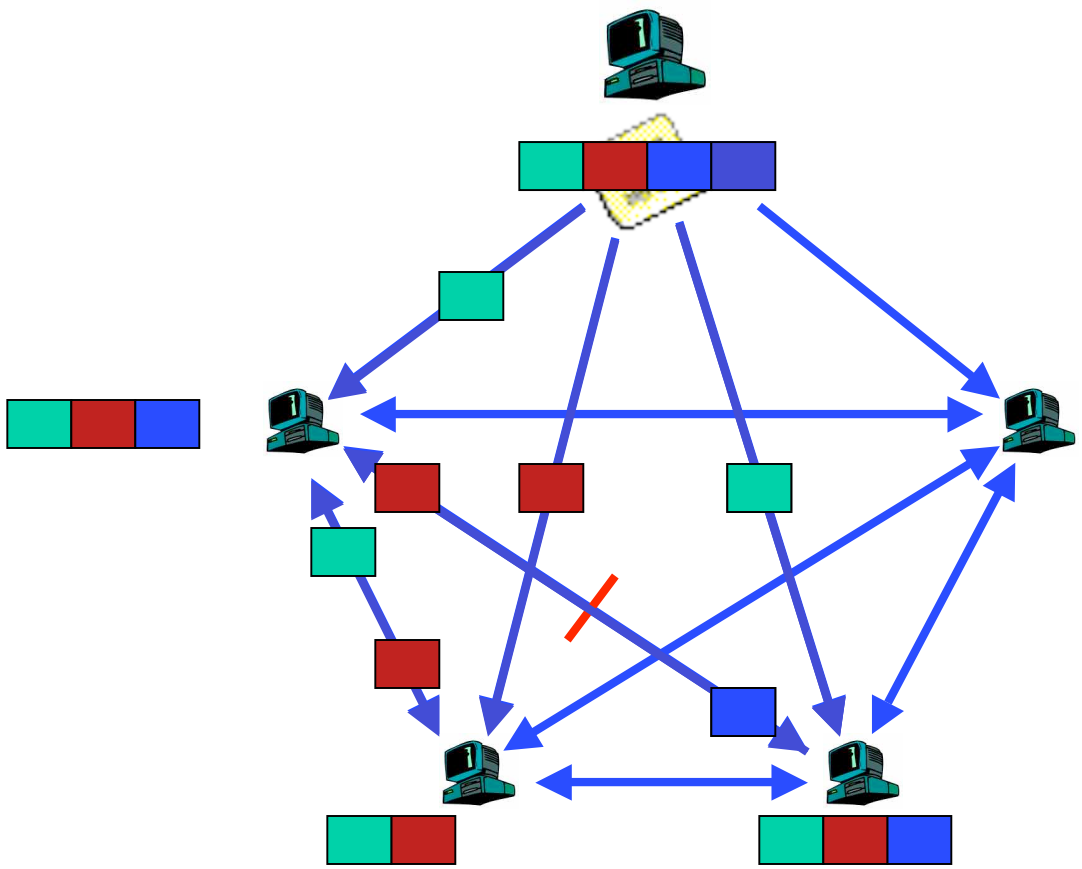
BitTorrent Strategy

- Users finds content (.torrent of the content) via external search
  - E.g. google.
- Peer contacts tracker
- Peer gets random list of other peers
- Peer starts downloading & uploading

BitTorrent: Publish/Join



BitTorrent: Fetch



BitTorrent Design Descisions

- Distribution topology:
  - Random Graph vs.
    - Trees (lose bandwidth of leaves)
    - Hash codes
- Data encoding:
  - 2-tier piecewise w/ hash code checksum vs:
    - Erasure codes
    - Turbo codes

Piece & Sub-Piece Selection

- Pieces (256Kb) and sub-pieces (16Kb)
- Download single piece at once
  - Pipeline 5 sub-pieces
- Uses Rarest Piece First (RPF) selection strategy.
  - Random piece for the 1st one, avoid bottlenecks
- Endgame mode
  - Request all remaining sub-pieces too all peers when downloading last set

BitTorrent: Sharing Strategy

- Employ “Tit-for-tat” sharing strategy
  - “I’ll share with you if you share with me”
  - Be optimistic: occasionally let freeloaders download
    - Otherwise no one would ever start!
    - Also allows you to discover better peers to download from when they reciprocate
  - Similar to: Prisoner’s Dilemma
- Approximates Pareto Efficiency
  - Game Theory: “No change can make anyone better off without making others worse off”

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- .torrent files (.tor)
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Cooperative Strategy

- Keep freeloaders from dominating
- Choking:
  - Maintain connection, but refuse to upload
- Keep top 4 downloaders unchoked
  - Compute rate over 20 second window
  - Recompute set every 10 seconds
- Optimistic unchoke
  - Every 3 periods (30 sec), rotate peer to unchoke
- Anti-snubbing
  - if >1 minute no piece, “snubbed”, -> choke
  - Can perform optimistic unchoke

BitTorrent: Summary

- Pros:
  - Works reasonably well in practice
  - Gives peers incentive to share resources; avoids freeloaders
- Cons:
  - Pareto Efficiency relative weak condition
  - Central tracker server needed to bootstrap swarm (is this really necessary?)

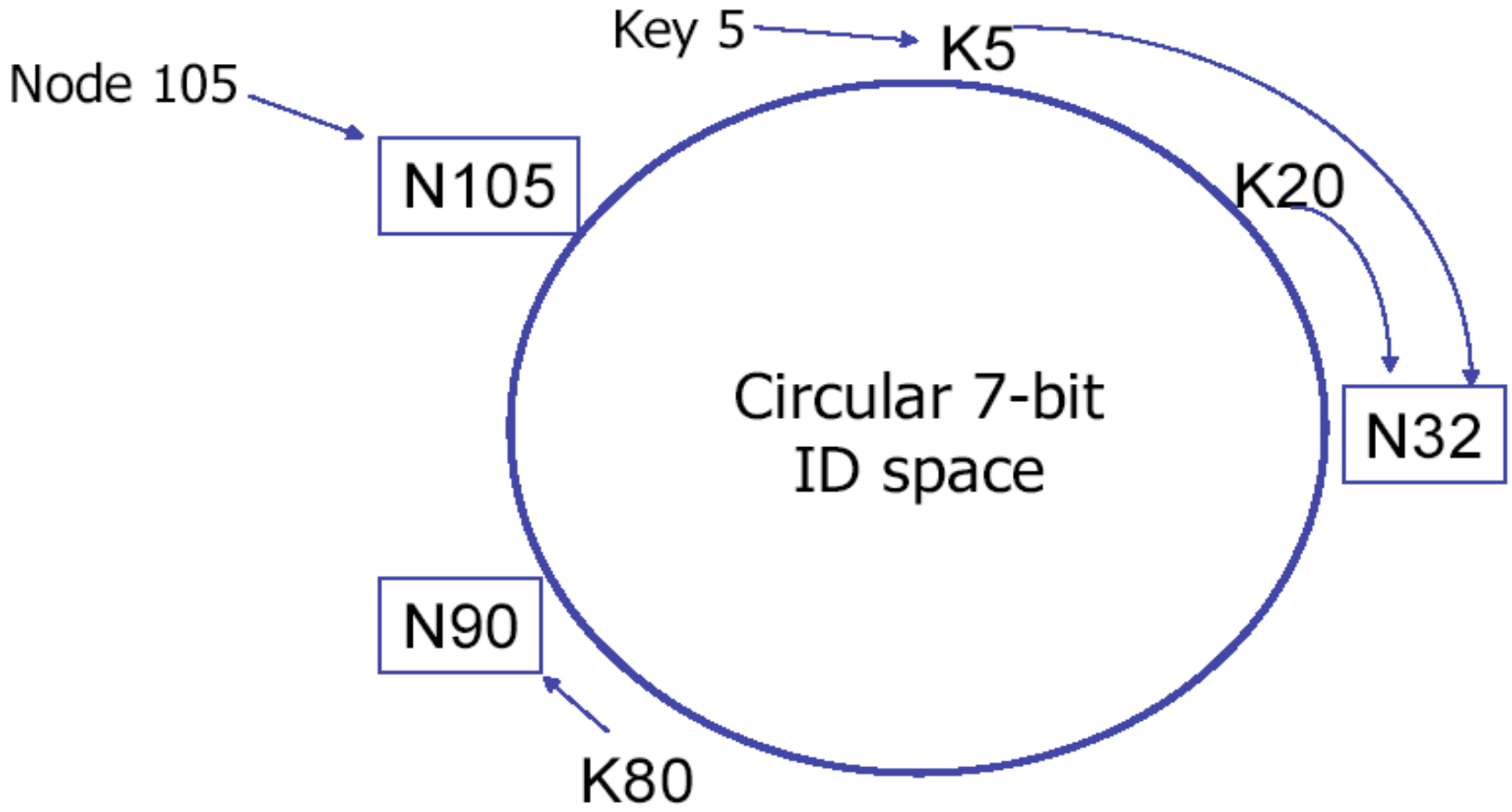
Chord

- Associate to each node and item a unique *id* in an *uni*-dimensional space
- Goals
  - Scales to hundreds of thousands of nodes
  - Handles rapid arrival and failure of nodes
- Properties
  - Routing table size O(log(*N*)) , where *N* is the total number of nodes
  - Guarantees that a file is found in O(log(*N*)) steps

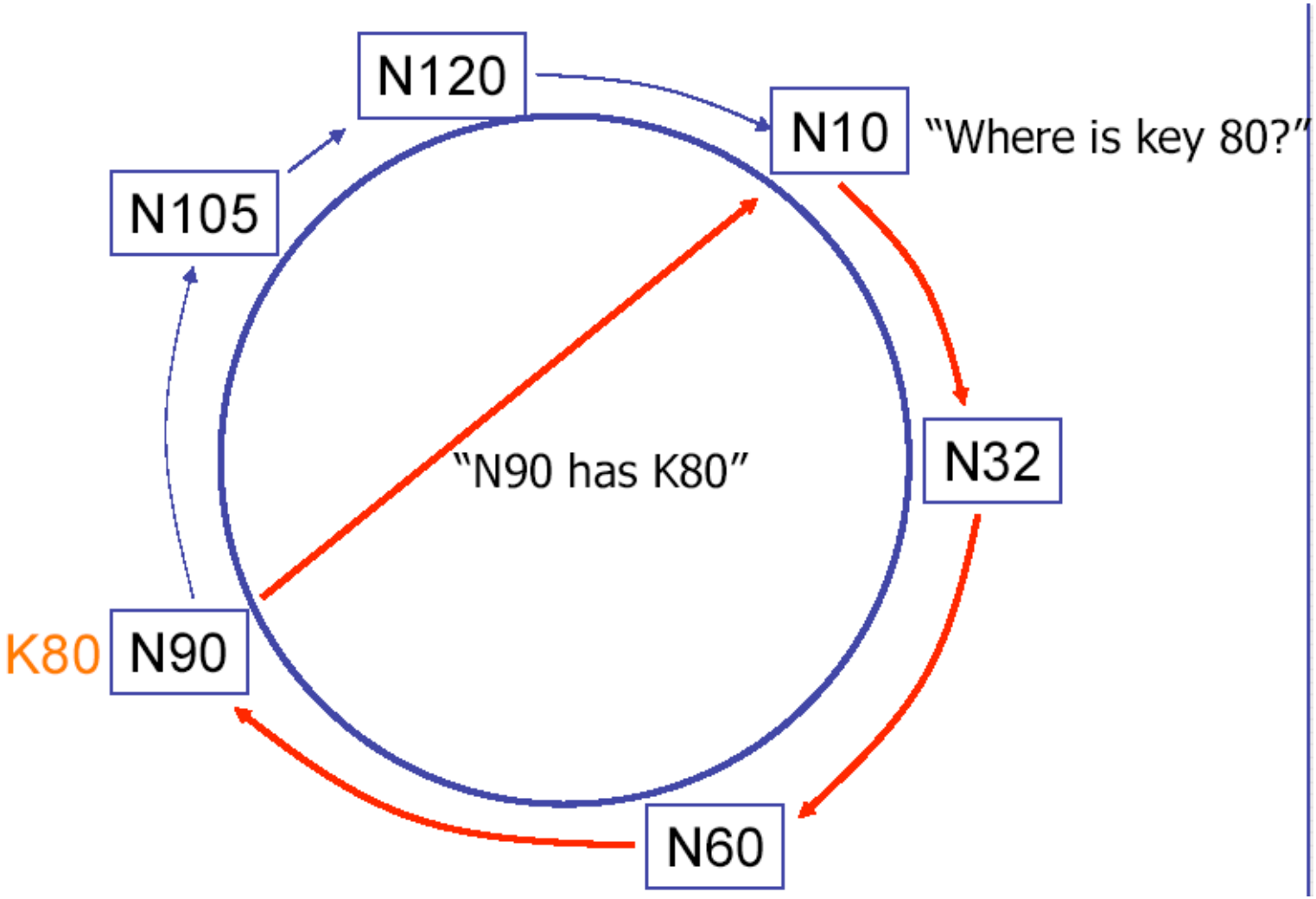
Data Structure

- Assume identifier space is $0..2^m$
- Each node maintains
  - Finger table
    - Entry *i* in the finger table of *n* is the first node that succeeds or equals $n + 2^i$
  - Predecessor node
- An item identified by *id* is stored on the succesor node of *id*

Hashing Keys to Nodes



Basic Lookup



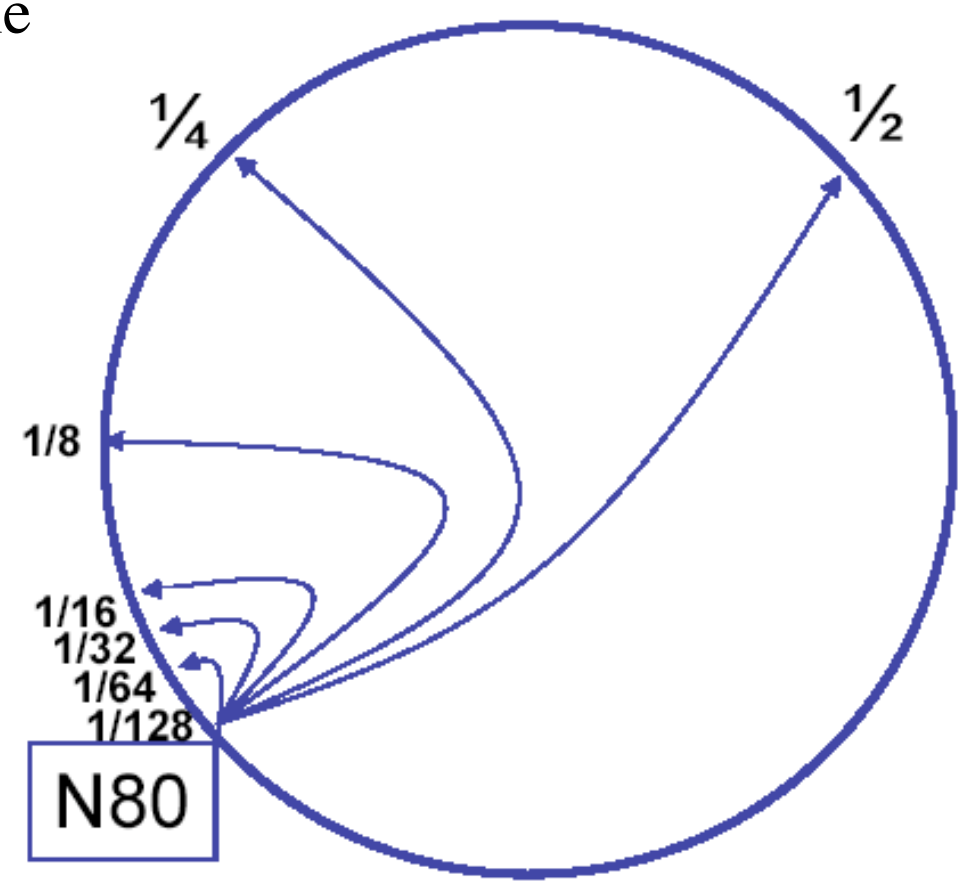
Lookup Algorithm

```
Lookup(my-id, key-id)
   n = my successor
   if my-id < n < key-id
     Lookup(id) on node n // goto next hop
   else
   return my successor // found the correct node
```

- Correctness depends only on successors
- O(N) lookup time, but we can do better

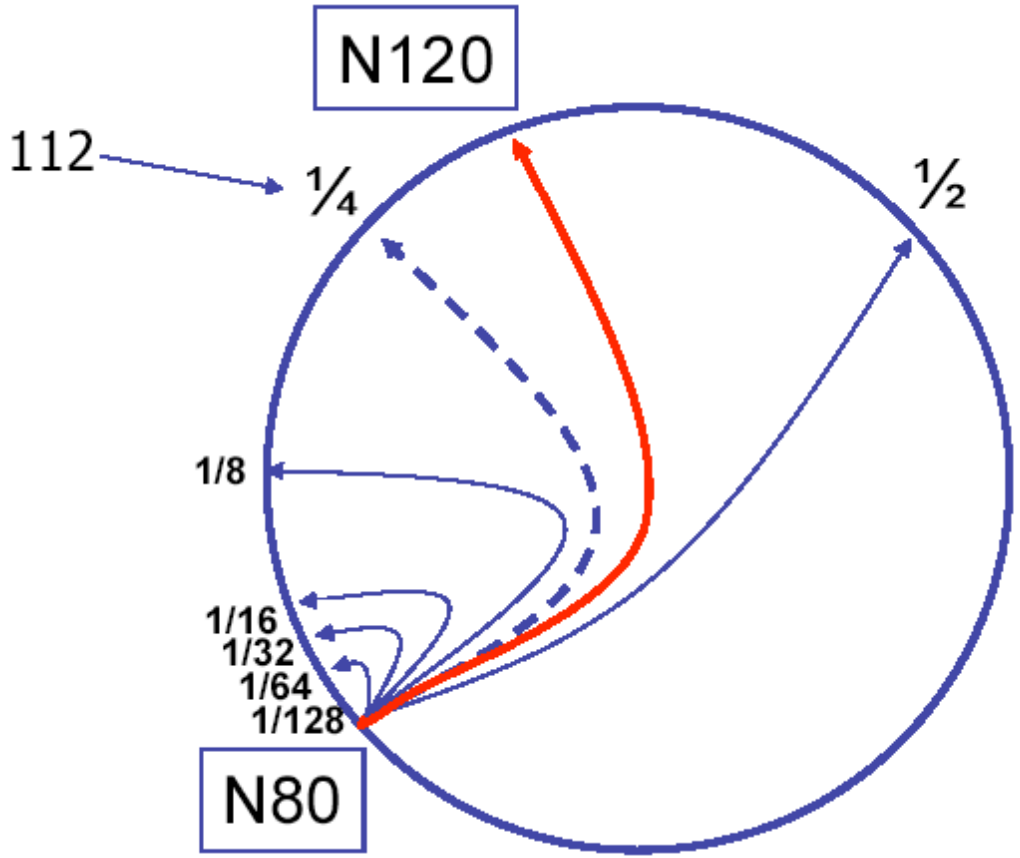
Shortcutting to Log(N) time

Finger table



Shortcutting

Finger i point to successor n+2i

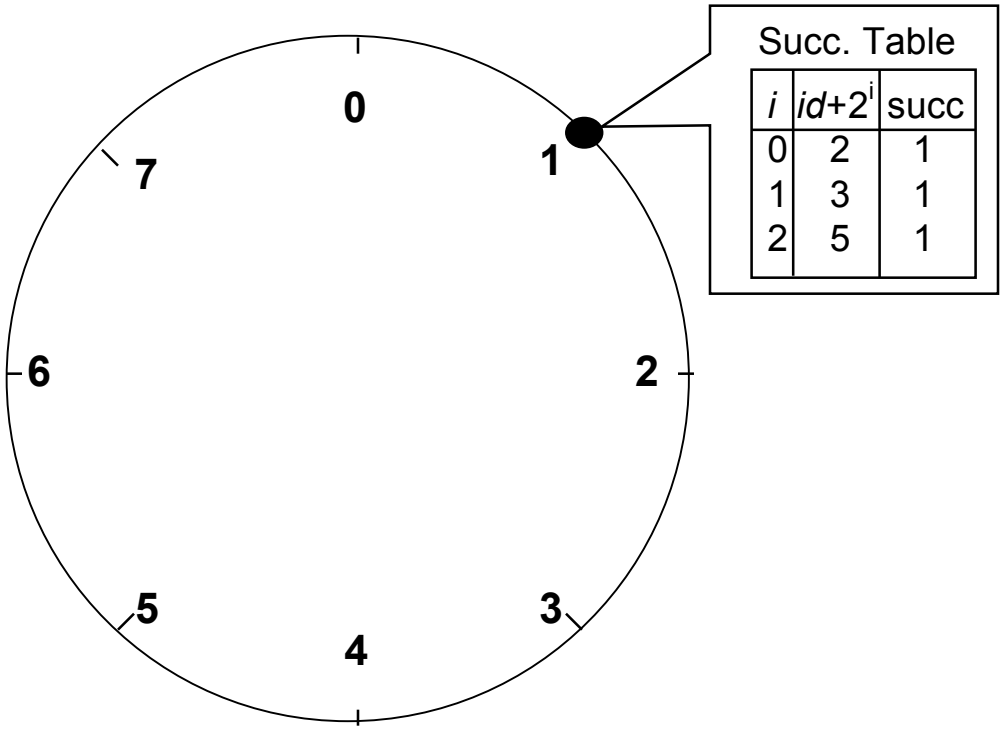


Basic Chord algorithm

```
Lookup(my-id, key-id)
    look in local finger table for
    highest node n such that my-id < n < key-id
    if n exists
       Lookup(id) on node n // goto next hop
    else
    return my successor // found the correct node
```

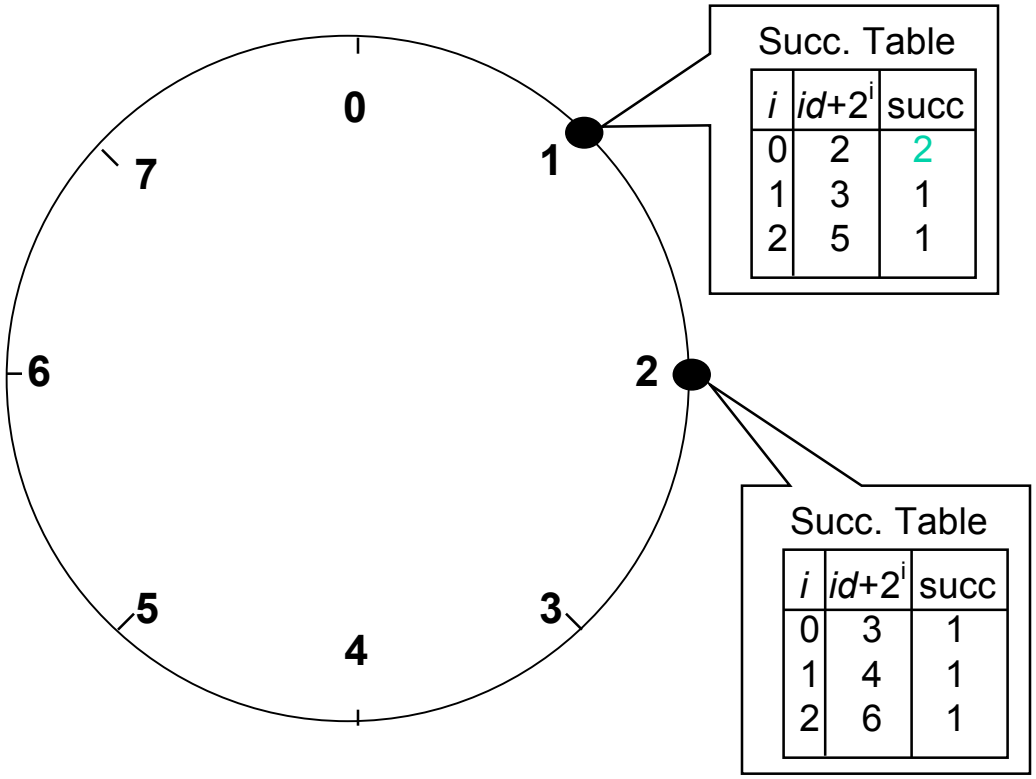
Chord Example

- Assume an identifier space 0..8
- Node n1:(1) joins→all entries in its finger table are initialized to itself



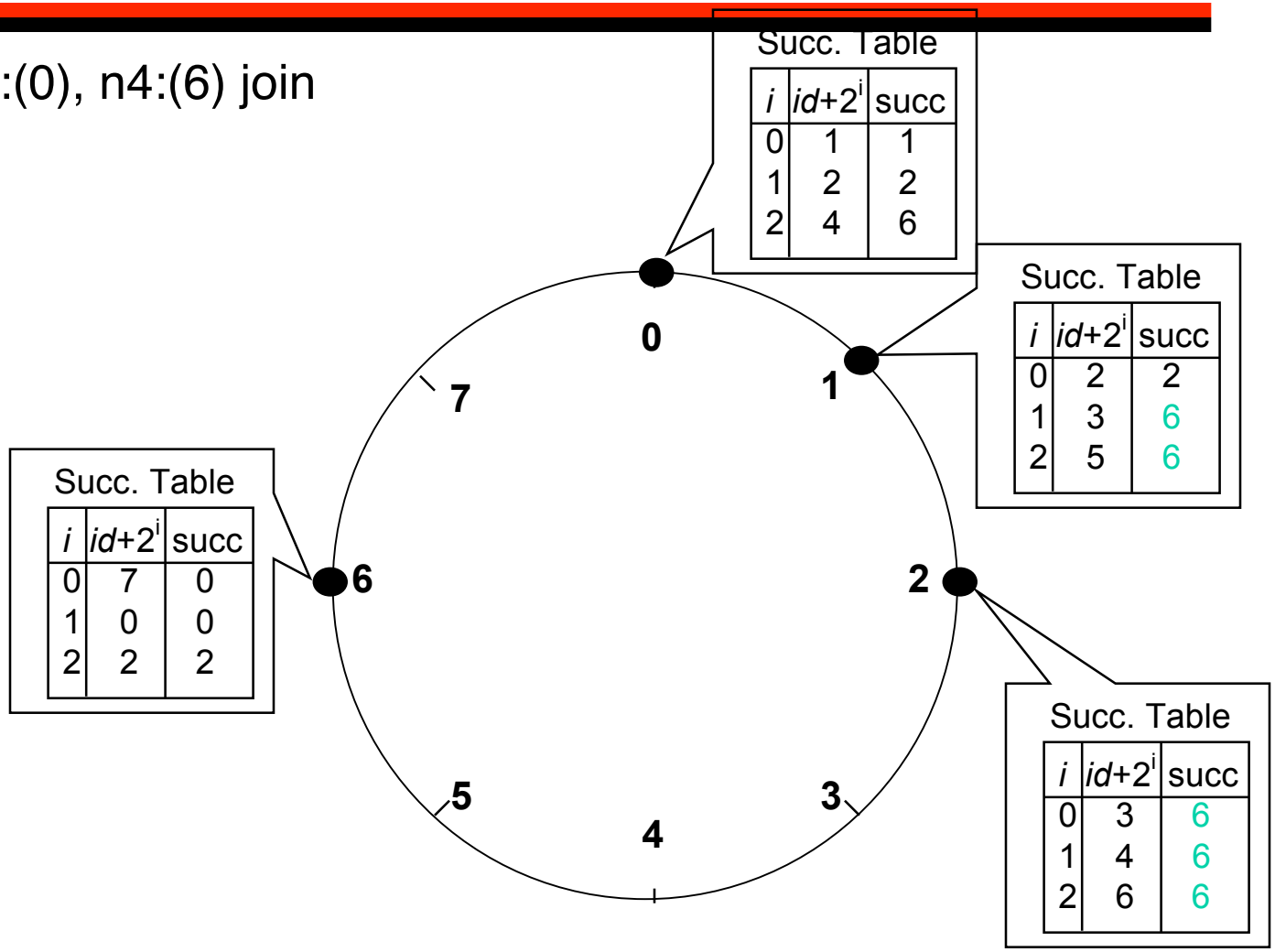
Chord Example

- Node n2:(3) joins



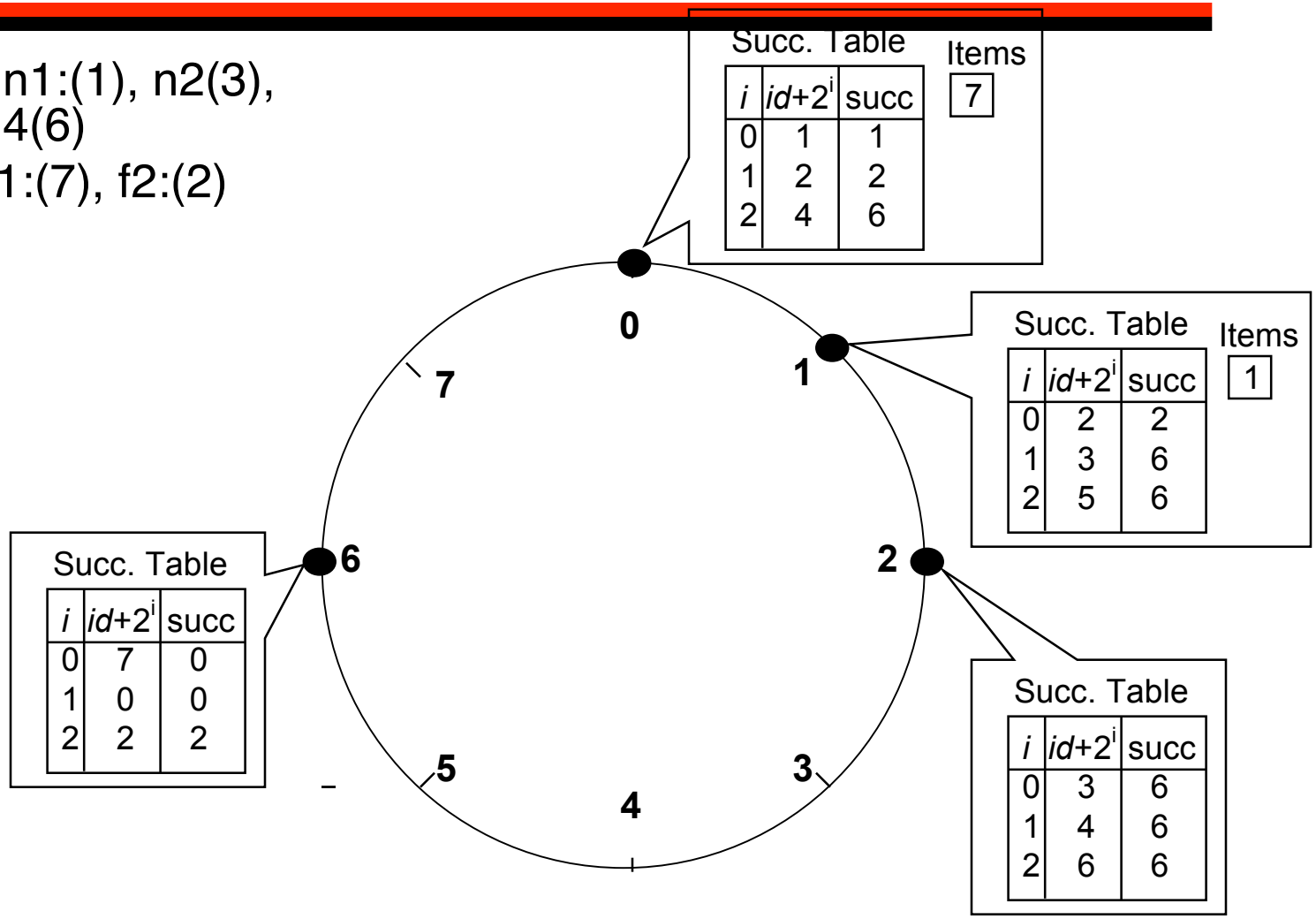
Chord Example

- Nodes n3:(0), n4:(6) join



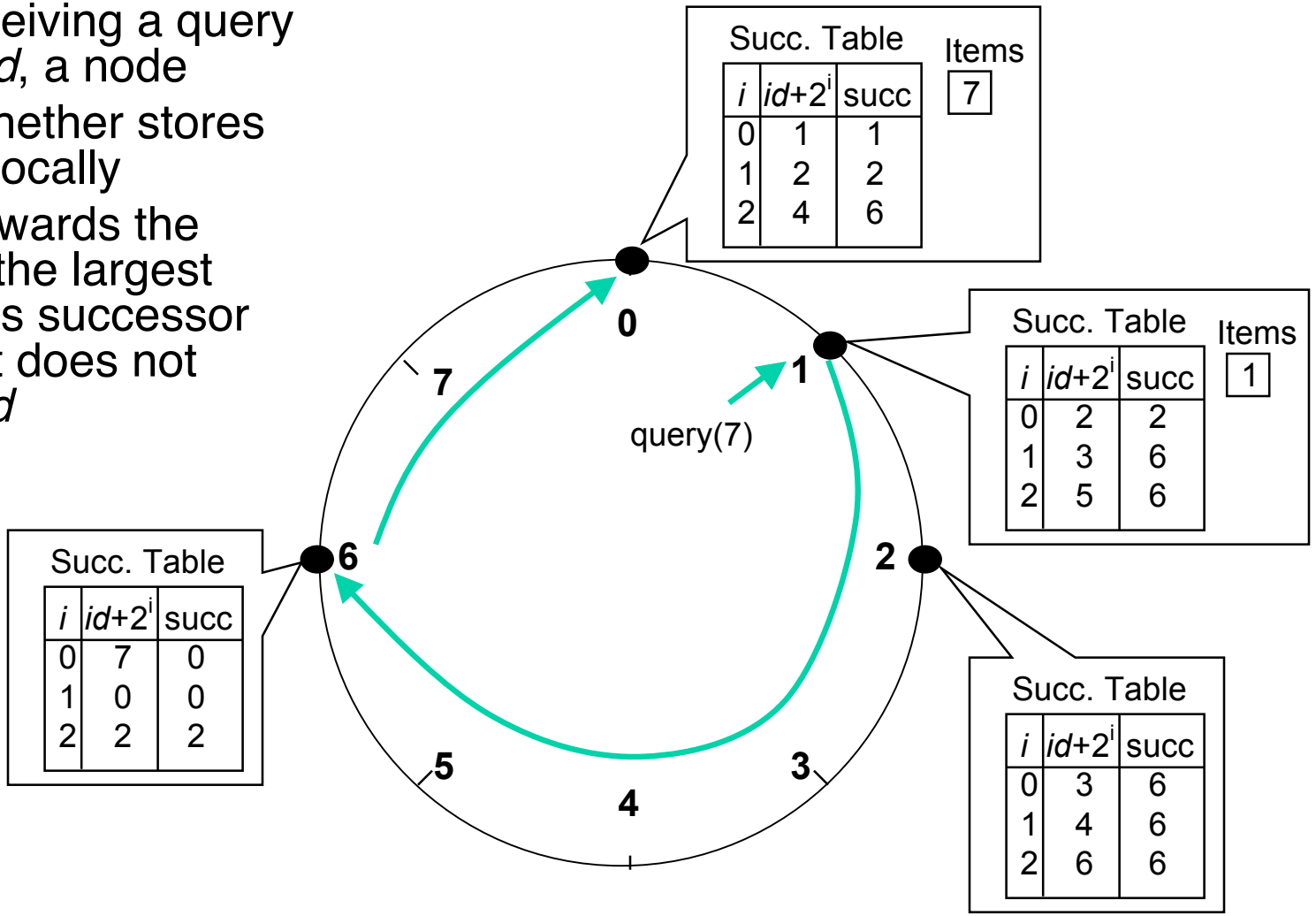
Chord Examples

- Nodes: n1:(1), n2(3), n3(0), n4(6)
- Items: f1:(7), f2:(2)



Query

- Upon receiving a query for item *id*, a node
- Check whether stores the item locally
- If not, forwards the query to the largest node in its successor table that does not exceed *id*



Node Joining

- Node n joins the system:
  - n picks a random identifier, id
  - n performs n' = lookup(id)
  - n->successor = n'

State Maintenance: Stabilization Protocol

- Periodically node n
  - Asks its successor, n', about its predecessor n''
  - If n'' is between n' and n''
    - n->successor = n''
    - **notify** n'' that n its predecessor
- When node n'' receives notification message from n
  - If n is between n''->predecessor and n'', then
    - n''->predecessor = n
- Improve robustness
  - Each node maintain a successor **list** (usually of size 2*log N)

Freenet Outline

- Introduction
- Freenet Basics
- Architecture
- File Storage
- Keys
- Requests
- Responses
- Adding a new peer
- Inserting Files
- Additional Readings

Introduction

- What is Freenet?
  - P2P system
  - Giant virtual hard drive
  - Provides a service for storing and retrieving files anonymously over the internet
- Goal of Freenet
  - Anonymity
    - For both file provider and requester
    - Number one design goal of Freenet
    - An absolute must for freedom of speech
      - Difficult to censor material if you do not know who is uploading it, who is requesting it, and where it is stored

Freenet

- Each user provides to the network
  - Bandwidth
    - For transmitting files
    - Routing requests for files
  - Hard drive space for storing files
    - Called a “data store” in Freenet
  - All Peers are equal
    - No nodes function as supernodes
- Uses for Freenet
  - Publishing web sites (Freesites)
    - E.g. “Banned” books
  - Message boards
  - Games
  - File sharing

File Storage

- Unlike other file sharing applications:
  - The user of a node has no control over or knowledge of what files their node stores
  - No user knows the identity of a node that provides a file they have requested or knows the identity of a node that has requested a file from them
    - Routing requests and responses through multiple nodes helps
    - Address of previous node is removed after each hop of a response
  - All files in each nodes data store are encrypted
    - No user of a node knows the contents of the files they are storing
    - This is done to protect the owner of each node from responsibility for the type of content stored in their data store

File Storage (2)

- Files remain in the system based on demand
  - Popular files will spread to many nodes
    - Each requested file located, will be copied to every node it passes through on the path from the source node to the requestor node
  - Rarely accessed files will slowly be removed from the network as room is required for new files
    - As a node runs out of space, files will be deleted in order of least recently requested to make room
    - Rarely requested files will ONLY be removed if space becomes limited

Keys

- In Freenet all files are requested based on a key assigned to the file when it was inserted into the network
  - Three types of keys:
    - SSK – signed subspace key
    - KSK – keyword signed key
    - CHK – content hash key
- Each Freenet key has the following structure
  - “freenet:” is the standard prefix
  - First three chars state key type: SSK, KSK, CHK
  - “@” symbol separates the key type from the rest of the message
  - Then a long set of characters used to identify the file
  - Example:
    - freenet:KSK@papers/p2p/freenet/keys

KSK – Keyword Signed Key

- Most basic type of file key
  - Easiest to use of all the key types
    - Descriptive set of words used to identify the file
- Steps to create the key:
  - 1. User writes a string describing the file
    - i.e., papers/p2p/freenet/keys.doc
  - 2. Specify that the key is of type KSK
  - 3. Add the prefix “freenet:”
  - 4. Specify the location of the file to insert
    - I.e., freenet:KSK@papers/freenet/keys.doc freenet_keys.doc

KSK – Keyword Signed Key(2)

- Advantages
  - Only the file description needs to be published
  - Easy to pass on to others and remember
- Disadvantages
  - No namespace is used
    - No way to prevent two users from inserting two completely different files with the same description
  - Users can abuse the names of popular files by inserting their file with the same name
    - This is made possible because the file description is published
  - Dictionary attacks

SSK – Signed Subspace Key

- Problems with KSK:
  - Duplicate file names - no protection
  - KSK@papers/brian/freenet.doc, KSK@papers/brian/p2p.doc
    - No way for others to know if these two files were both uploaded by me!
- SSK - Allows for declaring of namespaces
  - Randomly generated public/private key pair
  - Used to identify the users own subspace
  - To get the key for the subspace:
    - 1. Public key is hashed
    - 2. String that describes the file is hashed
    - 3. (1) XOR (2)
    - 4. (3) is hashed
    - 5. (4) is encrypted using the file description

SSK – Signed Subspace Key(2)

- Private Key
  - Only the person who posses the private key can insert files to the namespace in the network
  - Allows others to ensure a file was posted by a certain person
  - Insert example
    - SSK@my_private_key/papers/brian/freenet.doc
- Public Key
  - Allows users to retrieve the file from the network
  - Request example
    - SSK@my_public_key/papers/brian/freenet.doc
  - Guarantees the requester that the file is from my subspace
- Disadvantage - Updating of existing files

CHK – Content Hash Key

- Key
  - Creates a unique key based on hashing the files content
- Steps to create the key
  - 1. Hash the content of the file to generate the key
  - 2. File is encrypted with a randomly generated key
- To allow others to retrieve the file need to give them
  - Content hash key
  - Decryption key
  - i.e., CHK@AN2Iv5VzK9TdWHarflYmv-xtf2ELAwI,ymQiGP7s4ZFR9FiAgV-ZpQ
- Can be used in combination with an SSK subspace
  - Two step file retrieval
    - Use the subspace key to access files under that namespace
    - Use the content hash key to retrieve the file

CHK – Content Hash Key(2)

- Advantages
  - Updating of files
    - Insert an updated version of the file with new content hash key
    - Insert an indirect file (with the old versions name) that stores the location of the new version of the file
    - Key collision will happen when the indirect file reaches a node with the old version of the file
    - Verifies the key, date on file is newer, then replaces it
    - Allows for old files to remain, but will be replaced based on the popularity of the updated version
  - Splitting of files into several pieces
    - Insert each piece with it's own content hash key
    - Then use an indirect file to give the locations of each piece of the file

Clustering of Keys

- When a node successfully receives a file from another node
  - It associates that node in its routing table with the hash key of the file
- All future requests from this node will send the request to the node
  - listed in the routing table associated with the key closest to the key of the file being requested
- When an insert is performed
  - The file is passed to the node associated with the closest key

Why Group Files by Hash Key?

- The reason for this design is to spread files on related topics (i.e., P2P) all over the network
  - This prevents one topic from being dependent on a small group of nodes
  - If one node is removed from the network, should not cause most files on one topic, such as P2P, from no longer being accessible

Junk Files

- Keyword signed keys are not very secure
- What if someone wanted to get rid of some file by inserting junk files into the network to take the originals place?
  - Would have the opposite effect
  - Each time a key collision occurs it will see that the new version (junk file) being inserted has the same key as a file that already exists
    - So the junk file will be overwritten by the correct original version
    - Original file is propagated back to the node that inserted the file with the same key, placing a copy on each node the response passes through
- Inserting junk files can result in increasing the numbers of the file that the user is trying to destroy!

Inserting Files

- Insert a new file into Freenet
  - 1. Send an insert message
    - Key (ksk, ssk, chk)
    - # hops
  - 2. Check for file collisions
    - If the local nodes data store has a file with the same key
      - That file is returned as a response, insert is aborted
    - Inserted file is then sent to the node which is associated with similar keys based on the local nodes routing table
      - If a collision on any other node, file is returned, insert is aborted
  - 3. If no key collisions
    - Then # nodes will have copies of the file

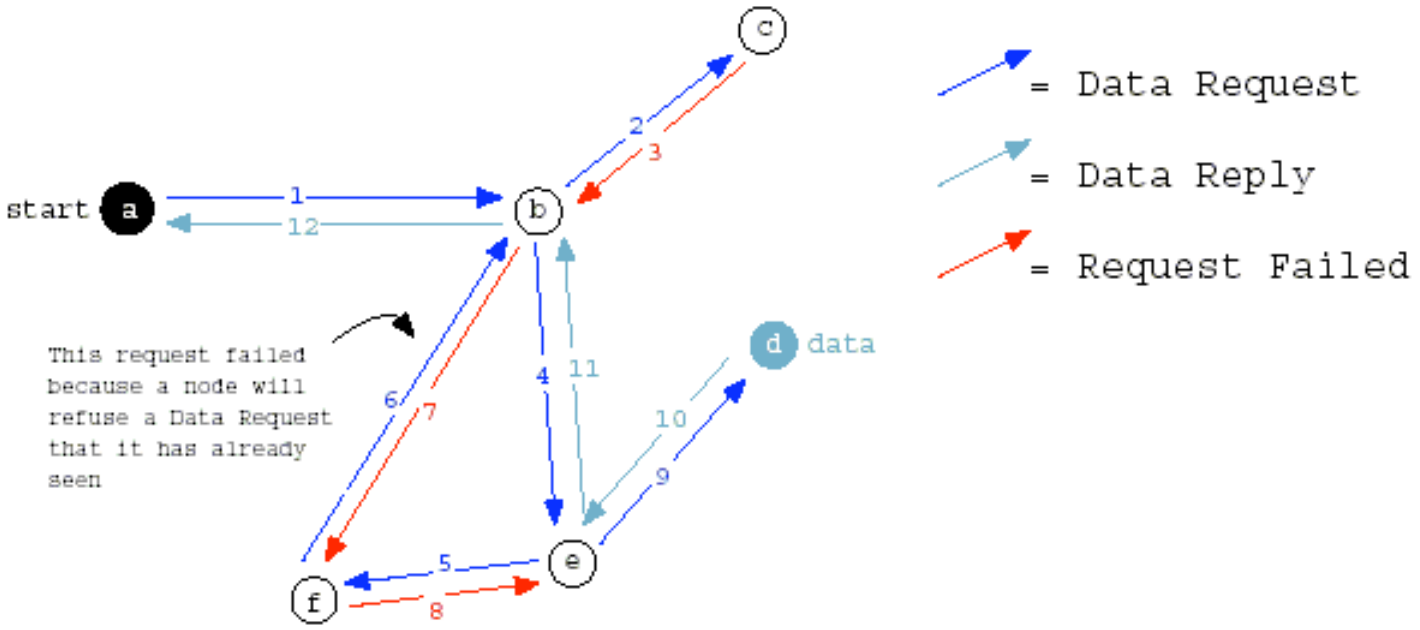
Requesting Files

- Availability of files improves over time
- Each time a requestor successfully receives a file from another node
  - 1. It adds that node to it's routing table
  - 2. Associates the file key with that node in the routing table
  - 3. All future searches for files with similar keys will be sent to nodes associated with these keys
- Overtime each node should have a better idea who to route a request to based on it's routing table

Requesting Files (2)

- Eventually a node that other nodes associate with a specific key type based on successful requests will:
  - Store more files with similar keys
  - Reasons:
    - Other nodes send requests for files that have similar keys to that node
    - If it does not have the file it forwards the request to another node based on it's routing table
    - When the file is located, the response gets passed back
    - Each node on the responses path gets a copy of the file stored
    - This includes the node the request was initially sent to
    - Over time this node will start to store more and more files with this key type

Standard Request Sequence



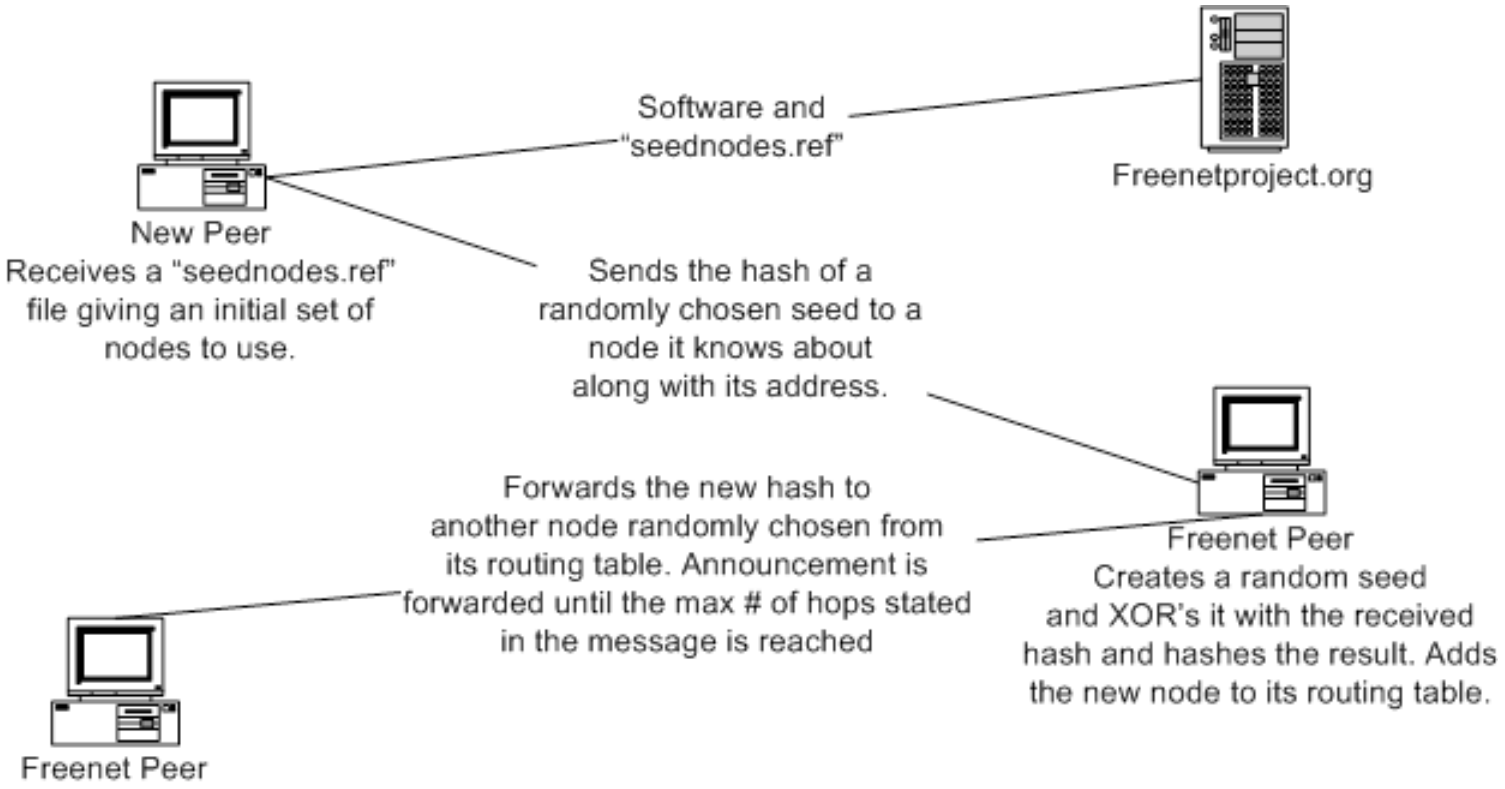
Source: "Freenet: A Distributed Anonymous Information Storage and Retrieval System"
http://www.doc.ic.ac.uk/~twh1/academic/papers/icsi-revised.pdf (Page 7)

Response

- No user knows the identity of the node that provides a file they have requested
  - Routing responses through multiple nodes helps to do this
  - Address of previous node is removed after each hop a response message takes
- Each node on the response path gets a copy of the file
  - Helps to increase the number of copies that exist in the network of popular files
  - Makes network less reliant on a single node being connected to make that file available

Announcing Presence

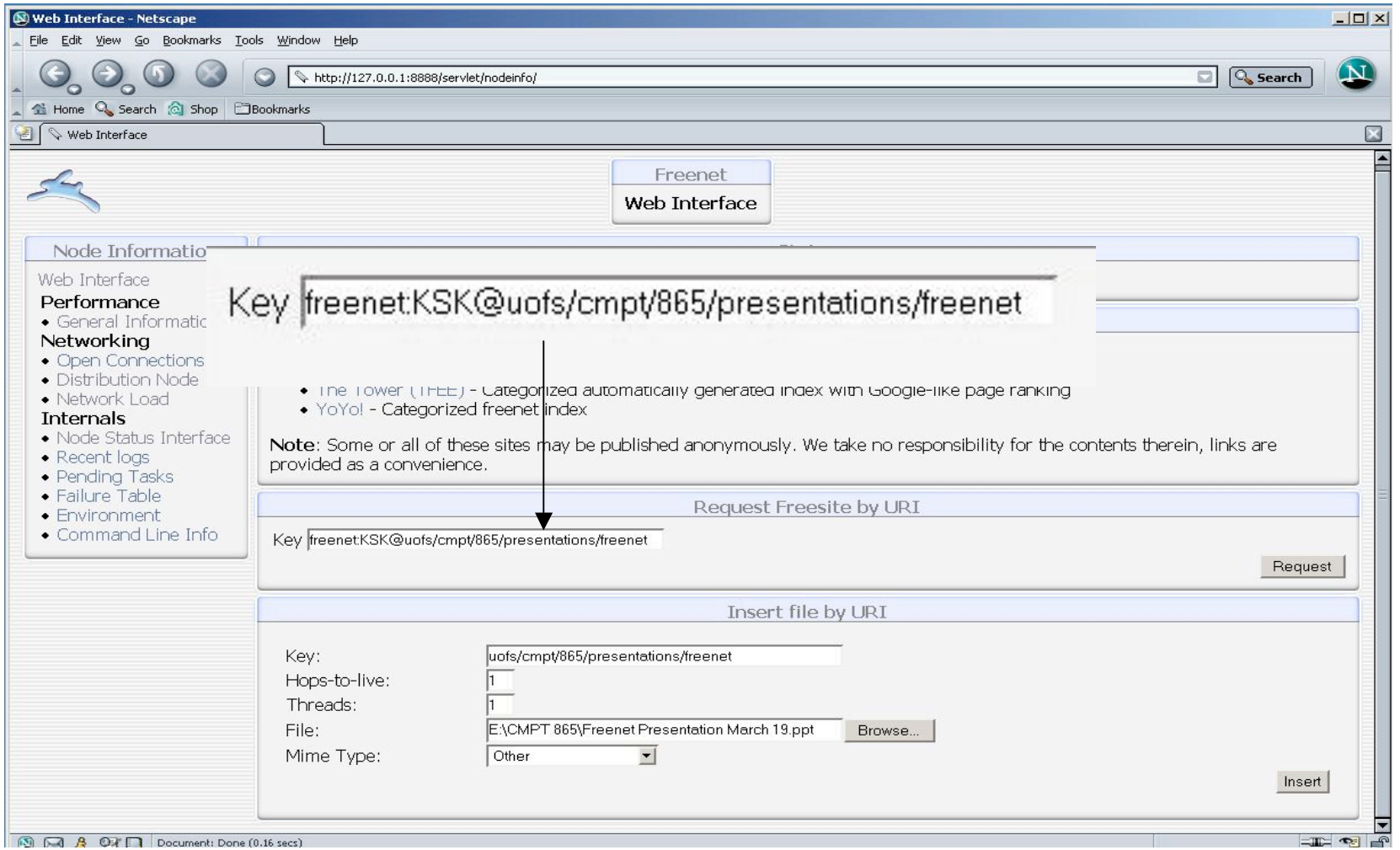
- A new node must announce that it is a part of the network and let other nodes know it is available



Searching

- You cannot search Freenet in the same manner as other file sharing software
  - Must know the key of a file
    - If file is stored in the network strictly for your own retrieval later on, then you can save the key
    - To allow others to retrieve this file must provide them with the key

Retrieve File Request



Freesites

- Freenet allows users to host web sites
- A subspace key (SSK)
  - Used for access to the web site files
  - SSK@_my_website_private/school
- MapSpace Keys (MSK)
  - Provides accessing of a Freesite based on date
  - Allows users to access older versions of site
    - If they still exist somewhere on the network
- How to create Freenet hosted web sites
  - http://www.firenze.linux.it/~marcoc/index.php?page=content

Protection of Users and Files

- Users
  - Each user does not know the content of the files they store:
    - All files are stored encrypted
    - Protects users from being prosecuted for the content stored in their data store
- Files
  - Since no user knows the location of every copy of a file and each copy is encrypted:
    - They cannot censor the content by removing a specific file from the network or shutting down one node
  - Since each user can create a subspace that only they have access to and signs each file with a private key:
    - No other user can try to spam the network with fake copies of a file claiming to be from another user

Freenet Summary

- Anonymity is the number one design goal
  - To protect both file providers and requesters
- Freedom of speech protection
  - Prevents censorship by:
    - Encrypting of all content
    - Hiding the locations of nodes that files are being provided from
    - Hiding the identity of file requestors from file providers
    - Allows all users to anonymously insert new files into the network preventing anyone from locating the original source of the file
- Grouping of files based on hash key
  - Prevents network from being dependent on any one node for files all related to one topic
- Increasing copies of files
  - Files that are popular rapidly increase in numbers
    - Responses copy the file to every node the response passes through

Is Freenet Perfect?

- How long will it take to search or insert?
  - Trade off between anonymity and searching efforts: Chord vs Freenet
  - Can we come up a better algorithm? A good try: “Search in Power-Law Networks”
- Have no idea about if search fails due to no such document or just didn’t find it.
- File lifetime. Freenet doesn’t guarantee a document you submit today will exist tomorrow!!