CS348: Computer Networks

P2P Applications

Dr. Manas Khatua

Assistant Professor

Dept. of CSE, IIT Guwahati

E-mail: manaskhatua@iitg.ac.in

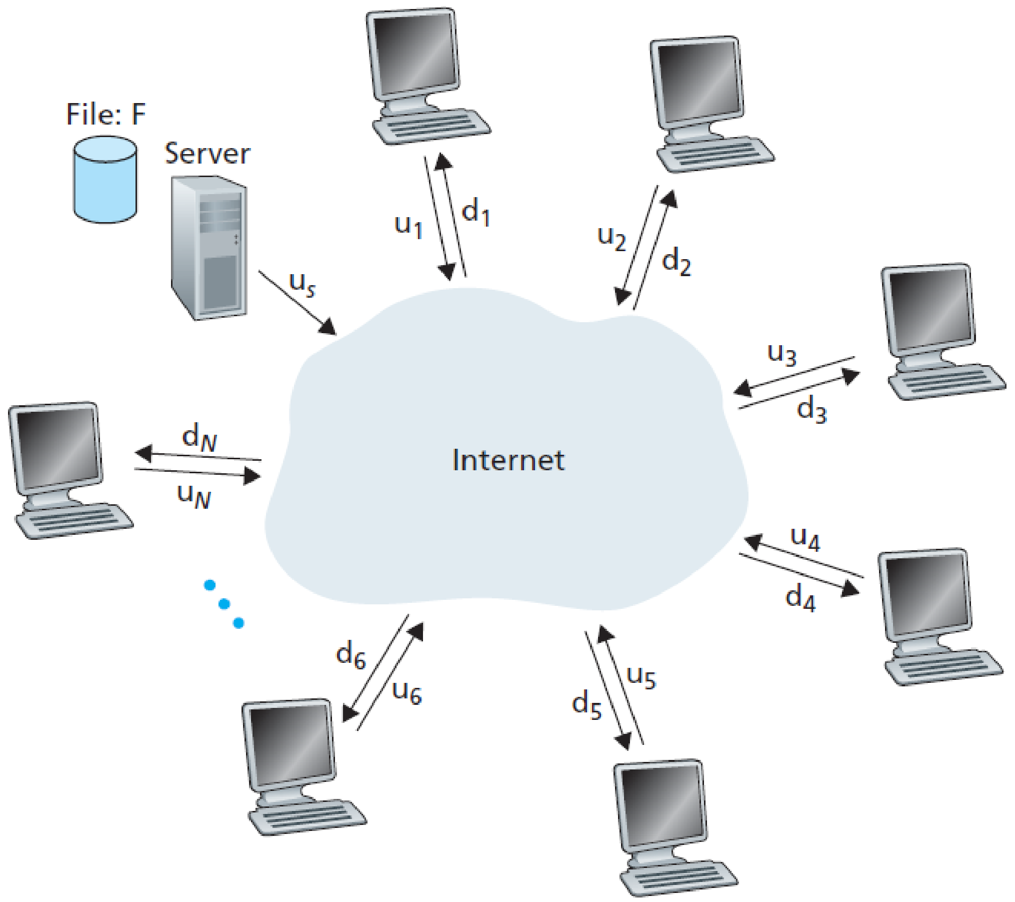
Peer-to-Peer Applications

- Web, E-mail, FTP, DNS - all employ client-server architectures
- With a P2P architecture, there is minimal (or no) reliance on always-on infrastructure servers.
- In P2P, pairs of intermittently connected hosts communicate directly with each other.
- Few applications well-suited for P2P
  - **File Distribution**: the application distributes a file from a single source to a large number of
    - BitTorrent system
  - **Distributed database**: a database distributed over a large community of peers
    - Distributed Hash Table (DHT).

File Distribution

- Let the task is of
  - distributing a large file from a single server to a large number of hosts
- The file might be
  - a new version of OS
  - a software patch
  - an MP3 music file
  - an MPEG video file
- In **client-server file distribution**, the server must send a copy of the file to each of the peers.
  - places enormous burden on the server
  - consuming a large amount of server bandwidth
- In **pear-to-pear file distribution**, each peer can redistribute any portion of the file it has received to any other peers.
  - assisting the server in the distribution process

Scalability of P2P Architectures



- upload rate of the *i*-th peer's access link is u_i
- upload rate of the server's access link is u_s

- download rate of the *i*-th peer's access link by d_i.

- the size of the file to be distributed (in bits) is F
- the number of peers that want to obtain a copy of the file is N.

- The **distribution time** is the time it takes to get a copy of the file to all N peers
- Let the Internet core has enough bandwidth

Cont…

In client-server architecture:

- Case1: server must transmit one copy of the file to each of the *N* peers. the time to distribute the file must be at least NF/u_s.

- Case2: Let $d_{\min} = \min\{d_1, d_p, \ldots, d_N\}$.
- The peer with the lowest download rate cannot obtain all *F* bits of the file in less than $F/d_{\min}$ seconds.

- So, the distribution time for the client-server architecture is

$$D_{cs} \geq \max\left\{\frac{NF}{u_s}, \frac{F}{d_{min}}\right\}$$

- for *N* large enough, the client-server distribution time is given by NF/u_s
- Thus, distribution time increases linearly with the number of peers *N*

Cont…

In P2P architecture:

- In P2P, when a peer receives some file data, it can use its own upload capacity to redistribute the data to other peers.

Calculating the distribution time for the P2P architecture is somewhat more complicated.
A simple expression for the minimal distribution time:

- Case1: At the beginning, only the server has the file.
- To get this file into the community of peers, minimum distribution time is at least F/u_s.

- Case2: the peer with the lowest download rate cannot obtain all F bits of the file in less than F/d_{min} seconds.

- Case3: the total upload capacity of the system is, $u_{\text{total}} = u_s + u_1 + \ldots + u_N$.
- The system must deliver (upload) F bits to each of the N peers.
- This cannot be done at a rate faster than u_{total}.
- So, the minimum distribution time is also at least $NF/(u_s + u_1 + \ldots + u_N)$.

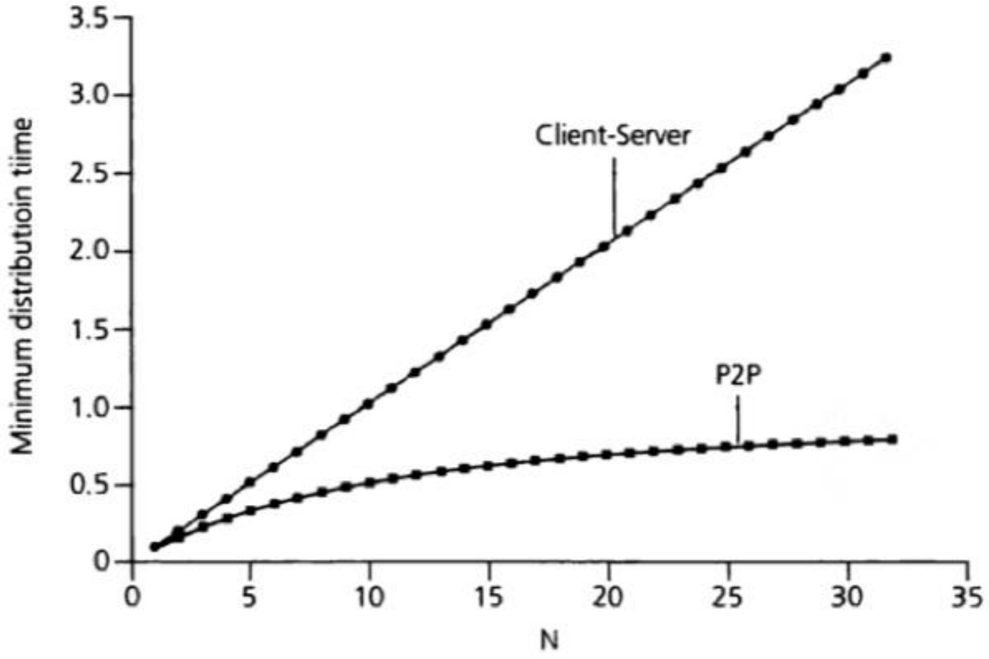
- Finally, the minimum distribution time for P2P

$$D_{\text{P2P}} \geq \max\left\{\frac{F}{u_s}, \frac{F}{d_{min}}, \frac{NF}{u_s + \sum_{i=1}^{N} u_i}\right\}$$

Cont…

- if we imagine that each peer can redistribute a bit as soon as it receives the bit, then there is a redistribution scheme that actually achieves this lower bound
- In reality, where chunks of the file are redistributed rather than individual bits, the above estimation serves as good approximation of distribution time.

Comparison of the minimum distribution time for the client-server and P2P



BitTorrent

- BitTorrent is a popular P2P protocol for file distribution
- the collection of all peers participating in the distribution of a particular file is called a *torrent.*
- Peers in a torrent download *equal-size chunks* of the file from one another (typical chunk size = 256 KBytes).
- When a peer first joins a torrent, it has no chunks. Over time it accumulates more and more chunks.
- Any peer may join/leave the torrent at any time.
- P2P live streaming applications, such as PPLive and ppstream, have been inspired by BitTorrent

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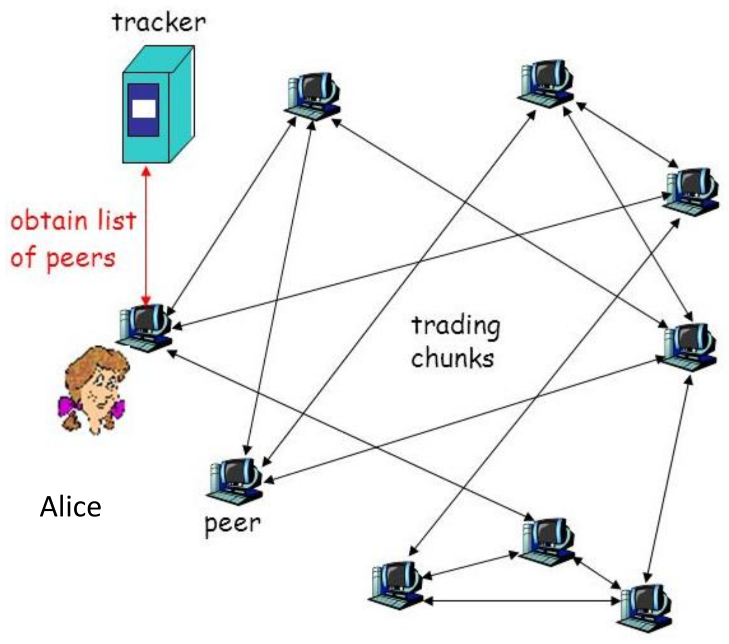

- Each torrent has an infrastructure node called a *tracker*
  - Each pear registers itself with the tracker
  - Each pear periodically informs the tracker that it is alive
- So, tracker keeps track of all the registered peers
- After registering with torrent, Alice gets a list of peers (subset of full torrent) from the tracker
- Alice try to establish concurrent TCP connections with all peers of the list
- Connected pears are called neigboring peers (see the figure – Alice has 3 neighbours at present)
- A peer's neighboring peers will fluctuate over time.
- Alice will ask each of her neighboring peers for the list of chunks they have
- Alice will obtain *L* lists of chunks from *L* neighbors

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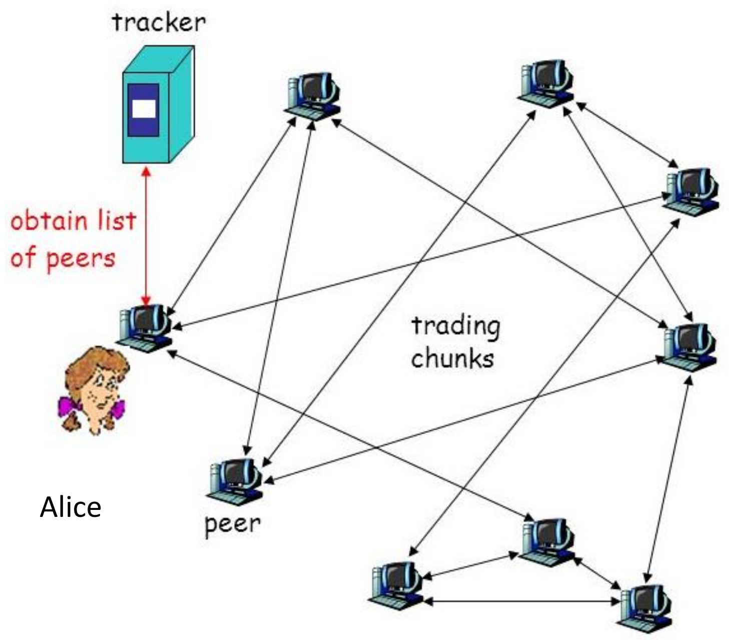


- Alice will issue requests for a chunk she doesn't have.
- Alice uses **rarest first** technique for deciding the chunk she needs first

- Similarly, Alice also gets requests from other pears
- To determine which requests she responds to
  - a clever trading algorithm is used
  - gives priority to the neighbors that are currently supplying her data at the highest rate.

- Alice continually measures the rate and determines the four peers feeding her at highest rate.
- these four peers are said to be **unchoked**

Randomly choose a new trading partner:

- Periodically she also picks one additional neighbour at random and sends it chunks.
- This peer is said to be **optimistically unchoked**
- **Objectives:** over the time this peer could include Alice in its unchoked list and then will send file with high rate to Alice

- All other neighboring peers besides these five peers (four “top” peers and one probing peer) are “choked,” that is, they do not receive any chunks from Alice.

Distributed Hash Tables (DHTs)

- Goal: implement a database in a P2P network
- Hash Table: data structure that maps "keys" to "values"

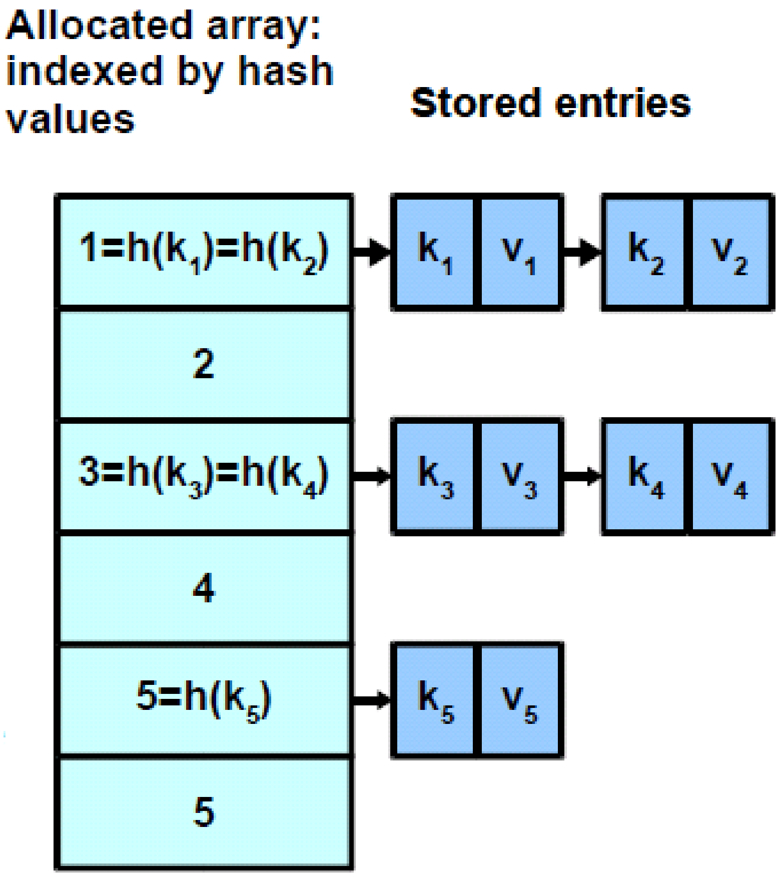
- Single-node hash table:
  - key = Hash(name)
  - put(key, value)
  - get(key) -> value

- How do I do this across millions of hosts on the Internet?

Ans: **Distributed Hash Table**

- Interface
  - insert(key, value)
  - lookup(key)

Example: A Hash Table



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- In the P2P system, each peer/node will
  - only hold a small subset of the totality of the (key, value) pairs.
  - route messages to node holding the key

- Any peer is allowed
  - to insert new key-value pairs into the database
  - to query the distributed database with a given key.

- The distributed database application will
  - locate the peers that have the corresponding (key, value) pairs,
  - return the key-value pairs to the querying peer.

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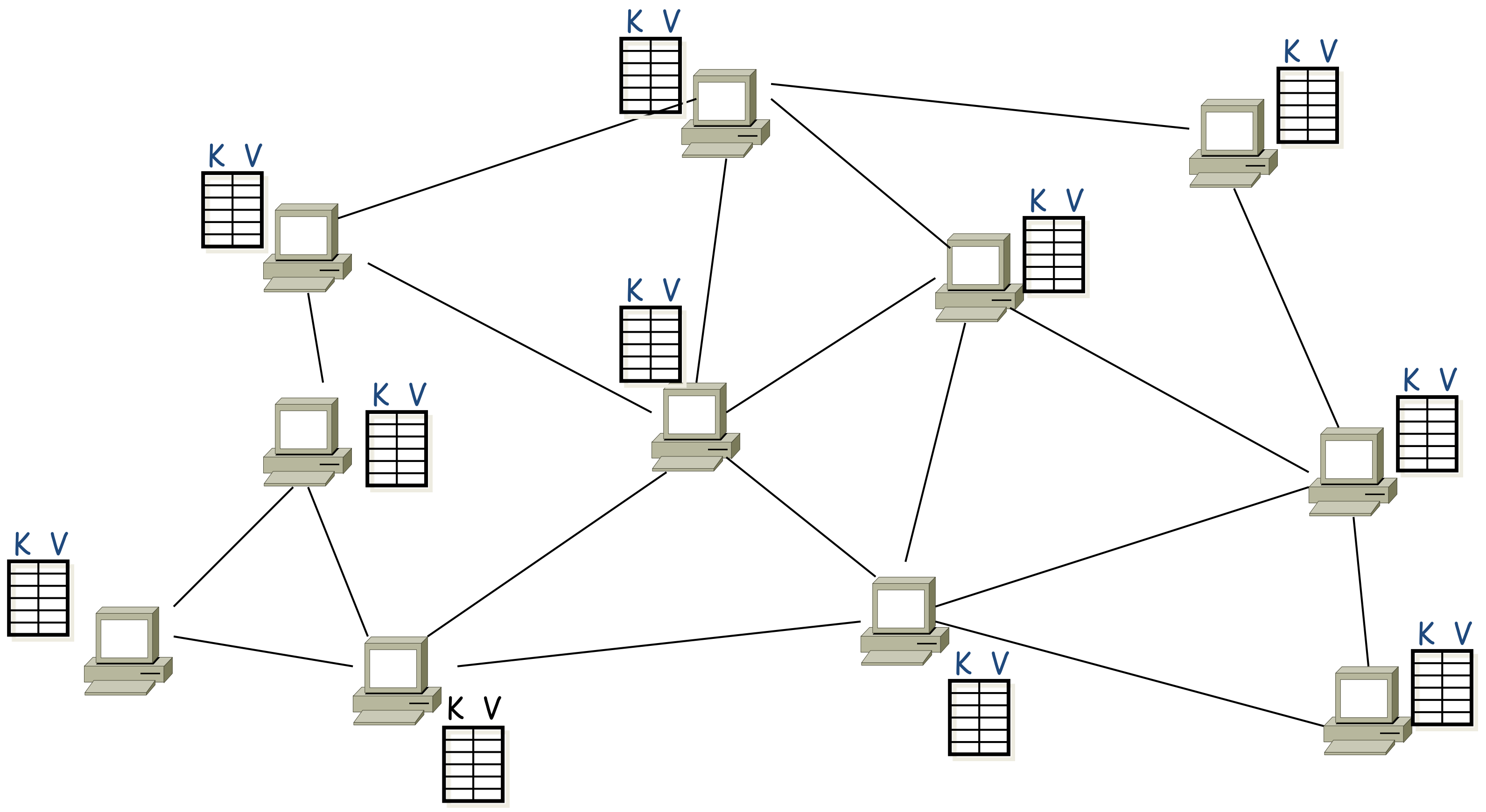
How do DHTs work?



Neighboring nodes are "connected" at the application-level

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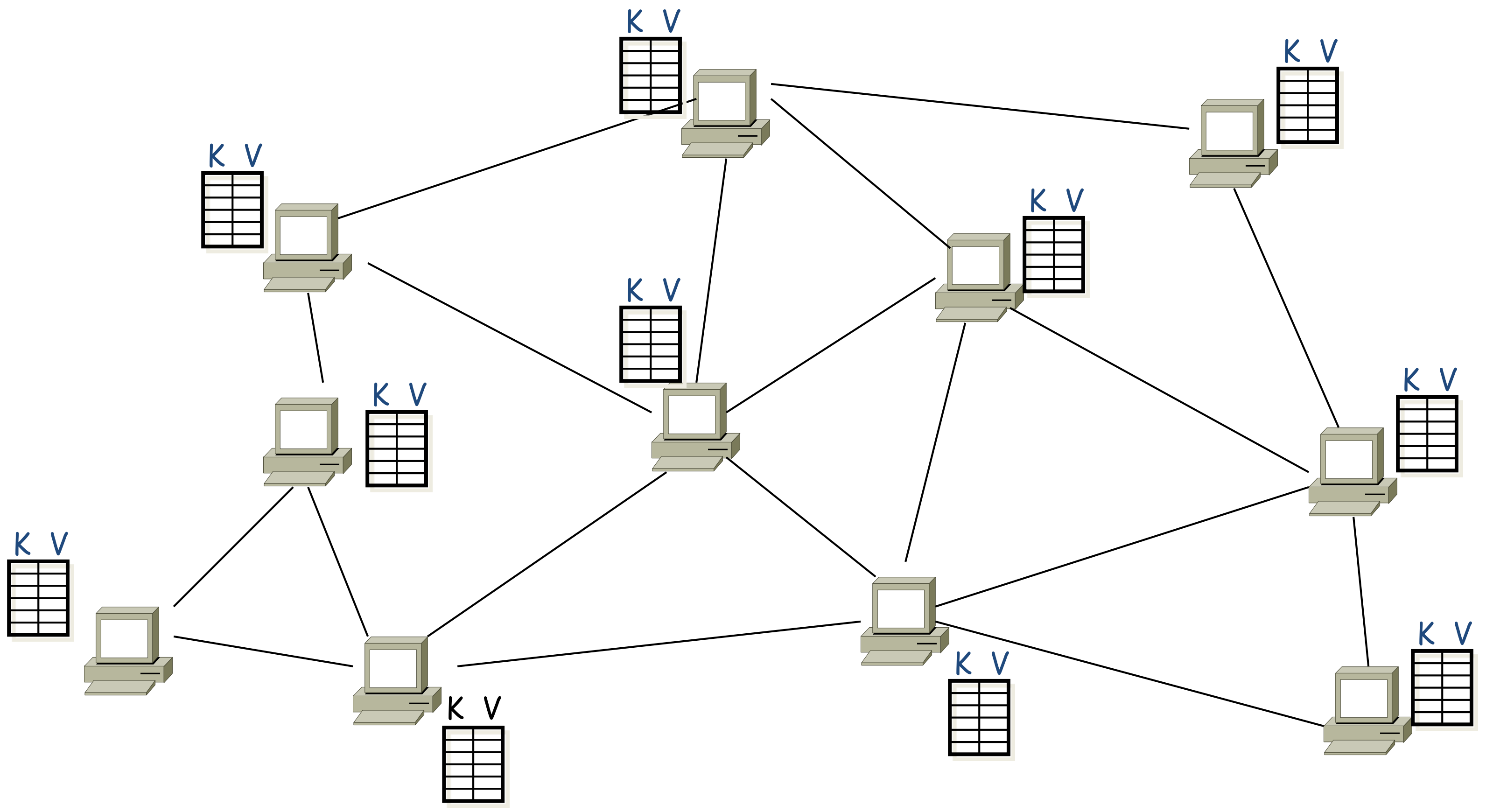

Operation: take *key* as input; route messages to node holding *key*

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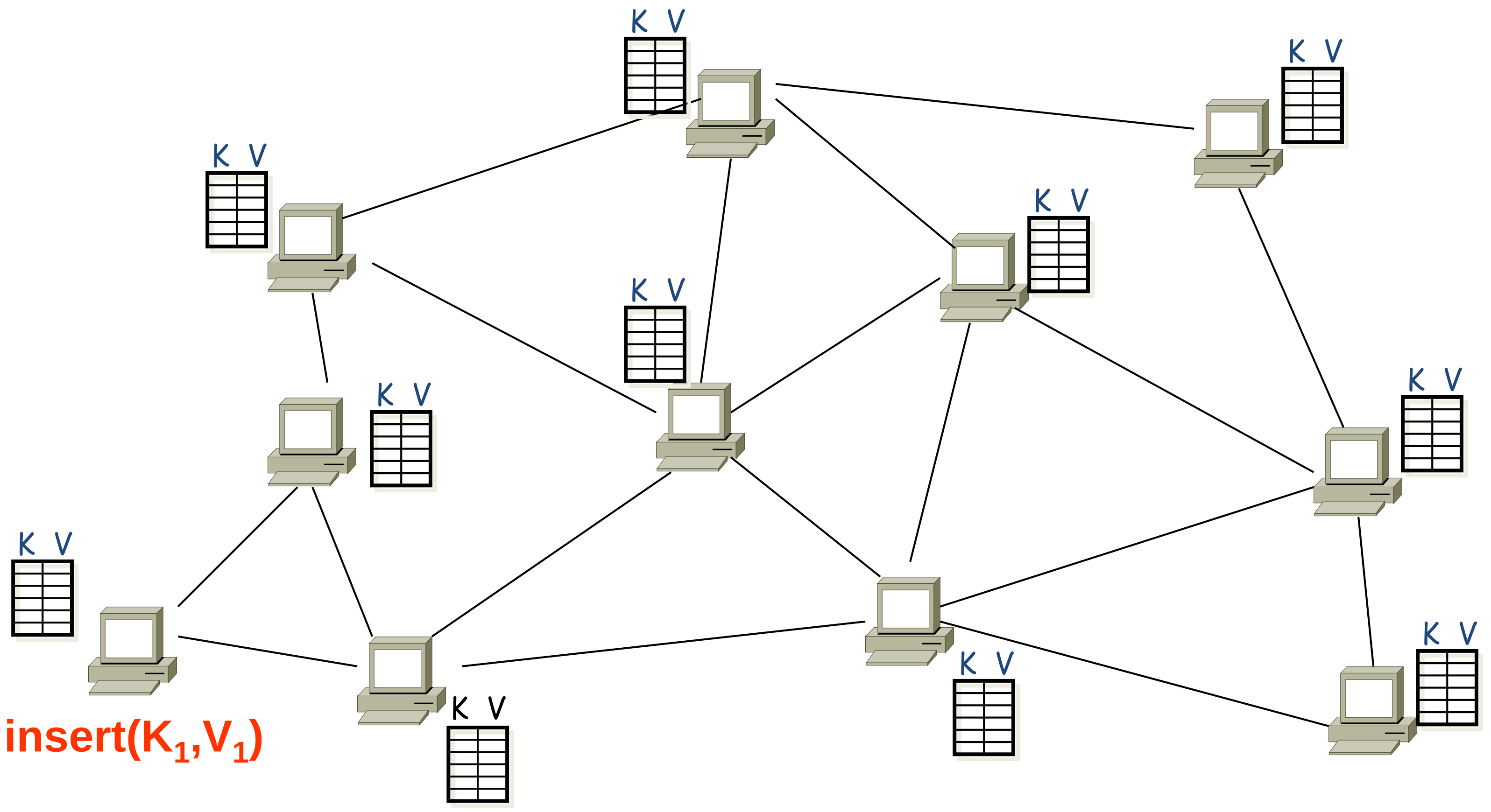

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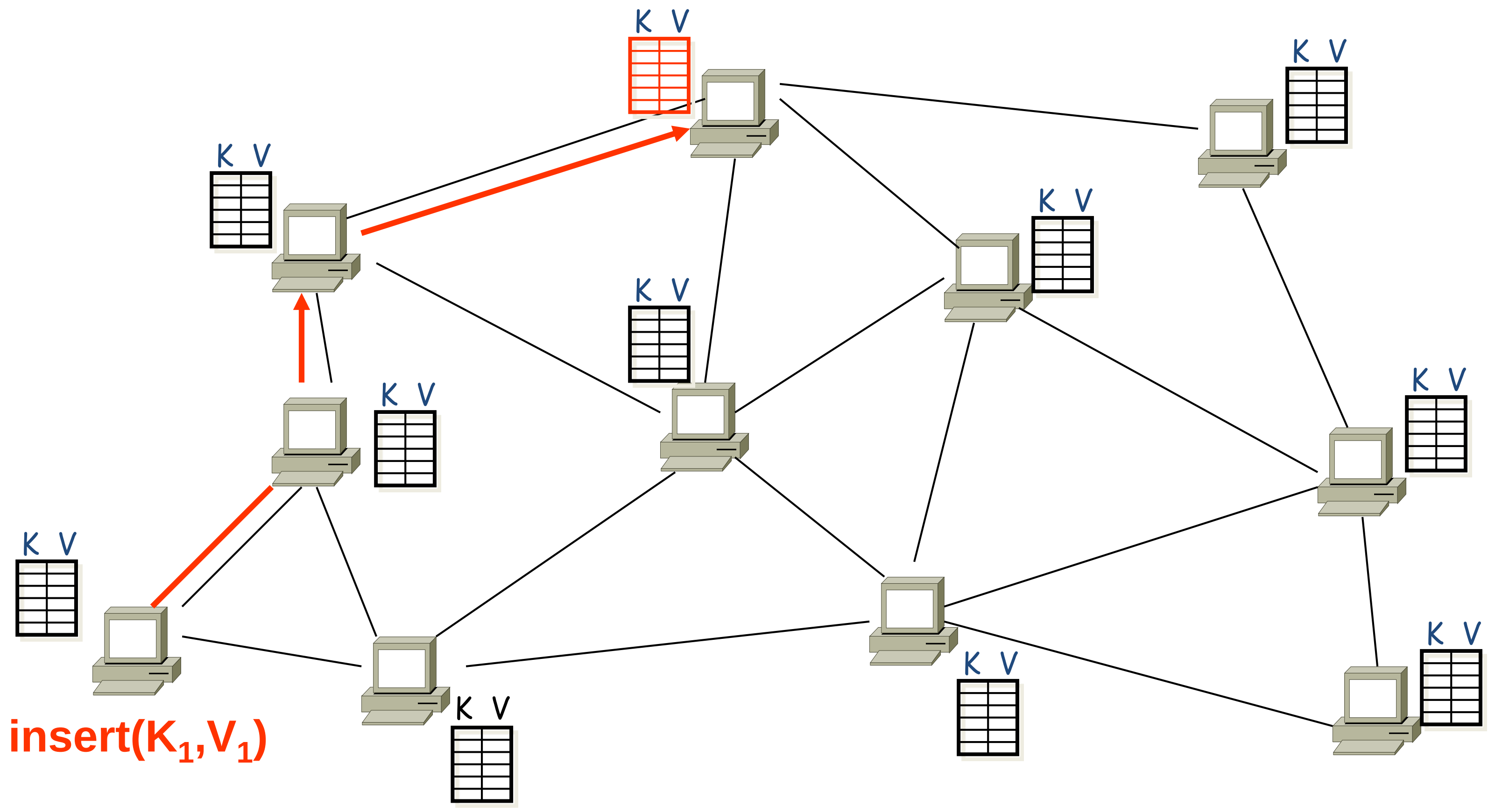

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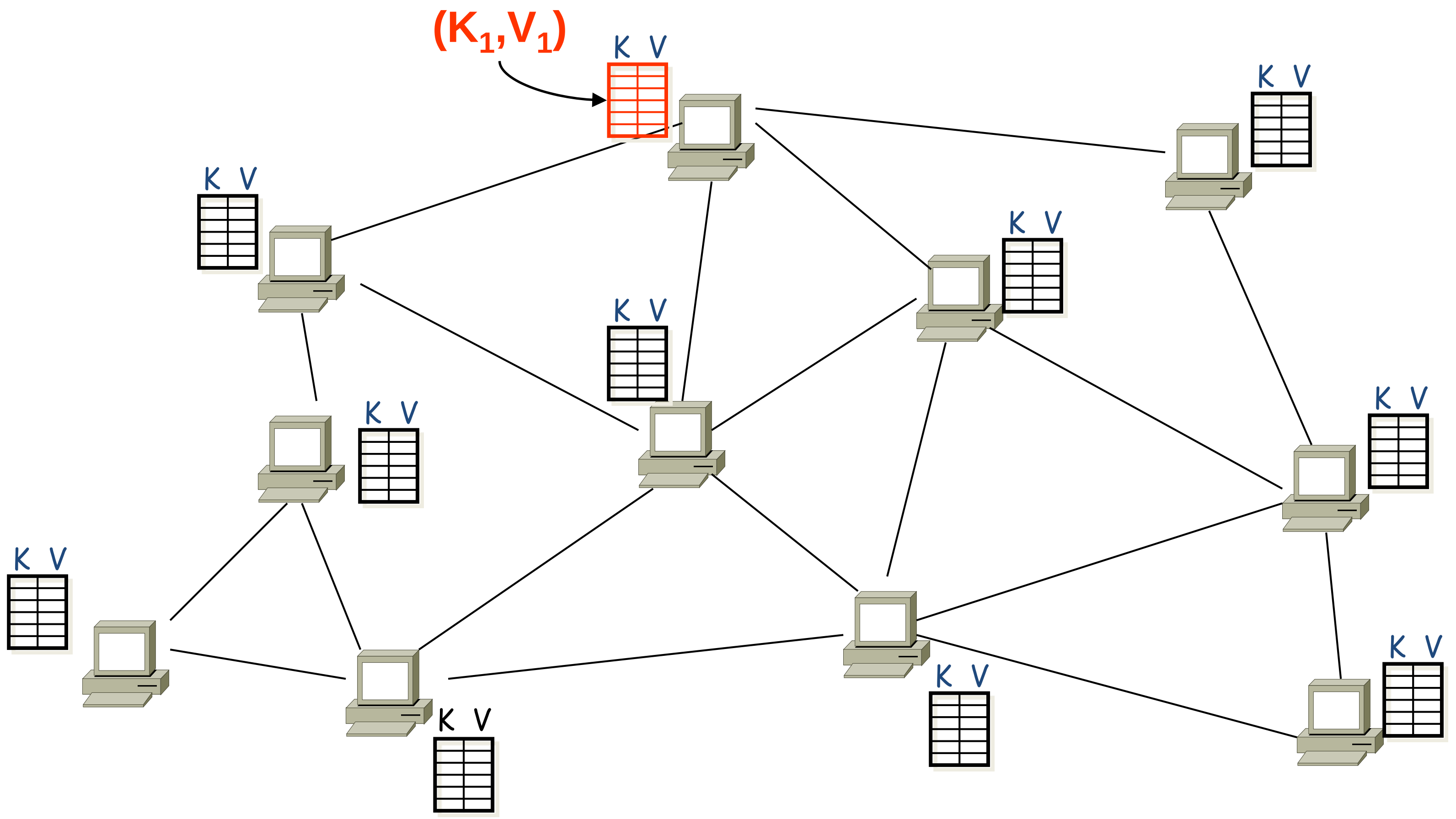

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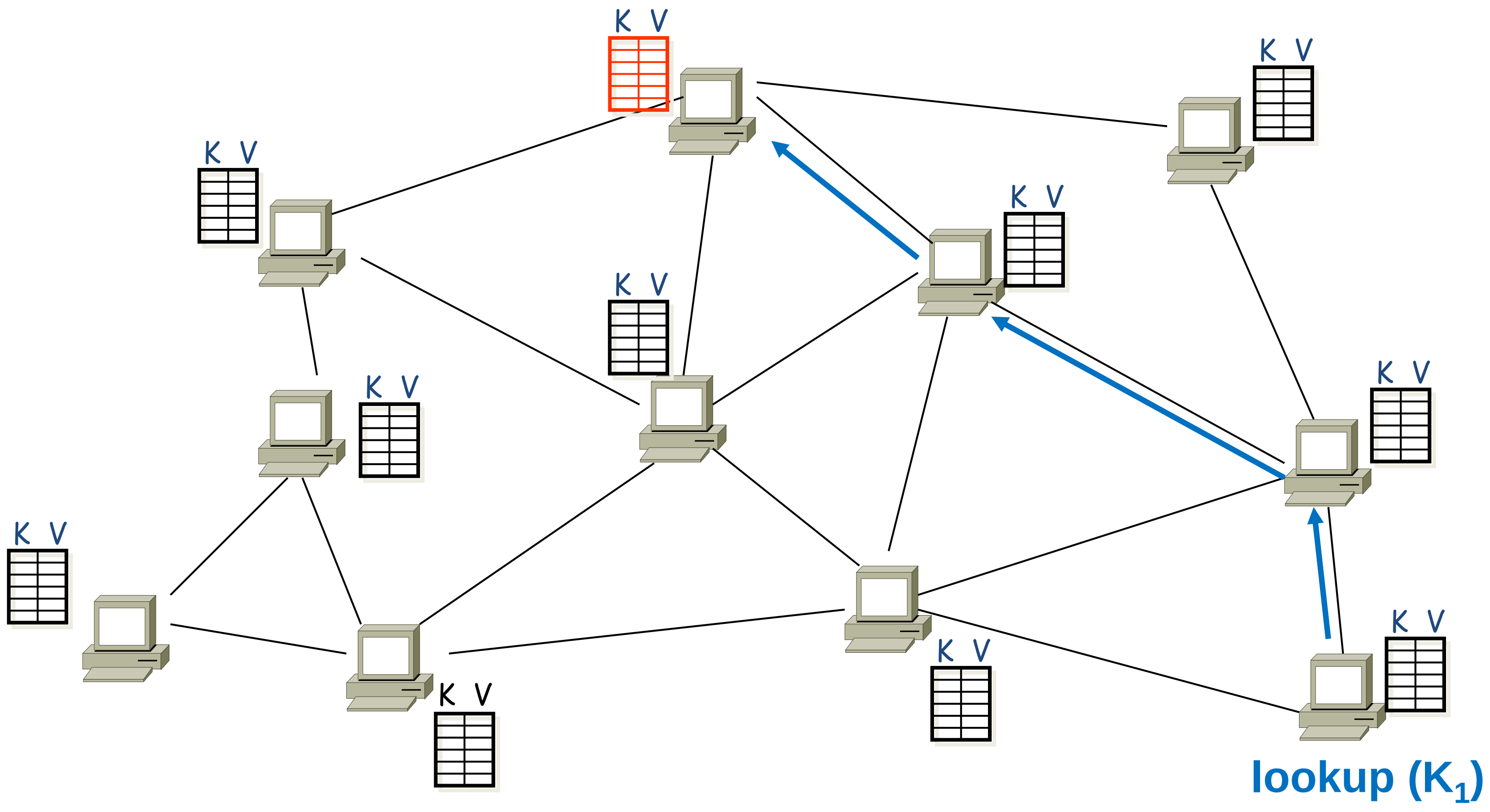
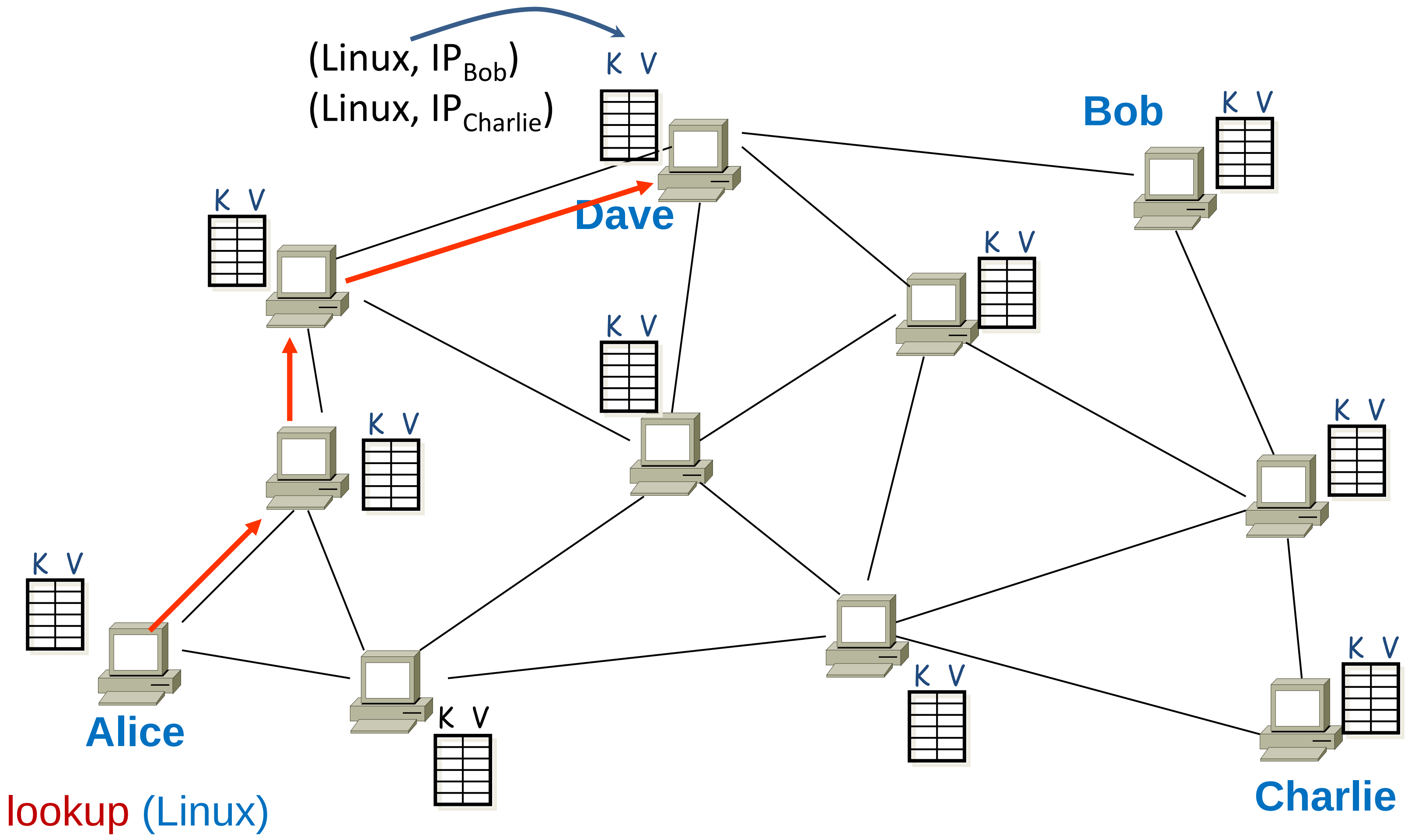


Operation: take *key* as input; route messages to node holding *key*

DHT Service – P2P File Sharing

- "key" is the content name
- "value" is the IP address of a peer that has a copy of the content



DHT Design

- Naïve approach:
  - Randomly scatter the (key,value) pairs across all the peers
  - Each peer maintain a list of the IPs of all participating peers
- Querying peer sends its query to whom?
  - Answer: To all other peers
- Who will respond to the query?
  - Answer: The peers containing the (key,value) pair corresponding to the lookup ‘key’
- Limitations of this design:
  - Unscalable as each peer needs to know about all other peers
  - Traffic overhead as each query is sent to all peers

How to design a DHT?

- State Assignment:
  - what "(*key, value*) tables" does a node store?
  - How do the "keys" are associated with "peers"?

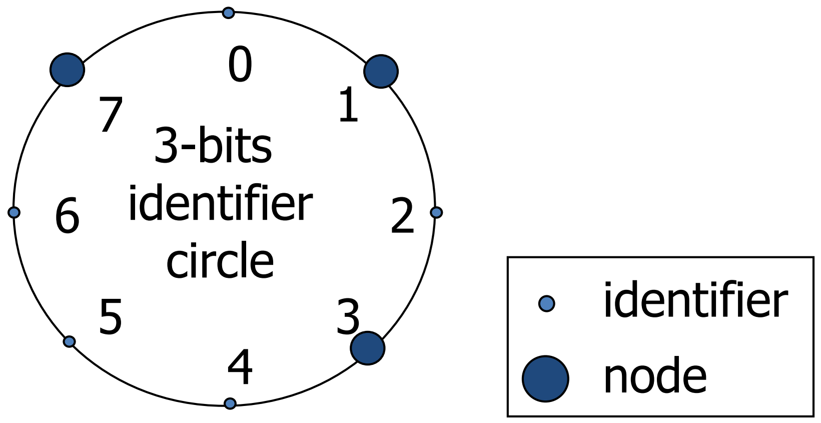
- Network Topology:
  - how does a node select its neighbors?

- Routing Algorithm:
  - which neighbor to pick while routing to a destination?

- Various DHT algorithms make different choices
  - Chord, CAN, Pastry, Tapestry, Plaxton, Viceroy, Kademlia, Skipnet, Symphony, Koorde, Apocrypha, Land, ORDI …

Circular DHT - Chord

- Chord is a protocol and algorithm for a P2P distributed hash table (DHT).
- Chord specifies
  - how keys are assigned to nodes,
  - how a node can discover the value for a given key by locating the node responsible for that key.
- It was introduced in 2001 by Stoica et al. at MIT
- Nodes and keys are assigned an m-bit identifier using consistent hashing.
  - Consistent hashing uniformly distribute both the keys and nodes in the same identifier space with a negligible possibility of collision
- The SHA-1 algorithm is the base hashing function for consistent hashing.
- Using the Chord lookup protocol,
  - nodes and keys are arranged in an identifier circle that has at most 2^m nodes, ranging from 0 to 2^m-1.
  - Some of these nodes will map to machines or keys, while others will be empty.



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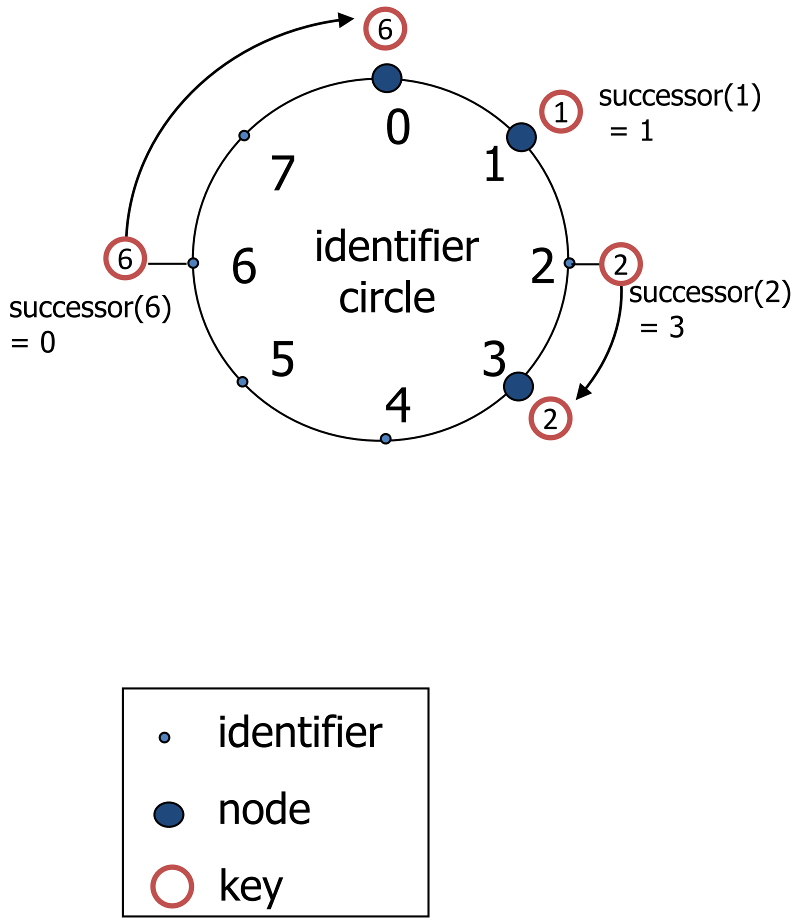

- Each node has a *successor* and a *predecessor*.
- The *successor node* of a key *k* is the first node whose ID equals to *k* or follows *k* in the identifier circle, denoted by *successor*(*k*)
- A key is stored at its successor node
- So looking up a key *k* is to query *successor*(*k*)
- The basic approach is to pass the query to a node's successor, if it cannot find the key locally.
- This will lead to a ***O***(*N*) query time where *N* is the number of machines in the ring.

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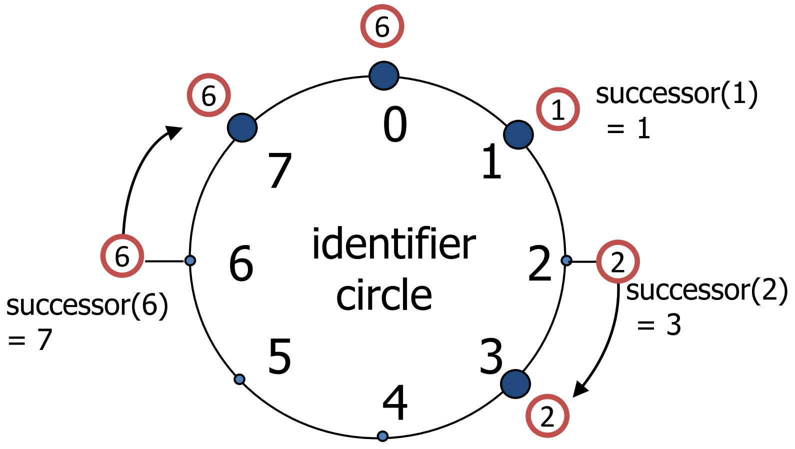
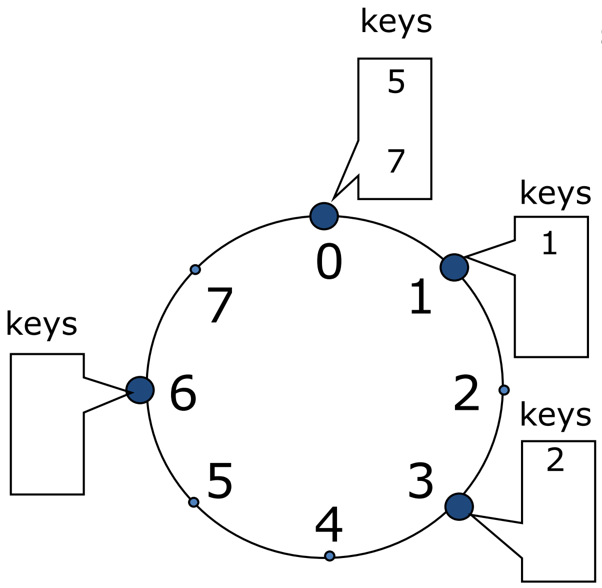
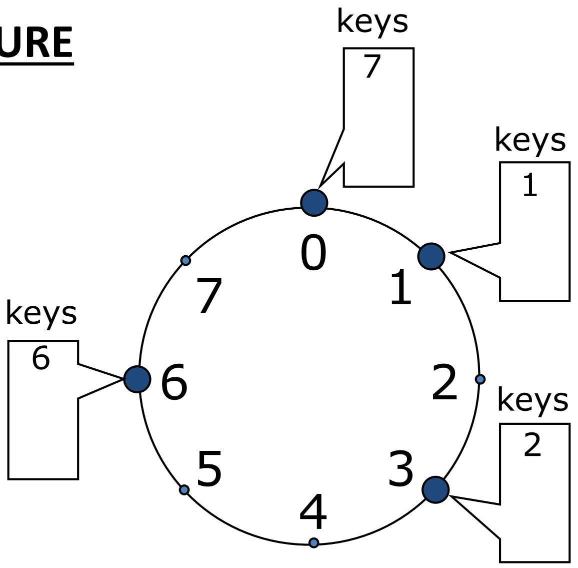


- Node **Joins** and **Departures** in the circle
- When a node *n* joins the network, certain keys previously assigned to *n*'s successor now become assigned to *n*.
- When node *n* leaves the network, all of its assigned keys are reassigned to *n*'s successor.
- Consistence Hashing Function balances load: all nodes receive roughly the same number of keys
- When an *n*-th node joins (or leaves) the network, only an **O**(*1/n*) fraction of the keys are moved to a different location

JOIN



DEPARTURE



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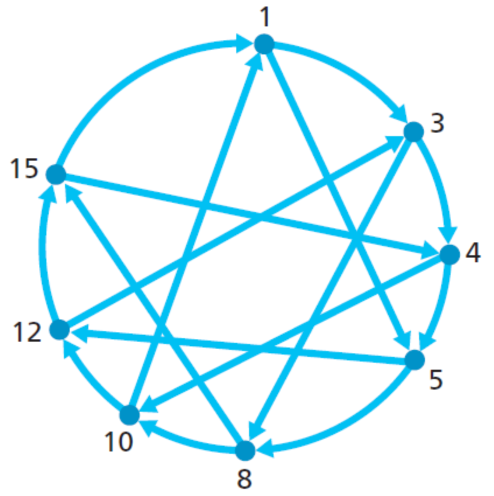
- Although each peer is only aware of two neighboring peers, to find the node responsible for a key (in the worst case), all *N* nodes in the DHT will have to forward a message around the circle; *N*/2 messages are sent on average.

- Thus, in designing a DHT, there is tradeoff between
  - the number of neighbors each peer has to track and
  - the number of messages that the DHT needs to send to resolve a single query.

- we can refine our designs of DHTs
  - use the circular overlay as a foundation,
  - but add "shortcuts" so that each peer not only keeps track of its immediate successor and predecessor, but also of a relatively small number of shortcut peers scattered about the circle.



- Shortcuts are used to expedite the routing of query messages.
- For example, when peer 4 receives the message asking about key 11, it determines that the closet peer to the key (among its neighbors) is its shortcut neighbor 10, and then forwards the message directly to peer 10.

- It has been shown that the DHT can be designed so that both the number of neighbors per peer as well as the number of messages per query is ***O***(*log N*), where *N* is the number of peers.

Thanks!