

程序代写代做 CS编程辅导



ECS855J/ECS796P
Distributed Systems
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What ~~is~~ lecture is about



- Peer to Peer
- Distributed Hash Tables

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Peer to Peer
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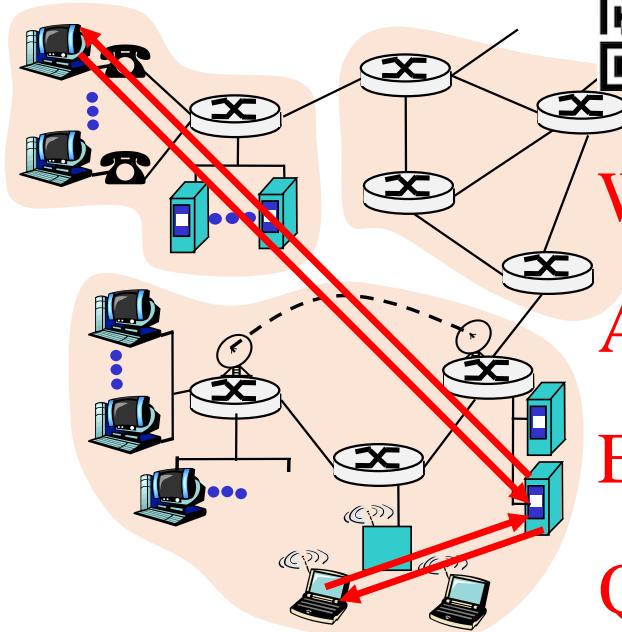
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Thanks to Prof. Marco Chiesa

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Introduction: client-server architecture



server:

Always-on host

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 - Permanent IP address
 - Server farms for scaling
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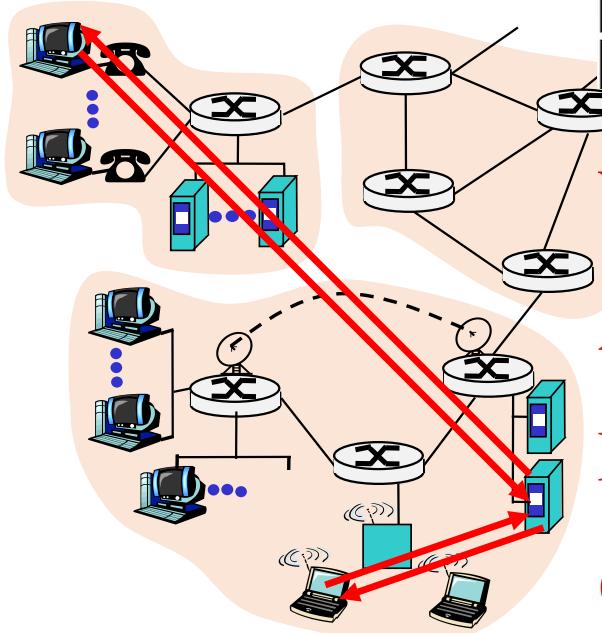
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Introduction: client-server architecture



clients:

May be intermittently connected

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- May have dynamic IP addresses
- Communicate with server

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- Do not communicate directly with each other

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Introduction: peer-to-peer architecture

- No always-on server ("peer")
- Arbitrary end-systems communicate directly
- Peers are intermittently connected and change IP addresses – like clients

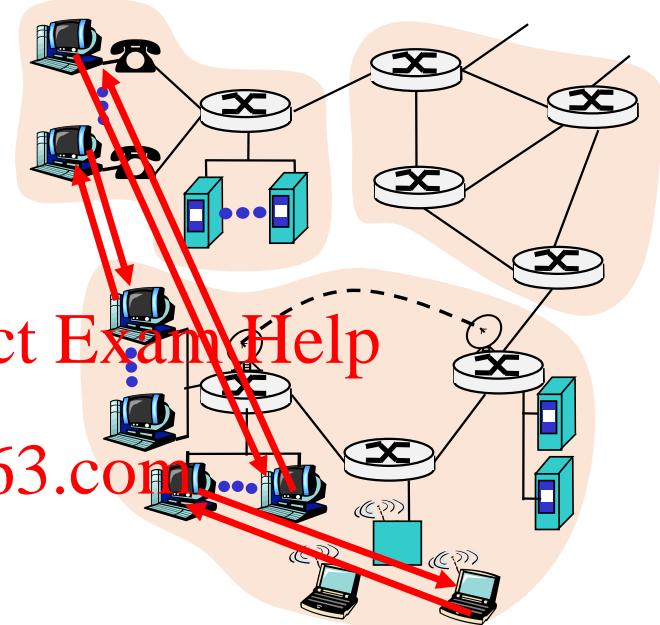
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Introduction: peer-to-peer architecture

- P2P Examples:

- File sharing: Napster, Gnutella, Kazaa, BitTorrent
- Streaming: KanKan, Tribler
- VoIP: Skype



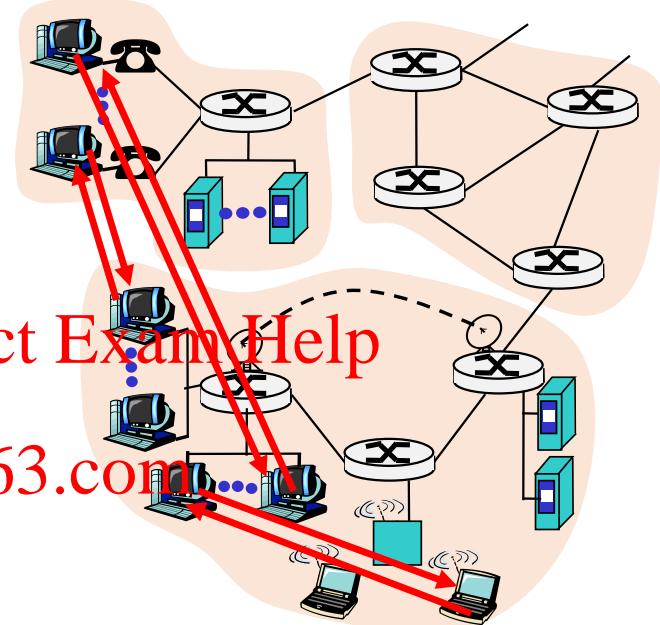
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Why Peer-to-peer?



- Scaling: system scales with number of clients, by definition
- Eliminate centralization:
 - No single point of failure
 - No single point of control
- Self managing

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P2P example



- Alice runs P2P client application on her notebook computer
- Intermittently connects to Internet; gets new IP address for each connection
- Asks for MP3 file “Hey Jude”
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- Application displays other peers that have a copy of “Hey Jude”
- Alice chooses one of the peers, say Bob

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P2P example

- File is copied from Bob's notebook to Alice's notebook, e.g., by HTTP
- While Alice does this, other users download from Alice
 - E.g., some other MP3 file
- Alice's peer is both a Web client and a transient Web server



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P2P for the win!



- ✓ More users = more servers
- ✓ Scalability!

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In short:

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- Client/Server: Adding a user mean less resources per user
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- P2P: Adding a user adds that peer's resources to the system

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So, what's P2P have in common with this course?

- Typically, each member provides access to content



- Basically, a replication system for files

- P2P allows files to be anywhere -> searching is the challenge
 - Dynamic member list makes it more difficult

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P2P fundamental



static

localization

distribution

*how to find a
resource?*

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*how to distribute
resources?*

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dynamic

joining

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*how to enter a P2P
network?*

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*how to leave a P2P
network?*

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Mapping Keys (files/resources) to IP addresses



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dynamic joining Email: tutorcs@163.com leaving

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network? how to leave a P2P
network?

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Locating content



- Locating content is often a three-step procedure
 - What content is available? i.e., can MP3 "Hey Jude" be found at all?
 - Who (what peers) can provide the content?

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- We need a directory with the content available!

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Distributing content



- Central directory
 - Easy to manage ❤️
 - Bottleneck and single point of failure 💔
 - If content directory is overloaded or down, whole system suffers 💔

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- Distributed directory
 - No bottlenecks, no single point of failures or overloading ❤️
 - Hard to manage 💔
 - Harder the more peers and/or content you have in system 💔

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Locating and distributing content

- Three basic architectures
 - Centralized directory (Napster, early BitTorrent)
 - Query flooding (Gnutella)
 - Hierarchical and non-hierarchical overlay designs (Kazaa, BT DHT)

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Napster

- Original “Napster” design
- Step 1: connection



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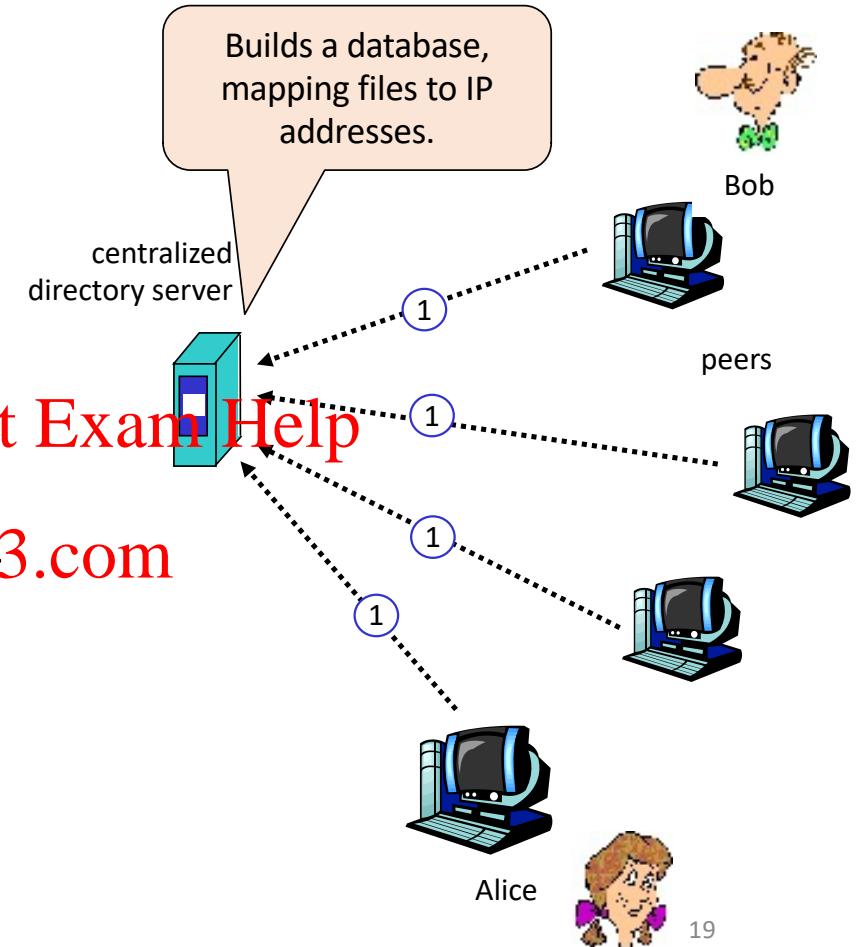
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1. Client upload a list of files that want to share
2. Server maintains a global list <filename, host>

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Note: Server does not store any file

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程序代写代做 CS编程辅导

Napster

- Original “Napster” design
- Step 1: connection
- Step 2: search



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1. Client sends to server keywords to search with
2. Servers returns a list of hosts
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3. Client pings each host in the list to find transfer rates
4. Client fetches file from best host

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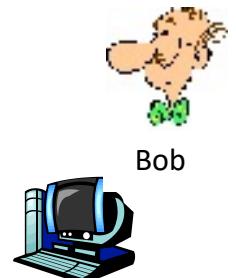
centralized
directory server



2



Alice



Bob



20

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Napster

- Original “Napster” design
- Step 1: connection
- Step 2: search
- Step 3: download



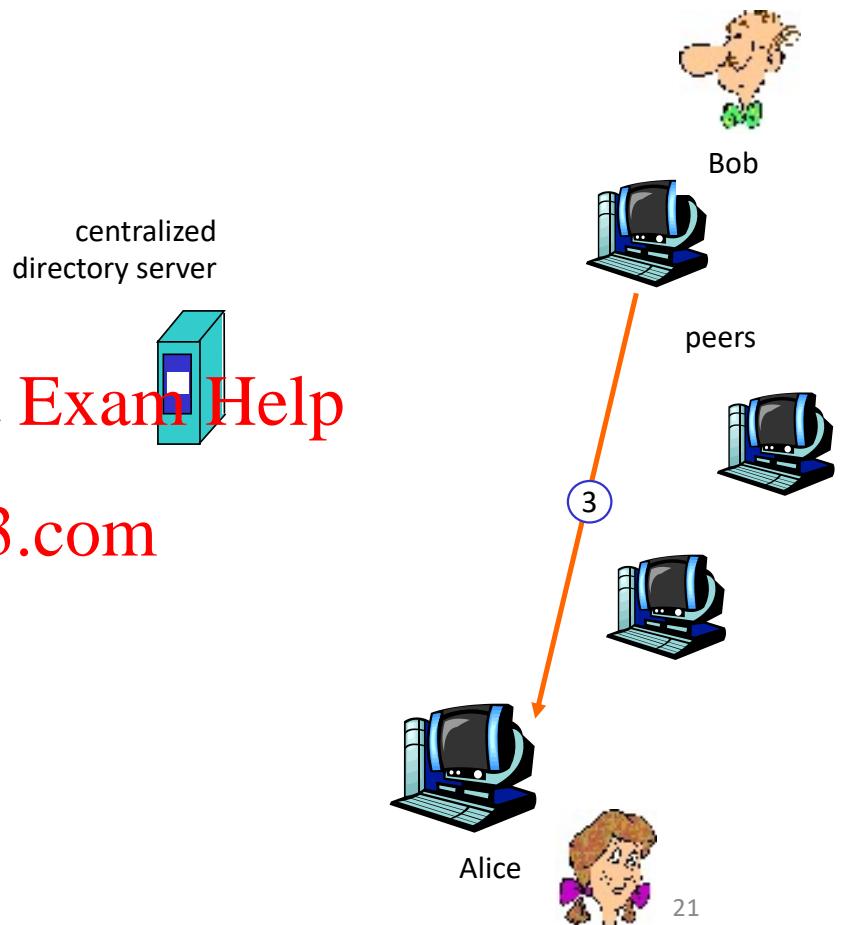
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All communication uses TCP protocol
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Napster

- Original “Napster” design
- Step 1: connection
- Step 2: search
- Step 3: download



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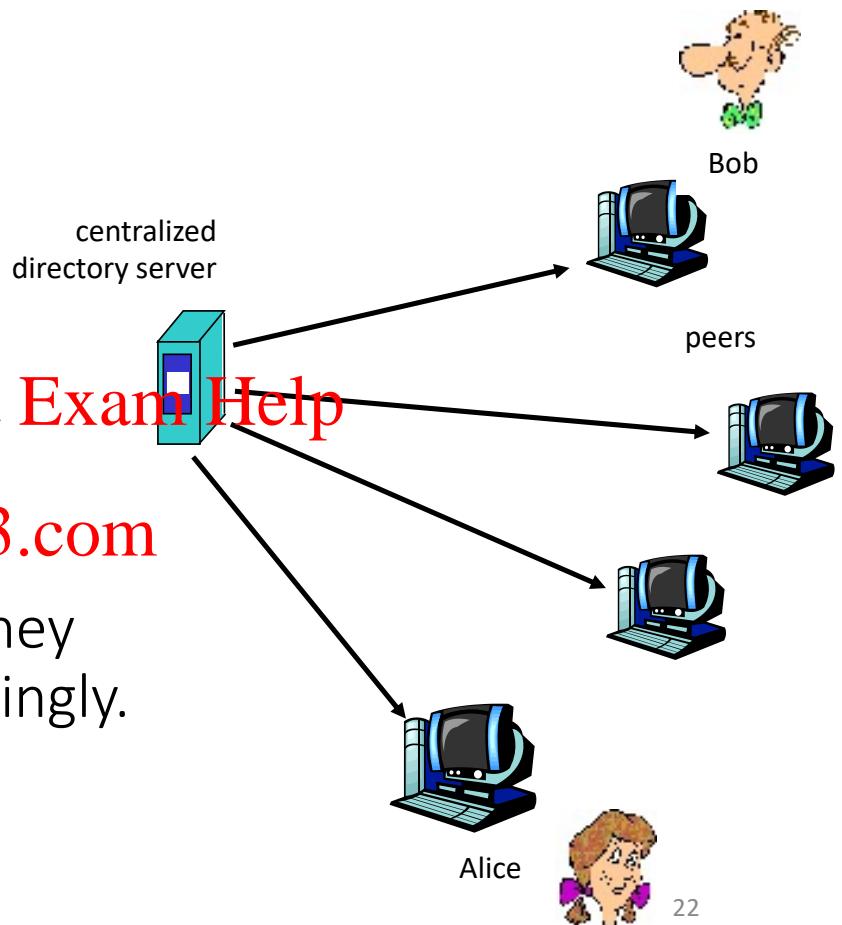
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Server can regularly probe peers to determine if they
are still connected and update its database accordingly.

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Napster

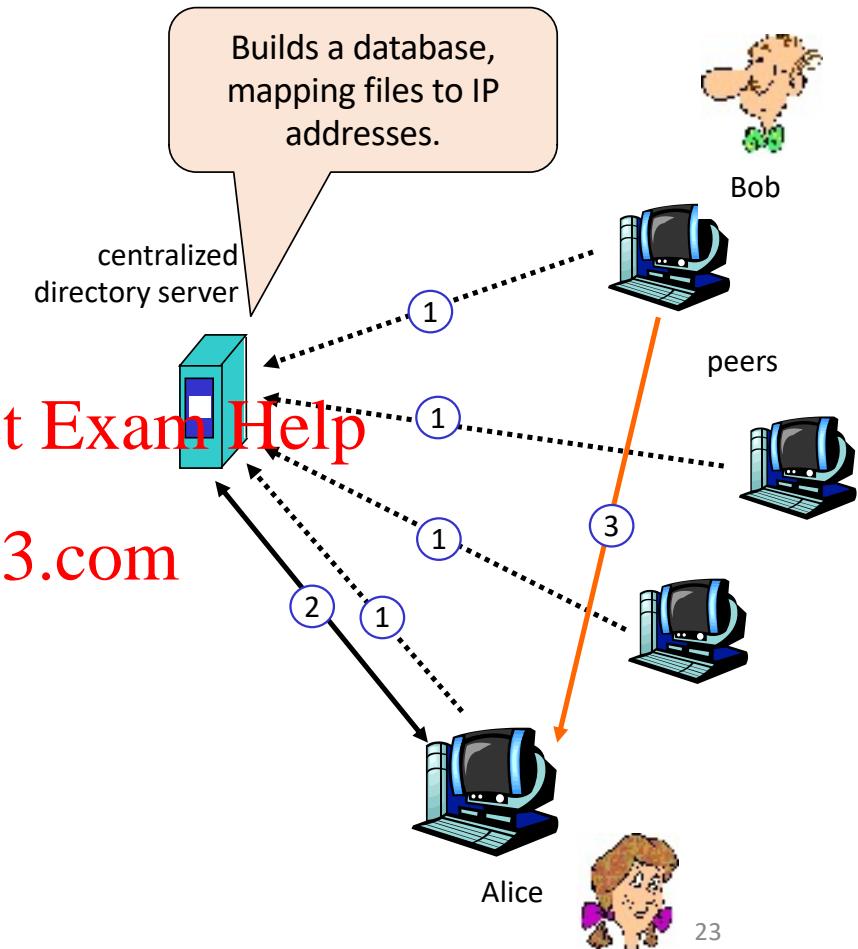


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Can be seen as a hybrid
between P2P and Assignment Project Exam Help

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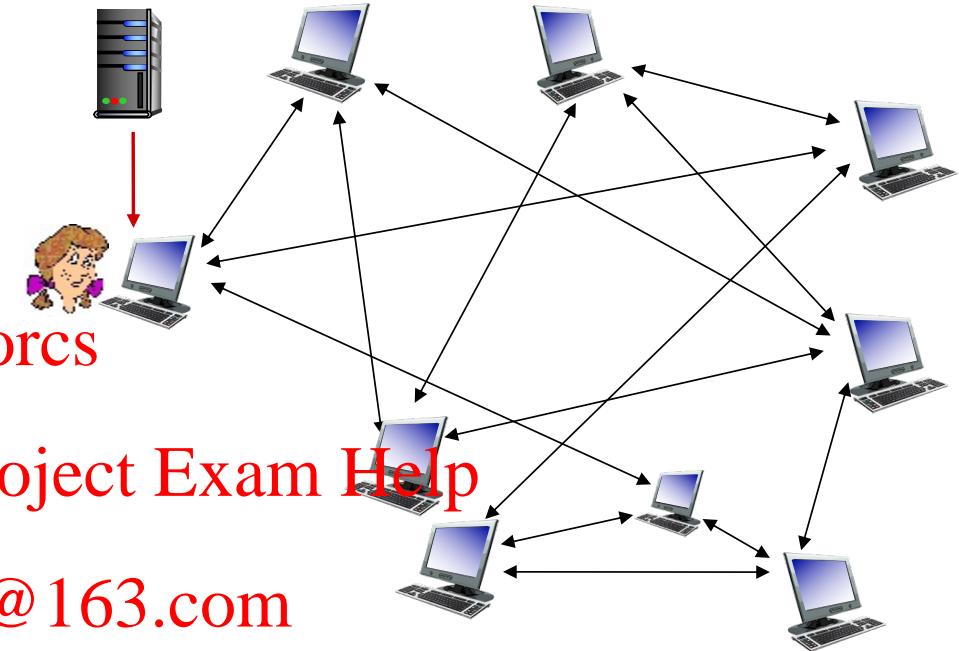
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BitTorrent: overview

- Contact a centralized **tracker** to have a list of peers



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- The **torrent** file contains the list of trackers associated to that specific file

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- If Alice wants to join the torrent:
 - Register with the tracker **QQ: 749389476**
 - Tracker randomly selects peers and send to Alice the IP addresses **<https://tutorcs.com>**

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BitTorrent: the peer-to-peer protocol



- **Tracker:** a special type of server

It keeps track of where file copies reside on peer machines, which ones are available at time of the client request (it does so by receiving heartbeats from peers) and helps coordinate efficient transmission and reassembly of the copied file.

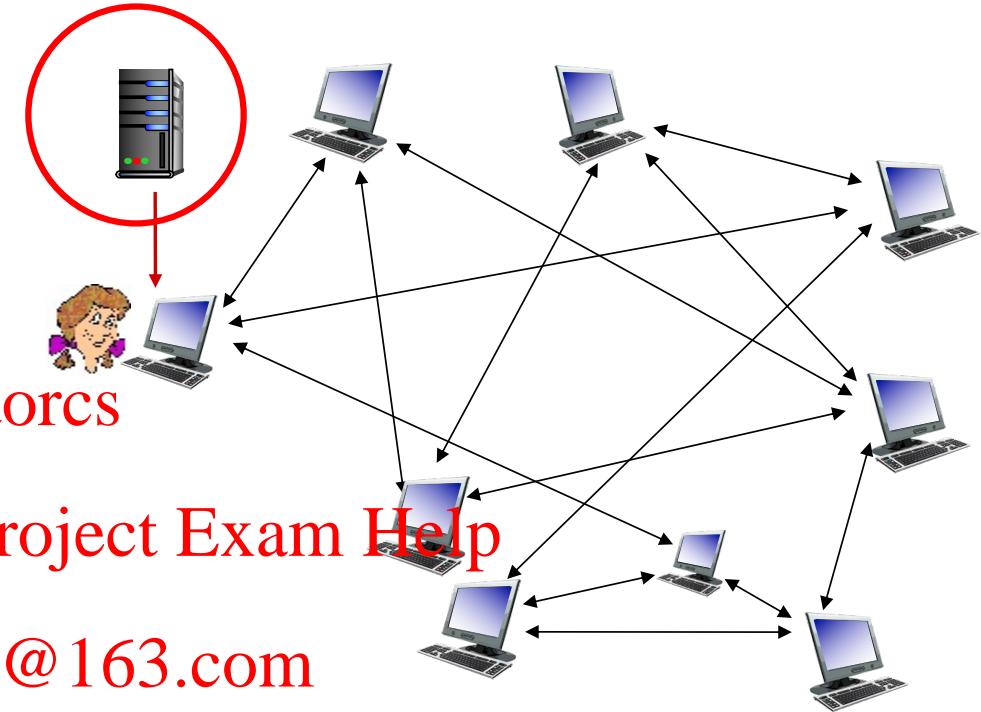
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BitTorrent: the peer-to-peer network

- Two kinds of peers
- Seed: has the full file. It continues to be part of the system and help the other peers to download the file

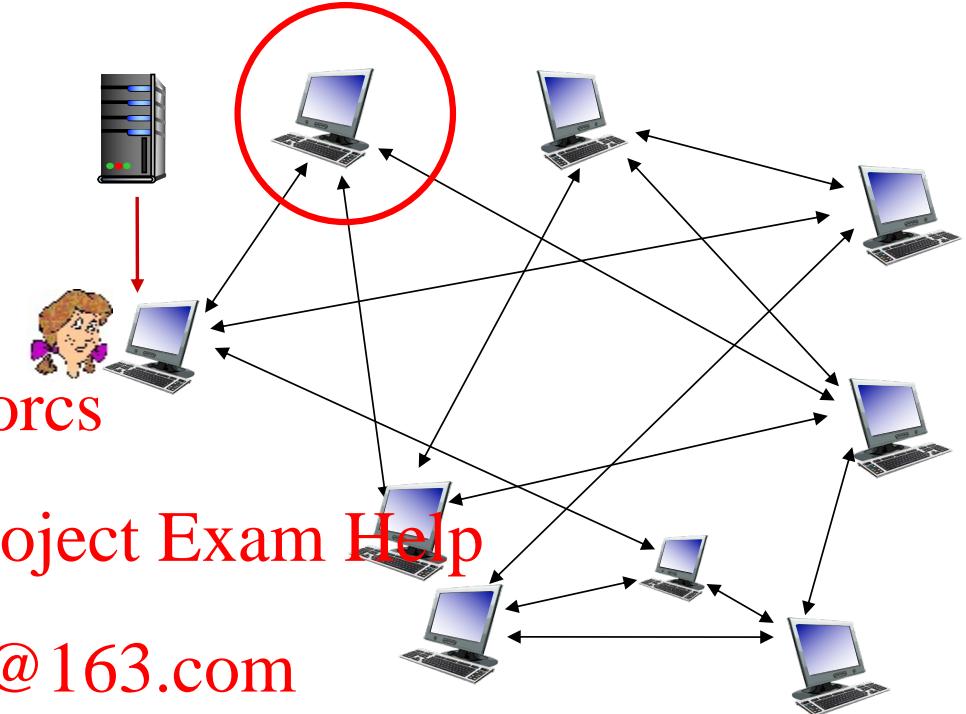
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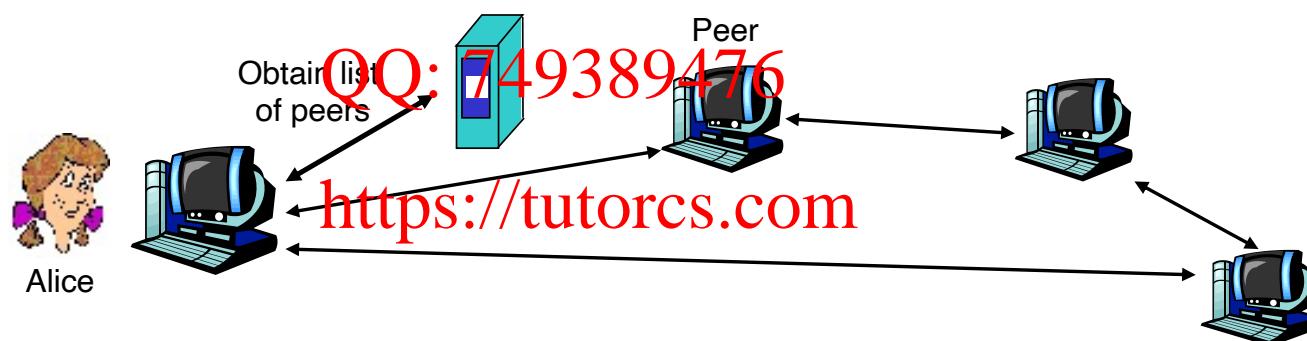
BitTorrent: open



- Alice receives list of peer IP addresses from the Tracker
- Attempts to establish TCP connections to these peers
 - TCP-connected peers are “neighbouring peers”
- Neighbouring peers will fluctuate over time

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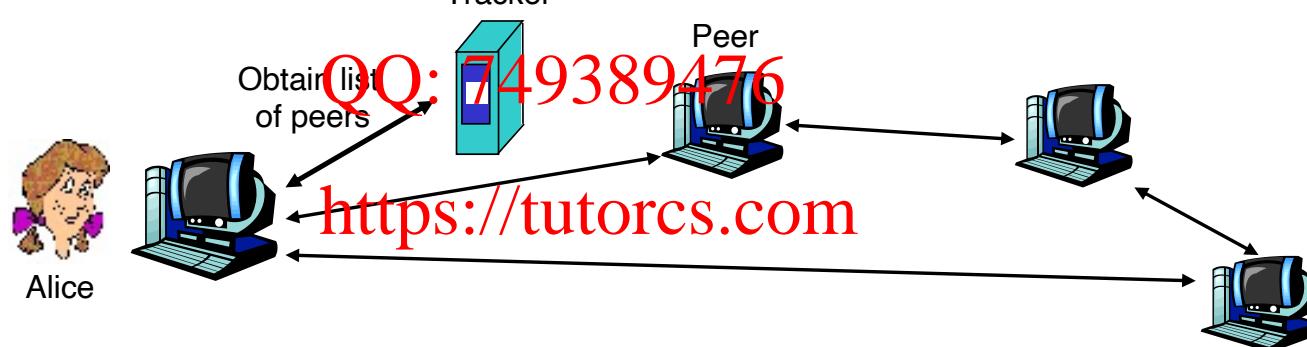
BitTorrent: open



- File split into chunks (32KB)
- Alice periodically asks neighboring peers for lists of chunks
- Alice will issue requests for chunks she is currently missing
- Alice will receive requests for chunks she has

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BitTorrent: open

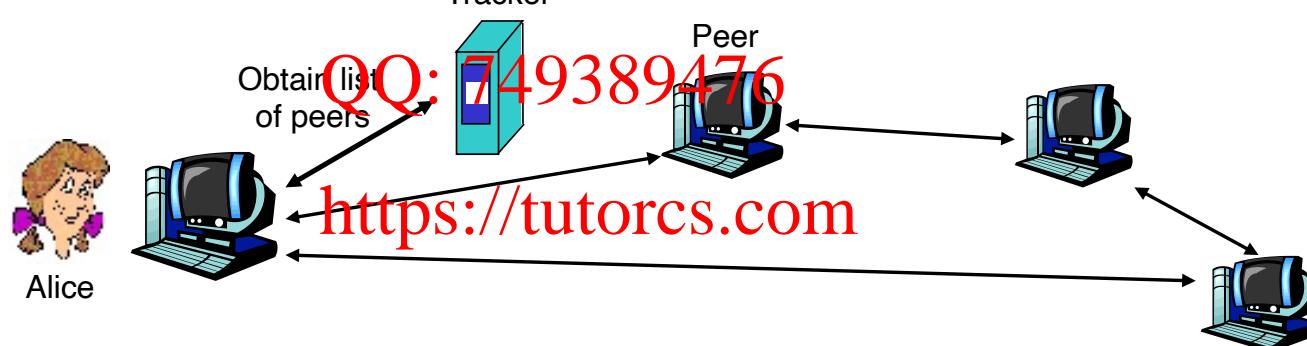


- At any given time, Alice has
 - A subset of chunks
 - Knowledge about chunks her neighboring peers have

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- Two important decisions to make
 - Which chunks should be requested next?
 - To which neighbor should she send requested chunks?

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BitTorrent: open source



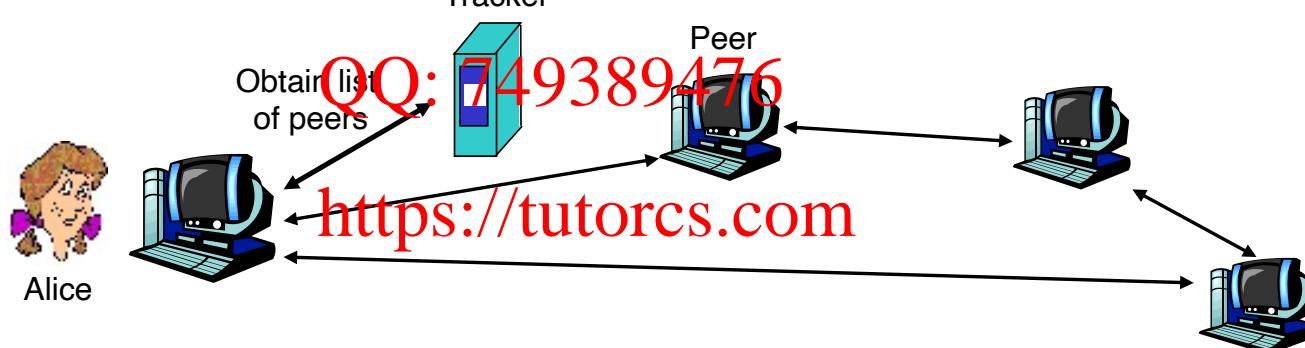
- Rarest chunks first

- Determine chunks that are rarest among her neighbors
- Request those rarest chunks first
- Rarest chunks will then get more quickly redistributed
 - Equalizing the number of copies of each chunk in the torrent

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BitTorrent: open

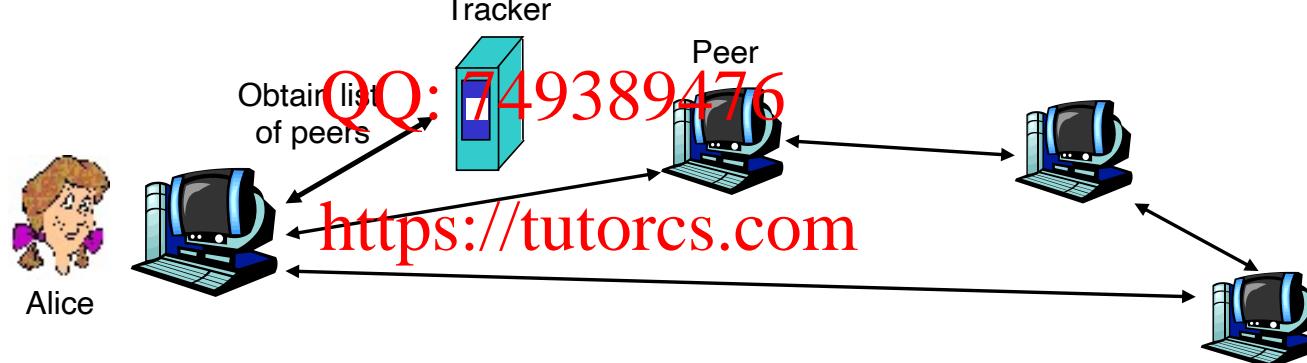


- At any given time, Alice has
 - A subset of chunks
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- Two important decisions to make
 - Which chunks should be requested next?
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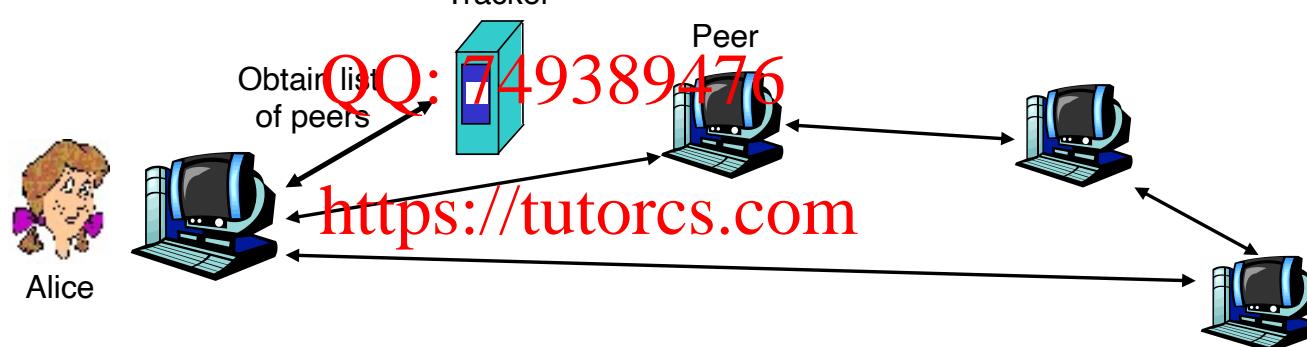
BitTorrent: open



- Give priority to neighbors supplying her data *at the highest rate*
 - For each of her neighbors, Alice measures her receiving rate
 - Determine the four neighbors feeding her at highest rate
 - Return favor by sending chunks to the top four neighbors

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BitTorrent: open-source (bit-for-bit)

- Give priority to neighbors supplying her data *at the highest rate*
 - For each of her neighbors, Alice measures her receiving rate
 - Determine the four neighbors feeding her at highest rate
 - Return favor by sending chunks to the top four neighbors

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BitTorrent: open



- Every 10 seconds, recalculate top four peers
 - Possibly modifying the set of top four peers

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- Every 30 seconds, be optimistic!
 - Pick a new neighbor, Bob, at random and send it chunks
 - Alice may then become one of Bob's top four uploaders
 - Bob would then start sending to Alice and maybe become one of her top four uploaders

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BitTorrent: open



- Random neighbor selection
 - Peers capable of uploading at compatible rates tend to find each other
 - New peers will get chunks so that they can start trading

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BitTorrent compared to Napster

- Chunk based downloading



- Anti-freeloading mechanisms

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Centralized directory limitations



- Single point of failure
 - If server crashes, the entire P2P application crashes

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- Performance bottleneck
 - Huge amount of users → huge database and many queries/second

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- Directory size
 - When peers connect, they upload their content manifest (list of files)
 - As the number of peers increases, the resulting database does too

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Centralized directory limitations

- Single point of failure
 - If server crashes, all data is lost
 - Performance bottleneck
 - Huge amount of data stored in one place
 - Directory size
 - When peers connect, they upload their content manifest (list of files)
 - As the number of peers increases, the resulting database does too
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Locating and distributing content

- Three basic architectures
 - Centralized directory (Napster, early BitTorrent)
 - **Query flooding** (Gnutella)
 - Hierarchical and non-hierarchical overlay designs (Kazaa, BT DHT)

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Query flooding



- No central directory of either client or peers

- Search by sending query to all directly connected peers

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- Peers forward query to their directly connected peers, etc. i.e., flooding network with queries.

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- Some rules to limit reach, prevent loops etc. Still very costly.

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Gnutella

- Each Peer stores:
 - Their own files
 - Peer pointers (to the neighbour)
- Peers connected in a ~~overlay~~ network



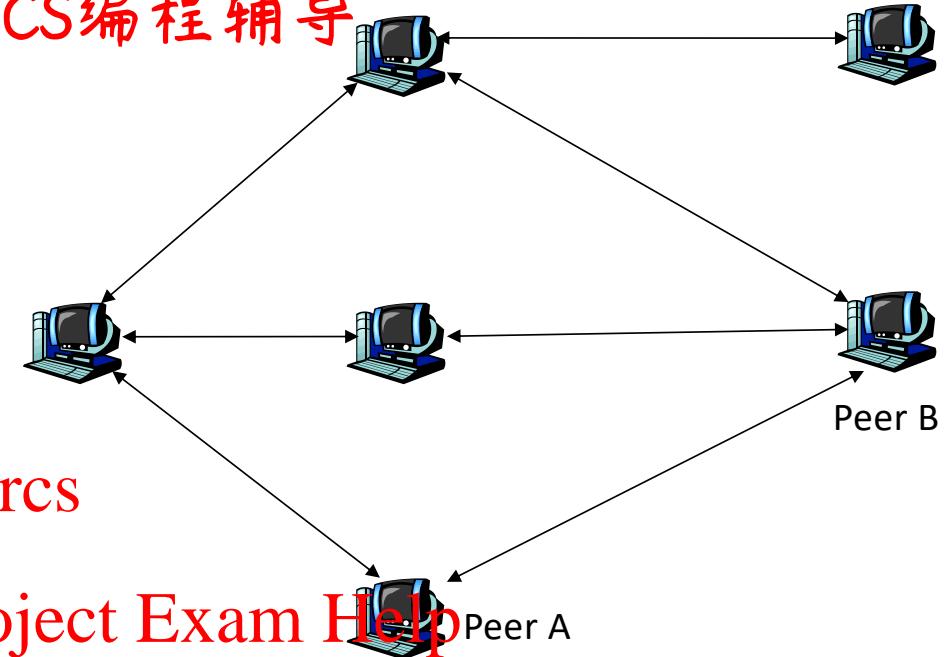
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- Each link is an implicit Internet path
- Peer A and Peer B are neighbour if they know their IP addresses and can send/receive messages



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Gnutella

- How to find a file:

- Send request to all neighbors (Query)
- Neighbours recursively forward the request
- Eventually a machine that has the file receives the request, and it sends back the answer (QueryHit)
- Transfers are done with HTTP between peers. If several QueryHits, select one!



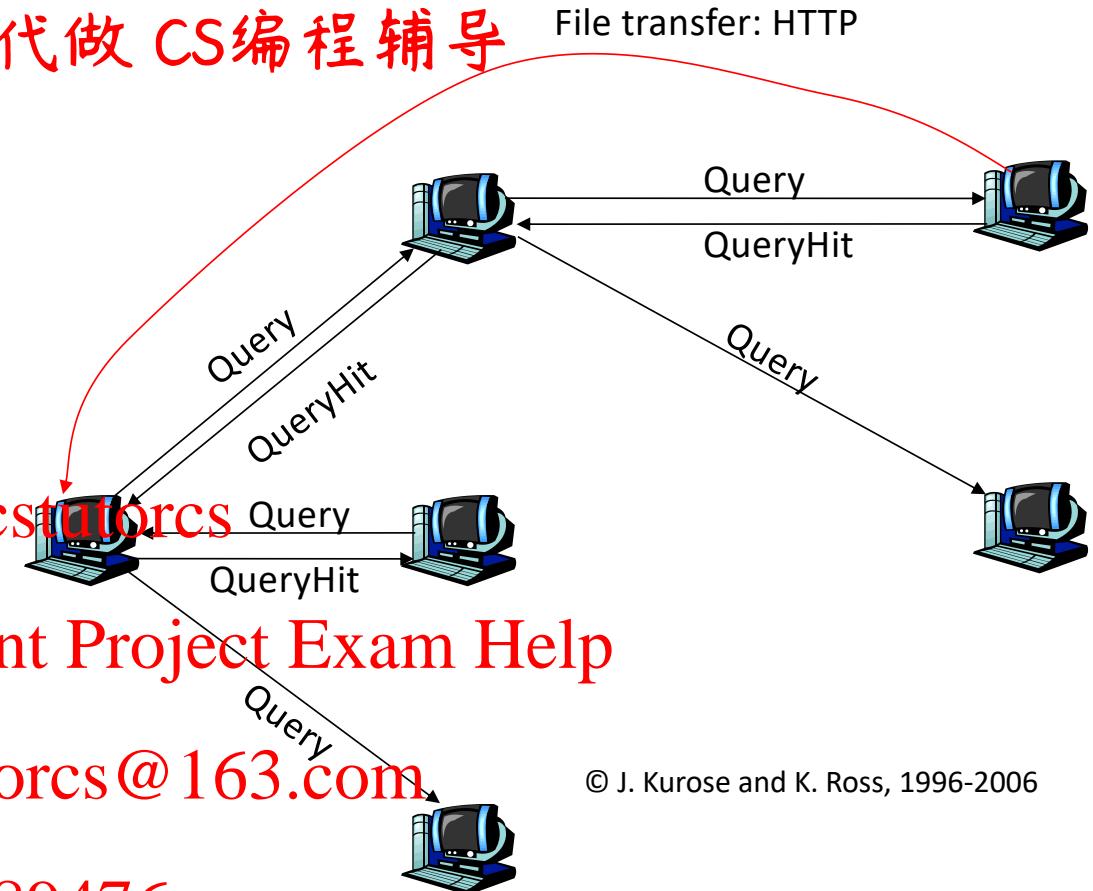
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Gnutella: avoiding duplicate traffic

- To avoid duplicate transmission, each peer to maintain a list of recently received messages
- Query forwarded to all neighbours except from which received it
- Each Query forwarded only once (it has an ID associated)
- TTL associated to each Query to avoid messages running forever in the network

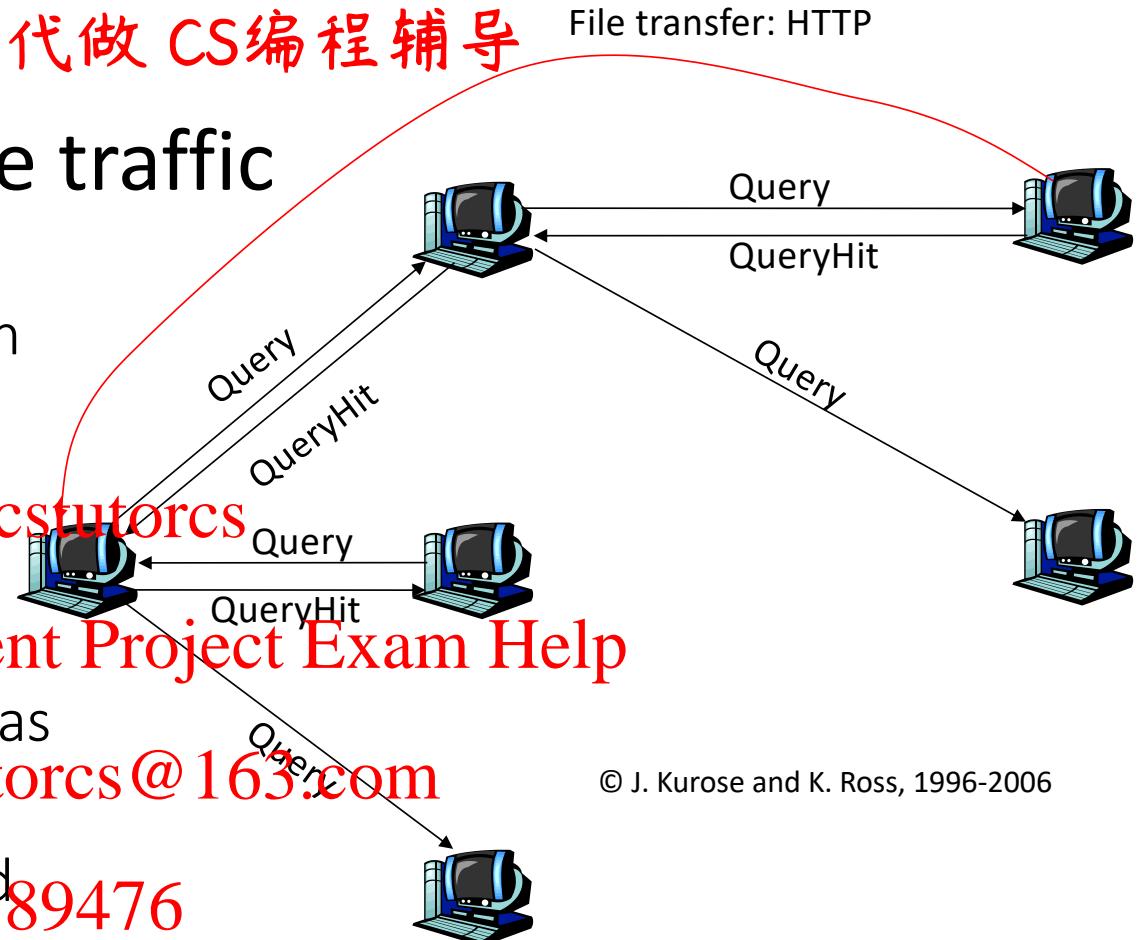
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Gnutella: how to join network



- Joining peer X must find some peer in the Gnutella network: use list of candidate peers that are often up (e.g., at a Gnutella site)

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- X sequentially attempts to establish TCP connections with peers on list until connection setup with peer Y

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- X sends Ping message to Y; Y forwards Ping message (peer-count field used - TTL)

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- All peers receiving Ping message respond with Pong message back through the overlay

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Gnutella: problems

- Ping-Pong constituted 50%



- Popular files are requested many times: lots of Query

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- Some peers might not have enough traffic for all Query/Pings/Pongs

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- 70% of users in 2000 were freeloaders: just downloading never uploaded any file

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- Flooding causes excessive traffic

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KaZaA



- Basic idea: leverage heterogeneity of peers-> assign more responsibility to peers with better resources to impose a hierarchy

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- Kazaa borrows ideas from Napster and Gnutella
 - Like in Gnutella, there is no dedicated server (or server farm) for tracking and locating content
 - Unlike Gnutella, all peers are not equal in Kazaa—group leaders (or super peers) exist

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KaZaA



- Group leaders maintain a database of content and IP addresses in a Napster-like fashion (group leaders act as a Napster-like hub)
 - In contrast to Napster, a group leader is not a dedicated server

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KaZaA: hierarchical overlay network

- Each peer is either a group member or assigned to a group leader



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- Group leader tracks the content in all its children

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- Group leaders have high bandwidth connections and high Internet connectivity

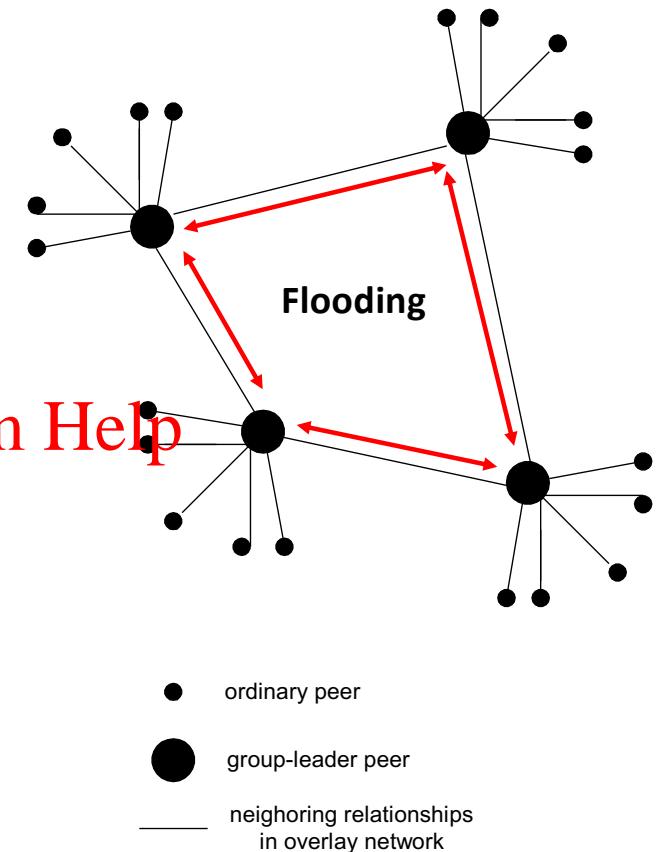
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- A hierarchical overlay network

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- Flooding limited to overlay of super peers

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KaZaA: operation

- Publish:

- Node inform group-leader of the list of files it wants to share

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- Search:

- Node queries group-leader. If file not found, group-leader flood the query to a subset of group-leaders
- Group-leader responds to node

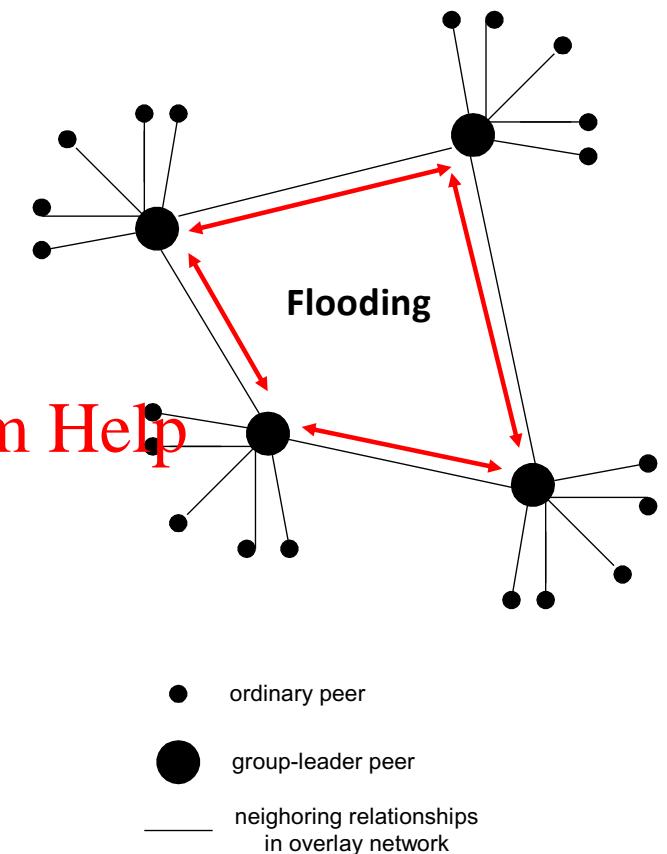
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- Fetch:

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KaZaA: pros and

- Pros

- Improves scalability and search efficiency by exploiting node heterogeneity

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- Cons

- No guarantees on search time
- No mechanism to tackle free-riding

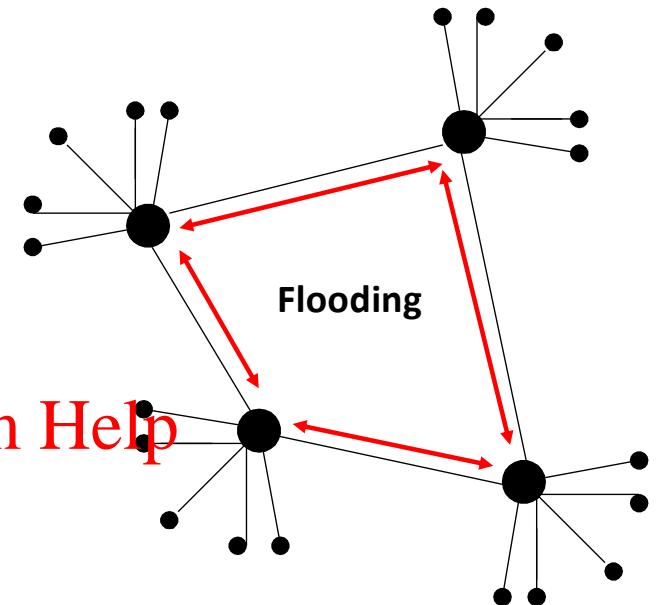
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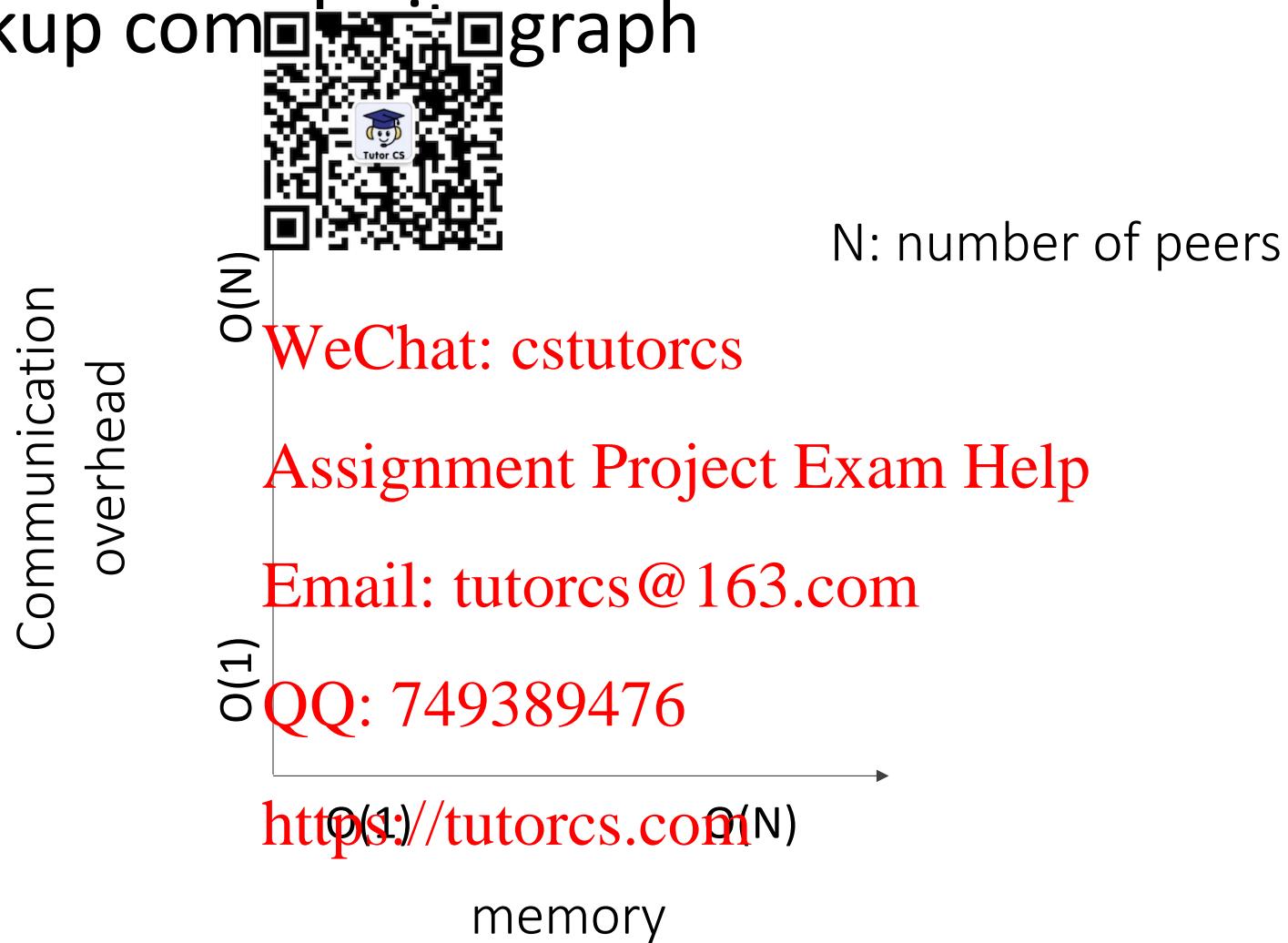
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- ordinary peer
- group-leader peer
- neighboring relationships in overlay network

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The lookup communication graph



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The lookup communication graph



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The lookup communication graph



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The lookup communication graph



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Distributed Hash Table (DHT)

Hash function

- Turns data into a small number (a "fingerprint")
- Input → Hash function → Hash (or hash sum, or hash value)
- Choosing a good hash function can be tricky

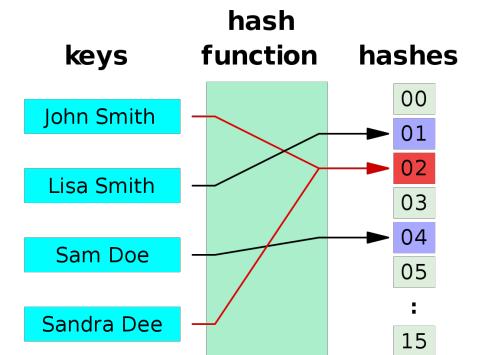
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• Hash table

- a structure that can map keys to values. It uses a hash function to compute an index into an array, from which the desired value can be found

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Distributed Hash Table (DHT)

- Widely adopted in Peer-to-Peer systems
 - Creates a fully decentralized index that maps file IDs to locations
 - Allows a user to determine (basically) all the locations of a file without generating an excessive amount of search traffic

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DHT for locating content



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Can we cleverly distribute the mapping so that finding the resource is easy?

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DHT basics

The hash function maps a key to a point
in the hash output space



hash co-domain space

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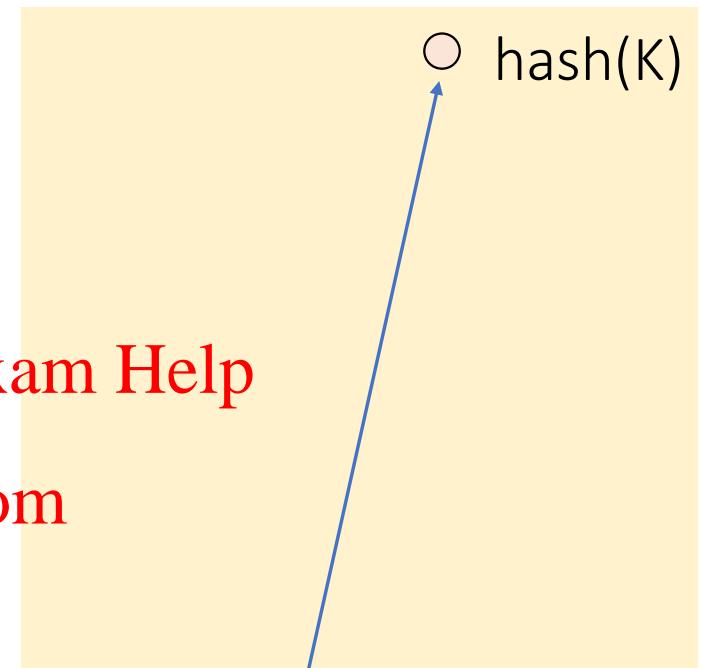
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DHT basics

The hash function maps a key K to a point in the hash output space



hash co-domain space



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DHT basics

The codomain of the hash
split among
the peers



split among

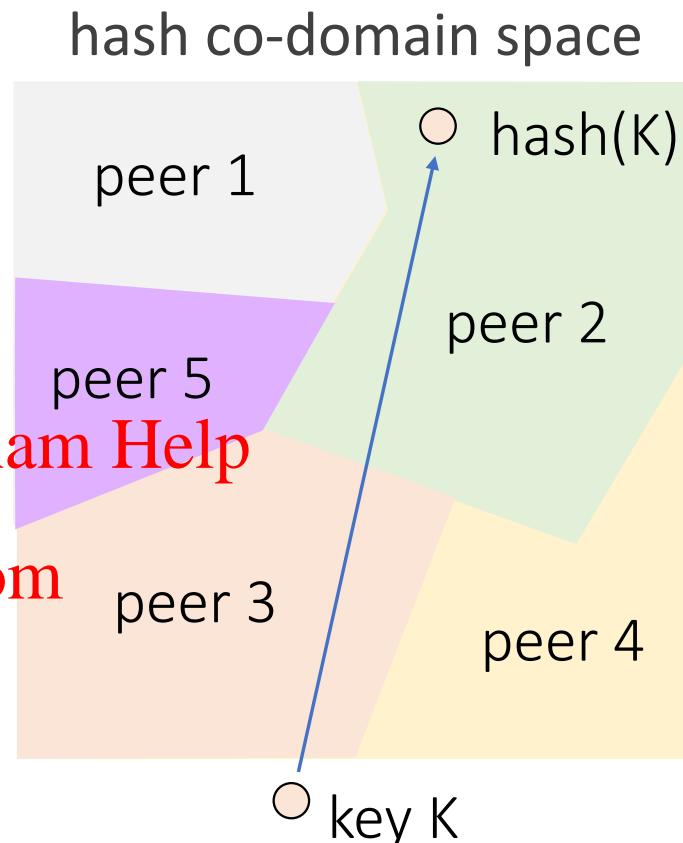
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- each peer is responsible to **map** a hashed ID to the IP address that can provide the content

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the peer does ~~not store~~ the
resource, just the mapping!
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DHT basics

The codomain of the hash
split among
the peers



split among

- to fetch a resource, the client must contact the correct peer

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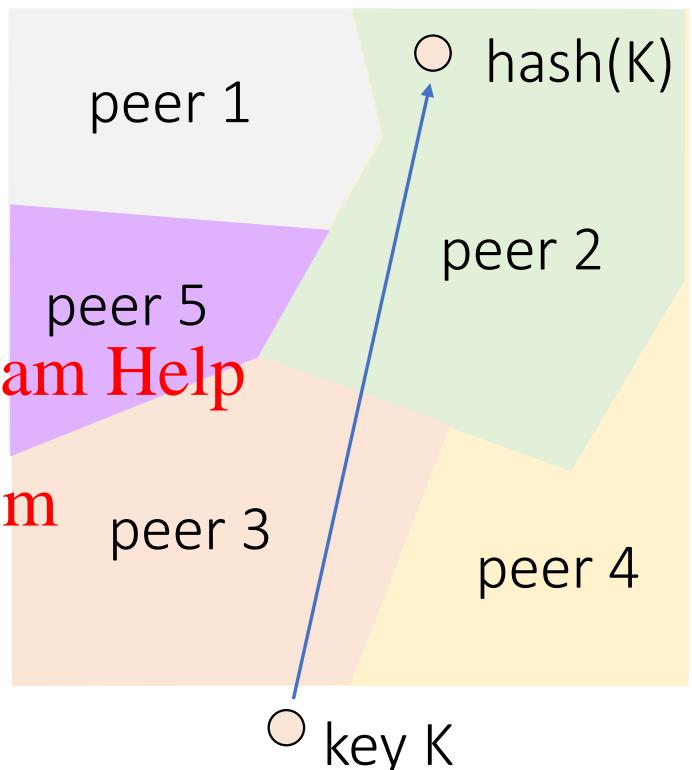
- the hash table maps keys to the peer that is responsible for that key

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hash co-domain space



DHT basics

This is challenging!!!!



- How to keep uniformly distributed load?
- How to handle peers that join and leave?
- How does a peer find who knows about a resource with key K?

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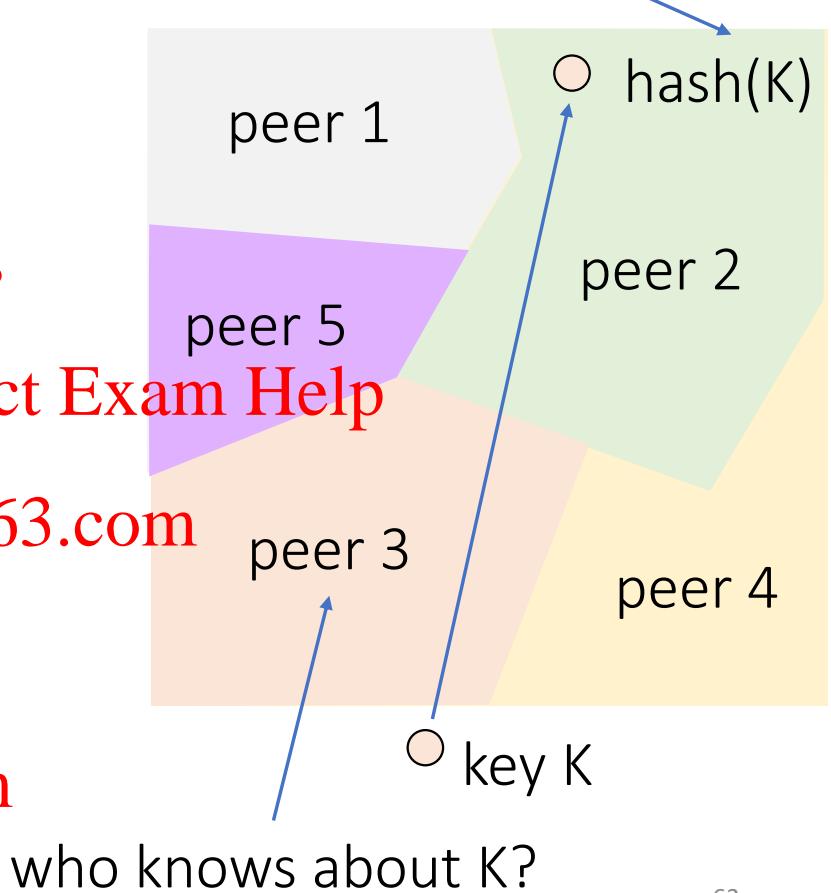
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knows the owner of K



程序代写代做 CS编程辅导

The Chord example

- Developed at MIT



- Basic idea: assign to each node and key an m -bit *identifier* using a base hash function such as SHA-1

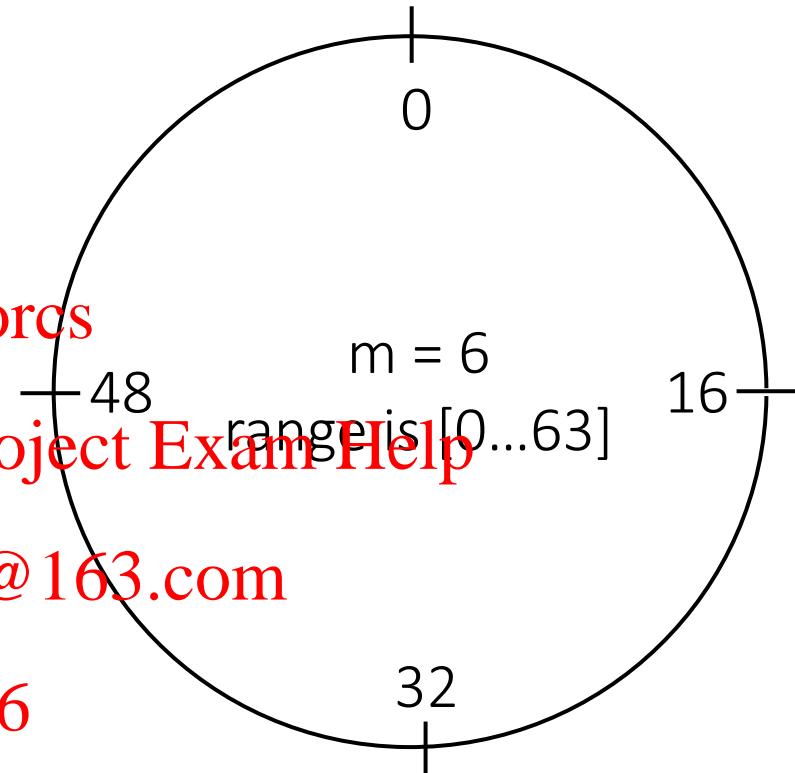
- $\text{ID}(\text{node}) = \text{hash}(\text{IP}, \text{Port})$
- $\text{ID}(\text{key}) = \text{hash}(\text{key})$

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The Chord example

- Developed at MIT



- The key id space

- interval between 0 and $2^m - 1$

- chord uses $m = 160$

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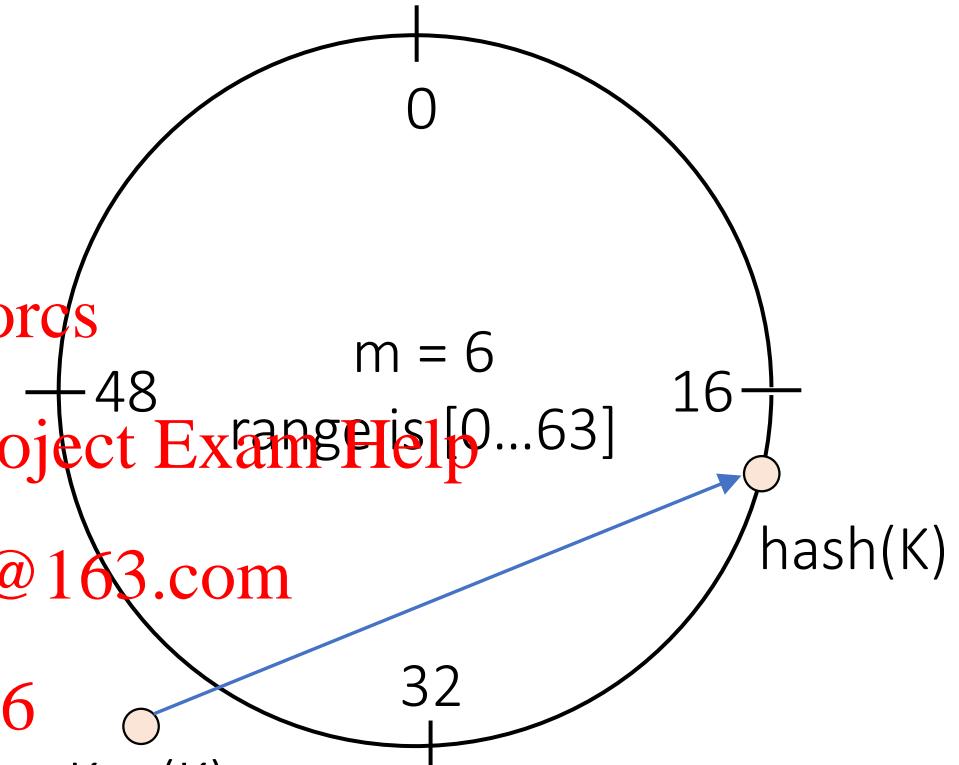
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range is [0...63]

- one can assume $m = O(\log N)$

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The Chord example

- The key id space
 - interval between 0 and 2¹⁶ - 1
 - chord uses $m = 160$
 - one can assume $m = O(\log N)$
- we assume $m = 6$



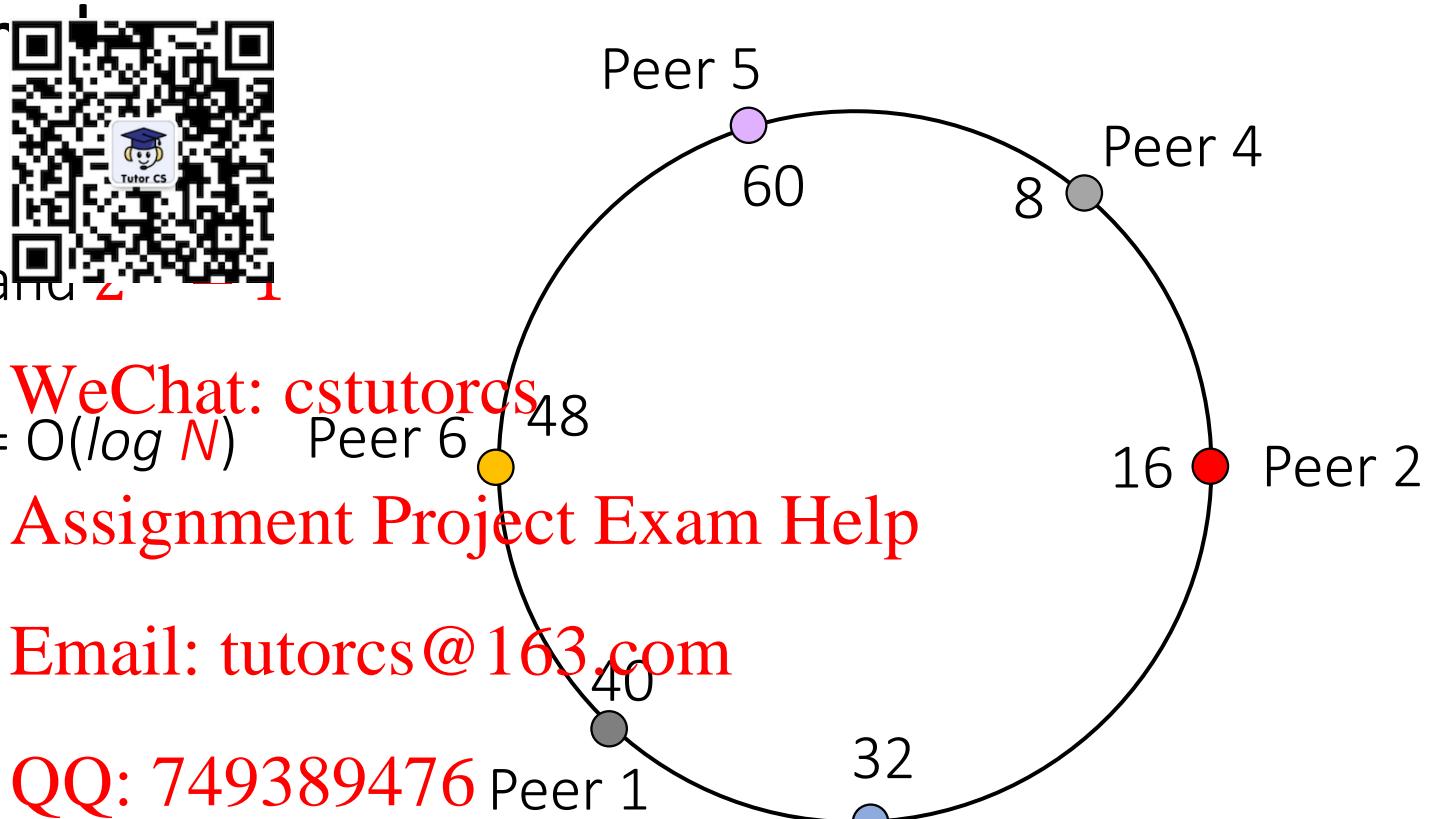
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The Chord example

- The key id space
 - interval between 0 and 2¹⁶ = 65536
 - chord uses $m = 160$
 - one can assume $m = O(\log N)$
- we assume $m = 6$



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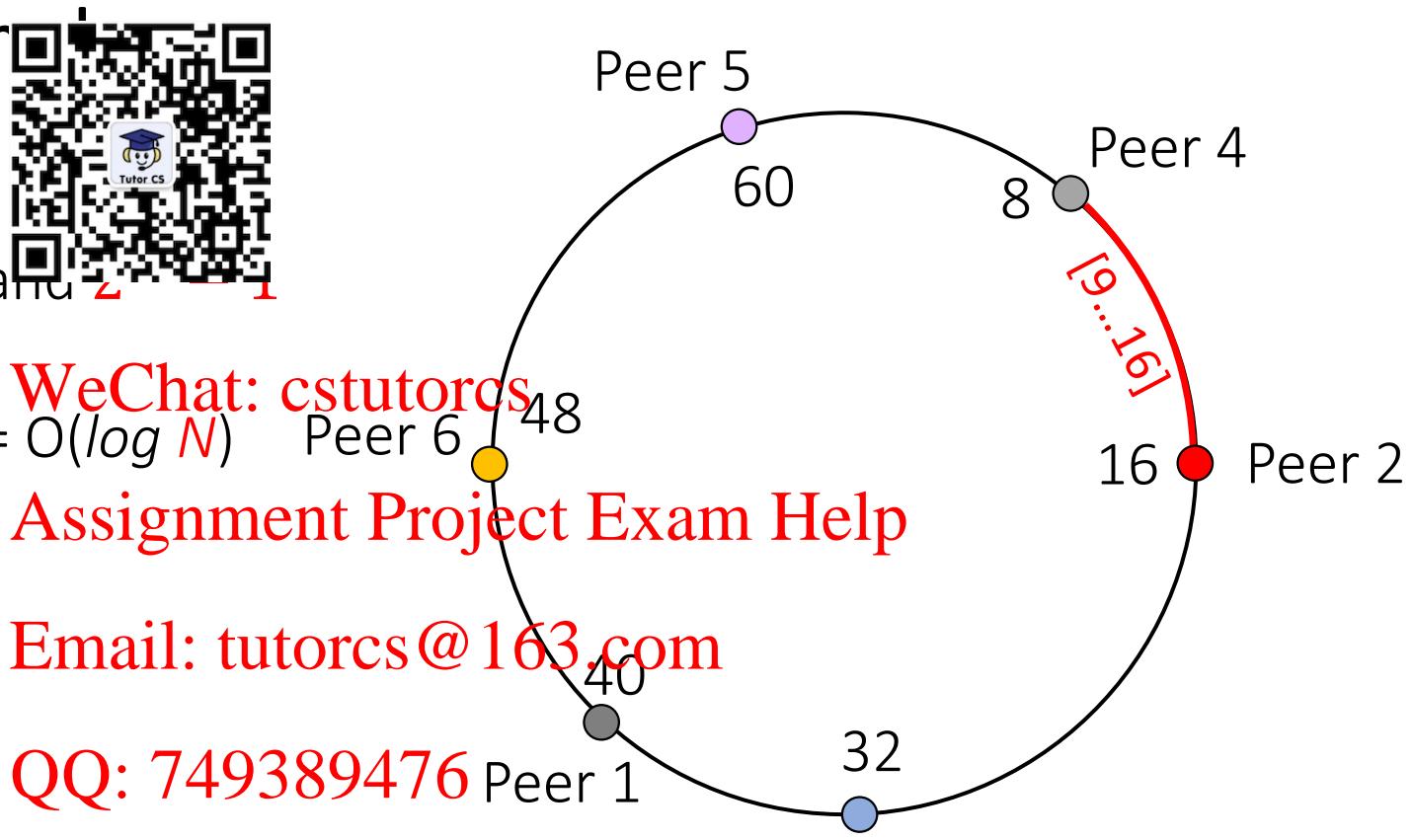
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smaller ones until its predecessor peer



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The Chord example

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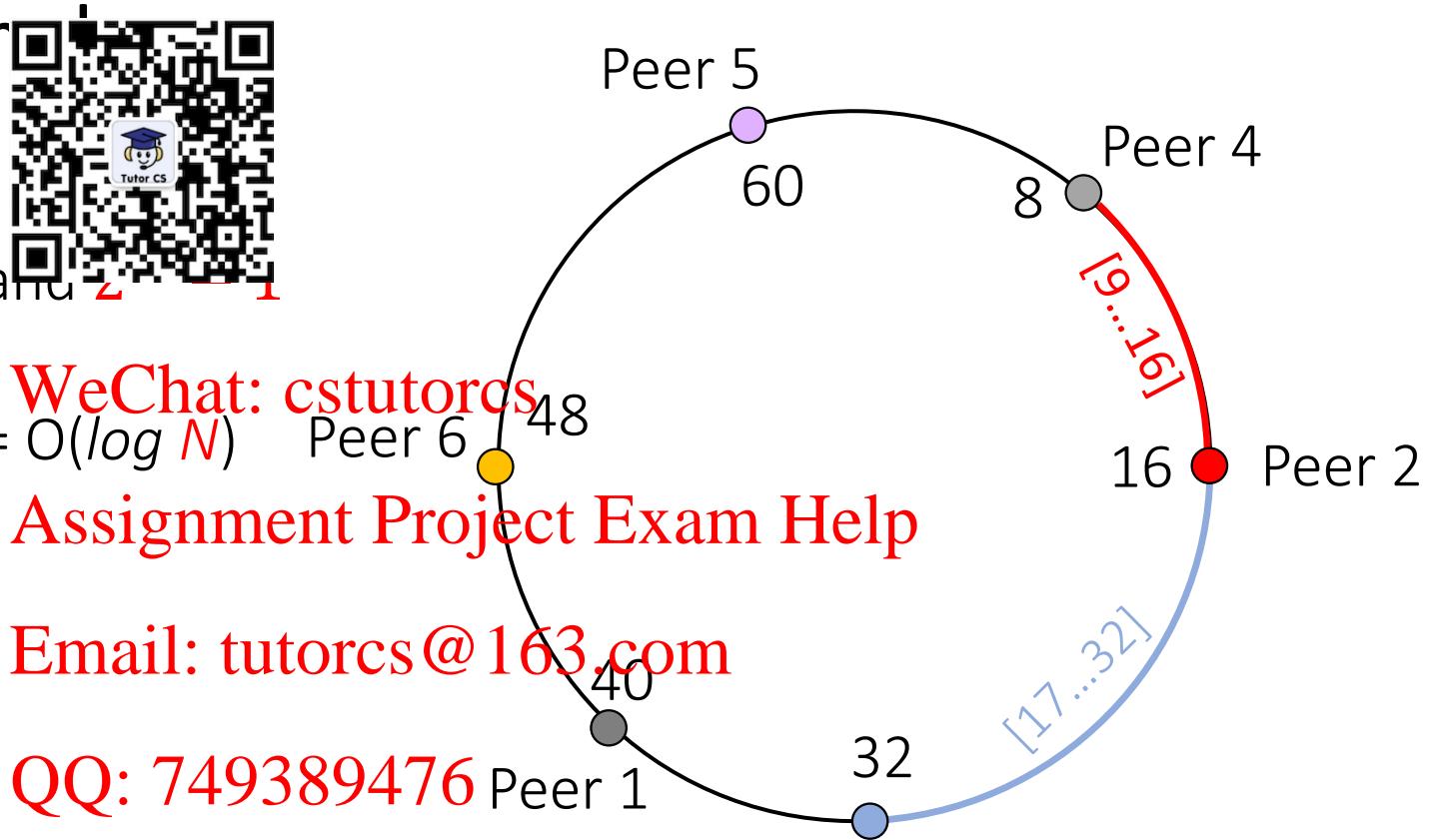


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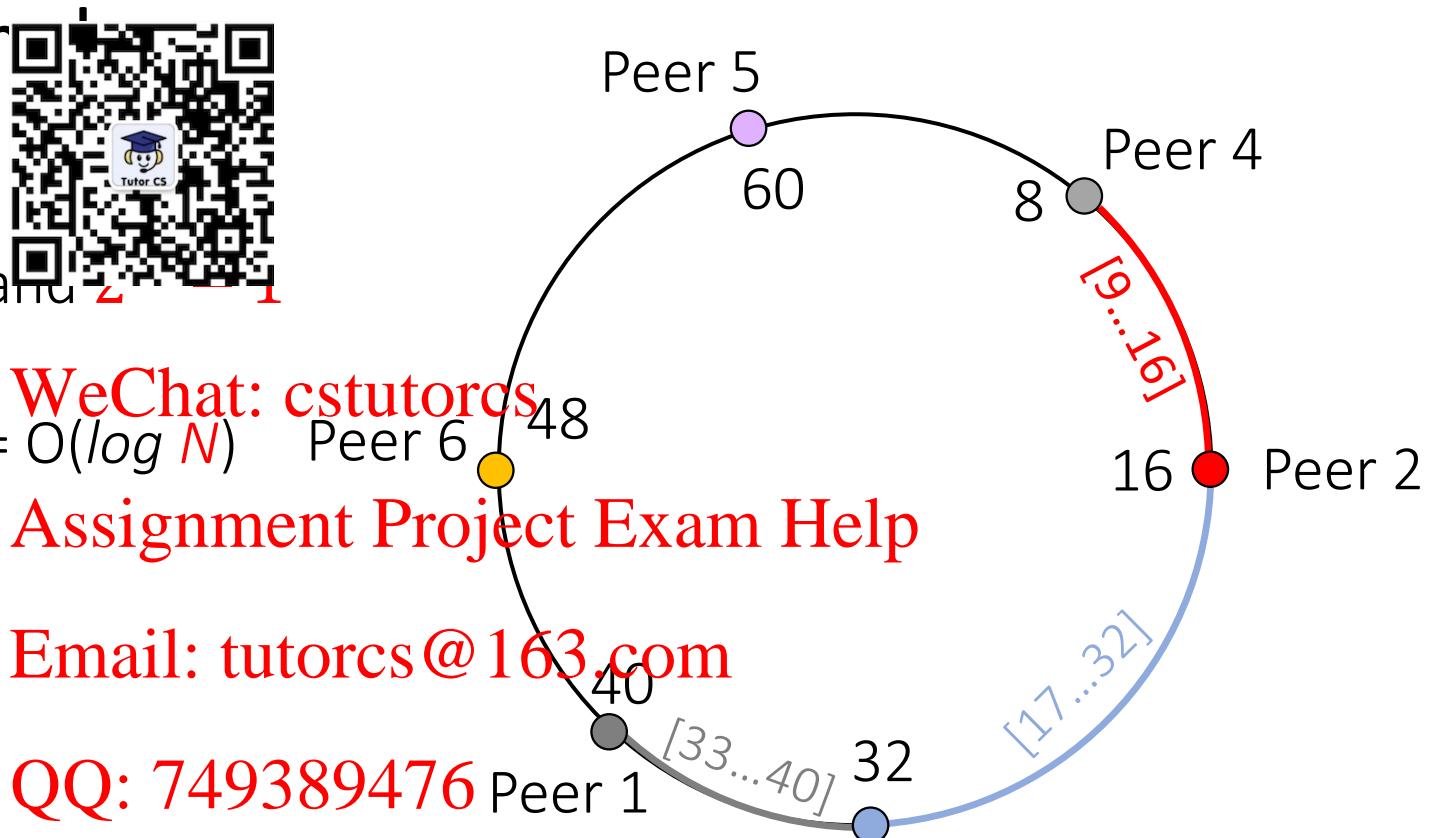
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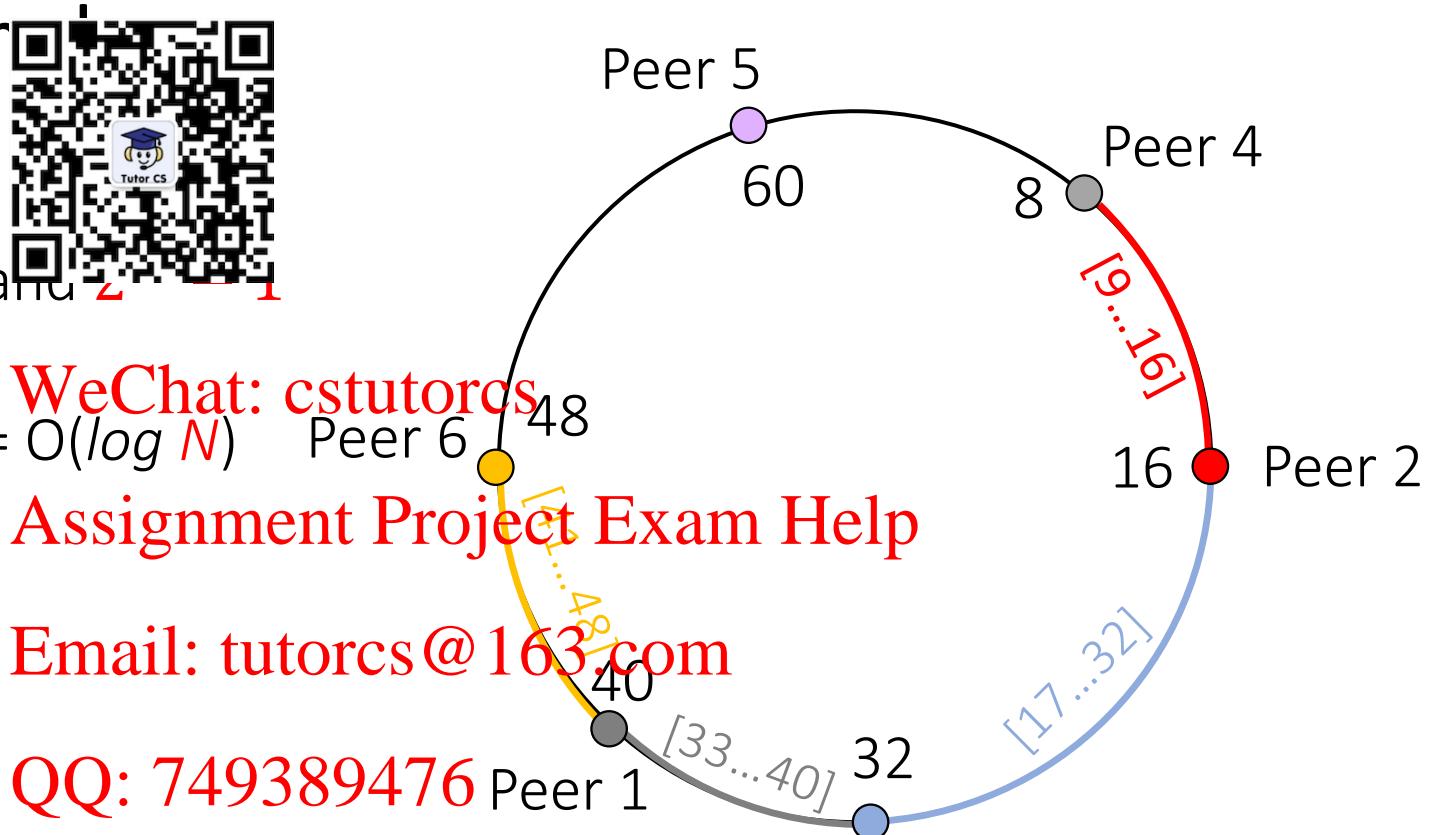
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The Chord example

- The key id space
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- we assume $m = 6$



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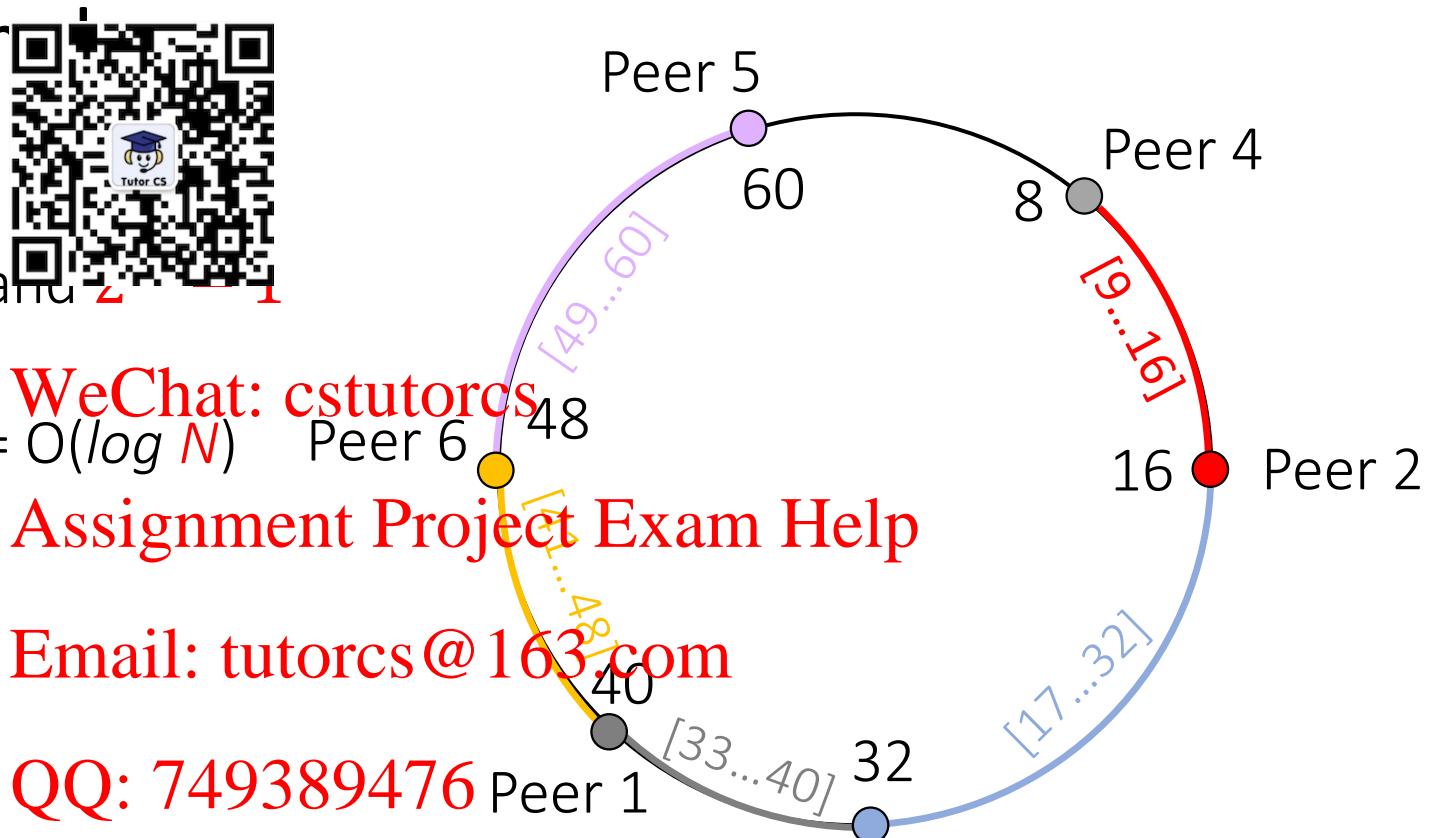
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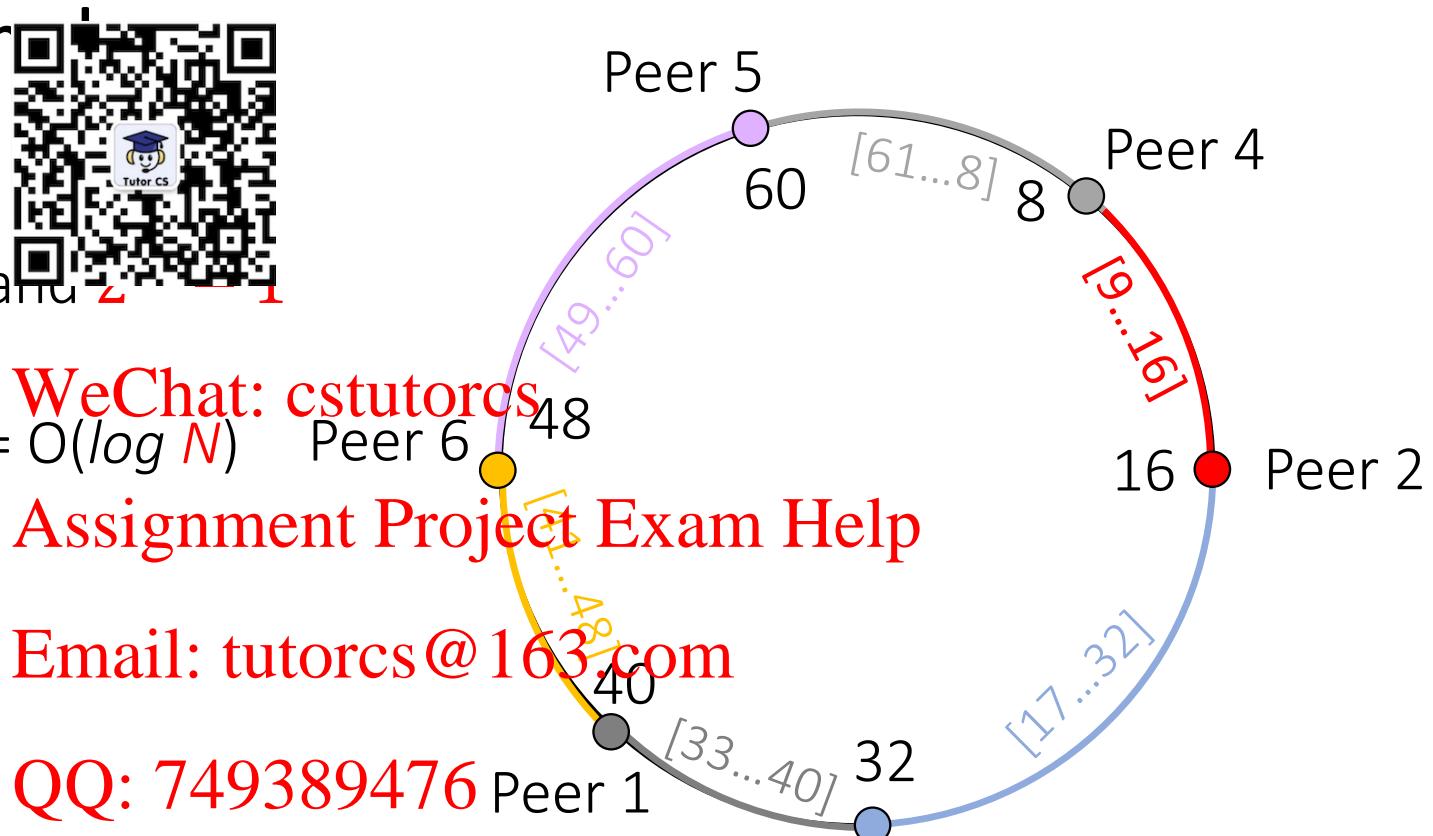
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Each peer has authority over <https://tutorcs.com>

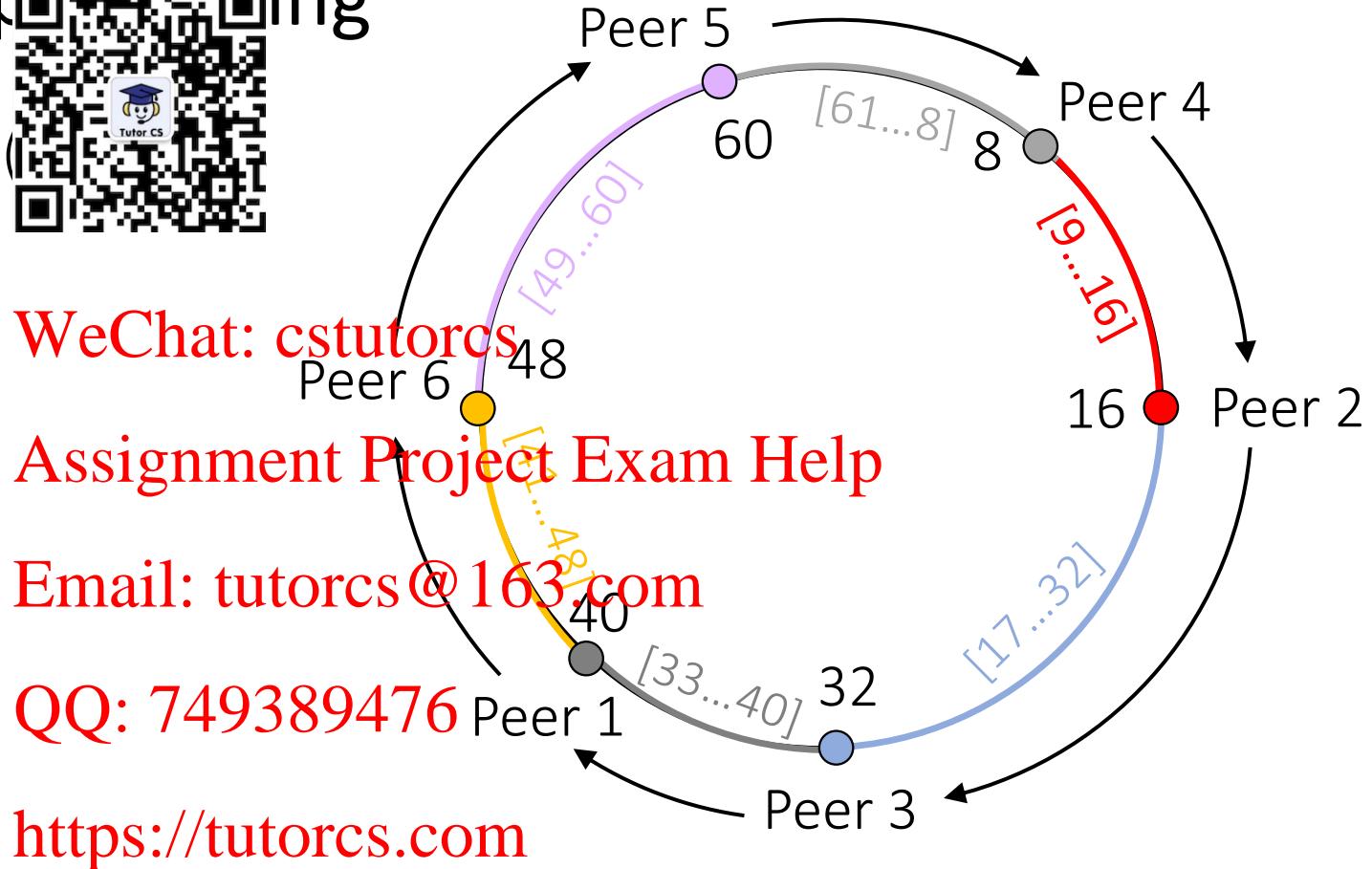
smaller ones until its predecessor peer



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Chord with simple routing

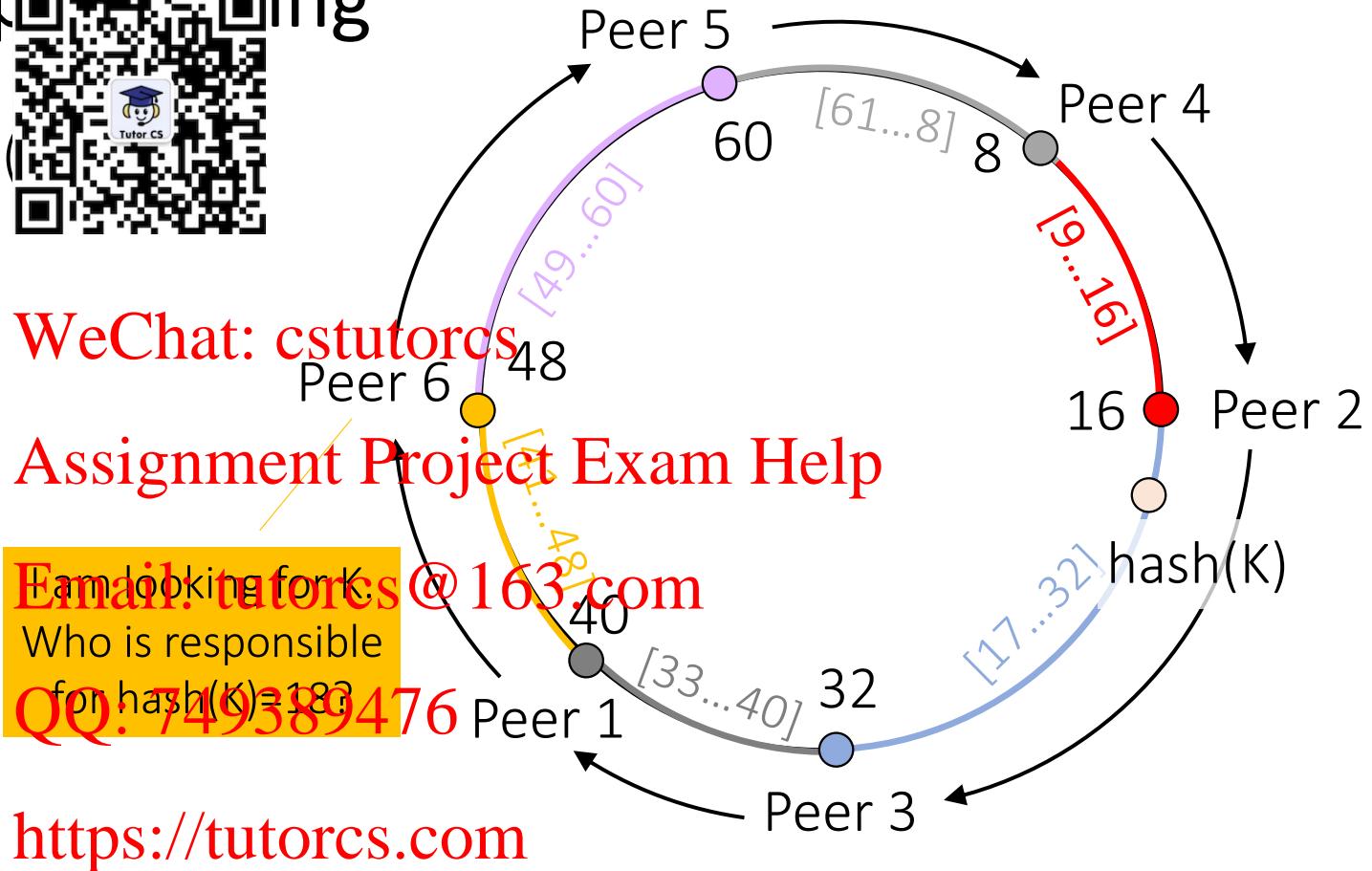
Each peer keeps a pointer
and port) to its successor



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Chord with simple routing

Each peer keeps a pointer
and port) to its successor



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Chord with simple routing

Each peer keeps a pointer (IP and port) to its successor

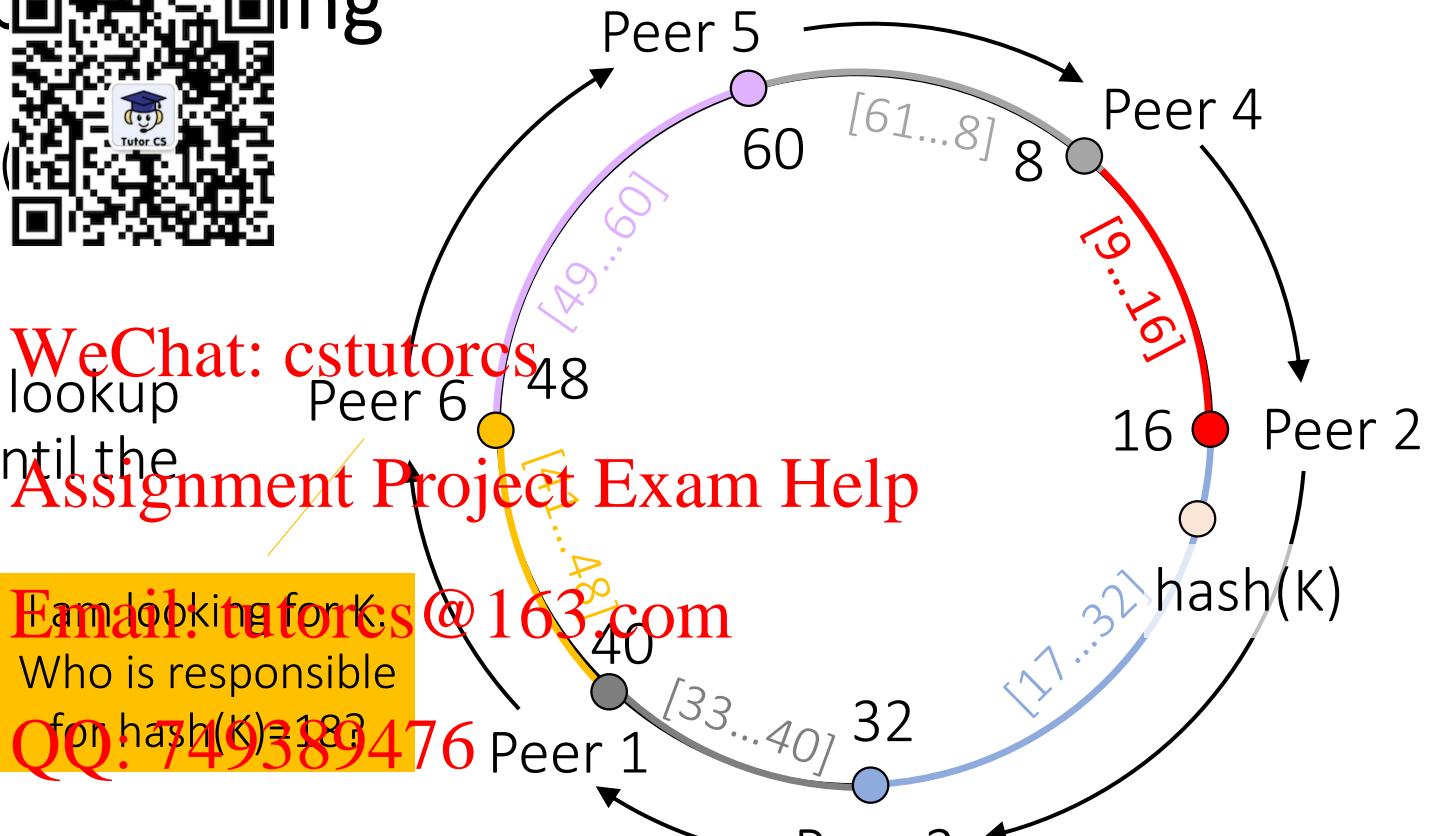


Simple Routing: Forward a lookup request to the successor until the correct peer is found

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Who is responsible
for $\text{hash}(K)=18$?
QQ: 749389476

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Chord with simple routing

Each peer keeps a pointer (IP and port) to its successor



Simple Routing: Forward a lookup request to the successor until the correct peer is found

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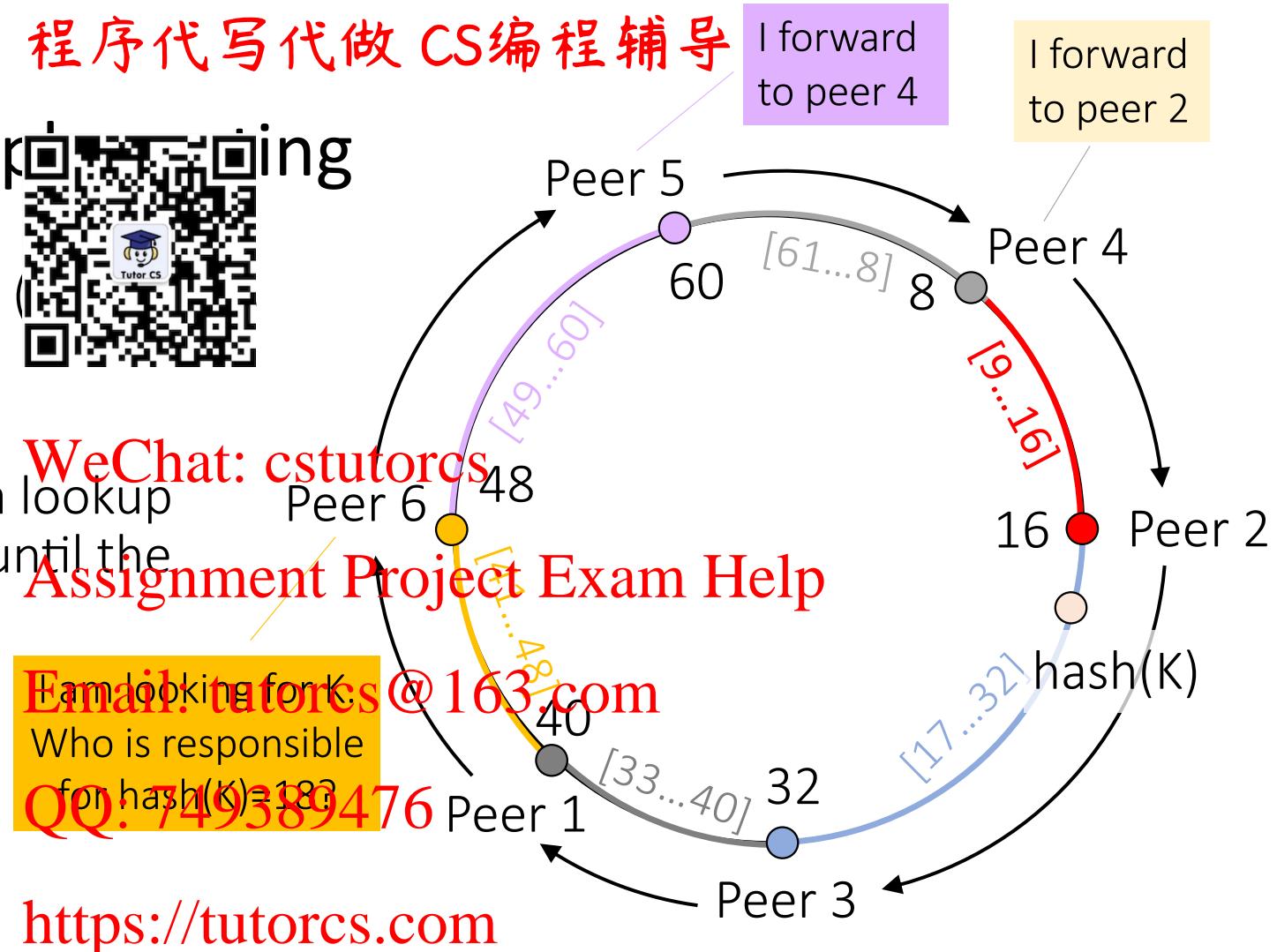
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Chord with simple routing

Each peer keeps a pointer (IP address and port) to its successor



Simple Routing: Forward a lookup request to the successor until the correct peer is found



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Chord with simple routing

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Simple Routing: Forward a lookup request to the successor until the correct peer is found

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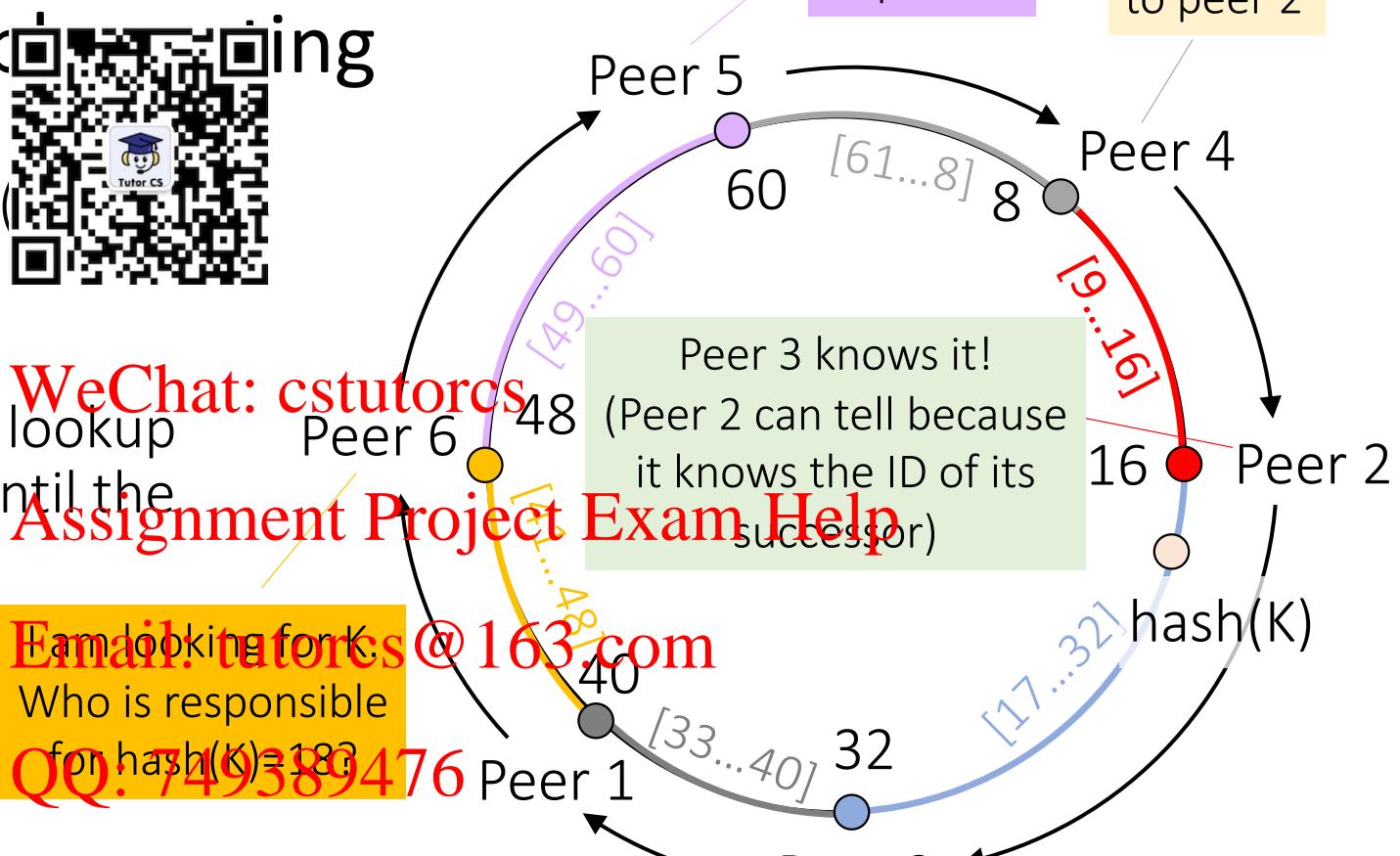
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Chord with simple routing

Each peer keeps a pointer (IP address and port) to its successor



Simple Routing: Forward a lookup request to the successor until the correct peer is found

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for hash(K)=18?
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Simple routing



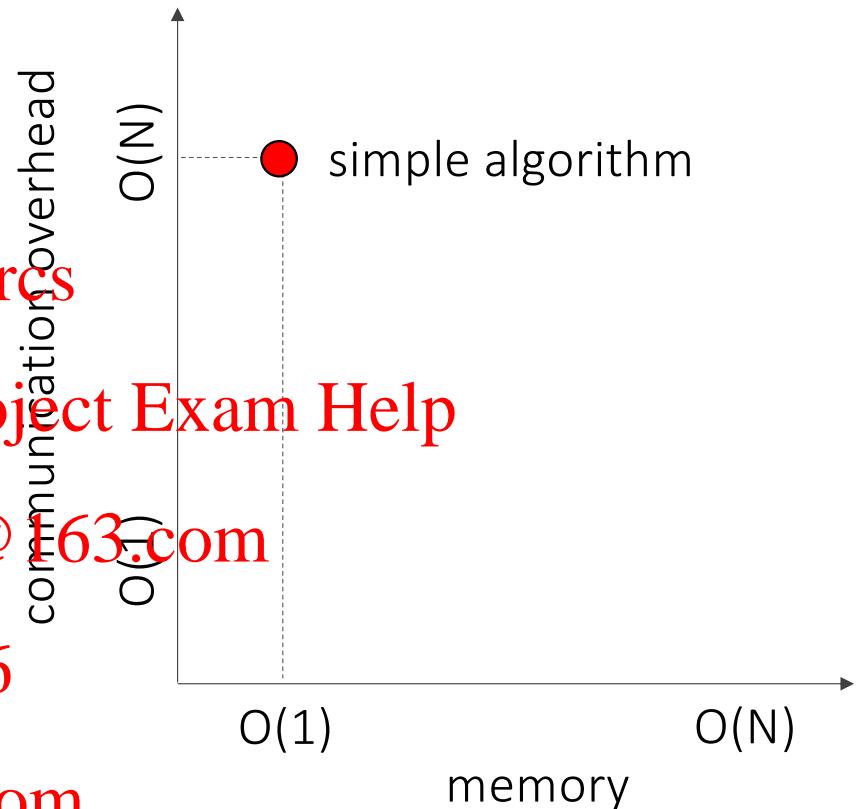
- Each node stores just its successor: $O(1)$ memory
- A request traverses $n/2$ hops on average: $O(N)$ communication
- **Not robust**: if one node fails, communication is interrupted until the mechanism converges

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Chord with simple C++

Each peer keeps a list of all peers



No routing is needed

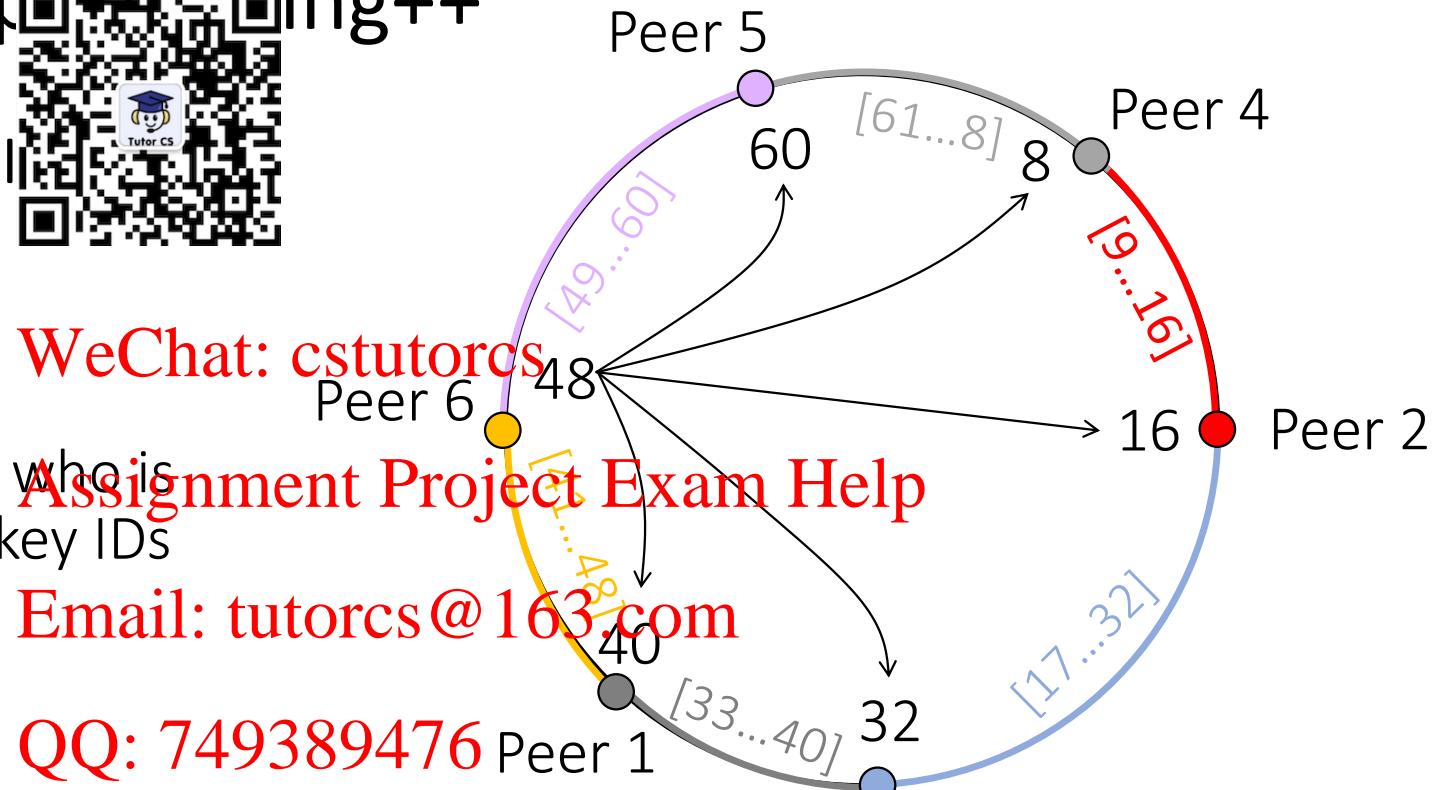
- a peer already knows who is responsible for what key IDs

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Simple routing+



- Each node stores the address of all the others: $O(N)$ memory
- A request traverses 1 hop: $O(1)$ communication
- Can we do better?

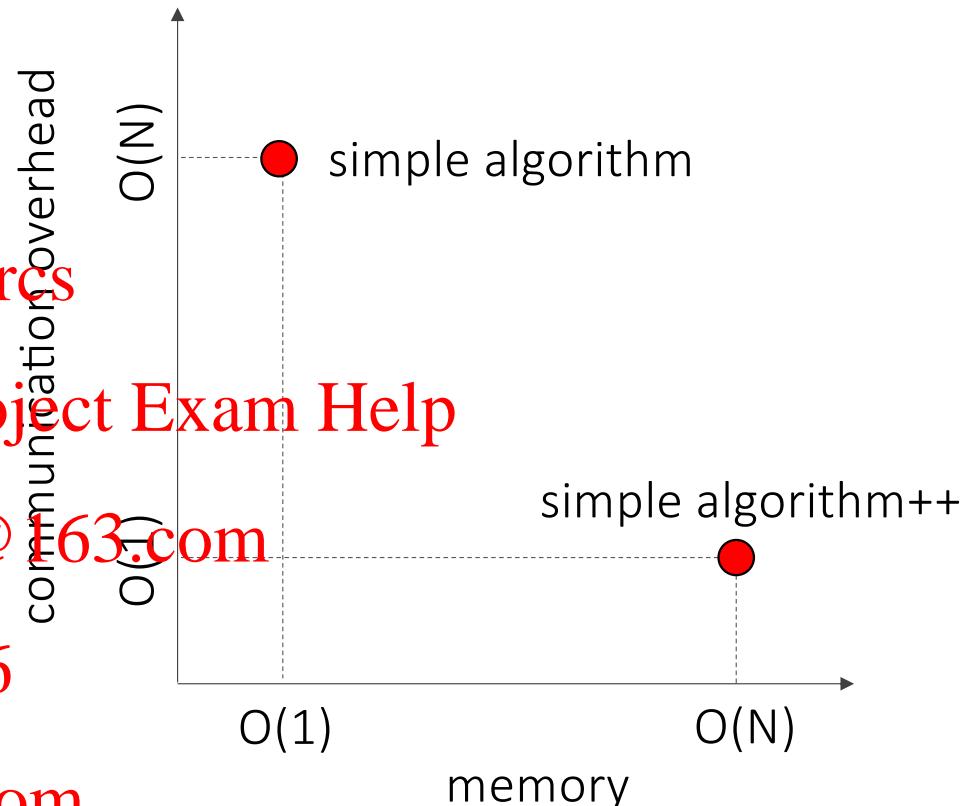
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Simple routing+



- Each node stores the address of all the others: $O(N)$ memory overhead
- A request traverses 1 hop: $O(1)$ communication overhead
- Can we do better?

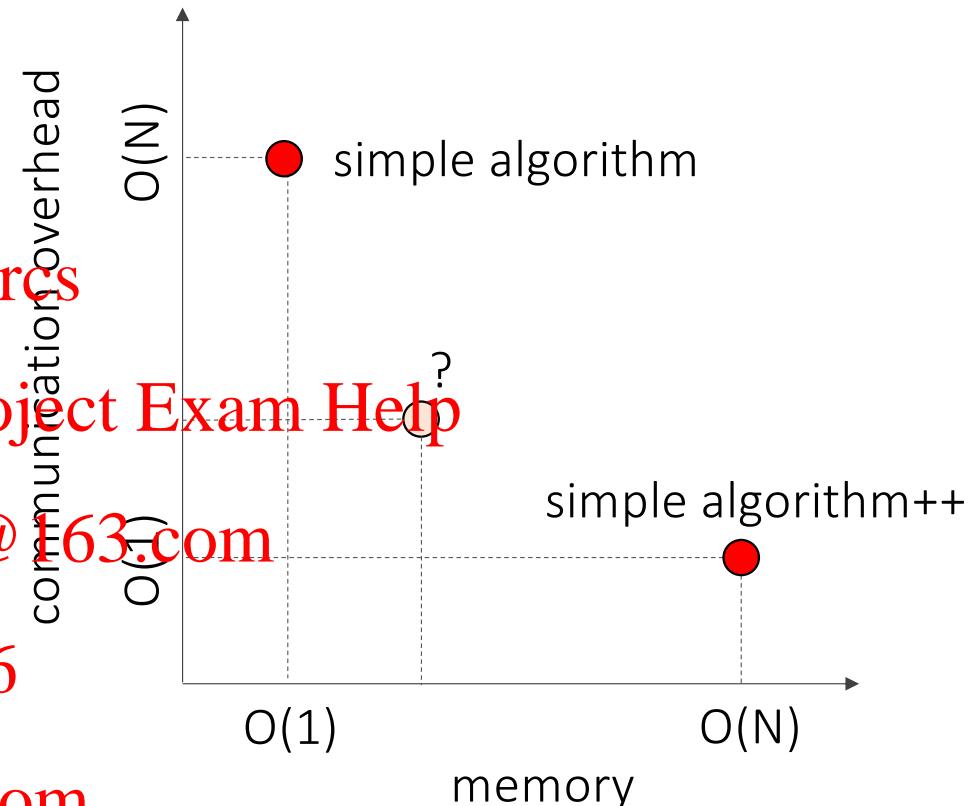
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Finger tables

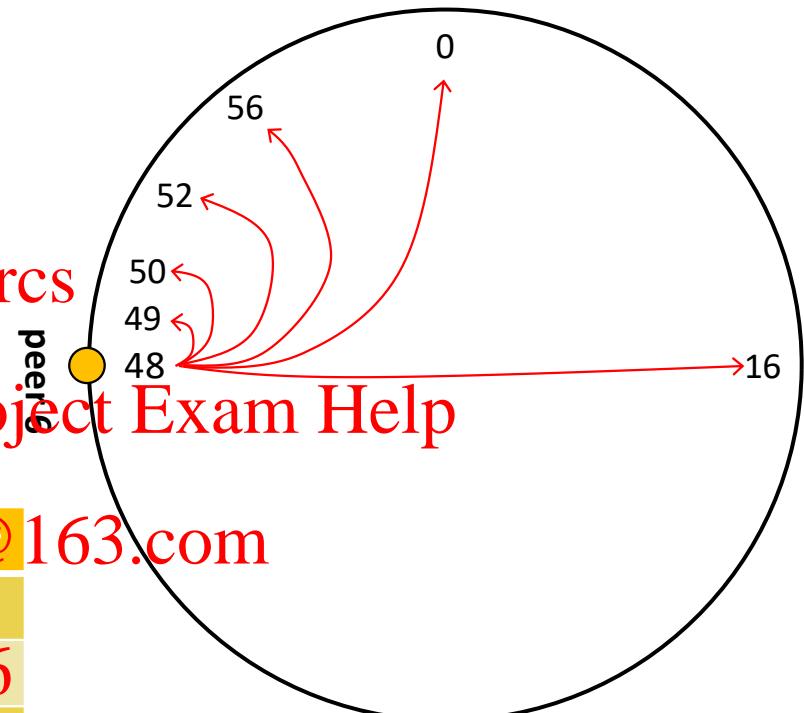
Peer k stores information about its authority at increasing exponentially increasing distance

- distances are power of 2
- $k + 2^i \bmod (2^m)$, for each $i=0, \dots, m-1$

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i	$48 + 2^i \bmod 64$
0	$48 + 2^0 \bmod 64 = 49$
1	$48 + 2^1 \bmod 64 = 50$
2	$48 + 2^2 \bmod 64 = 52$
3	$48 + 2^3 \bmod 64 = 56$
4	$48 + 2^4 \bmod 64 = 0$
5	$48 + 2^5 \bmod 64 = 16$

Finger table at
peer 6



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Routing with finger tables

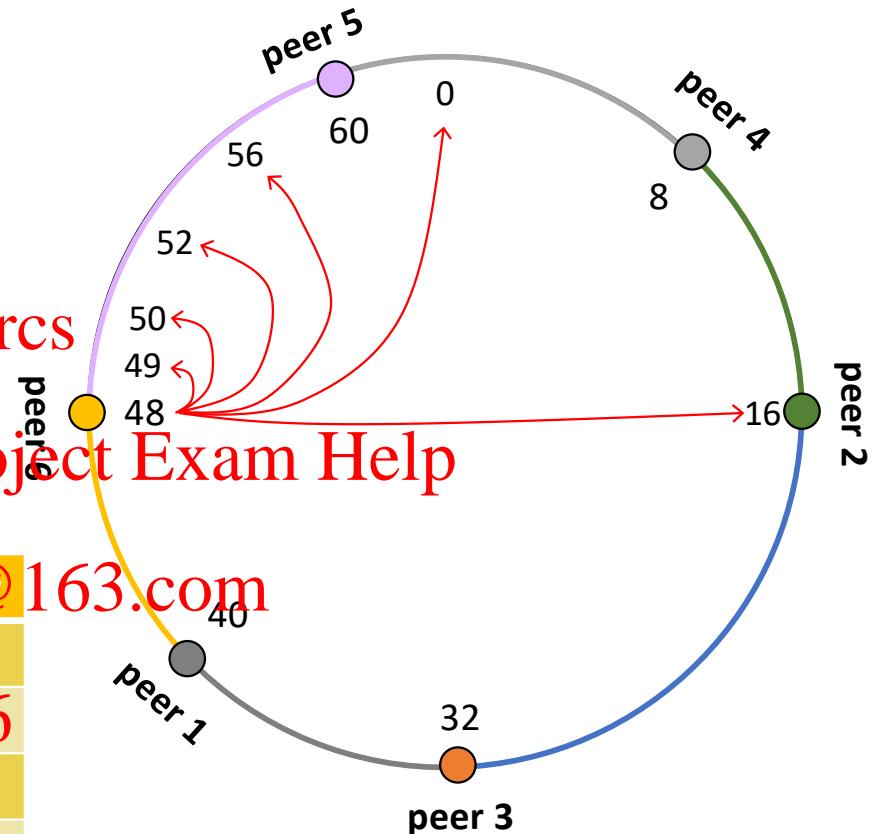
Peer k stores information about authority at increasing exponential distance

- distances are power of 2
- $k + 2^i \bmod (2^m)$, for each $i=0, \dots, m-1$

i	Rep ID	Successor
0	$48 + 2^0 \bmod 64 = 49$	Peer 5
1	$48 + 2^1 \bmod 64 = 50$	Peer 5
2	$48 + 2^2 \bmod 64 = 52$	Peer 5
3	$48 + 2^3 \bmod 64 = 56$	Peer 5
4	$48 + 2^4 \bmod 64 = 0$	Peer 4
5	$48 + 2^5 \bmod 64 = 16$	Peer 2

Finger table at
peer 6

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Routing with finger tables



I am looking
for 18

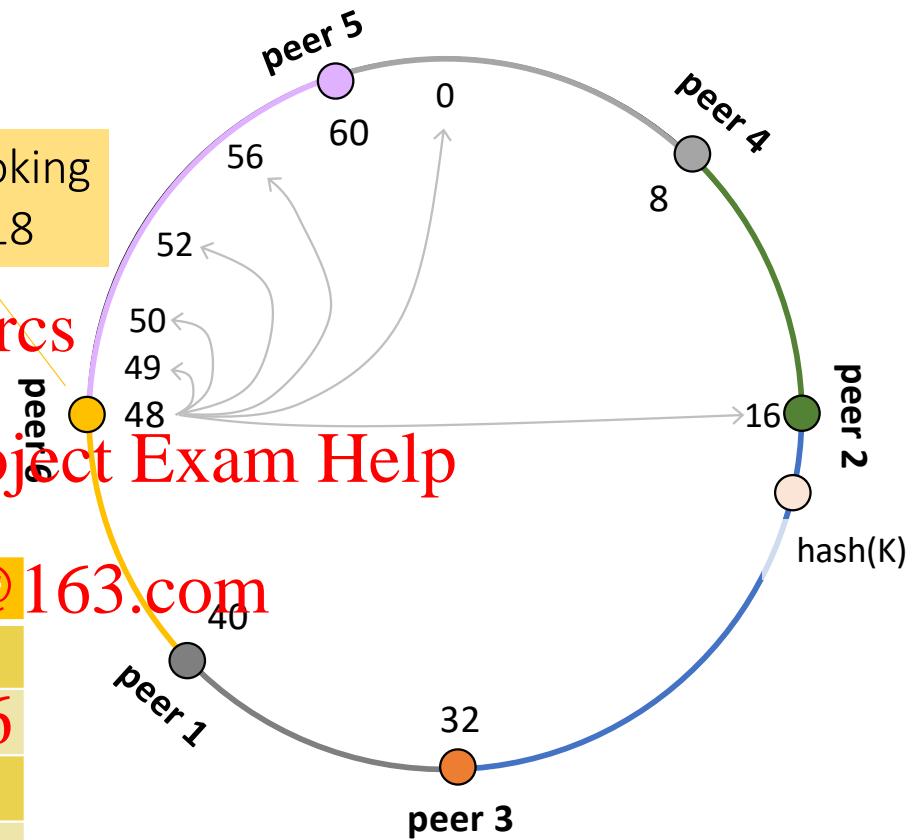
Each peer sends a request to the closest successor peer that precedes or equal the key ID

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Finger table at
peer 6

i	key range	successor
0	$48 + 2^0 \bmod 64 = 49$	Peer 5
1	$48 + 2^1 \bmod 64 = 50$	Peer 5
2	$48 + 2^2 \bmod 64 = 52$	Peer 5
3	$48 + 2^3 \bmod 64 = 56$	Peer 5
4	$48 + 2^4 \bmod 64 = 0$	Peer 4
5	$48 + 2^5 \bmod 64 = 16$	Peer 2

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Routing with finger tables



I am looking
for 18

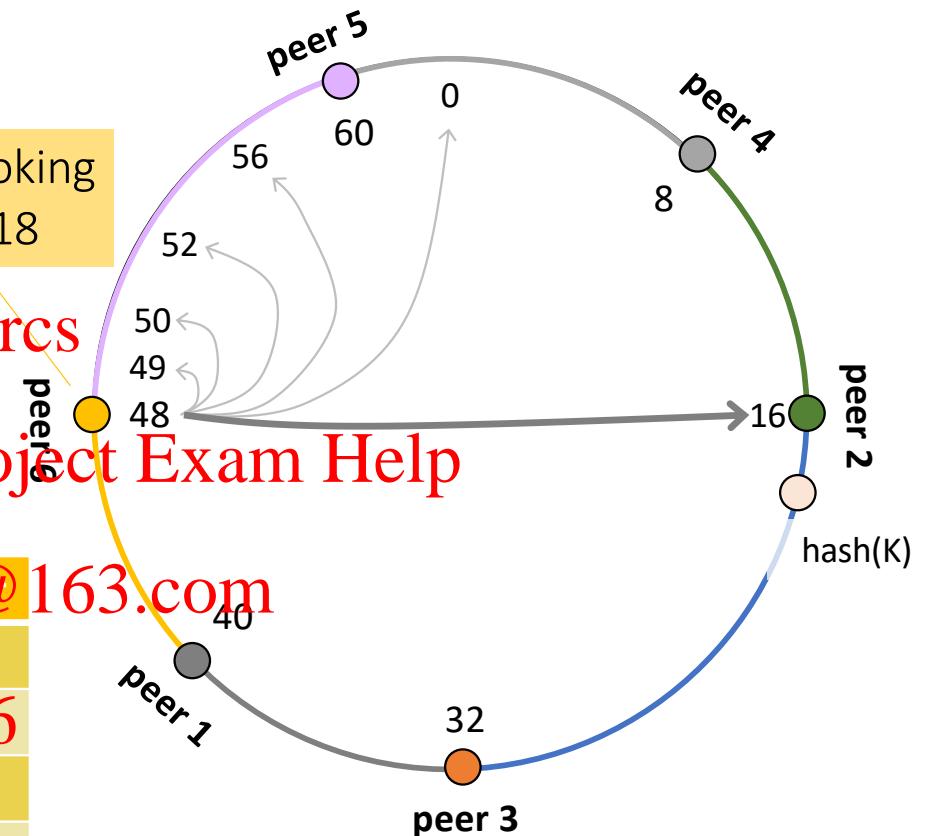
Each peer sends a request to the closest successor peer that precedes or equal the key ID

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Finger table at
peer 6

i	key range	successor
0	$48 + 2^0 \bmod 64 = 49$	Peer 5
1	$48 + 2^1 \bmod 64 = 50$	Peer 5
2	$48 + 2^2 \bmod 64 = 52$	Peer 5
3	$48 + 2^3 \bmod 64 = 56$	Peer 5
4	$48 + 2^4 \bmod 64 = 0$	Peer 4
5	$48 + 2^5 \bmod 64 = 16$	Peer 2

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Routing with finger tables



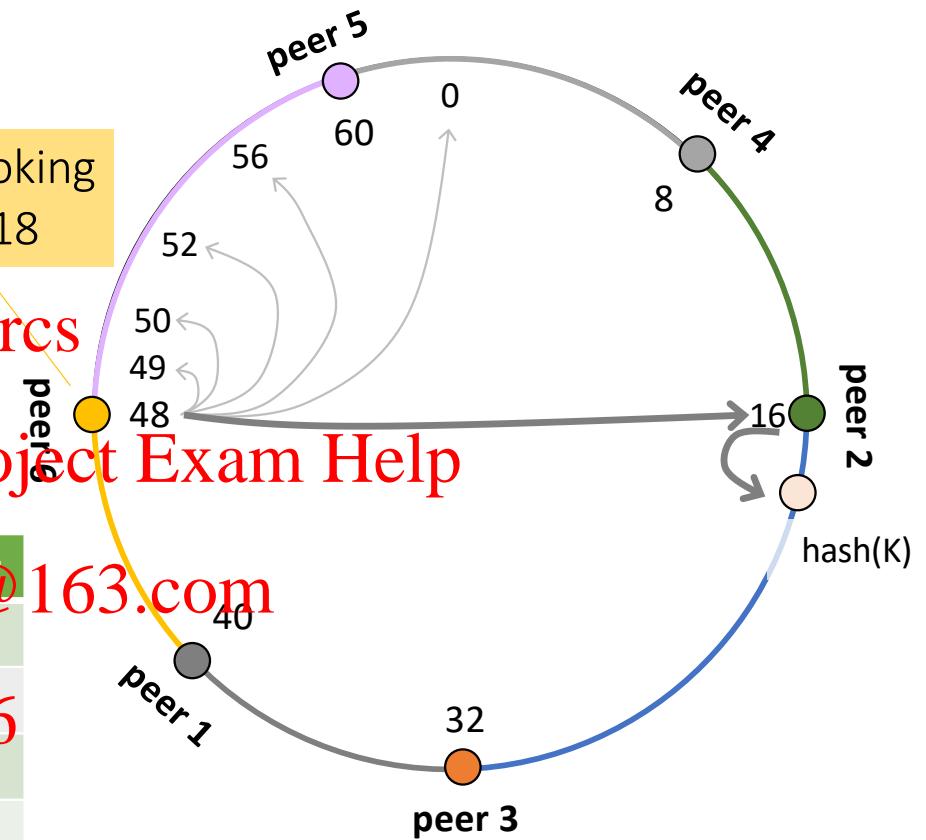
I am looking
for 18

Each peer sends a request to the closest successor peer that precedes or equal the key ID

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Finger table at
peer 2

i	key id	successor
0	$16 + 2^0 \bmod 64 = 17$	peer 3
1	$16 + 2^1 \bmod 64 = 18$	peer 3
2	$16 + 2^2 \bmod 64 = 20$	peer 3
3	$16 + 2^3 \bmod 64 = 24$	peer 3
4	$16 + 2^4 \bmod 64 = 32$	peer 3
5	$16 + 2^5 \bmod 64 = 48$	peer 6



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Routing with finger tables



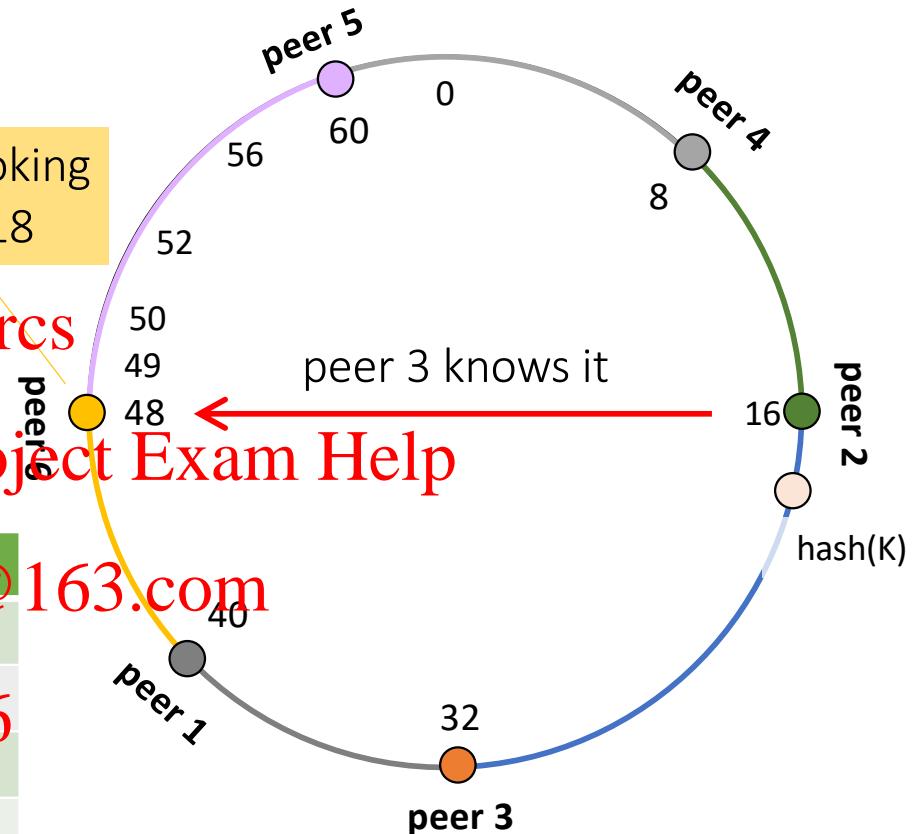
I am looking
for 18

Each peer sends a request to the closest successor peer that precedes or equal the key ID

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Finger table at
peer 2

i	key id	successor
0	$16 + 2^0 \bmod 64 = 17$	peer 3
1	$16 + 2^1 \bmod 64 = 18$	peer 3
2	$16 + 2^2 \bmod 64 = 20$	peer 3
3	$16 + 2^3 \bmod 64 = 24$	peer 3
4	$16 + 2^4 \bmod 64 = 32$	peer 3
5	$16 + 2^5 \bmod 64 = 48$	peer 6



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Chord (finger table analysis)

Each node stores a subset of other nodes:

- $O(\log N)$ memory



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The search space is halved at each hop:

- $O(\log N)$ communication

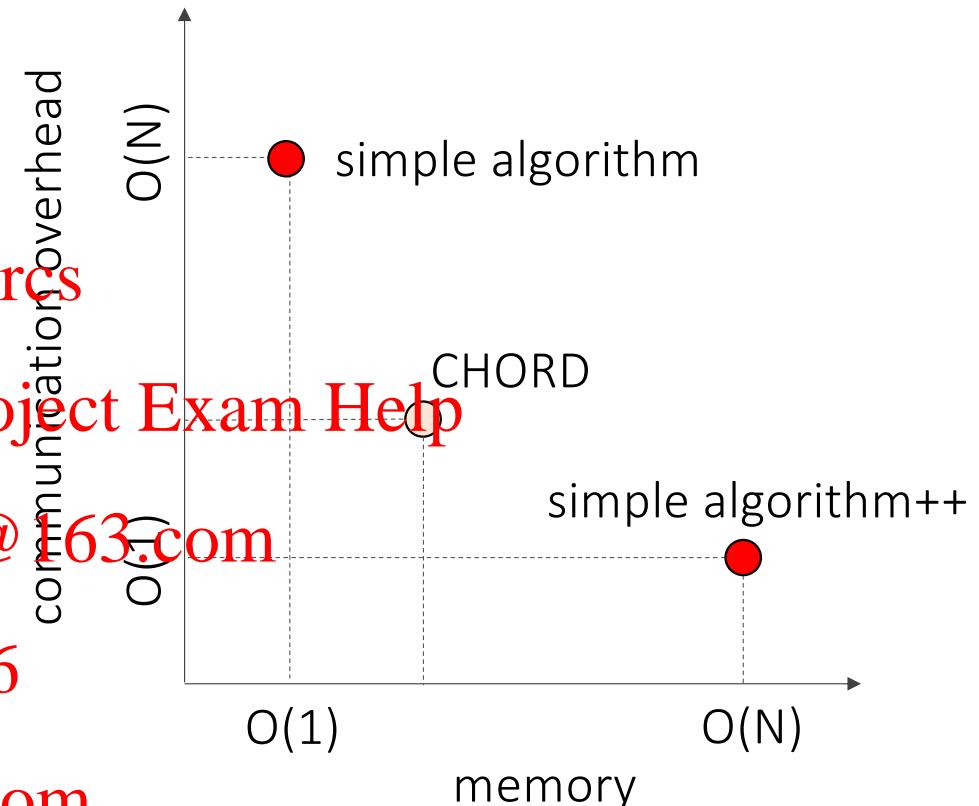
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More robust: unless the authority peer
of the key ID fails, lookup operations
work correctly

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What we have seen in one slide summary

- Many different types of networks: centralized, flooding, hierarchical



- Issues:

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- Failure mode: single point of failure?
- Flooding is onerous
- Network topology different than overlay topology
- Nodes are not all the same
- Search can be hard

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