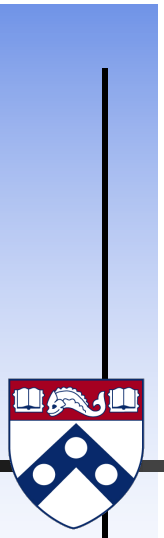


CIS 5530: Networked Systems

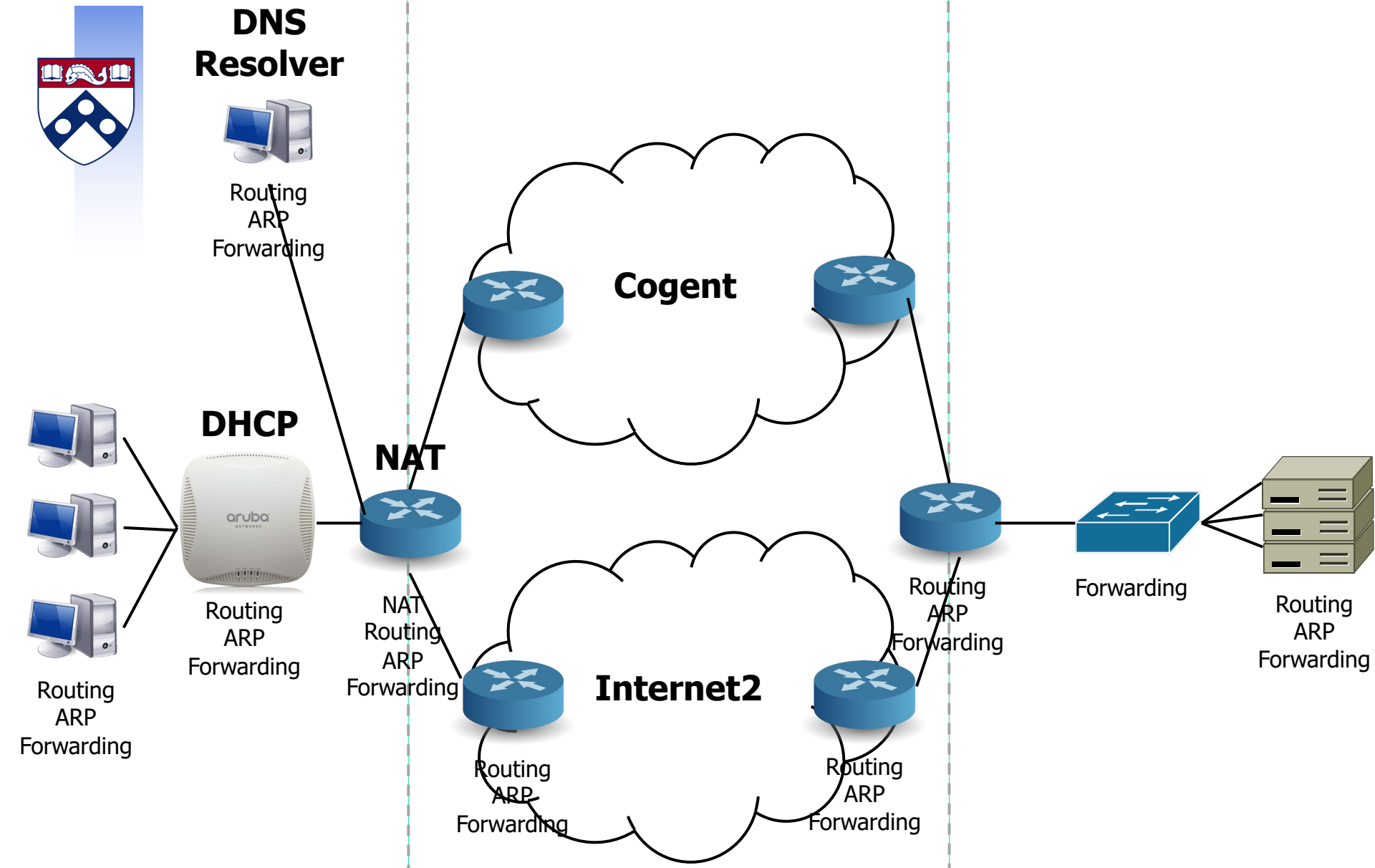
Overlay Networks

February 27, 2023

Agenda

- Putting it all together 
- Overlay Networks 

  - DHTs
  - Content Addressable Networks


DNS Resolver
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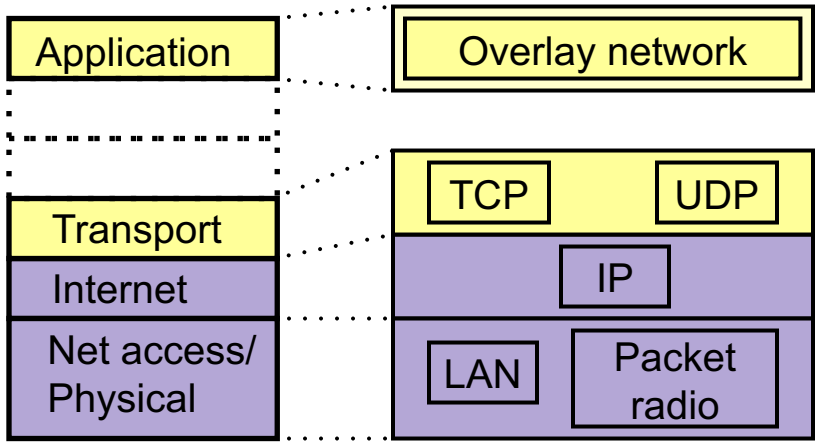
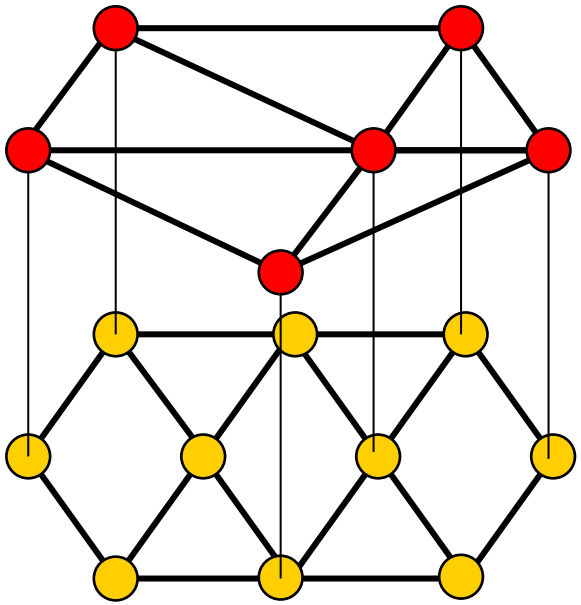
What Is an Overlay?

- "Overlay network"
  - Network layer at the application level
  - Each node is an end-host. Forms a network among end-hosts.
- Examples: Bittorrent, Tor, etc.
- Why overlay networks?
  - Add new functionalities. E.g. route by content rather than addresses, route to many nodes (multicast)
  - Address existing limitations - reliability, security, performance



Overlay Network



Overlay

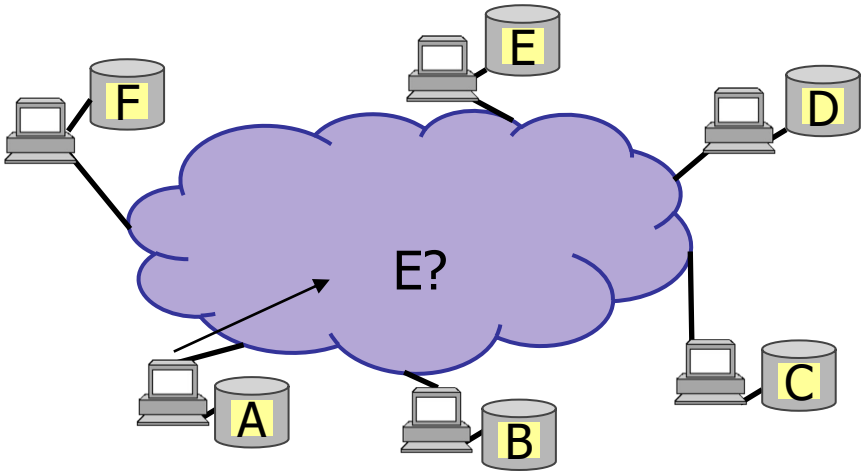
Internet

Overlay API
E.g. route(key), send(group,Msg), etc.

Transport API:
send(Addr:Port, Packet)

Example: P2P Keyword Search

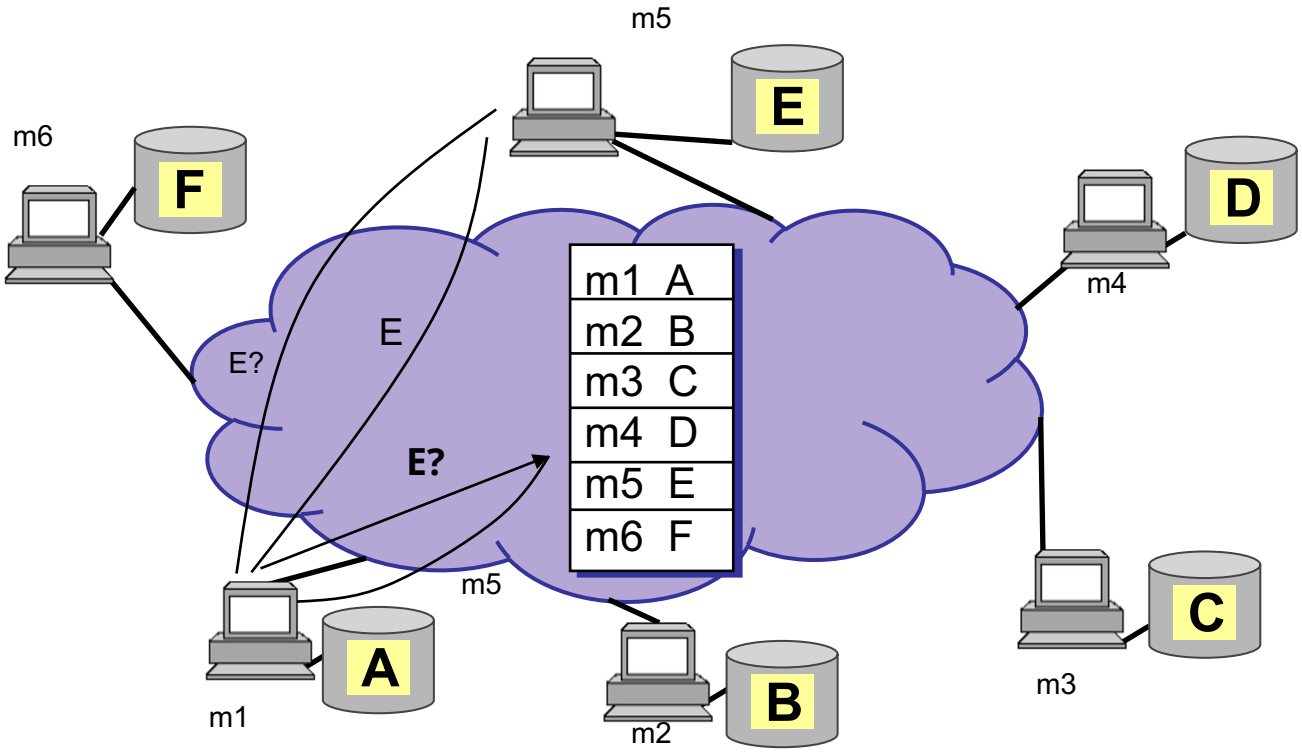
- Each user stores a subset of items (files). Each item has a number of keywords associated with it.
- Given keyword (or keywords), find where a particular item is stored based on its name



Solution 1: Centralized Index

- Example: Napster
- Assume a centralized index system that maps files to machines that
  are alive
- How to find a file
  - Query the index system → return a machine that stores the required file
    - Ideally this is the closest/least-loaded machine
  - Download the file via FTP
- Advantages:
  - Simplicity, easy to implement sophisticated search engines on top of the index system
- Disadvantages:
  - Robustness, scalability

Example

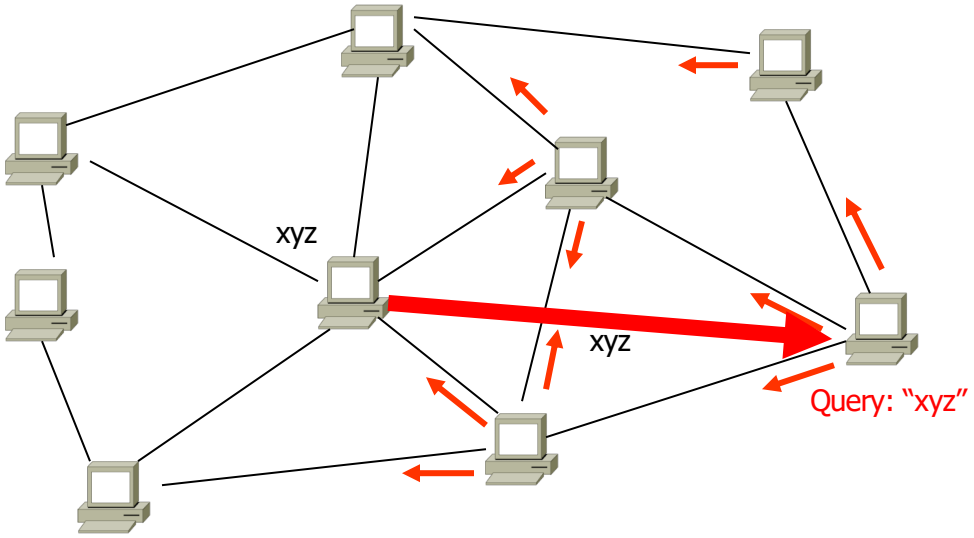


Solution 2: Flood-based Approach

- Example: Gnutella network
- Flood-based protocol:
  - Send request to all neighbors
  - Neighbors recursively forward the request
  - Eventually a machine that has the file receives the request, and it sends back the answer
- Advantages:
  - Totally decentralized, highly robust
- Disadvantages:
  - Not scalable; the entire network can be swamped with request (to alleviate this problem, each request has a TTL)

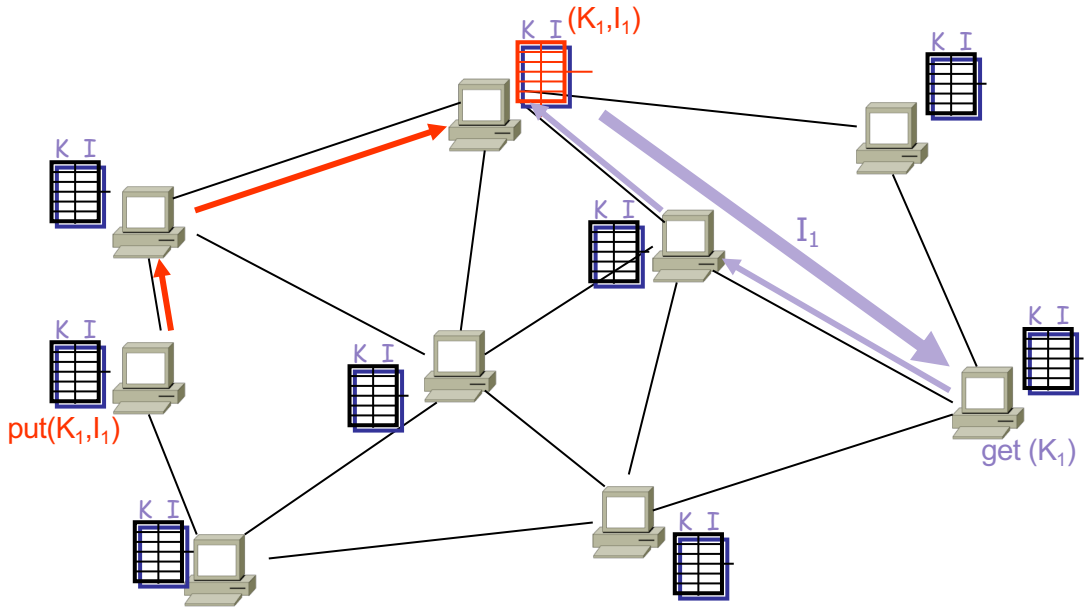
Flood-based Approach

- Ad-hoc topology
- Queries are flooded for bounded number of hops
- No guarantees on recall



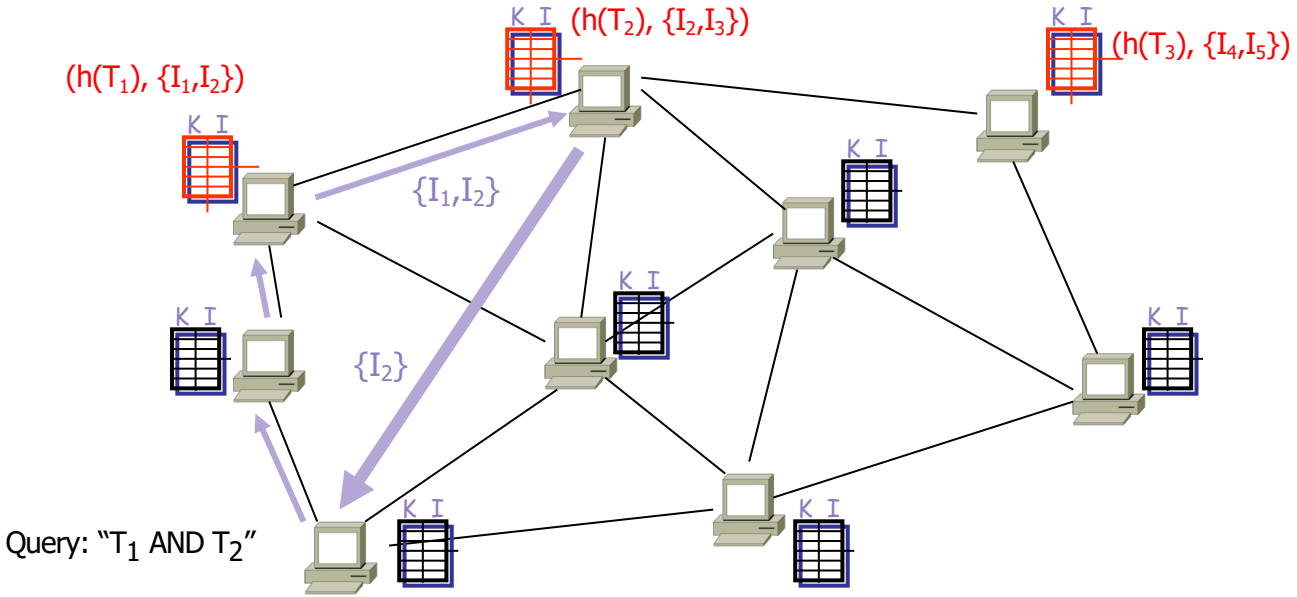
Solution 3: DHT-based Approach

- Distributed Hash Tables (DHTs)
- Hash table interface: put(key,item), get(key)
- O(log n) hops
- Guarantees on recall



Keyword Search Using DHTs

- Inverted Lists hashed by keyword (term) in the DHT



Agenda

- Putting it all together ✓
- Overlay Networks ✓
  - DHTs ✓
  - Content Addressable Networks ← NEXT
  - Chord

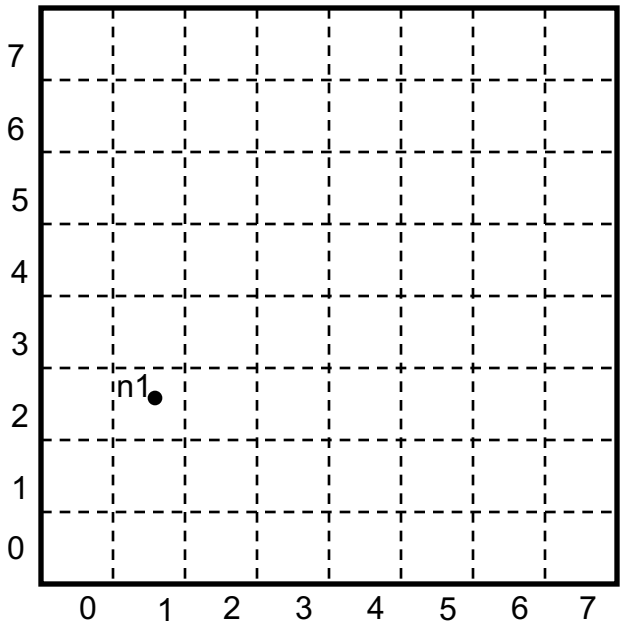
Content Addressable Network (CAN)

- Associate to each node and item a unique id in an d-dimensional Coordinate space

- Properties
  - Routing table size O(d)
  - Guarantees that a file is found in at most d*n1/d steps, where n is the total number of nodes

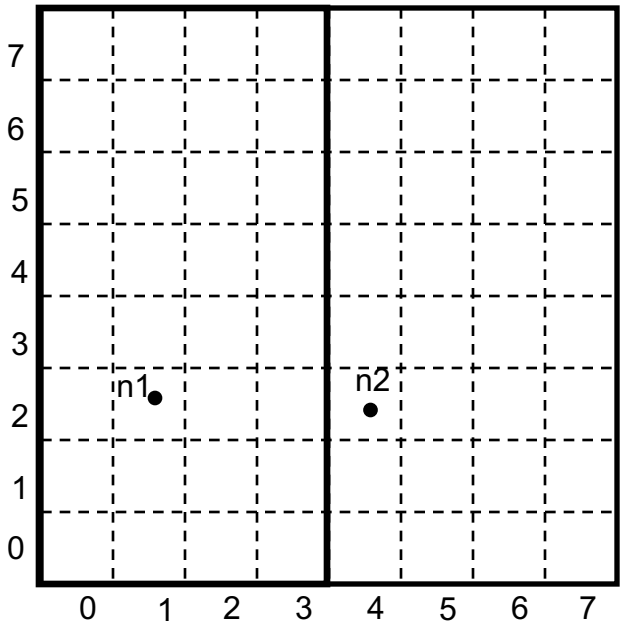
CAN Example: Two Dimensional Space

- Space divided between nodes
- All nodes cover the entire space
- Each node covers either a square or a rectangular area of ratios 1:2 or 2:1
- Example:
  - Node n1:(1, 2) first node that joins → cover the entire space



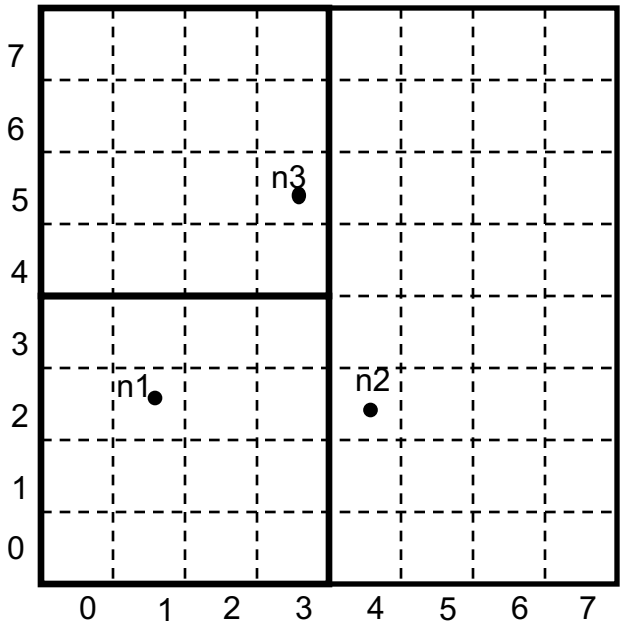
CAN Example: Two Dimensional Space

- Node n2:(4, 2) joins → space is divided between n1 and n2



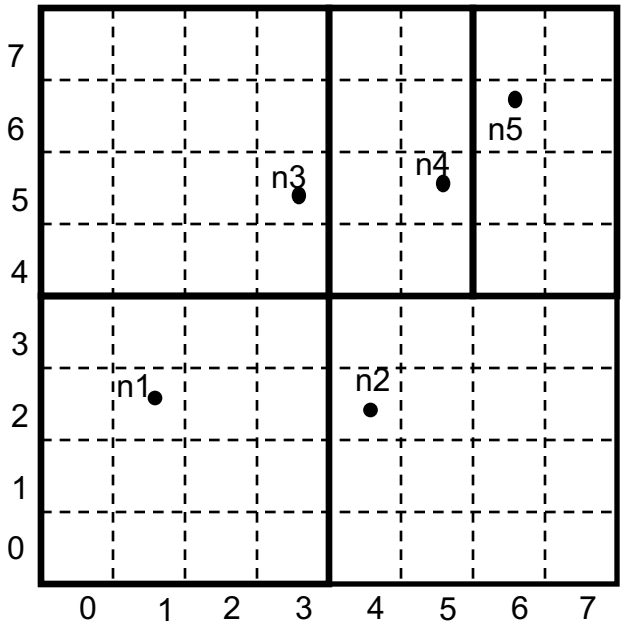
CAN Example: Two Dimensional Space

- Node n3:(3, 5) joins → space is divided between n1 and n3



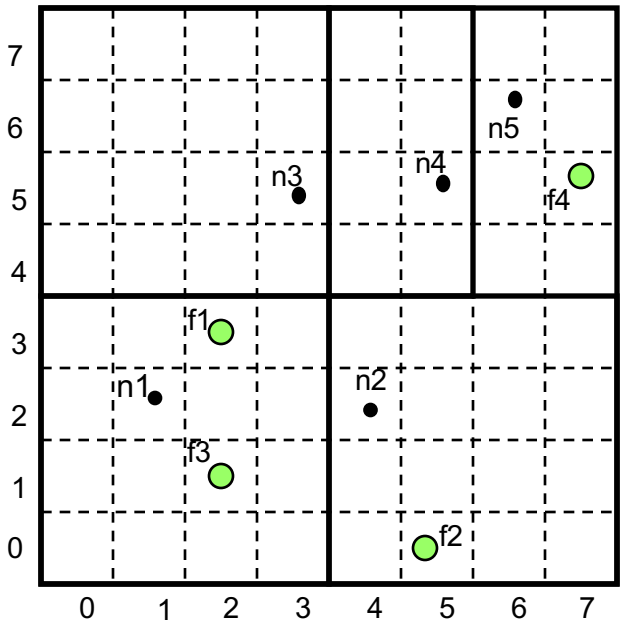
CAN Example: Two Dimensional Space

- Nodes n4:(5, 5) and n5:(6,6) join



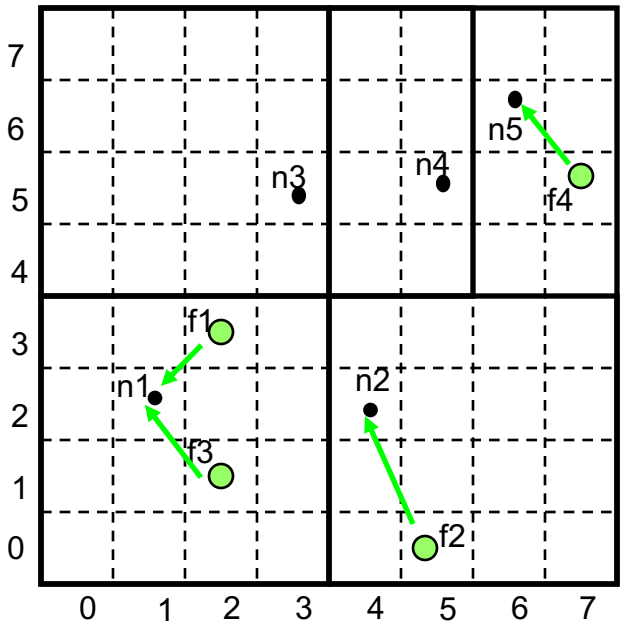
CAN Example: Two Dimensional Space

- Nodes: n1:(1, 2); n2:(4,2); n3:(3, 5); n4:(5,5);n5:(6,6)
- Items: f1:(2,3); f2:(5,1); f3:(2,1); f4:(7,5);



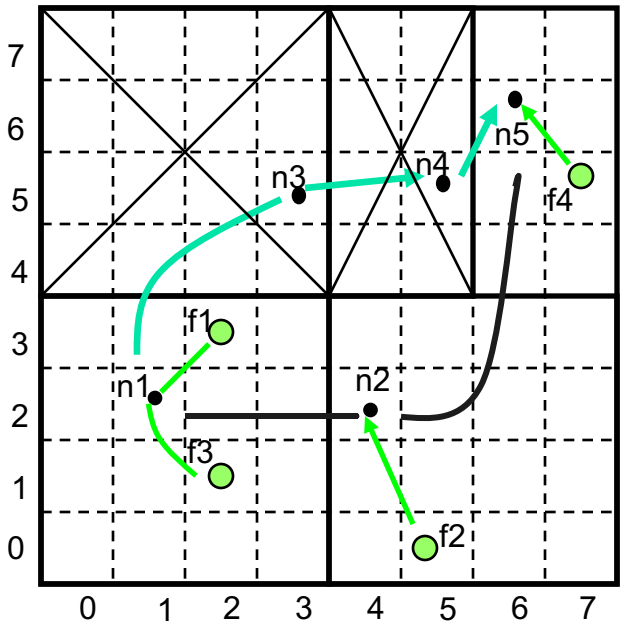
CAN Example: Two Dimensional Space

- Each item is stored by the node who owns its mapping in the space

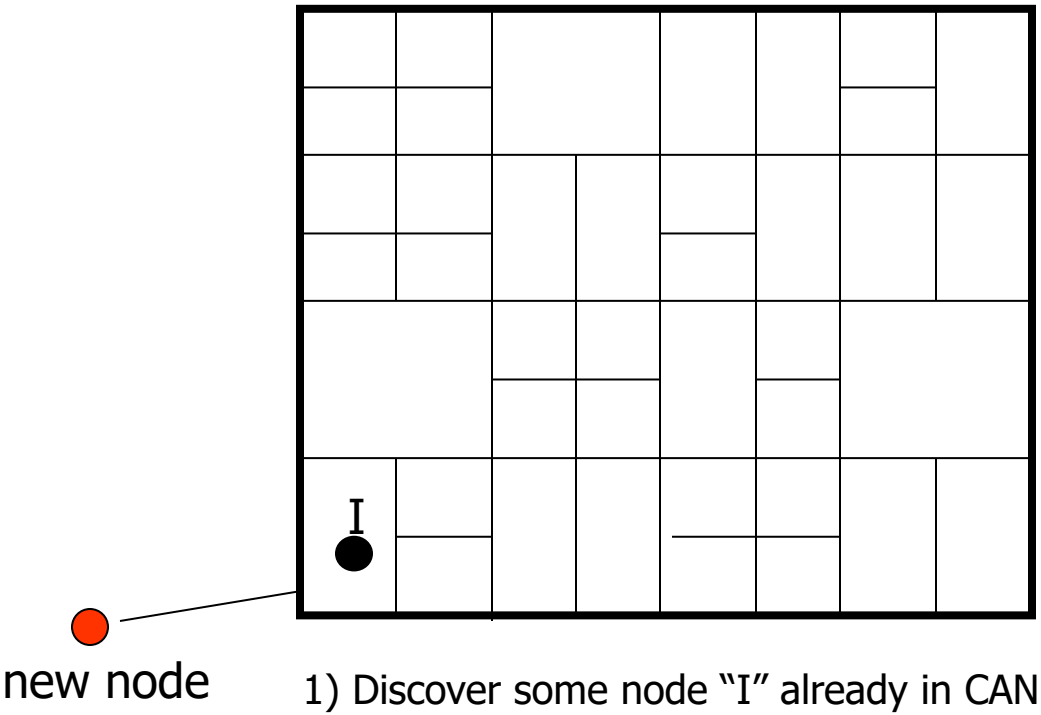


CAN: Query Example

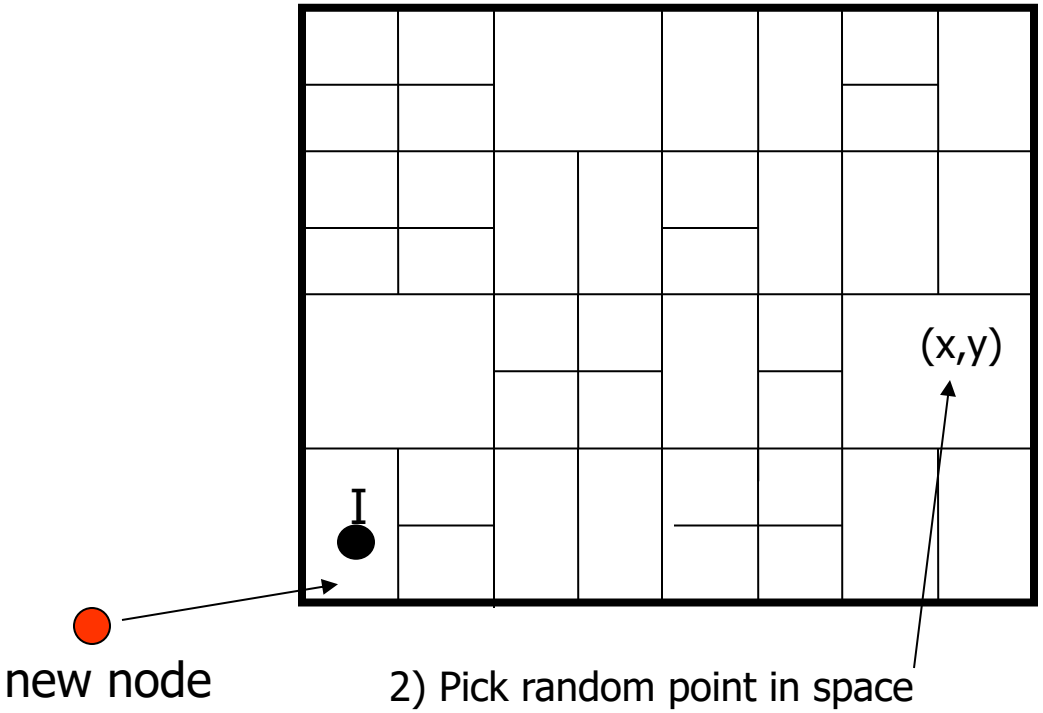
- Each node knows its neighbors in the d-space
- Forward query to the neighbor that is closest to the query id
- Example: assume n1 queries f4
- Can route around some failures



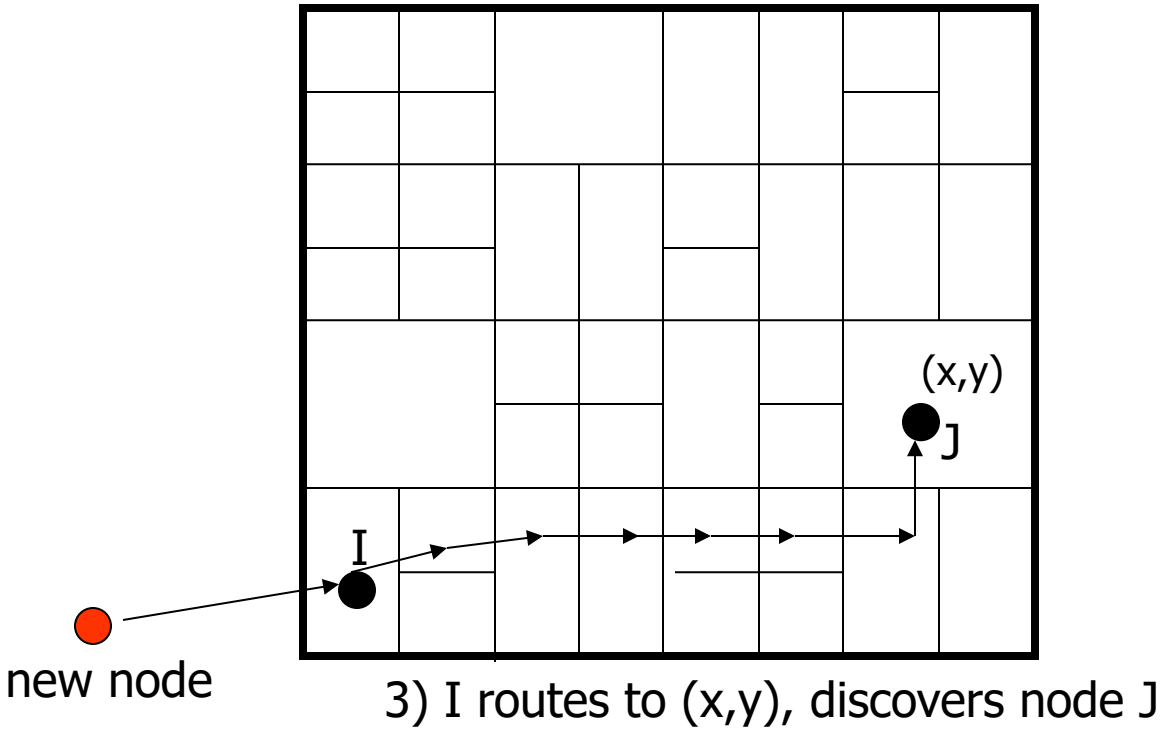
CAN: Node Joining



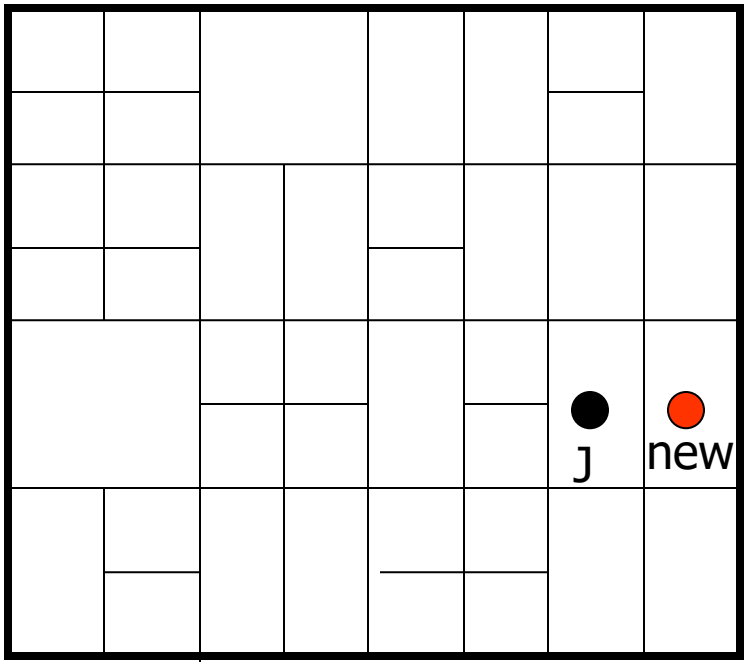
CAN: Node Joining



CAN: Node Joining



CAN: Node Joining



4) split J's zone in half… new node owns one half

Node Departure

- Node explicitly hands over its zone and the associated (key,value) database to one of its neighbors
- In case of network failure this is handled by a take-over algorithm
- Problem : take over mechanism does not provide regeneration of data
- Solution: every node has a backup of its neighbours

Chord

- Associate to each node and item a unique id in an uni-dimensional space 0..2m-1
- Key design decision
  - Decouple correctness from efficiency
- Properties
  - Routing table size O(log(N)) , where N is the total number of nodes
  - Guarantees that a item is found in O(log(N)) steps using its key

Review: Simple Hashing

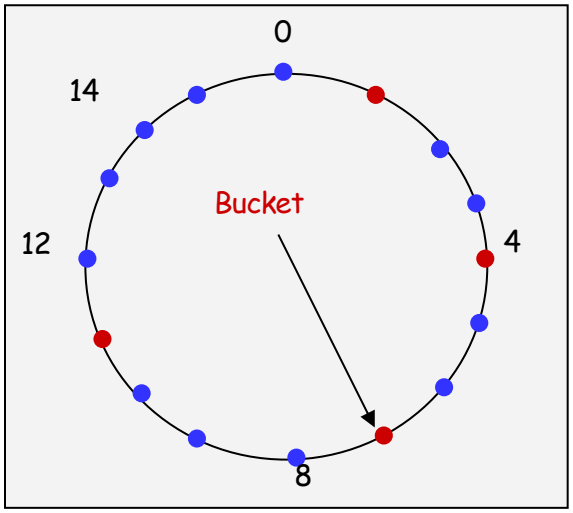
- Given document XYZ, we need to choose a server to use
- Suppose we use modulo
- Number servers from 1…n
  - Place document XYZ on server (XYZ mod n)
  - What happens when a servers fails? n → n-1
  - Why might this be bad?

Consistent Hash [Karger 97]

- David Karger, et al. Consistent Hashing and Random Trees: Tools for Relieving Hot Spots on the World Wide Web. STOC '97.
- Used by Akamai CDN for load balancing
- Desired features
  - Balanced – load is equal across buckets
  - Smoothness – little impact on hash bucket contents when buckets are added/removed

Consistent Hash [Karger 97]

- Construction
  - Assign each of C hash buckets to random points on mod 2n circle, where, hash key size = n.
  - Map object to random position on circle
  - Hash of object = closest clockwise bucket



- Smoothness → addition of bucket does not cause movement between existing buckets

- Balance → no bucket is responsible for large number of objects