Distributed Hash Tables

What is a DHT?

- Hash Table
  - data structure that maps “keys” to “values”
  - essential building block in software systems
- Distributed Hash Table (DHT)
  - similar, but spread across many hosts
- Interface
  - insert(key, value)
  - lookup(key)

How do DHTs work?

Every DHT node supports a single operation:

- Given *key* as input; route messages to node holding *key*
- DHTs are *content-addressable*

DHT: basic idea

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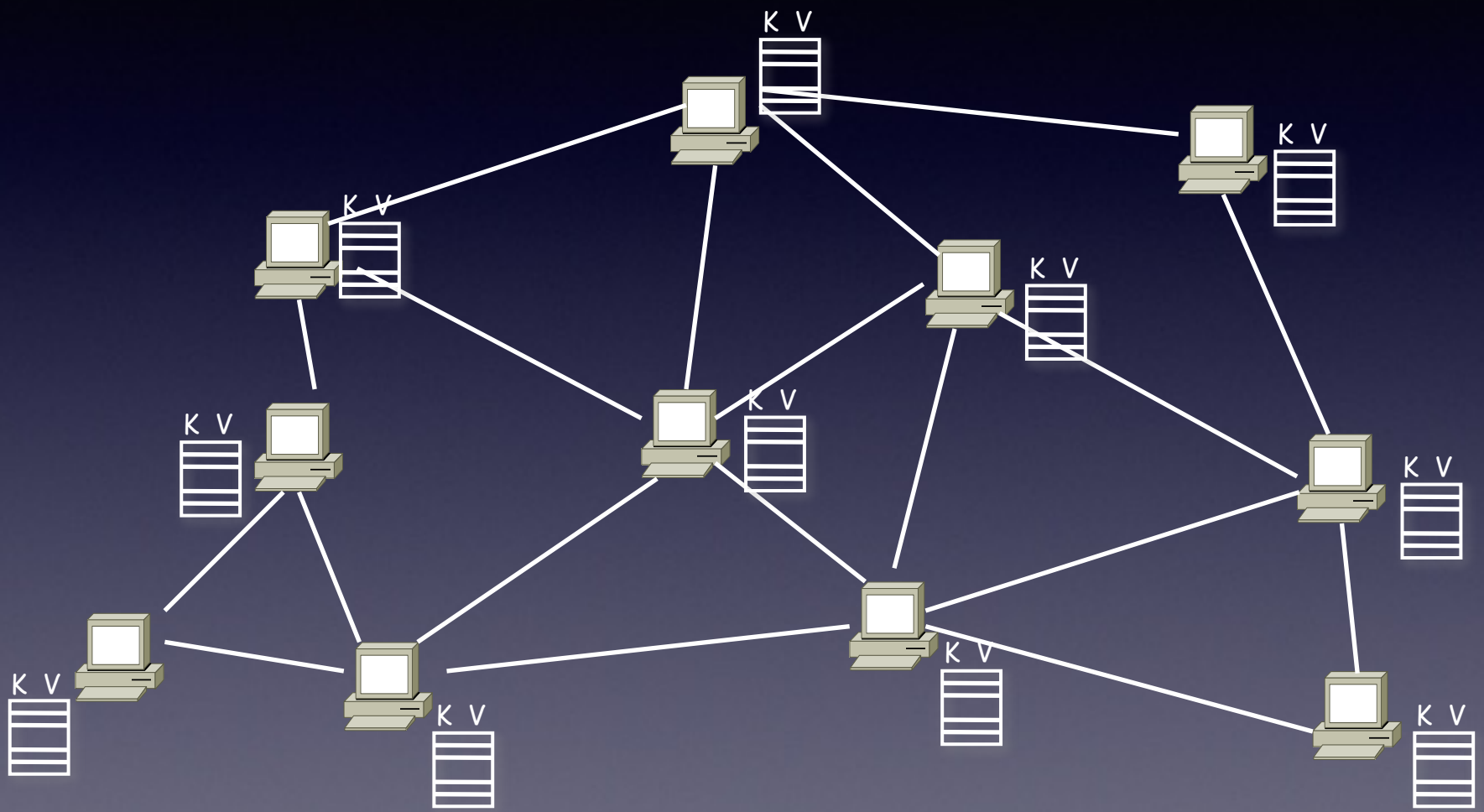
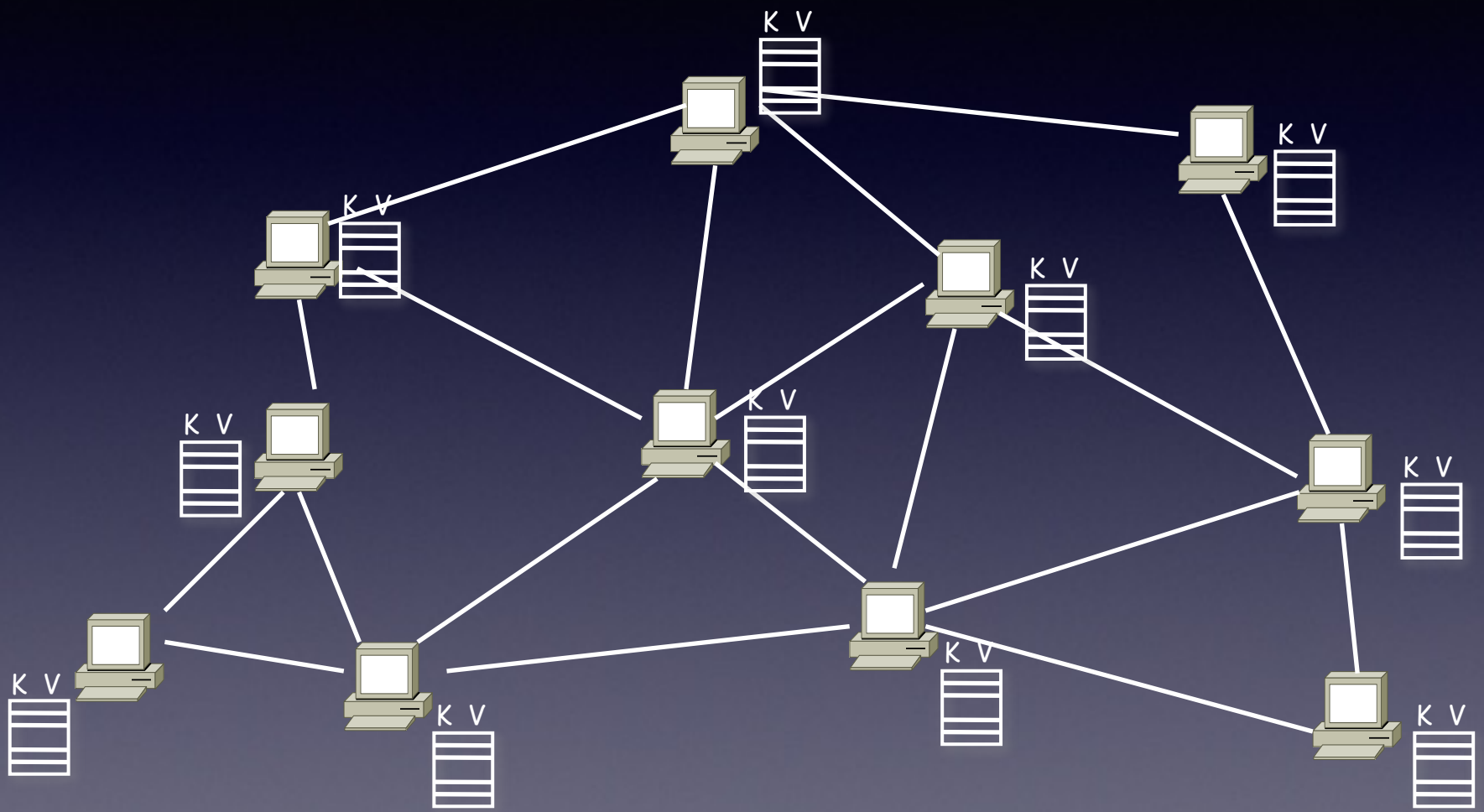


Neighboring nodes are "connected" at the application-level

DHT: basic idea



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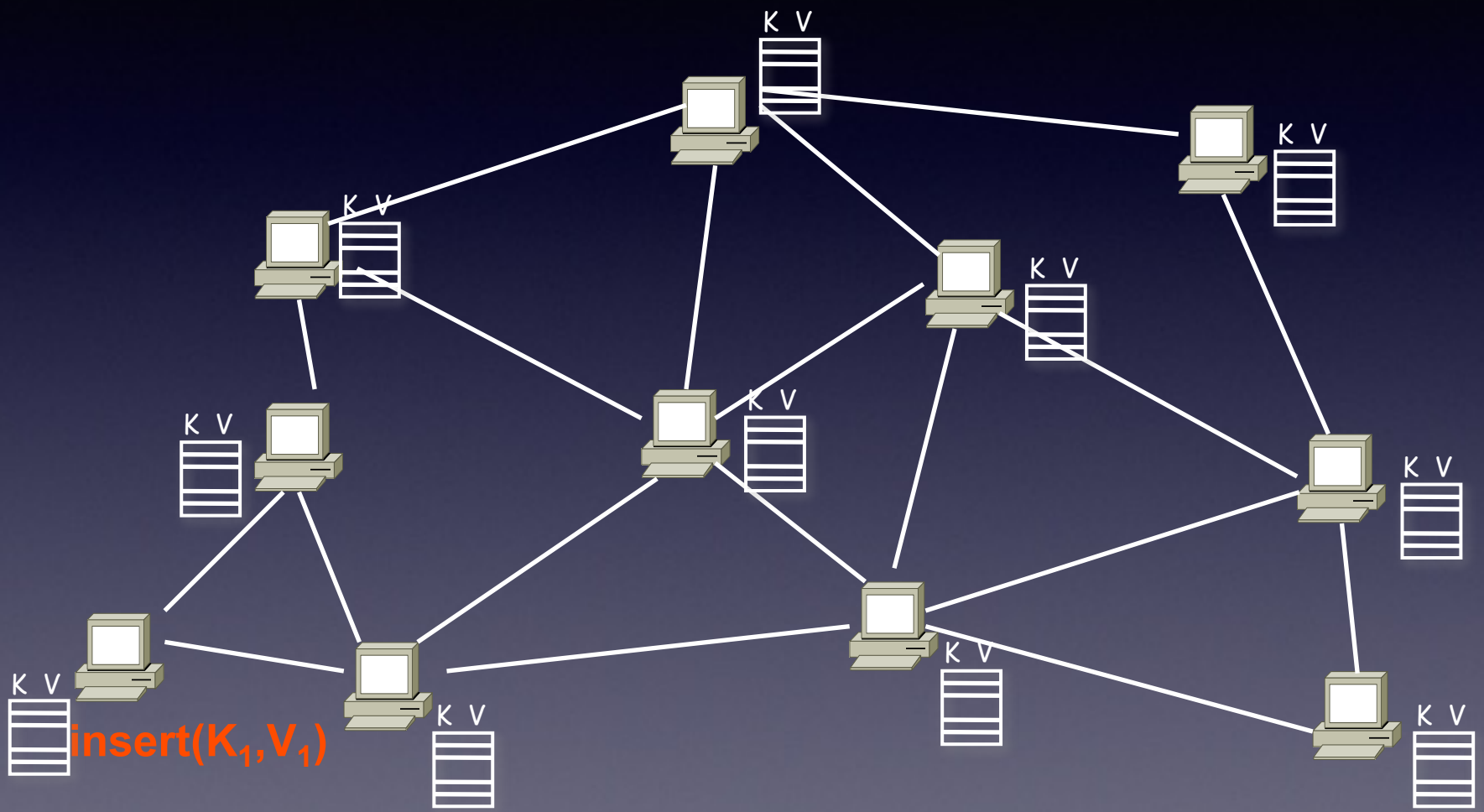

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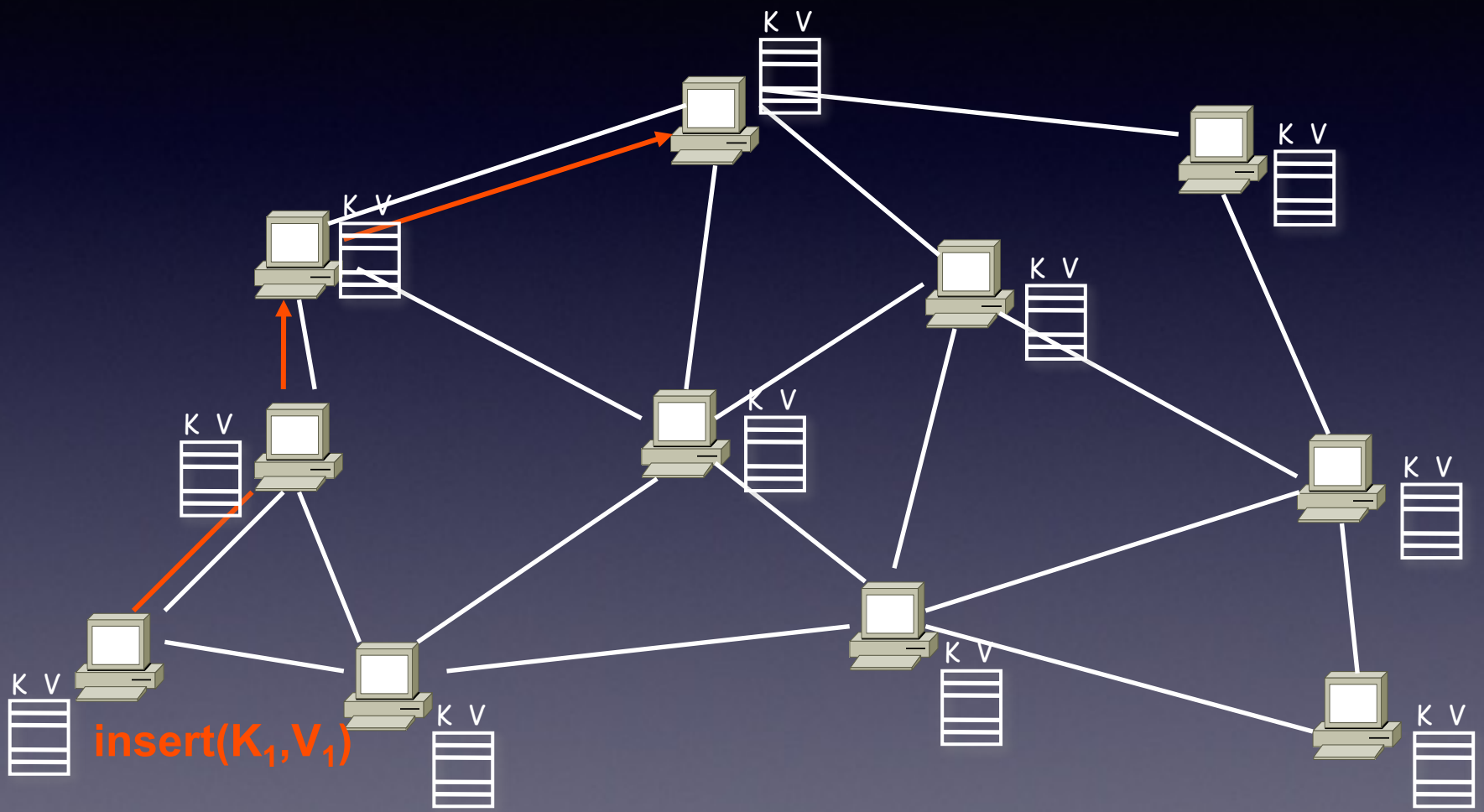

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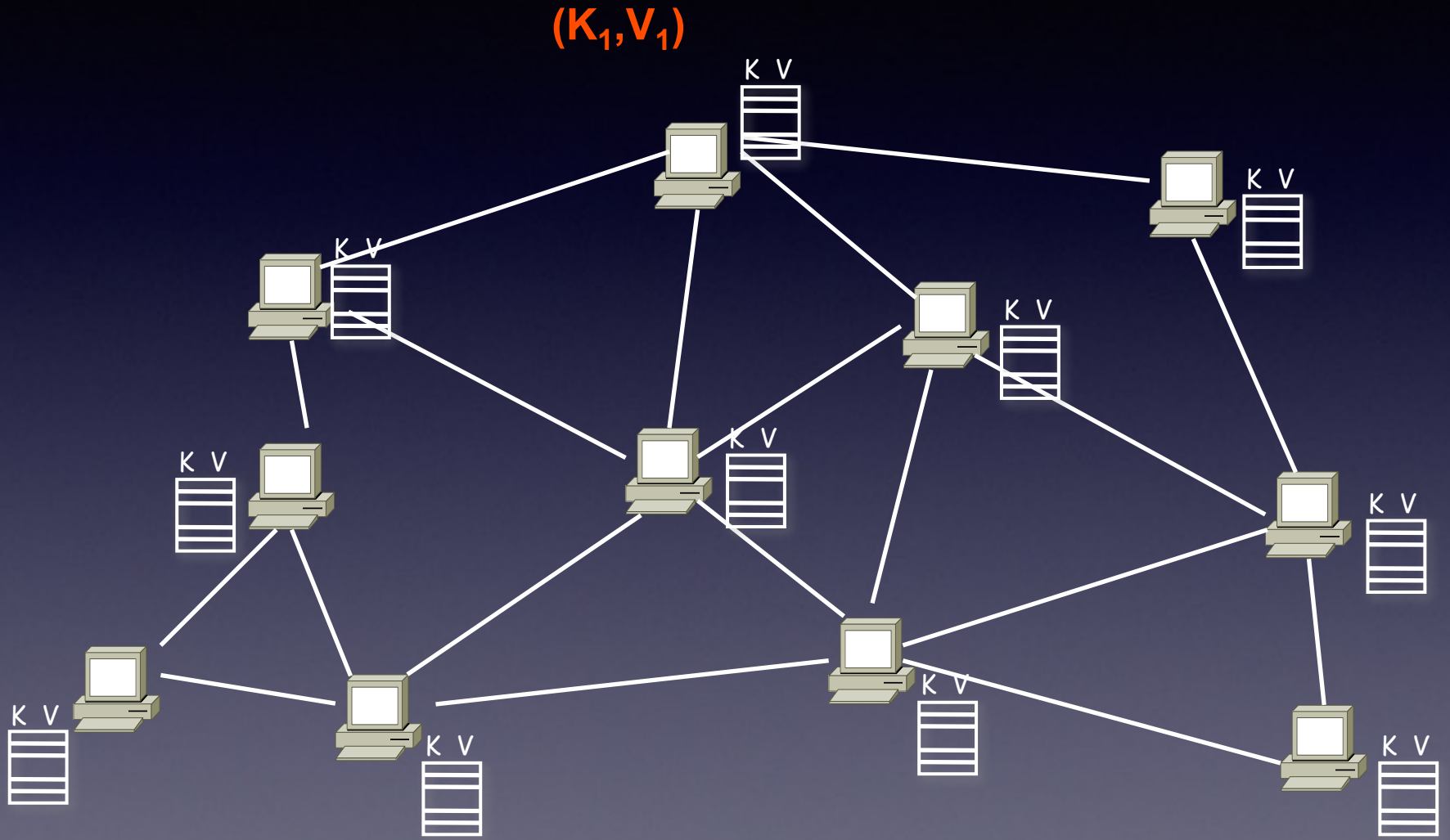

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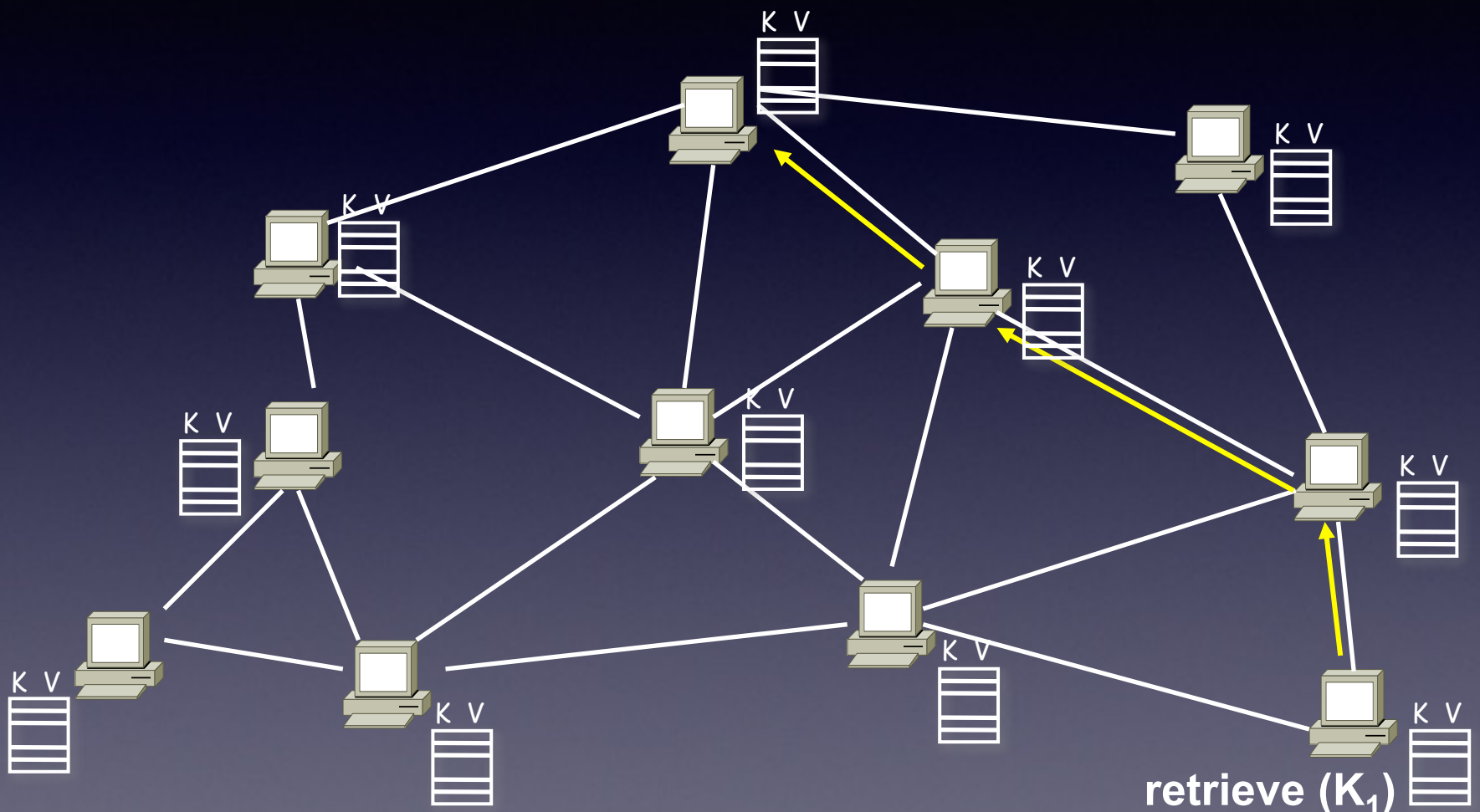

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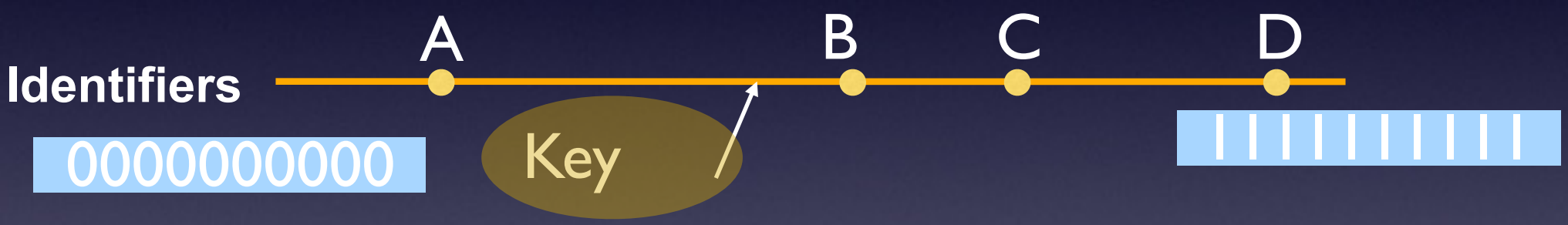
- For what settings do DHTs make sense?
  - Why would you want DHTs?

Fundamental Design Idea I

- Consistent Hashing
  - Map keys *and* nodes to an *identifier* space; implicit assignment of responsibility

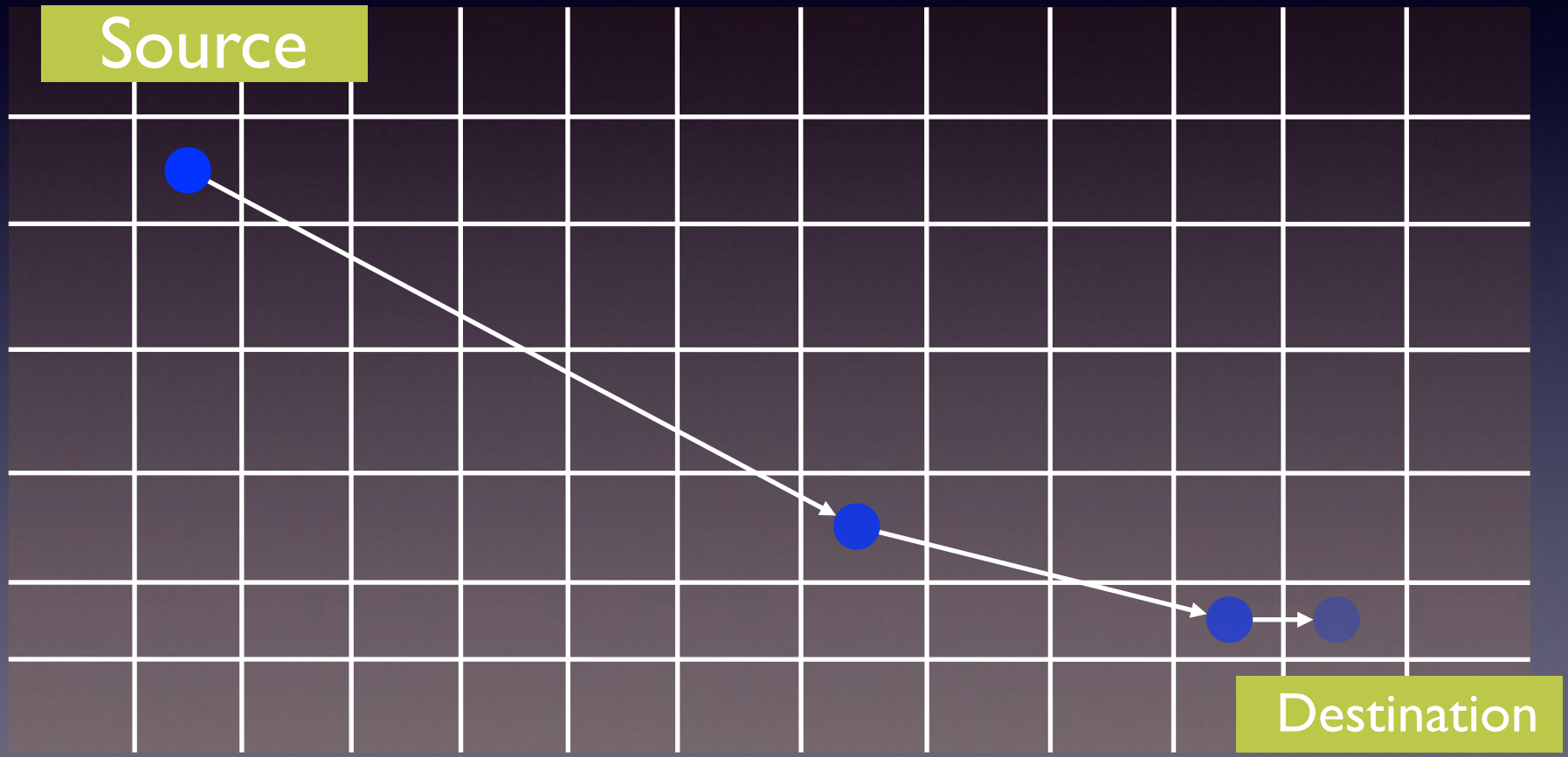


Mapping performed using hash functions (e.g., SHA-1)

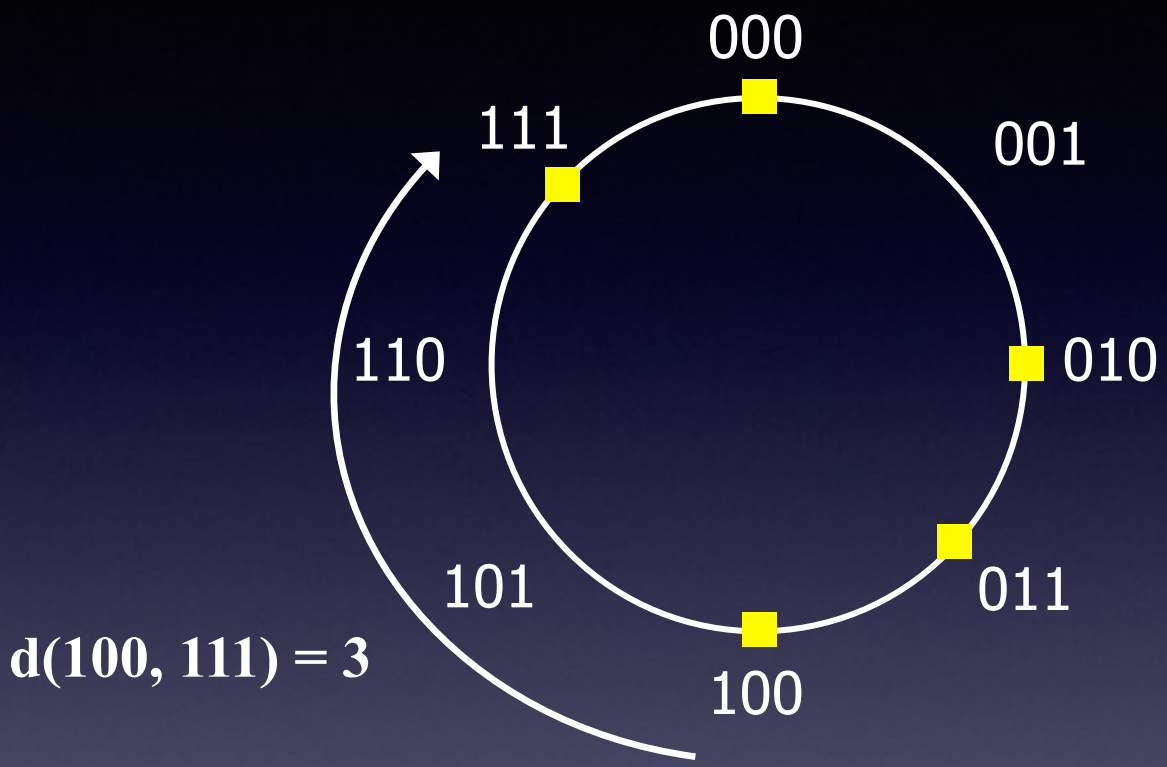
- What is the advantage of consistent hashing?

Fundamental Design Idea II

- Prefix / Hypercube routing

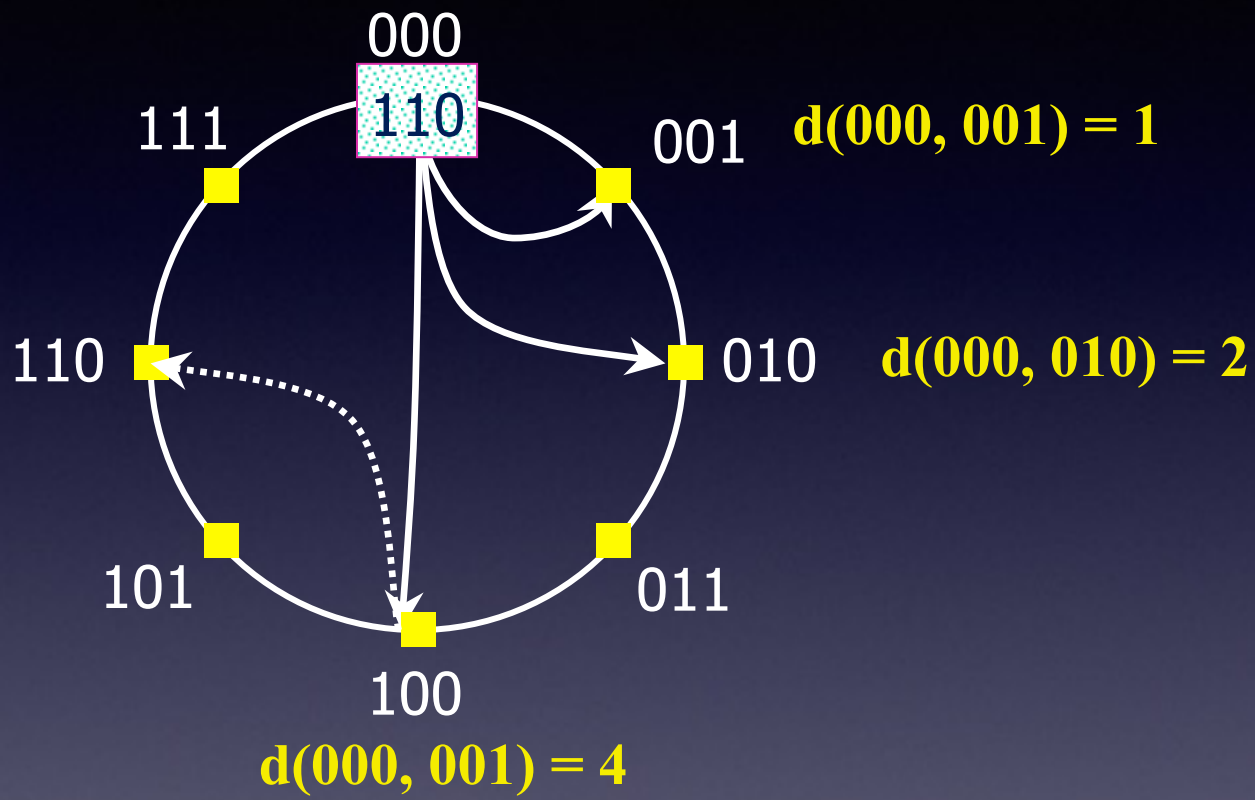


State Assignment in Chord



- Nodes are randomly chosen points on a clock-wise ring of *values*
- Each node stores the *id space* (*values*) between itself and its predecessor

Chord Topology and Route Selection



- Neighbor selection: i^{th} neighbor at 2^i distance
- Route selection: pick neighbor closest to destination

How to design a DHT?

- State Assignment:
  - what "(*key, value*) tables" does a node store?
- 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
  - CAN, Chord, Pastry, Tapestry, Plaxton, Viceroy, Kademlia, Skipnet, Symphony, Koorde, Apocrypha, Land, ORDI …

Issues

- How do you characterize the performance of DHTs?

Issues

- How do you improve the performance of DHTs?

Issues

- What are the fault tolerance/correctness issues?
  - how do you improve fault-tolerance or reliability?

Issues

- What are the security issues?
  - how do you improve security?

Issues

- What are the load balance issues?
  - how do you improve load balance?

Dynamo

- Real DHT (1-hop) used inside datacenters
- E.g., shopping cart at Amazon
- More available than Spanner etc.
- Less consistent than Spanner
- Influential — inspired Cassandra

Context

- SLA: 99.9th delay latency < 300ms
- constant failures
- always writeable

Quorums

- Sloppy quorum: first N reachable nodes after the home node on a DHT
- Quorum rule: R + W > N
  - allows you to optimize for the common case

Eventual Consistency

- accept writes at any replica
- allow divergent replicas
- allow reds to see stale or conflicting data
- resolve multiple versions when failures go away
  - latest version if no conflicting updates
  - if conflicts, reader must merge and then write

More Details

- Coordinator: successor of key on a ring
- Coordinator forwards ops to N other nodes on the ring
- Each operation is tagged with the coordinator timestamp
- Values have an associated “vector clock” of coordinator timestamps
- Gets return multiple values along with the vector clocks of values
- Client resolves conflicts and stores the resolved value