

# Peer to Peer Networks

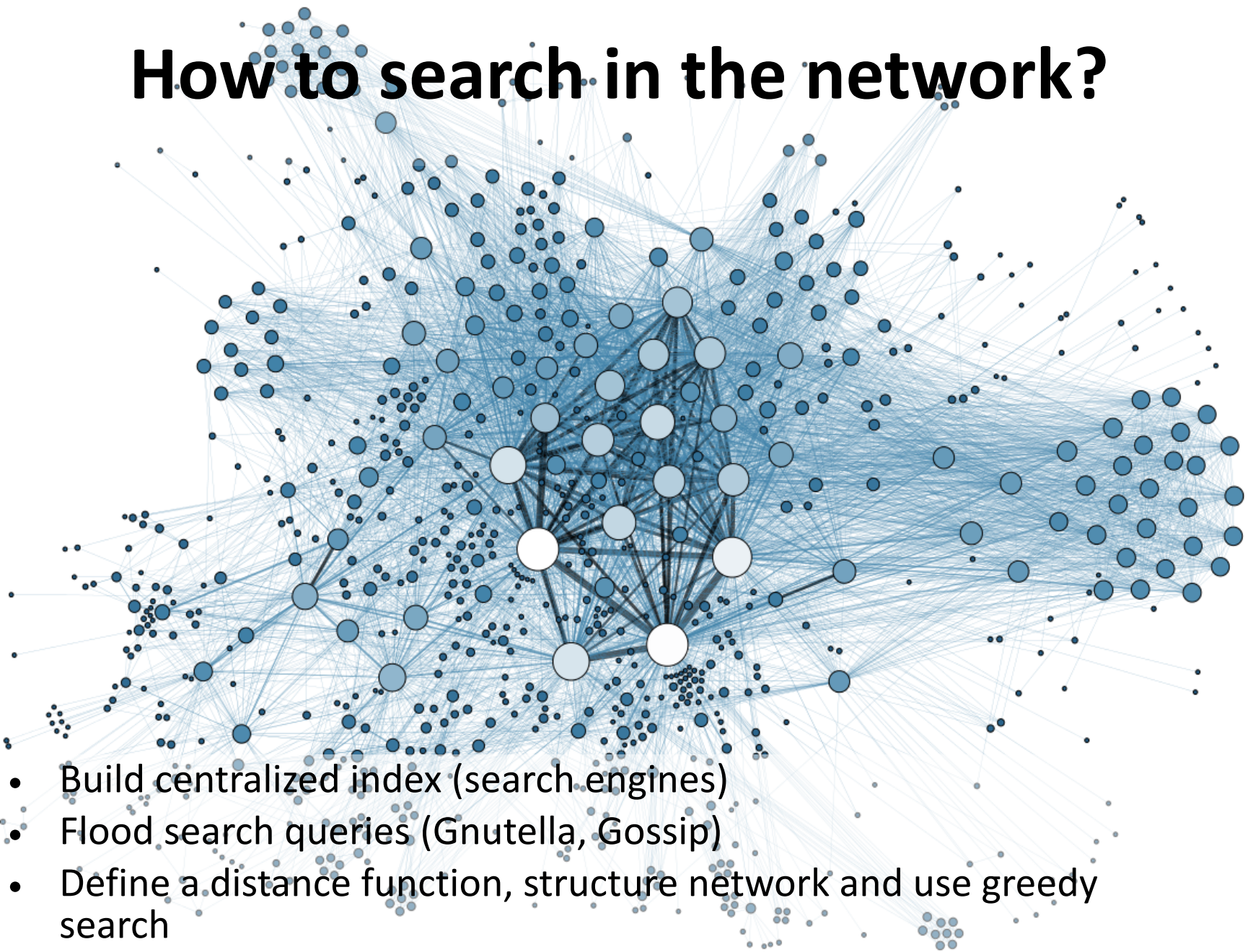


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# Outline of the talk

- Structured Peer-to-Peer networks: Chord protocol, Kademlia
- Kleinberg's Navigable Small World model
- Voronet
- RayNet
- The Metrized Small World algorithm
- Computational experiments

# How to search in the network?



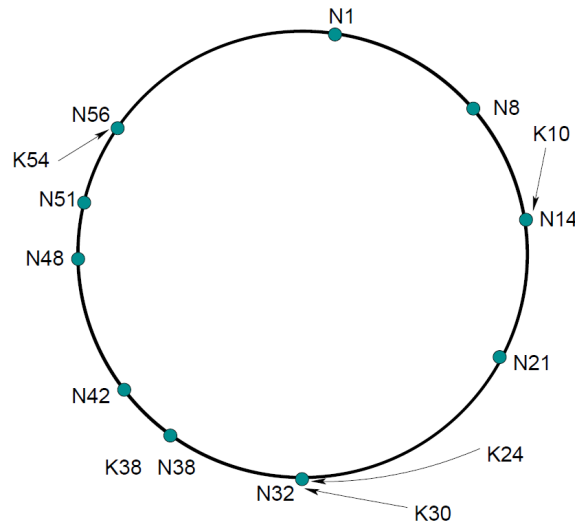
- Build centralized index (search engines)
- Flood search queries (Gnutella, Gossip)
- Define a distance function, structure network and use greedy search



Our goal to construct the network such that:

- every node knows only small number of other nodes
- Search can be started from any node
- Search uses only local information
- The expected number of steps to rich destination is polylogarithmic from number of all nodes

# Structured Peer-to-Peer Networks: Chord Protocol

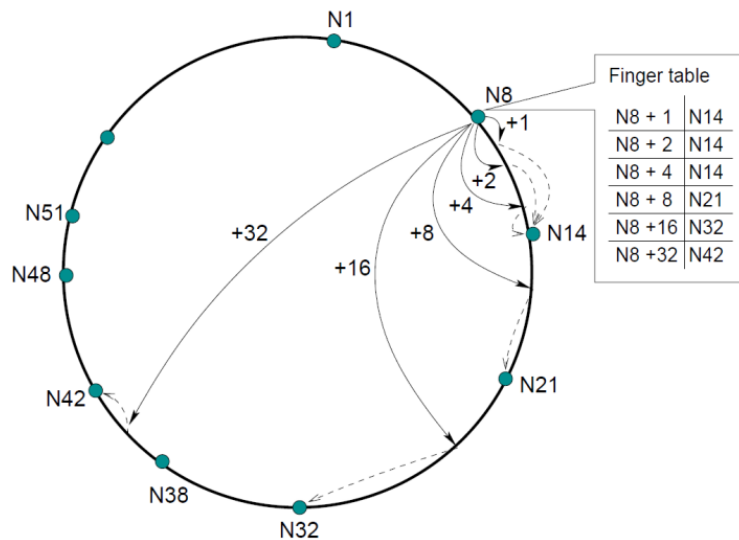


An identifier circle consisting of 10 nodes storing five keys.

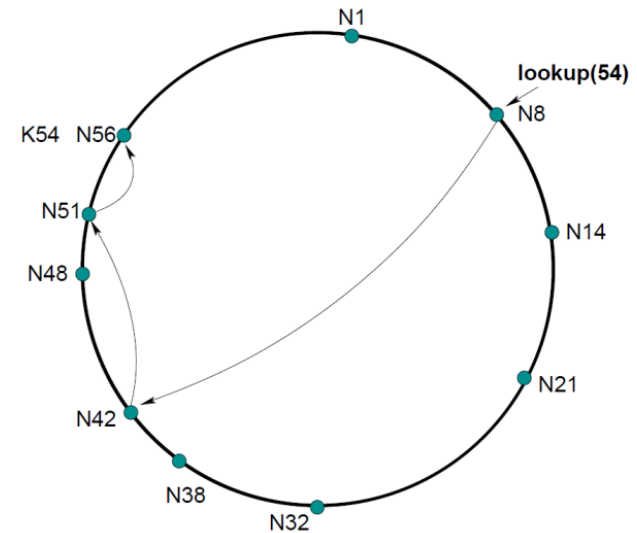
Identifiers are ordered in an identifier circle modulo  $2^m$ .

Key  $k$  is assigned to the first node whose identifier is equal to or follows  $k$  in the identifier space. This node is called the successor node of key  $k$ , denoted by  $\text{successor}(k)$ . If identifiers are represented as a circle of numbers from 0 to  $2^m - 1$ , then  $\text{successor}(k)$  is the first node clockwise from  $k$ .

# Structured Peer-to-Peer Networks: Chord Protocol



Routing table of node «N8»

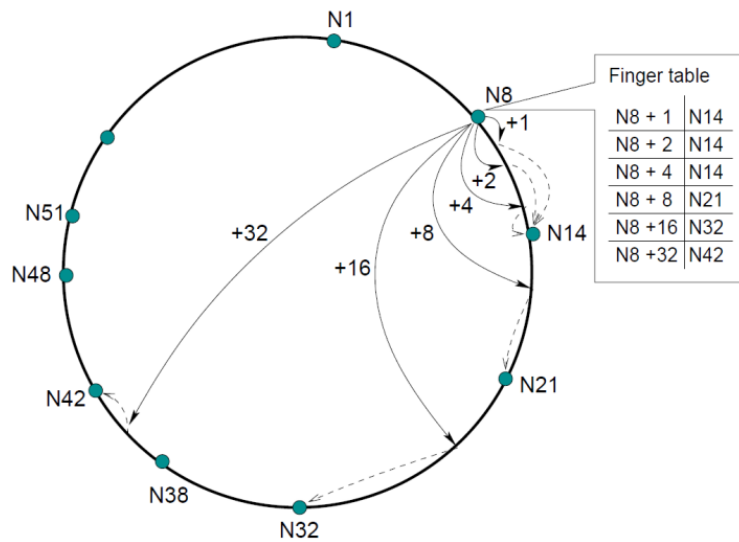


Searching of key 54 starting from «N8».

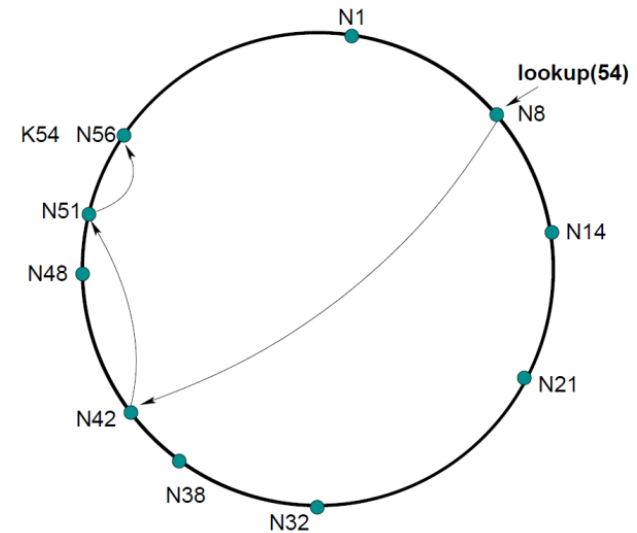
Distance function:  $d(x, y) = (y - x) \bmod 2^m$

Each node,  $n$ , maintains a routing table with (at most)  $m$  entries, called the *finger table*. The  $i$ -th entry in the table at node  $n$  contains the identity of the first node,  $s$ , that succeeds  $n$  by at least  $2^{(i-1)}$  on the identifier circle, i.e.,  $s = \text{successor}(n + 2^{(i-1)})$ , where  $1 \leq i \leq m$

# Structured Peer-to-Peer Networks: Chord Protocol



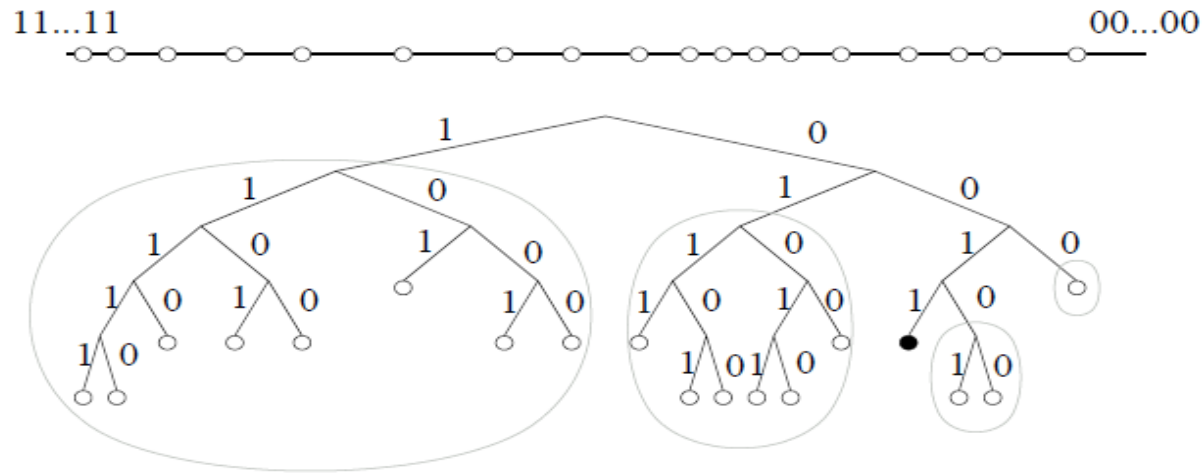
Routing table of node «N8»



Searching of key 54 starting from «N8».

**Theorem:** *With high probability (or under standard hardness assumptions), the number of nodes that must be contacted to find a successor in an  $N$ -node network is  $O(\log N)$ .*

# Structured Peer-to-Peer Networks: Kademlia



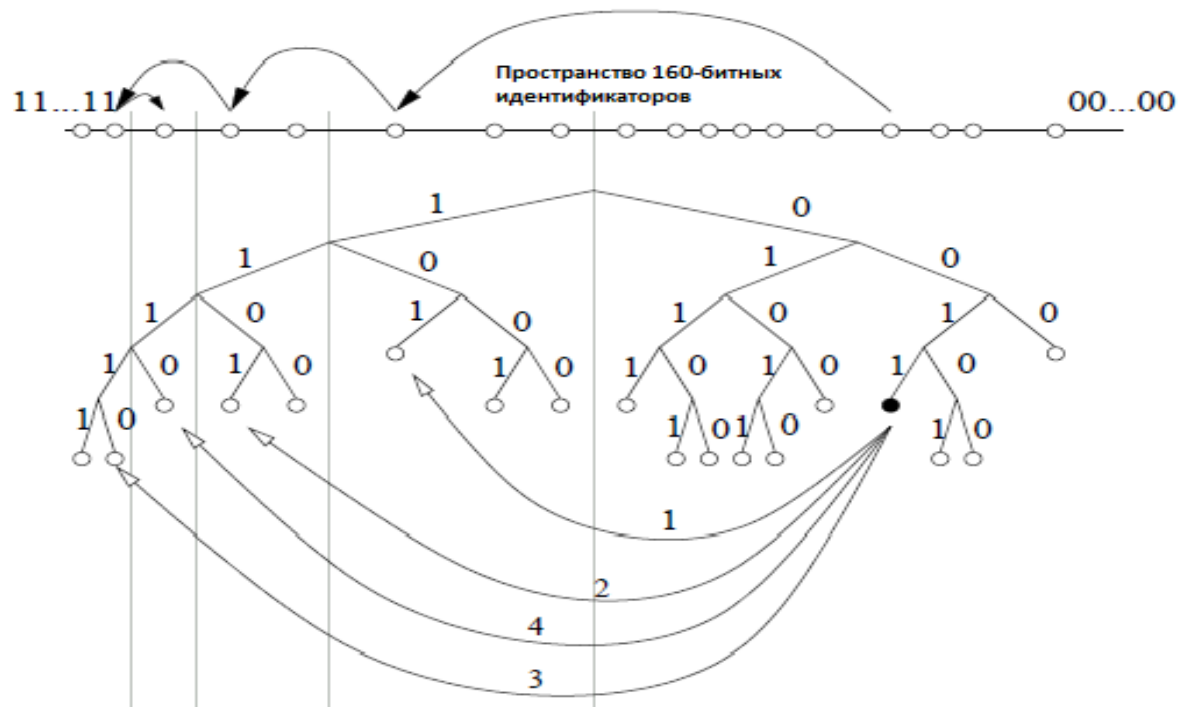
## Identifier space of Kademlia

Distance function:  $d(x,y)=x \text{ xor } y$

Maymounkov P., Mazieres D. Kademlia: A peer-to-peer information system based on the xor metric // Peer-to-Peer Systems. – Springer Berlin Heidelberg, 2002. – С. 53-65.



# Structured Peer-to-Peer Networks: Kademlia



The node with unique prefix id 0011 finding node with id 1110

# Structured Peer-to-Peer Networks: Applications

- Peer-to-Peer file sharing systems
- Key-Value Storages
- Load Balancers
- Cooperative Mirroring