System Design for Large Scale

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law of diminishing returns (Wikipedia)

According to this relationship, in a production system with fixed and variable inputs (say factory size and labor), beyond some point, each additional unit of variable input yields less and less additional output.

Early History

- Altough P2P designs can be tracked in early systems such as Usenet News, DNS, Ficus, Bayou and others; the current expression of the concept arises on the turn of the century with Napster and Seti@Home.
- However, neither Napster nor Seti@Home are purelly P2P.

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- No direct contact among peers.

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- Bootstrapping is done by HTTP hosted host caches and by local host caches from previous sessions. Due to high churn, local host caches can quickly become outdated.
- Routing on the overlay is based on flooding and reverse path routing (further data on the paper *Mapping the Gnutella Network* and a topology graph on `http://snap.stanford.edu/data/index.html`).

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- This early design was found out not to scale, and PING/PONG traffic was dominant in the overlay.

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- Gnutella kept scaling and achieved 40% of P2P file sharing, around 2005.

Distributed Hash Tables

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- Many alternative solutions to this problem are achieved by Distributed Hash Tables.
- DHTs provide ways of mapping *keys* to network *nodes*. Node joins and leaves should be accounted for in the protocols, in order to preserve some structure in the routing supporting the DHT. In this sense, they can require more maintenance that unstructured approaches.

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- Here we will look deeper into *Chord* and Kademlia.

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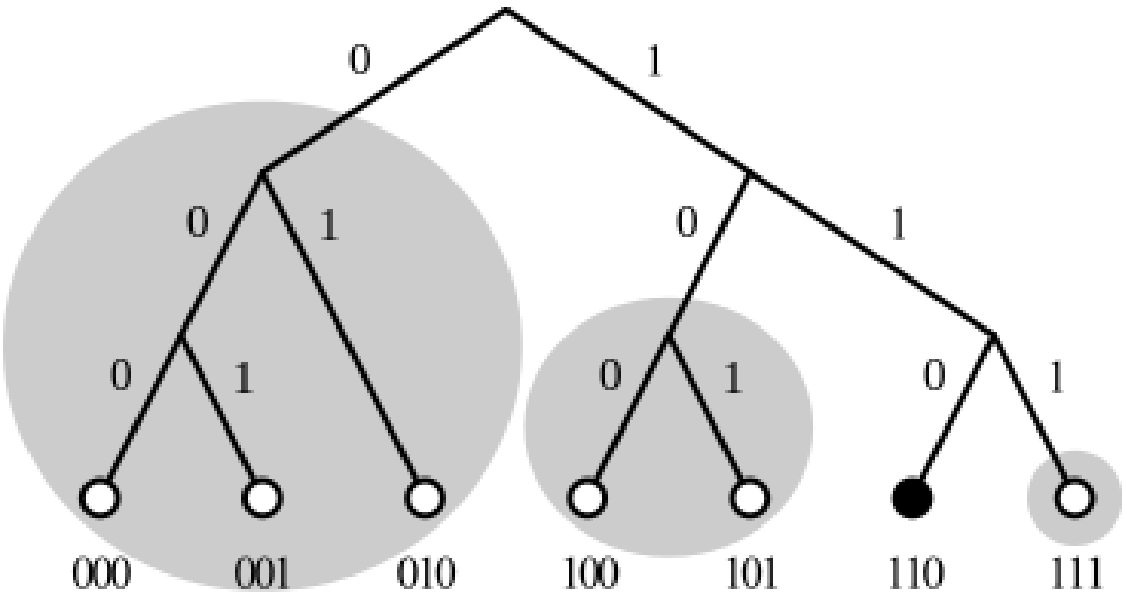
- Nodes keep $O(\log n)$ knowledge on other nodes and routing takes $O(\log n)$ steps.

Kademlia (2002)

- Nodes and Keys share a 160 bits space of ids. Keys are stored on "close by" nodes.
- Id distance is computed by a XOR metric. XOR is an interesting symmetric distance metric that respects the triangle property.
- Unlike Chord, here routing is symmetric and alternative next hops can be chosen for low latency or parallel routing.
- Routing tables consist of a list for each bit of the node id.
- A node in list position i, must have bits 0 to $i-1$ identical to the list owner, a different i^{th} bit, and can differ from position i onwards. Its easy to find nodes for the first positions.

Kademlia
Routing tables



For node 110, groups must match initial sequences: $\perp, 1, 11$

Kademlia

- To account for failing nodes and alternative paths in each position up to k nodes are stored. k is about 20.
- Candidate node uptimes is considered when competing for k limited positions.