A WebRTC DHT

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Preface I

- Existing DHT overlays have been optimized using **one criteria** (network proximity, social links, content caching or others).

- An ***adaptable overlay*** that uses **more than one criteria**, should improve **performance**, **reliability** and **availability** in distributed (social) applications.

Preface II

- Currently we are experimenting with **Web browsers** to build an **initial DHT overlay**.

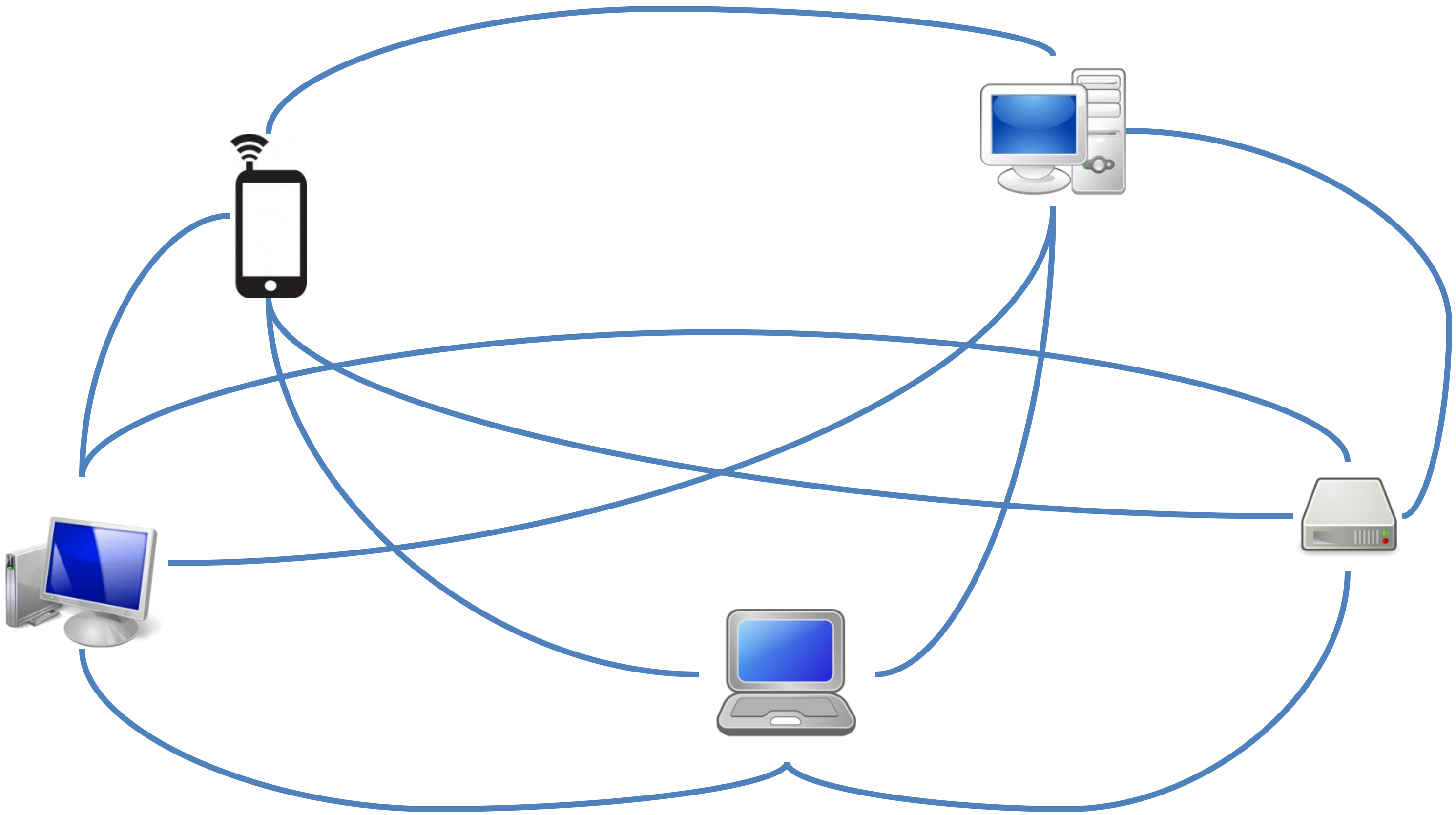
- After the implementation, we will extend the overlay to be ***adaptable***.

What do we mean by ***adaptable*** overlay?

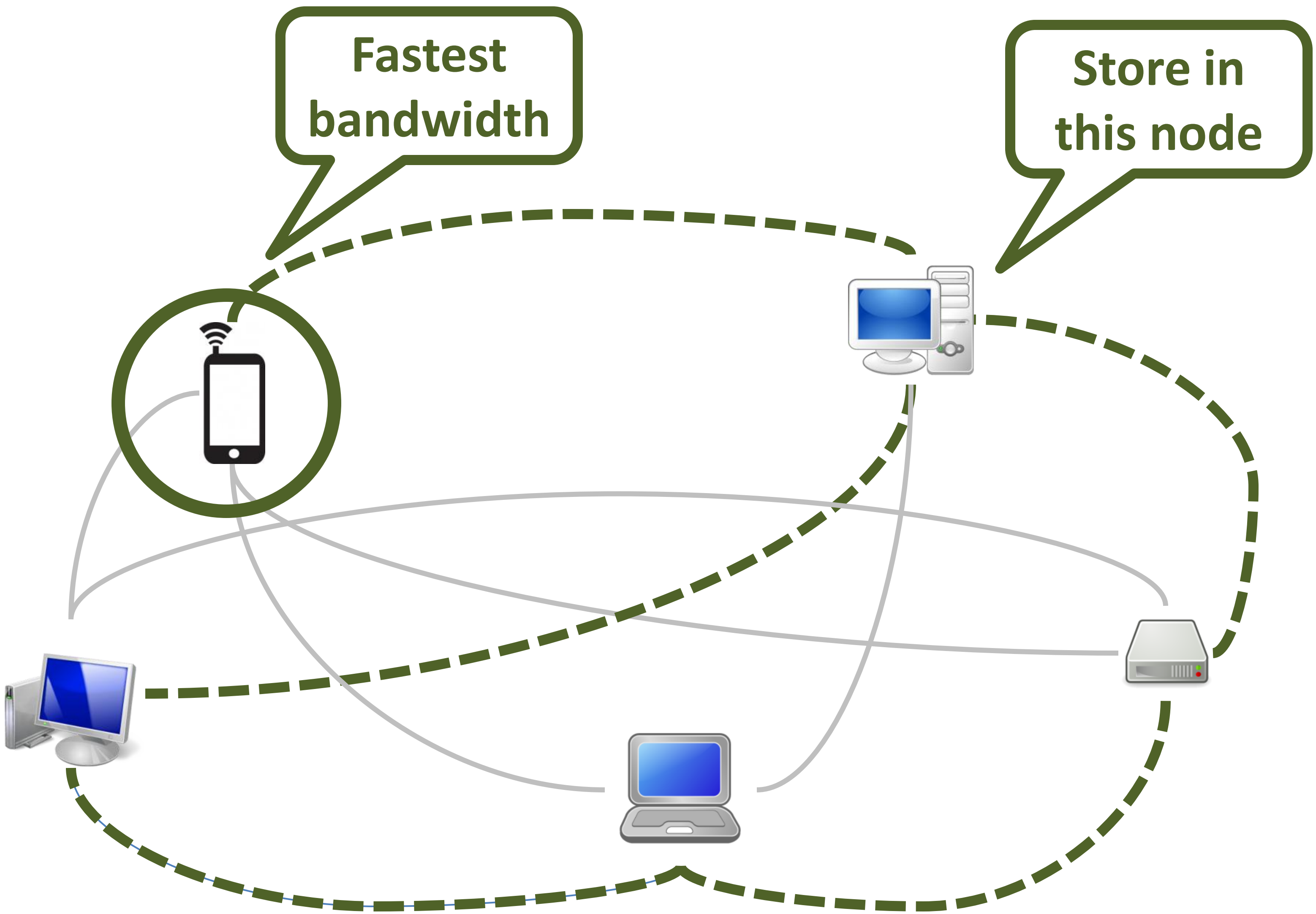
Different applications have different requirements.

- **A distributed YouTube would prefer high bandwidth among the peers.**
- **A cloud storage would prefer peers with sufficient storage and perhaps “good” reputation.**
- **A social network would favor peers that belong to actual friends.**

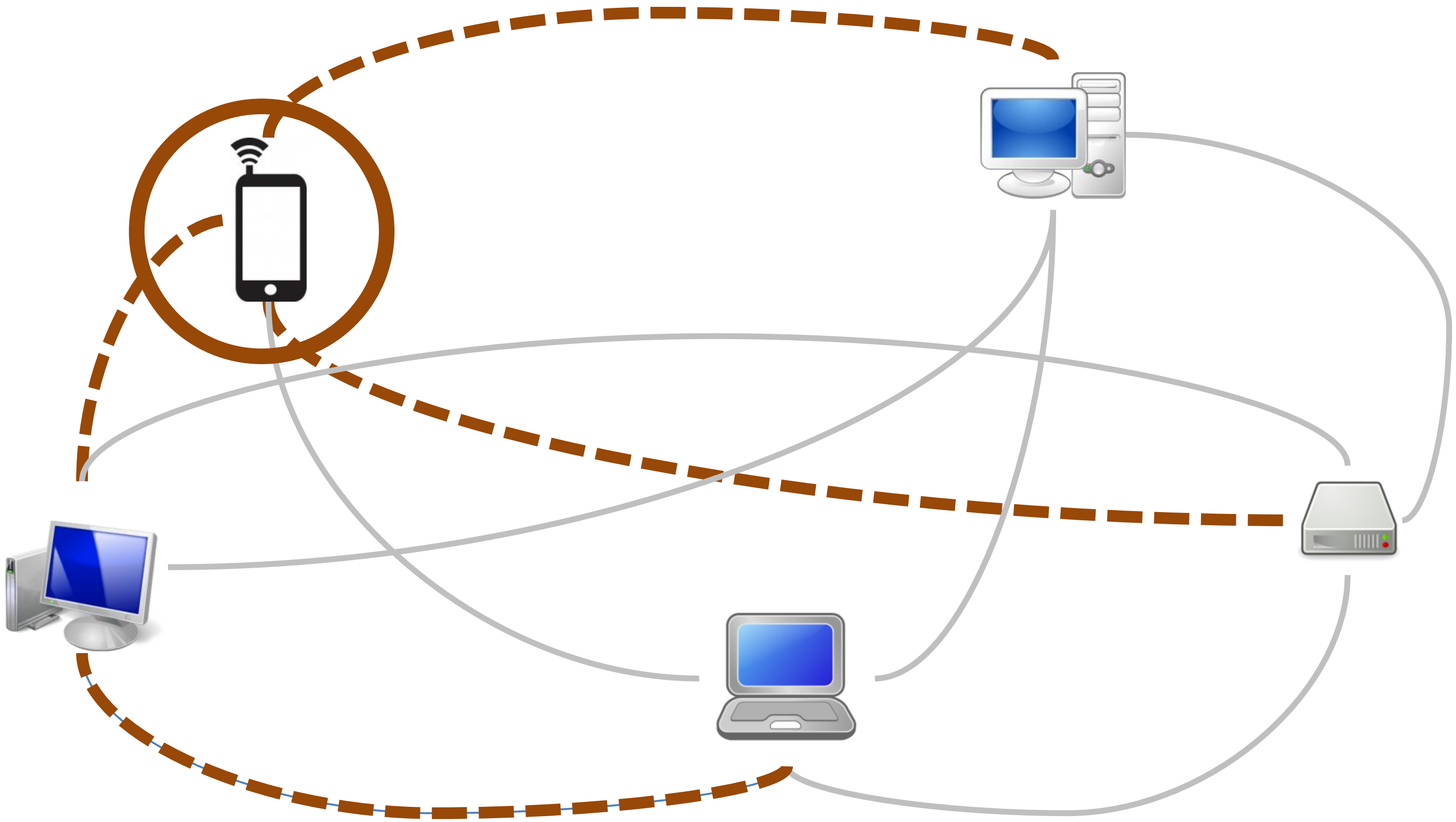
Example



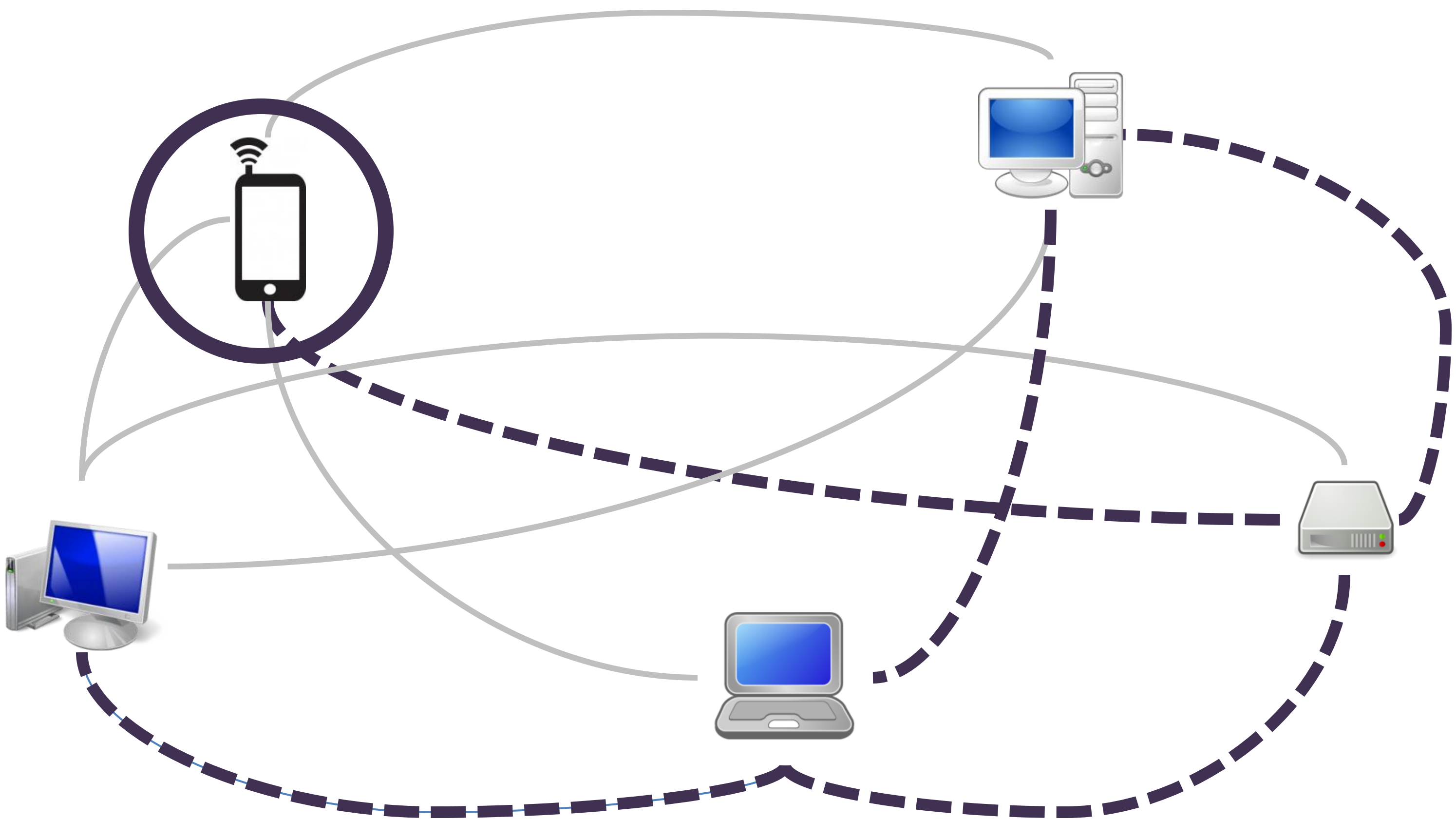
Fastest Possible Bandwidth



Social Links



Reputation



Problem Formulation

A node is a processing entity connected to a network. The network implements a Distributed Hash Table (DHT). Given that:

- Node $u \epsilon V$ and a set of functions f_i: $0 < i < C$ such that $f_i(u, v) \rightarrow R, u \epsilon V, v \epsilon N(u)$ (*v* is connected or it is considered to be a "neighbor" of *u*)
  - where C is the number of criterion specified by the application
  - where $N(u) = \{v: (u, v) \epsilon \exists\}$ (there is a connection between the nodes)
- Vector $w \epsilon 1 \times C$ where w_i is the element and represents the weight of f_i

Node u needs to find v such that:

$$v^* = \arg\max v \, [\sum_{i=0}^{C} w_i f_i(u, v)]$$

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Among the options that a peer has to send data, use the one that gives the best match given a criteria.

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Node u needs to find v such that:

$$v^* = \arg\max v \left[\sum_{i=0}^{C} w_i f_i(u, v)\right]$$

Research Objectives

- Extend existing state-of-the-art DHT techniques
  - ***Adaptable*** overlays: adapt to application requirements
  - Backend for distributed and social applications
- **First step**: build an overlay for a DHT comprised of web browsers using WebRTC and HTML5.

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"Long-term" research direction

- **First** ... DHT comprised of web browsers using WebRTC and HTML5.

Research Objectives

- Extend existing state-of-the-art DHT techniques
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  - Bac … plications

“Short-term” research direction

- **First step**: build an overlay for a DHT comprised of web browsers using WebRTC and HTML5.

Recap from Barcelona Sept. 2013

An ideal DOSN…

- No installation
- No extra hardware
- No configuration

All in the browser! ☺

A WebRTC DHT

Objective: Build a backend for distributed applications using web browsers.

- Select DHT to Implement
- **Build overlay**
- Test it
- Build apps with it

Select DHT to Implement: **Kademlia**

- Most suitable DHT for **unreliable peers**.
- Several improvements over the years.

Building a Reliable P2P System Out of Unreliable P2P Clients: The Case of KAD. Damiano Carra and Ernst W. Biersack. Institut Eurecom. Sophia-Antipolis, France. *ACM Conference on Emerging Network Experiment and Technology (CoNEXT), 2007.*

Active Research on Kademlia

- Fast Lookups
- Social analysis
- Network proximity
- Caching system

Active Research on Kademlia

<ins>**Embracing the Peer Next Door: Proximity in Kademlia.**</ins>
Sebastian Kaune, *et al*. Technische Universitat Darmstadt. KOM Multimedia Communications Lab. *International Conference on Peer-to-peer Computing 2008. IEEE Computer Society Press.*

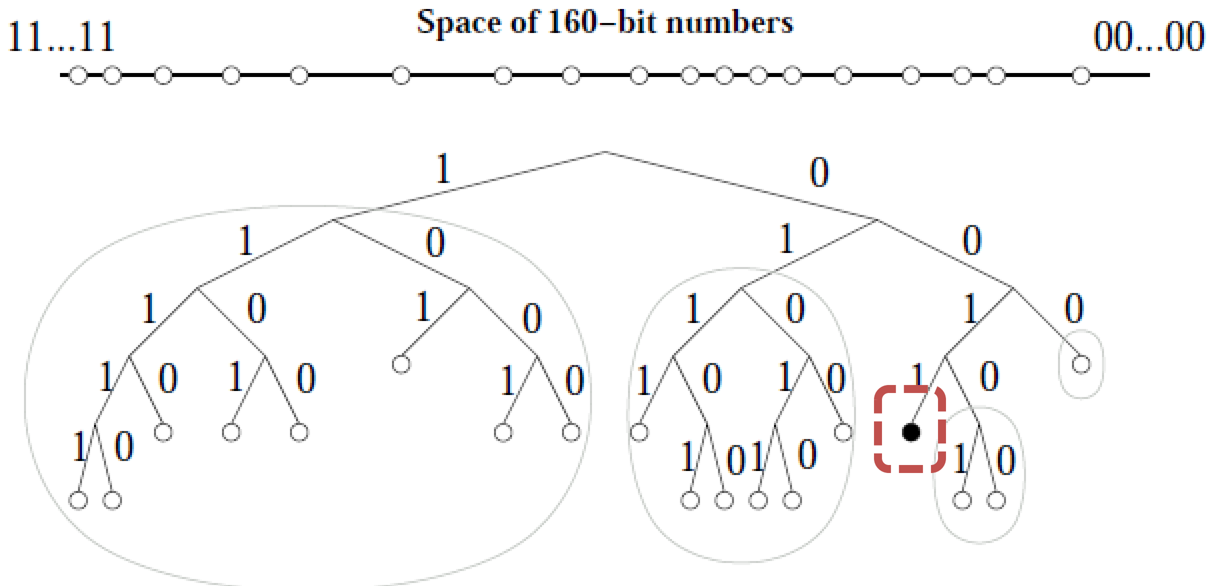
<ins>**Improving the Routing Performance of KAD through Social Network Analysis.**</ins>
Xiangtao Liu, *et al*. Institute of Computing Technology, Chinese Academy of Science. *International Symposium on Computers and Communications, 2010.*

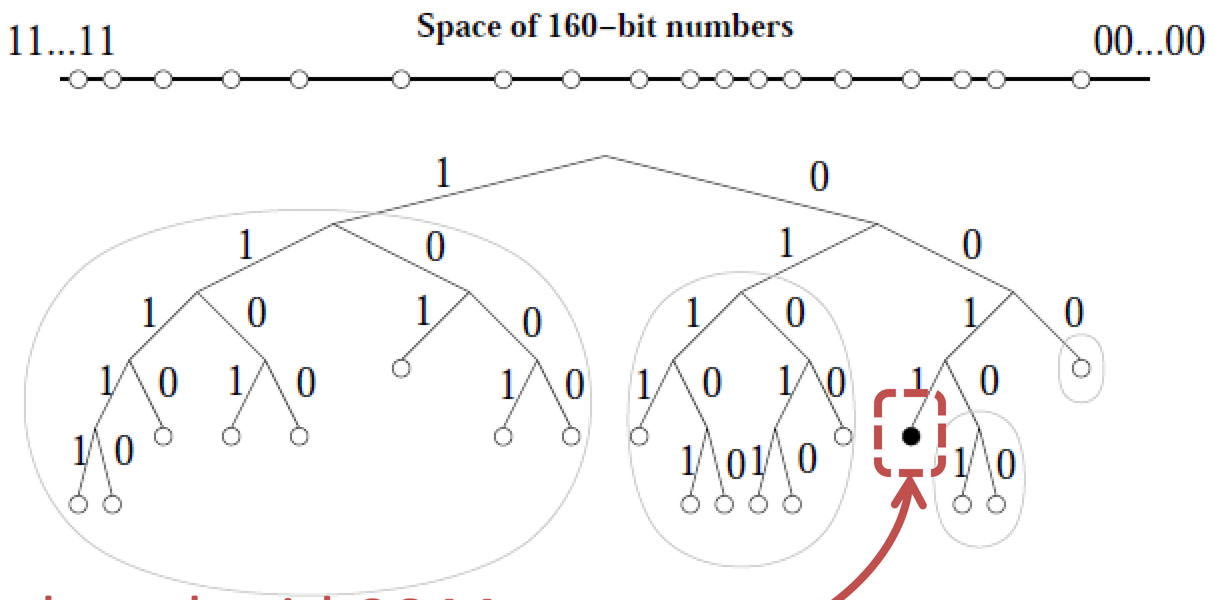
<ins>**Revisiting Why Kad Lookup Fails.**</ins> **Bingshuang Liu, *et al*. Peking University, Beijing, China. *IEEE International Conference on Peer-to-Peer Computing, 2012.***

<ins>**Kaleidoscope: Adding Colors to Kademlia.**</ins> **Gil Einziger, *et al*. Computer Science Department, Technion Haifa. *IEEE International Conference on Peer-to-Peer Computing, 2013.***

How does **Kademlia** work?

- 160-bit keys and 160-bit node identifiers
- Distances between nodes and keys are calculated using XOR
- **Each step is one bit closer to the destination**.
  - Peers have routing tables
  - Routes are grouped on 160 buckets (one for each different bit)


Space of 160−bit numbers
11...11
00...00



This node has the id **0011**

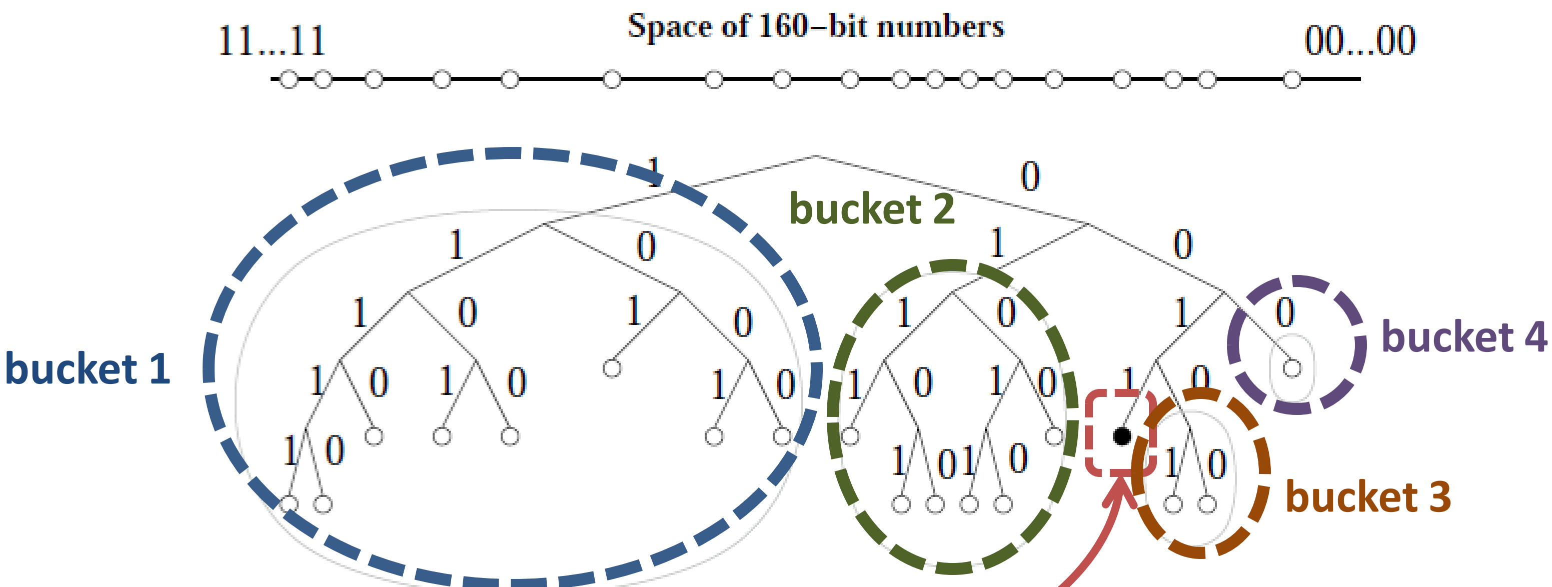
In this node the others are grouped in buckets:

1* bucket 1**

01 bucket 2**

0001 bucket 3

0000 bucket 4 (contains one node)



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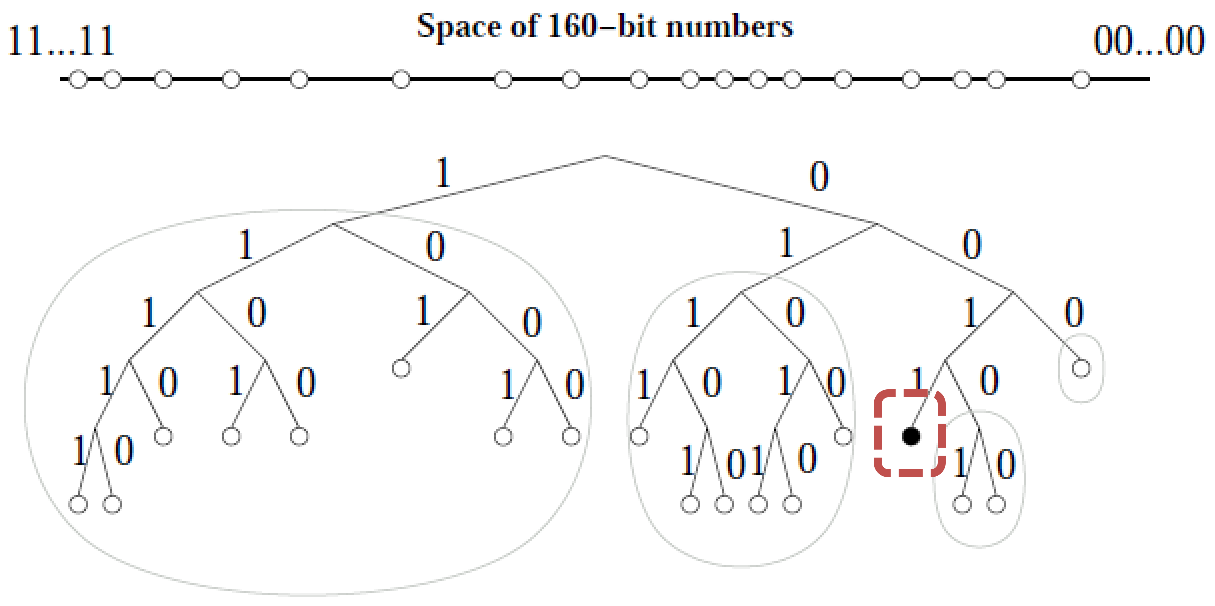


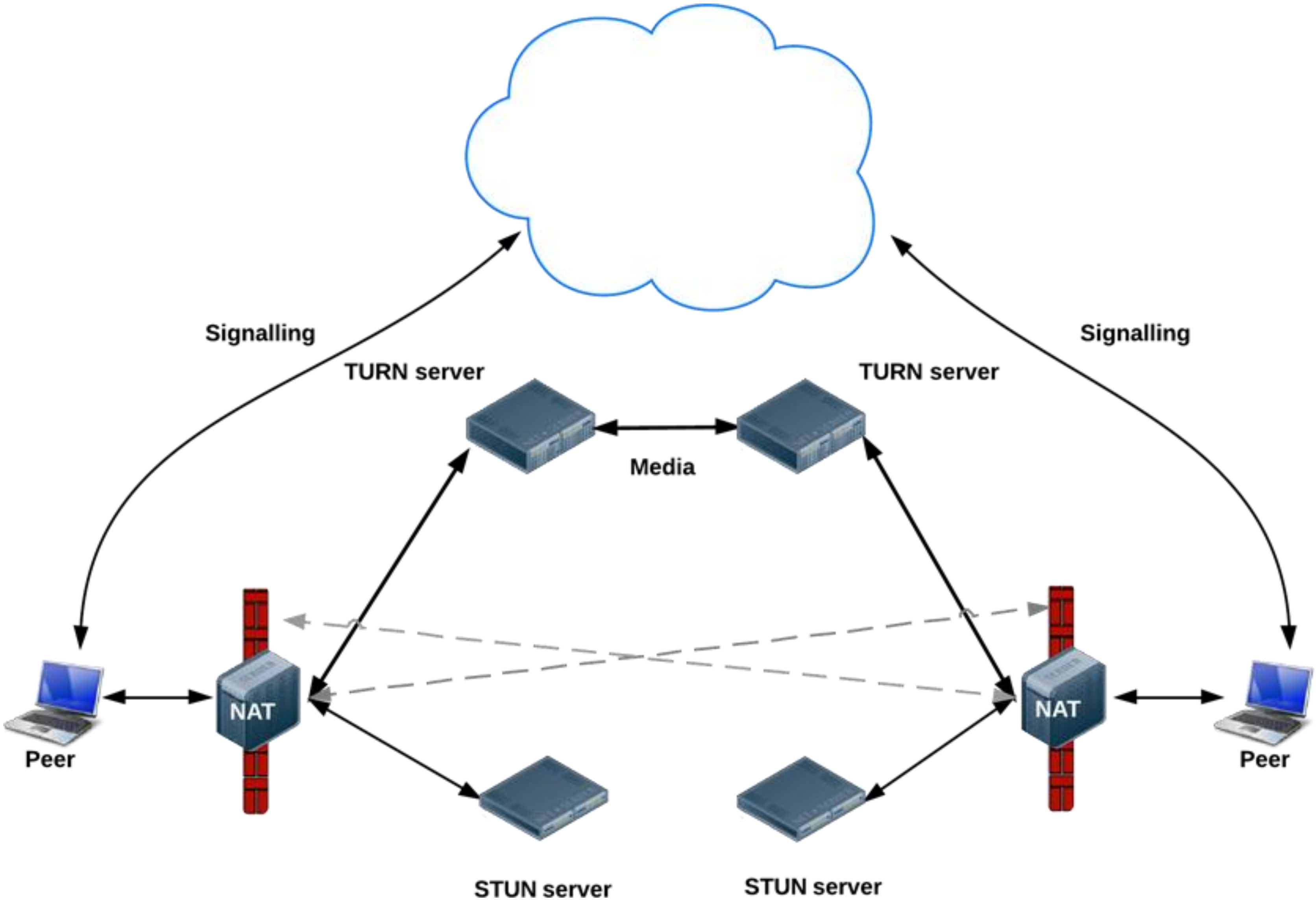
<u>Kademlia: A Peer-to-peer Information System Based on the XOR Metric.</u>
Petar Maymounkov and David Mazieres. New York University.
International Workshop on Peer-to-peer Systems, 2002.

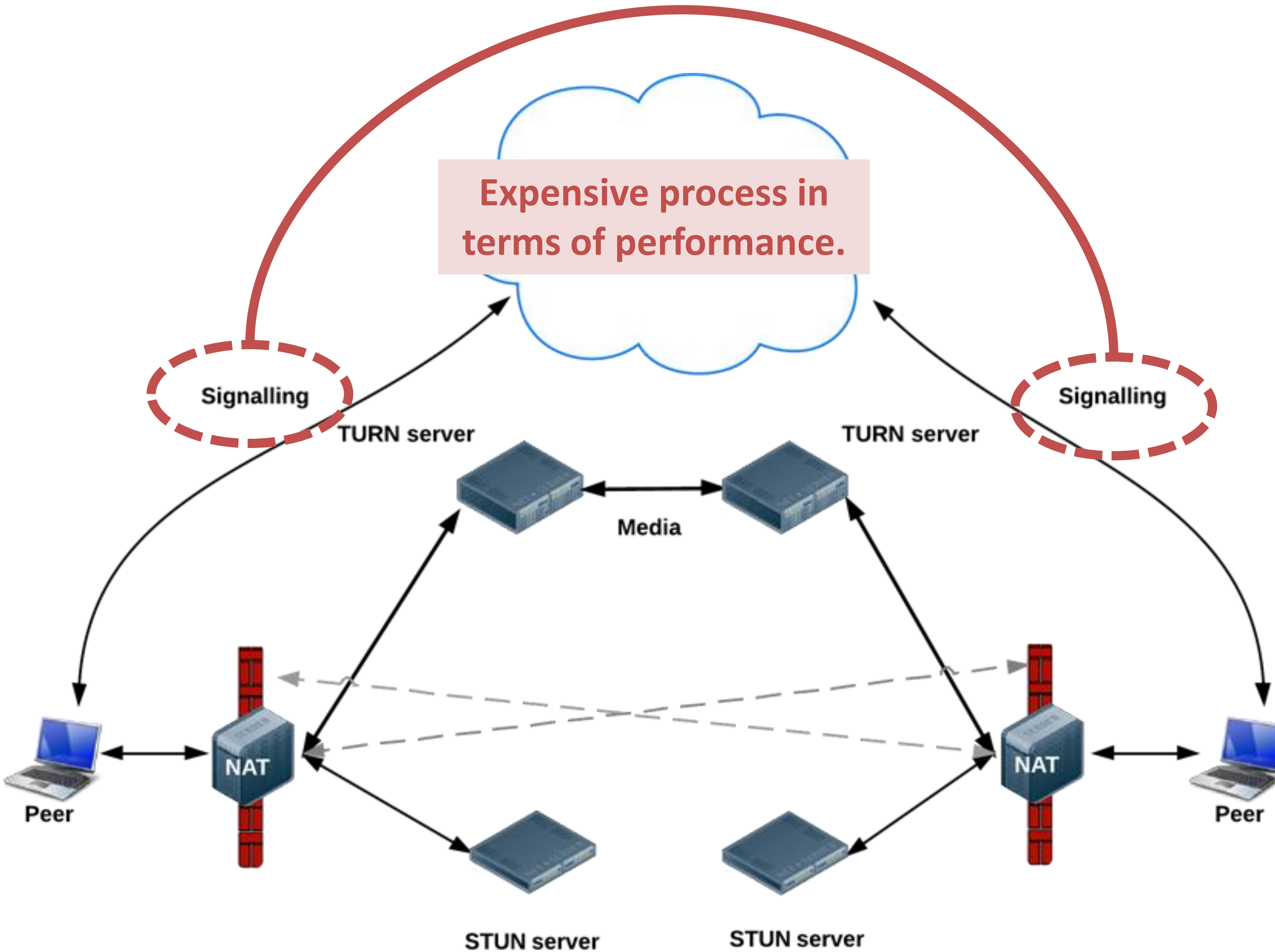
Tools used to build a WebDHT

- **Storage:** HTML5 (through providing the “localstorage” object that enables permanent storage)
- **P2P Communication :** WebRTC a W3C Standard and the only mechanism to enable browser-to-browser communication without plug-ins or third-party extensions (Java, ActiveX, Flash, etc.).

WebRTC Considerations

- For peers to contact each other, they need a signal server for the initial connection.
  - **ICE** (Interactive Connectivity Establishment)
  - **STUN** (Session Traversal Utility for NAT)
  - **TURN** (Traversal Using Relays around NAT)


Signalling
Signalling
TURN server
TURN server
Media
NAT
NAT
Peer
Peer
STUN server
STUN server



Expensive process in terms of performance.
Signalling
Signalling
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Media
NAT
NAT
Peer
Peer
STUN server
STUN server

Memory

- There is a limited amount of RAM the OS assigns to the browser (between 2 to 4 Gigabytes of RAM).
- Each connection demands a chunk of this memory.

...Aw, Snap...!

- Kademlia requires communication with 160 buckets. There are two ways of doing this:
  - Connect and disconnect
    - OR
  - Keep connections open

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- **This will trigger too many hits on the signal server.**
- **For every request to the signal server, the performance is affected.**

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- **Memory limitations of the browser.**
- **Consider mobile devices…**
- **Consider peers leaving…**

Can we “extend” Kademlia?

=Memory=

- Keep as few open connections as possible

=Performance=

- Try to avoid opening and closing connections

=Distribution=

- Use XOR to compute distances

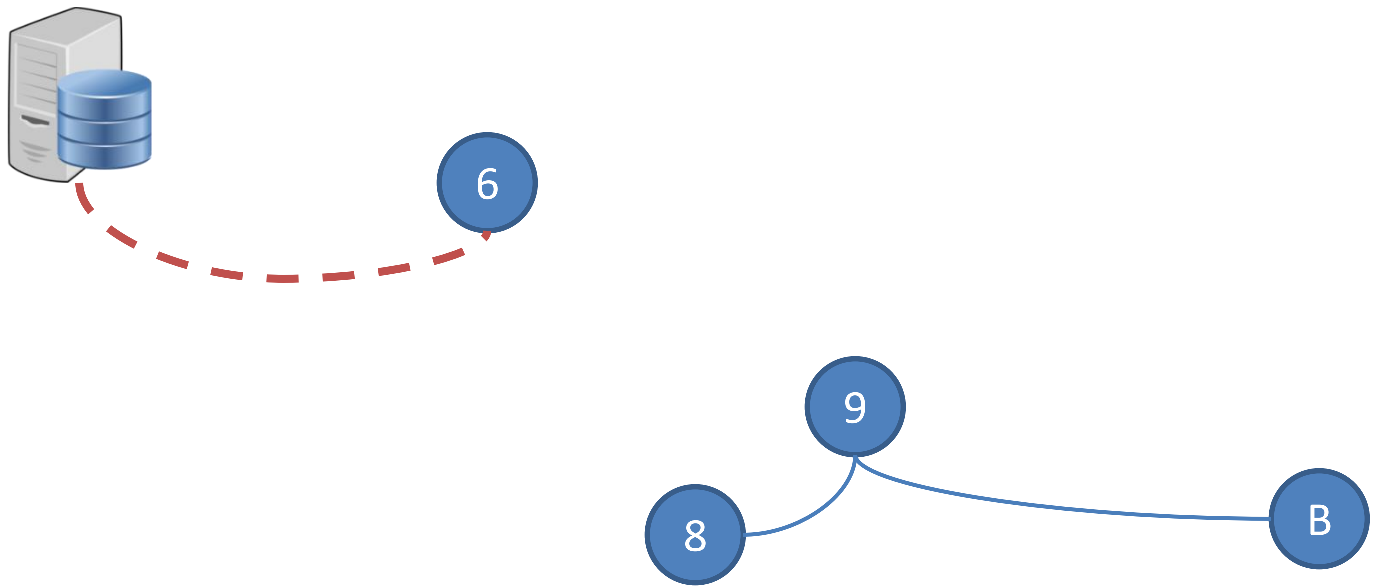
This is how we “extended” Kademlia…

- Node aggregation and find/store key operations are done via **routing** instead of **opening new connections**.
- **XOR-wise**
  - Forward OR
  - Store/Connect

(-)Disadvantages:

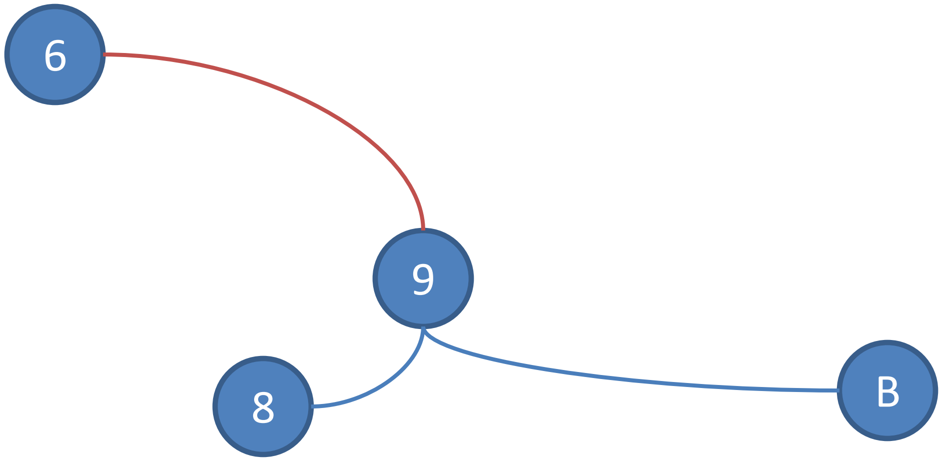
- Lookups will not perform as fast as opening and keeping the connections open.
- TTL is needed when packages cannot be delivered.

Node Aggregation



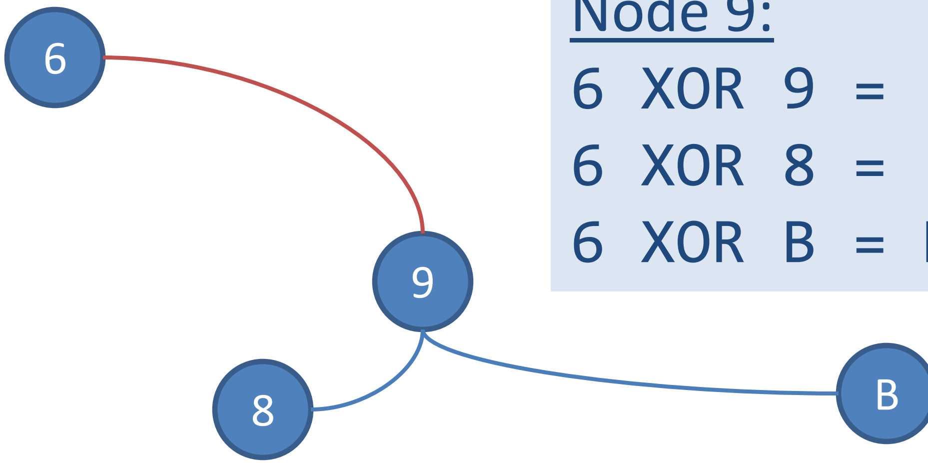
A new node contacts the signal server to receive an identifier and a list of peers. The identifier is a string such as “xpqr34trs”. The node uses SHA1 to transform it into a 160-bit identifier.

Node Aggregation

A new node contacts any other peer in the network.

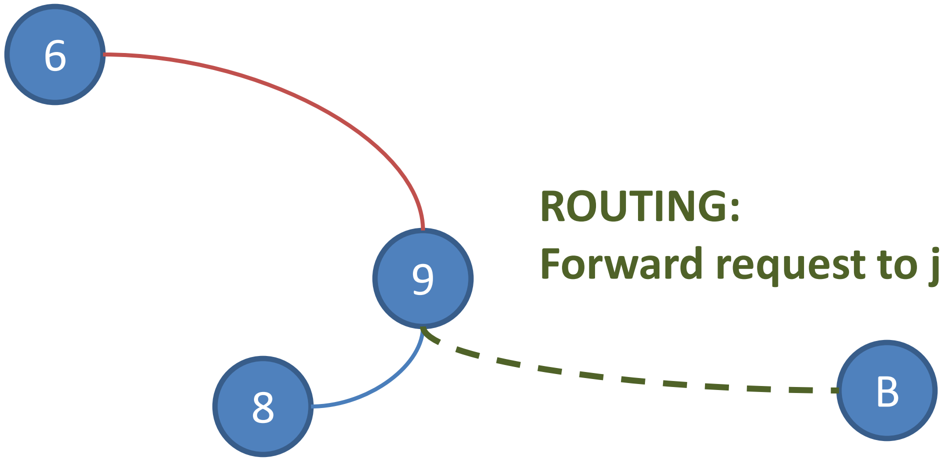
Node Aggregation



Node 9:
6 XOR 9 = F
6 XOR 8 = E
6 XOR B = D

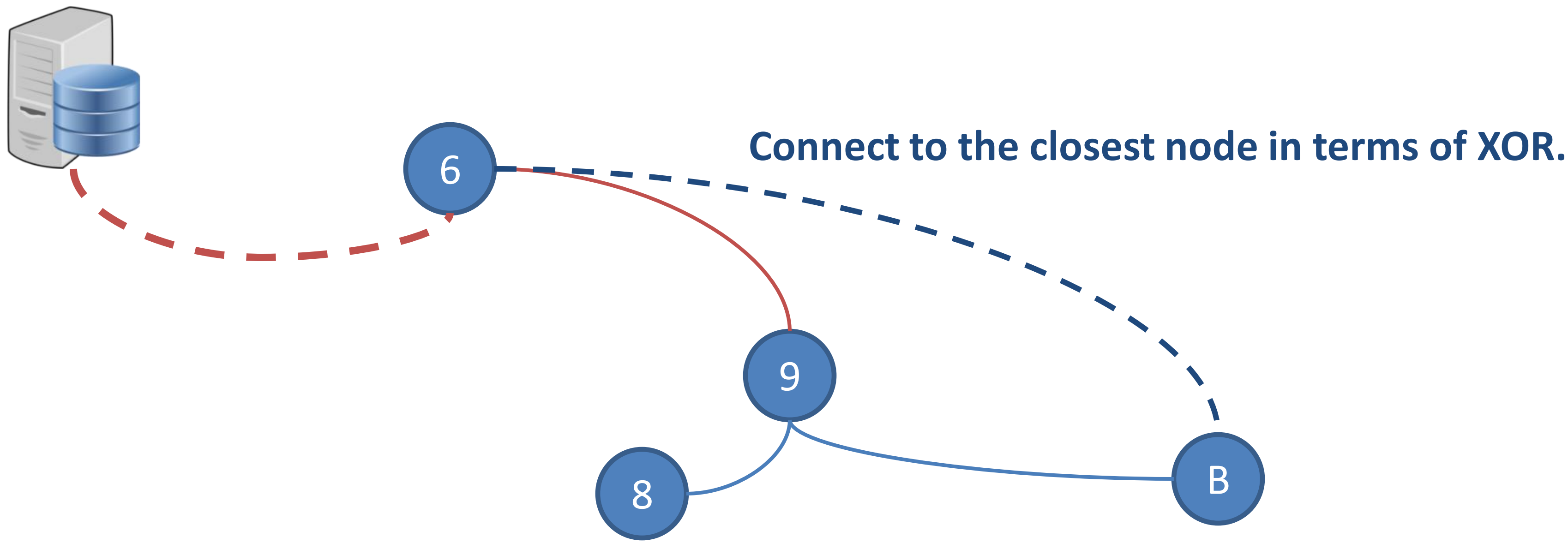
The contacted peer finds among itself and its open connections the closest node in terms of XOR.

Node Aggregation



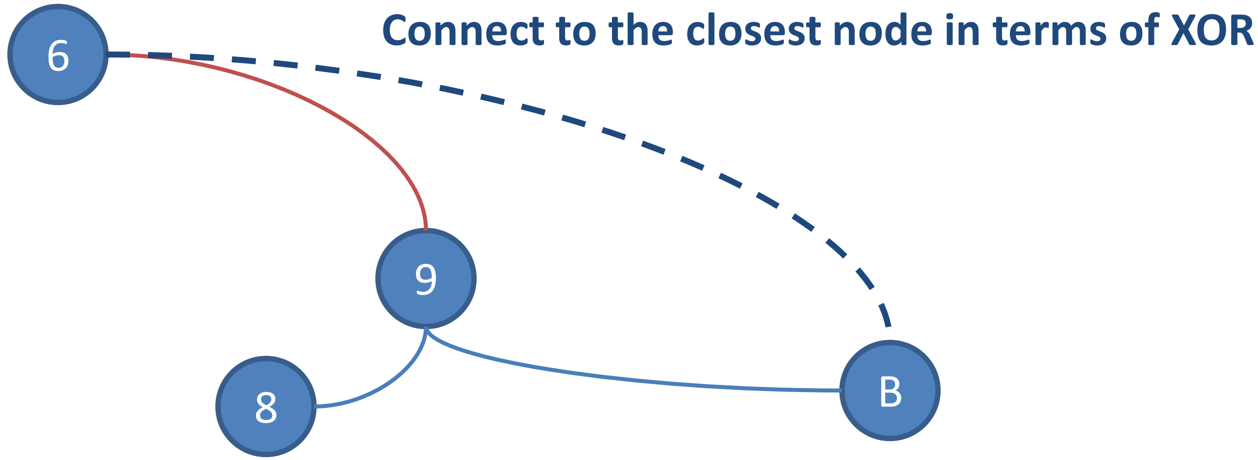
ROUTING:
Forward request to join the network.

Node Aggregation



Node 9 forward the request to node B. Node B would compute in the same way and ultimately connect to the new node, node 6.

Node Aggregation



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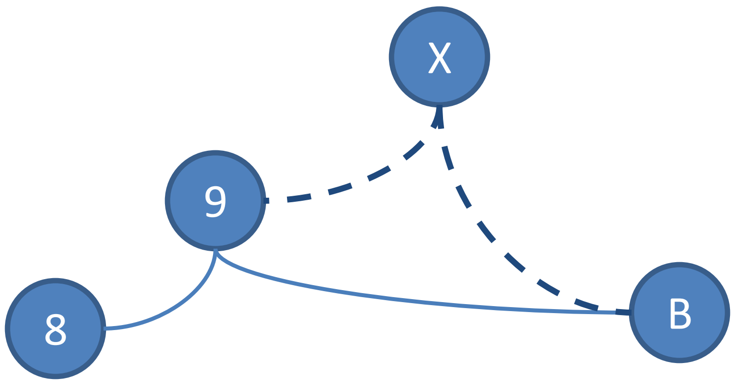
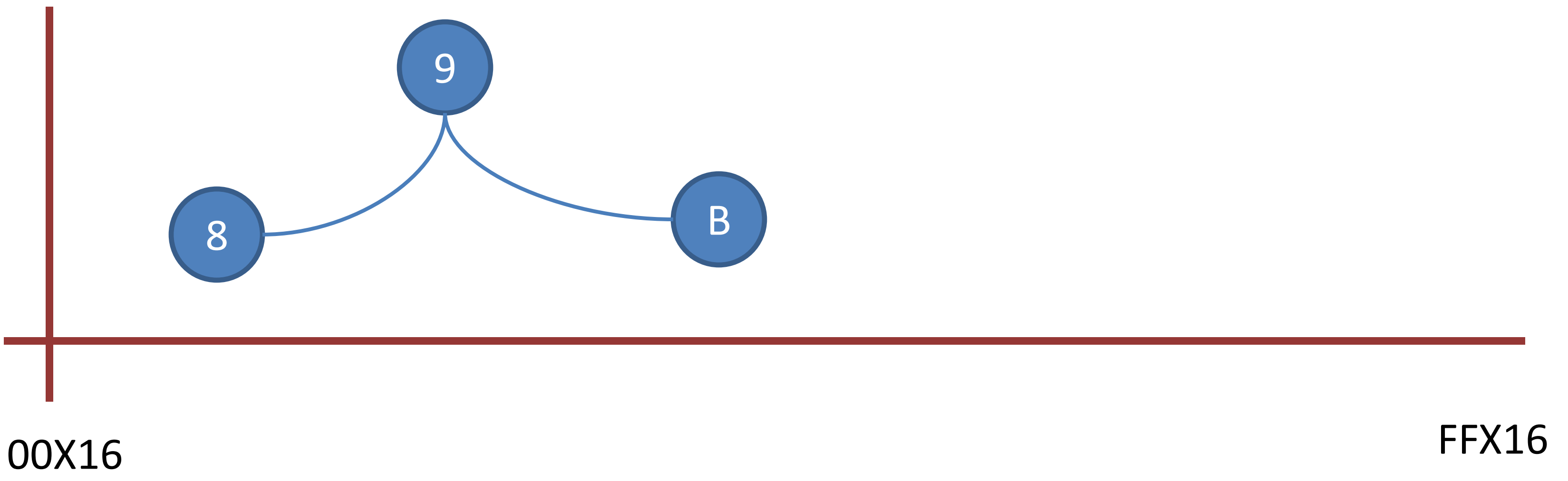
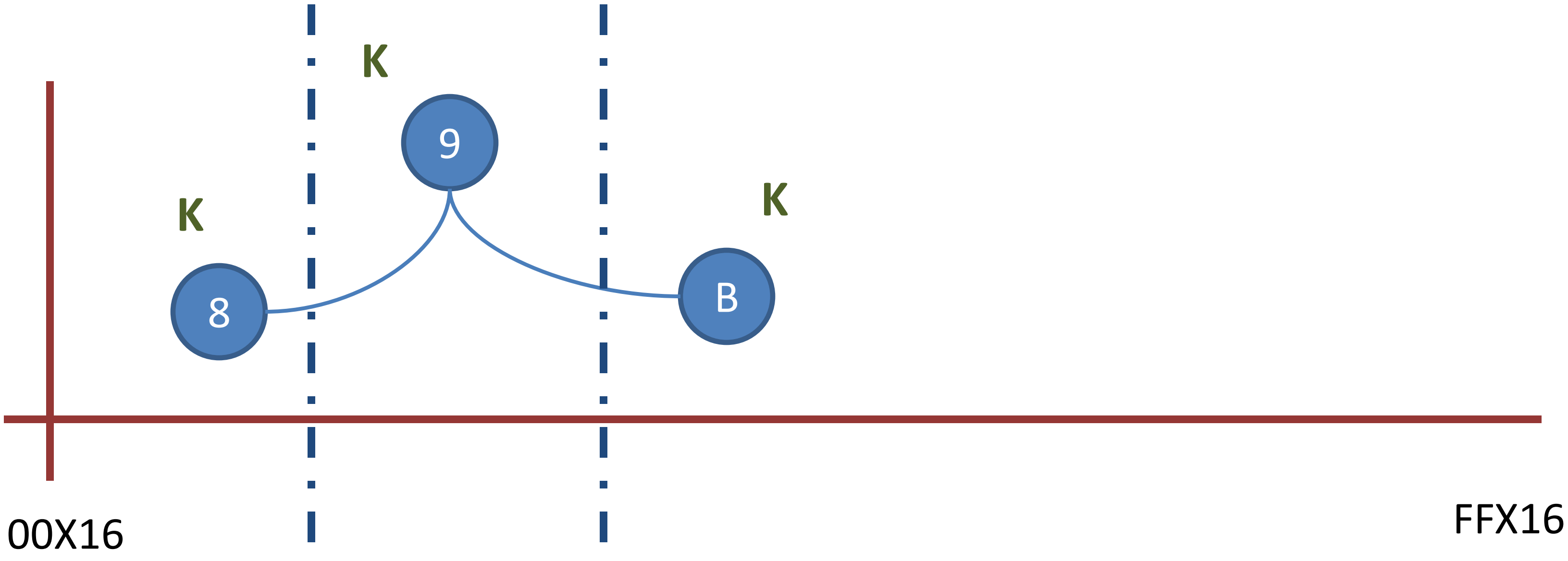


If a new node is inserted in between two other nodes, a connection from both ends is opened.

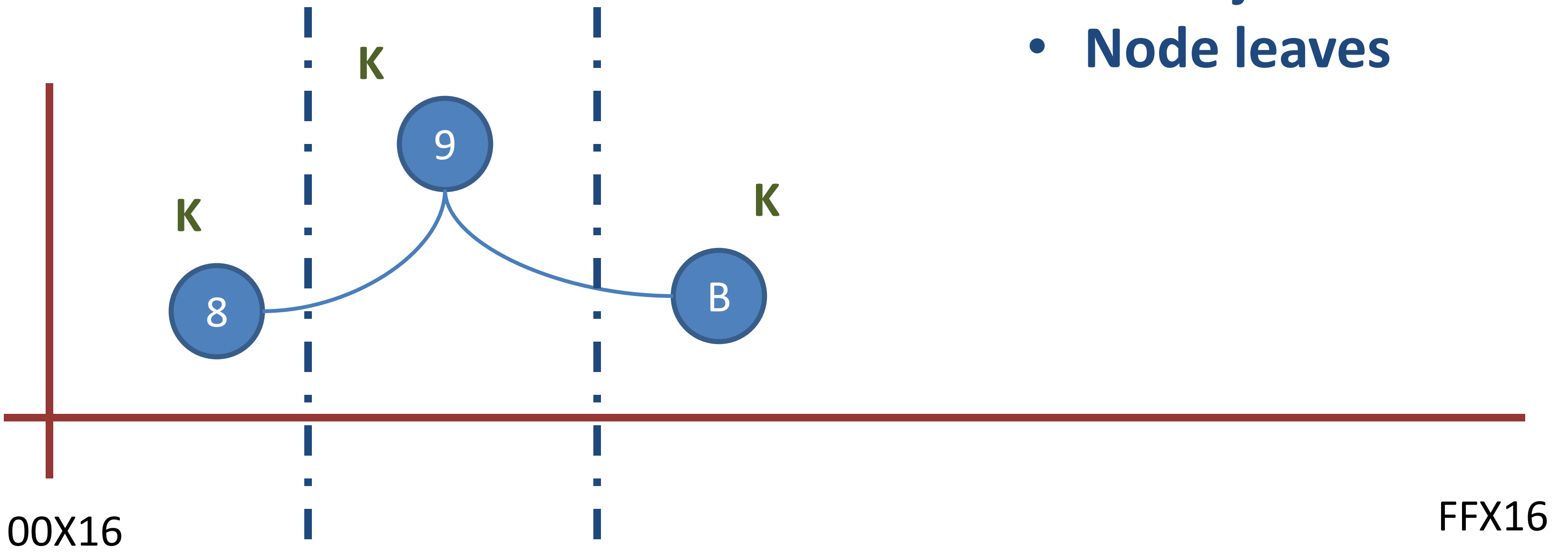
Key Space



Key Space

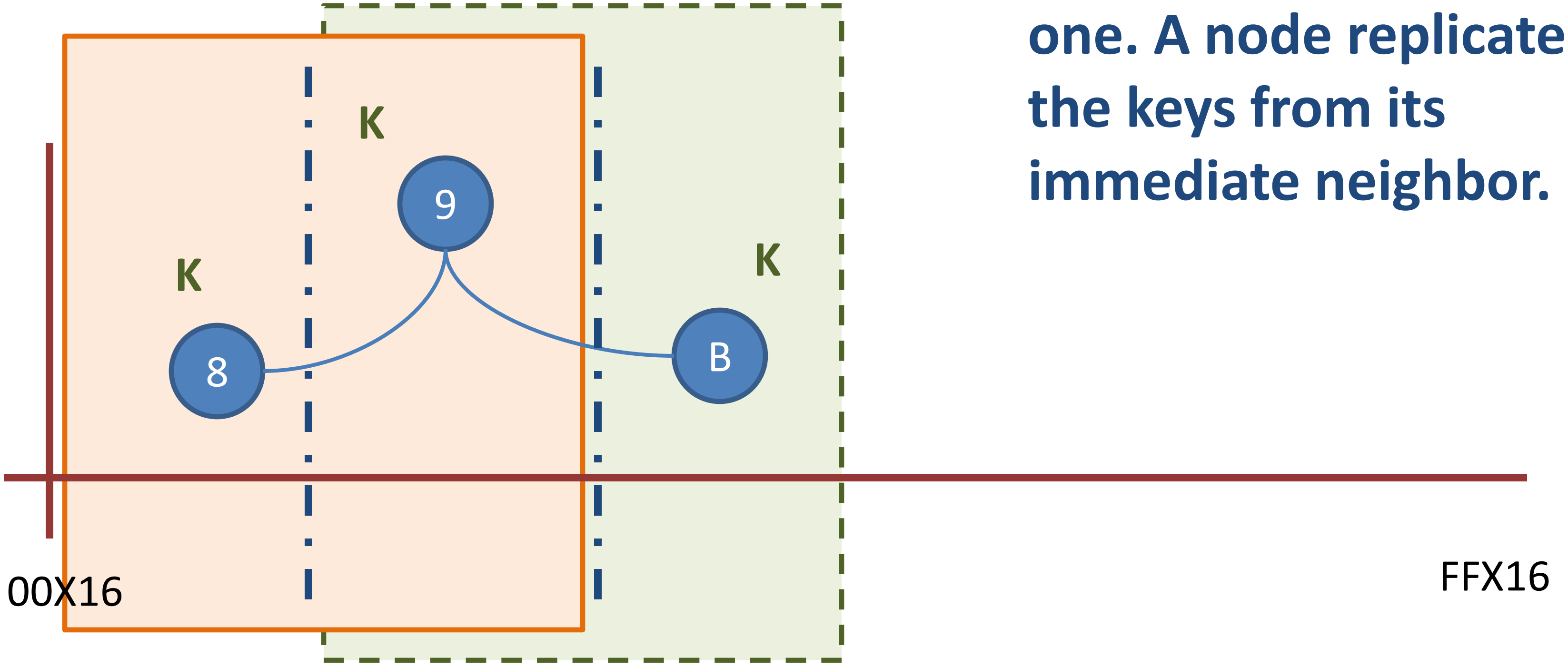


Key Space



Key redistribution:
- **Node joins**
- **Node leaves**

Key Space



Replication of degree one. A node replicates the keys from its immediate neighbor.

Find / Store Key

- Serialize data (JSON)
- Hash with SHA1 (node identifier as salt)
  - The result is a 160-bit key
- Find the closest XOR distance among the open connections and the peer itself.
  - Forward OR
  - Store
- On each peer "stamps" its id to the message => create a **trace route**

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Just like node aggregation

Example : Serialization and Key Construction

```
nodeId = “rqpws49p321”;
data = [
  {
    hello: “world:,
    name: “andres”,
    project: “iSocial”
  }
];

var value = JSON.Stringify(data);
var key = SHA1(nodeId + value);

console.log(“key: ” + key);
console.log(“value: ” + value);
```

```
> key: 97295d659d44340d72f084553239428de4b4f094
> value: [{hello: “world:, name: “andres”, project: “iSocial”}]
```

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- Commit logs
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alias project

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- Commit logs
- Latest version

What do we have so far?

- 160-bit key management
- XOR-wise distance calculation
- Node aggregation
- Find node and key
- Store
  - put(key, value)
- Retrieve
  - get(key)
- Trace communication route
  - Avoid deadlocks
- TTL

Finalize the first step…

- Implement look-ahead to speed up the finding process
- Testing:
  - Simulate 100 000+ nodes
  - Aspects to measure
    - Performance – response time of a find key operation
    - Reliability – how many nodes can fail while still maintaining an operation network?
  - More testing along with Peerialism…
- Come up with improvements
  - Allow new connections under certain conditions to reduce the number of hops => **subject to testing**
- Build demo applications
  - Micro-blogging
  - Social network
- Put it on paper ☺

What comes after the first step?

- Investigate DHT overlays
  - Design ***adaptable*** or ***multiple-criteria*** overlays
    - bandwidth
    - network proximity
    - reputation
    - social links
    - etc…
  - Implementation of a prototype
  - Allow applications to choose overlays based on requirements
- Experiment with key space
  - Faster recovery when nodes go offline
  - Faster lookups in large systems
  - Improve replication strategy (performance and reliability)

Thank you for your attention! ☺

Questions? Feedback?