IEEE ISCC 2014
June 2014

A Structured Overlay
for Non-uniform Node Identifier Distribution Based on Flexible Routing Tables

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Overlay Weaver

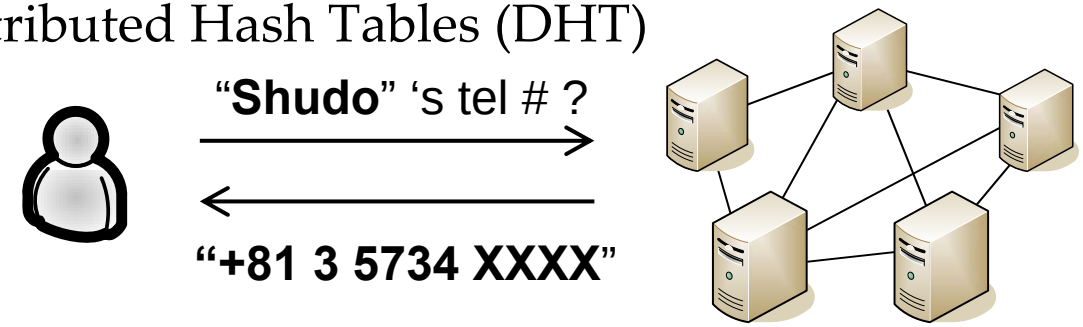
Background: Structured Overlay

- An application-level network
  - routes a query to the responsible node.

Index range (digest)	Responsible node
ab – dz	192.168.0.2
ea – gb	192.168.0.3
gc – …	192.168.0.4

Routing table

  - enables scalable data store and messaging.
    - e.g. Distributed Hash Tables (DHT)

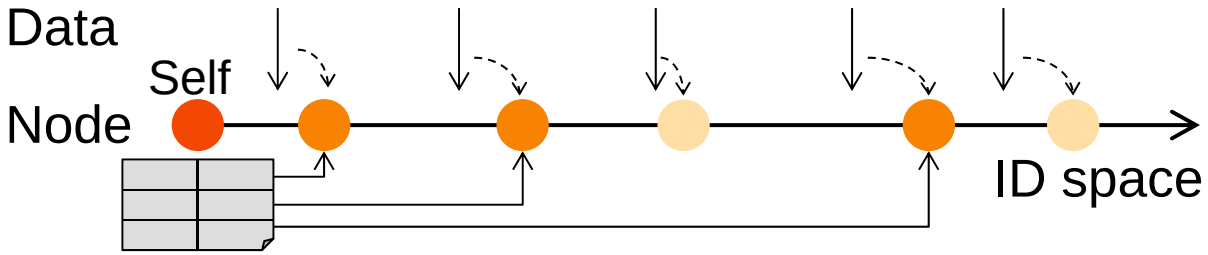


Contribution

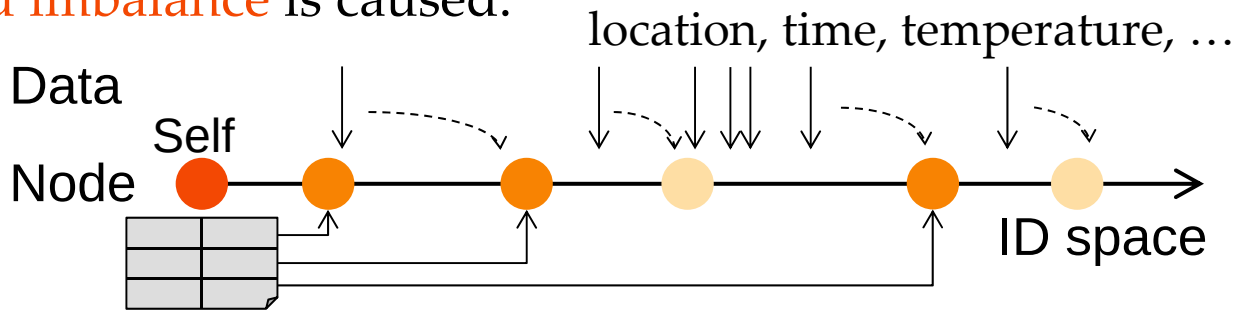
- A routing algorithm FRT-Chord#
  - supports non-uniform node ID distribution.
    - Range queries require it.
    - by **Chord#** [Schütt 2008] -inspired routing table maintenance.
  - has features existing overlays do not provide.
    - Extensibility, arbitrary routing table size, and one-hop property.
    - by **Flexible Routing Tables (FRT)** [Nagao 2011] -based design.

Non-uniform node ID distribution

- Traditional structured overlays
  - Node and data ID are generated with a hash function such as SHA-1.
  - Nodes in a routing table are selected based on **node IDs**.

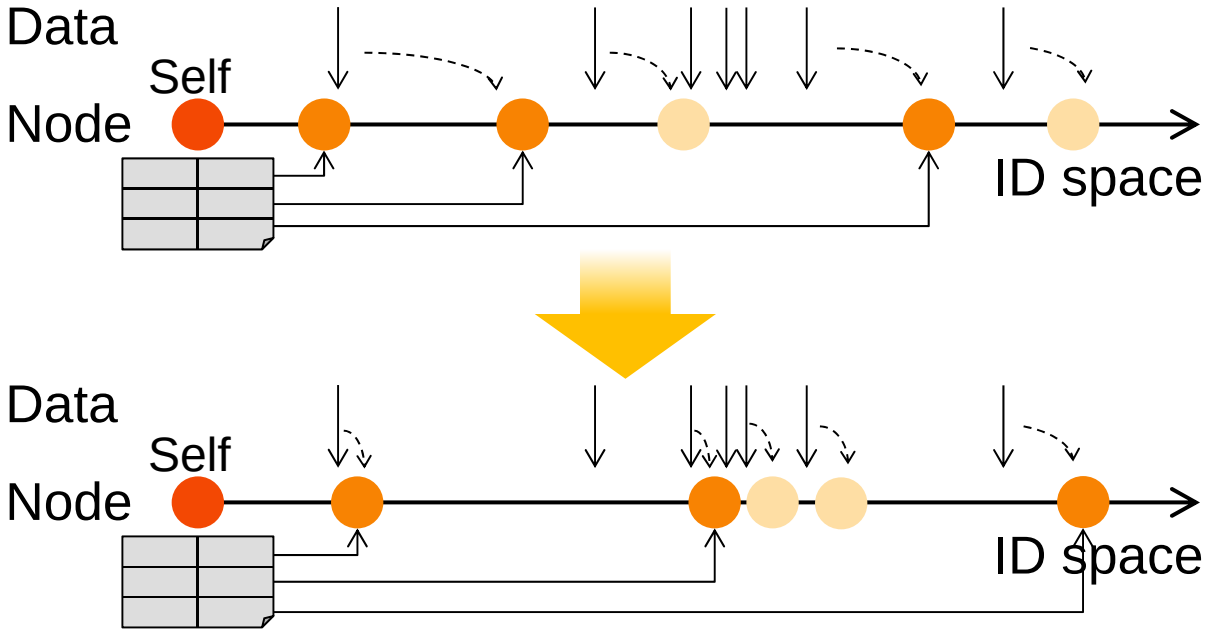


- To support range queries
  - Data are not hashed. Otherwise a query involves almost all nodes.
  - Load imbalance is caused.



Non-uniform node ID distribution

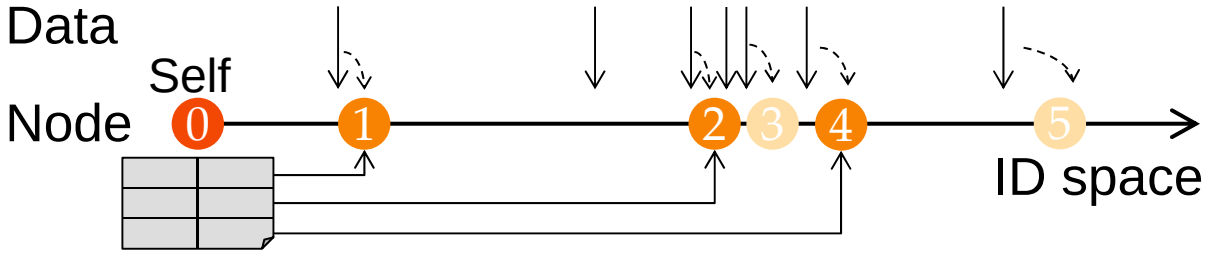
- To support range queries
  - 1) Virtual nodes
  - 2) Making a node ID distribution follow a data ID distribution



  - But a non-uniform node ID distribution leads larger hop numbers / longer path length.

Non-uniform node ID distribution

- **Node order** based routing table maintenance
  - **Chord#** [Schütt 2008] does it.
  - cf. Node ID based
  - Efficient lookups = smaller hop numbers / shorter path length by having enough number of pointers to dense areas.



  - Our algorithm FRT-Chord# adopts it.

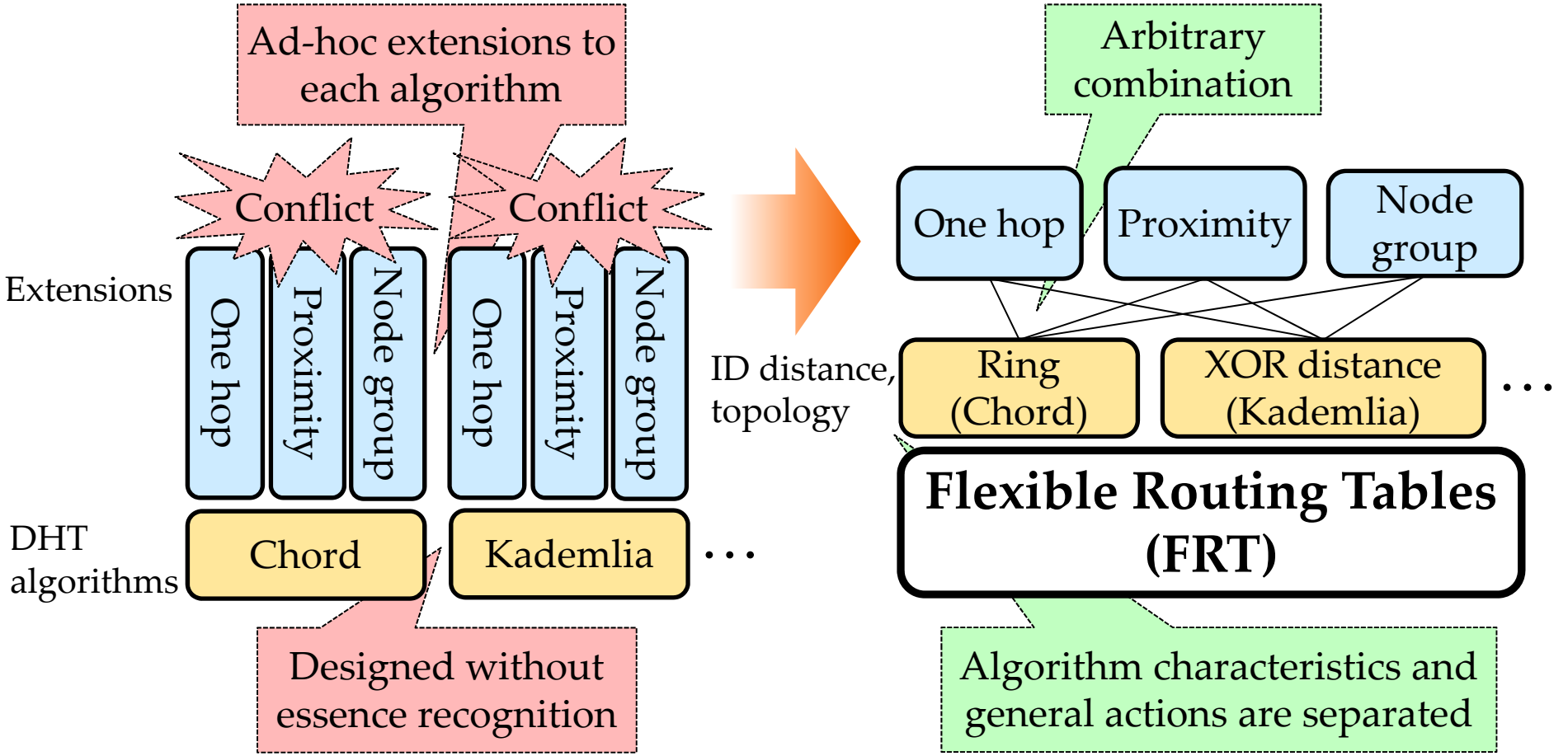
We designed a Flexible Routing Table (FRT) based algorithm that perform it.

described in next pages

Flexible Routing Tables (FRT)

[Nagao 2011]

- A unified framework for structured overlays.
  - A methodology to design a routing algorithm



Flexible Routing Tables (FRT)

[Nagao 2011]

- Declarative algorithm definition and common actions are separated.
- A routing table is just a list of entries.
- Algorithm definition — an algorithm designer provides
  - $\leq_{RT}$ A total order on the set of all routing table patterns
    Better is higher. "Better" means smaller hop numbers / shorter path length.
  - Sticky entries
    Routing table entries not to be removed from the table.
    E.g. successor in Chord
- Common actions — FRT provides
  - Entry learning — A node notices another node and put it to the table.
  - Entry filtering — A table overflows, an entry is selected and removed.

Flexible Routing Tables (FRT)
[Nagao 2011]

- FRT-based algorithms
  - FRT-Chord [Nagao 2011]
  - FRT-2-Chord [Ando 2014]
  - FRT-XOR, that borrows ID space and distance from Kademlia
  - FRT-Chord# (this paper)
- Extensions
  - Proximity-aware FRT (PFRT) [Miyao 2013]
  - Grouped FRT (GFRT)
  - Virtual Node Fusion (VNF)

- Features of FRT
  - Extensibility
    - Algorithms and extensions can be combined arbitrarily.
  - Arbitrary routing table size
  - One-hop property
    - A query reaches the responsible node in one-hop if # of nodes $\leq$ the routing table size.
    - Note that FRT-Chord# itself does not perform one-hop lookup, but 2-hop, that is lowest and the same as Chord and Chord#.

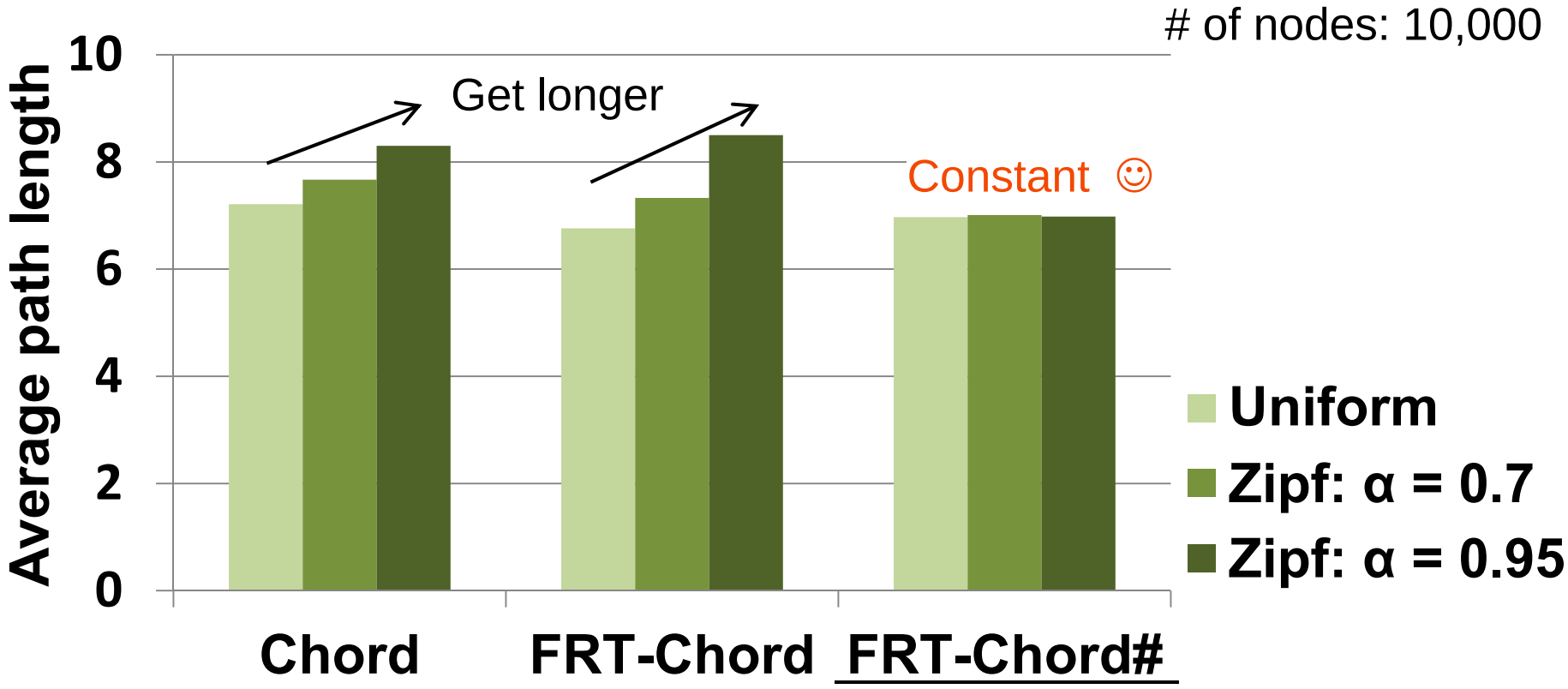
- FRT-Chord# achieves efficient lookups with non-uniform ID distribution while providing the features of FRT.

Evaluation

- Goals: to confirm that
  - Path length does not get longer even with non-uniform node ID distributions
  - FRT-Chord# retains features of FRT
- Compared with Chord and FRT-Chord
- Configuration
  - Routing table size: 16, determined to be fair with Chord
  - Distributed environment emulator of Overlay Weaver 0.10.1
  - Java SE 6 Update 22
  - Linux 2.6.35

Overlay Weaver

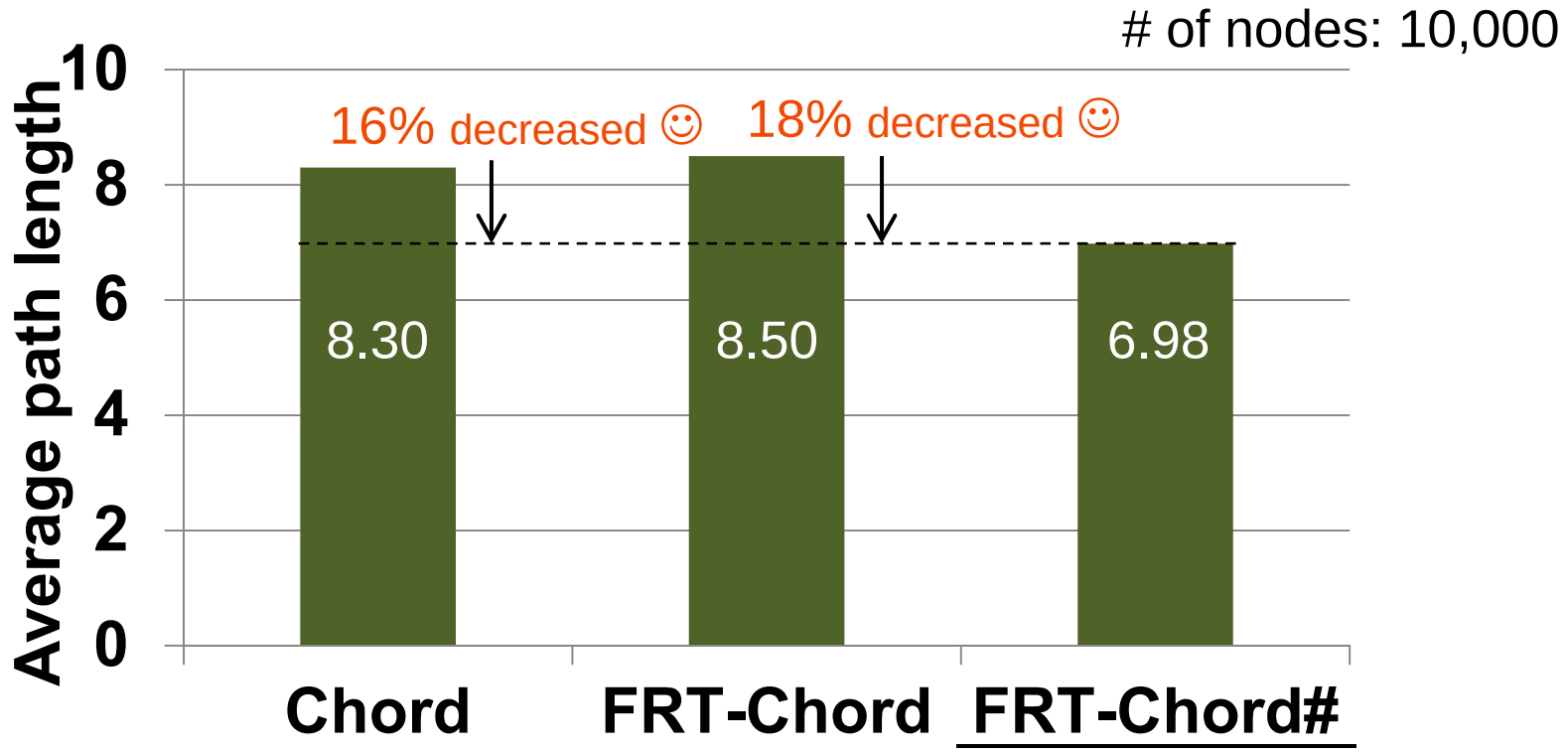
Node ID distributions and path length



- Path lengths do not depend on node ID distributions.

Node ID distributions and path length

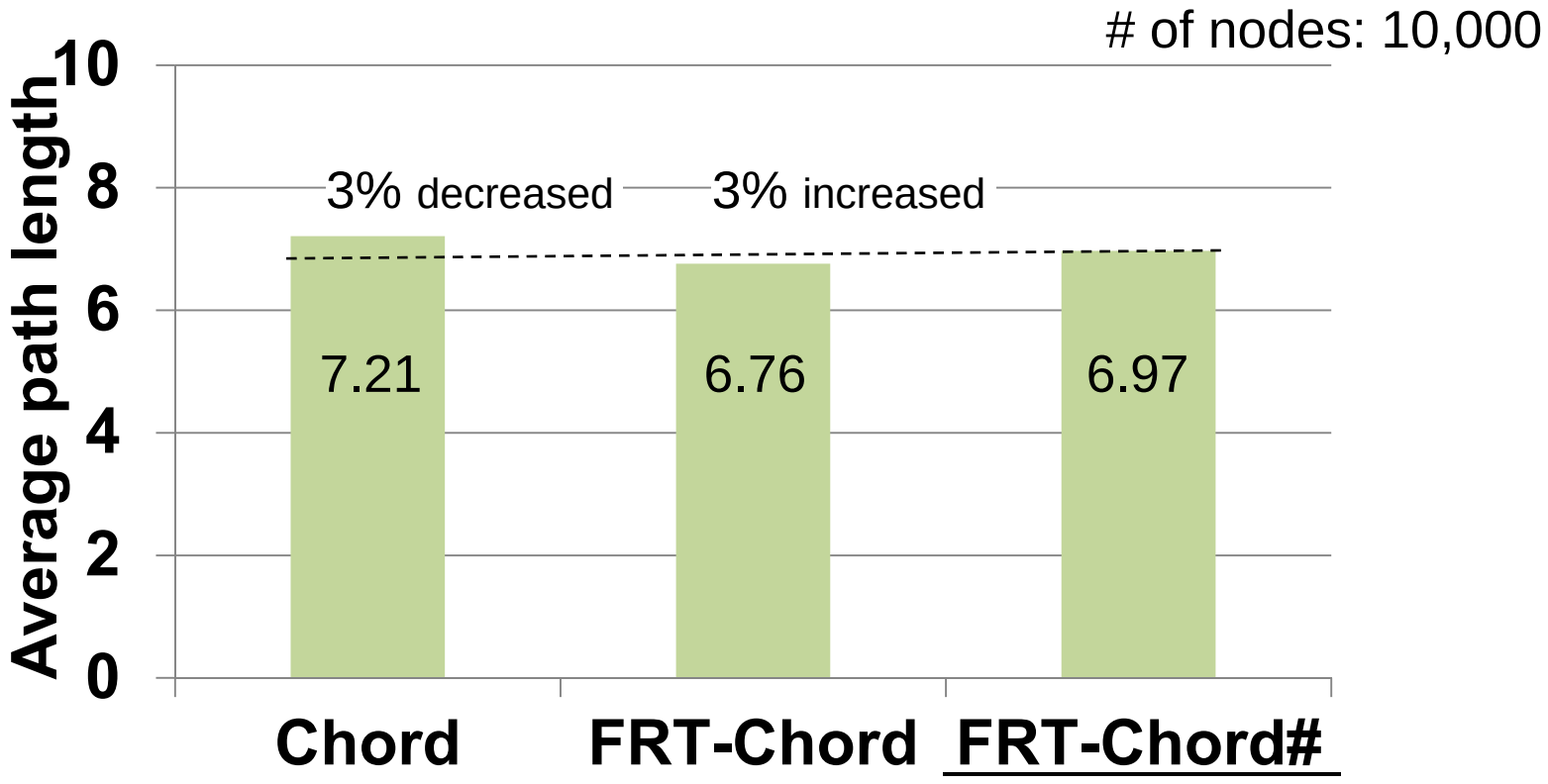
- Zipf distribution with $\alpha = 0.95$



- FRT-Chord# shows shorter path length.

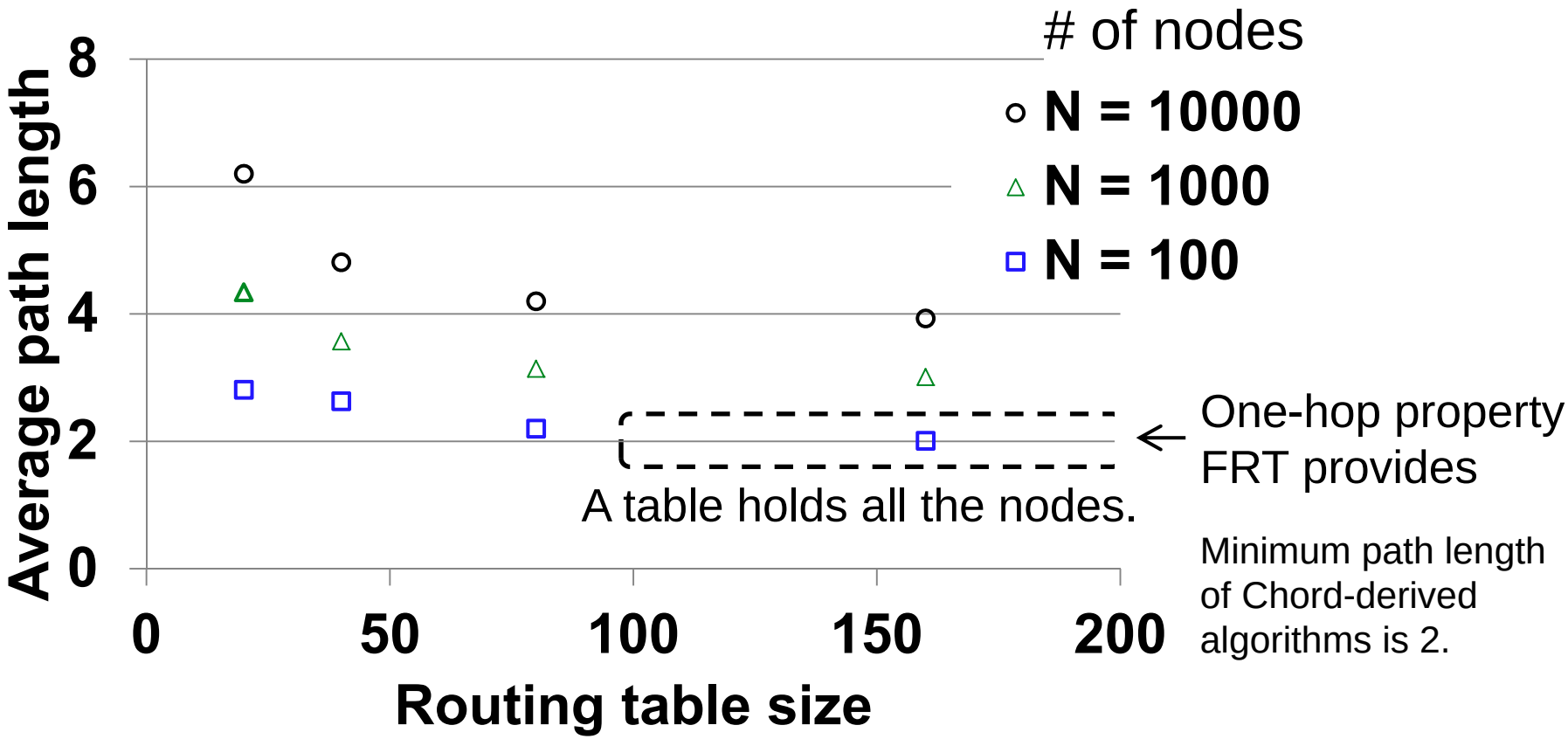
Node ID distributions and path length

- Uniform distribution



- Comparable with existing algorithms.

Arbitrary routing table size



- Larger tables show shorter path lengths.
- FRT-Chord# retains this feature: arbitrary …

Summary

- **FRT-Chord#** is a routing algorithm for structured overlays
  - supports non-uniform node ID distributions
    - Range queries require this feature.
  - designed along Flexible Routing Tables (FRT)
    - Features: extensibility, arbitrary routing table size, and one-hop property