Efficient Slot Assignment for the Many-to-One Routing Pattern in Sensor Networks

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Introduction

- Many-to-One routing pattern
- Task: Nodes have stored data records that need to be routed reliably towards a sink
- Tree Routing
- Objectives: Minimize energy consumption & Maximize throughput
- Problems:
    - Channel congestion
    - Buffer congestion
    - Reliability
    - Energy efficiency
- TDMA schedule with send and receive times is very energy efficient

TDMA Schedules

- Classical TDMA schedules based on k-hop neighborhood
  - produce collisions in the order of 10%
  - are difficult to set up distributedly
  - lead to buffer congestion
- Contribution: *Spatial path-based reuse (SPR)*
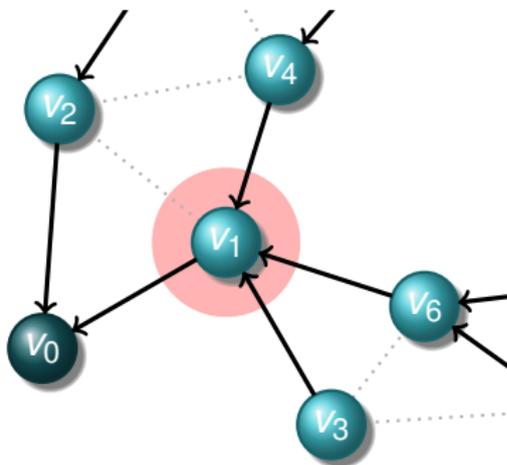
Interference versus communication radius
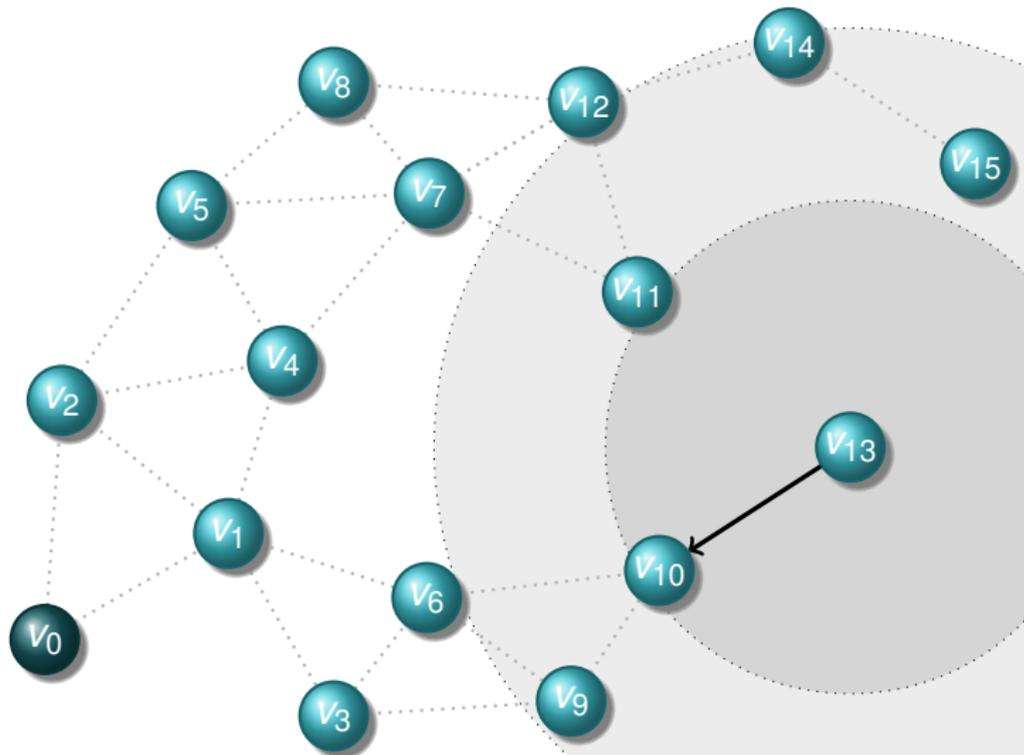
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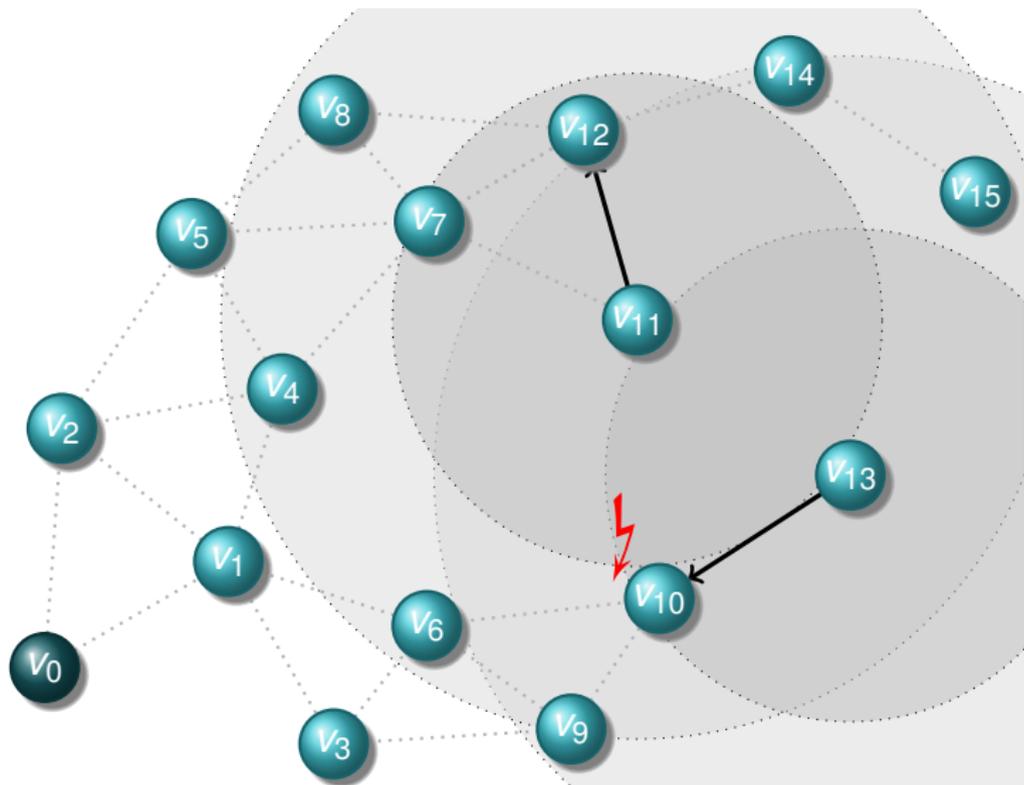
Buffer Congestion

Problem

If each node in a tree sends a single packet during each round, then buffers will overflow.
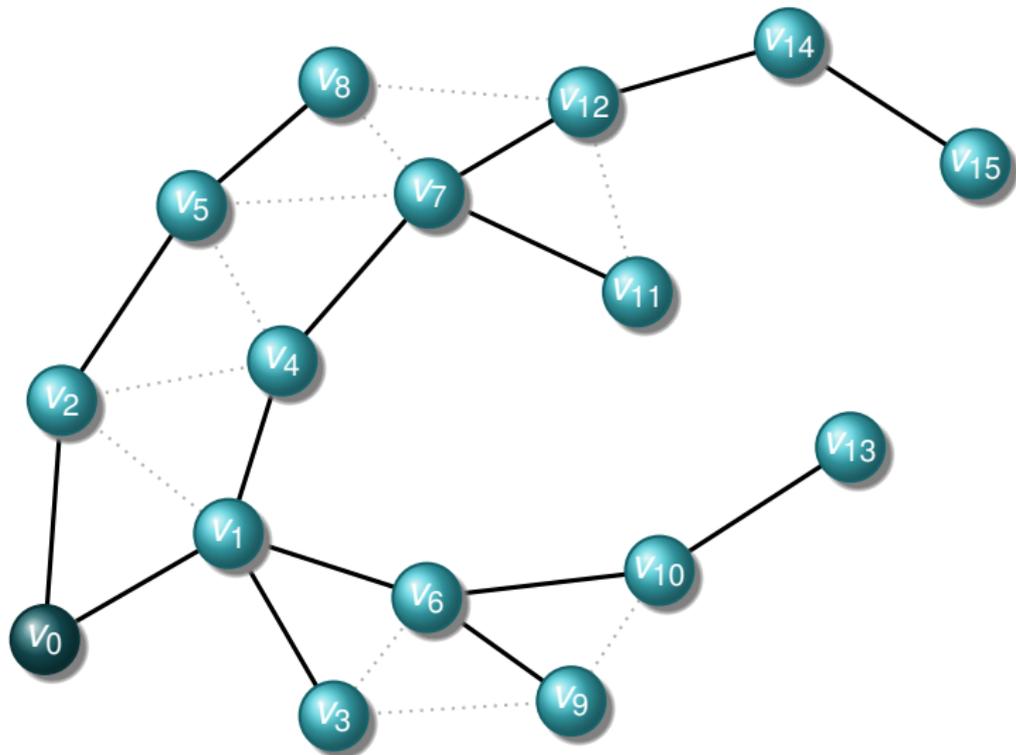

- Requirement: Each node must forward on the average as many packets as it receives during each round
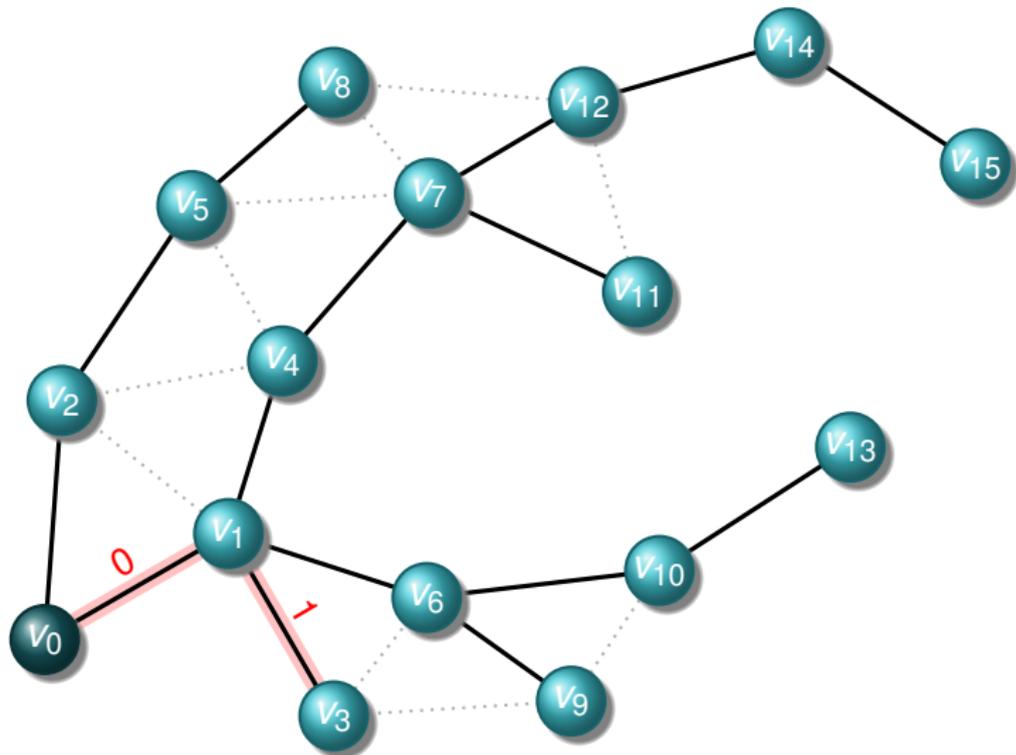
Spatial path-based reuse (SPR)

- SPR solves previously mentioned problems
- Routing tree is an overlay of the paths from sink to each leaf
- Each path has its private set of slots
- Final slot assignment: Union of individual slots
  $\implies$ no inter-path collisions
- How to assign slots to nodes of a path?
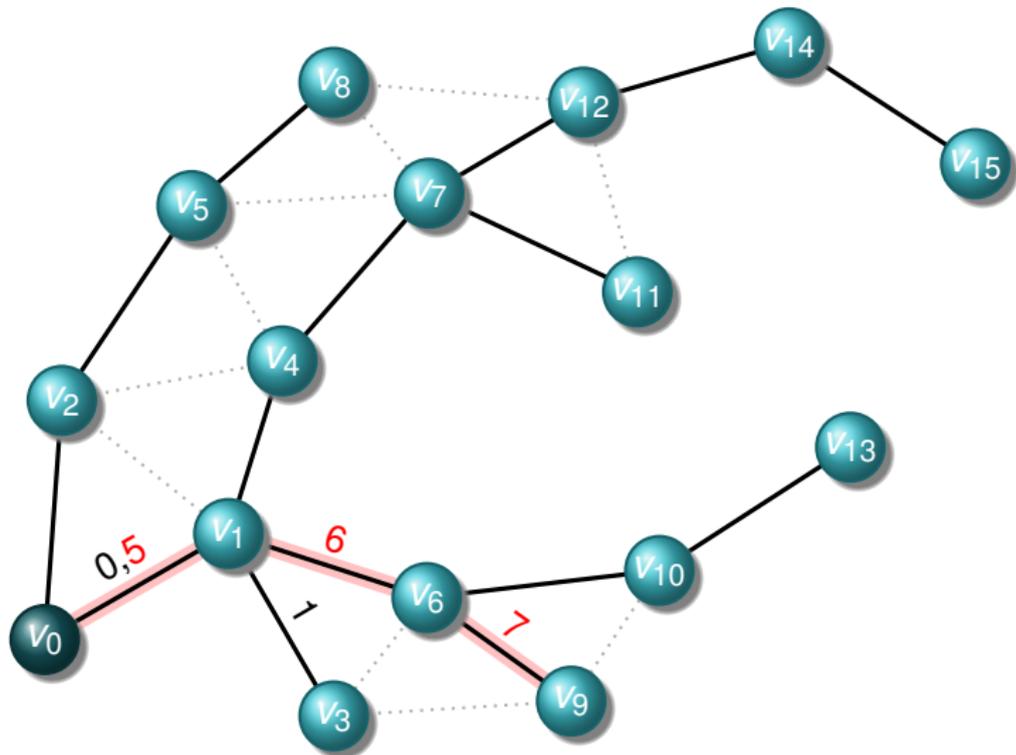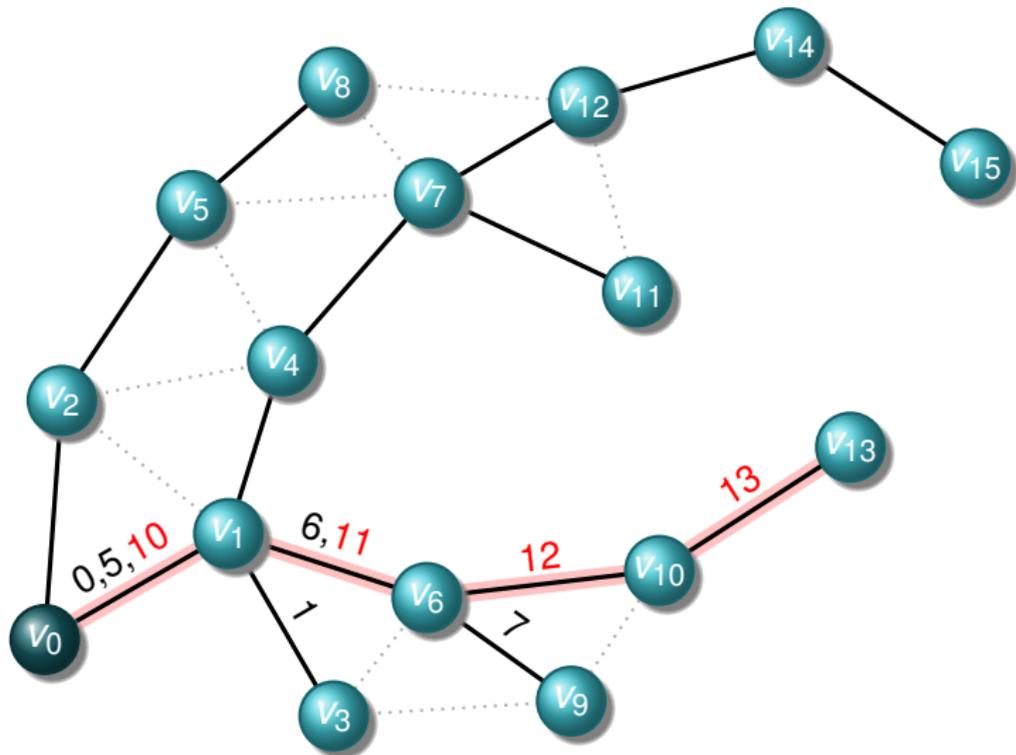 - Use κ slots per path, assigned in ascending order modulo κ

Example I

Path-based Slot Assignment - $\kappa = 5$

Example I

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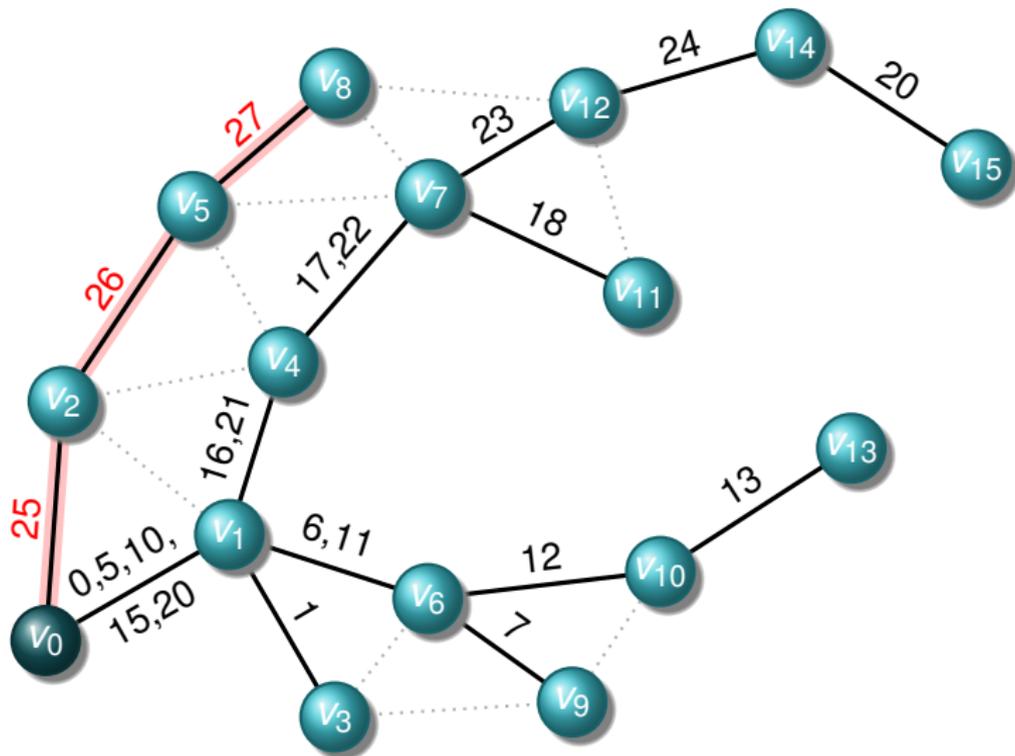Example I

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Example I

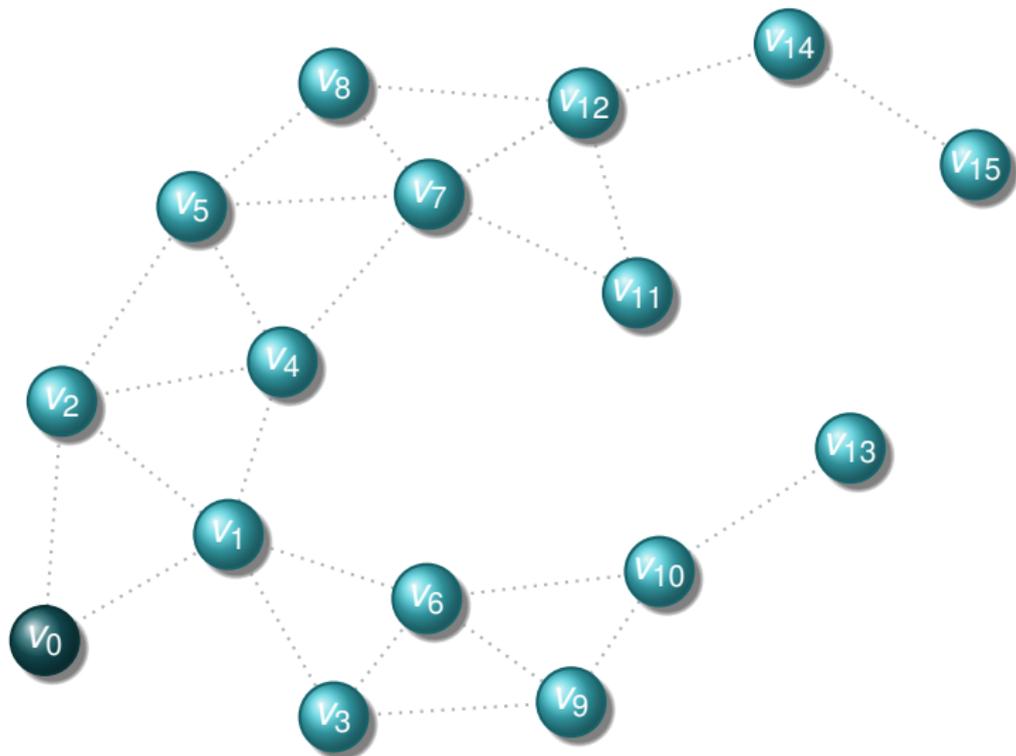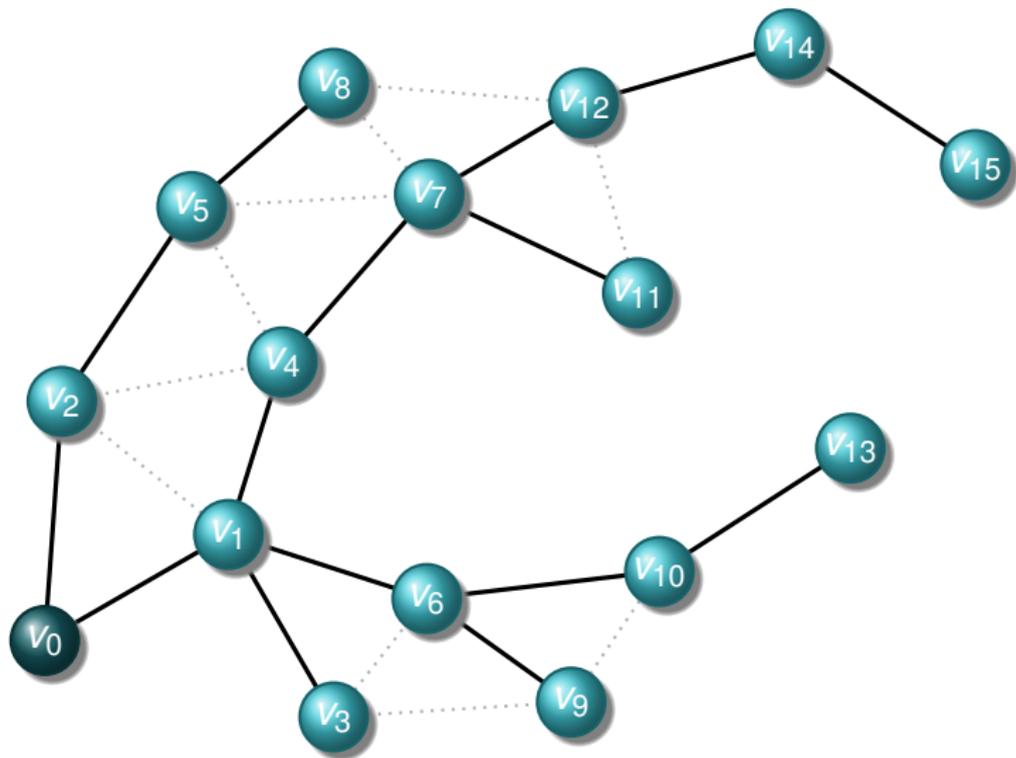# Path-based Slot Assignment - $\kappa = 5$
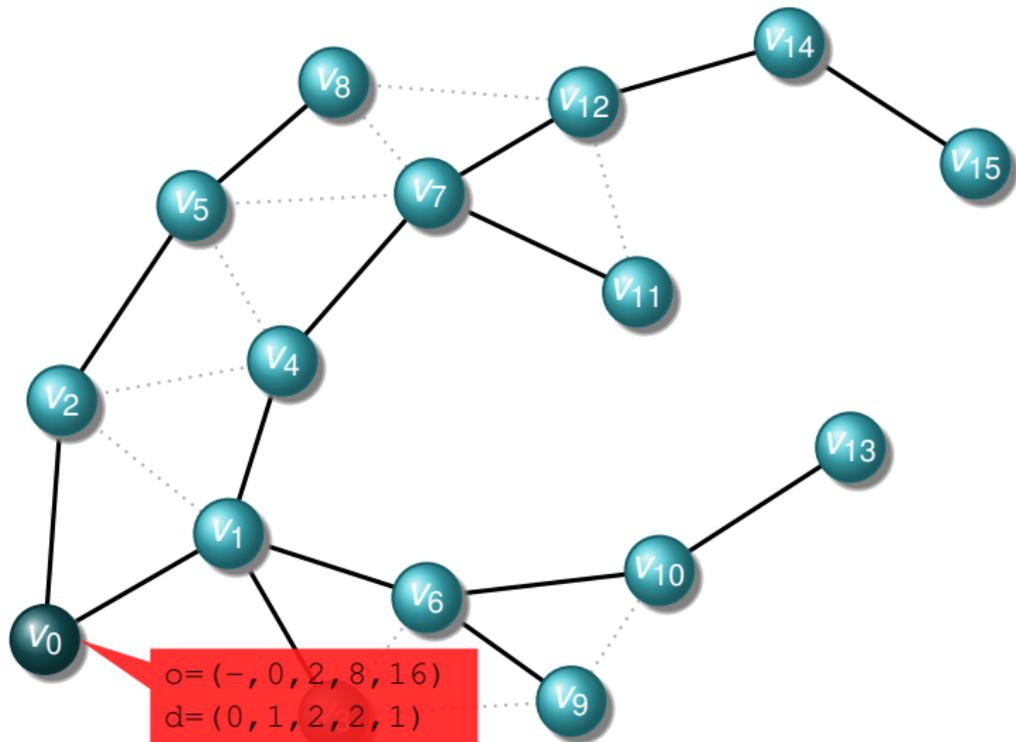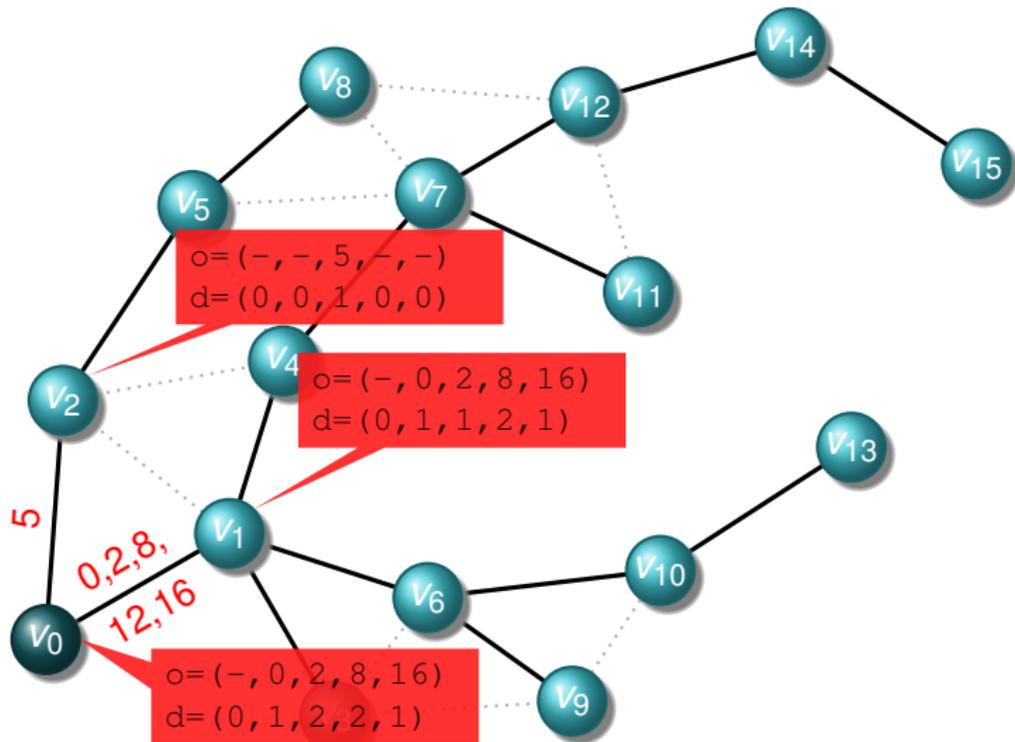
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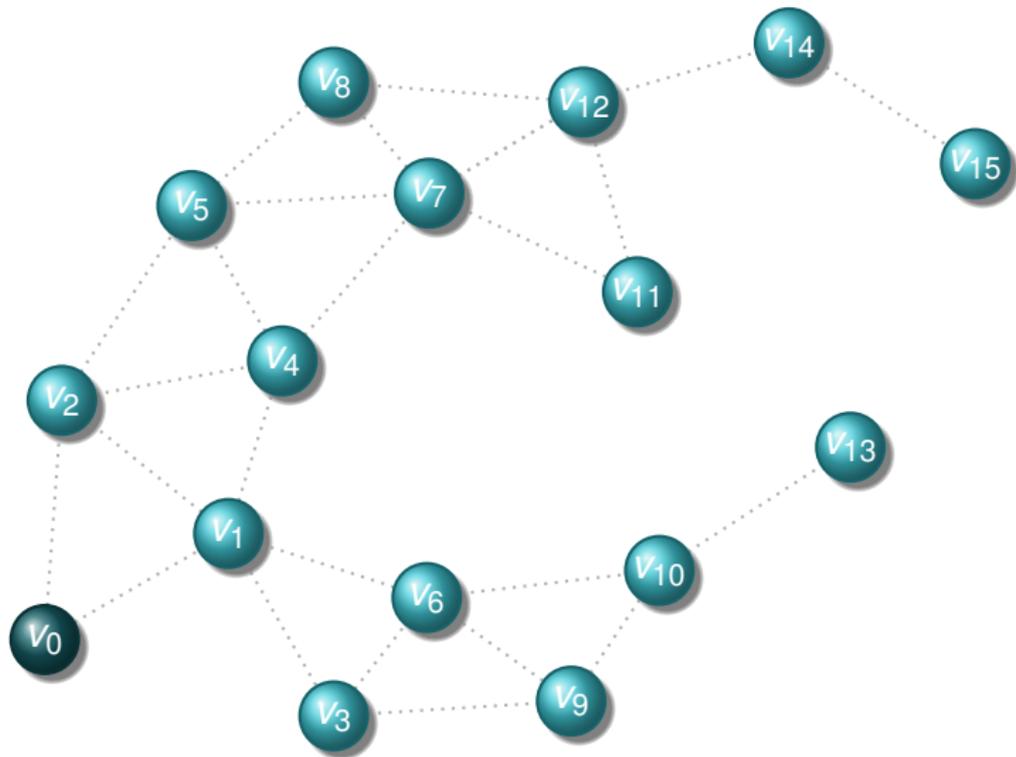
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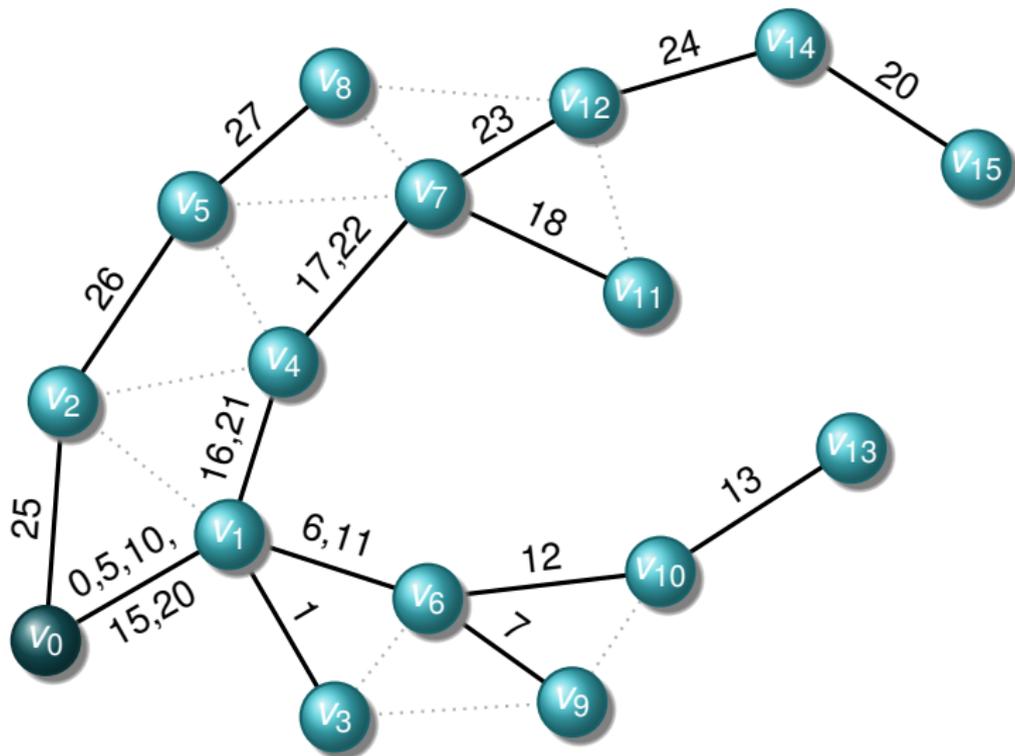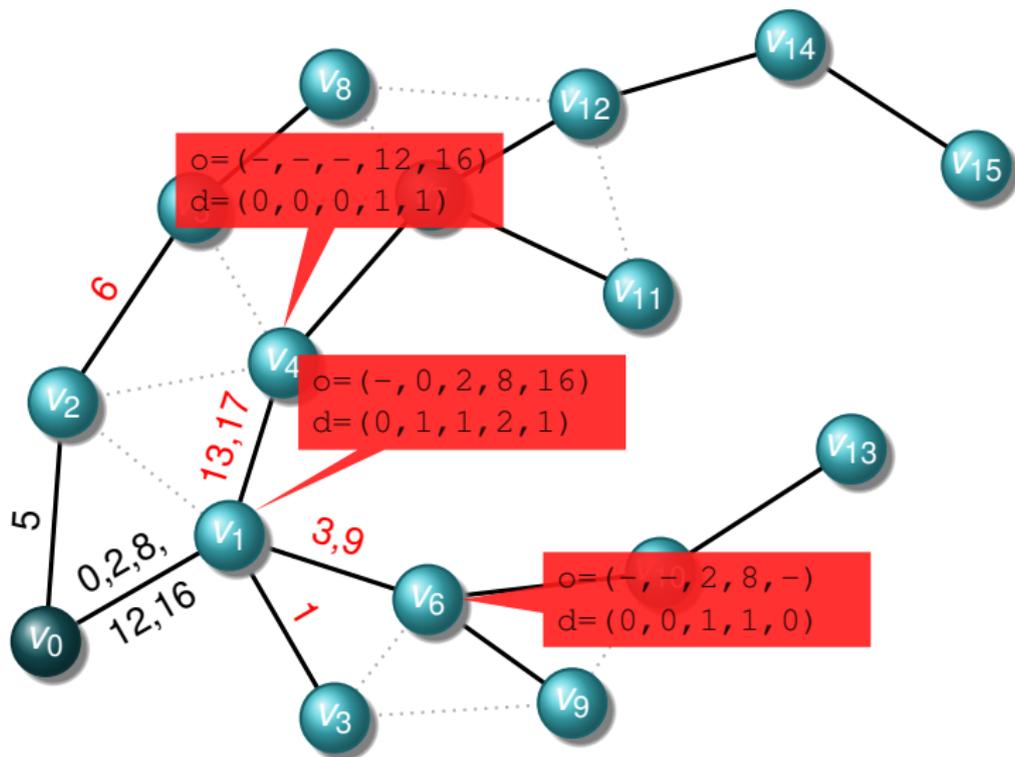
Path-based Slot Assignment

☞ Nodes only need to store start and end slot

☞ Some slots are unused in case of leaves having depth less than κ

- SPR avoids this problem
- Storage requirement $O(d)$, d number of children

Example II

SPR Slot Assignment - $\kappa = 5$

Example II

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SPR Slot Assignment - $\kappa = 5$

o=(-,0,2,8,16)
d=(0,1,2,2,1)

Example II

SPR Slot Assignment - $\kappa = 5$

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Example II

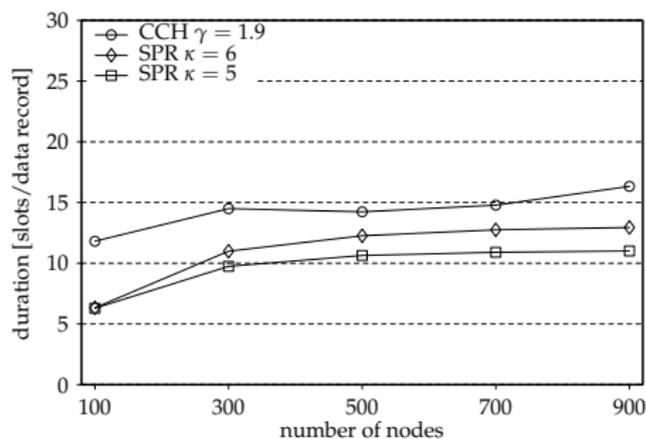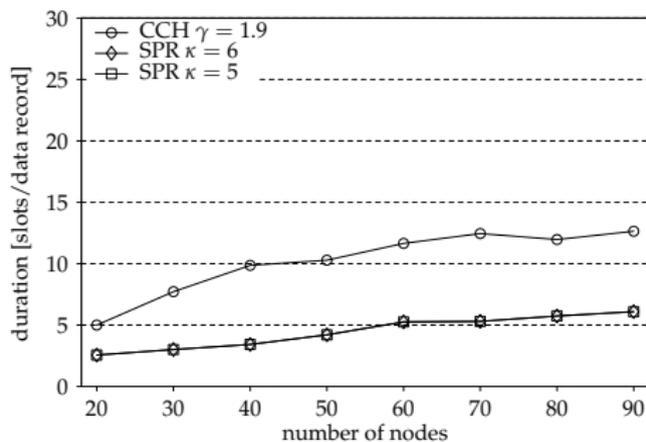# SPR Slot Assignment - $\kappa = 5$

Example II

SPR Slot Assignment - $\kappa = 5$

Example II
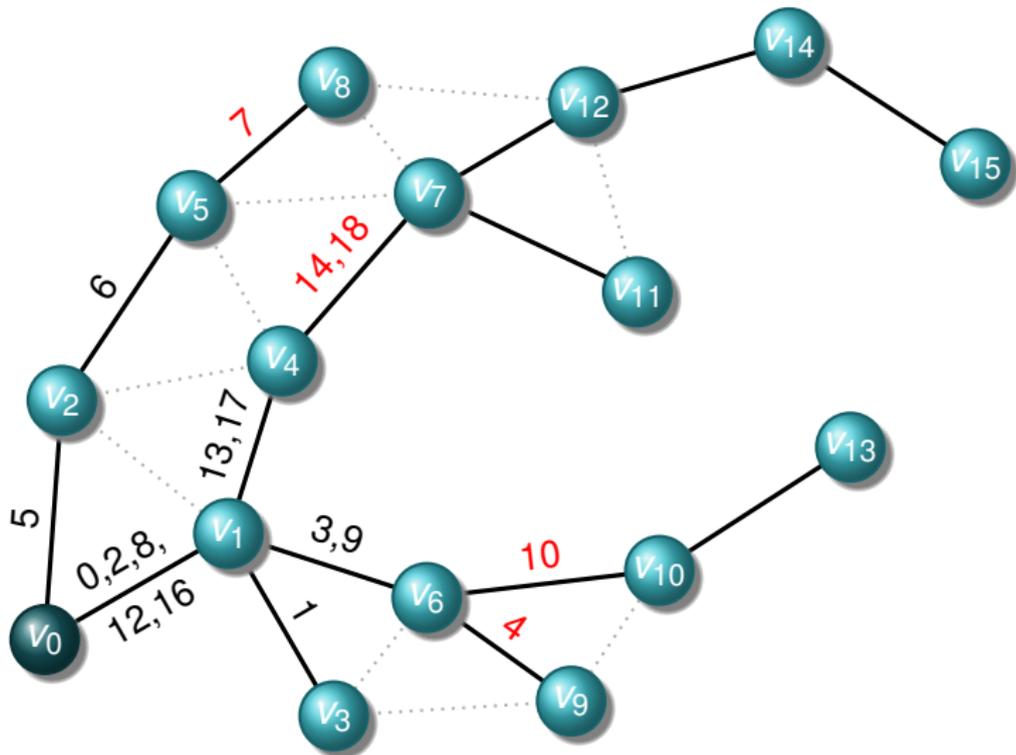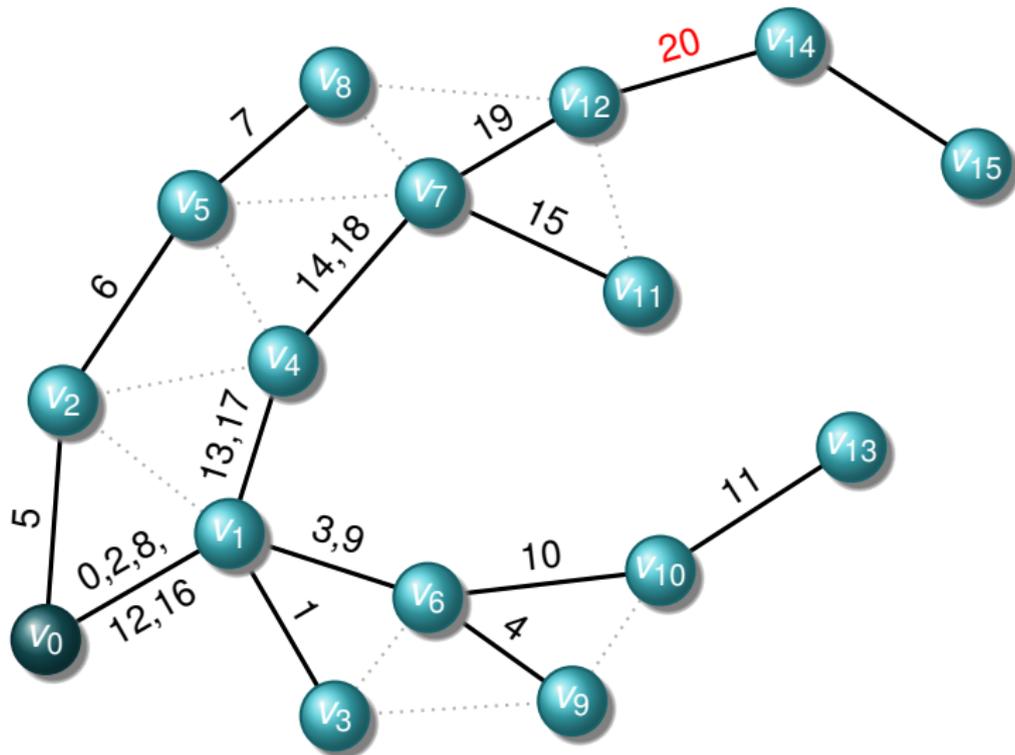
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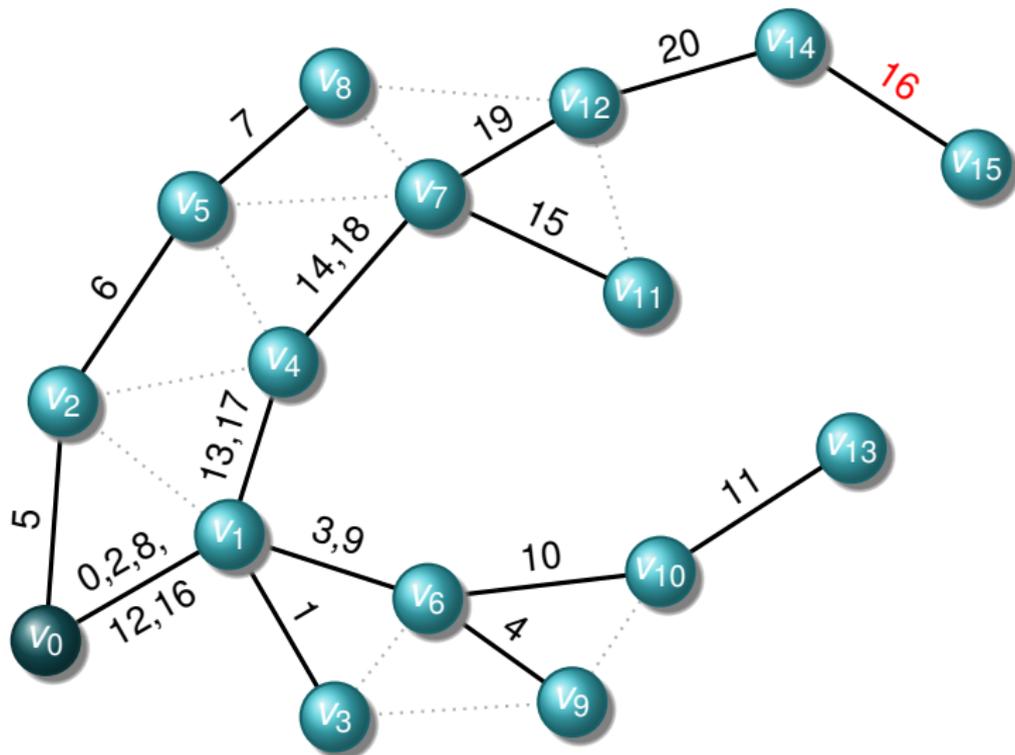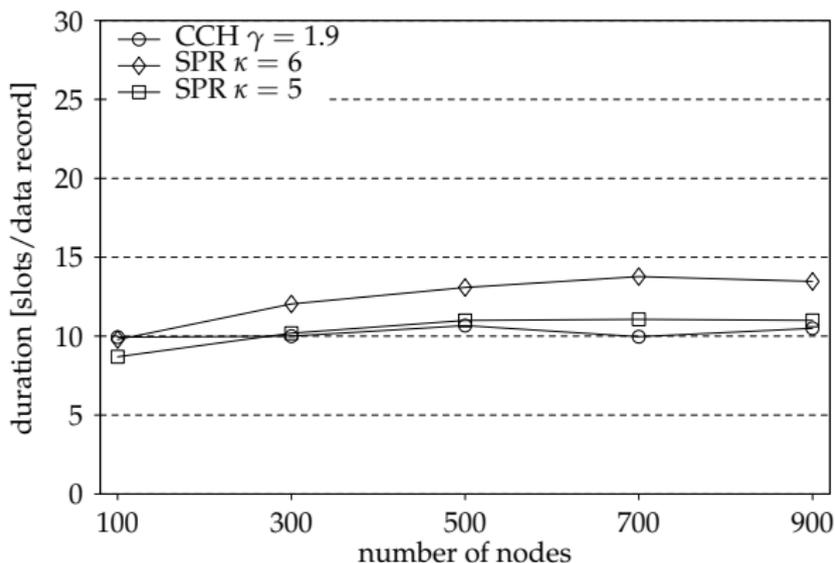
Simulations

- Comparison with centralized schedule based on CCH
- Varied parameters
  - Network size and density
  - Number of children
  - Buffer sizes and initial fill levels
  - Value for κ
- Measured values
  - Collisions
  - Average time per data record
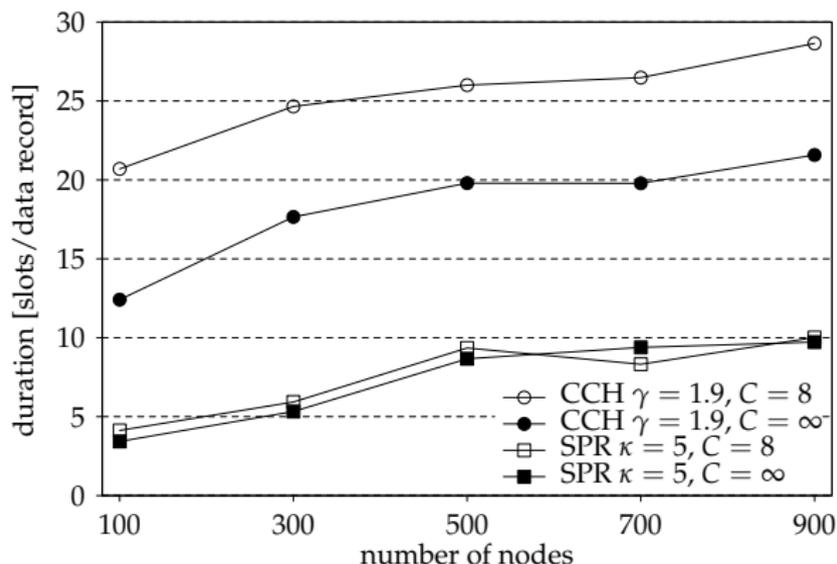 - Energy usage
- Ns-2

Medium Density

- SPR superior to CCH
- For small networks no difference between $\kappa = 5, 6$
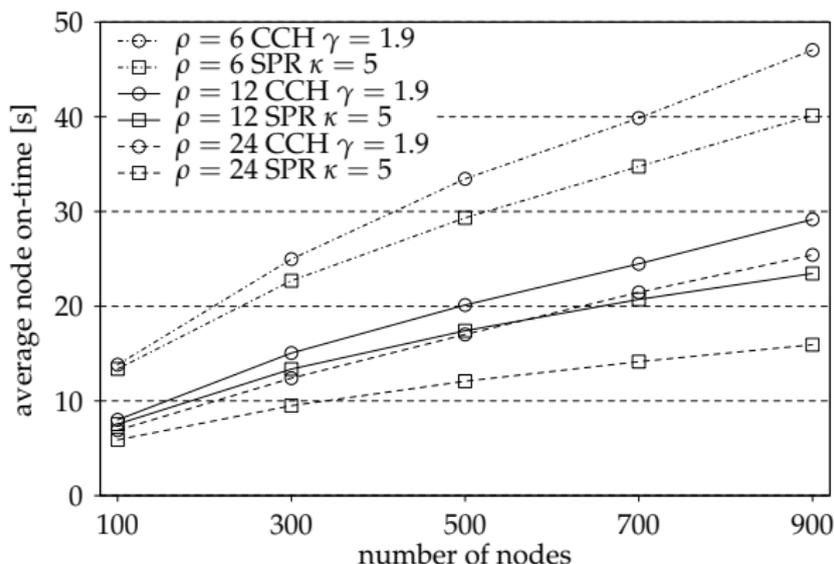
Low Density

- At low densities CCH marginally better
- Reason: Large variation of depth of leaves in each subtree

Number of Children

- SPR insensitive to maximal number of children
- CCH better for unlimited number of children (sink has more children)

Energy Consumption

- Generally SPR requires less energy than CCH (buffer overflow)
- Energy consumption decreases with increasing density (average depth decreases)

Conclusion

- Purely localized algorithms do not completely avoid interference
- SPR uses some global knowledge (depth in tree)
- SPR has significantly lower energy-consumption and higher throughput
- SPR has small memory footprint and is easy to implement

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