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Load Balancing in Periodic Wireless Sensor Networks for Lifetime Maximisation

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2nd year PhD

Multi-Service Networks 2011

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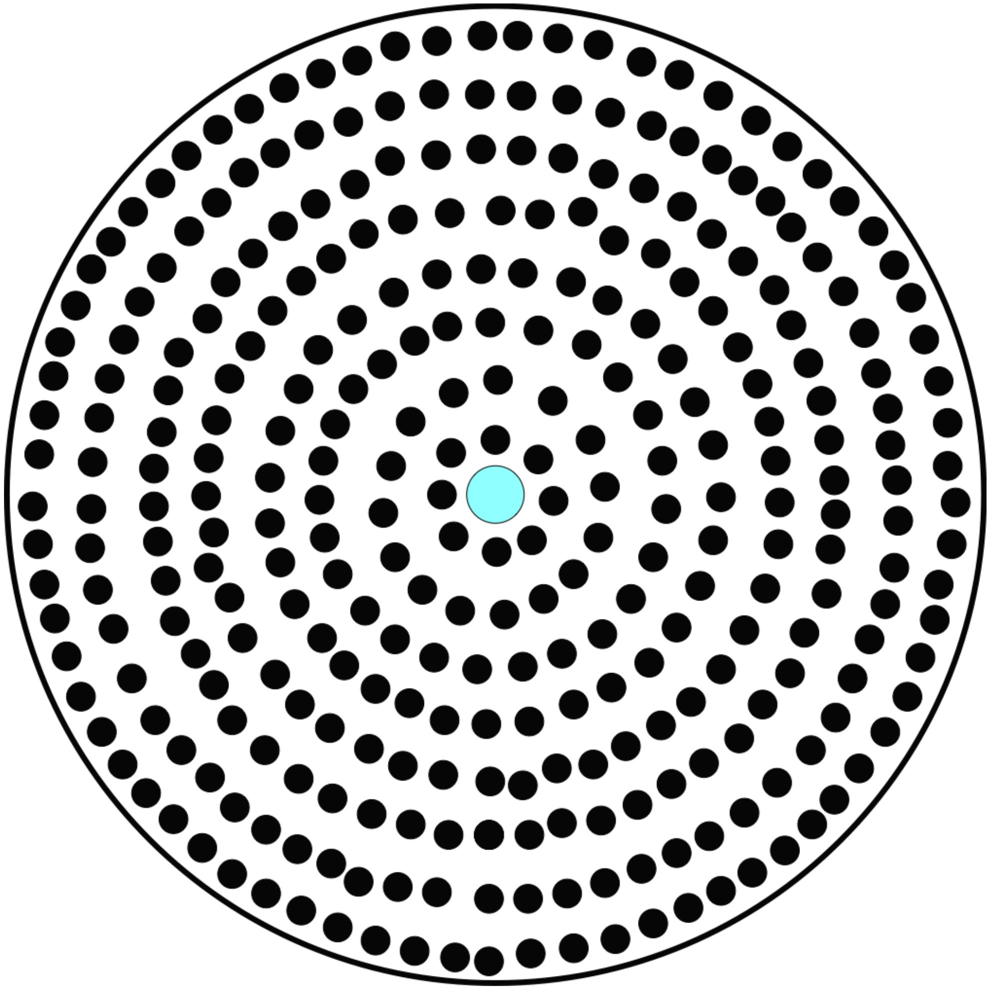
The Energy Hole Problem

- Uniform distribution of motes
- Regular, periodic reporting

  eg. Habitat monitoring
- Many-to-one traffic flow
- Multi-hop communication



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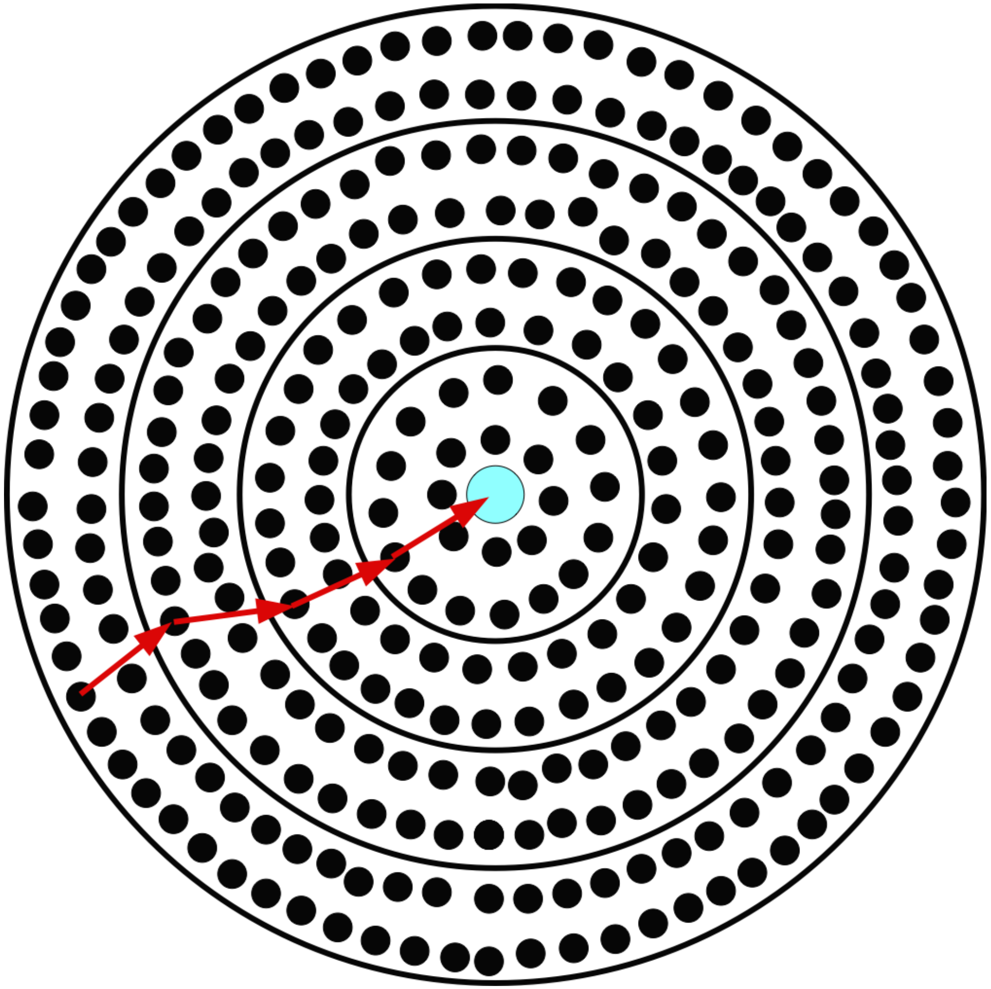

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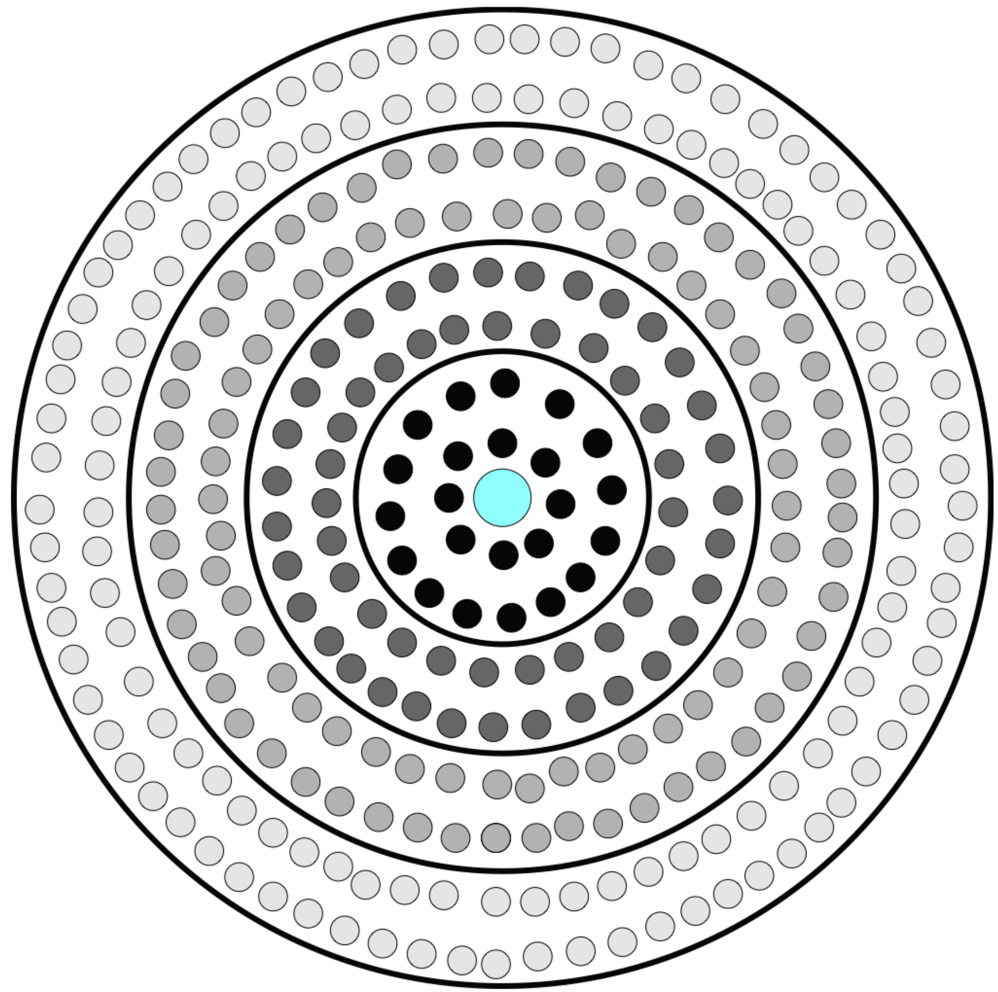
The Energy Hole Problem

- Non-uniform distribution of work
- Central motes die first



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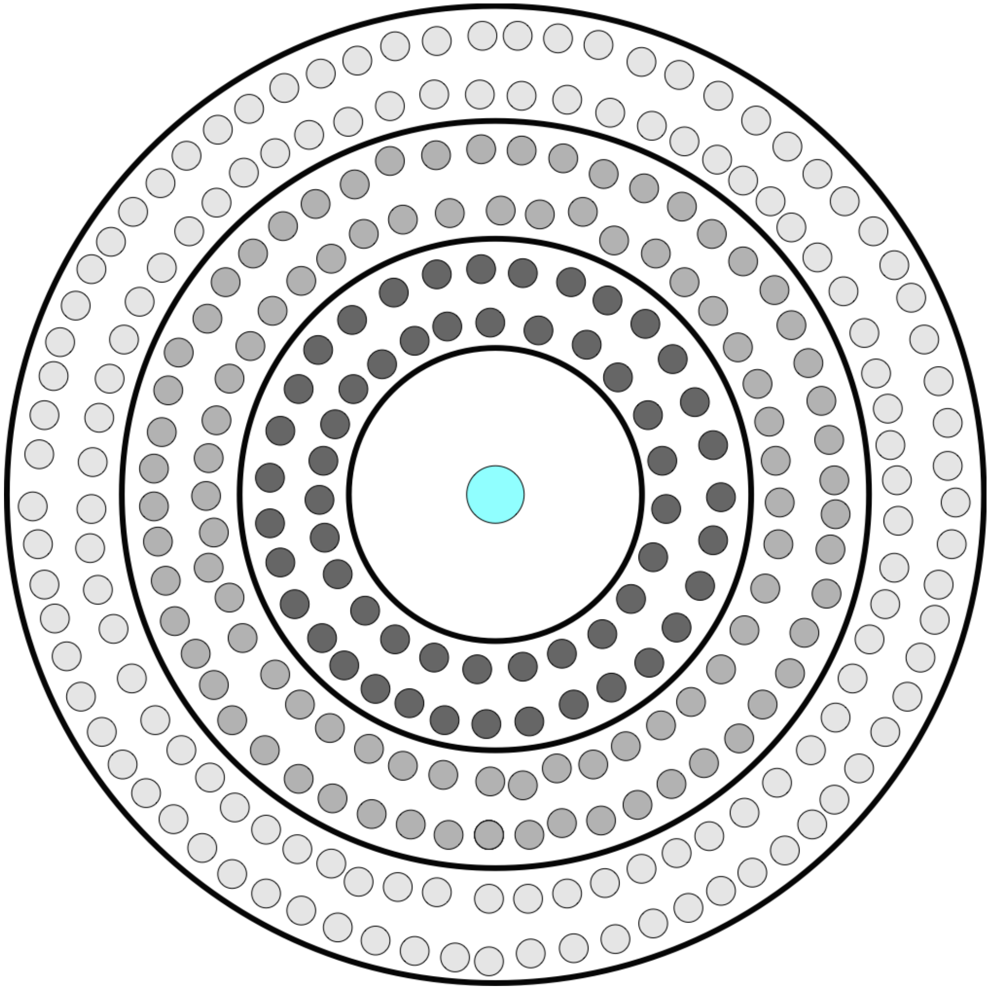
The Energy Hole Problem

- Energy hole appears
- No packets get to sink

- Uniform distribution of location and non-uniform distribution of work



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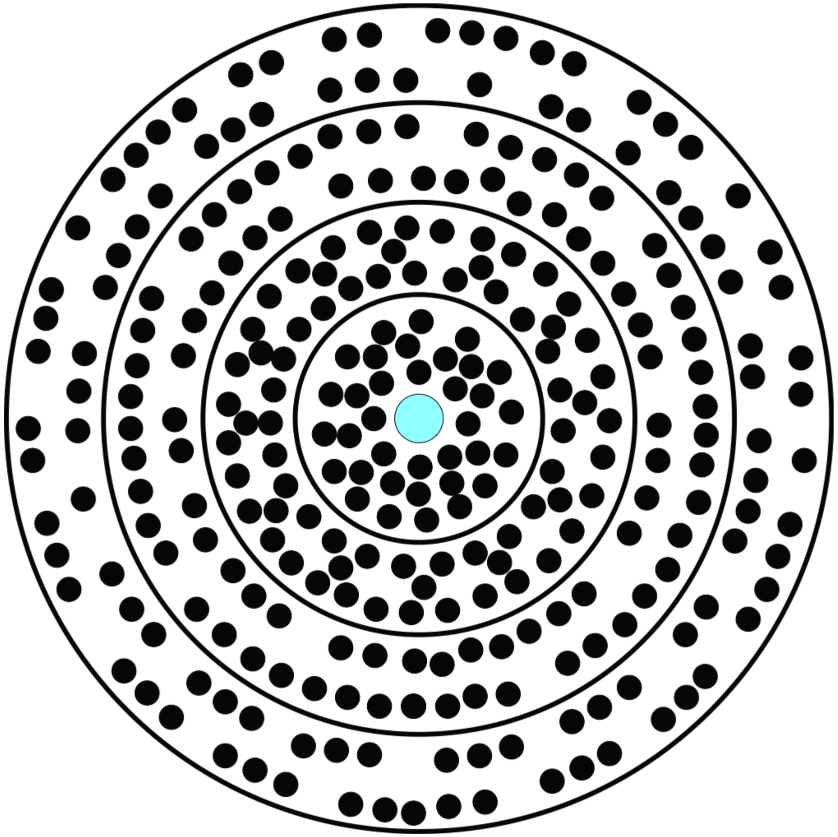
Existing Solutions

Avoidance

- **Non-uniform distribution**
- Power control
- Mobile sink
- Clustering



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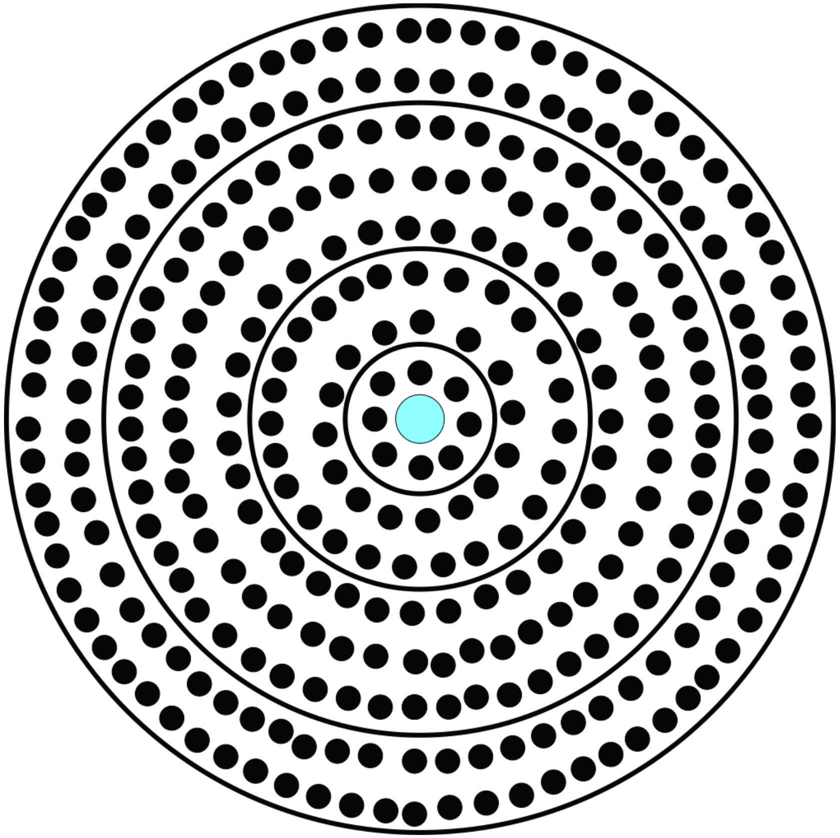

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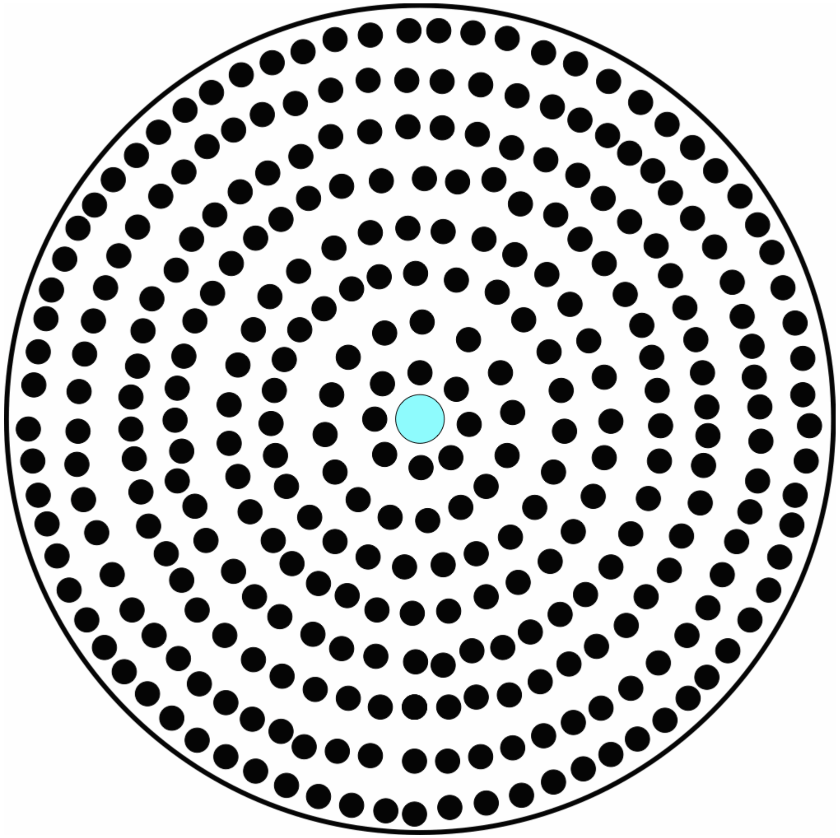

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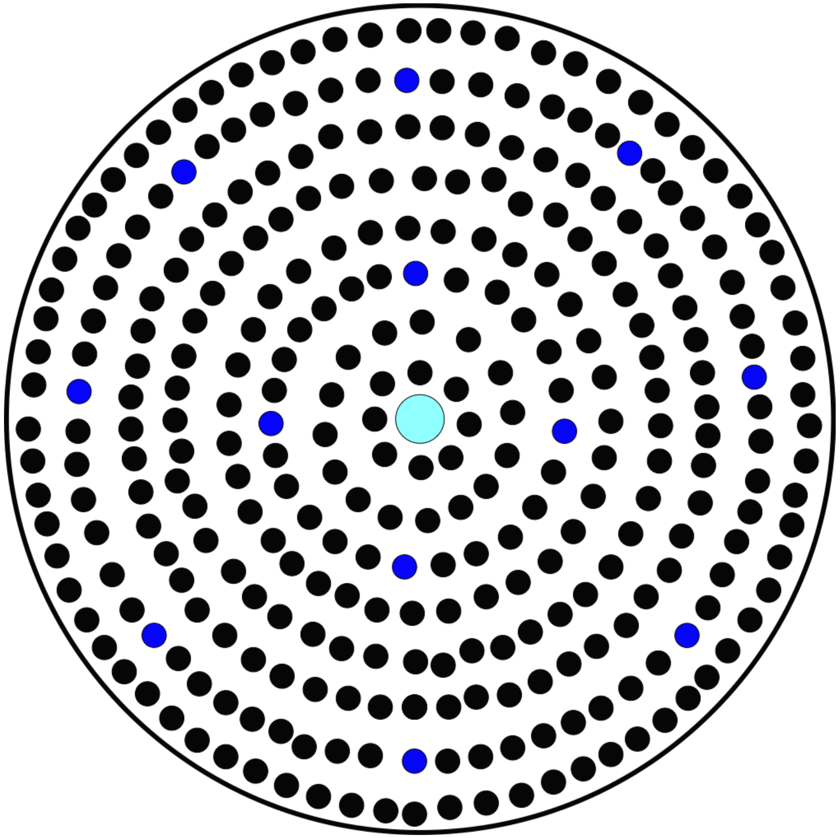

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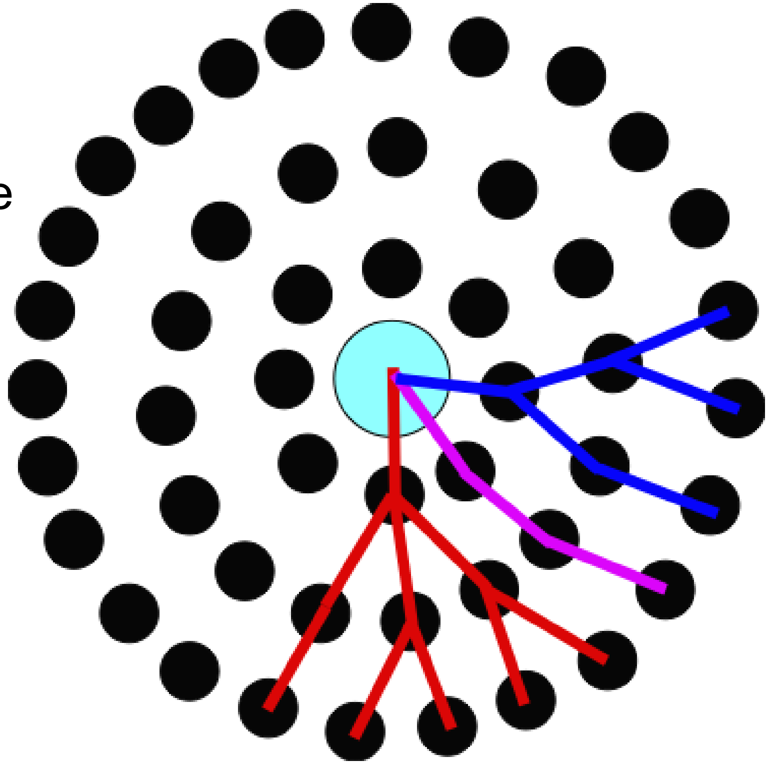
Existing Solutions

Mitigation

- Focus on same level balance
- Dynamically switch parents
- Create top load-balanced tree



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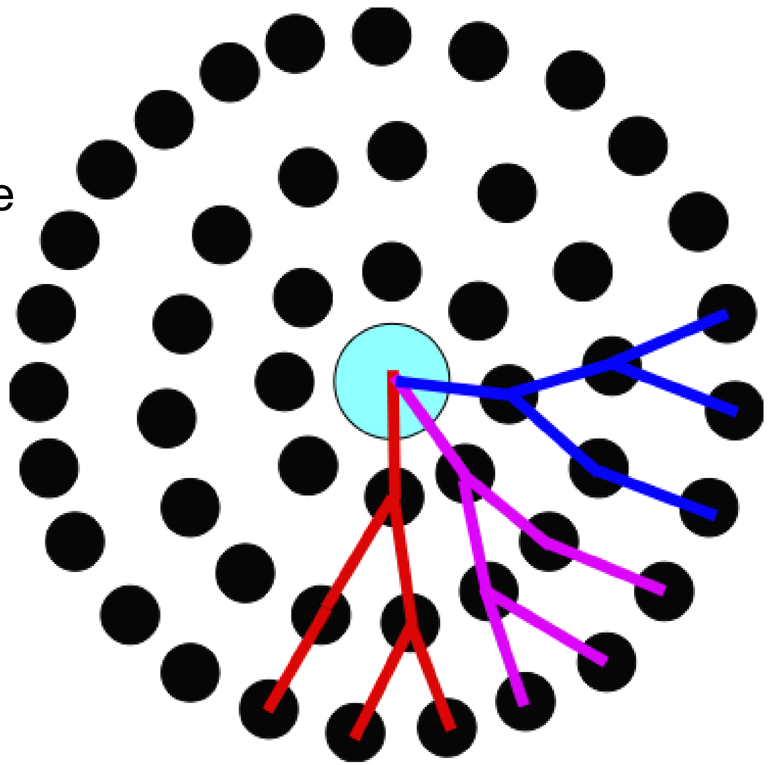

DECOR Proposal

DEgree COnstrained Routing

- Construct degree-constrained minimum spanning tree
- Distributed
- Static routes
- Balanced
- No need for location information
- Designed for periodic applications

Trade-off connectivity and latency for extra lifetime

Assumptions

- Uniform distribution of motes in a circular network
- Single, central sink
- Every mote produces 1 new packet per “round”
- Perfect MAC – no collisions, no interference
- All motes transmit the same distance

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DECOR Preliminaries

Average number of children per parent:

$$N(n) = \frac{2n+1}{2n-1}$$

Level	Avg Children
1	3
2	1.66667
3	1.4
4	1.286

Ratio of motes in level n to motes in level 1:

$$r(n) = 2n - 1$$

Level	Ratio
1	1
2	3
3	5
4	7

DECOR Theory I

- Limit the number of children per parent during tree construction
- All motes have same number of children = balance
- Average number of children per parent usually not a whole number
- Round down to nearest whole number

  i.e. 1 for most levels

Very few motes connected to tree

DECOR Theory II

- Level 1 motes can have 3 children each
- Find levels when ratio to level 1 motes is 3^x
- Have 3 children per parent in those levels

In practice delay by one level because of imperfect uniformity

DECOR Algorithm

Phase One

- Start with sink
- Leaf motes broadcast “advert” (incl hop count and subtree number)
- Unconnected motes gather all adverts
- Send offer to “best” parent
- Parents gather all offers respond to “best” child
- Rejected motes reevaluate and send new offers
- Wait until all child motes have finished
- Parent signal children to start next round

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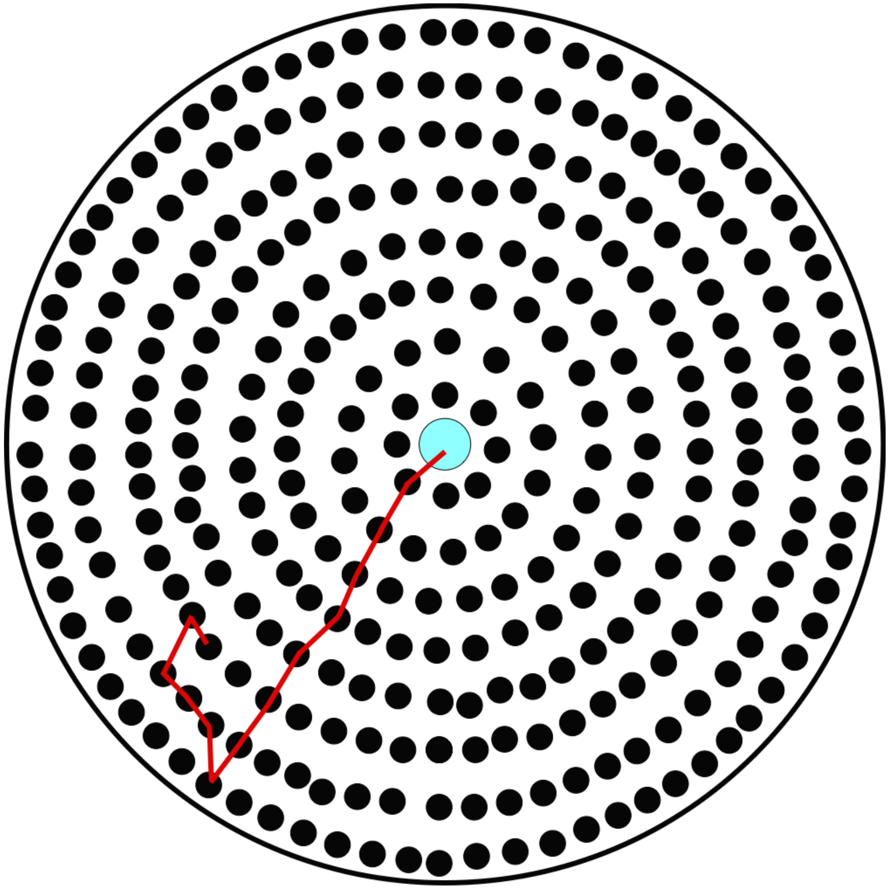
Example Subtree After Phase One

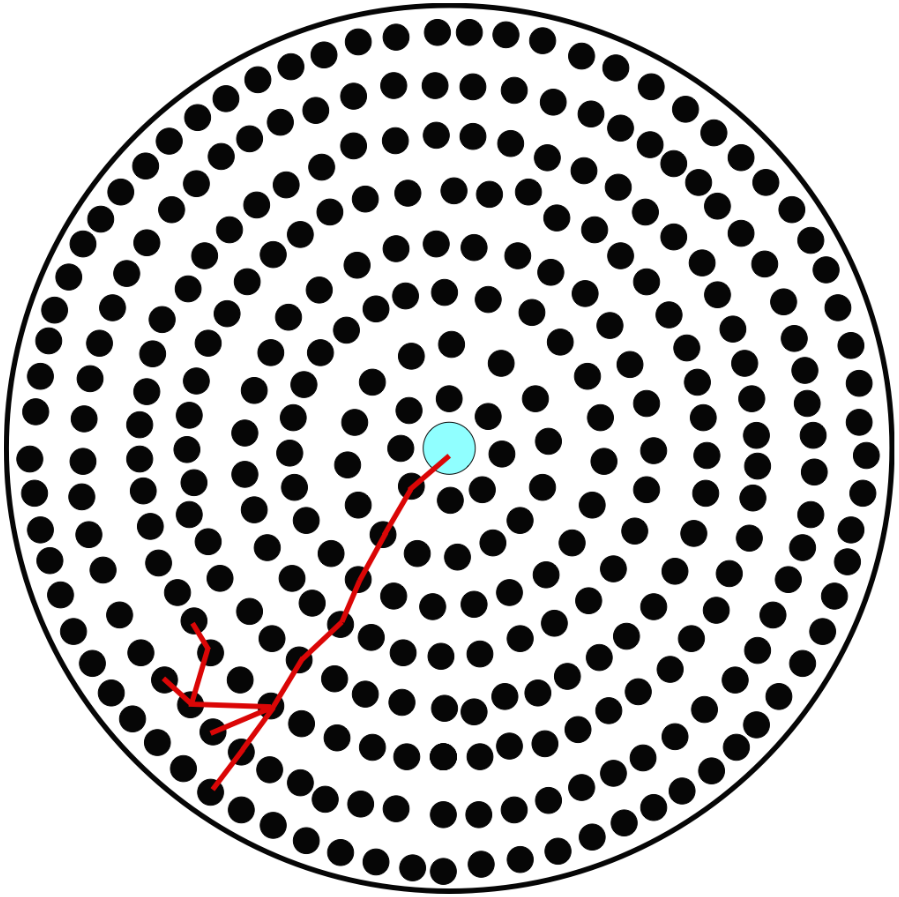


DECOR Algorithm

Phase Two

- Basic distributed minimum spanning tree algorithm
- Motes may only become children of parents in the same original subtree

Example Subtree After Phase Two



DECOR Choices

Best Parent

- Maintain network topological shape
- Choose most distant parent
- Use RSSI to indicate distance

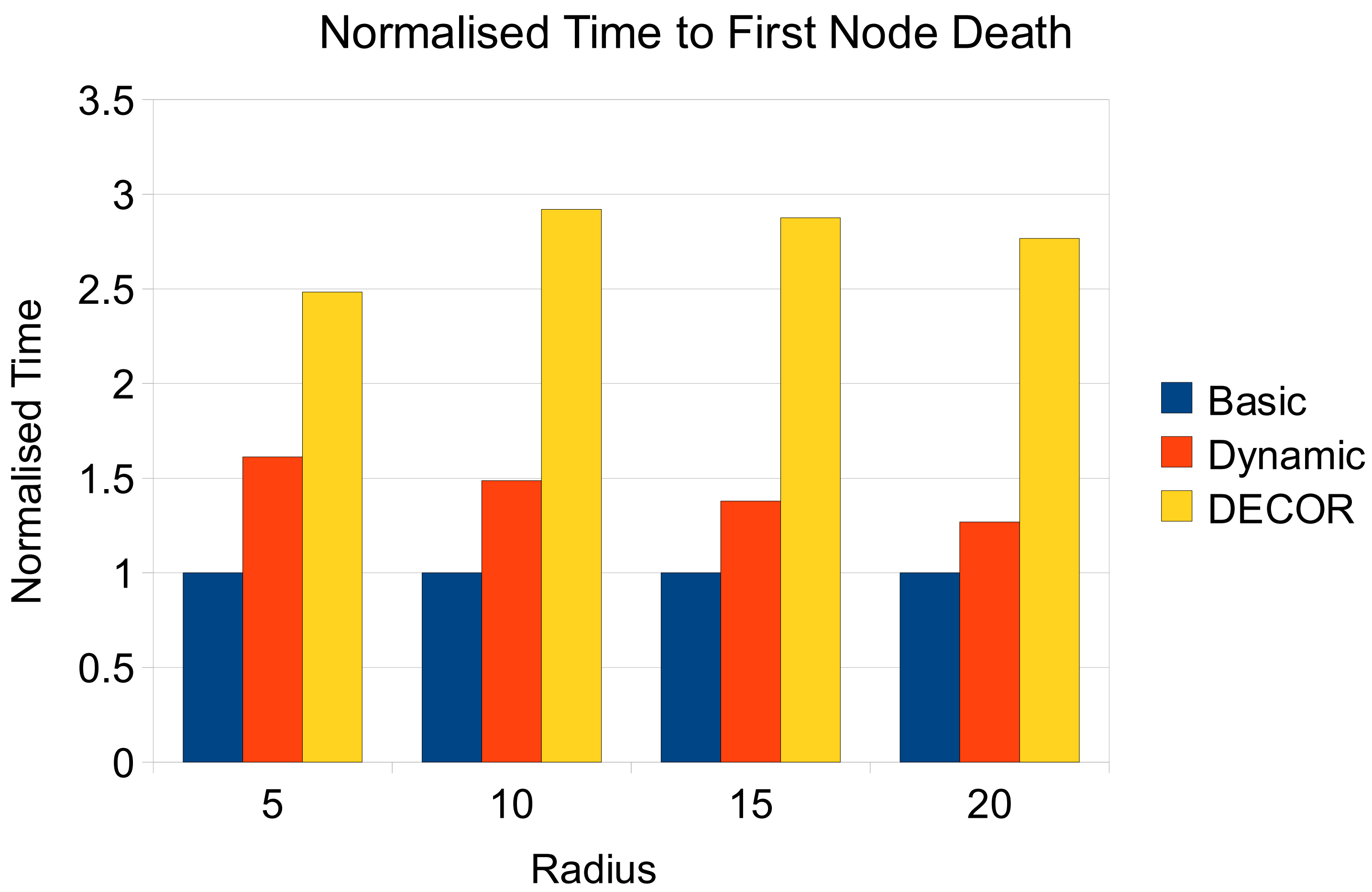
Best Child

- Maintain network topological shape
- Not deny children only option
- Choose child with fewest parent options
- Distance as tie-breaker

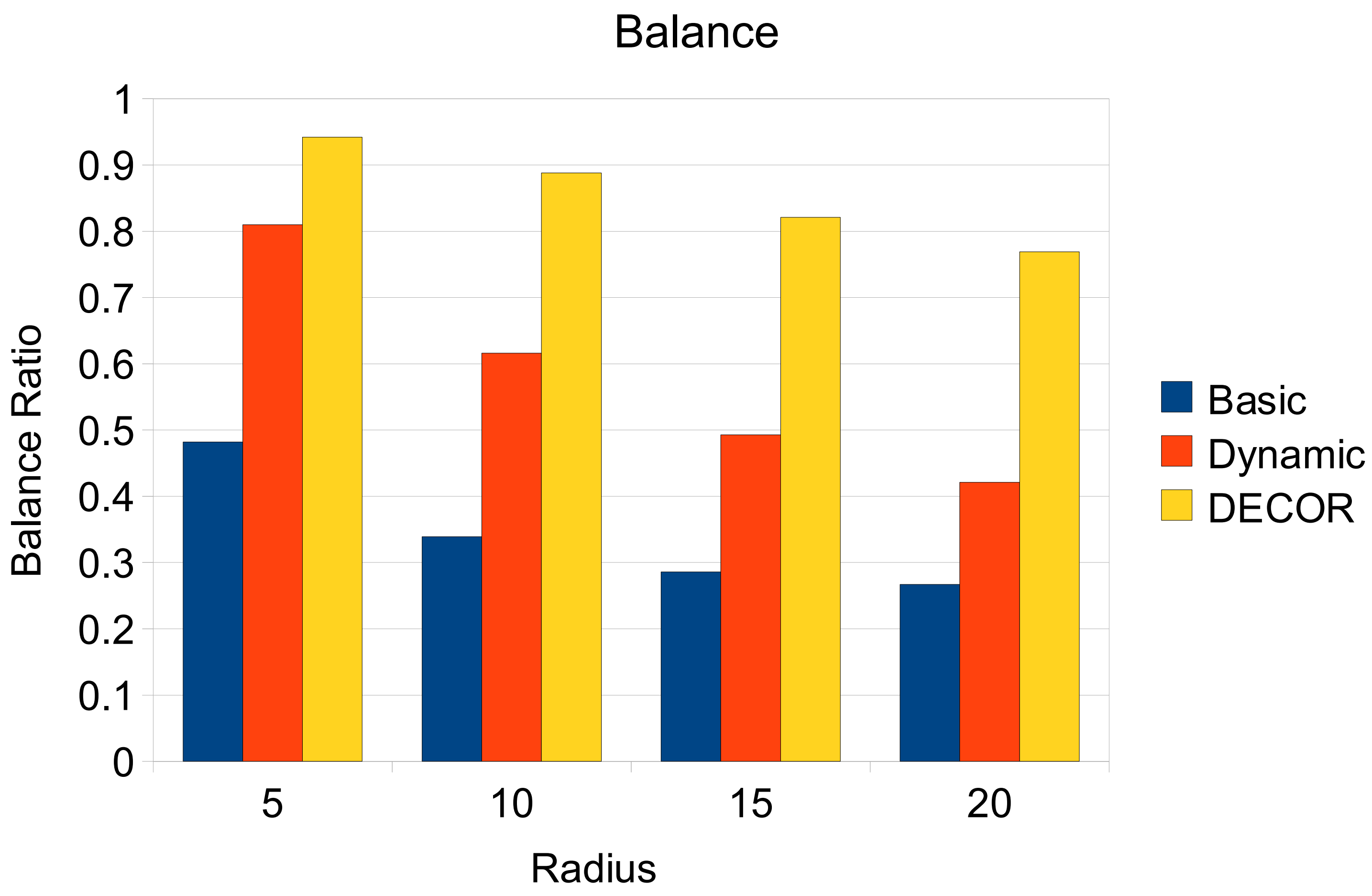
Simulation Set-up

- Radius of network defined in terms of transmission range
- Constant density (10 motes per unit area)
- Sink is unconstrained
- Fixed initial energy values (50J)
- Fixed packet size (50 bytes)
- Average results from 200 runs
- Compare basic minimum spanning tree, dynamic scheme and DECOR

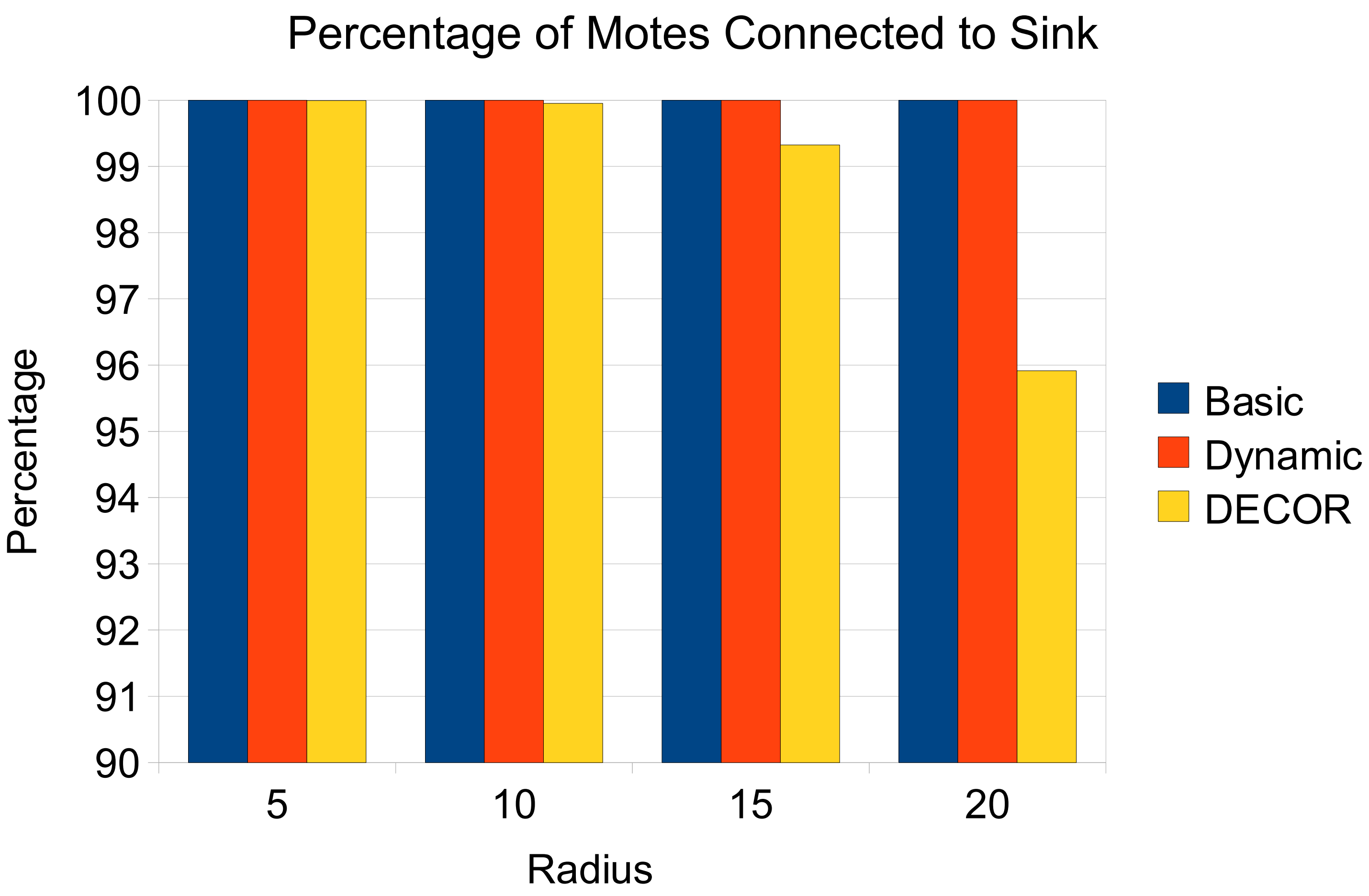
Time to First Mote Death



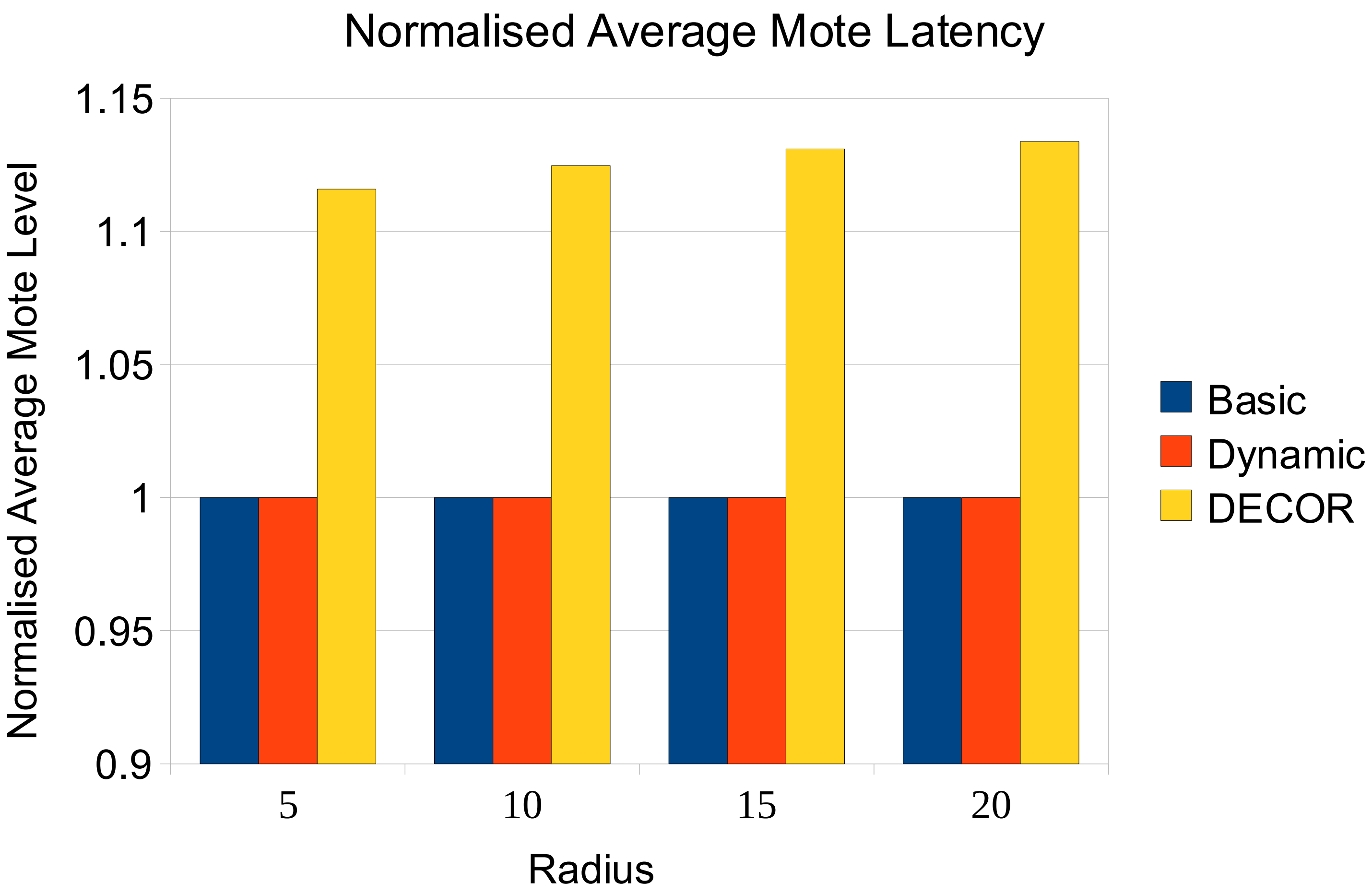
Balance


Balance
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Balance Ratio
5
10
15
20
Radius
Basic
Dynamic
DECOR

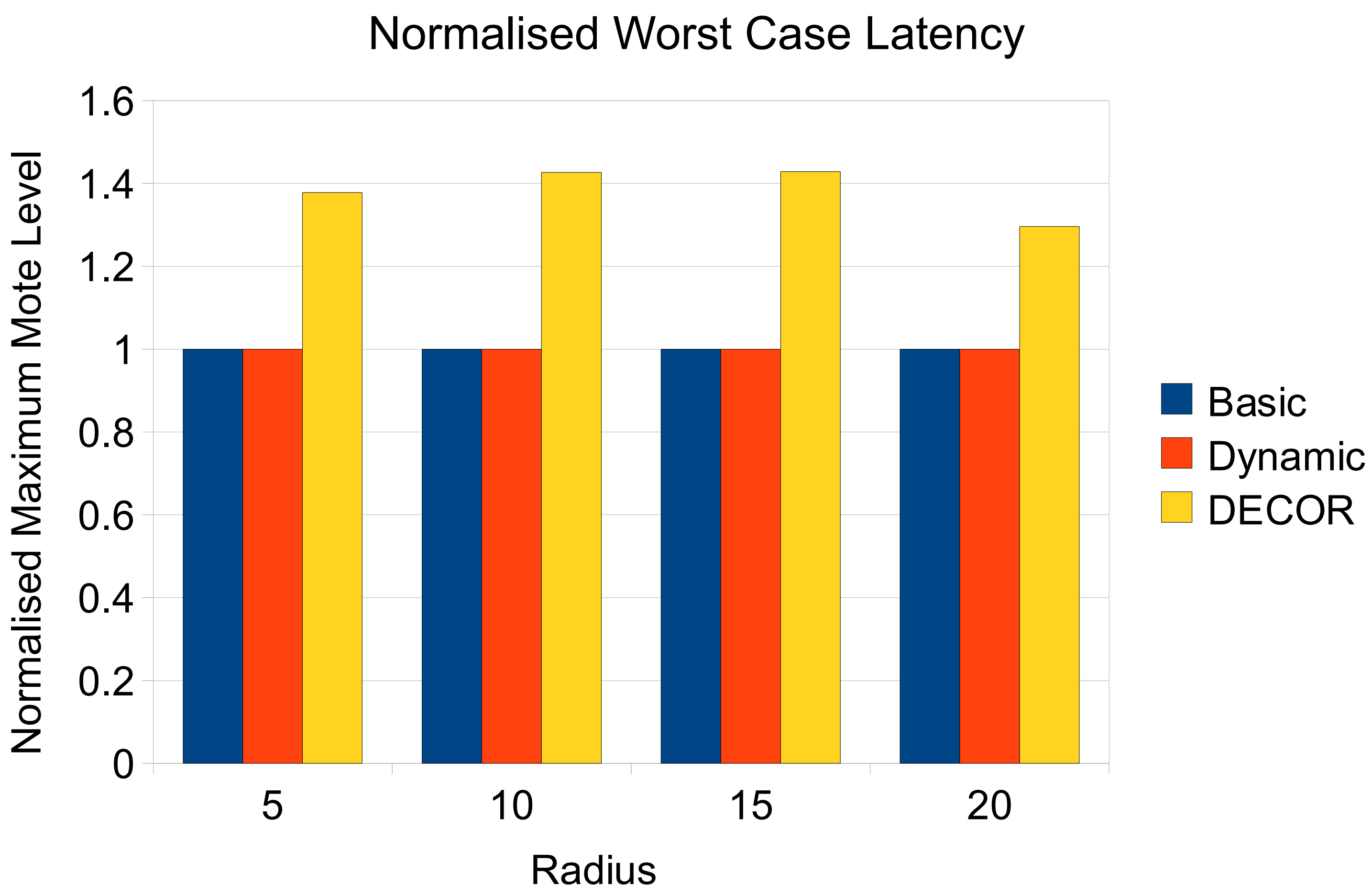
Connectivity



Average Latency



Worst Case Latency



Discussion

- DECOR provides a large increase in time to first mote death
- Trade-off for lower connectivity and higher latency
- Improvement by much larger factor than trade-offs
- Implicit use of global information

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Further Work

Investigate the effects of:

- Imperfect uniform distribution
- Non-central sink
- In-network aggregation
- Mobility
- Density
- Shadowing / Random events

Conclusion

- Energy hole problem has many existing solutions
- DECOR tailored for periodic applications
- Introduces new trade-offs
- Large increase in lifetime for small loss of connectivity and latency

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Thanks for Listening

Any Questions?