



Funneling- MAC: A Localized, Sink-Oriented MAC for Boosting Fidelity in Sensor Networks

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Talk outline

- Motivation



Talk outline

- Motivation
- Related work



Talk outline

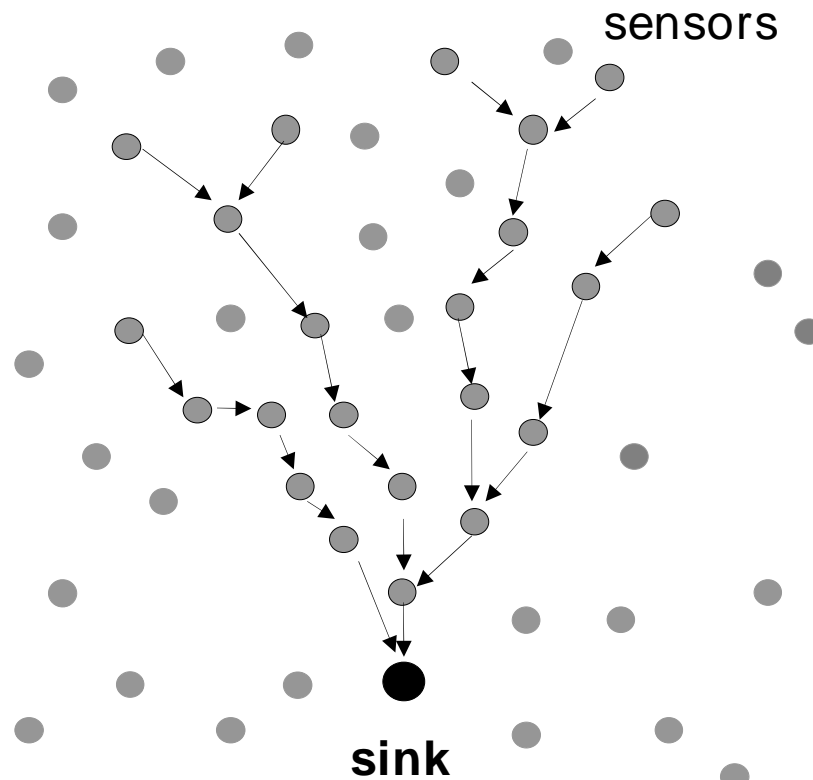
- Motivation
- Related work
- **Funneling- MAC design**



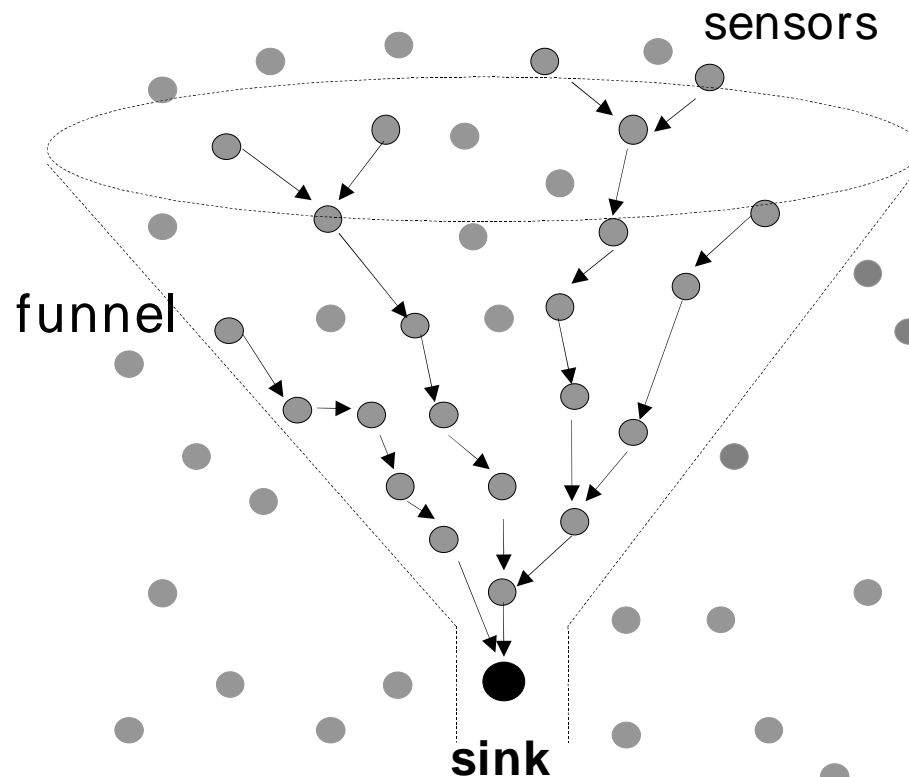
Talk outline

- Motivation
- Related work
- Funneling- MAC design
- **Experimental results**

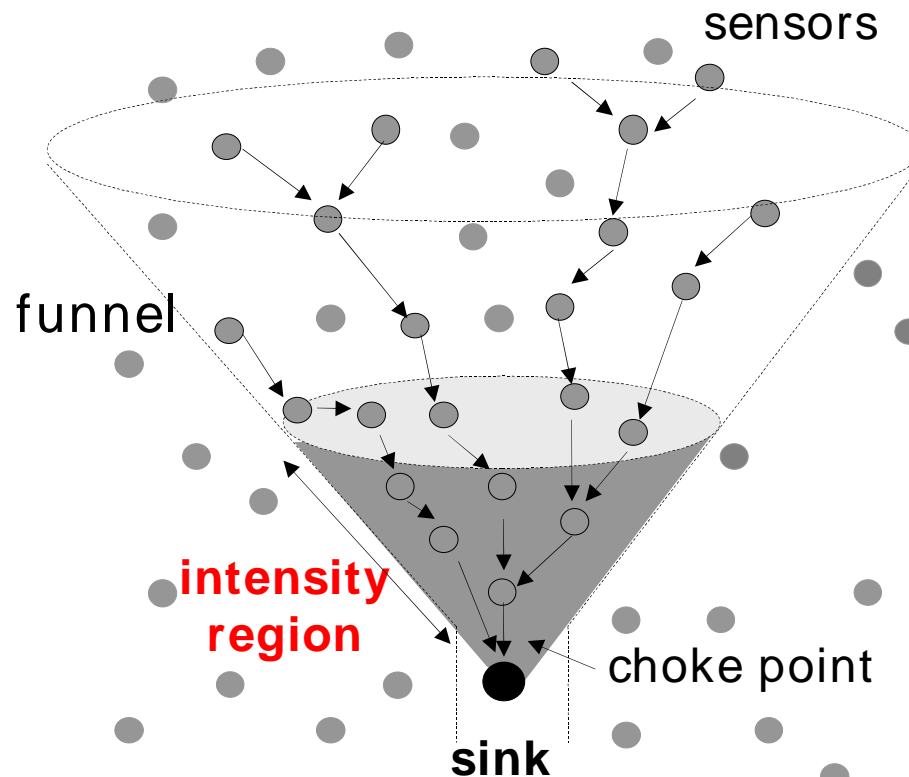
The funneling problem



The funneling problem

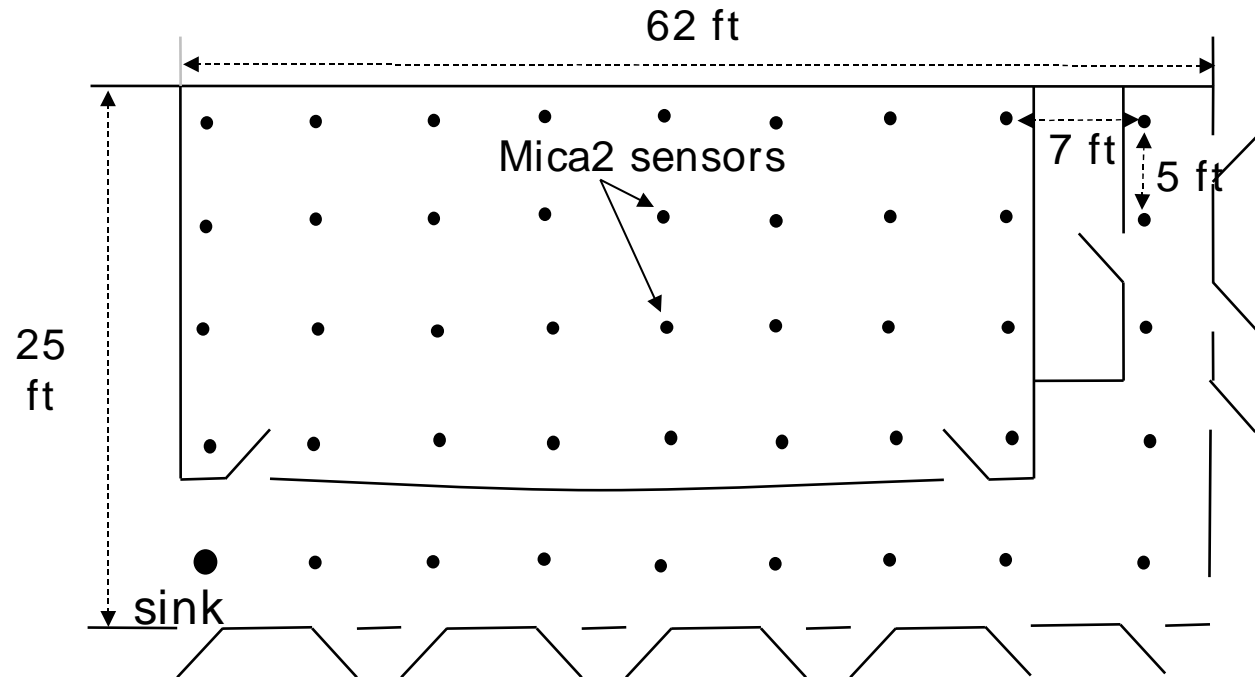


The funneling problem



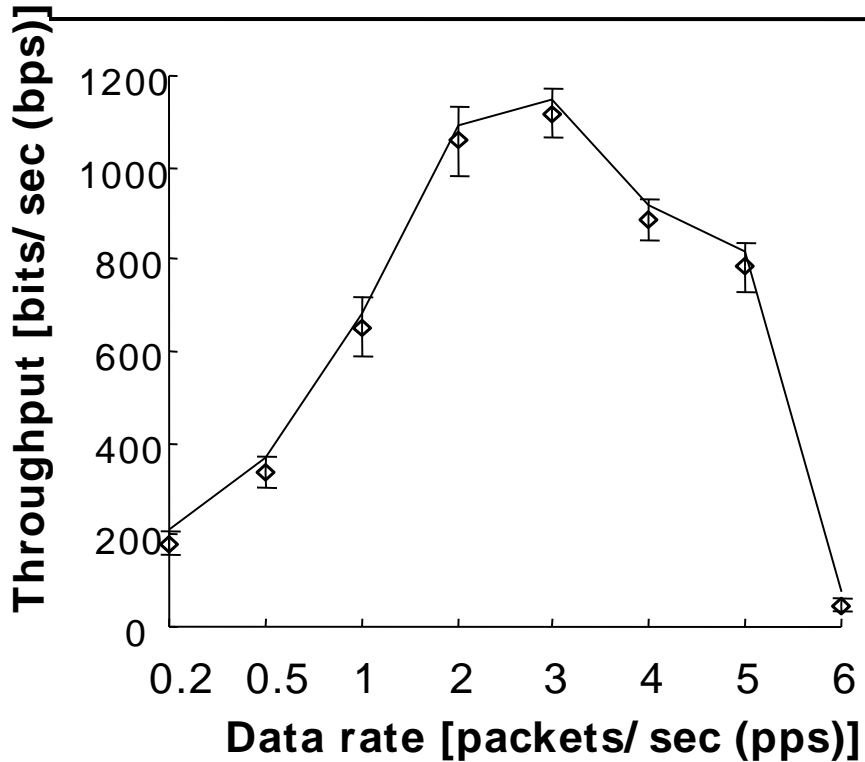
Quantifying the funneling effect

Tested set-up



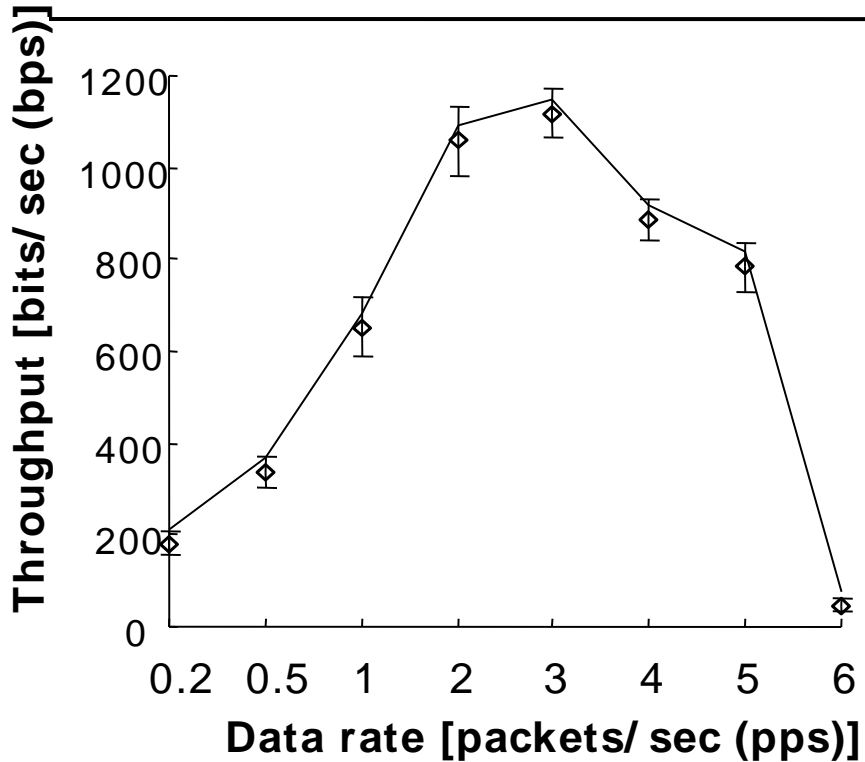
- 45 Mica2 in a 9x5 grid topology
- Grid calibration: 1 hop more than 80%, 2-hop less than 20%
- TinyOS 1.1.15 (Surge, MintRoute)

Funneling effect impact



**BMAC and 16
random sources**

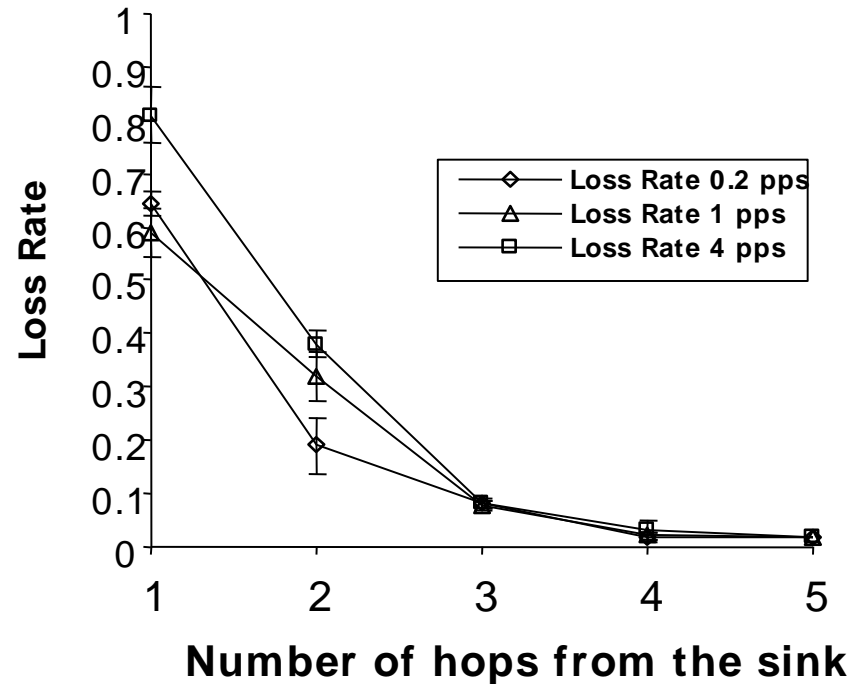
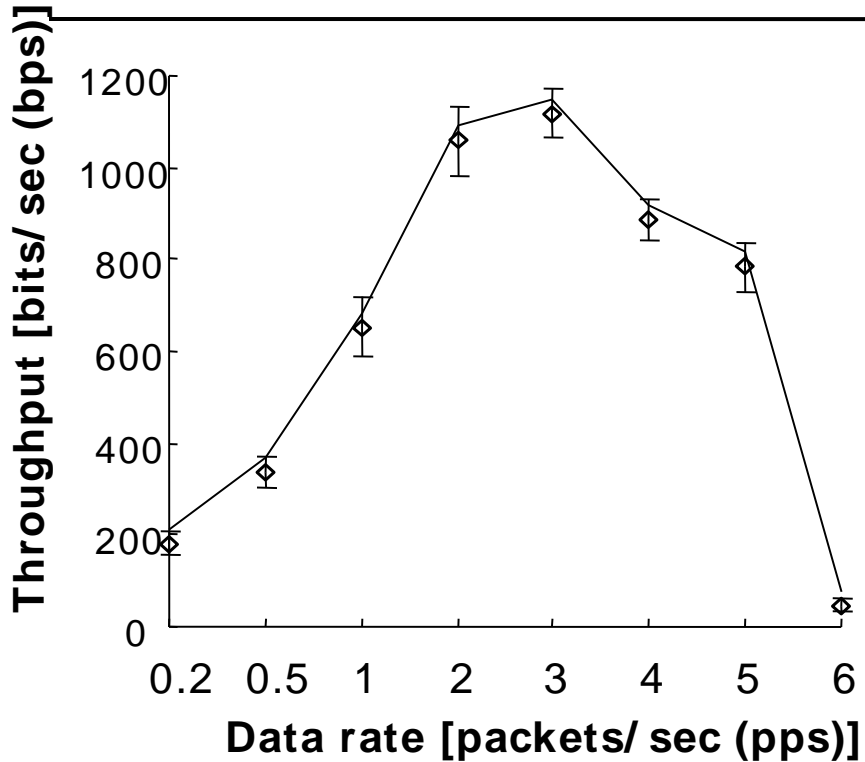
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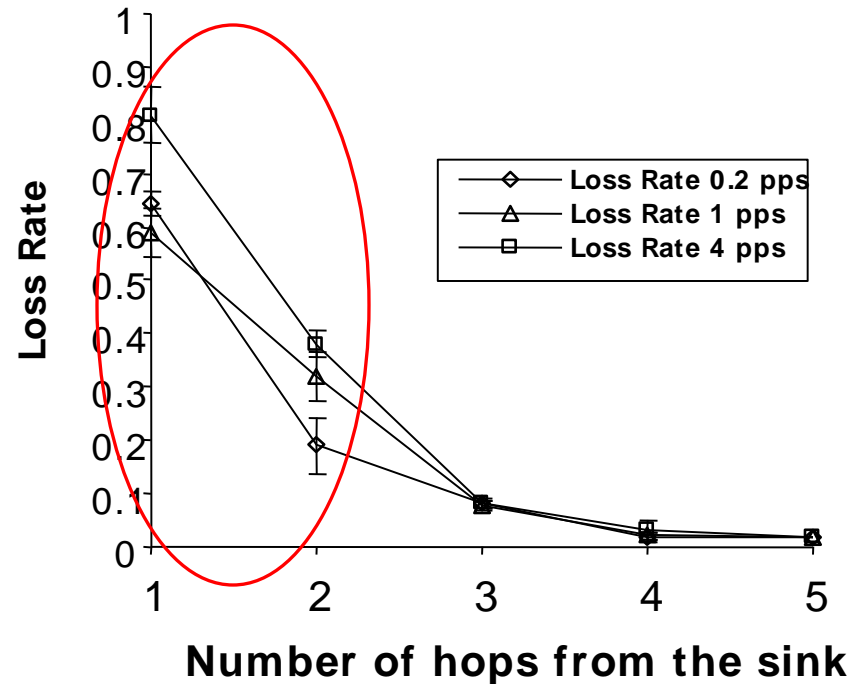
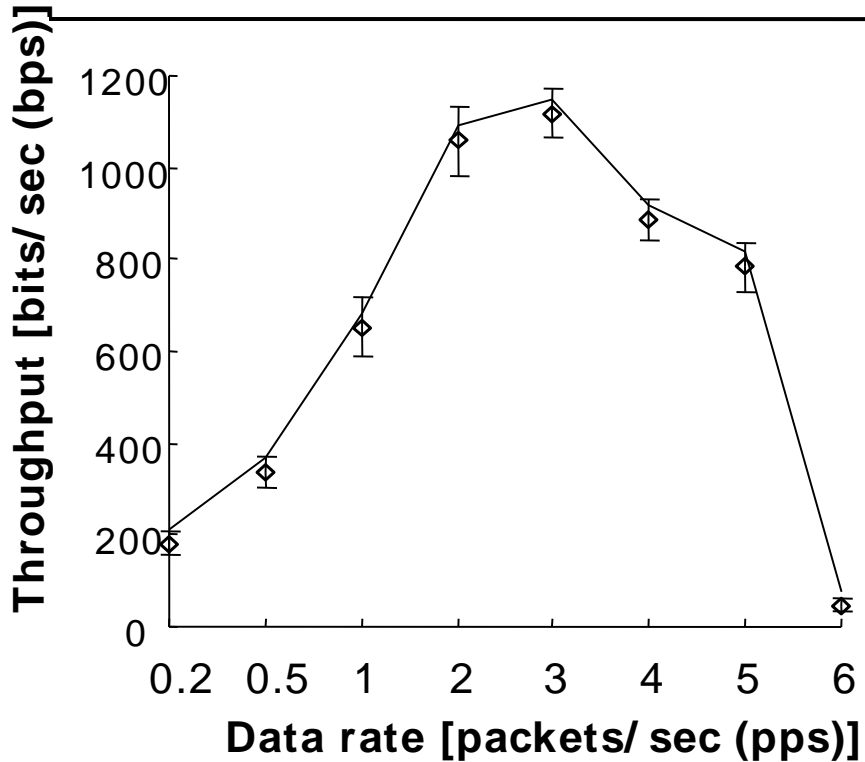
- At the sink overall loss rate: between 67%(at 0.2 pps) and 95%(at 4 pps)

Funneling effect impact



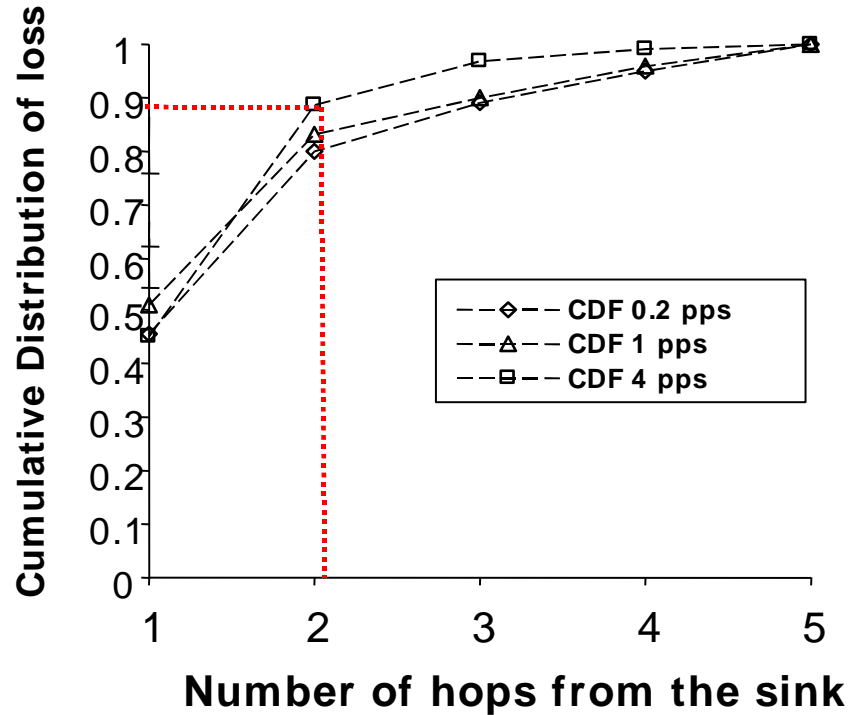
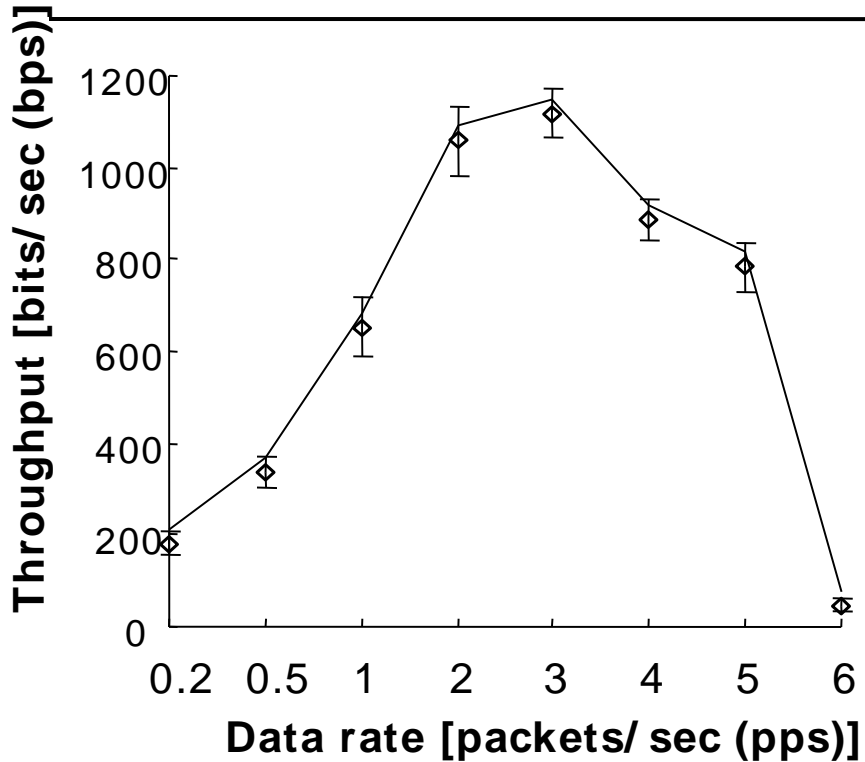
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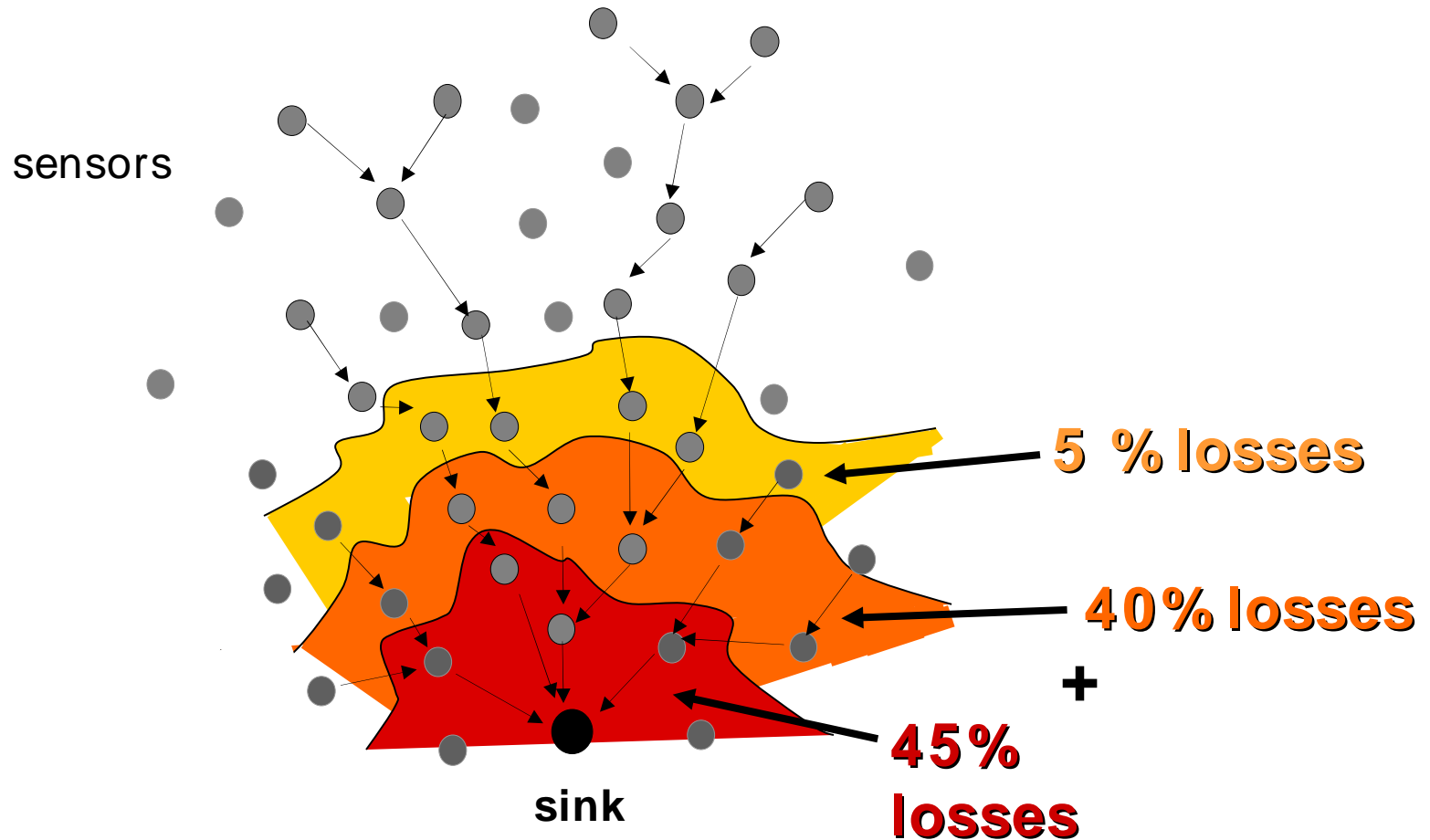
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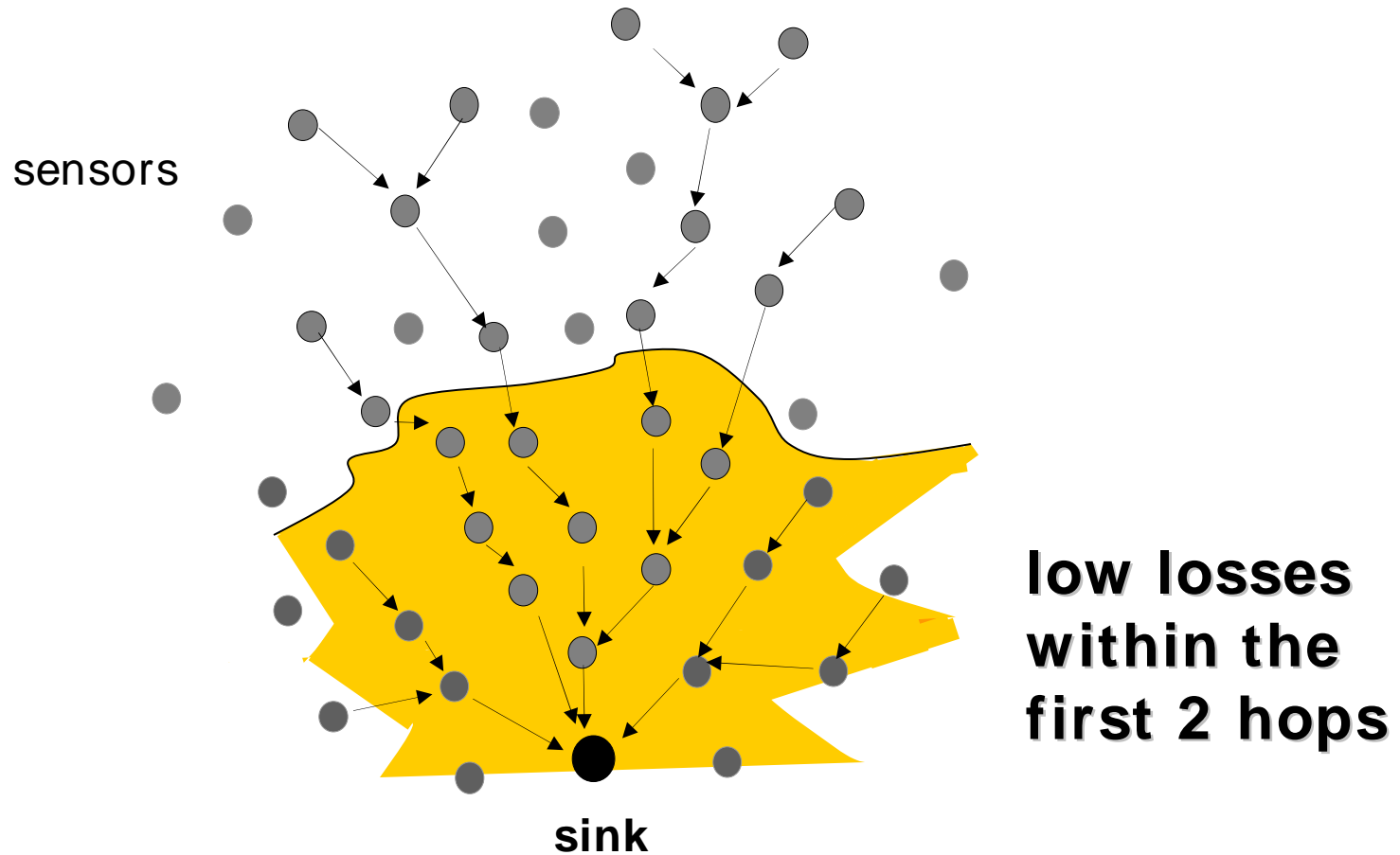


- At the sink overall loss rate: between 67% and 95%
- **80- 90% of losses happen within the first 2 hops from the sink!**

Is there a simple solution to this problem?



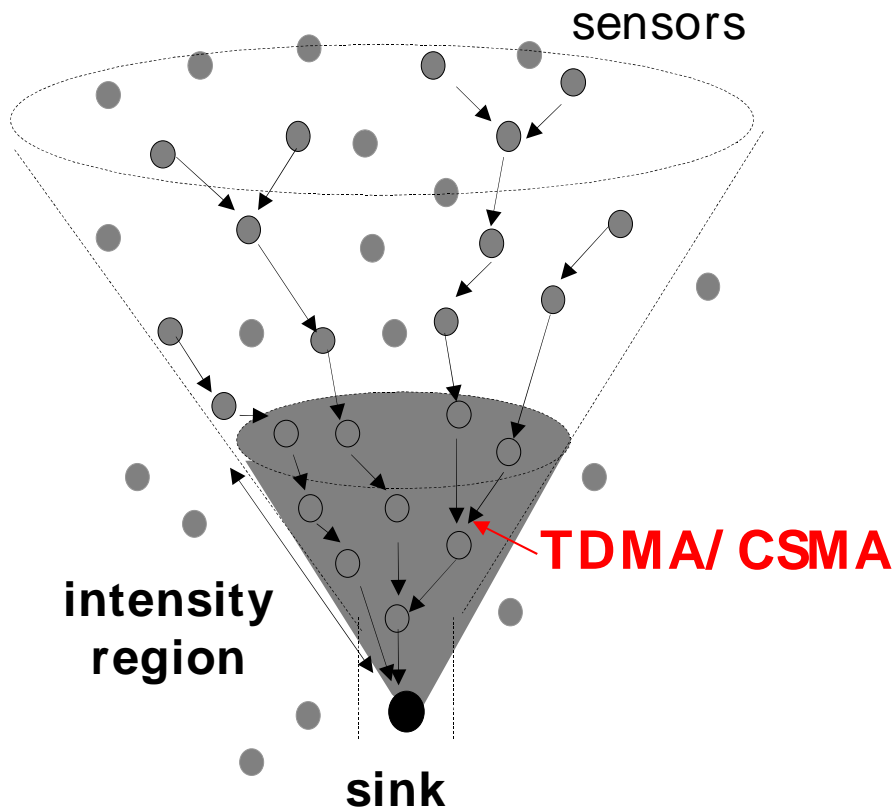
Is there a simple solution to this problem?



Answer

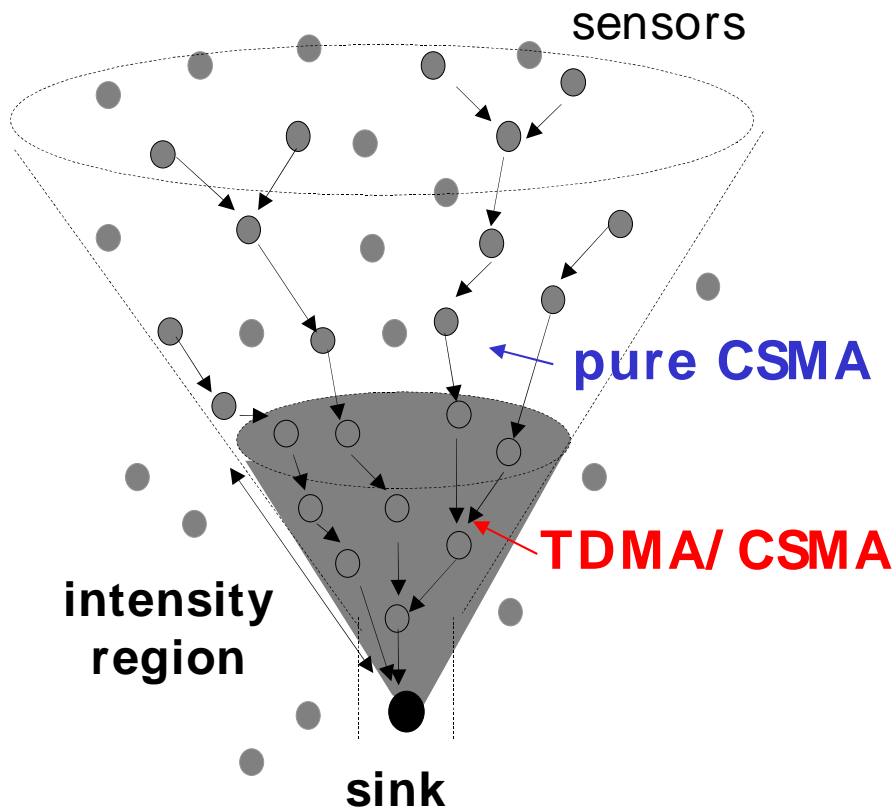
- Yes, it is possible and the Funneling-MAC is built to
 - exploit localized control over the intensity region
 - reacting dynamically to network conditions
- Such that it addresses scalability while proposing an efficient scheduling protocol

Funneling- MAC design considerations



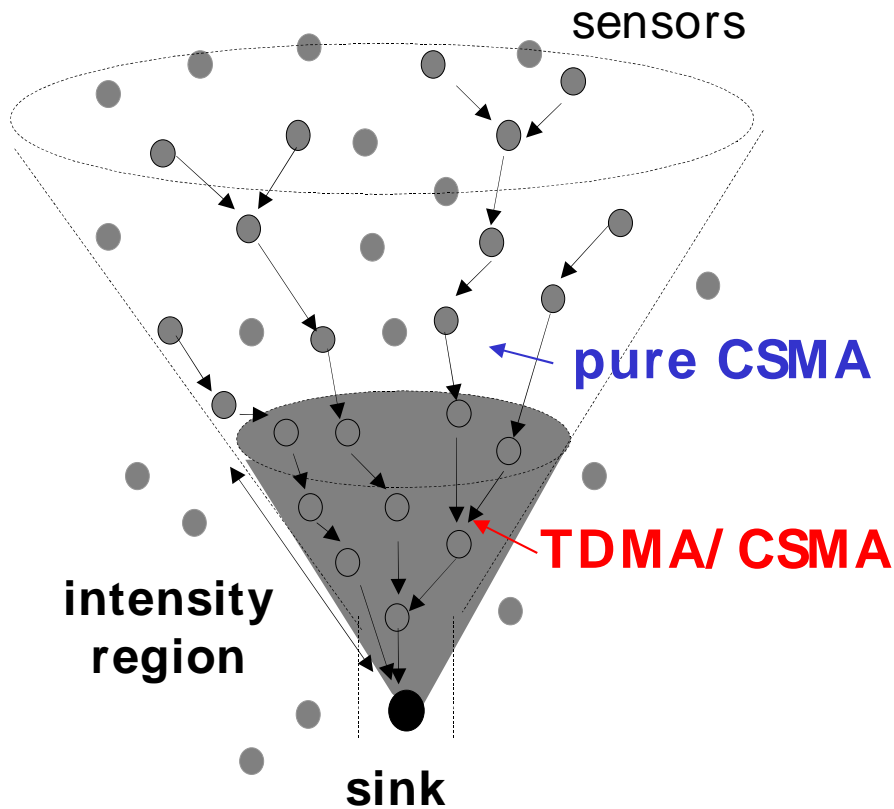
- hybrid **TDMA/ CSMA** scheme inside the intensity region

Funneling- MAC design considerations



- hybrid **TDMA/ CSMA** scheme inside the intensity region
- pure **CSMA** scheme outside the intensity region

Funneling- MAC design considerations



- hybrid **TDMA/CSMA** scheme inside the intensity region
- pure **CSMA** scheme outside the intensity region
- **sink oriented** TDMA scheduling
- maintenance of the intensity region **dynamically** operated by the sink

Related work

- CSMA based MAC
 - [Woo01], S- MAC, T- MAC, B- MAC

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- CSMA based MAC
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- Scheduling based MAC
 - FPS, D- MAC, [Arisha02]
 - TRAMA, ZMAC

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- CSMA based MAC
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 - TRAMA, ZMAC
- Congestion mitigation schemes
 - Siphon



Funneling- MAC algorithm

- On- demand beaconing



Funneling- MAC algorithm

- On- demand beaconing
- Dynamic- depth tuning



Funneling- MAC algorithm

- On- demand beaconing
- Dynamic- depth tuning
- **Sink- oriented scheduling**



Funneling- MAC algorithm

- On- demand beaconing
- Dynamic- depth tuning
- Sink- oriented scheduling
- Meta- schedule advertisement

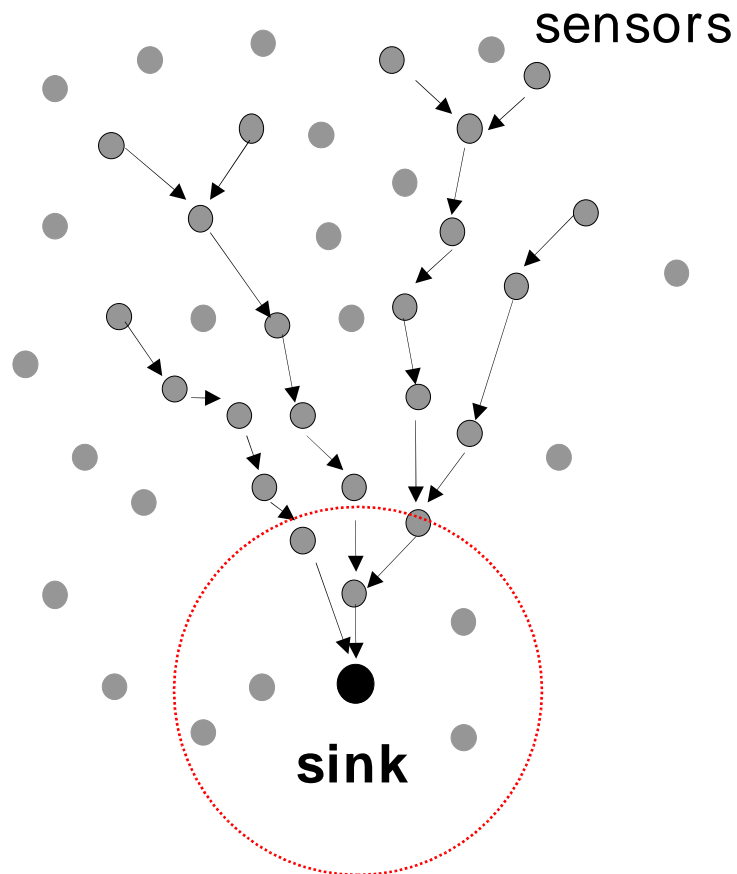
On- demand beaconing

- To dynamically drive the depth of the intensity region

On-demand beaconing

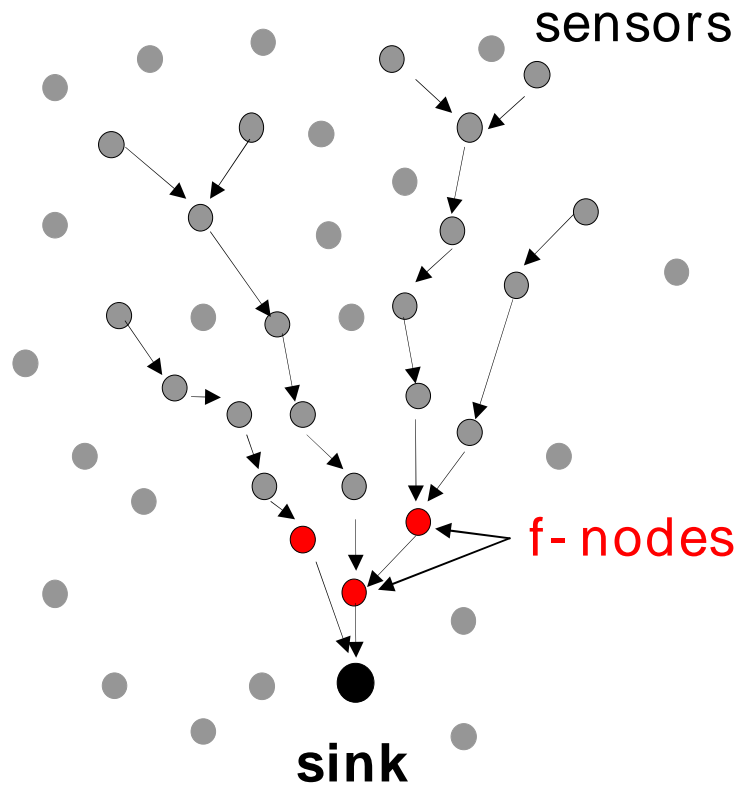
- To dynamically drive the depth of the intensity region
- To synchronize the nodes inside the intensity region

On-demand beaconing



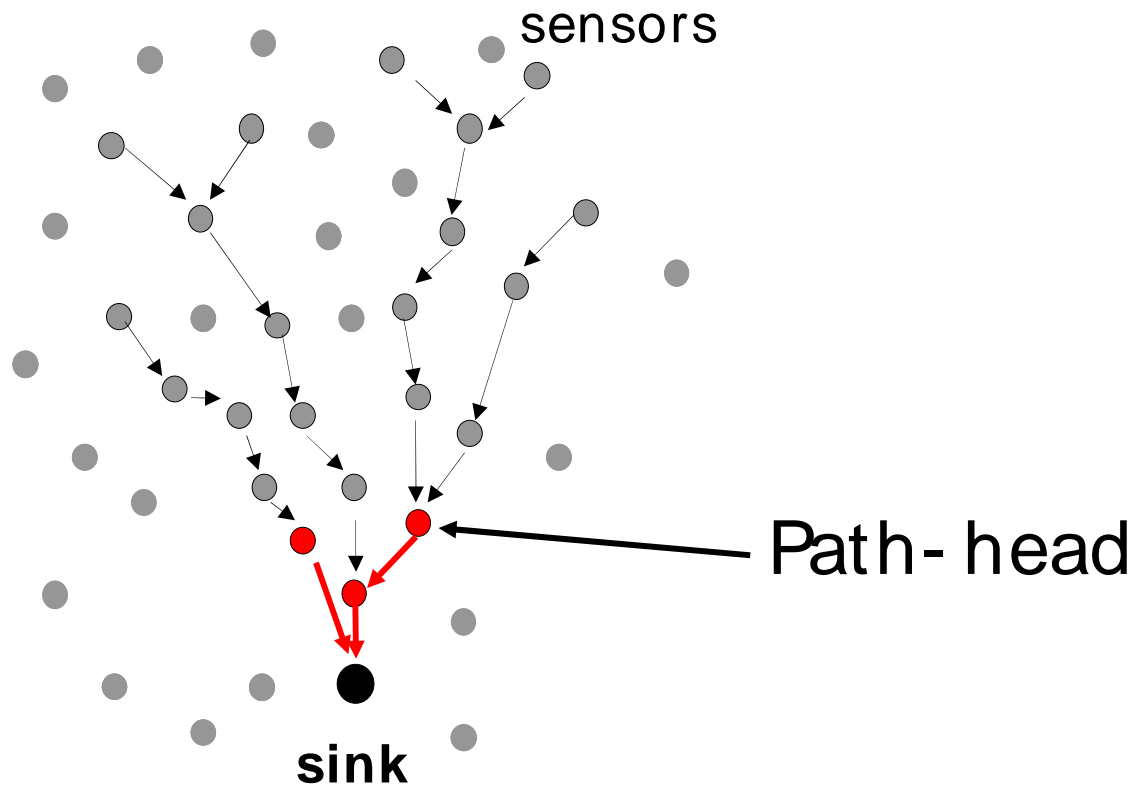
- The sink periodically broadcasts a *Beacon*
- At the bootstrap of the network or when starting with low traffic the Beacon transmission power is the same as the sensors

On-demand beaconing

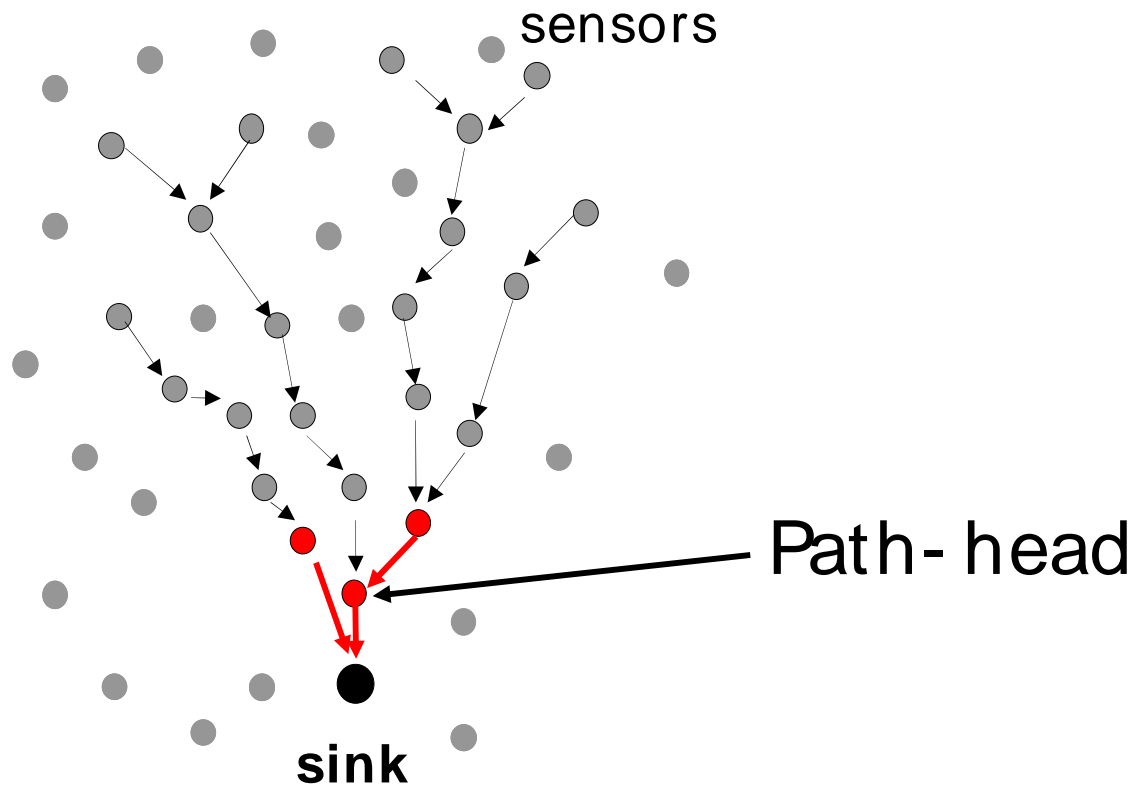


- Sensors receiving a *Beacon* become f-nodes and consider themselves inside the intensity region
- Upon receiving a beacon f-nodes synchronize with each other by initializing their clock

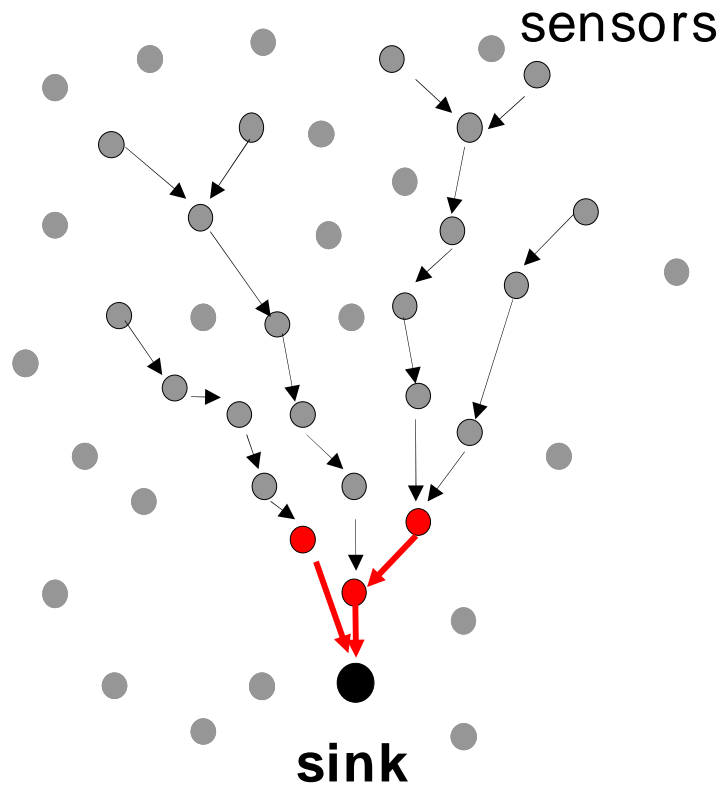
On-demand beaconing



On-demand beaconing

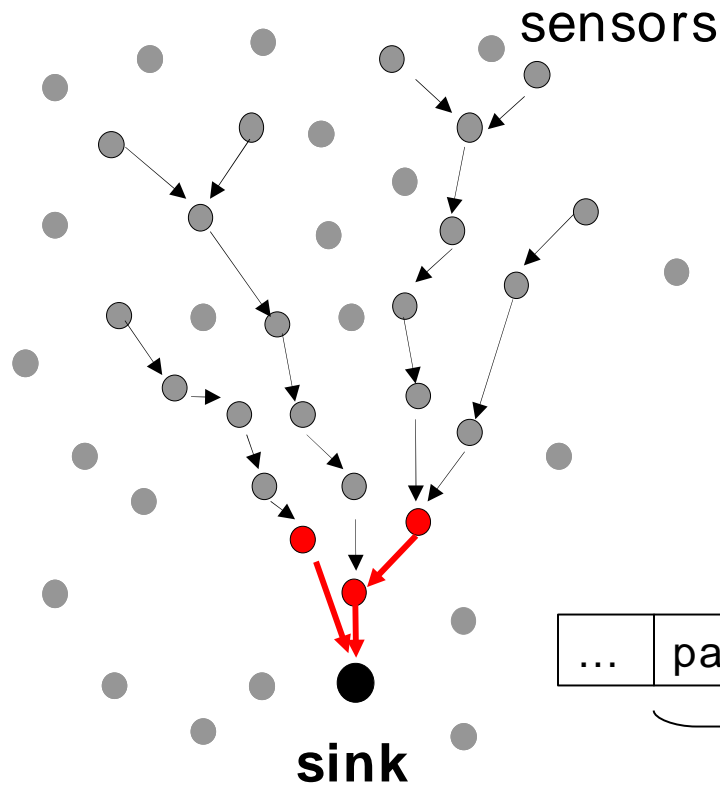


On-demand beaconing

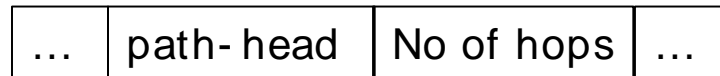


Path-heads operate a *passive registration* by which the sink knows the number of path heads and how many hops they are far away from the sink for scheduling purposes

On-demand beaconing



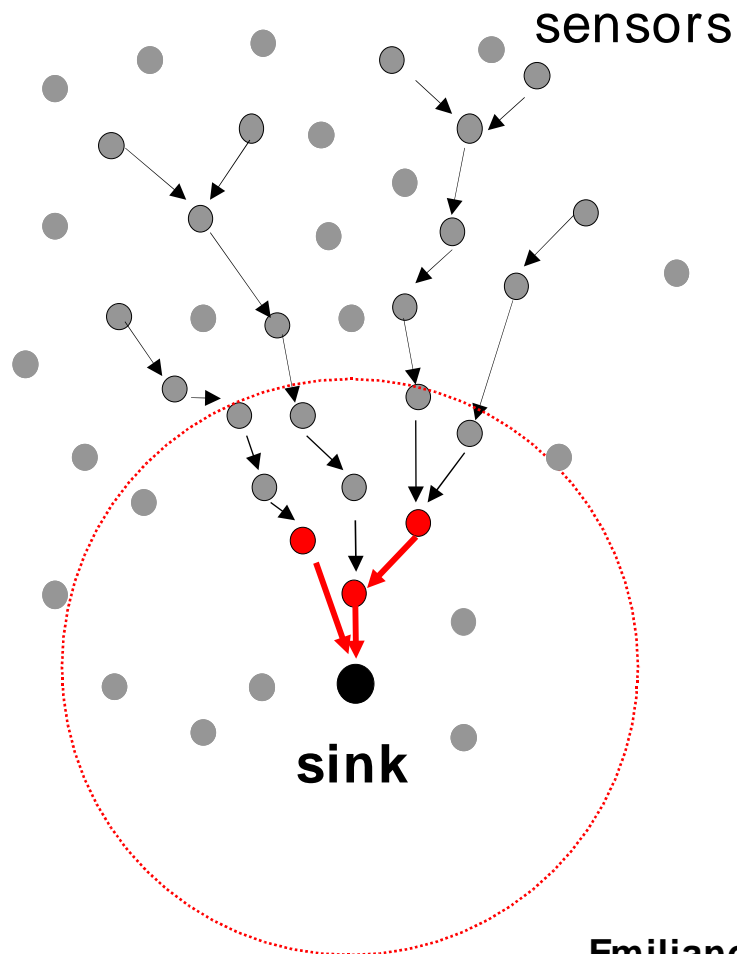
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Data packet

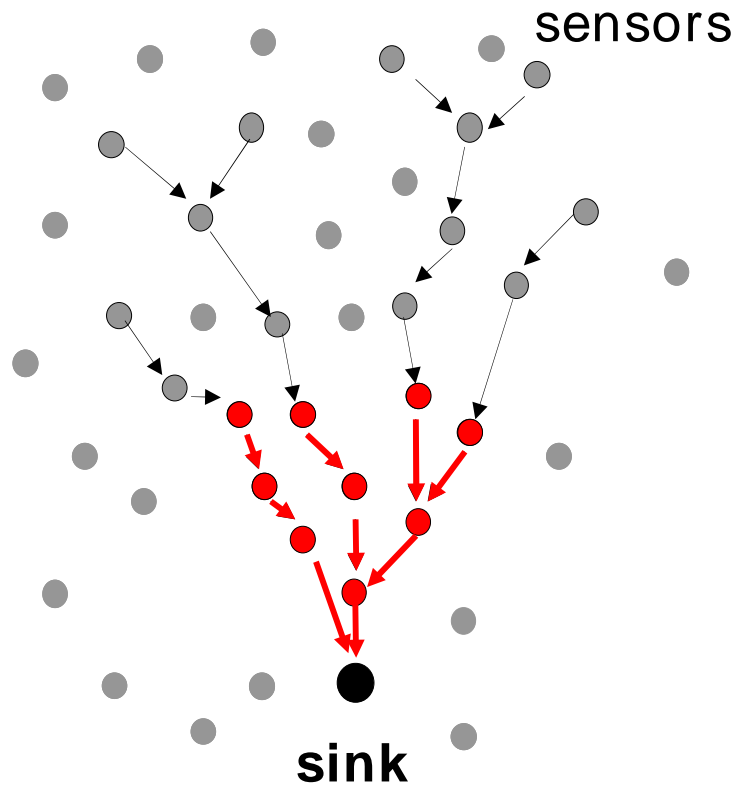
3 bytes

On-demand beaconing



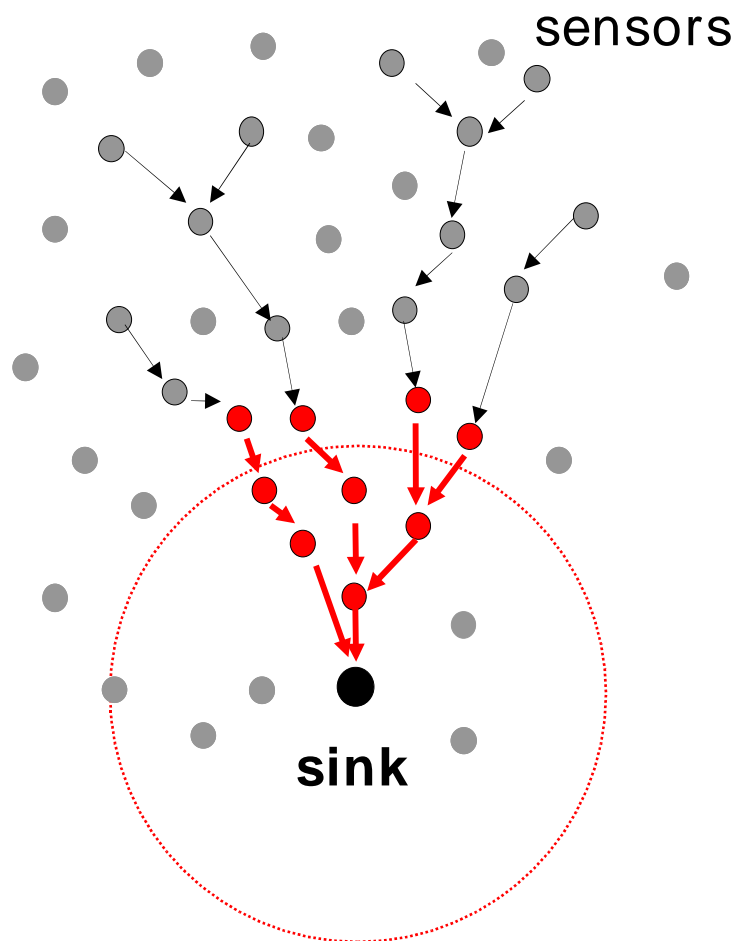
If the sink realizes that it can schedule more nodes, it increases the transmission power of the Beacon to expand the intensity region

On-demand beaconing



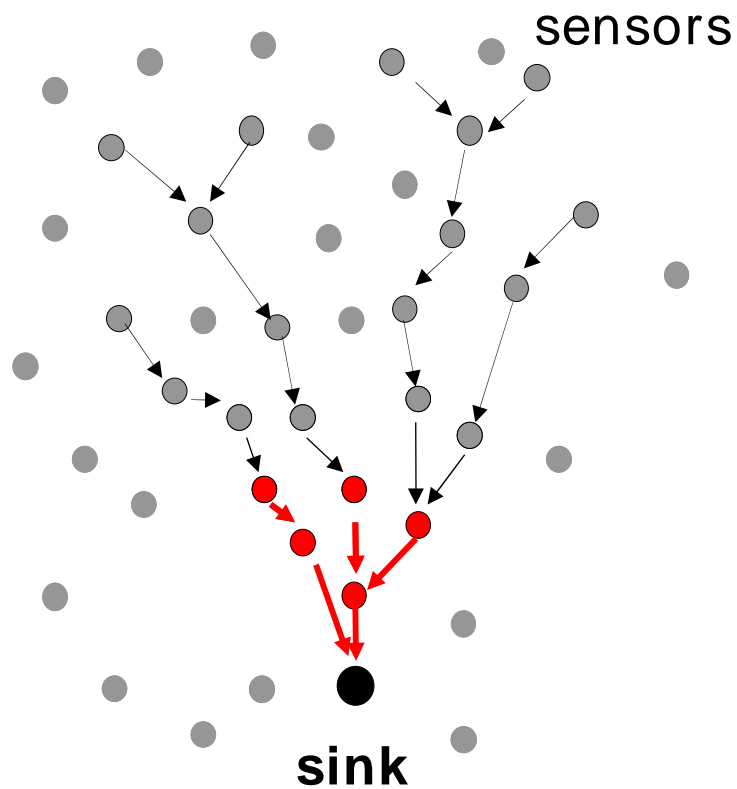
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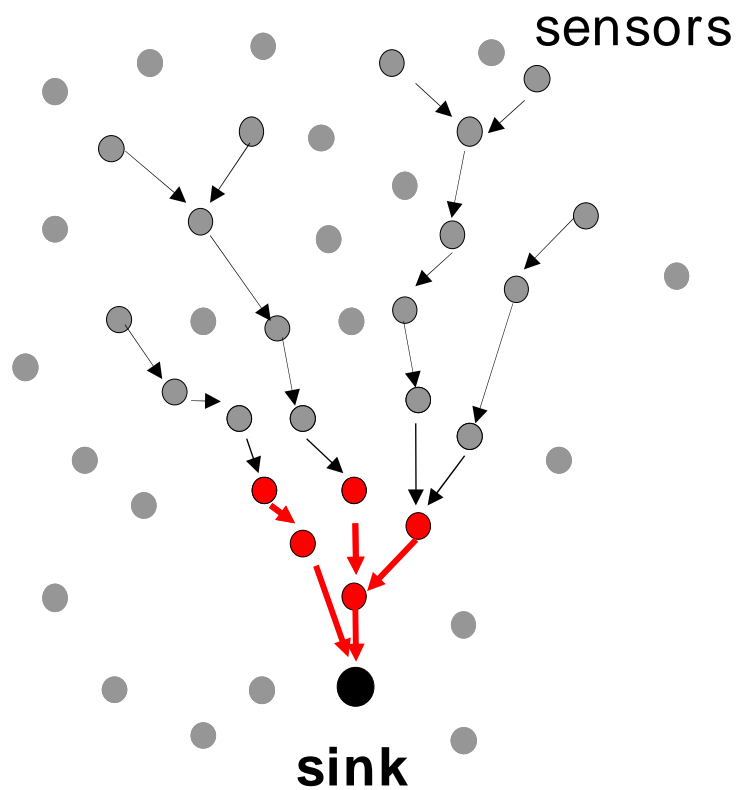
If the sink realizes that the number of f-nodes attempting the registration exceeds the maximum number of nodes that can be scheduled, then the sink reduces the beacon transmission power

On-demand beaconing



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On-demand beaconing



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The beacon transmission power is determined by the ***Dynamic-depth tuning*** algorithm

Dynamic- depth tuning

- A_{\max} = max number of slots that can be assigned given the TDMA capacity

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Dynamic- depth tuning

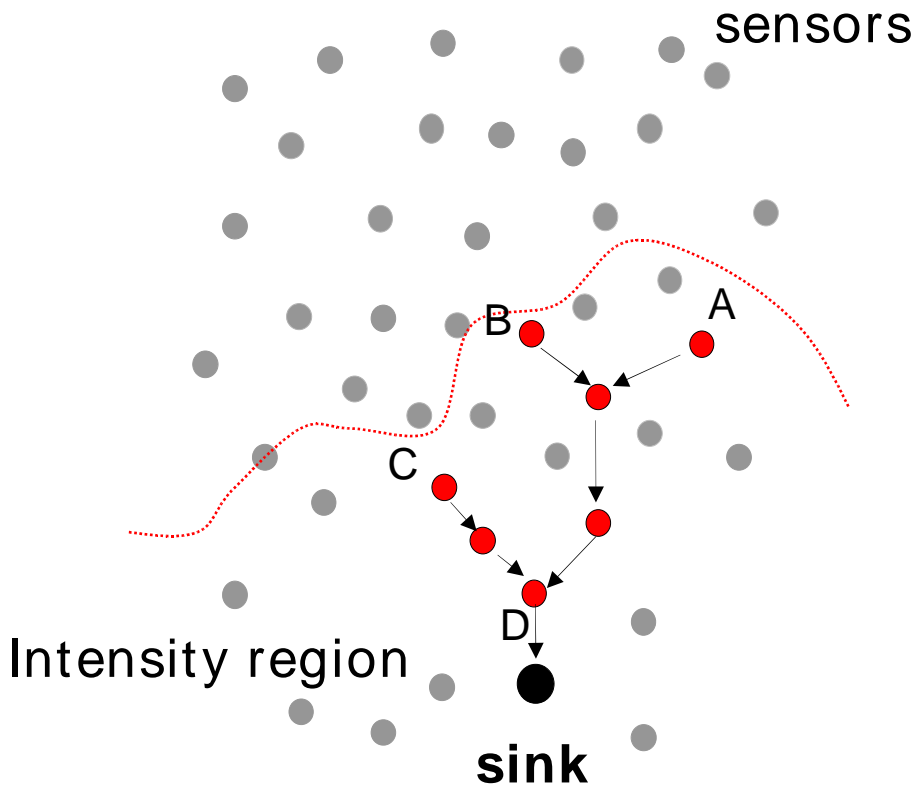
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- if $A \leq A_{\max}$ then sink increases beacon transmission power

Dynamic- depth tuning

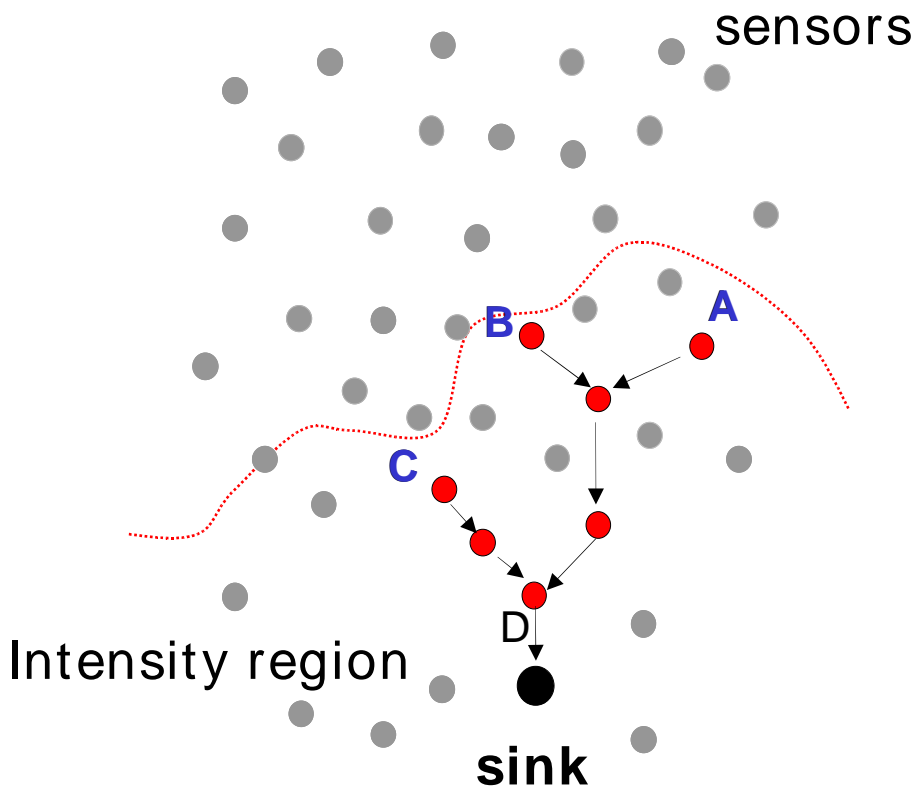
- A_{\max} = max number of slots that can be assigned given the TDMA capacity
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- if $A > A_{\max}$ then sink decreases beacon transmission power

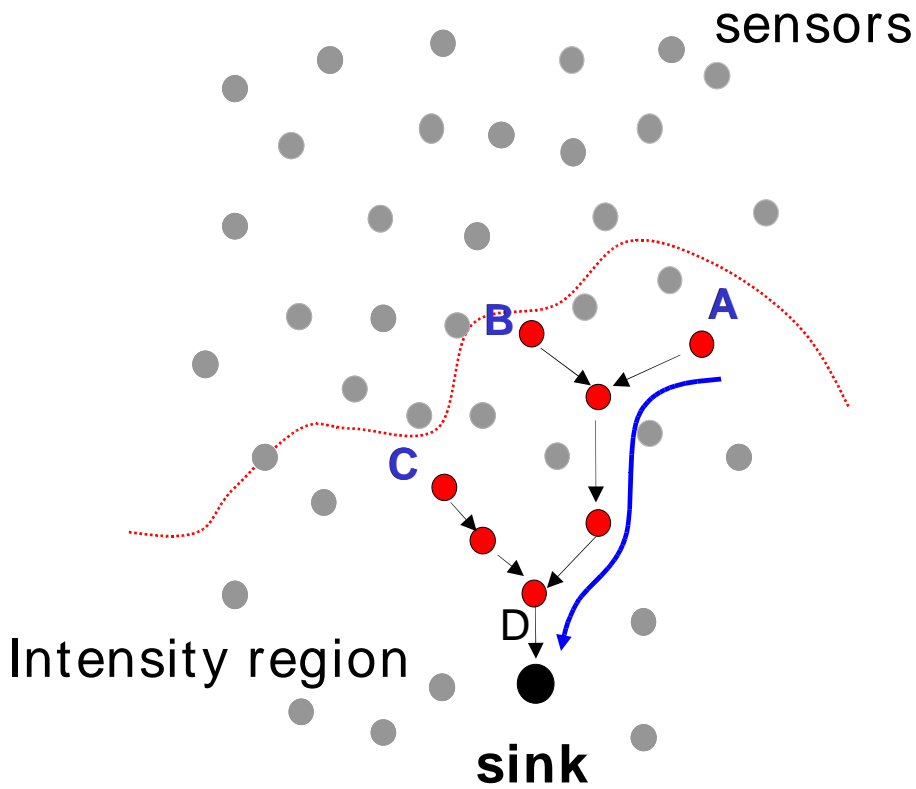
Sink-oriented scheduling



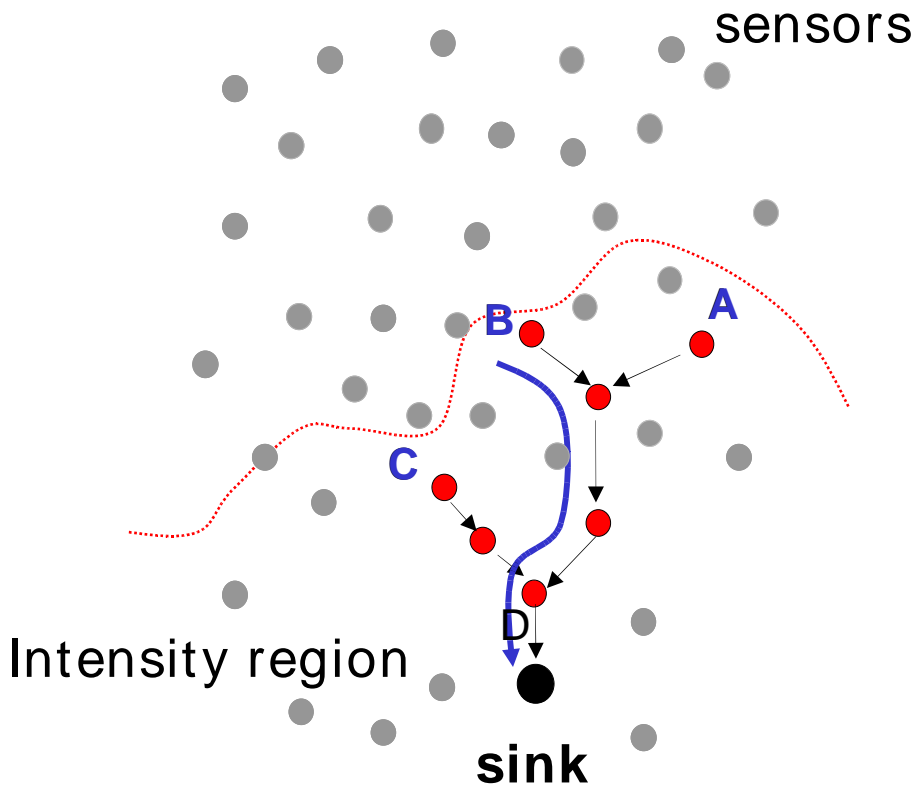
Sink-oriented scheduling



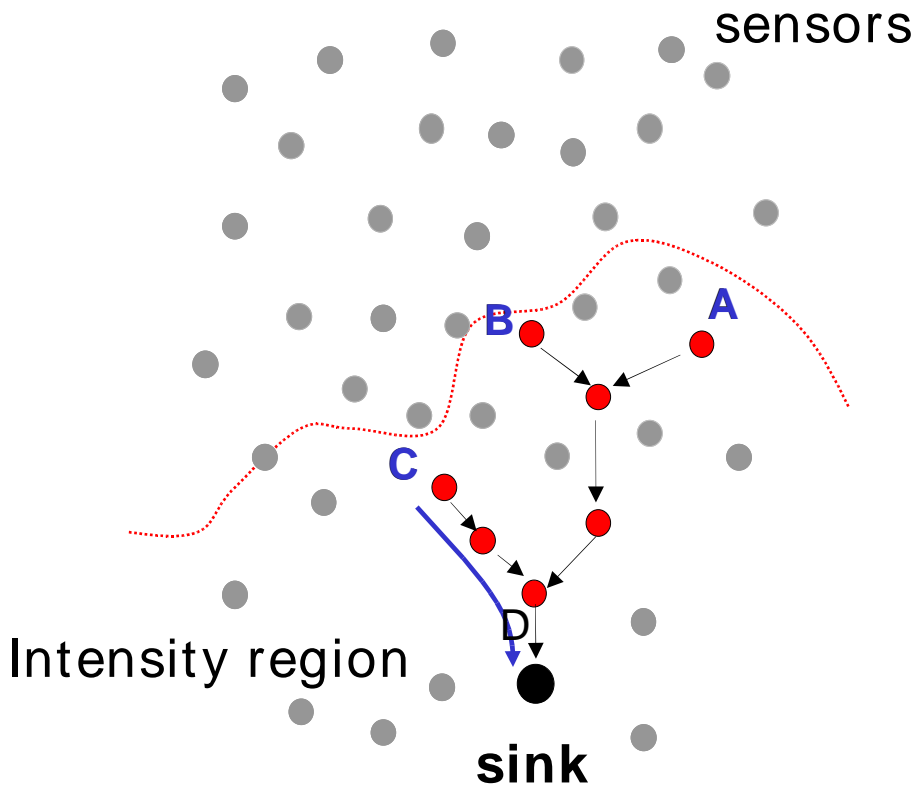
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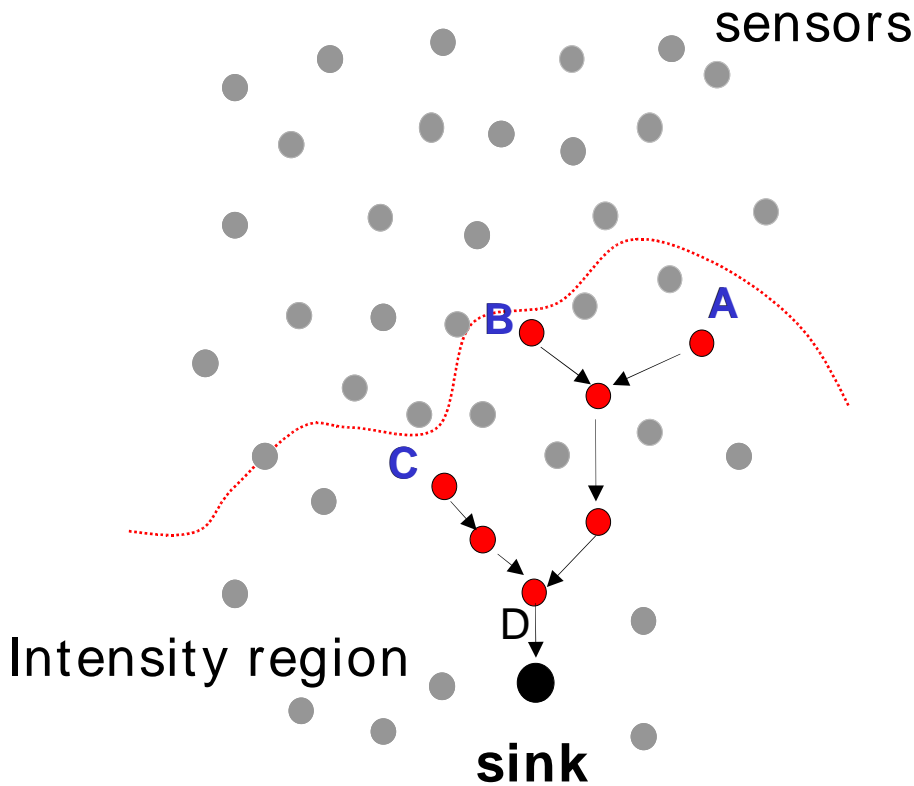
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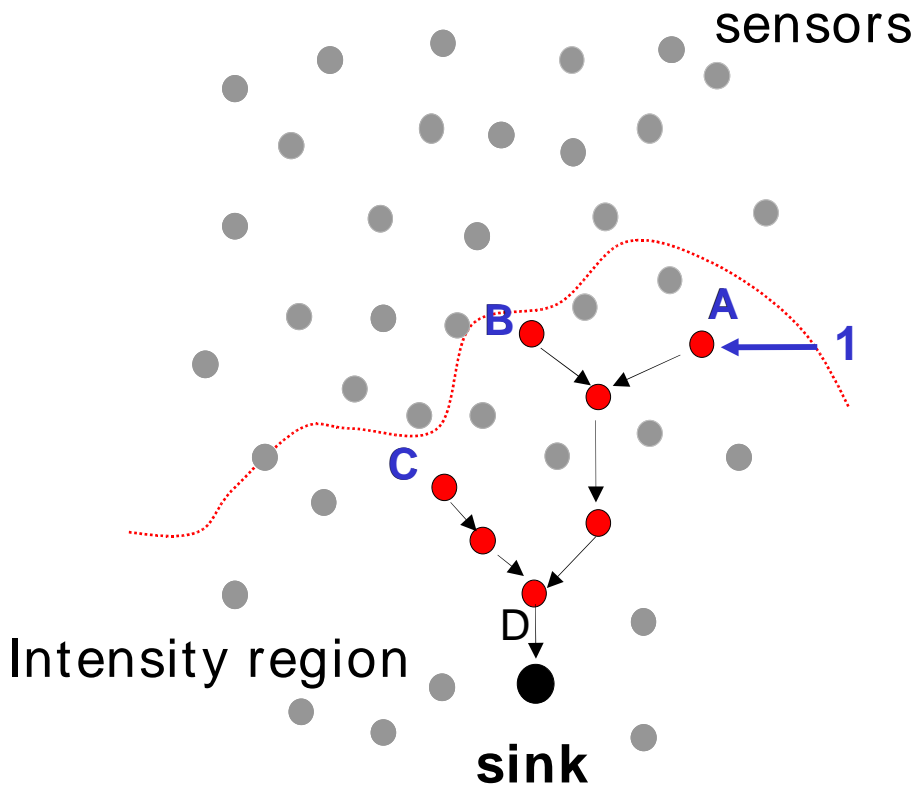


Schedule packet

Header	A ; 3	B ; 4	C ; 3
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- B starts 3 slots after A
- C starts 7 slots after A

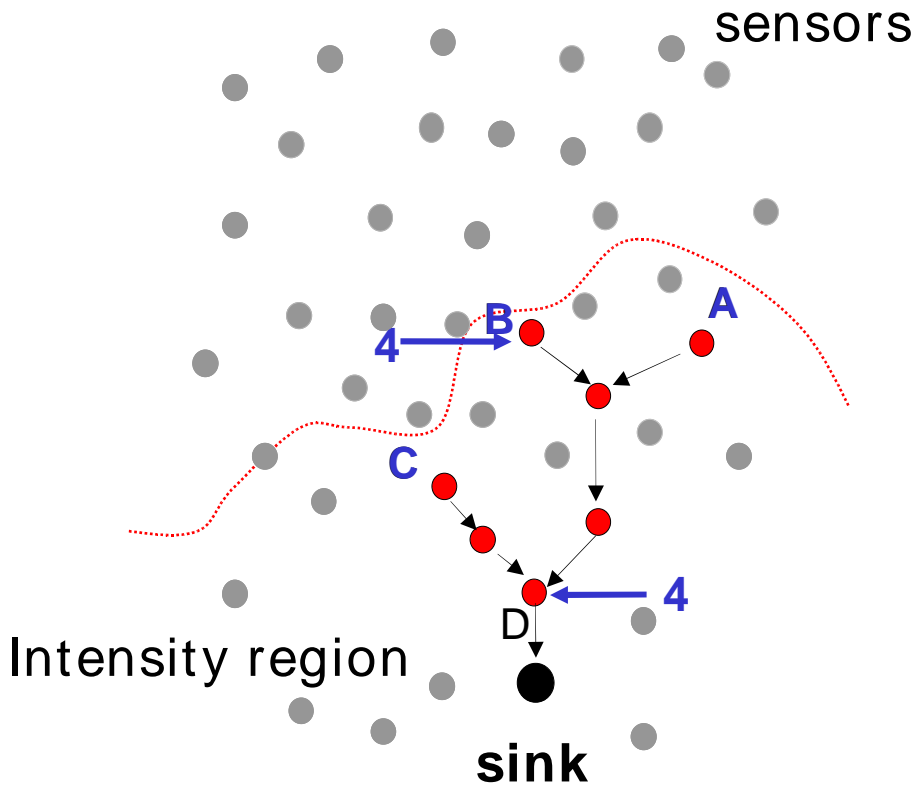
Sink-oriented scheduling



Schedule packet

Header	A ; 3	B ; 4	C ; 3
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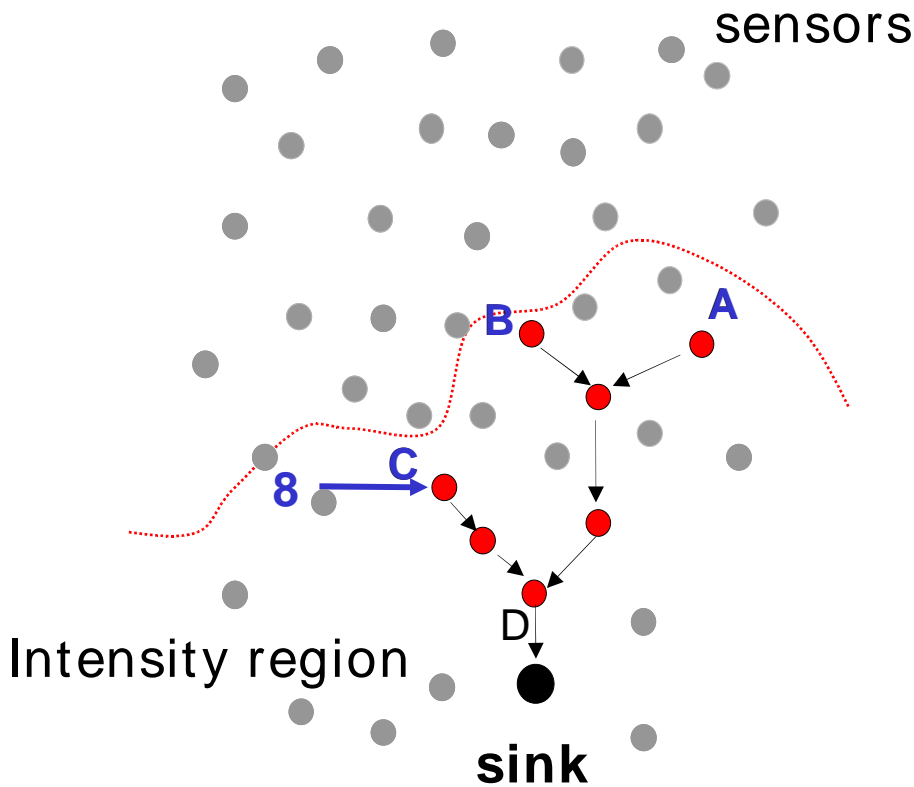
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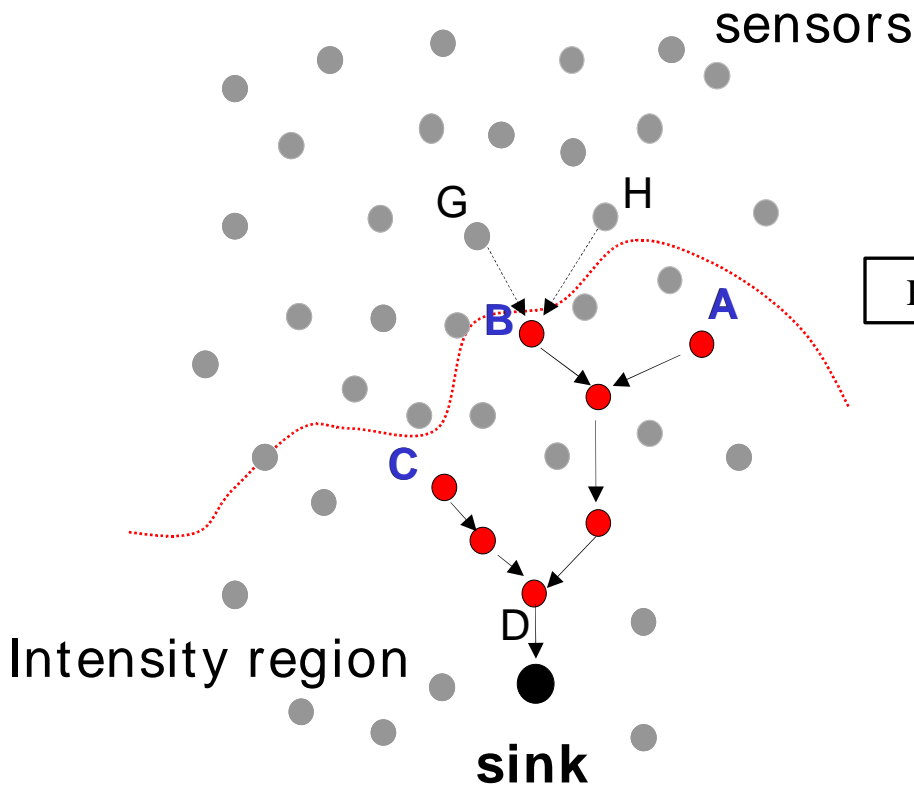
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Schedule packet

Header	A ; 3	B ; 4	C ; 3
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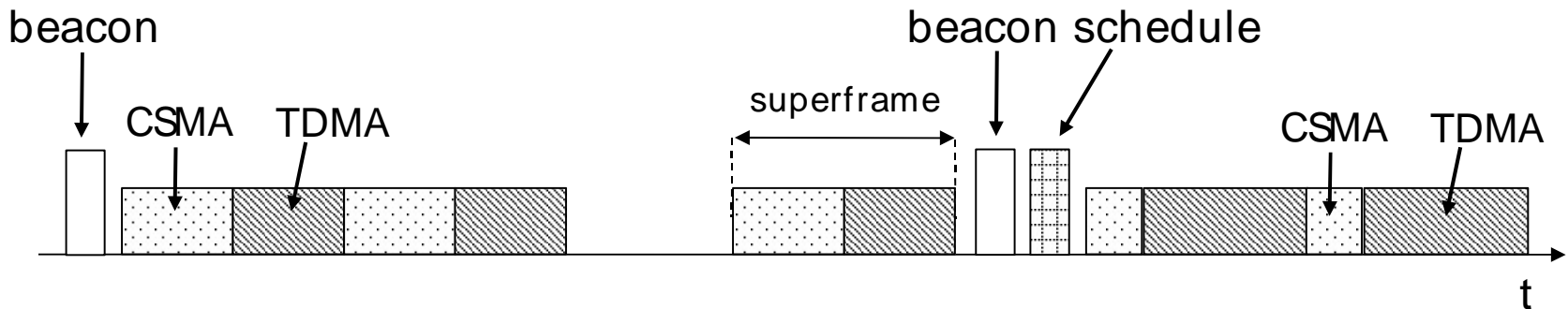
Sink-oriented scheduling



Schedule packet

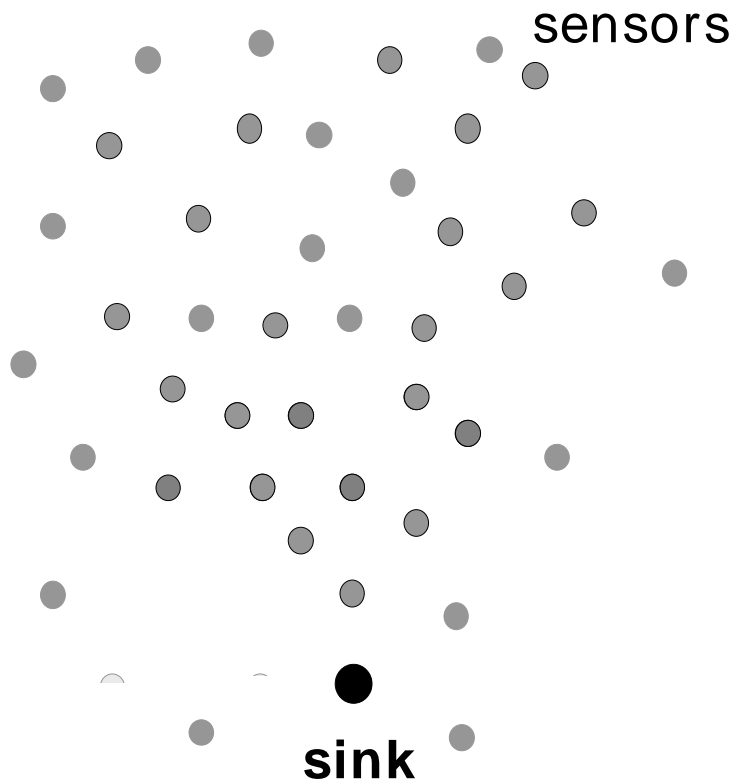
Header	A ; 3	B ; 4	C ; 3	B ; 3	B ; 3
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Framing

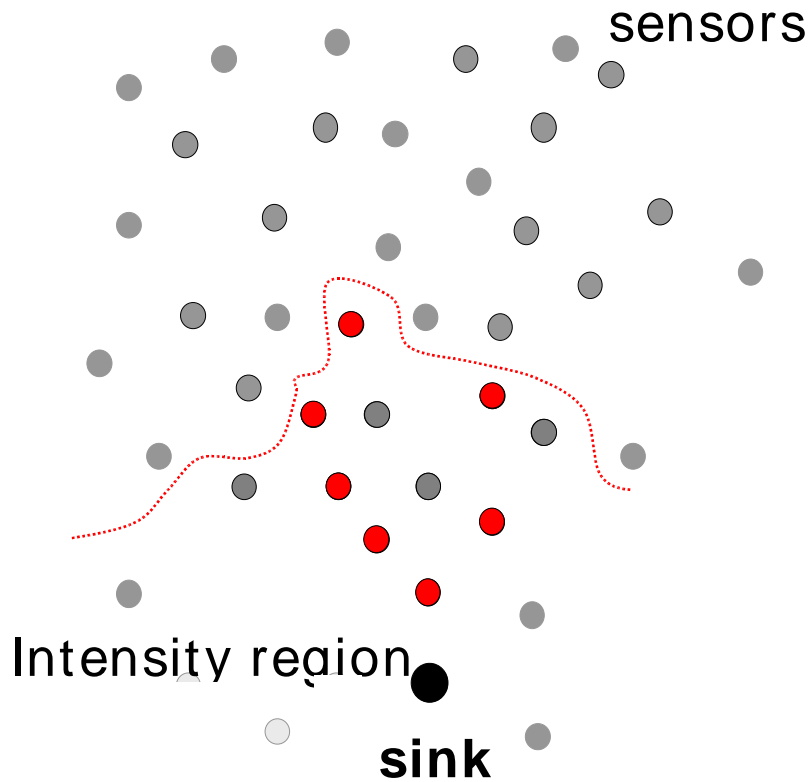


- **The Beacon carries information about the framing routine**

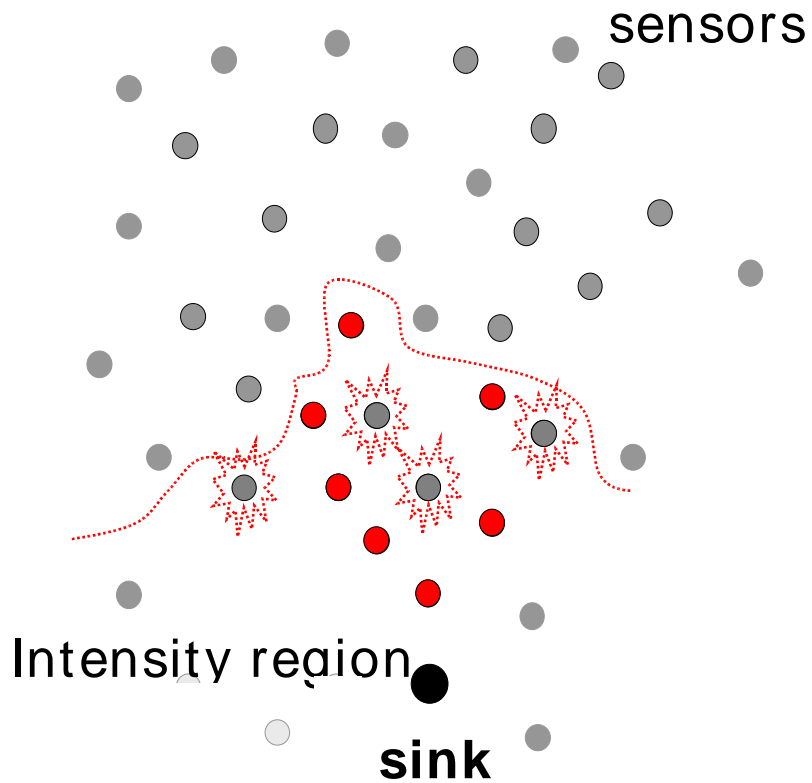
Meta- schedule advertisement



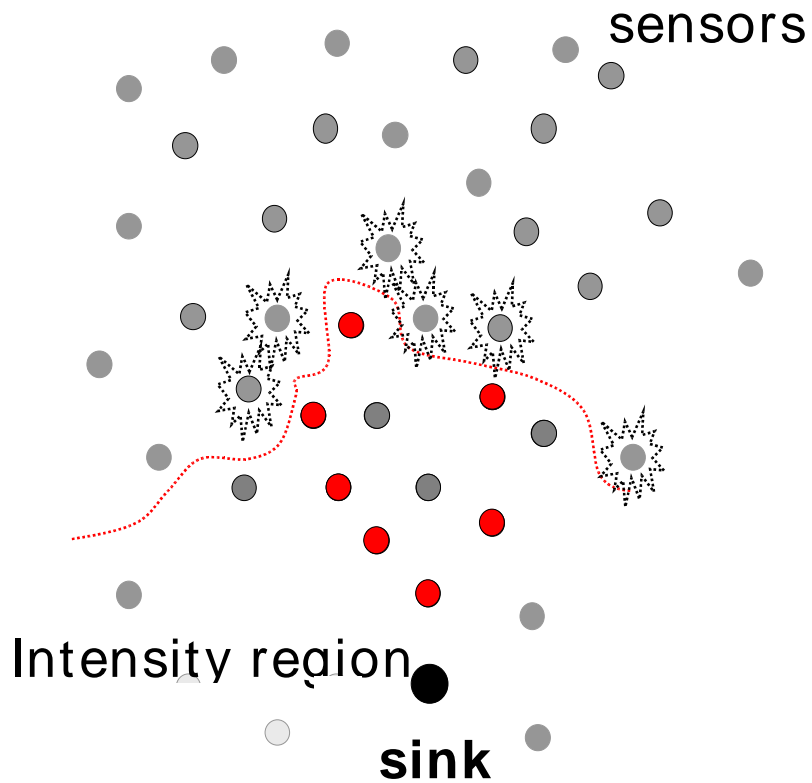
Meta- schedule advertisement



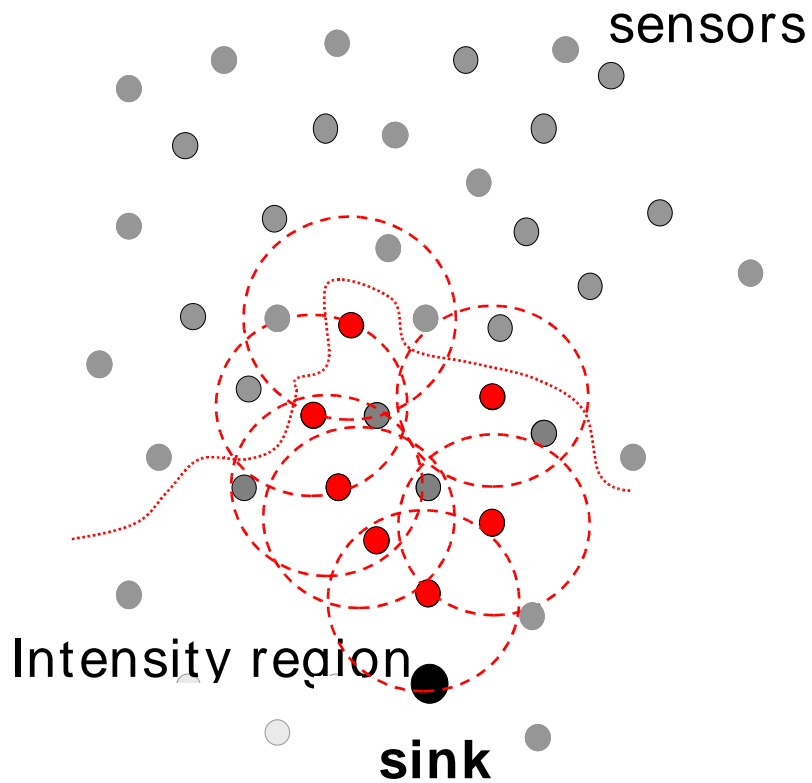
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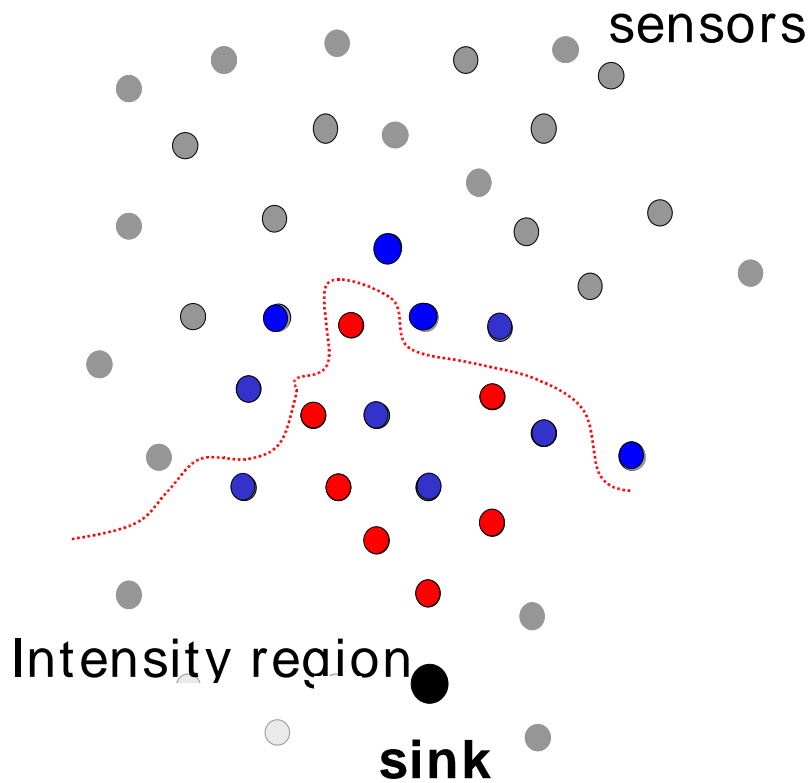
Meta- schedule advertisement



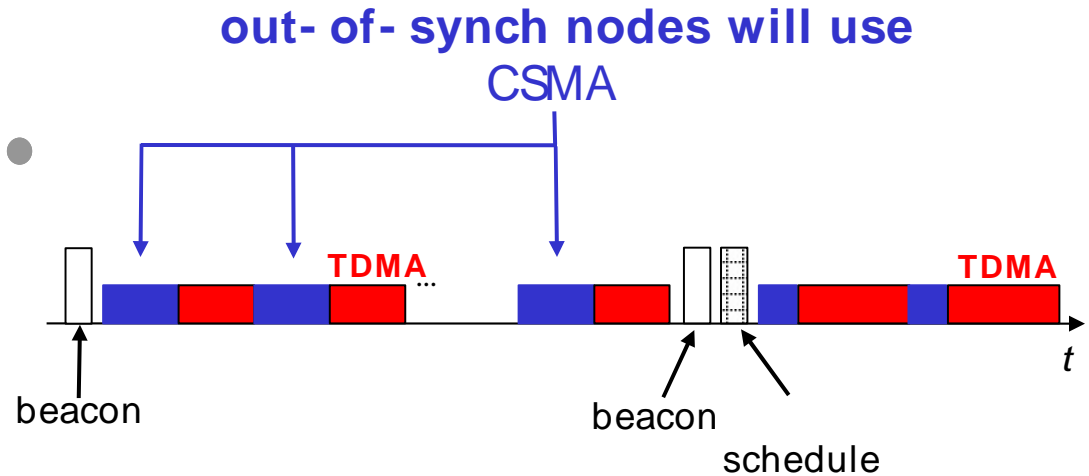
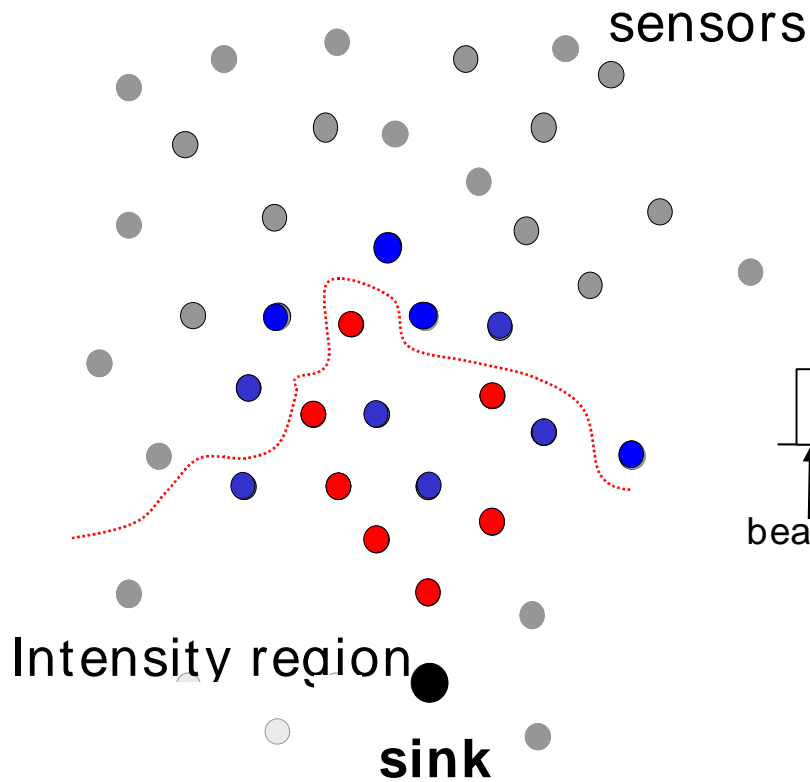
Meta- schedule advertisement



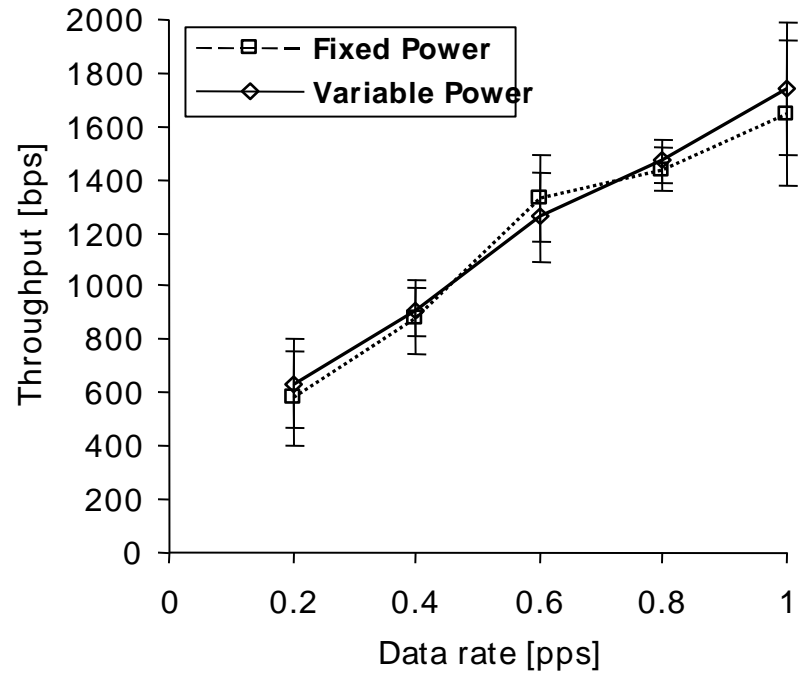
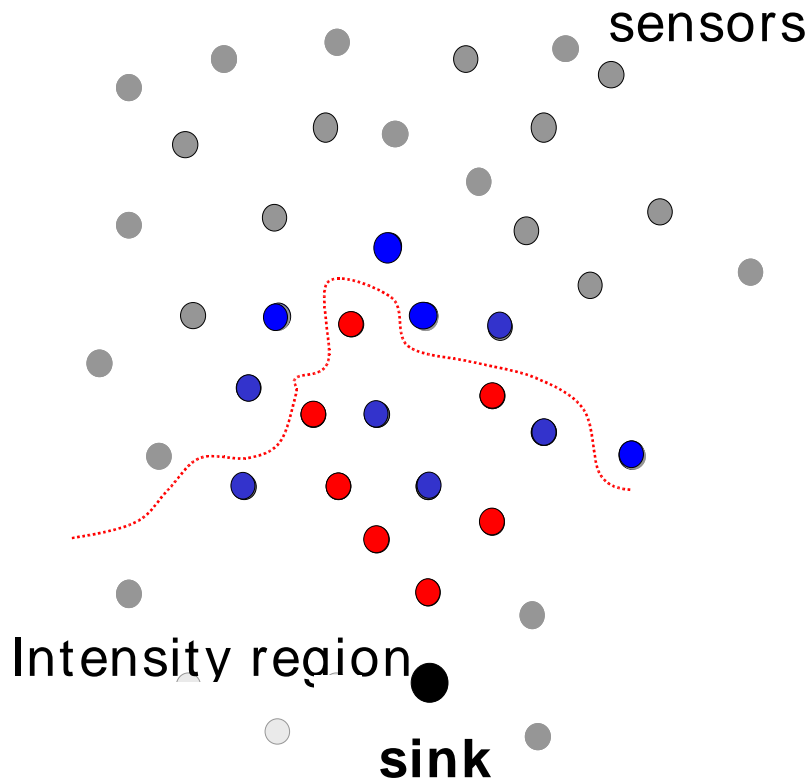
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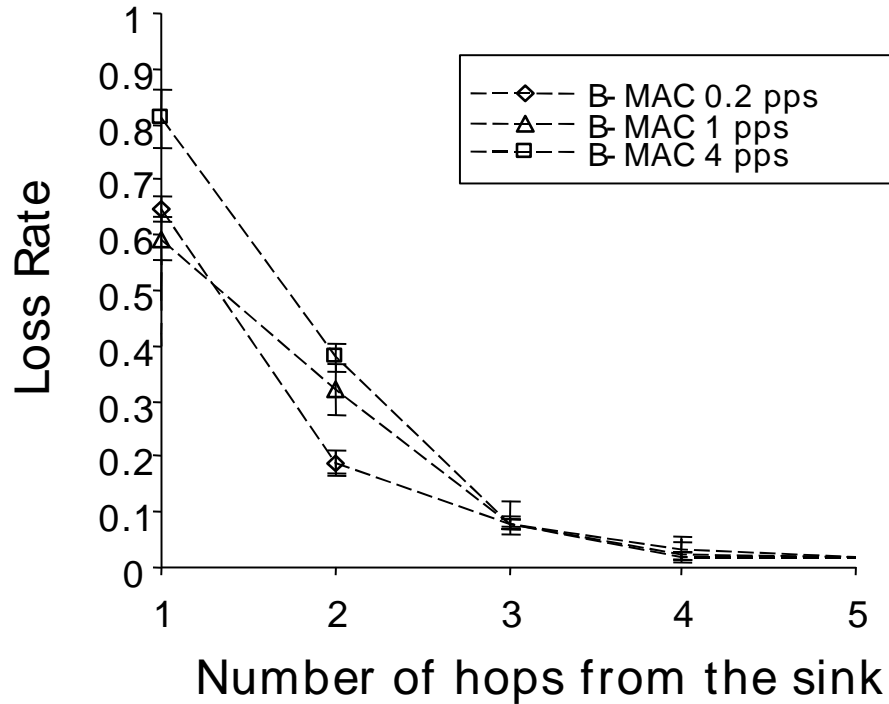
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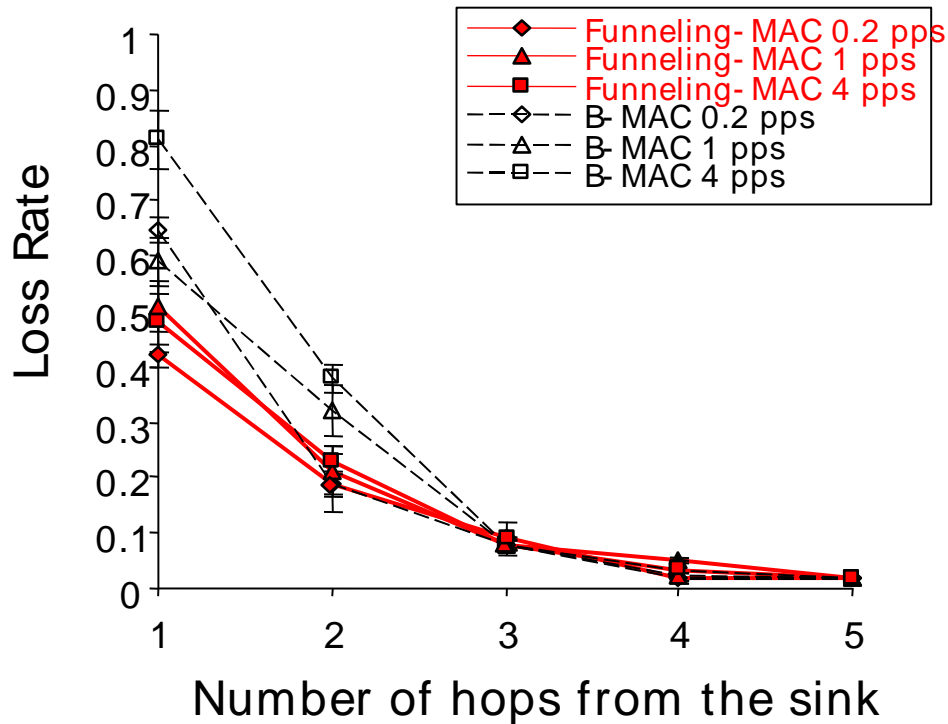
Performance evaluation

- Comparison with B- MAC and Z- MAC
- Throughput and energy efficiency metrics varying data rate and number of sources
- Data packet size = 36 bytes

Loss rate distribution



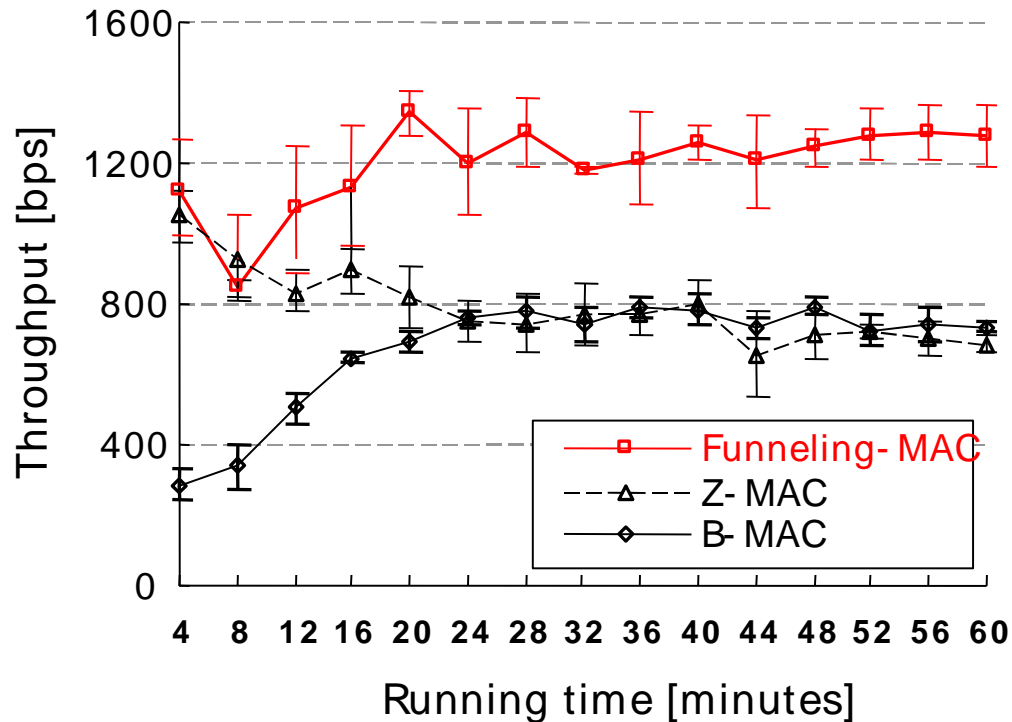
Loss rate distribution



**Loss reduction at
each hop
between 45- 90%**

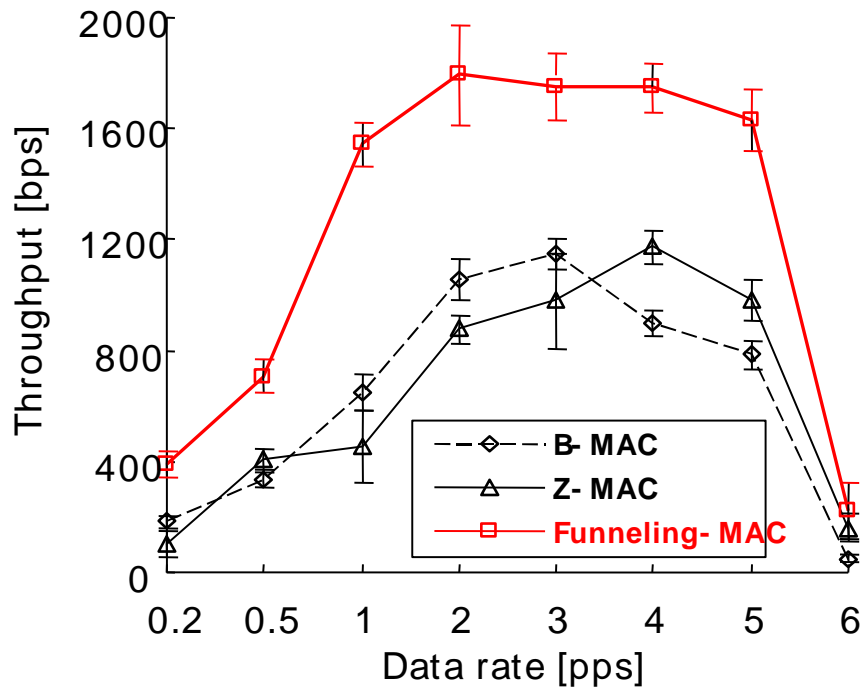
Funneling- MAC mitigates the funneling effect

Performance over time

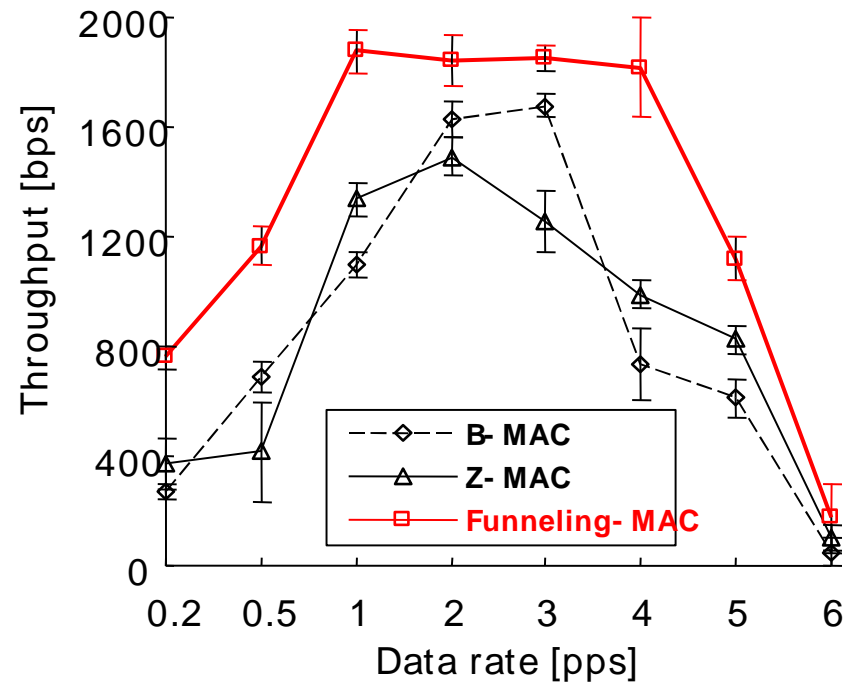


Funneling-MAC is robust against time-varying radio conditions

Multi-hop throughput



16 sources varying the data rate



44 sources varying the data rate

Funneling-MAC improves performance over B-MAC and Z-MAC

Energy tax

$$E_{tax} = \frac{D_t + C_t}{D_d \cdot n}$$

D_t = amount of data packets transmitted (in bits)

C_t = overhead (in bits)

D_d = amount of data packets delivered at the sink (in bits)

n = number of nodes

Energy tax

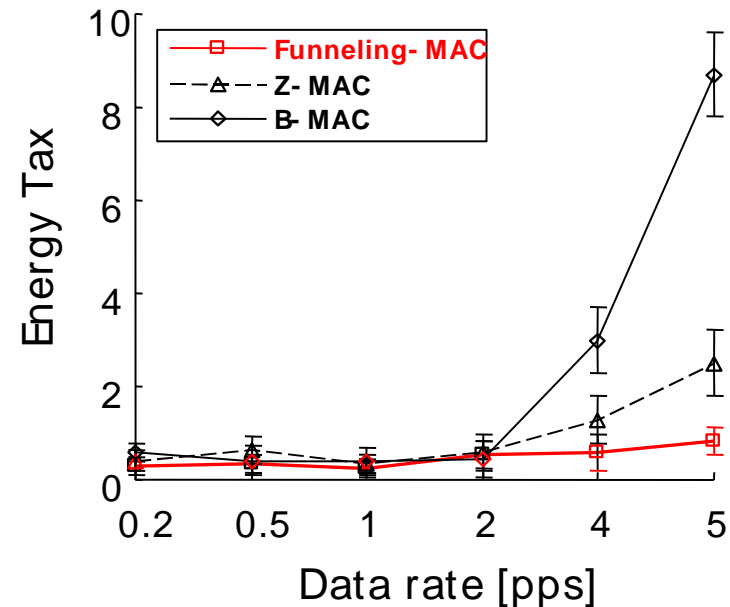
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44 sources with varying data rate

Funneling-MAC increases energy savings

Energy cost

$$E_{sig} = \frac{C_t}{D_d \cdot n}$$

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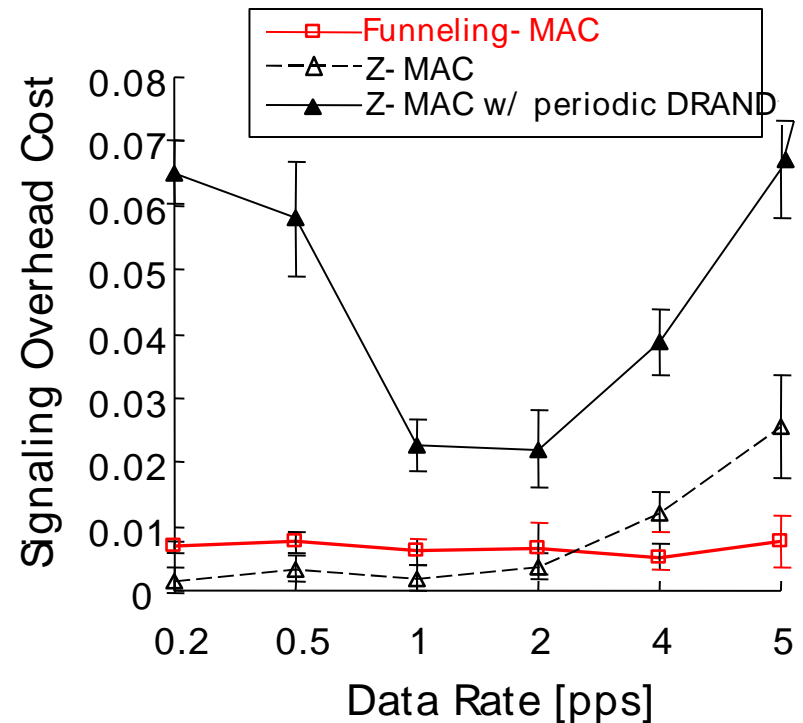
Energy cost

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Signaling overhead cost of the funneling-MAC and Z-MAC

Funneling-MAC minimizes signaling overhead



Conclusion

- Contribution
 - Boosts fidelity to the application by mitigating the funneling effect in choke points

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 - Boosts fidelity to the application by mitigating the funneling effect in choke points
 - Provides a lightweight, robust, and efficient hybrid TDMA/ CSMA scheme
 - Shows that multiple medium access schemes can seamlessly coexist
- Funneling- MAC could more generally operate on multiple sinks/ hierarchical sensor networks (Tenet, Siphon)



Thanks for listening

Contact:

`miluzzo@cs.dartmouth.edu`

`ahngang@ee.columbia.edu`

<http://www.cs.dartmouth.edu/~sensorlab/funneling-mac>