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Adaptive Random Sensor Selection for Field Reconstruction in Wireless Sensor Networks

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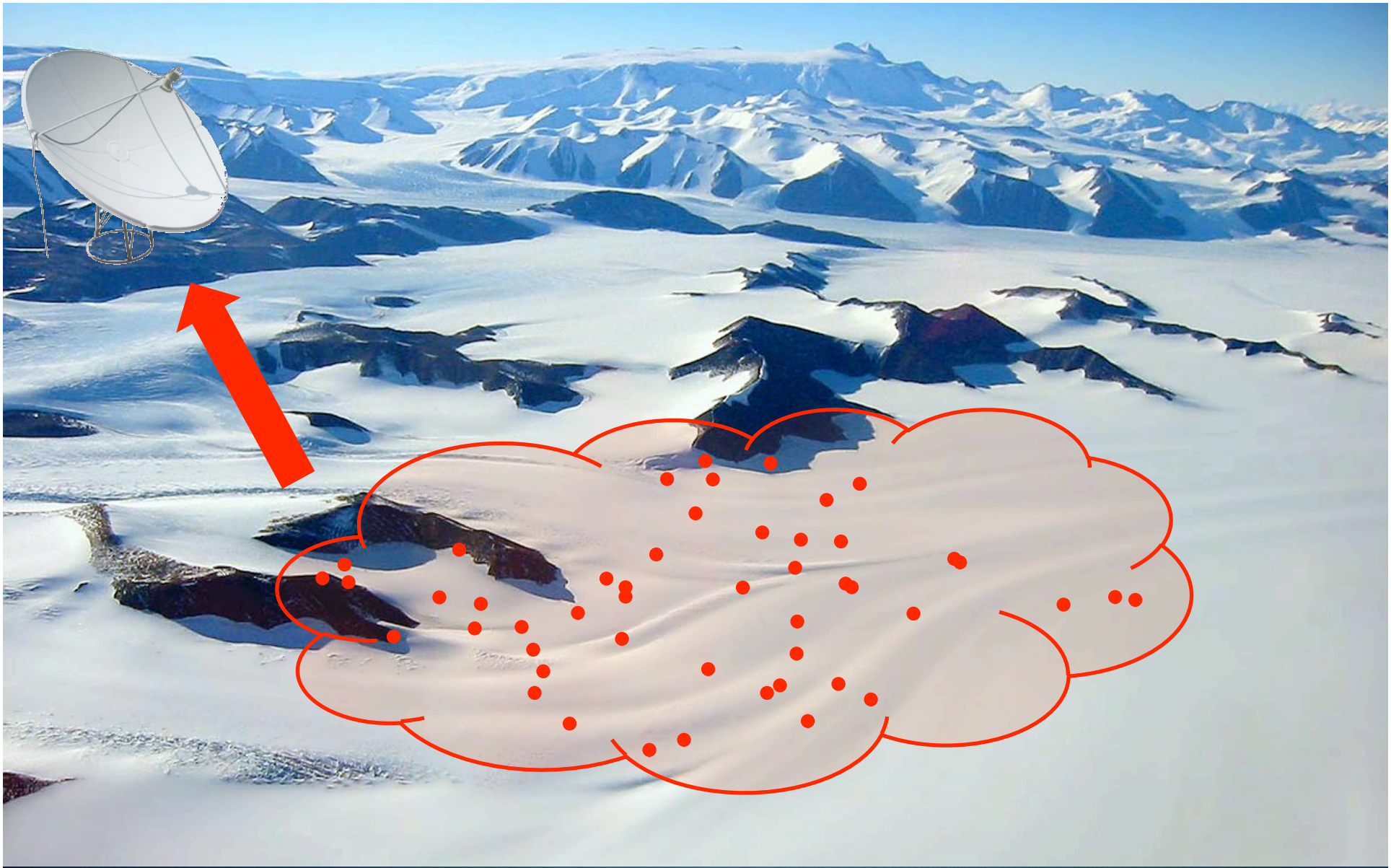

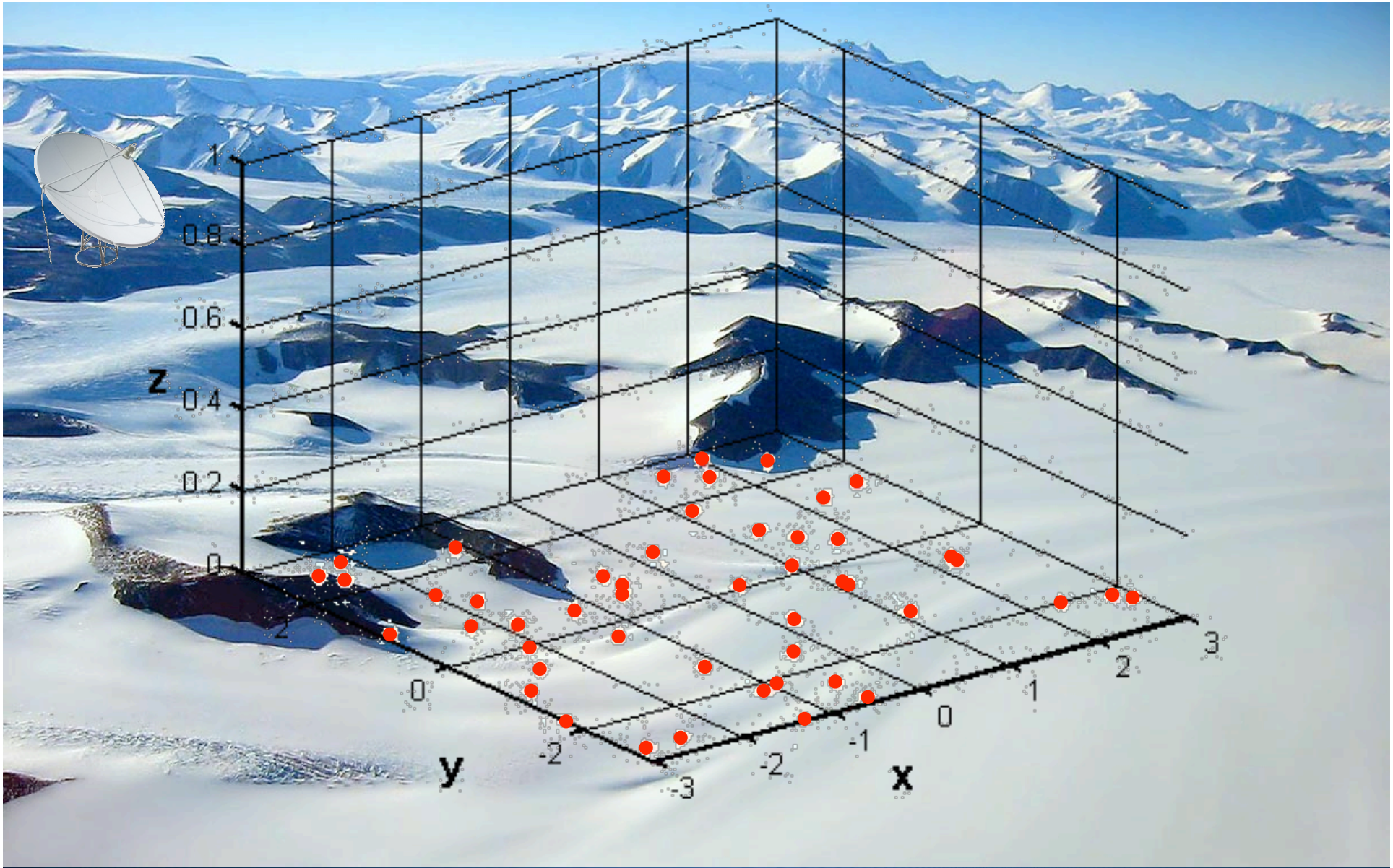
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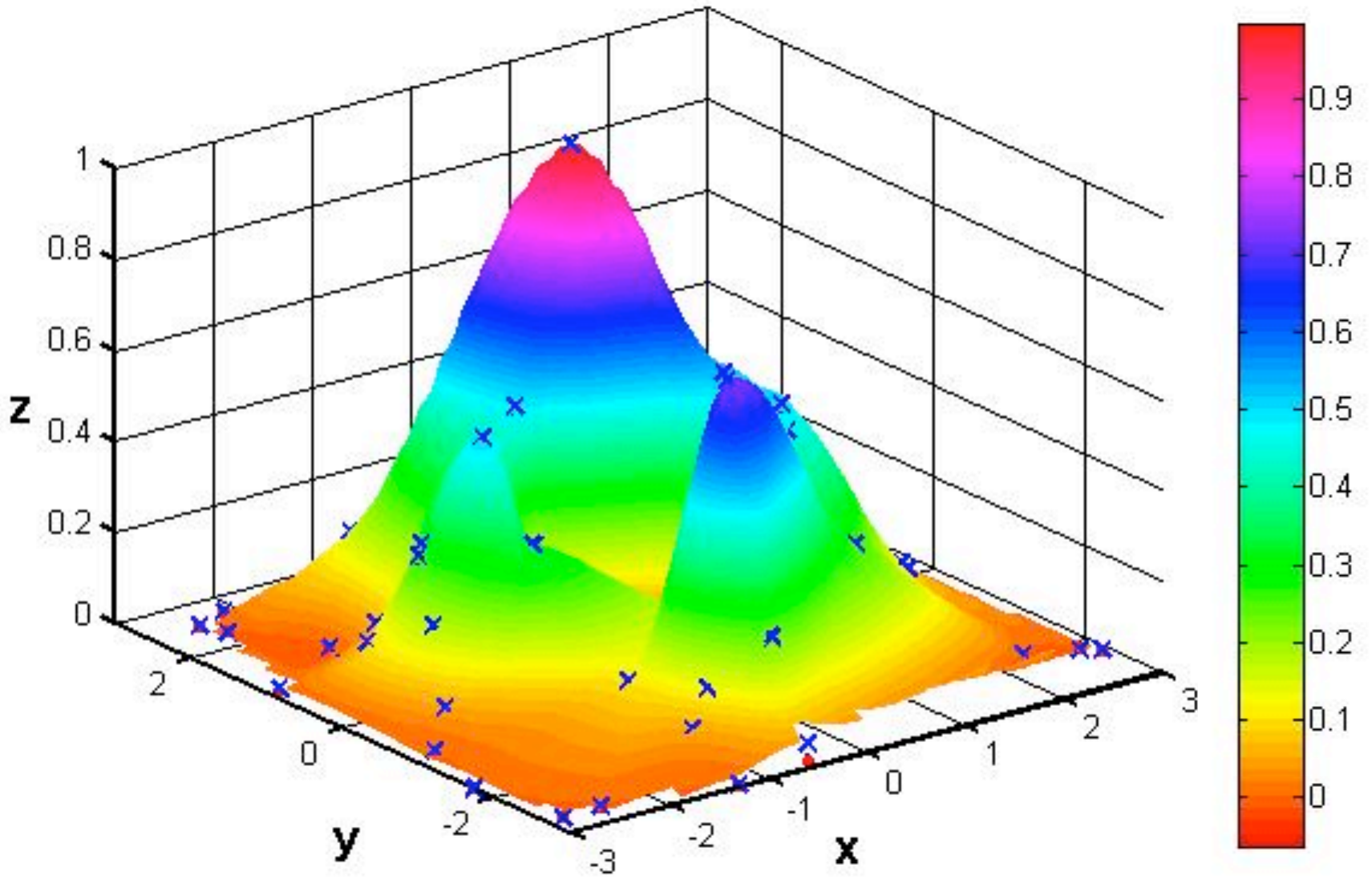
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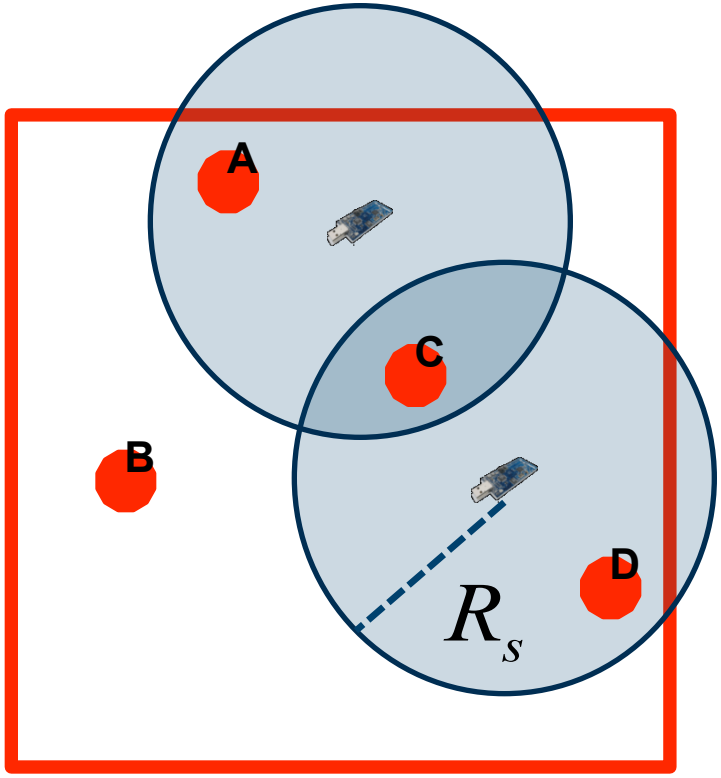
Requirements on Sampling Geometry

- Depend on reconstruction algorithm
  - Algorithm of choice: ACT [1]
- ACT requires
  - Coverage
  - (Rs is data-dependent)



[1] K. Gröchenig and T. Strohmer. *Numerical and Theoretical Aspects of Non-Uniform Sampling of Band-Limited Images*. Nonuniform Sampling: Theory and Practice, Springer, 2001.

Field Reconstruction as Coverage Problem

- Select subset of nodes providing coverage
  - Using coverage preserving algorithms
    - E.g., CCP [2]
  - Using random sensor selection
    - Nodes active with probability p
    - Activation of k nodes out of N requires p = k/N
    - How to select k, or, equivalently, p?

[2] Xing et al. *Integrated Coverage and Connectivity Configuration for Energy Conservation in Sensor Networks.* ACM Transactions on Sensor Networks, vol. 1, pages 36-72, 2005.

Coverage by Random Activation

- Theoretical results available [3,4], but
  - Nodes deployed according to known distribution (e.g., uniform at random)
  - High values of k
  - No adaptation to actual local topology

- Our approach: Adaptive sensor ranking
  - Sensor rank captures „sensing responsability“ of a node for ist own sensing area
  - Rank determines probability of activation p

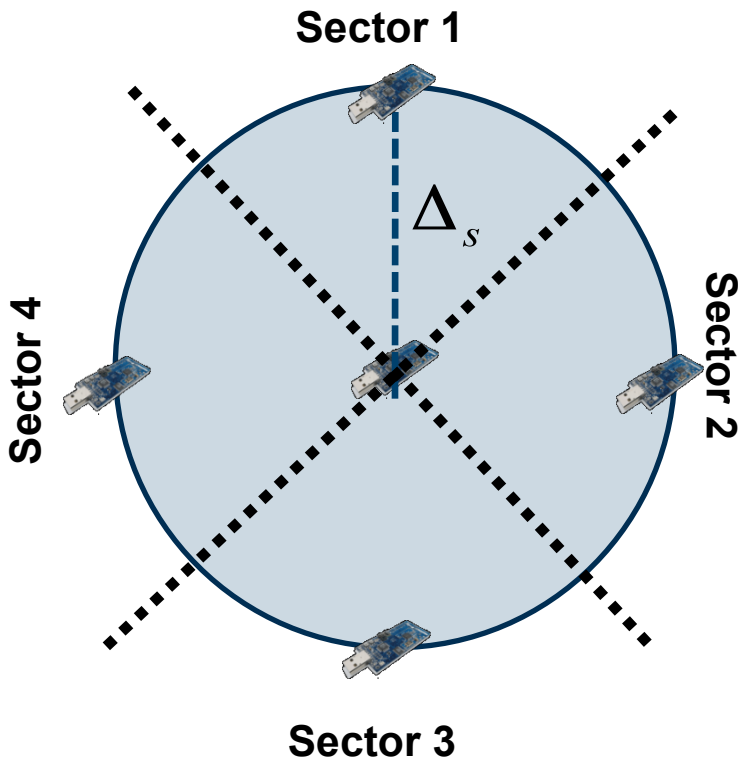
[3] F. Garwood. *The Variance of the Overlap of Geometrical Figures with Reference to a Bombing Problem.* Biometrika, Vol. 34, pages 1-17,1947.

[4] W. Choi,S. K. Das. *Coverage-Adaptive Random Sensor Scheduling for Application-Aware Data Gathering in Wireless Sensor Networks*. Elsevier Computer Communications, Vol. 29, pages 3467-3482, 2006.

Adaptive Sensor Ranking

- Sensor rank of node i

$$\Delta_s = 2R_s$$



Adaptive Sensor Ranking

- Sensor rank of node i
  - Weight neighbors using inverse distance weighting (IDW) [5]

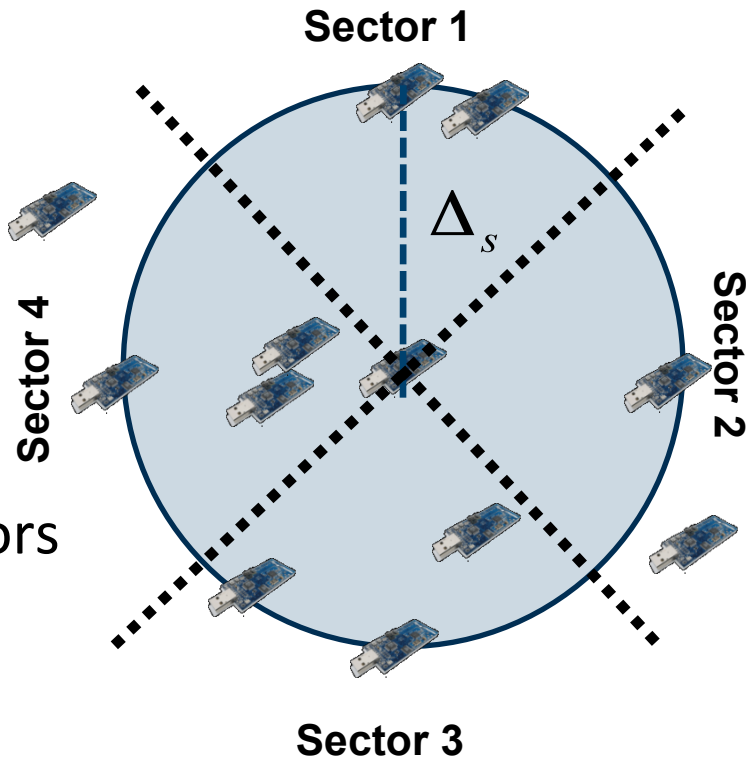
$$\phi_{ij} = 1 - \frac{d_{ij}}{\alpha \Delta_s}, \alpha = 0.5$$

  - Determine weight of each sector

$$\psi_{ik} = \frac{1}{1 + \sum_j \phi_{ij}}$$

  - Sensor rank is average over all sectors

$$\psi_i = \frac{1}{N_{sets}} \sum_{k=1}^{N_{sets}} \psi_{ik}$$



[5] D. Shepard. *A Two-Dimensional Interpolation Function for Irregularly-Spaced Data. ACM Annual Meeting, 1968.*

Adaptive Random Sensor Selection (ARS)

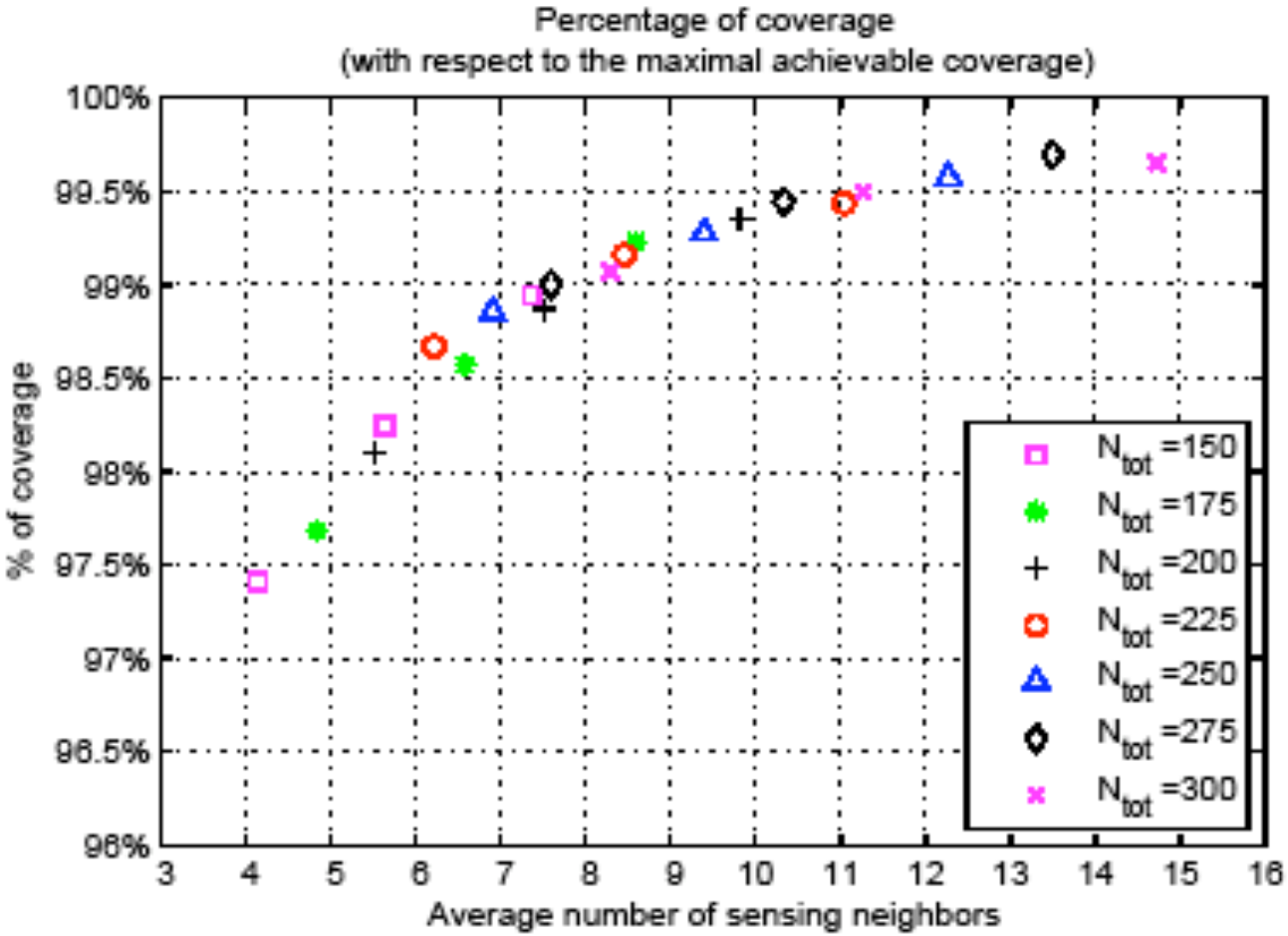
- Probability of activation of node i:

$$p_i = \psi_i$$

- Evaluation
  - 25 networks, 25 runs each
  - 100mx100m deployment area
  - N nodes deployed uniform at random
  - Rtx = 25m, Rs variable (<2Rtx),
  - N variable (from 150 to 300)

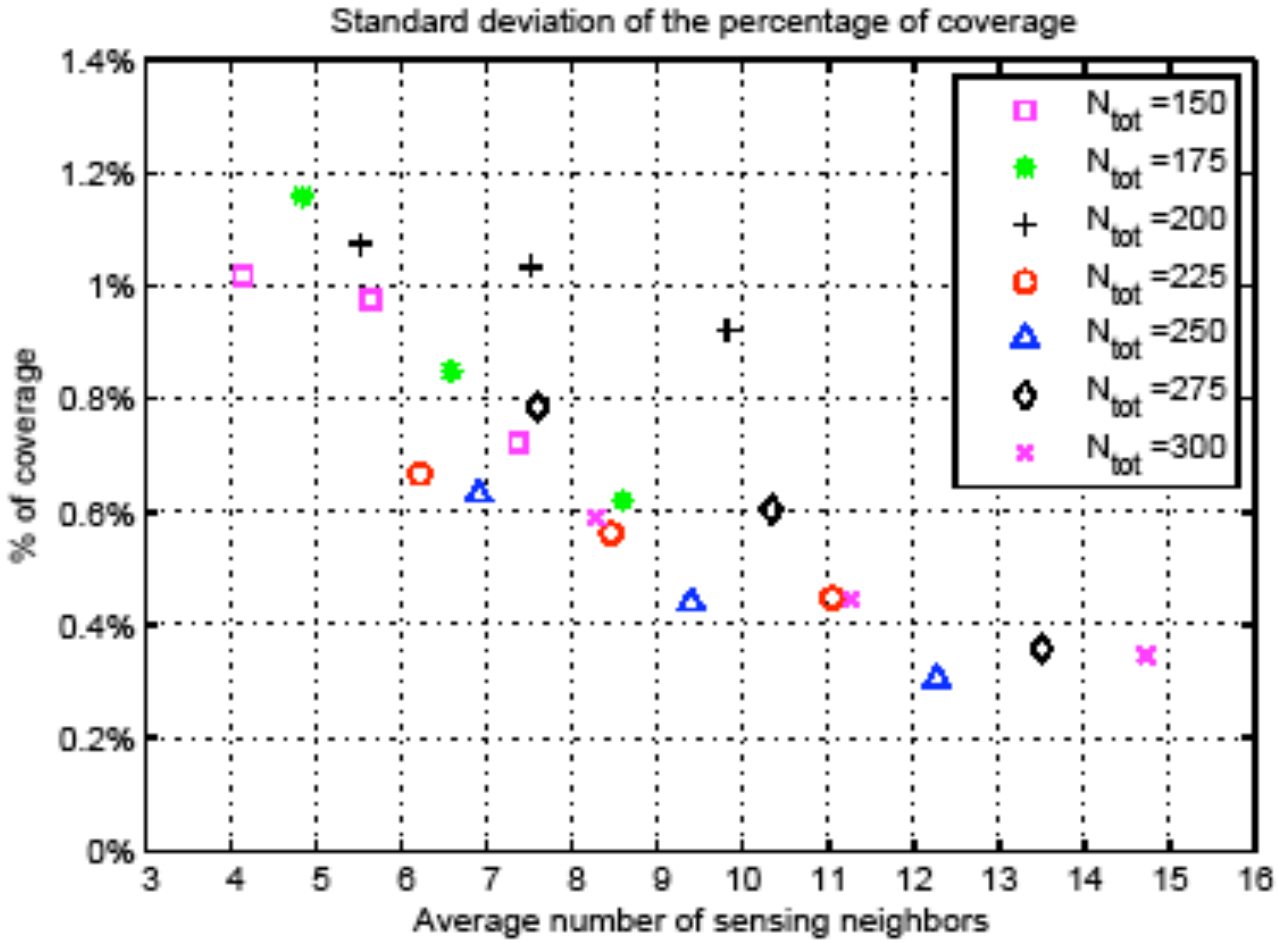
ARS – Coverage Performance (Average)

L_x=100, L_y=100, R_{tx}=25, Δ_s=2R_s=18.75,21.875,25, N_{tot}= 150,175,200,225,250,275,300



ARS – Coverage Performance (Standard Deviation)

L_x=100, L_y=100, R_{tx}=25, Δ_s=2R_s=18.75,21.875,25, N_{tot}= 150,175,200,225,250,275,300



Outlook

- More comprehensive evaluation of performance of the ARS
- Embed sensor ranking in CCP protocol to reduce its comunication overhead
- Use sensor ranking to influence sensor availability for routing

Thank you for your…

- Attention,
- Questions,
- Comments, and
- Suggestions!

References

[1] K. Gröchenig and T. Strohmer. *Numerical and Theoretical Aspects of Non-Uniform Sampling of Band-Limited Images*. Nonuniform Sampling: Theory and Practice, Springer, 2001.

[2] Xing et al. *Integrated Coverage and Connectivity Configuration for Energy Conservation in Sensor Networks.* ACM Transactions on Sensor Networks, vol. 1, pages 36-72, 2005.

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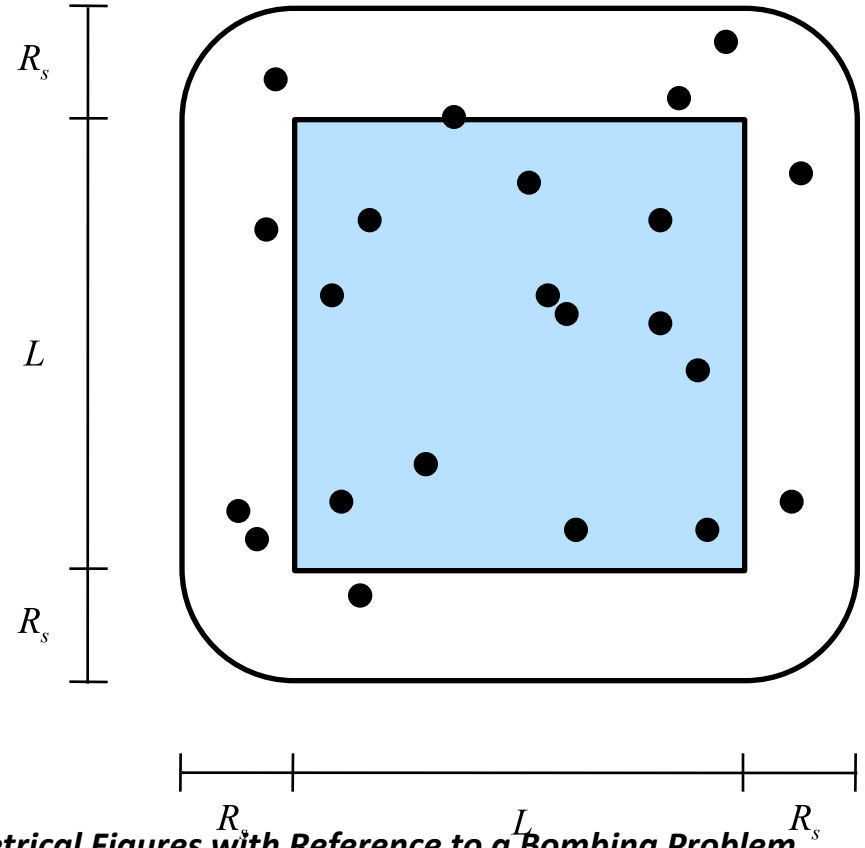
[5] D. Shepard. *A Two-Dimensional Interpolation Function for Irregularly-Spaced Data. ACM Annual Meeting, 1968.*

Backup slides

Coverage by Randomly Deployed Nodes

$$ESC = 1 - \left(\frac{L^2 + 4LR_s}{L^2 + 4LR_s + \pi R_s^2} \right)^k$$

$$k = \left\lceil \frac{\ln(1 - ESC)}{\ln\left(\frac{L^2 + 4LR_s}{L^2 + 4LR_s + \pi R_s^2} \right)} \right\rceil$$



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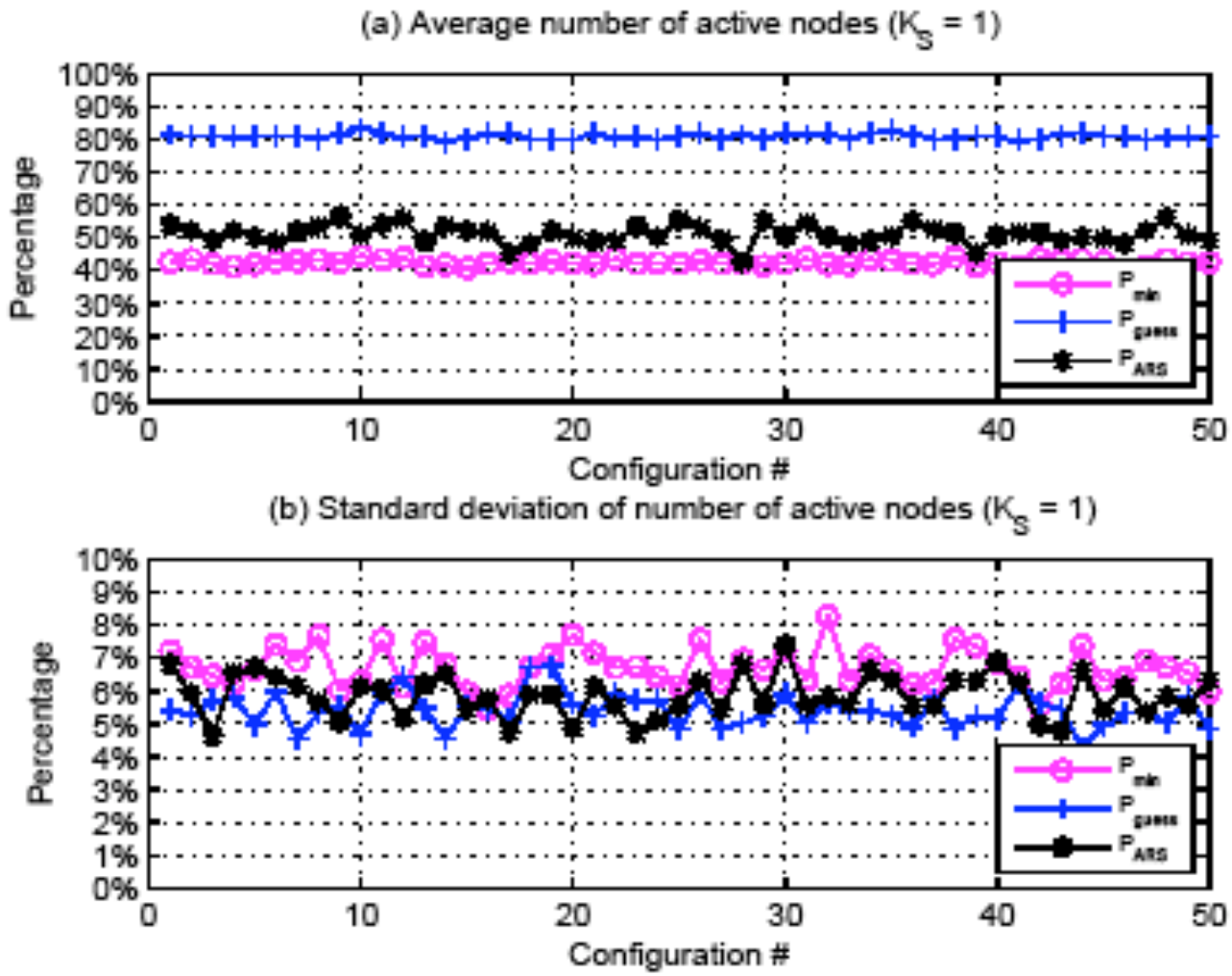
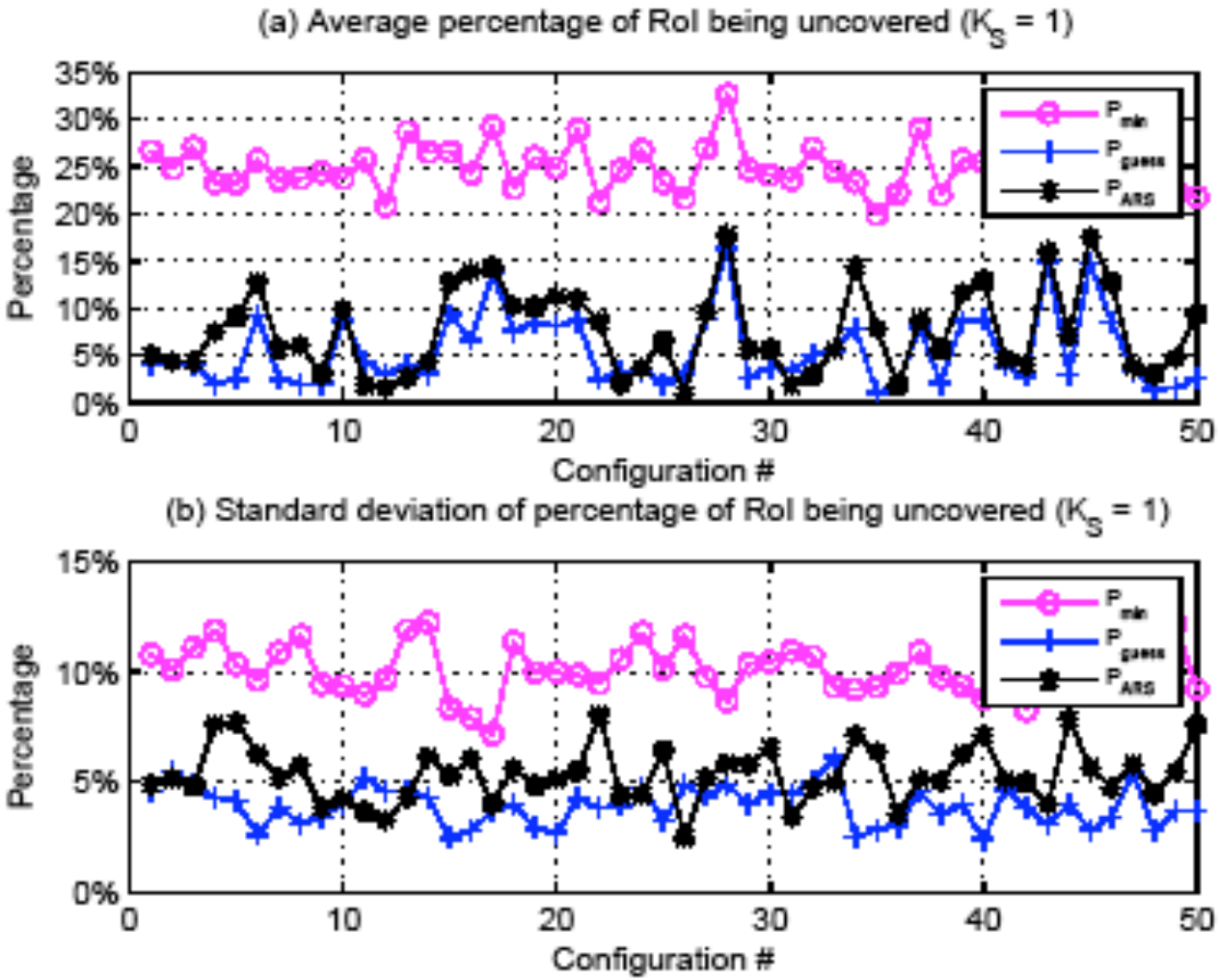
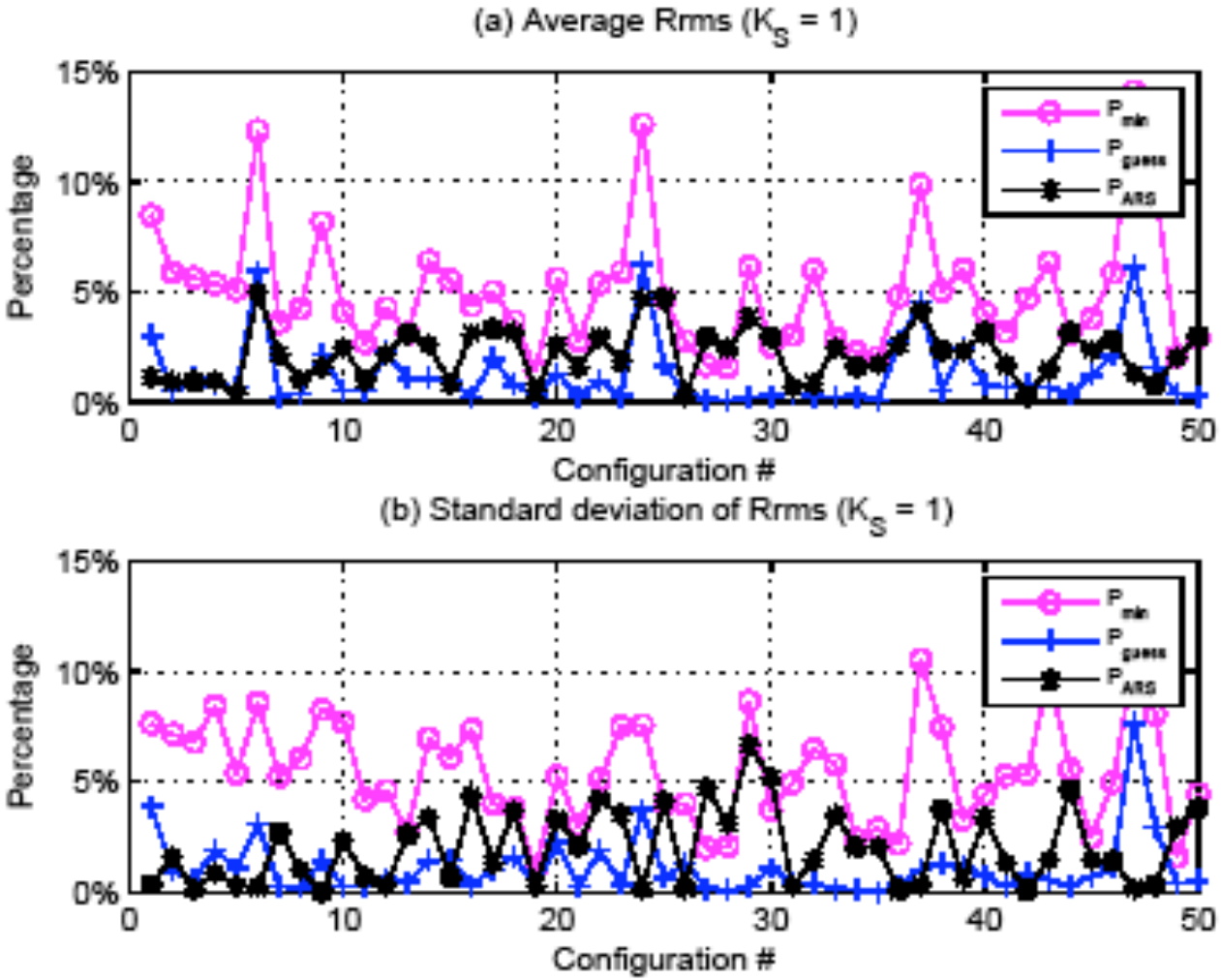
Results Paper DMSN 2009 (I)

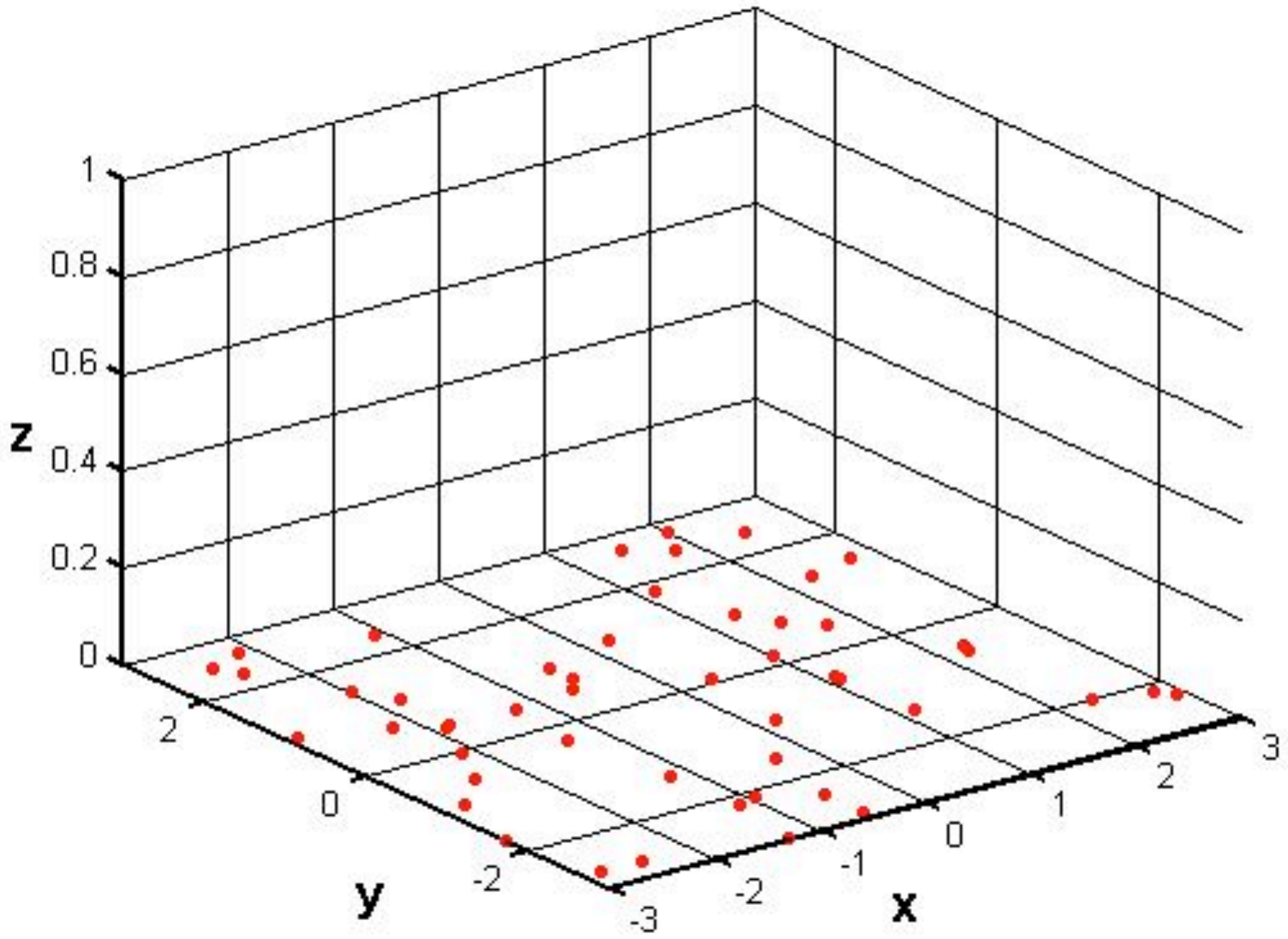


Results Paper DMSN 2009 (II)



Results Paper DMSN 2009 (III)

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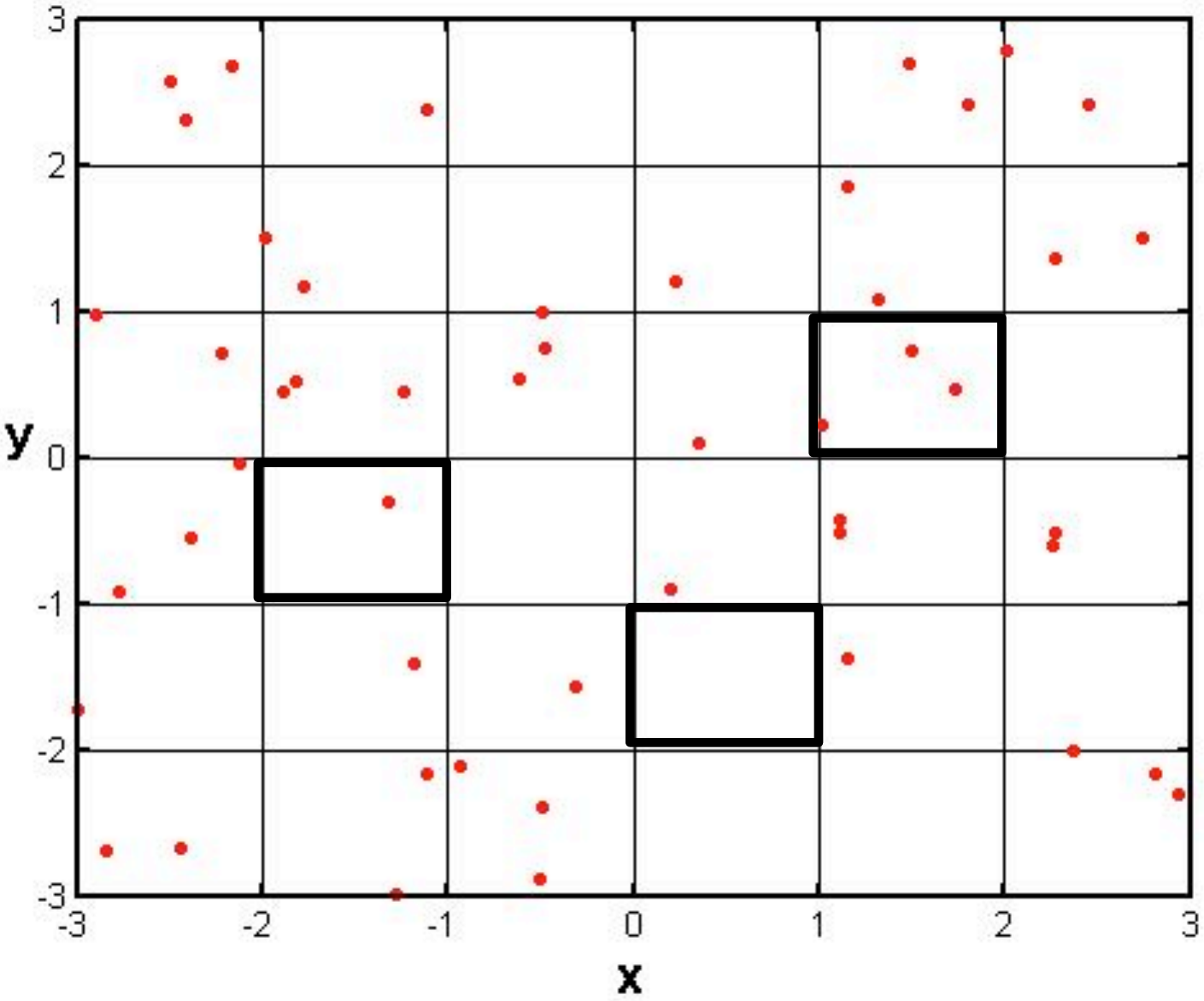
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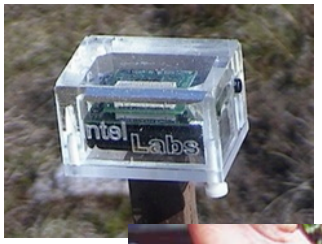
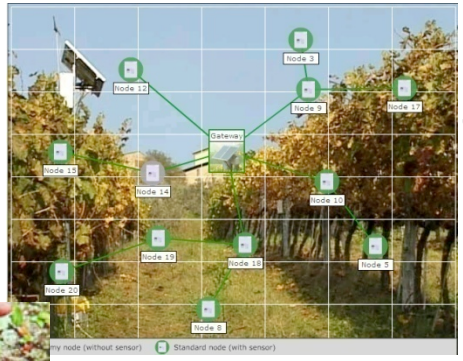
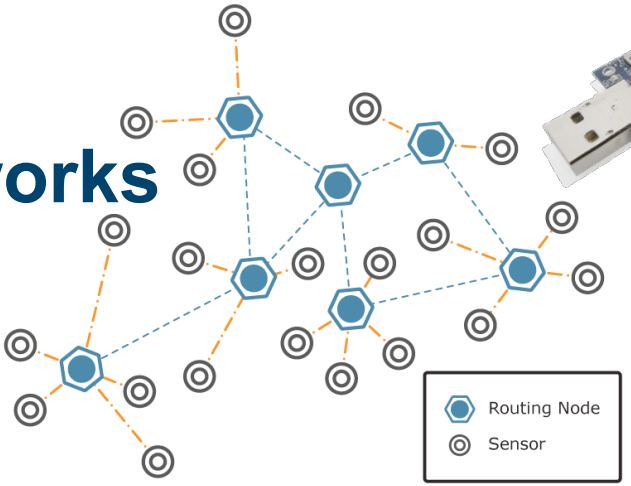
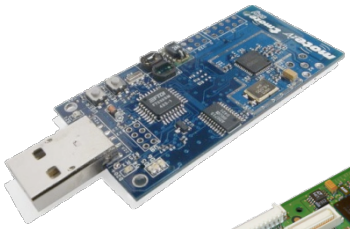
Wireless Sensor Networks



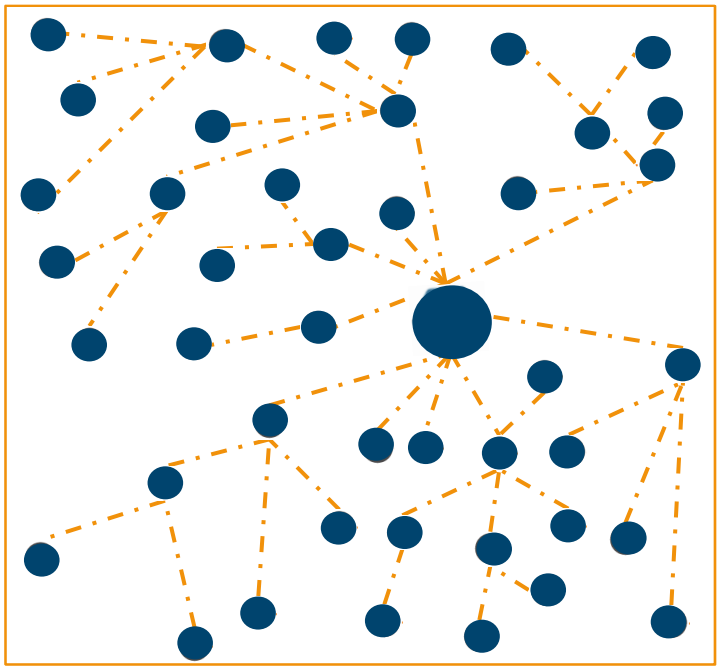






Non-uniform sampling approach

- Reconstruction of sensing fields from non uniformly spaced samples



- Estimation of
  - Required amount of samples
  - Accuracy of reconstruction
  - Optimal node configuration
- Advantages
  - No a-priori knowledge
  - Numerical efficiency