# Energy-Efficient Deployment of Intelligent Mobile Sensor Networks

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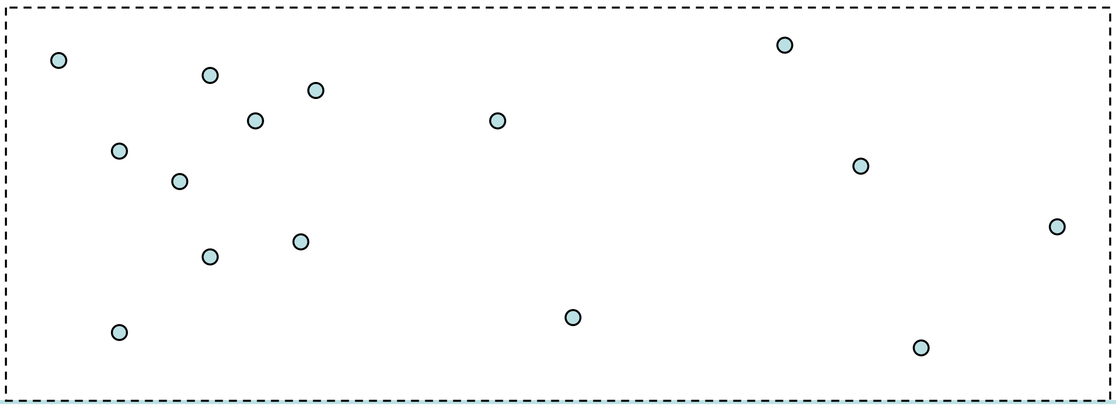
# Outline

- Introduction
- Mobile-Node Deployment Problem
- Performance Metrics in Mobile WSN
- Proposed Algorithms
  - Distributed Self-Spreading Algorithm (DSSA)
  - Intelligent Deployment and Clustering Algorithm (IDCA)
  - VD-Based Deployment Algorithm (VDDA)
- Experiment Results
- Conclusion

# Introduction

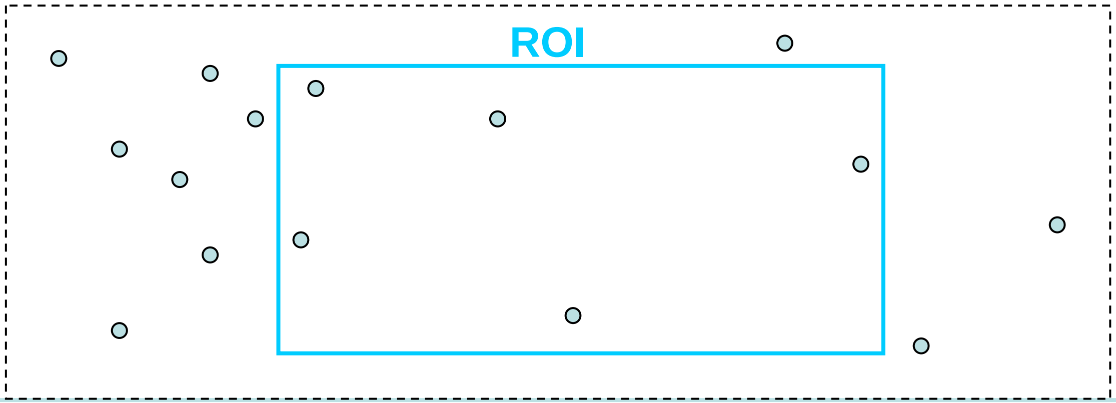
- In this paper, the authors proposed distributed energy-efficient deployment algorithms for mobile sensors and intelligent devices.
- Self-deployment methods using mobile nodes have been proposed to enhance network coverage and to extend the system lifetime.



# Introduction

- Many applications are envisaged including: habitat monitoring, wild fire detection, battlefield surveillance, especially in hazardous situations.

- The key issue in this area is the deployment of mobile sensor nodes in the region of interest (ROI).



# Mobile-Node Deployment Problem

- Initially, sensor nodes are randomly deployed
- Each node is mobile
- Each node knows its own location
- Each node has a limited amount of energy

# Performance Metrics in Mobile WSN

- Coverage
  - Defined as the ratio of the union of areas covered by each node and the area of the entire ROI

$$C = \frac{\bigcup_{i=1,\ldots,N} A_i}{A}$$

$A_i$ is the area covered by the $i$th node;
$N$ is the total number of nodes;
$A$ stands for the area of the ROI.

# Performance Metrics in Mobile WSN

- Uniformity
  - Defined as the average local standard deviation of the distances between nodes.
  - Uniformly distributed-sensor nodes spend energy more evenly than sensor nodes with an irregular topology.

$$U = \frac{1}{N} \sum_{i=1}^{N} U_i$$

$$U_i = \left( \frac{1}{K_i} \sum_{j=1}^{K_i} (D_{i,j} - M_i)^2 \right)^{\frac{1}{2}}$$

| | |
|---|---|
| $N$ | is the total number of nodes; |
| $K_i$ | is the number of neighbors of the $i$th node; |
| $D_{i,j}$ | is the distance between $i$th and $j$th nodes; |
| $M_i$ | is the mean of internodal distances between the $i$th node and its neighbors. |

# Performance Metrics in Mobile WSN

- Time
  - Defined as the time until all the nodes reach their final locations.
  - The required time depends on the complexity of the reasoning and optimization algorithm and physical time for the movement of nodes.
- Distance
  - Defined as the distance of a node movement.
  - If the variance of distance traveled is large, the variance of energy remaining is also large.

# Distributed Self-Spreading Algorithm (DSSA)

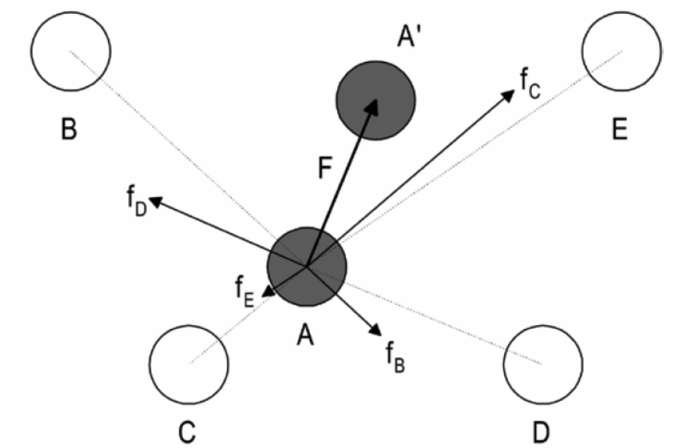
- DSSA
  - Initialization
  - Partial Force Calculation
  - Oscillation Check
  - Stability Check

# DSSA-- Initialization

- cR：communication range
- sR：sensing range
- node location(p0)：contains the longitude component and the latitude component
- ROI：region of interest
- D：local density
- $\mu$ ：expected density

# DSSA-- Partial Force Calculation

- Inverse relation: $f(d_1) >= f(d_2)$ , when $d_1<=d_2$
- Upper bound: $f(0+) = f_{max}$
- Lower bound: $f(d) = 0$ , where d > cR




$$(1) \quad f_n^{i,j} = \frac{D_n^i}{\mu^2}\left(\mathrm{cR}\left|p_n^i - p_n^j\right|\right)\frac{p_n^j - p_n^i}{\left|p_n^j - p_n^i\right|}$$

$p_n^i$ stands for the location of the $i$th node at time step $n$;
$D_n^i$ stands for the local density of the $i$th node at time step $n$.

# DSSA-- Oscillation Check

- Oscillation
  - Defined as a node moves back and forth between almost the same locations many times
  - ($O_{count}$)：to count the number of oscillations
  - ($O_{lim}$)：the oscillation limit
  - If ($O_{count}$) > ($O_{lim}$)
    - The movement of that node is stopped at the center of gravity of the oscillating points.

# DSSA-- Stability Check

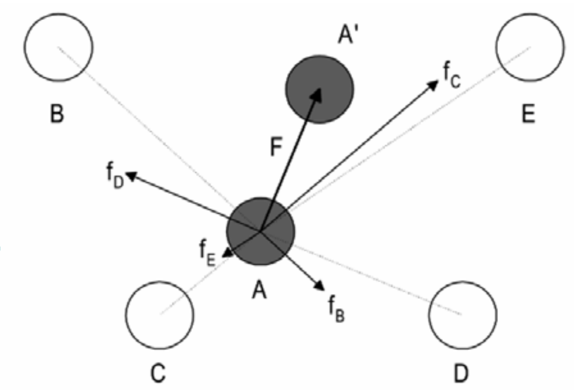
- Stability
  - Defined as a node moves less than threshold for the time duration Stability_limit(Slim)
    - Stop the node's movement

# Intelligent Deployment and Clustering Algorithm (IDCA)

- IDCA
  - Initialization
  - Mode Determination and Partial Calculation
  - Oscillation Check
  - Stability Check

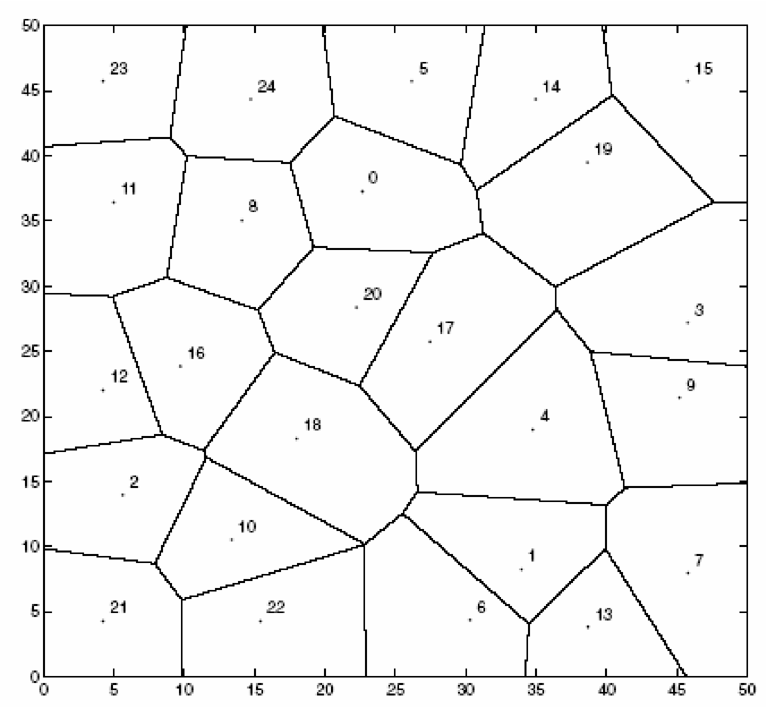
# IDCA-- Mode Determination and Partial Calculation

- If D is close to the expected density, the node selects the clustering mode.
- This partial force is modified by its rank based on its energy level in the neighborhood.
- The energy factor is *r / k* and the partial force calculated by (1) is multiplied by this factor.
- Energy factor = r/k * $f_n^{i,j} = \frac{D_n^i}{\mu^2}\left(cR\left|p_n^i - p_n^j\right|\right)\frac{p_n^j - p_n^i}{\left|p_n^j - p_n^i\right|}$

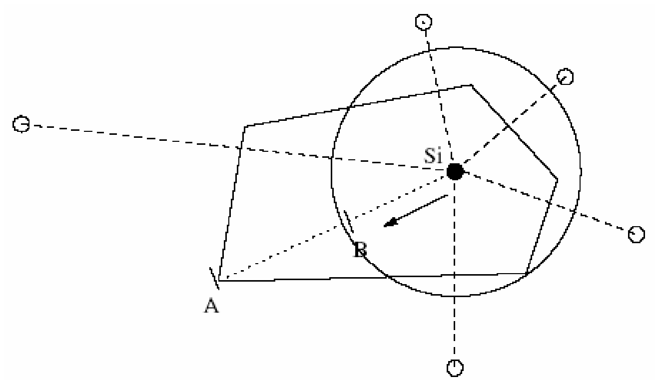


# VD-Based Deployment Algorithm (VDDA)

- Local VDs are used to reduce the search space.
- Moving to the centroid of the Voronoi region can be beneficial in terms of coverage and/or uniformity.

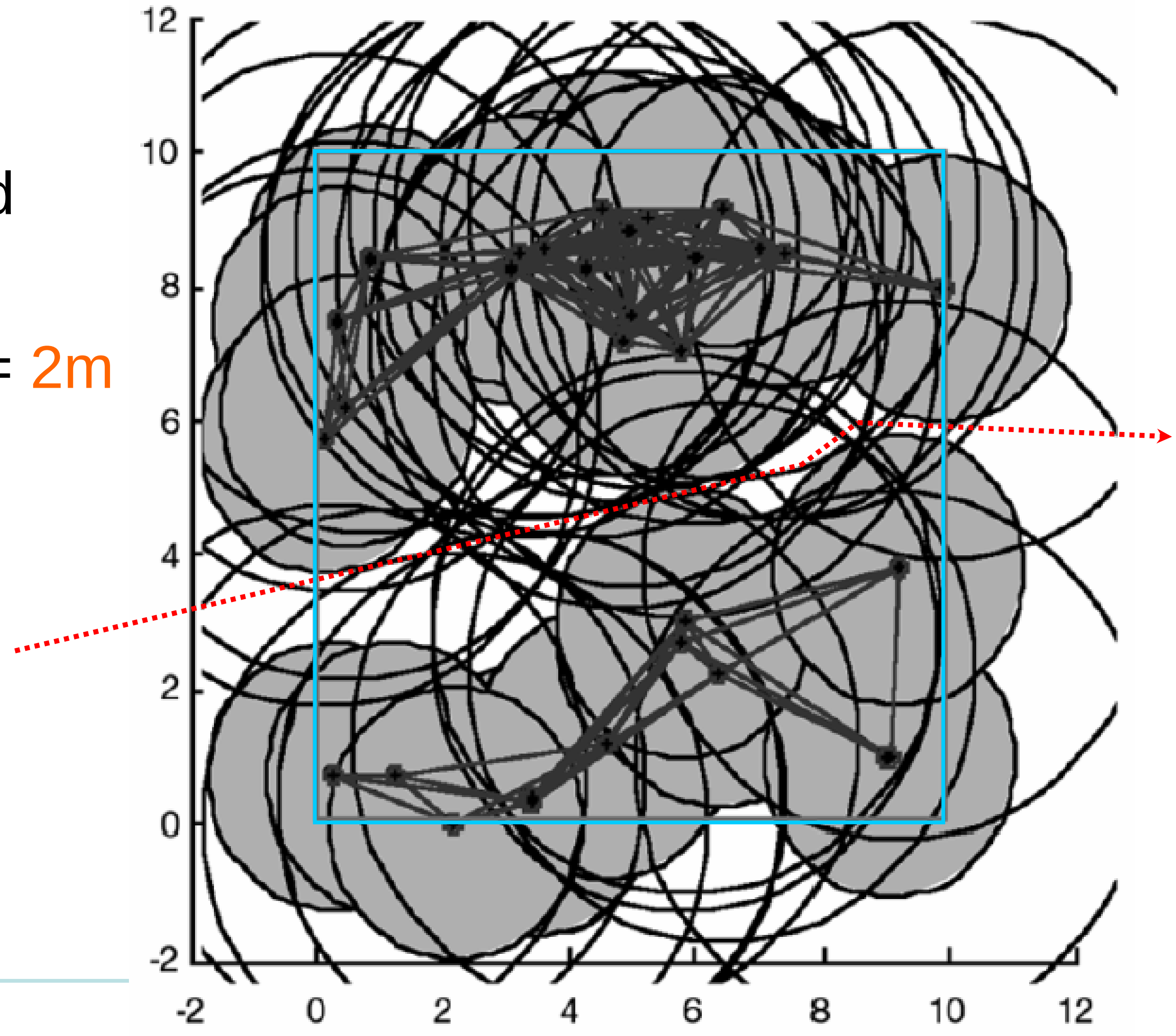


(a) Voronoi diagram



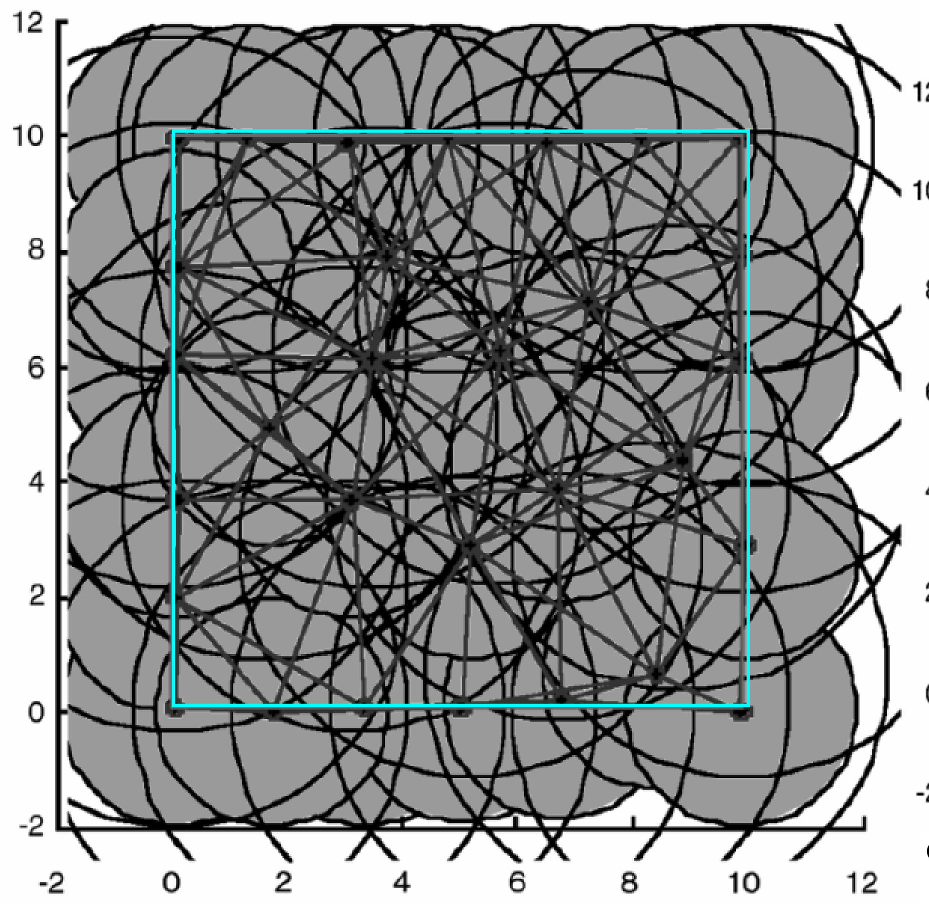
# Initial distribution of sensor nodes

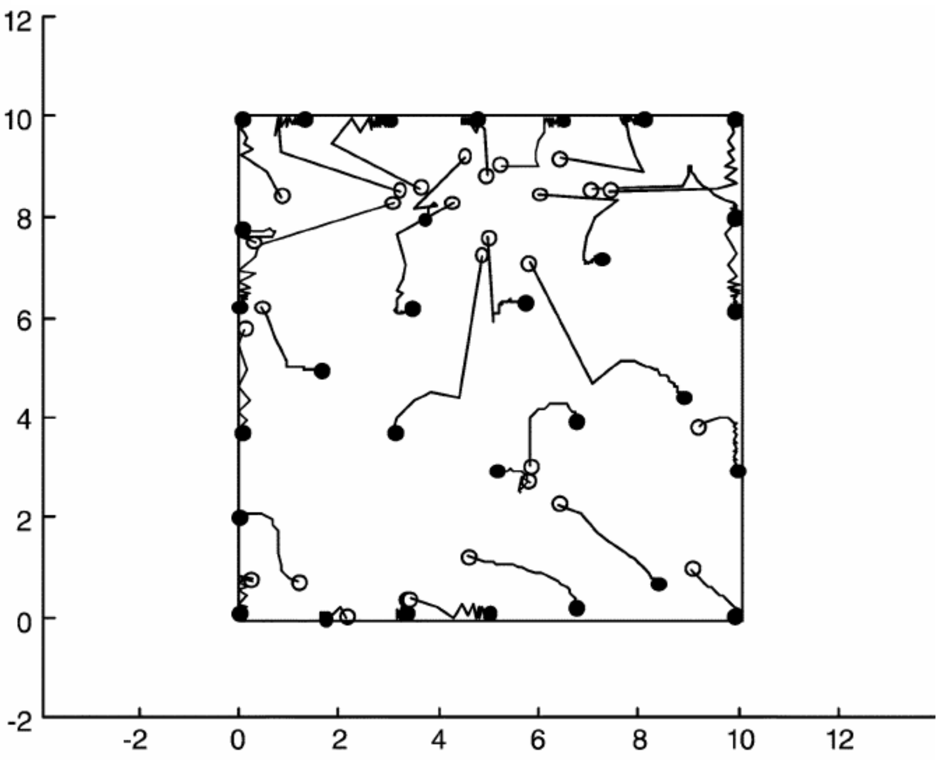
- 30 nodes are randomly placed
- 10m*10m size
- Sensing range = 2m
- Communication range = 4m



# Experimental Results--DSSA

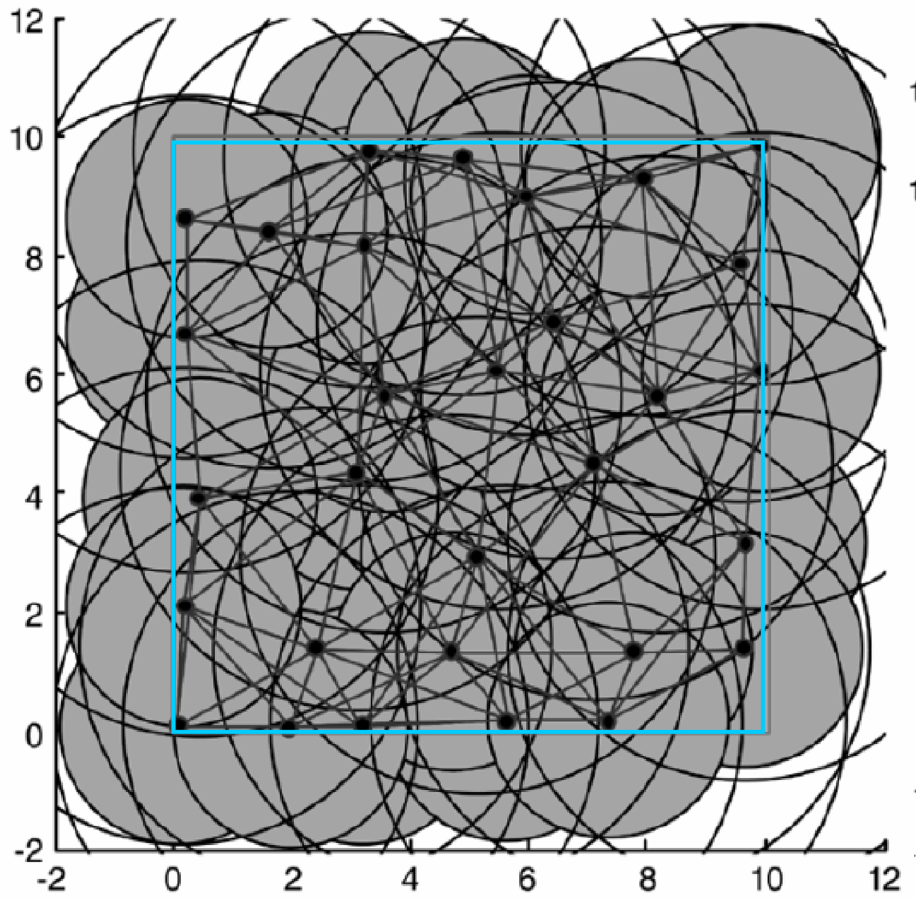
- Each node moved a distance of 3.8485 on average and the standard deviation of distance traveled is 1.6148.

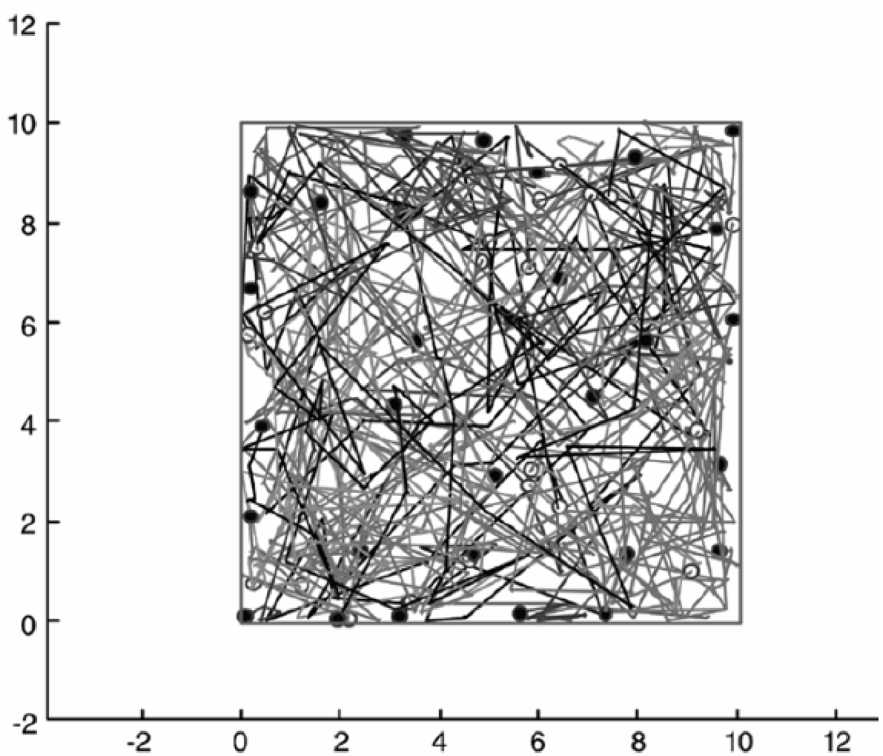


# Experimental Results-- SABA

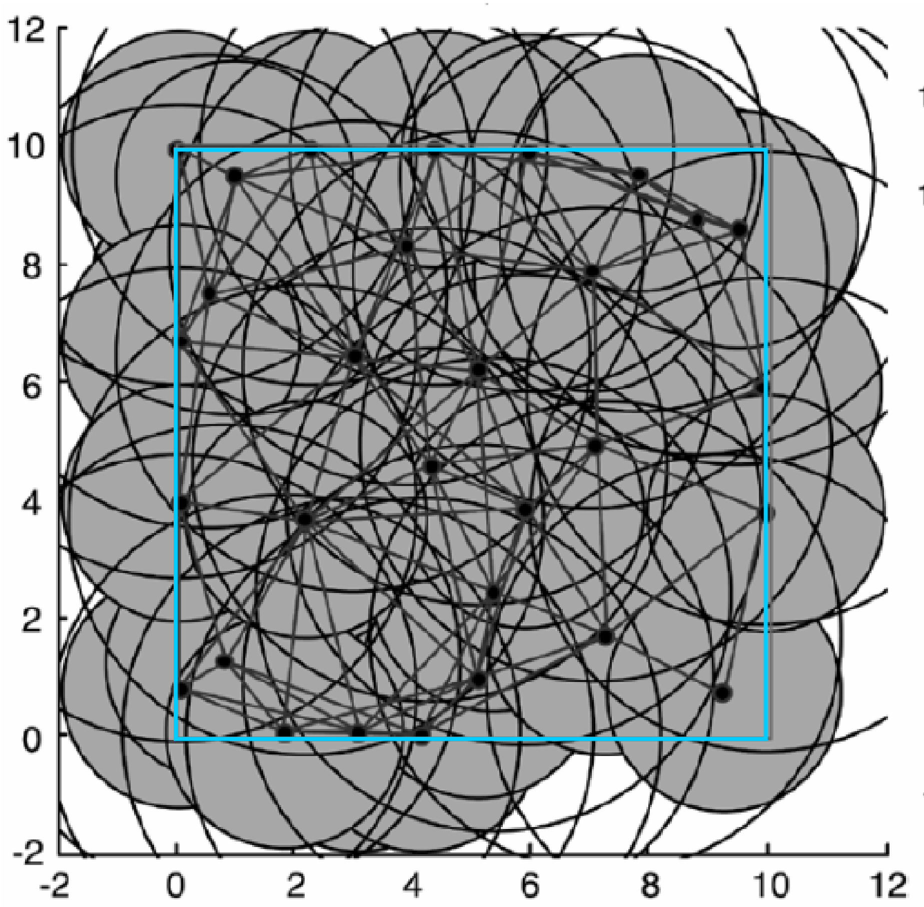
- SABA：simulated annealing-based algorithm
- Each node moved a distance of 46.4697 on average and the standard deviation of distance traveled is 14.5264.

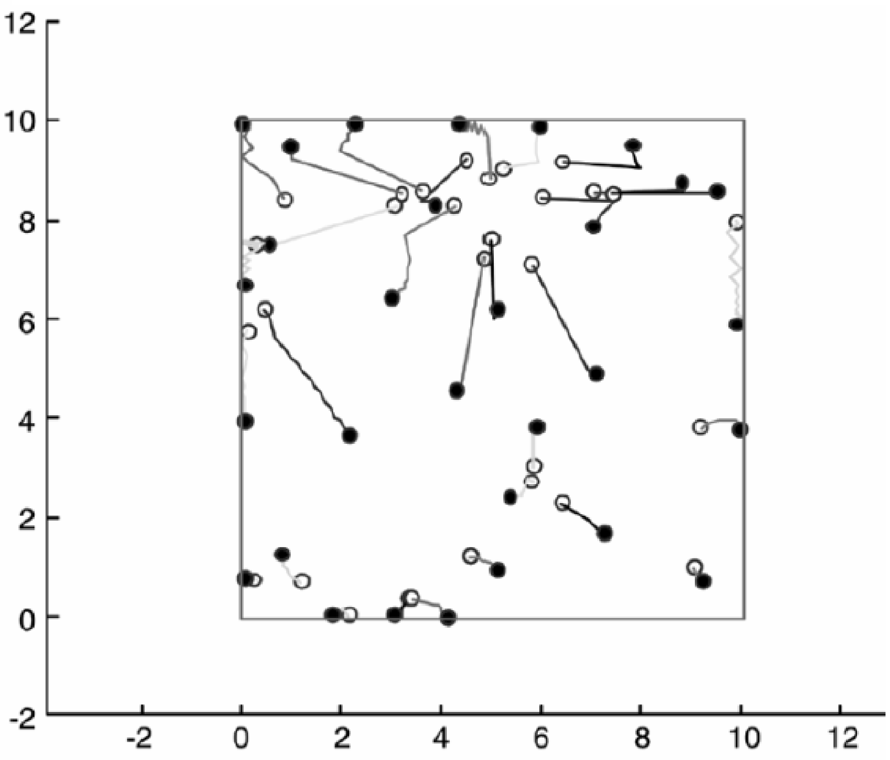


# Experimental Results-- IDCA

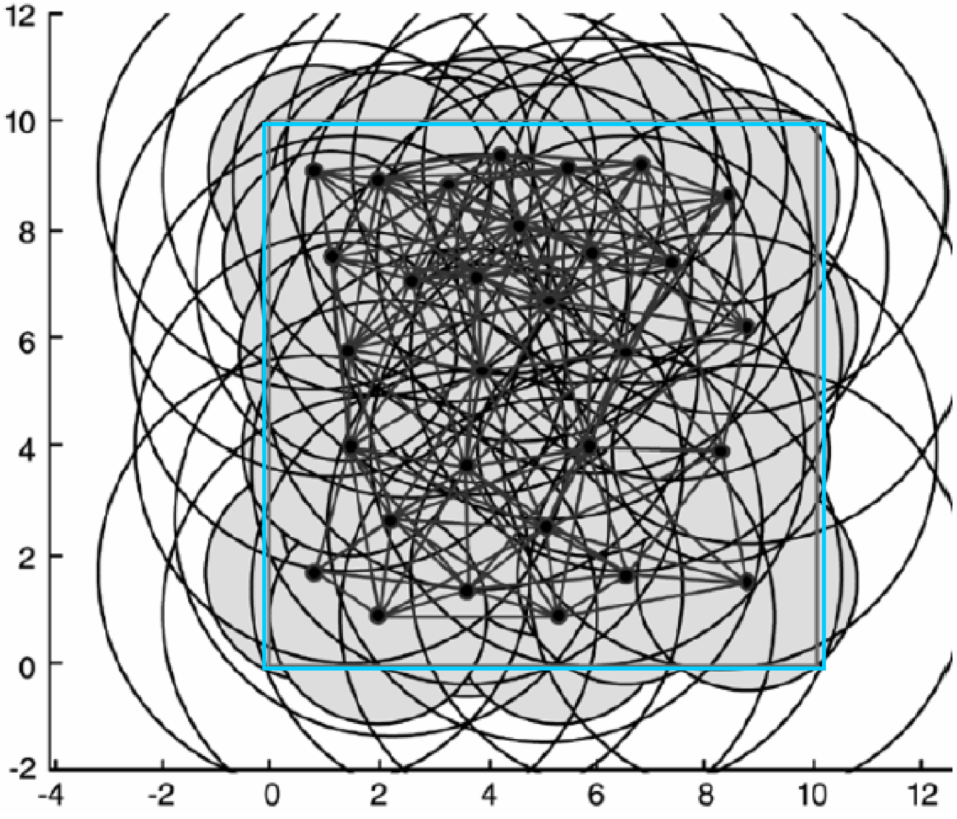
- Each node moved a distance of 1.866 on average and the standard deviation of distance traveled is 0.98409.

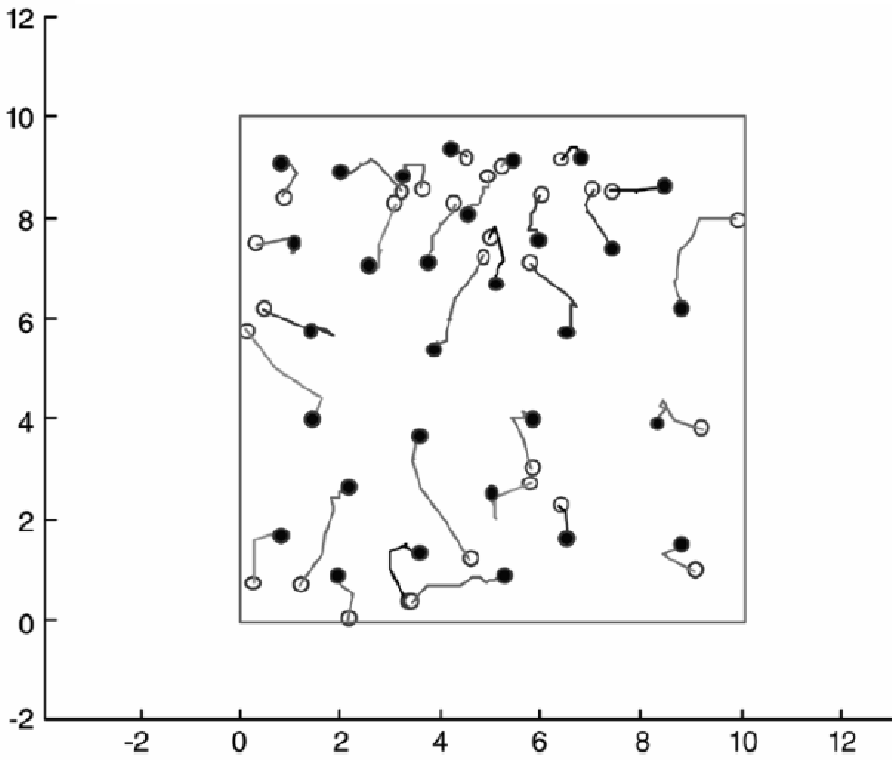


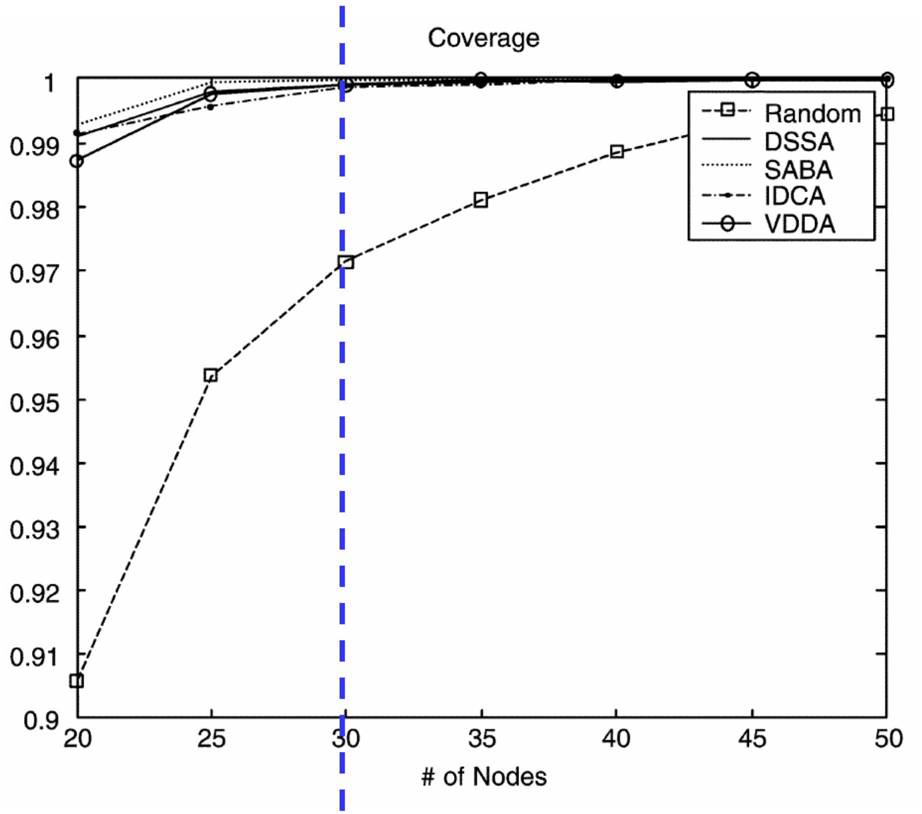
# Experimental Results-- VDDA

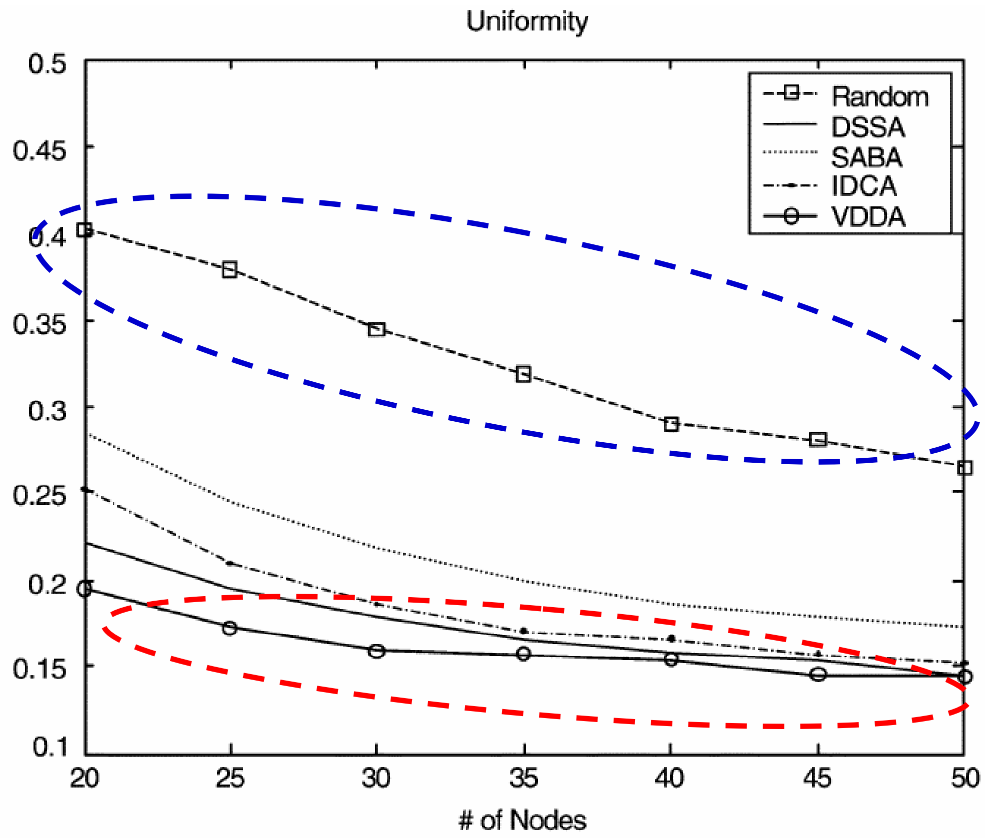
- Each node moved a distance of 1.5498 on average and the standard deviation of distance traveled is 0.67187.



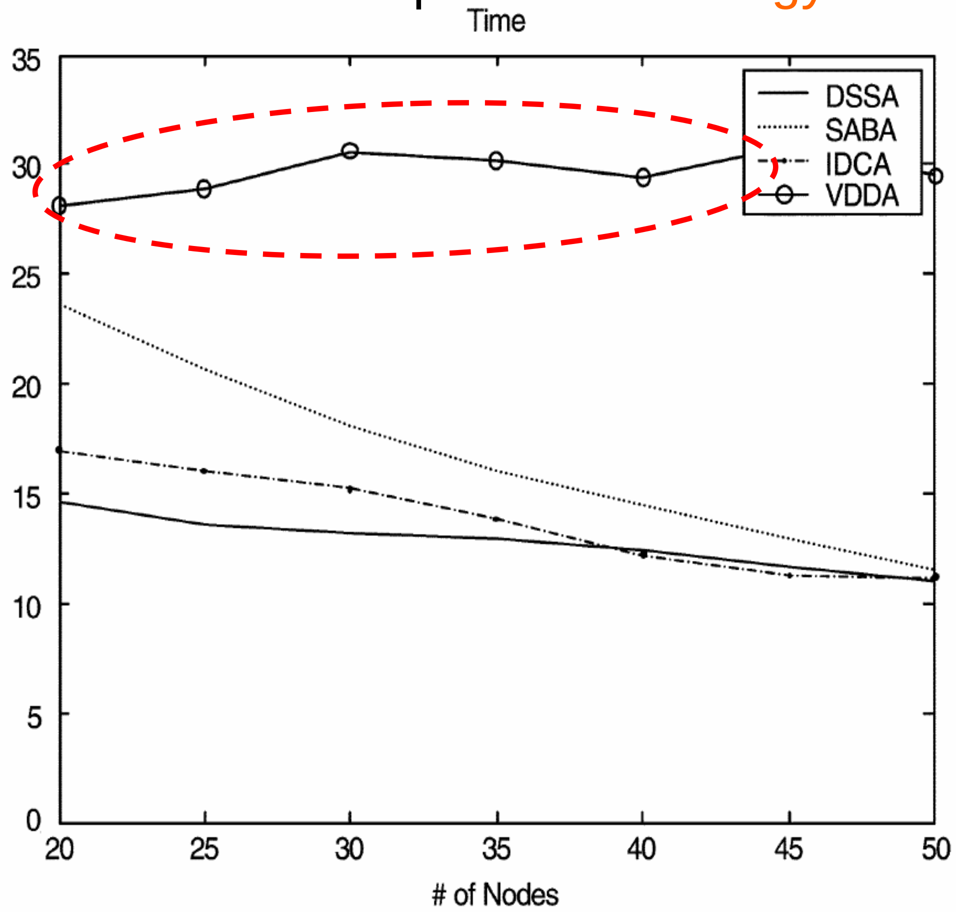
# Experimental Results

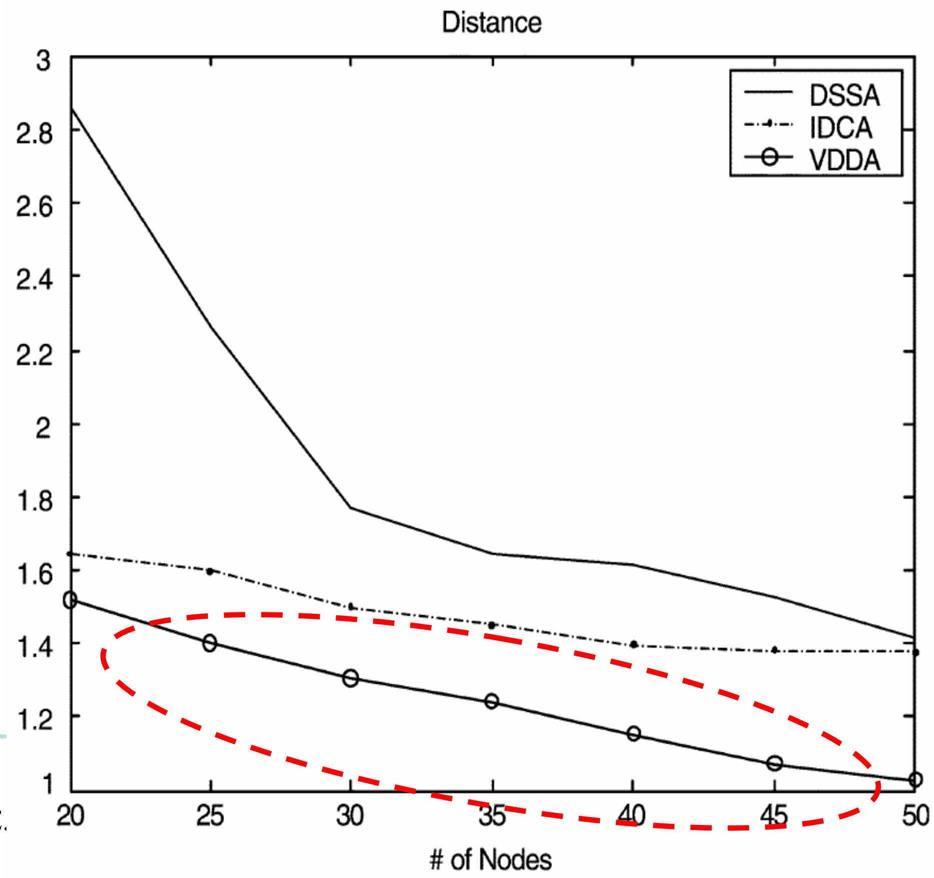


# Experimental Results

- VDDA can obtain more uniformly distributed node topology than DSSA
- VDDA needs a longer time to converge than DSSA.
- VDDA requires less energy for the movement of nodes than DSSA.



# Conclusions

- The deployment problem for mobile WSN is considered in this paper.
- A peer-to-peer and an enhanced intelligent energy-efficient deployment algorithm for cluster-based WSN are proposed.
- A distributed algorithm using VDs based on local computation is also proposed.
- Simulation results show that the proposed algorithms successfully obtain a more uniform distribution from initial distributions in an energy-efficient manner.
- Only one-hop neighbors were included while making the decision. Better solutions in terms of energy efficiency may be found when a wider neighborhood is used.