Distributed Navigation Algorithms for Sensor Networks

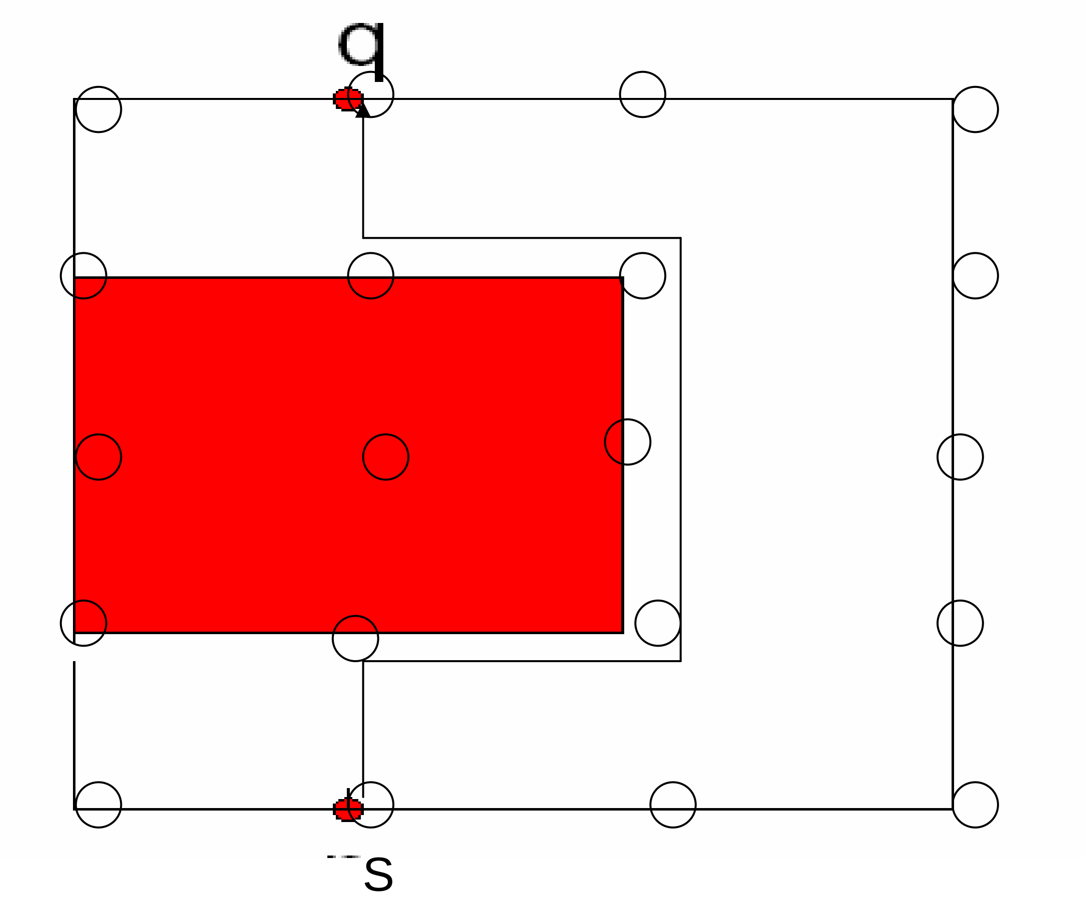
INFOCOM 2006

Speaker: Cheng-Han Wu

Outline

- Introduction
- The main advantage of this paper
- The main idea of this paper
- Simulation
- Conclusion

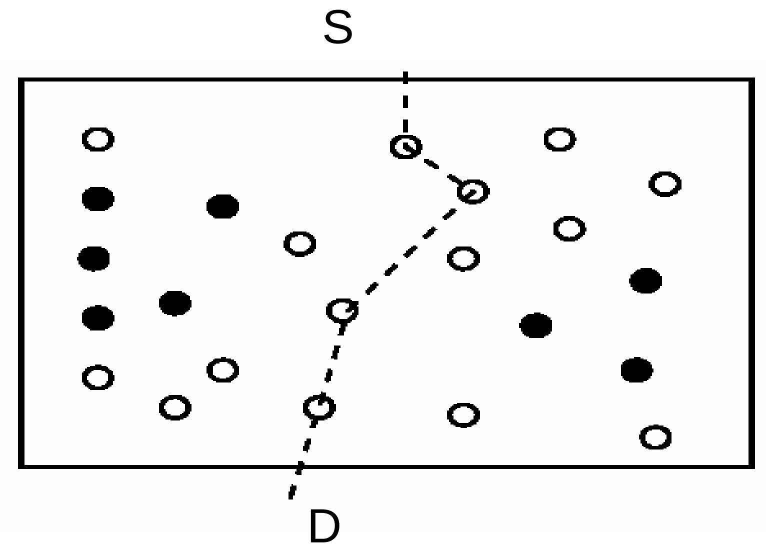
How to navigate ?

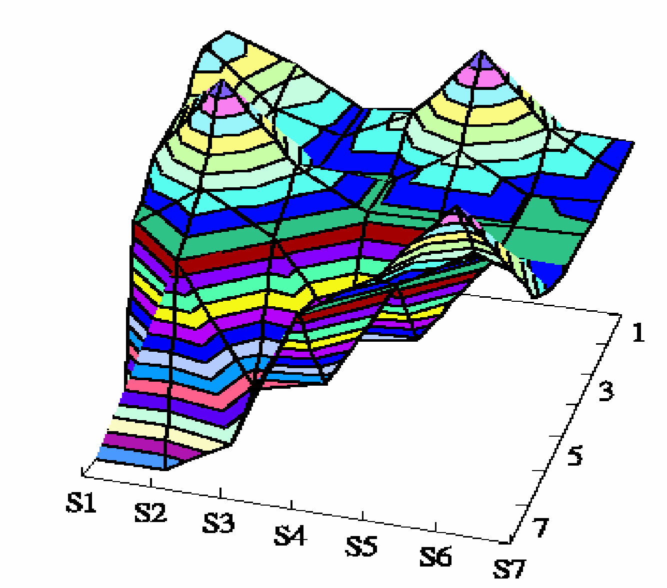


q: destination
s: start point

The Past Navigation Protocol

- Each sensor is assigned an altitude.
- We choose the path that has the lowest sum of altitudes as the guiding path.

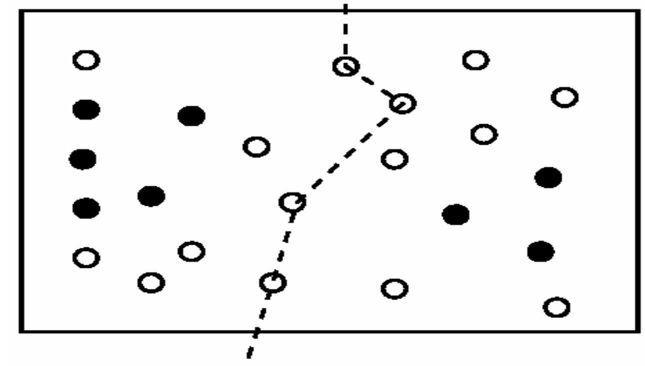




The Disadvantage of the past Method

- This scheme does not scale well due to a very high communication cost.

- In a network of n nodes, the number of total packet transmissions required for the past method to find the safe path is O(n).



The Advantage of this Paper

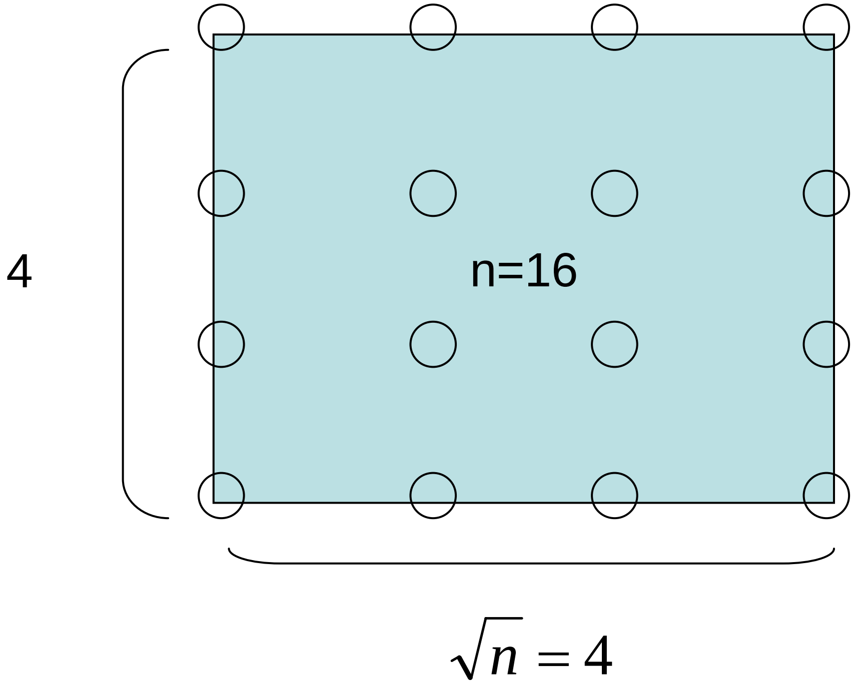
- The communication cost of discovering the shortest path is $O(n^{1/2+e})$,for any e such that 0<e<1/2.

Assumptions

- Each sensor knows its geographic location.
- The operational environment is assumed to have no large holes in the coverage by sensors.

Related Works

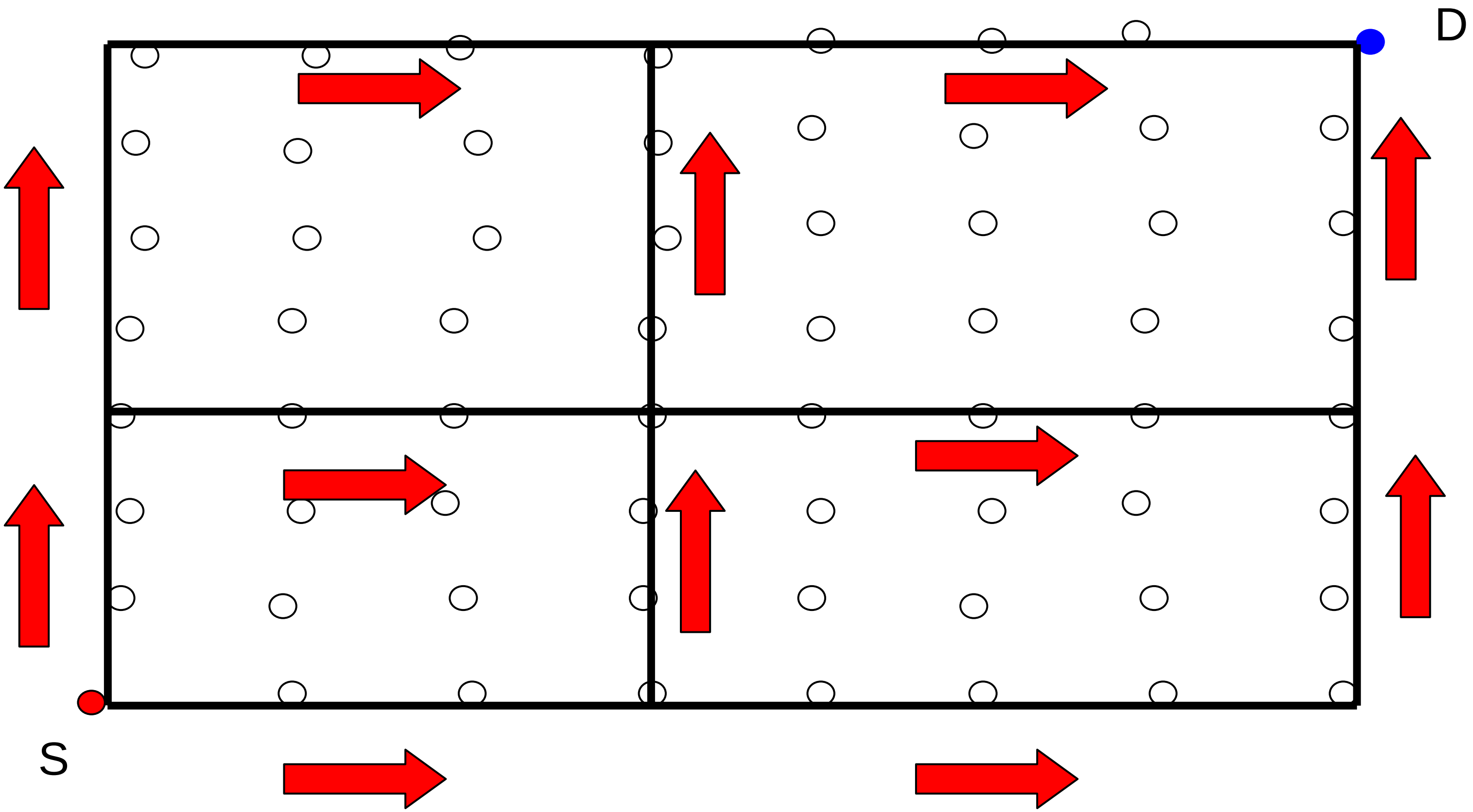
- We assume that n sensor nodes are placed uniformly in a square area.
- We choose units of length such that the size of area is $\sqrt{n}*\sqrt{n}$,i.e. on the average every unit area contains one single sensor.



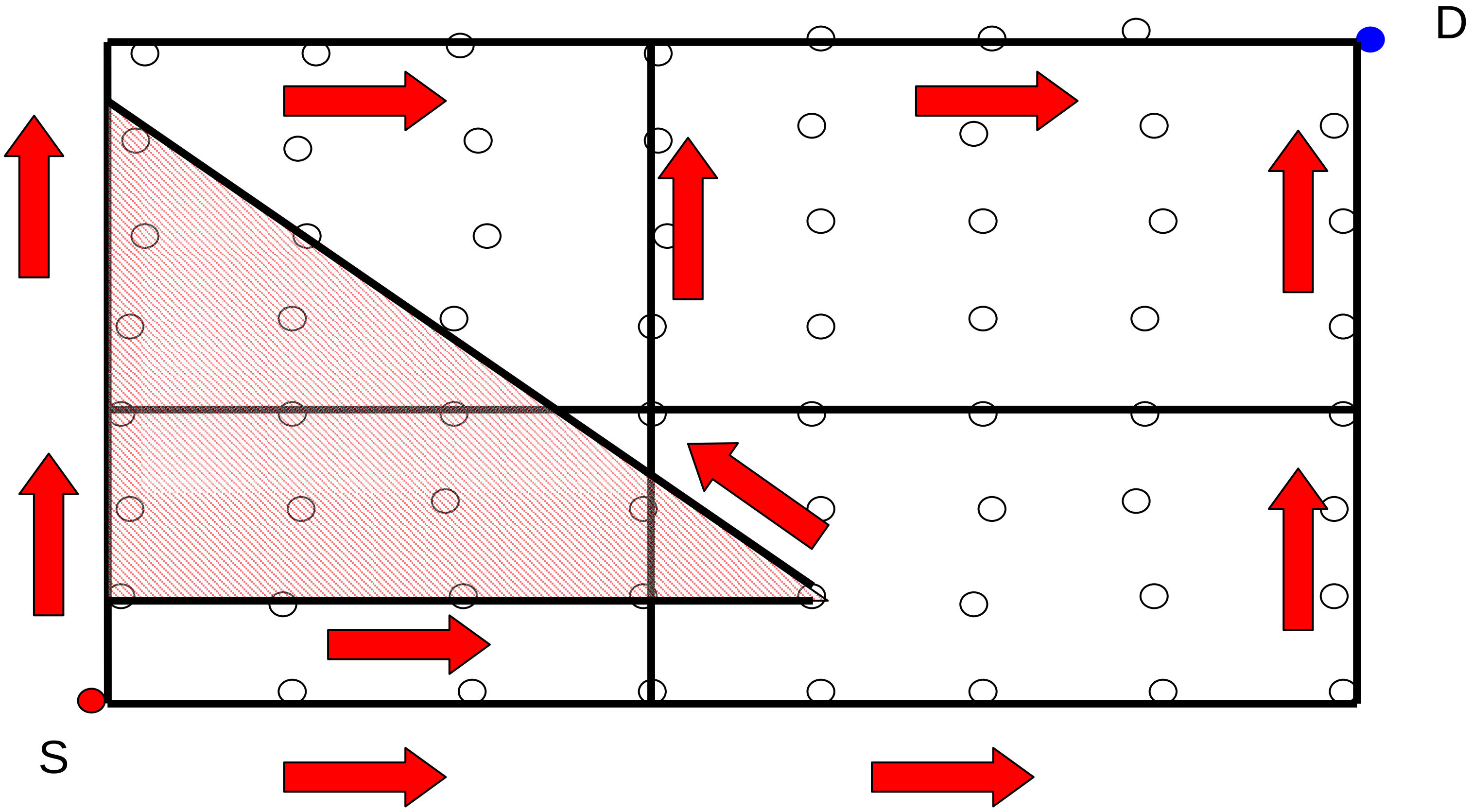
The Idea of this Paper(1/2)

Navigation using uniform Skeleton Graph

- Step1:Establishing the Skeleton Graph
- Step2:Using shortest path algorithm to find the safe path



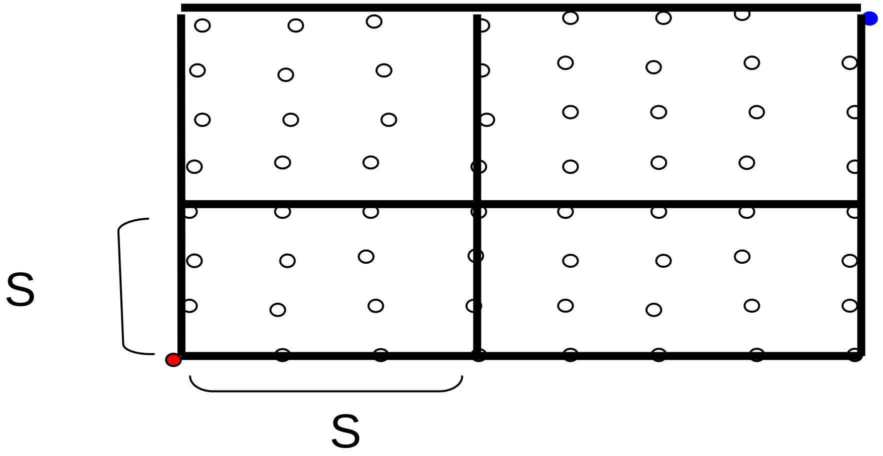
The Idea of this Paper(2/2)



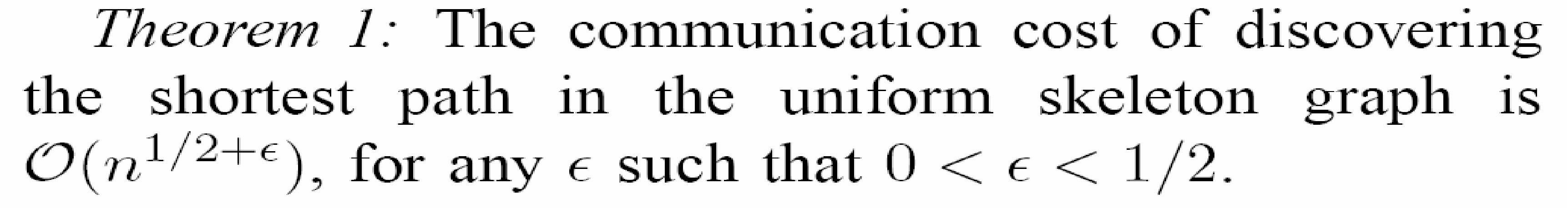
How to construct the Skeleton Graph

- All nodes know that the side length of the grid is S.
- Because each sensor knows its location,

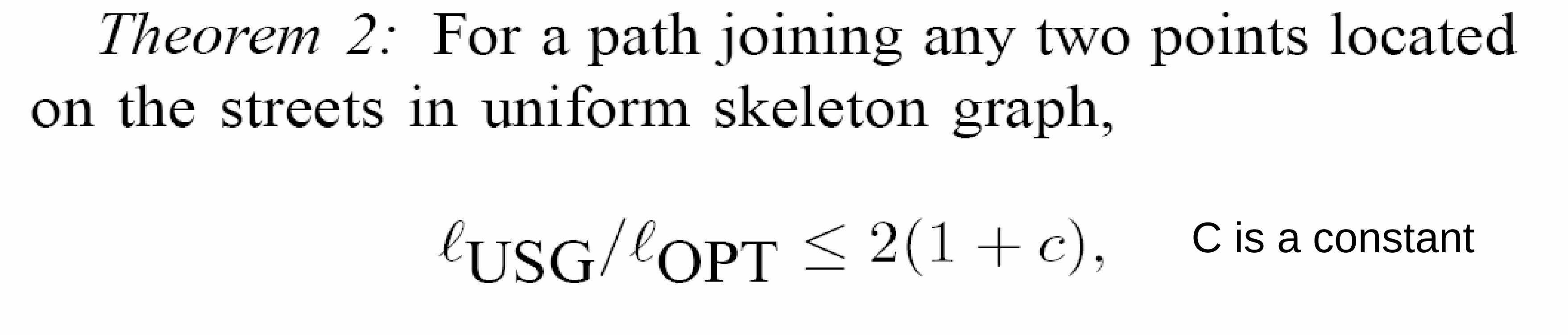
  it can independently decide if they are in the skeleton graph.



The properties of Skeleton Graph



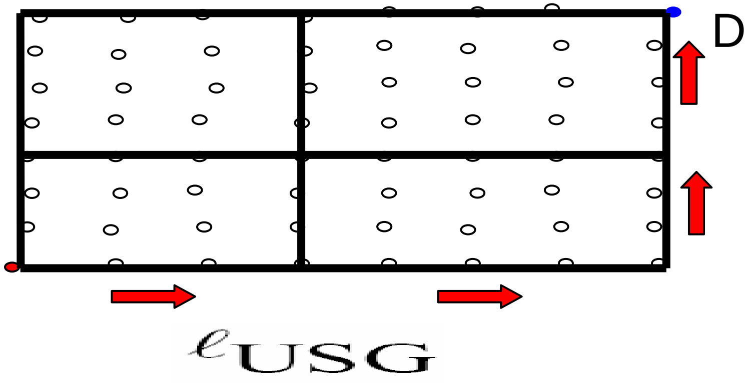
Theorem 1: The communication cost of discovering the shortest path in the uniform skeleton graph is $\mathcal{O}(n^{1/2+\epsilon})$, for any ϵ such that $0 < \epsilon < 1/2$.

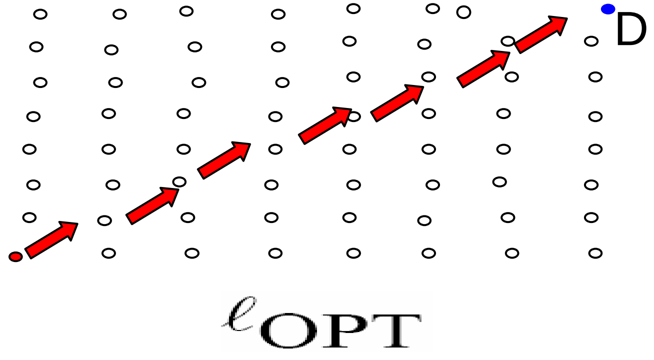


Theorem 2: For a path joining any two points located on the streets in uniform skeleton graph,

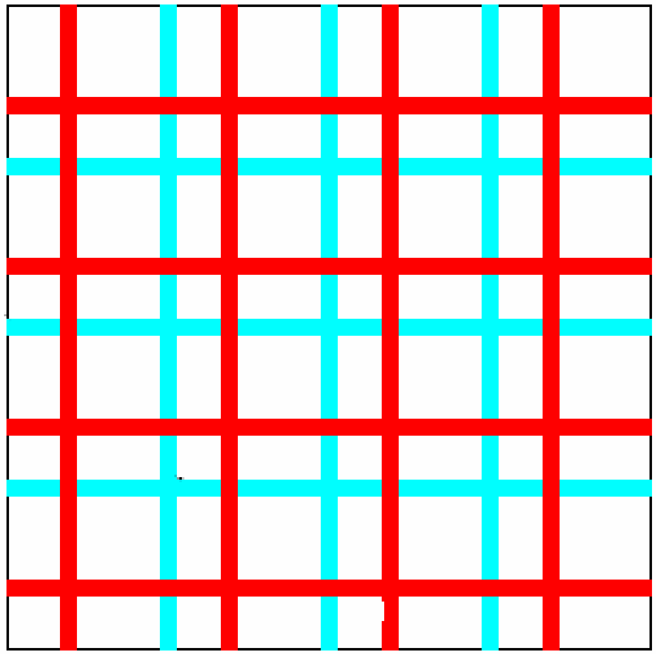
$$\ell_{\mathrm{USG}}/\ell_{\mathrm{OPT}} \leq 2(1+c),$$

C is a constant



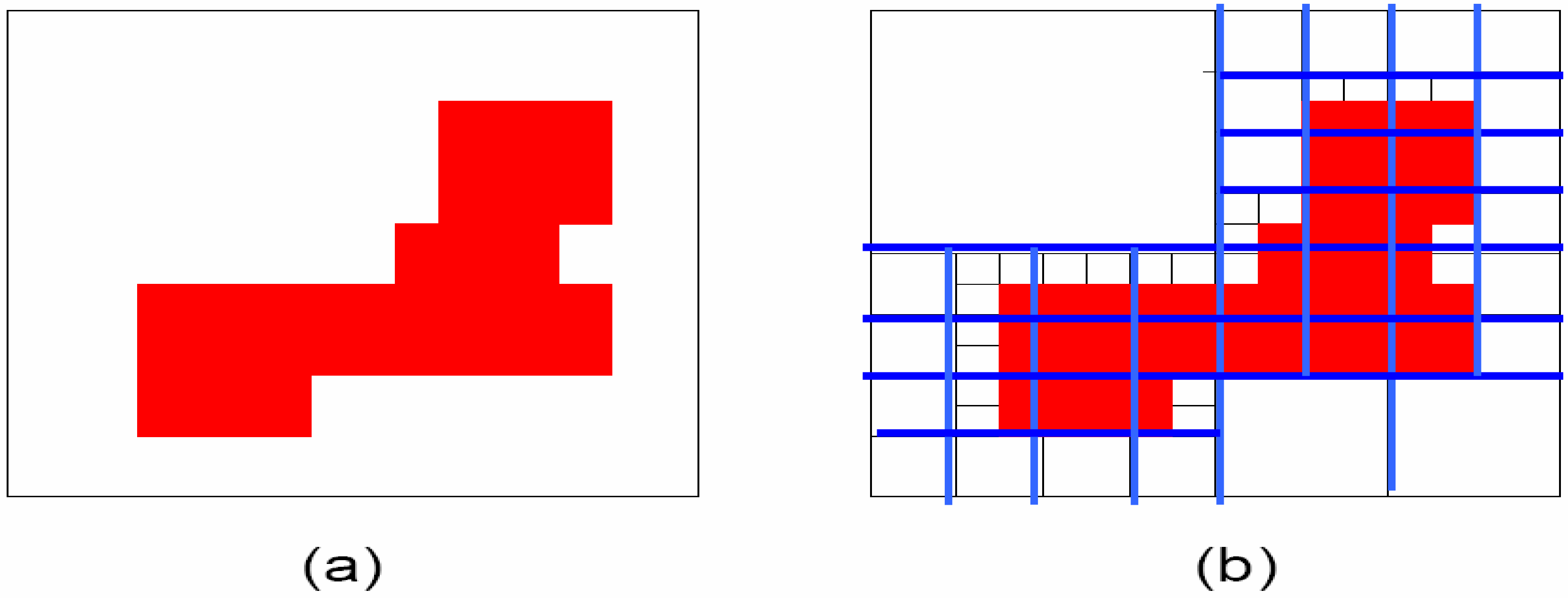


Load Balancing by shifting

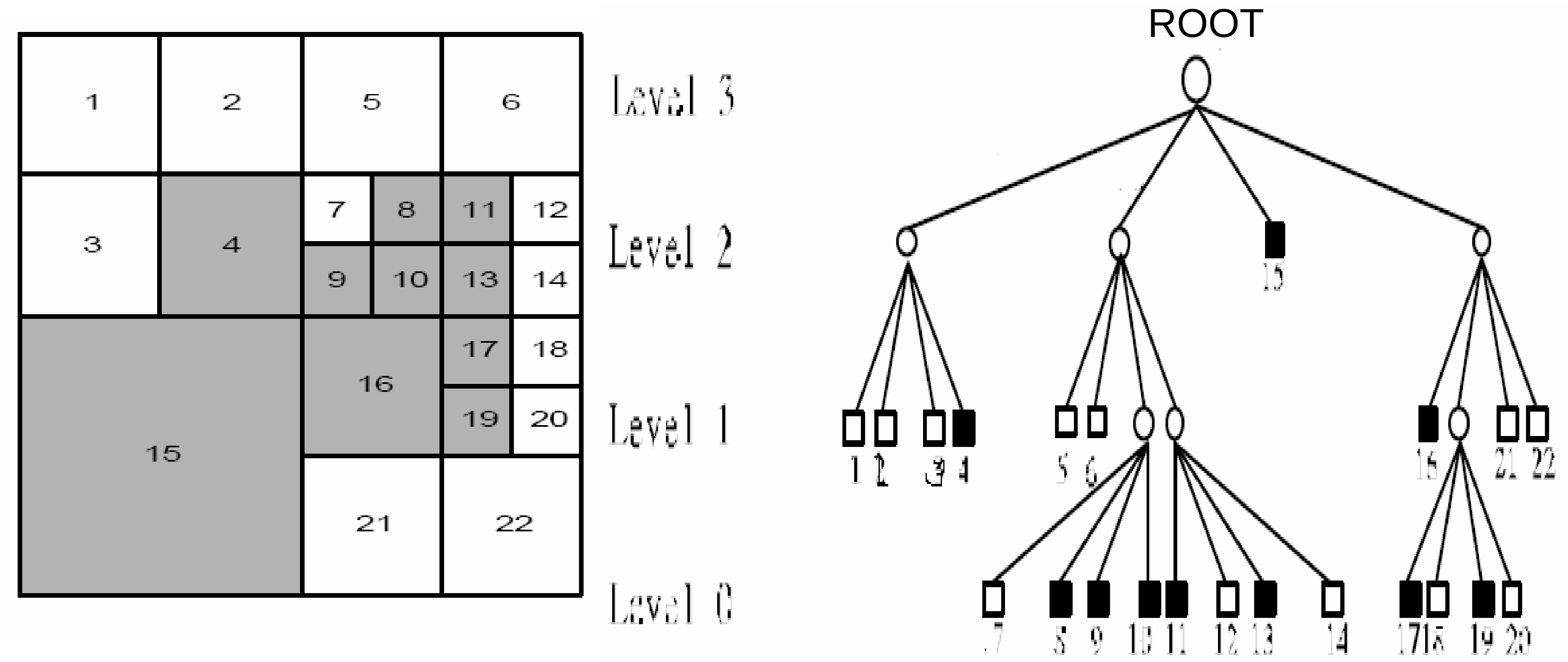


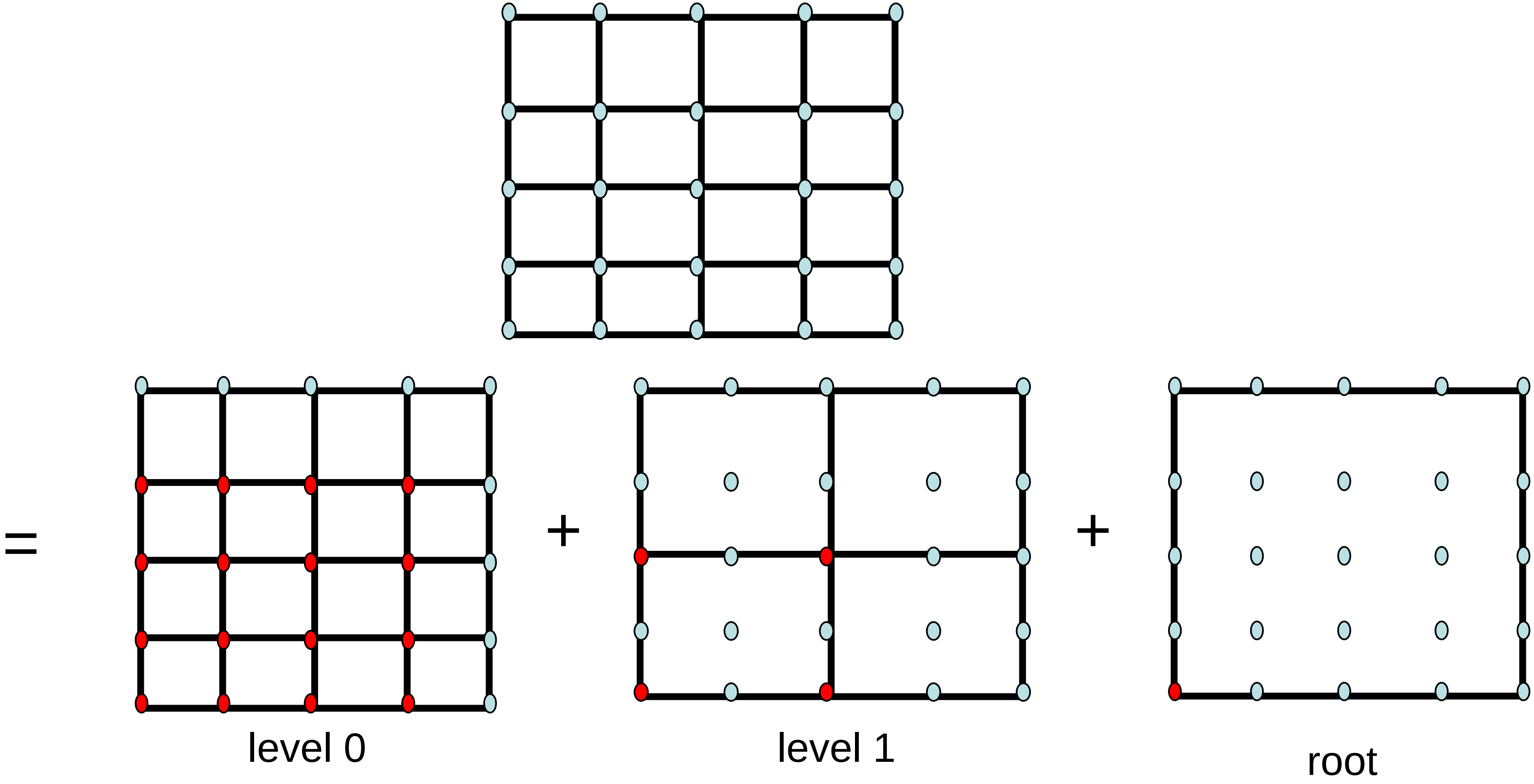
Navigation Using Adaptive Skeleton Graph

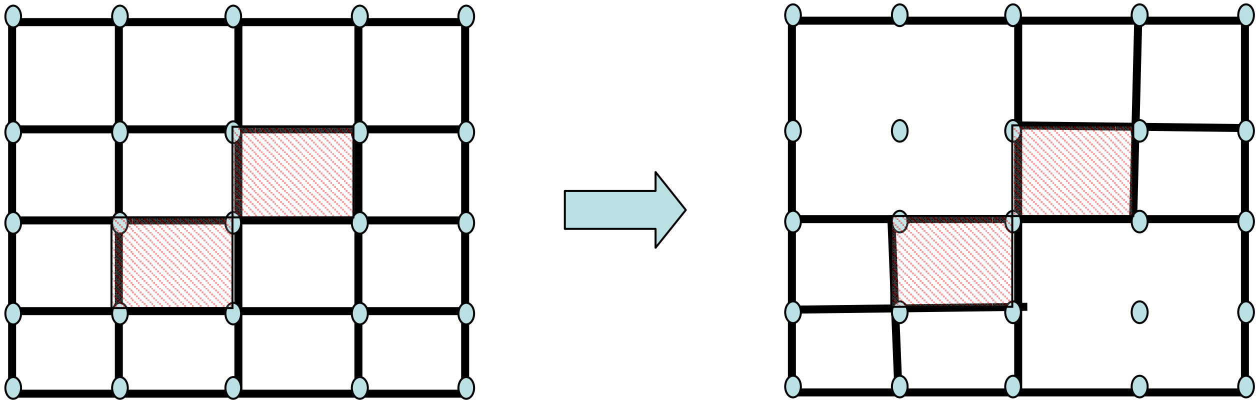
- We assume that danger zone boundary is axis aligned.
- The process of generating adaptive skeleton graph is very similar to quadtree mesh generation.



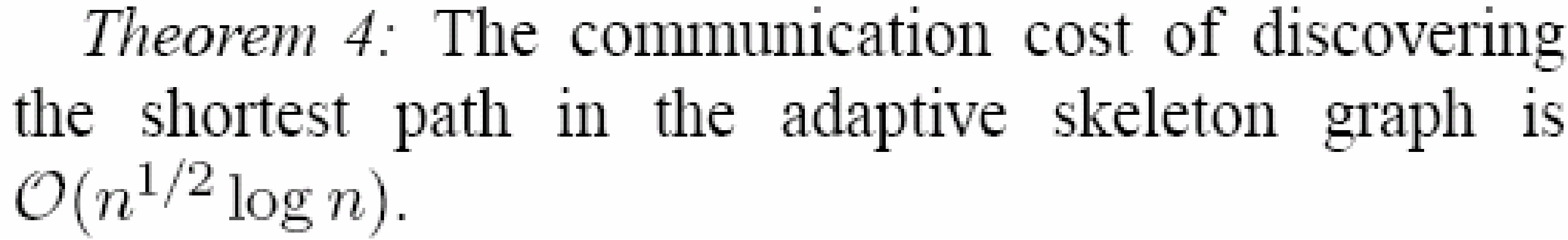
Quadtree


1
2
5
6
3
4
7
8
11
12
9
10
13
14
15
16
17
18
19
20
21
22
Level 3
Level 2
Level 1
Level 0
ROOT
15
1 2 3 4
5 6
16
21 22
7
8 9
10 11
12 13
14
17 18
19 20

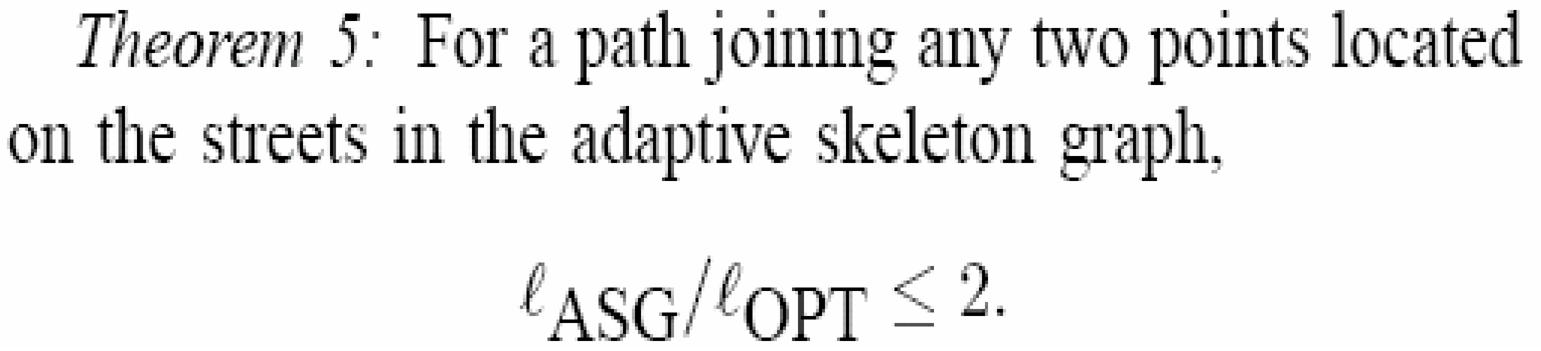

=
+
+
level 0
level 1
root



The Properties of Adaptive Skeleton Graph



Theorem 4: The communication cost of discovering the shortest path in the adaptive skeleton graph is $\mathcal{O}(n^{1/2}\log n)$.

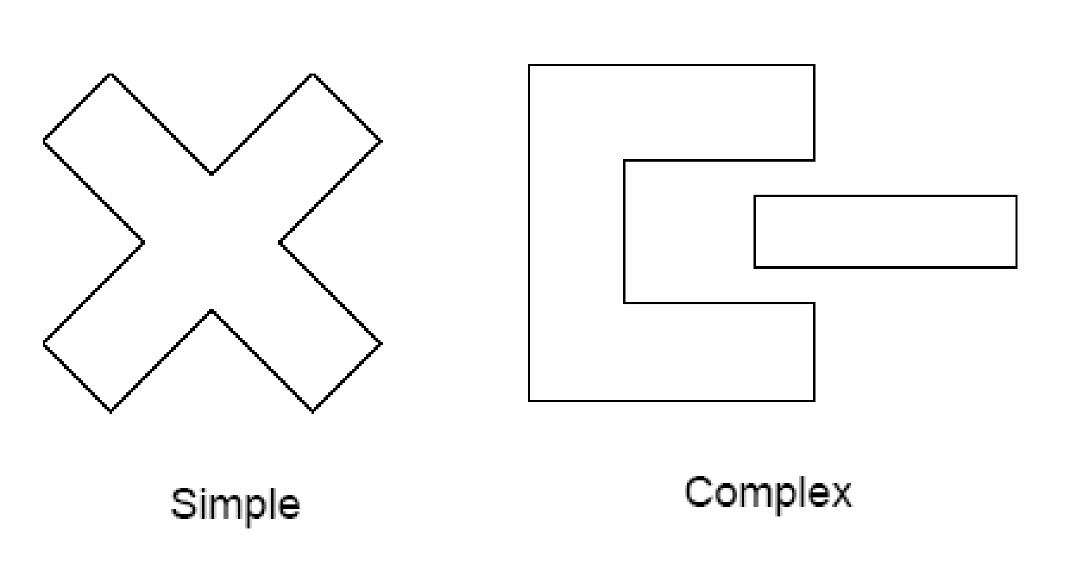


Theorem 5: For a path joining any two points located on the streets in the adaptive skeleton graph,

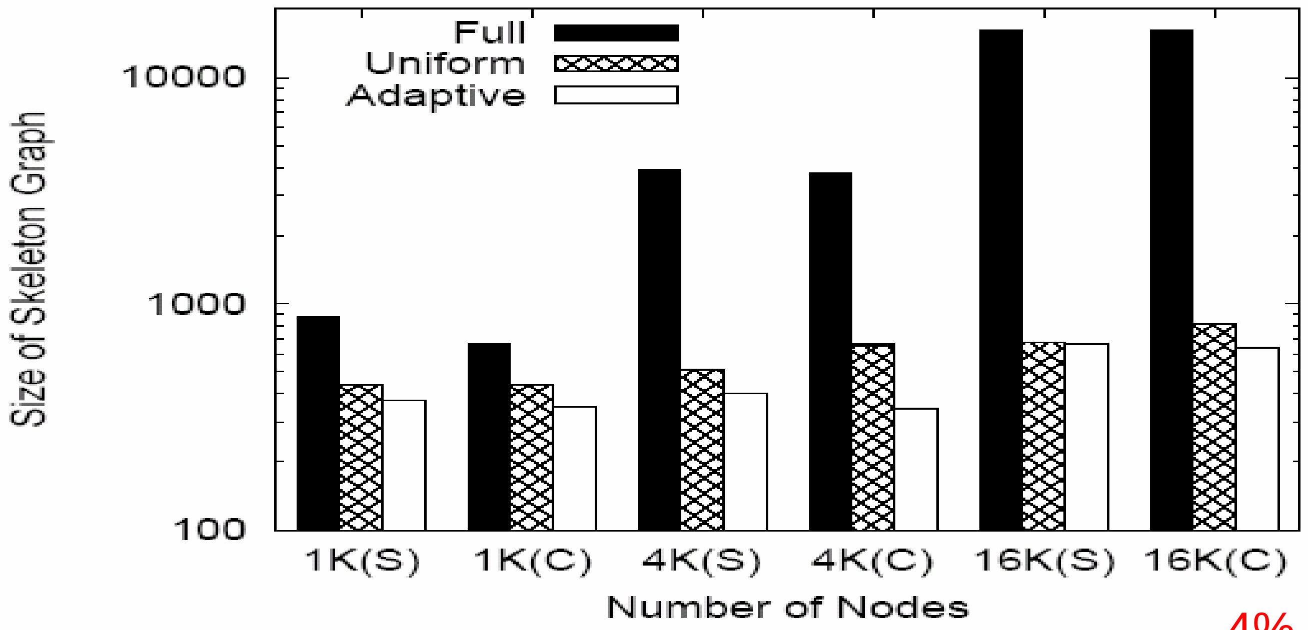
$$\ell_{\mathrm{ASG}}/\ell_{\mathrm{OPT}} \leq 2.$$

Simulation

- Placing n sensor nodes in a $\sqrt{n} * \sqrt{n}$ area.
- Simple and complex danger zone shapes used to test shortest path algorithm.



Simulation



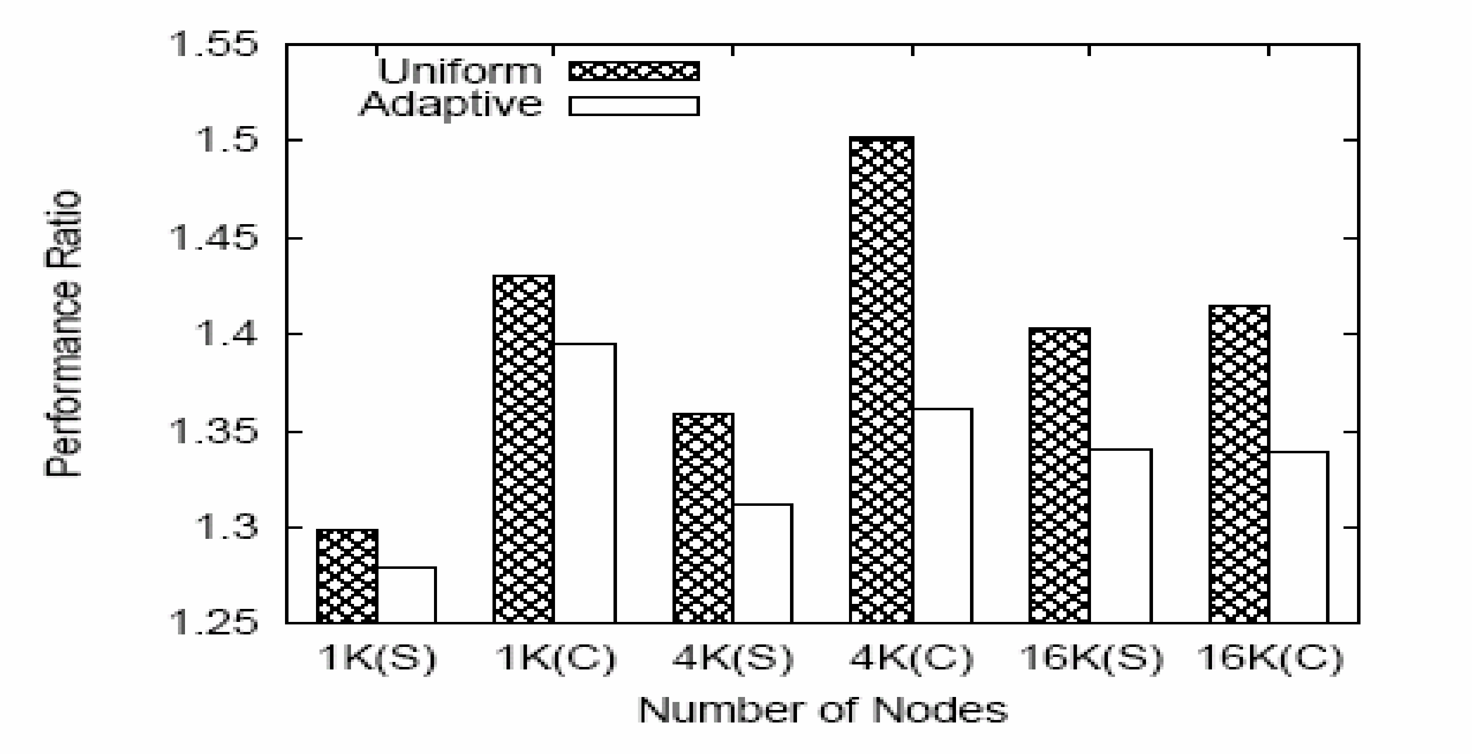
4%

1K(S) means 1024 nodes with simple danger zone.
1K(C) means 1024 nodes with complex danger zone.

The path length performance ratio= $\ell_{\mathrm{SG}}/\ell_{\mathrm{OPT}}$

ℓ_{SG} :the lengths of the approximate skeleton graph path

ℓ_{OPT} :the lengths of the optimal path



Conclusions

- The problem of finding shortest path on a sensor network can be sloved approximately with low communication cost using skeleton graphs.

- The uniform skeleton graph is superior to the adaptive graph in terms of its simplicity and load distribution.