Border Landmark Selection and Applications in Self-Configurable Wireless Networks

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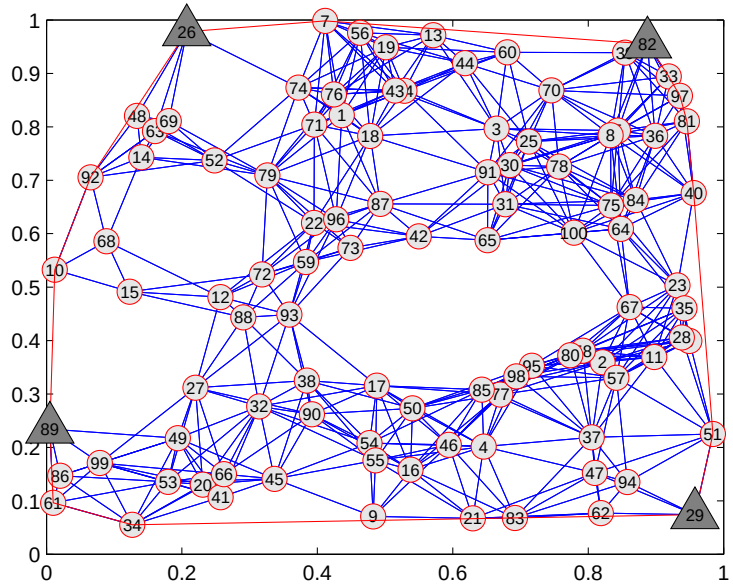
Problem Formation

Definition

The border landmarks are a set of K nodes in the network, which form a polygon with the maximum area.



Lemma

Given a set of N points in a planar space, the polygon formed by K out of these N points must overlay with the convex hull of the point set, if the polygon has the maximum area among all polygons formed by any K out of N points and the maximum is unique.

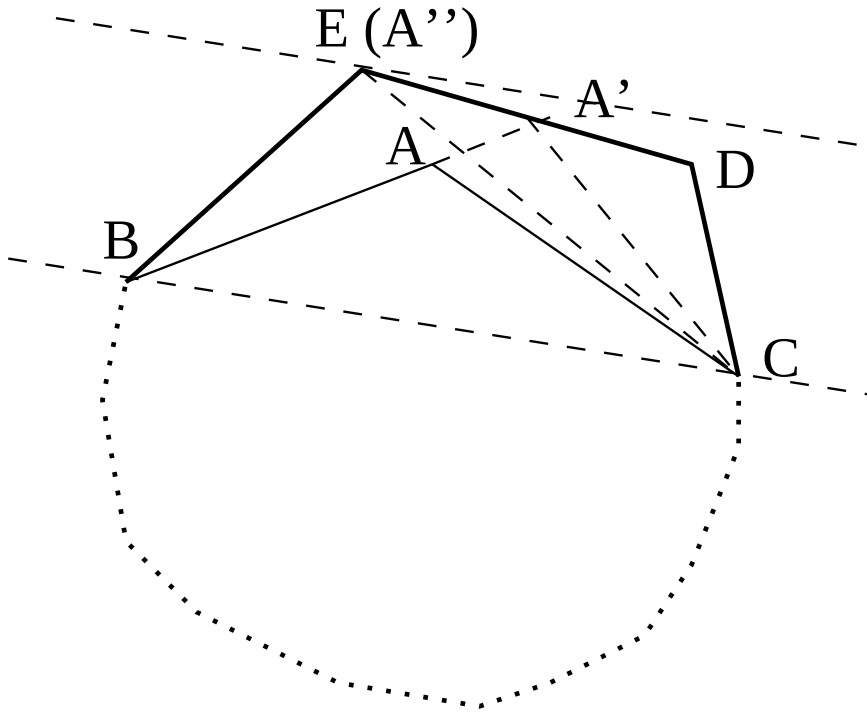
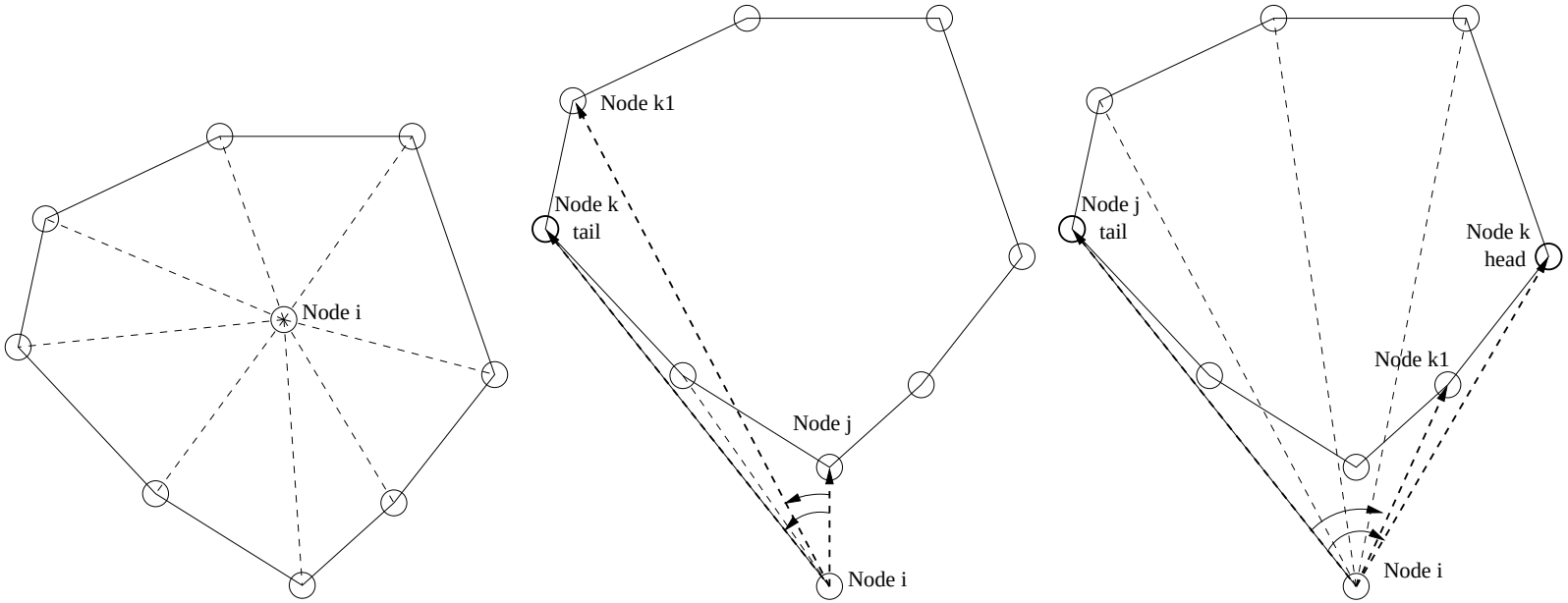


Figure: Illustration of Lemma.

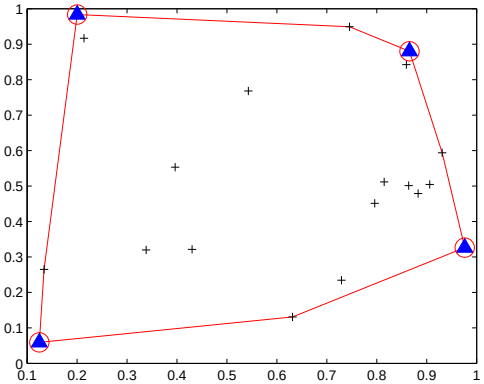
Convex Hull-based (CHB) Algorithm



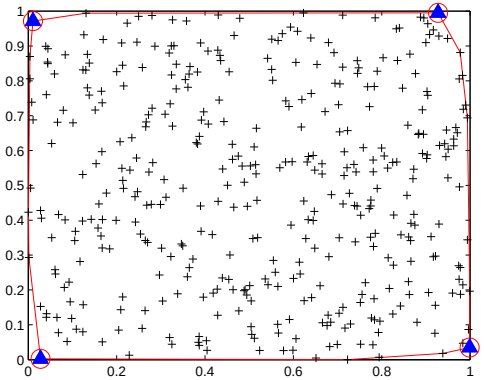
(a) Note *i* inside current polygon. (b) Tail extremal node. (c) Head extremal node.

Figure: Illustration of Algorithm CHB.

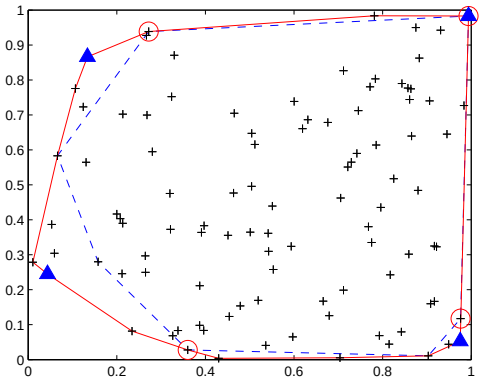
Examples of CHB



(a) No distance estimation errors. $N = 20$.



(b) No distance estimation errors. $N = 400$.

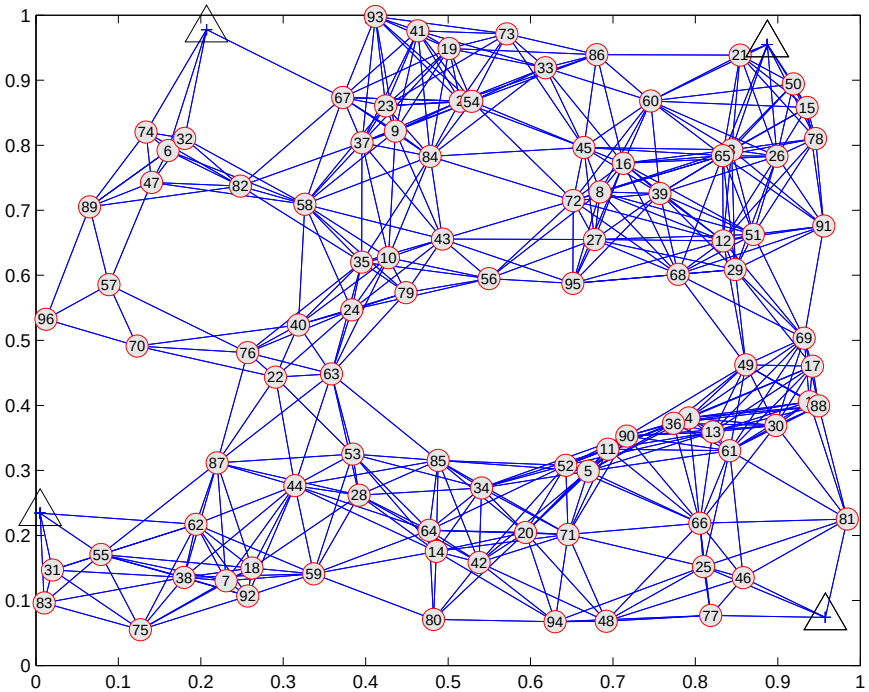


(c) With distance estimation errors. $N = 100$.

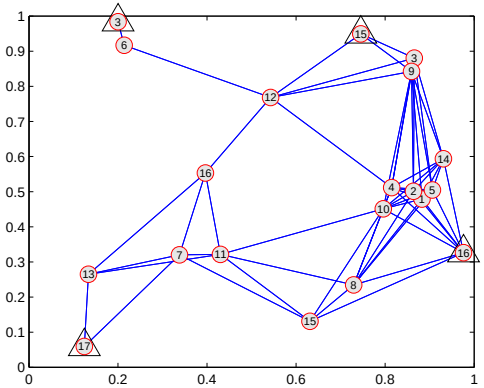
Figure: Results of the convex hull-based algorithm.

Center Node Elimination (CNE) Algorithm

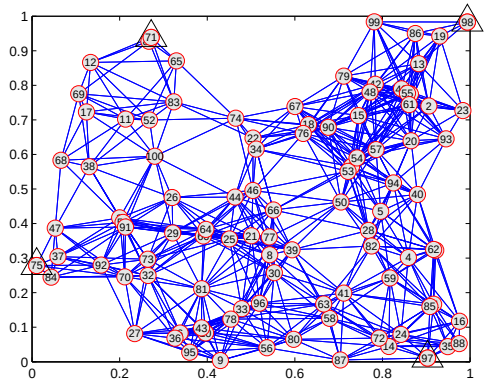
$\Psi = \emptyset$.
for $i = 1 : N$ **do**
  if node i has required stability and computing power **then**
    $\Psi = \Psi + i$.
  end if
end for
for $m = 1 : N - K$ **do**
  for all $i \in \Psi$ **do**
    $C_i = \sum_{j=1, j \neq i}^{N} \frac{1}{S_{i,j}^2}$.
  end for
  Search for node i, with $C_i \leq C_j$ ($j \in \Psi$ and $j \neq i$).
  $\Psi = \Psi - i$.
  $S_{i,j} = \infty$, for $1 \leq j \leq N$.
end for



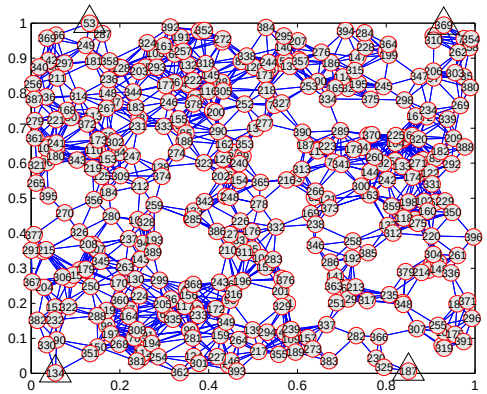
Examples of CNE



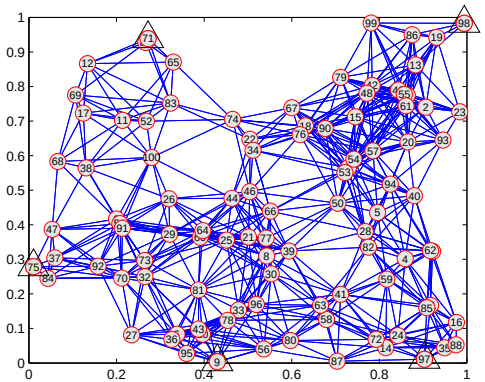
(a) N=20, K=4.



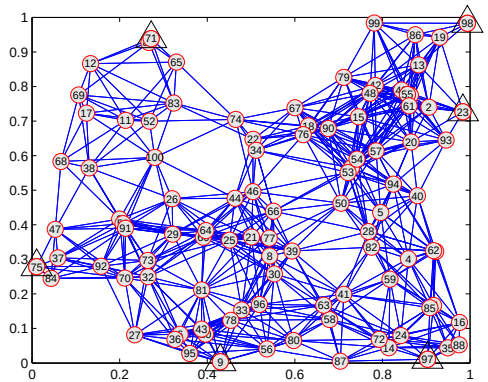
(b) N=100, K=4.



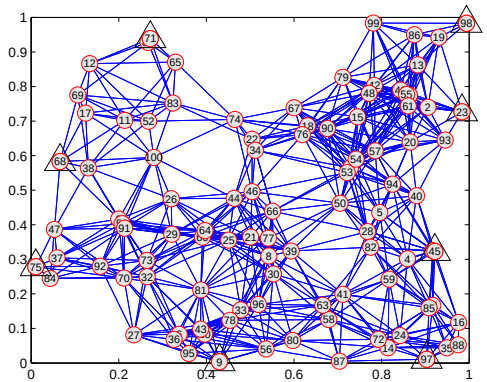
(c) N=400, K=4.



(d) N=100, K=5.



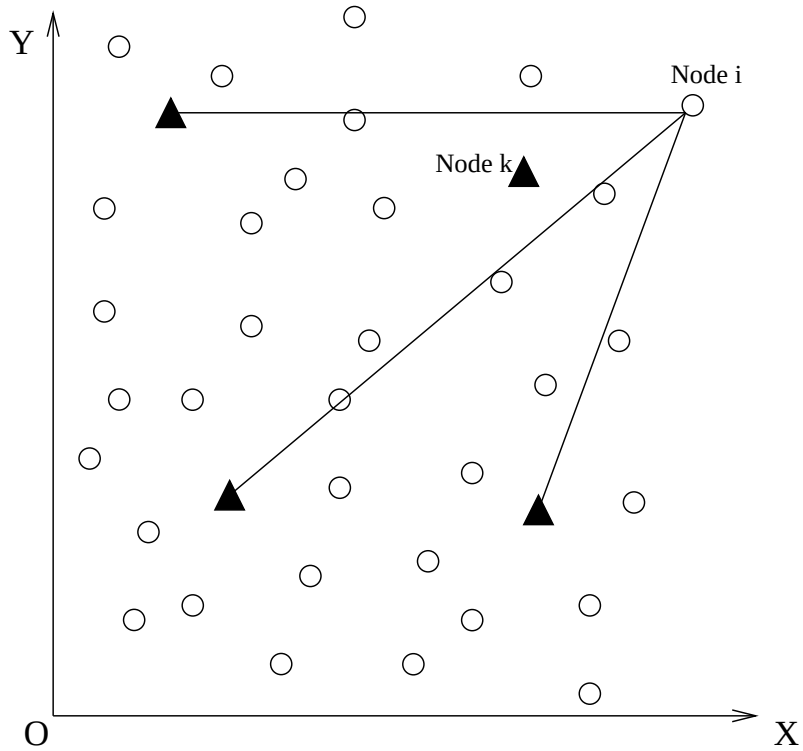
(e) N=100, K=6.



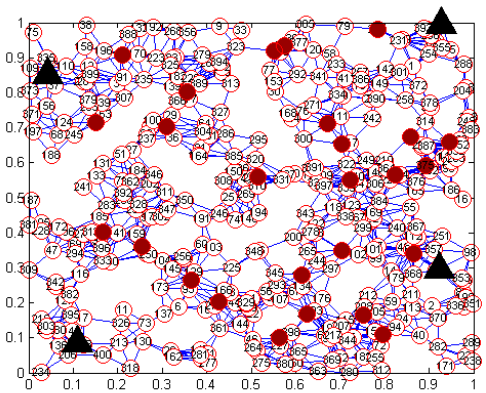
(f) N=100, K=8.

Hierarchy-Structured (HS) Algorithm

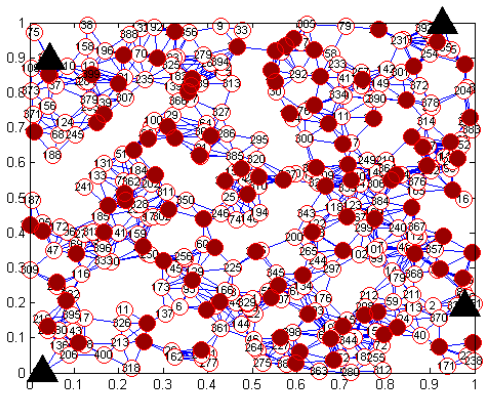
- Basic Ideas
- HS Algorithm



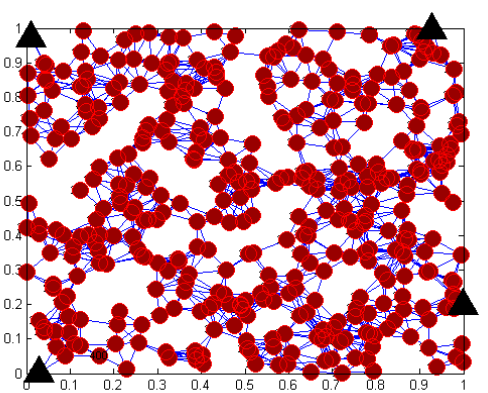
Examples of HS Algorithm



(a) Top layer.



(b) Middle layer.



(c) Lowest layer.

Figure: Examples of hierarchy-based approach. $N = 400$, $K = 4$.

Coverage Ratio

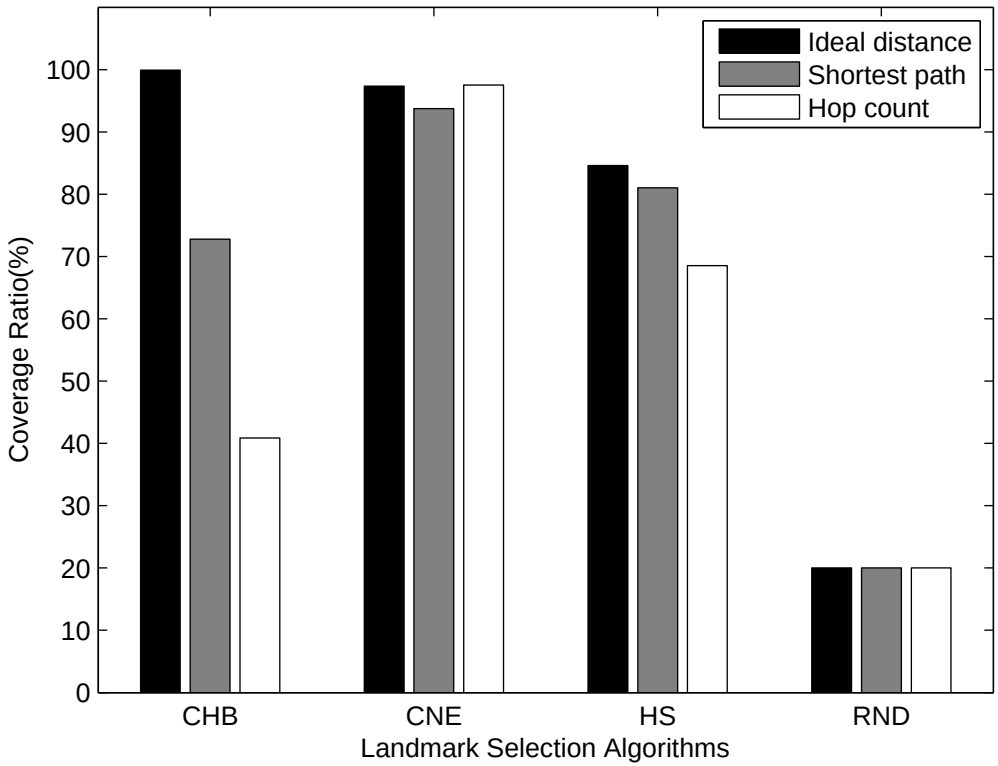


Figure: Coverage Ratio under different algorithms.

Impact of hierarchical layers

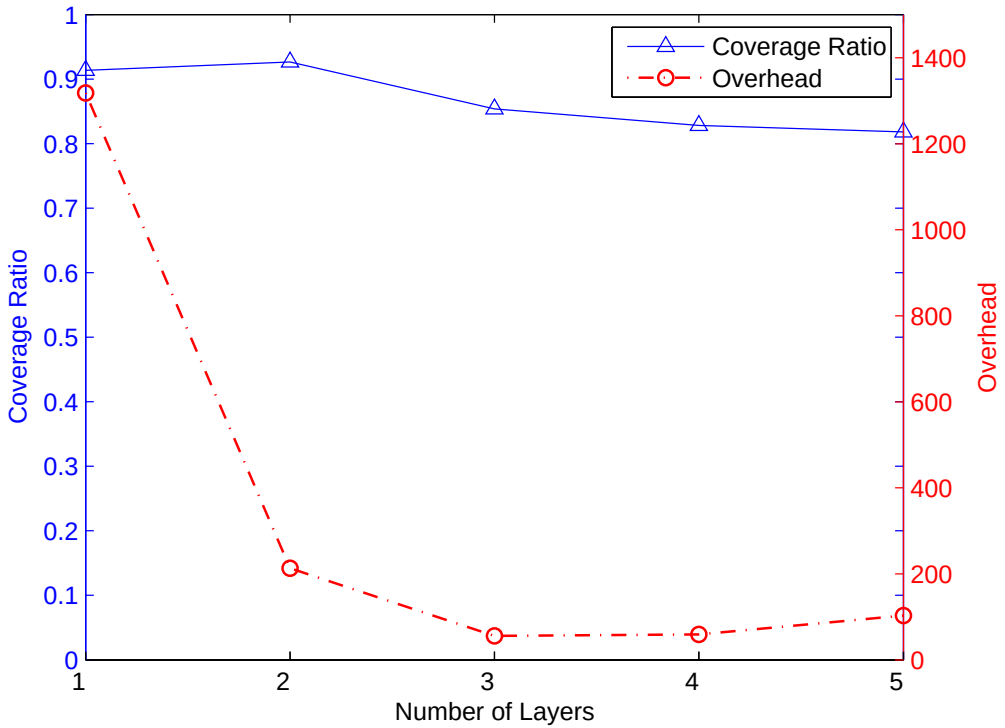
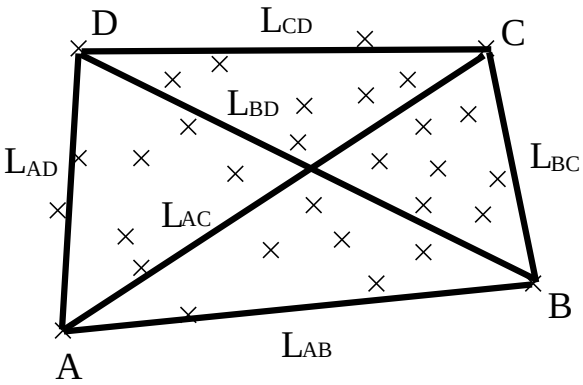
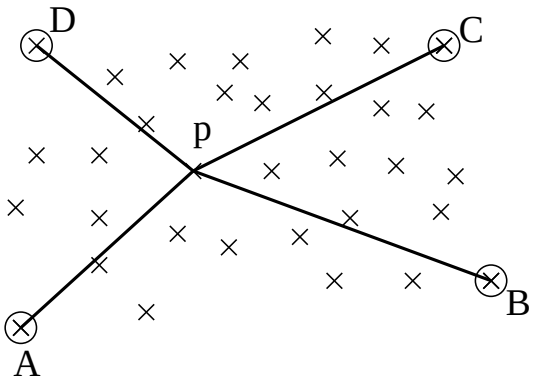


Figure: Impact of hierarchical layers

Coordinates Calculation



(a)



(b)

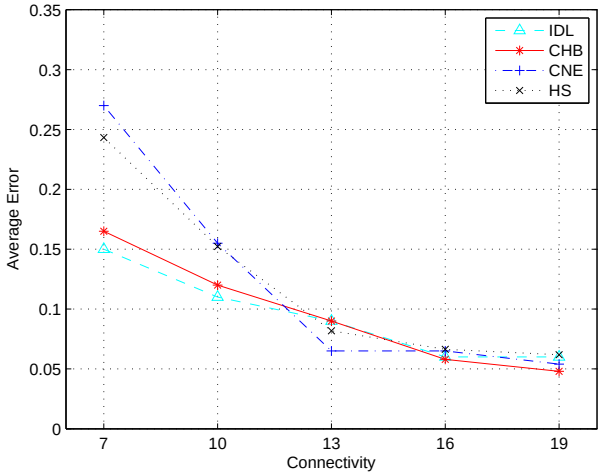


Figure: Coordinates errors.

Border Detection

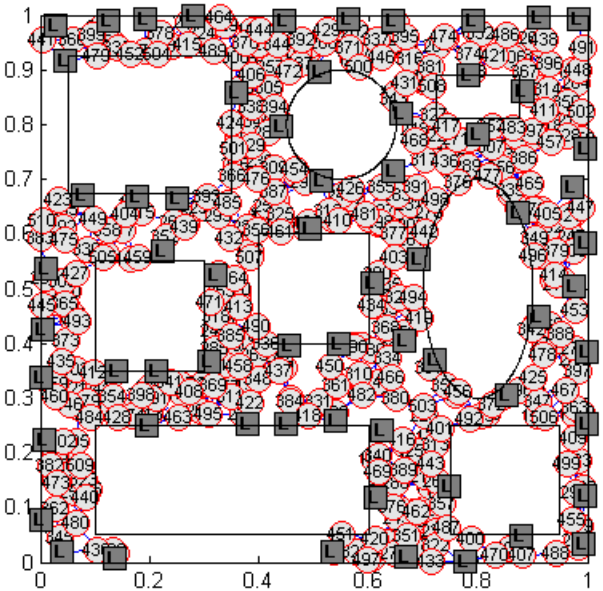


Figure: K = 64

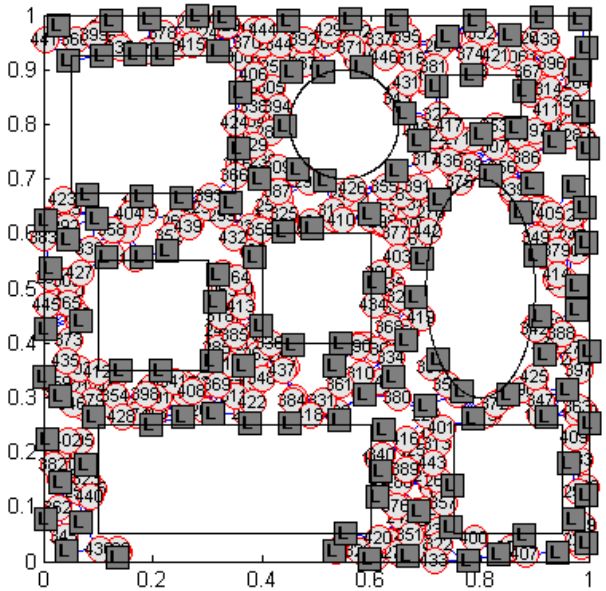


Figure: K = 128

Landmark-based Routing

- Greedy Forwarding Routing Algorithm
- Virtual Coordinates

$$V_i = [S_{il_1}, S_{il_2}, \cdots, S_{il_k}, \cdots], \tag{1}$$

where $l_k \in \Phi_0$. Based on the virtual coordinates, the virtual distance from Node i to Node j is defined in a way similar to Mahalanobis distance:

$$D_{ij} = ||V_i - V_j|| = \sqrt{\sum_{l_k \in \Phi_0} (\frac{S_{il_k} - S_{jl_k}}{S_{jl_k}})^2}. \tag{2}$$

Routing Success Rate

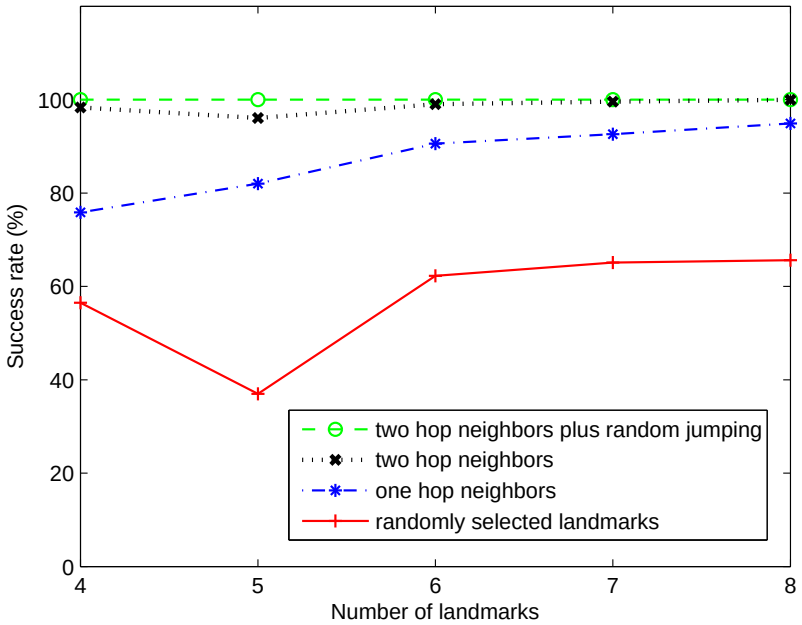


Figure: Routing success rate in regular network.

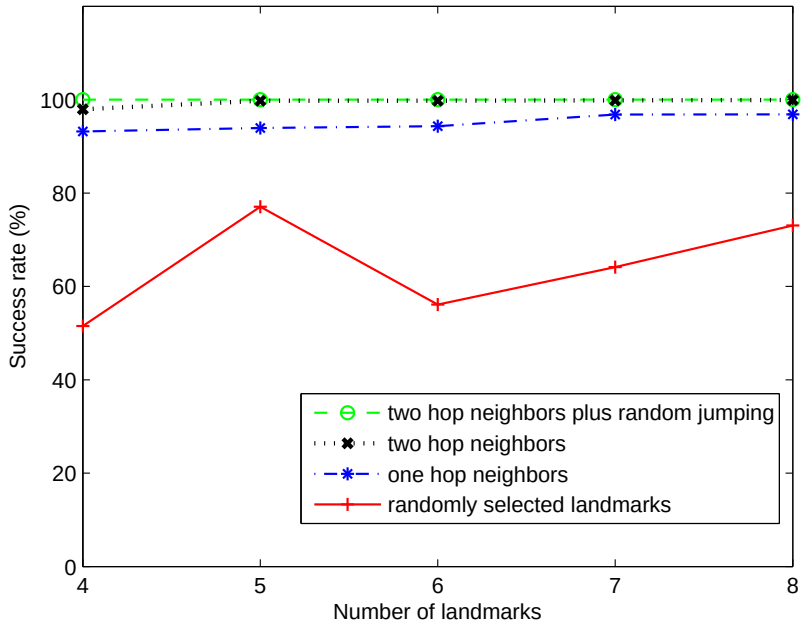


Figure: Routing success rate in irregular networks.

Conclusion

- We proposed three algorithms for border landmark selection.
- There are pros and cons for different algorithms.
- Applications in border detection, routing and positioning algorithms.