Bounded Radius Steiner Routing

BPRIM vs. BRBC

Roy D. McCord & Michael Yue

Physical Design Automation of VLSI Systems
December 1, 2009

Bounded Radius Routing

- Goal: Connect all nodes in a set while minimizing total wire length and radius.
- The tradeoff between wire length and radius represents the ever-present tradeoff between area and performance.
- We want a way to construct solutions at varying levels of weight between the two constraints.

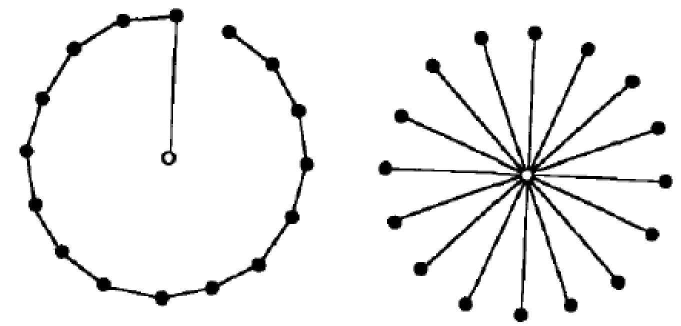


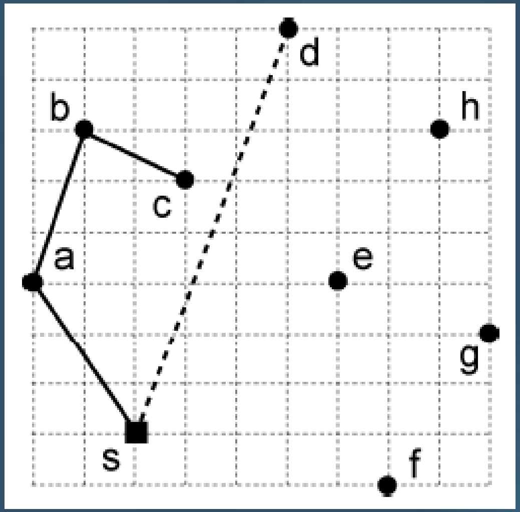
Fig. 1. An example where the cost of a shortest path tree (*right*) is $\Omega(|N|)$ times larger than the cost of a minimum spanning tree (*left*).

Two Solutions:

- Bounded Prim's Algorithm (BPRIM)
  - Connect new nodes to current tree using minimum wire length
  - Set a radius bound based on the maximum source-to-node distance
  - Compute "look-back" radius bound using variable ε
- Bounded Radius Bounded Cost (BRBC)
  - Start by constructing a minimum spanning tree using PRIM (i.e. BPRIM with $\varepsilon = \infty$)
  - Record the nodes visited on a depth first tour of a rooted tree version of the MST
  - Traverse the list of nodes keeping track of visited edge weights
  - Add edges as necessary

Bounded PRIM

- Start with source node S
- Compute distances from all connected nodes to all disconnected nodes
- Make connection with minimum wire length



- Institute boundary on maximum source-to-sink path based on variable ε
- Compute “look-back” radius boundary based on maximum source-to-node distance

Bounded PRIM

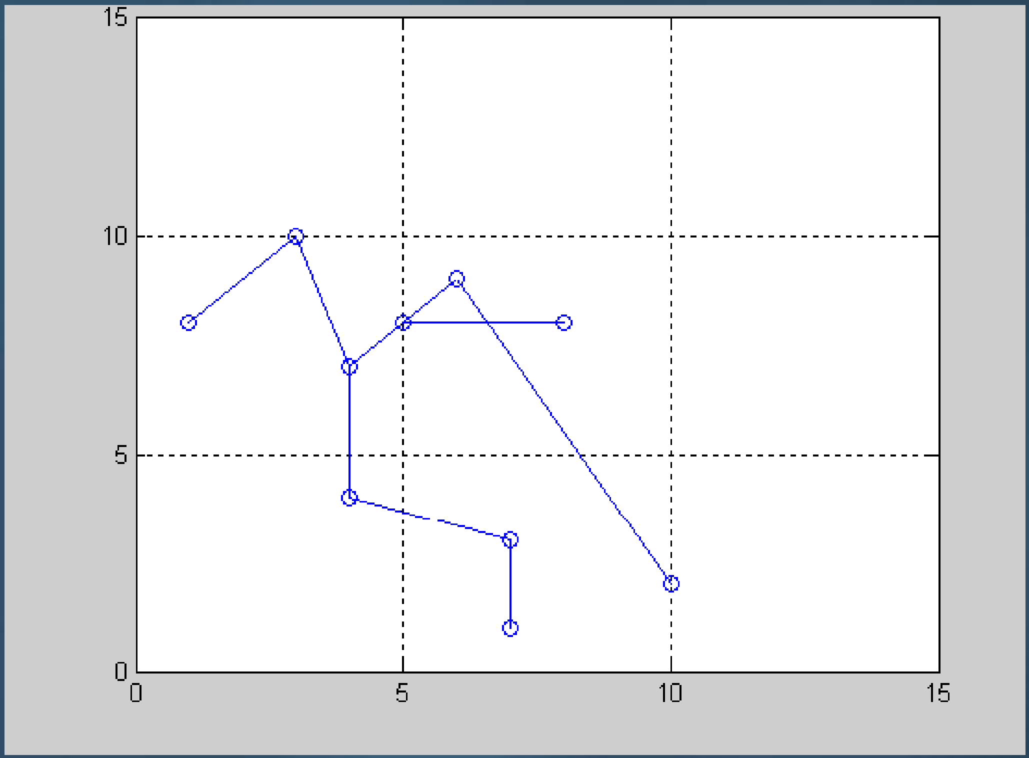
Specifics of our Implementation

- Take inputs to set grid length, grid width, number of nodes, and epsilon
- Use inputs to generate a random array of nodes in the grid. Set source node as the first in the set
- Keep three matrices: one for connected nodes, one for currently disconnected nodes, and one for the original point set
- Using three nested loops
  - Inner-most: Loop through possible connections to current root node
  - Second: Loop through possible root nodes in connected nodes matrix
  - Outer-most: Loop until all nodes are connected
- If minimum connection breaks "epsilon bound," trace back towards source node until connection doesn't break "radius bound." Ties broken by first-found minimum connection
- Each connected node keeps track of its parent node and the radius up to that node

Bounded PRIM

Demo with small point set

- Let’s start with a small set of nodes at ε = 0.5



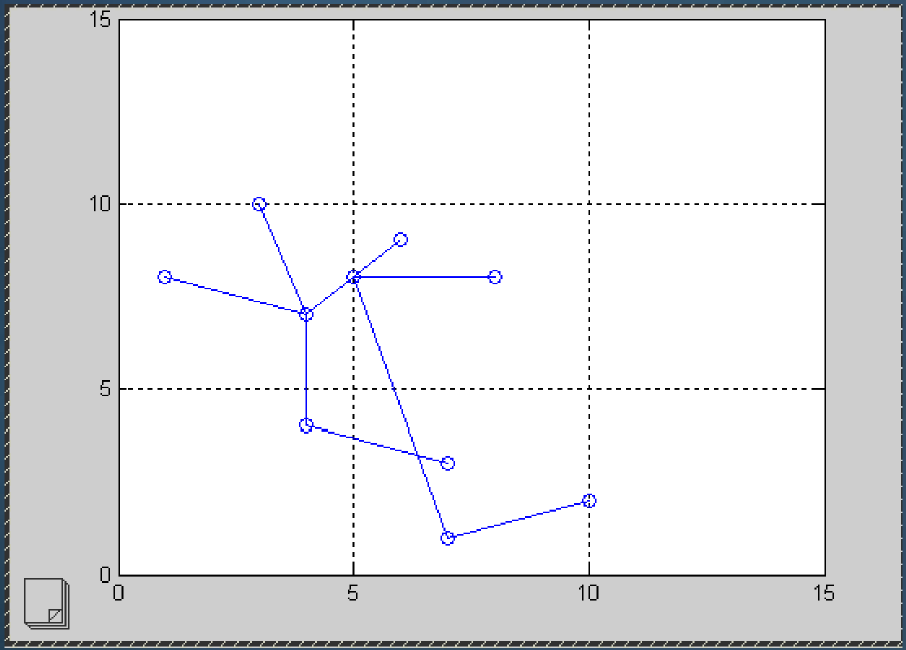
- Results:
  - Grid size: 10 x 10
  - Number of nodes: 10
  - Total Wire length: 35
  - Maximum Radius: 13
  - Total Runtime: 0.639 ms

Bounded PRIM

Demo with small point set

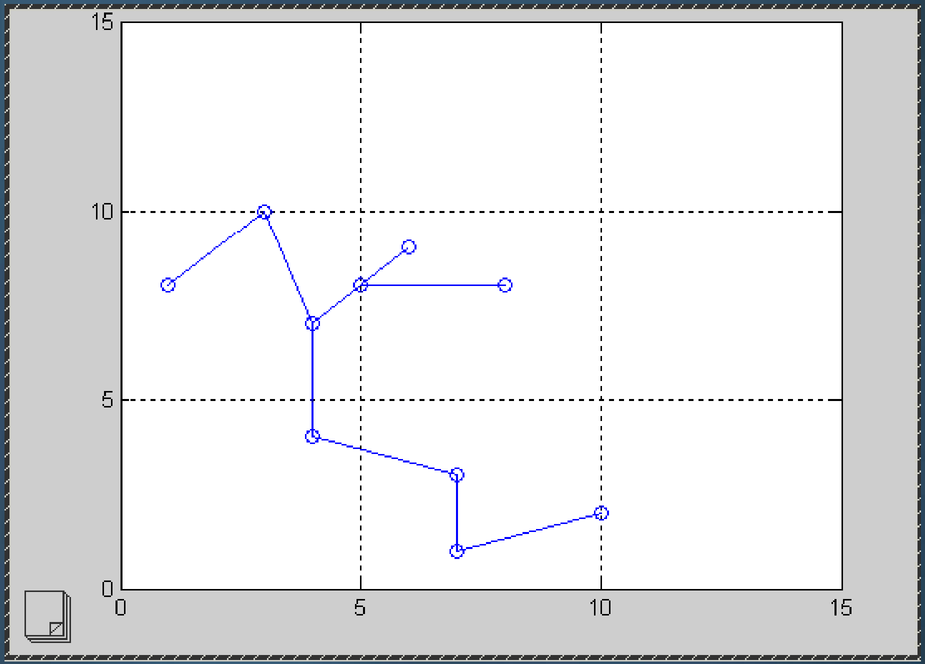
- How would the graphs differ if we used zero or infinity with this small point set?

ε = 0



Total Wire length: 35
Maximum Radius: 15
Total Runtime: 0.741 ms

ε = ∞

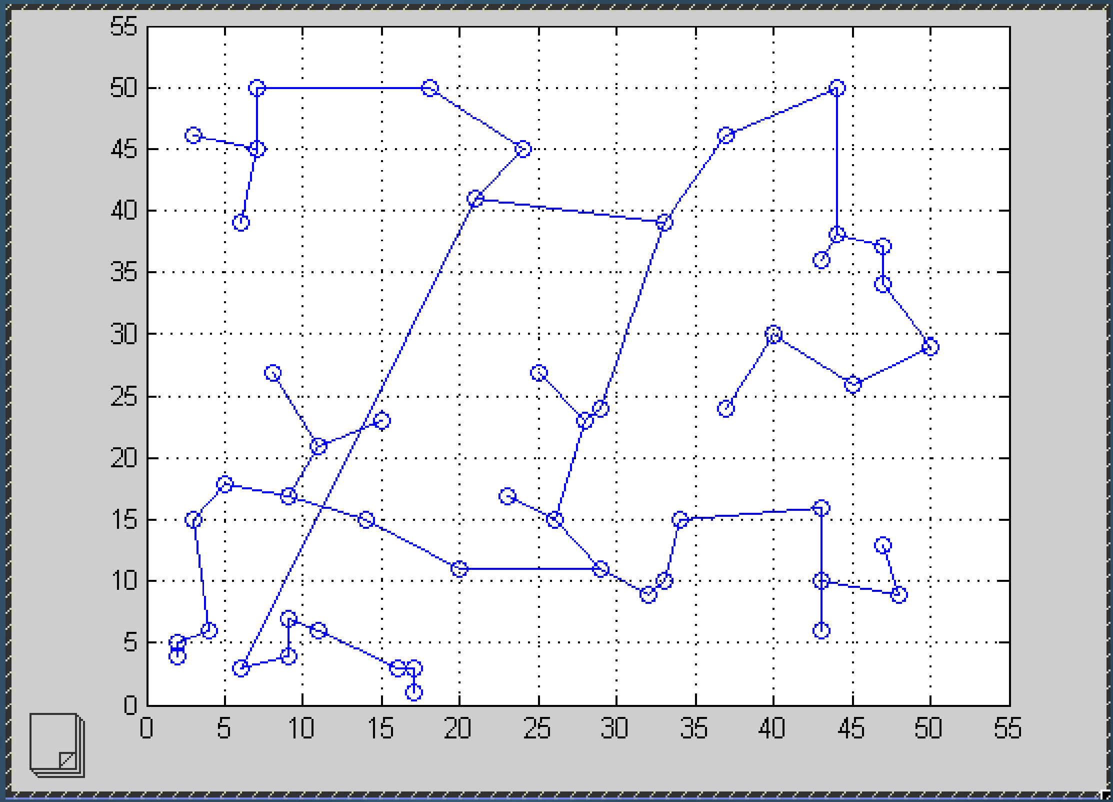


Total Wire length: 28
Maximum Radius: 17
Total Runtime: 0.727 ms

Bounded PRIM

Demo with medium point set

- Now we perform BPRIM with a medium set of nodes at ε = 0.5

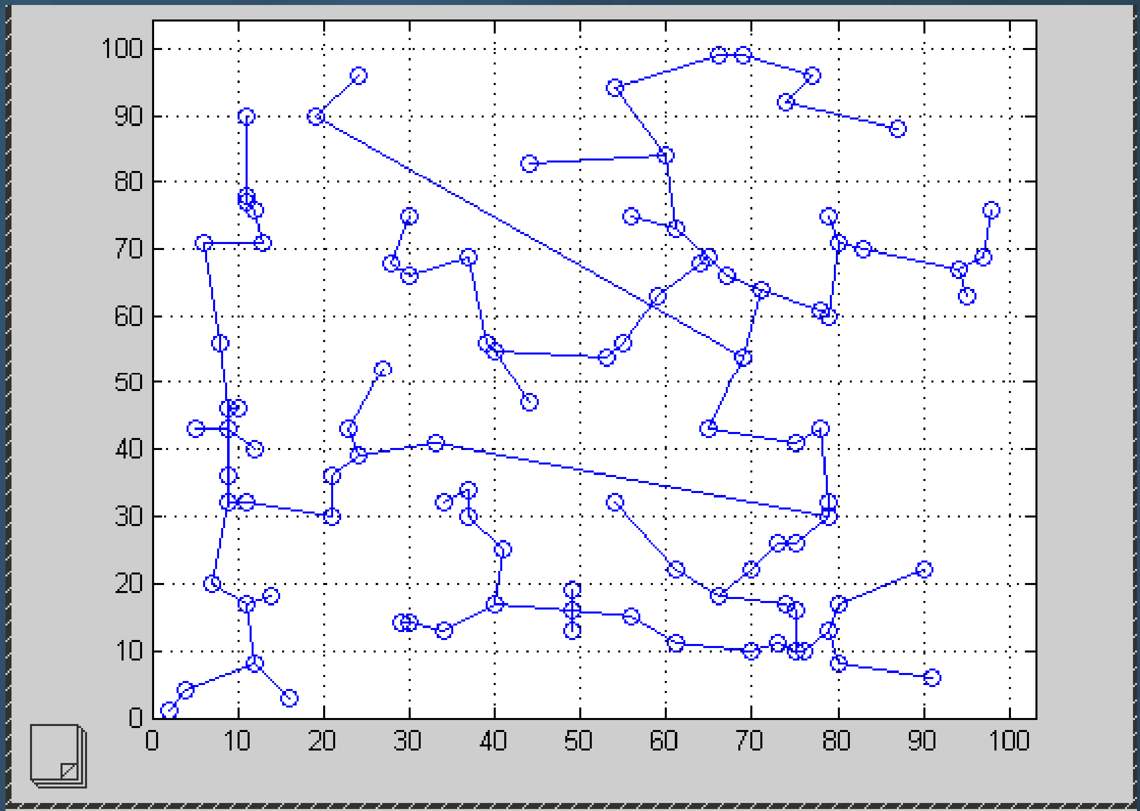


- Results:
  - Grid size: 50 x 50
  - Number of nodes: 50
  - Total Wire length: 377
  - Maximum Radius: 131
  - Total Runtime: 1.056 ms

Bounded PRIM

Demo with large point set

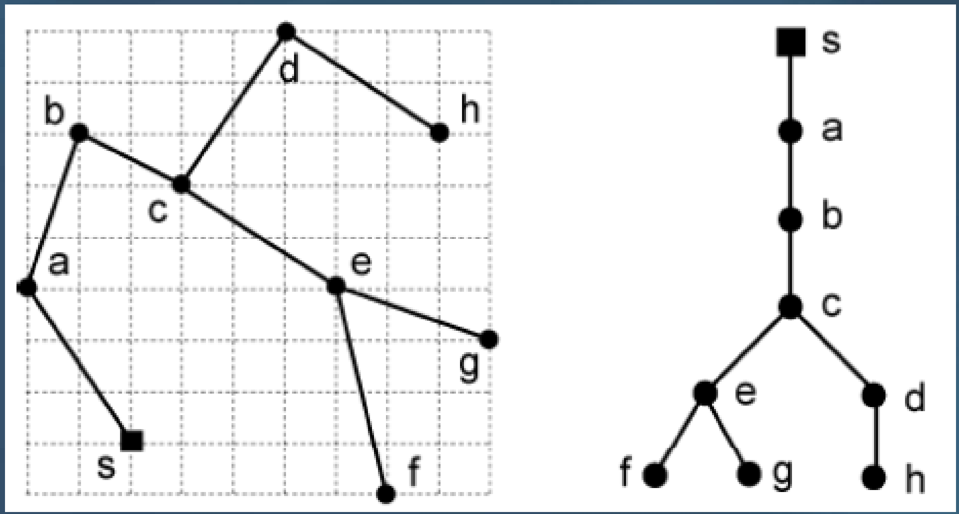
- Lastly, we perform BPRIM with a large set of nodes at ε = 0.5



- Results:
  - Grid size: 100 x 100
  - Number of nodes: 100
  - Total Wire length: 900
  - Maximum Radius: 235
  - Total Runtime: 7.417ms

Bounded Radius Bounded Cost

- Start with a MST
- Perform a depth first tour of a rooted-tree version of the MST, recording the nodes to a list, L.



- Traverse L while computing S (total visited edge weight)
- If S > ε x dist(source, current node in L), reset S to 0 and add an edge connecting the current node to the source
- After traversing L, compute a shortest path tree of the graph

Bounded Radius Bounded Cost

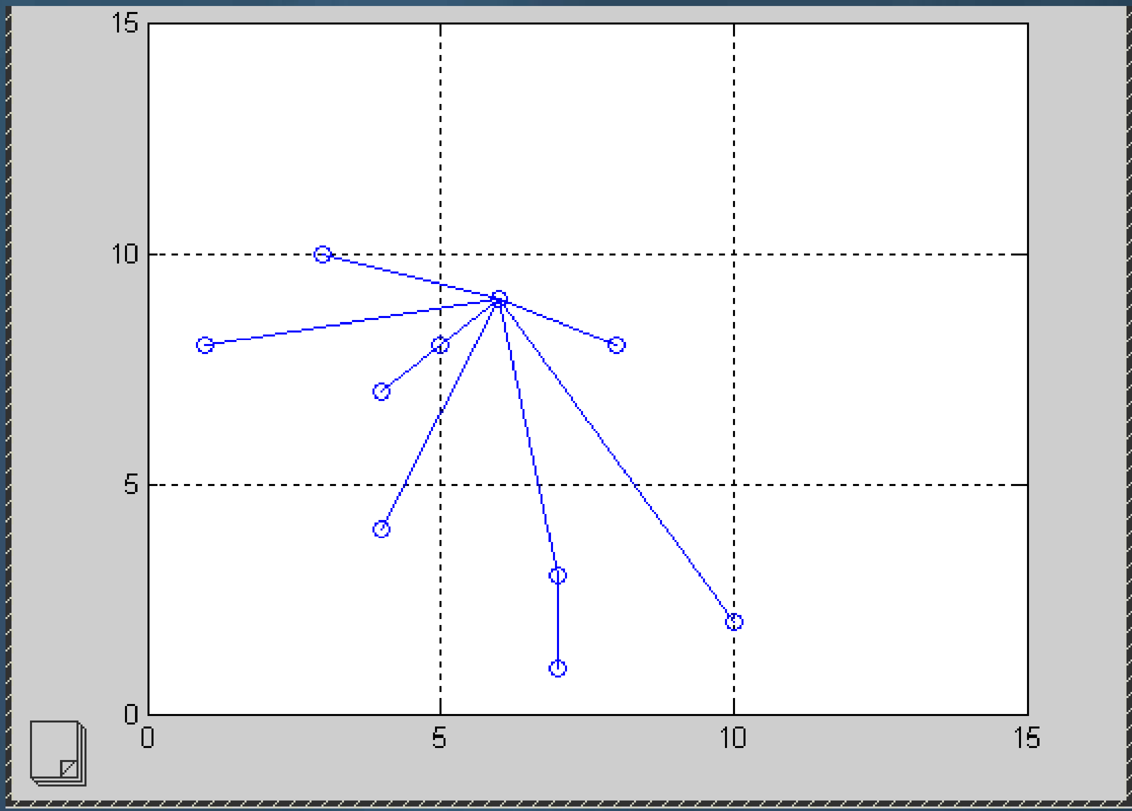
Specifics of our Implementation

- Achieve an initial minimum spanning tree (MST) by performing PRIM's algorithm on the point set (i.e. BPRIM with $\varepsilon = \infty$)
- Create a tree from the MST by designating the first node as the source
- Perform the depth first tour with a recursive function
- As new edges are added to the MST, immediately remove the node's old parent edge

Bounded Radius Bounded Cost

Demo with small point set

- Let's start with a small set of nodes at ε = 0.5



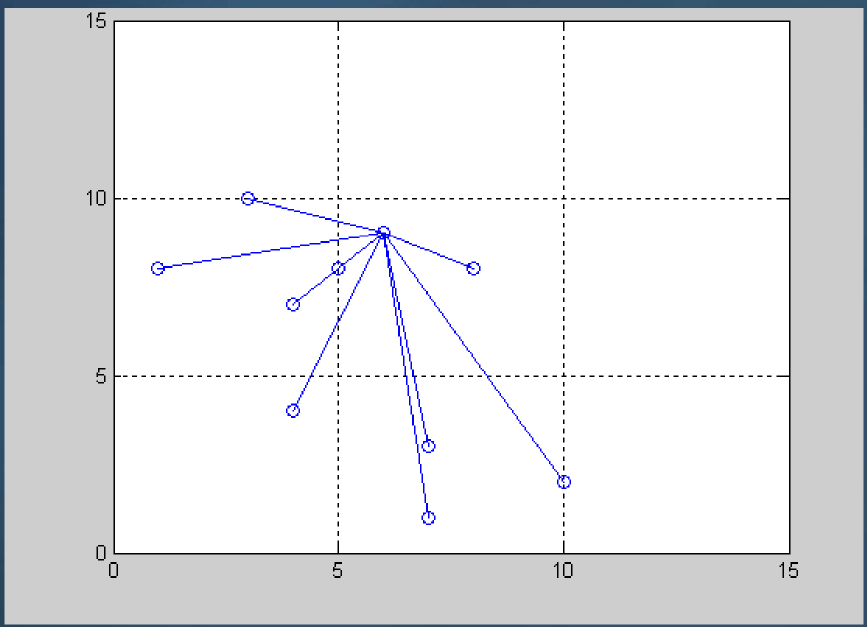
- Results:
  - Grid size: 10 x 10
  - Number of nodes: 10
  - Total Wire length: 46
  - Maximum Radius: 11
  - Total Runtime: 0.917 ms

BRBC

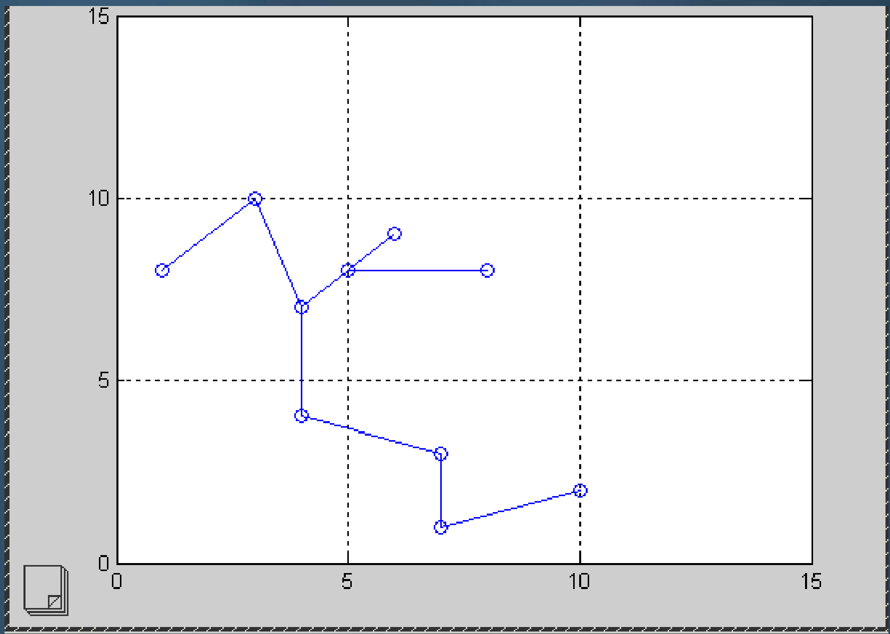
Demo with small point set

- How would the graphs differ if we used zero or infinity with this small point set?

ε = 0



ε = ∞



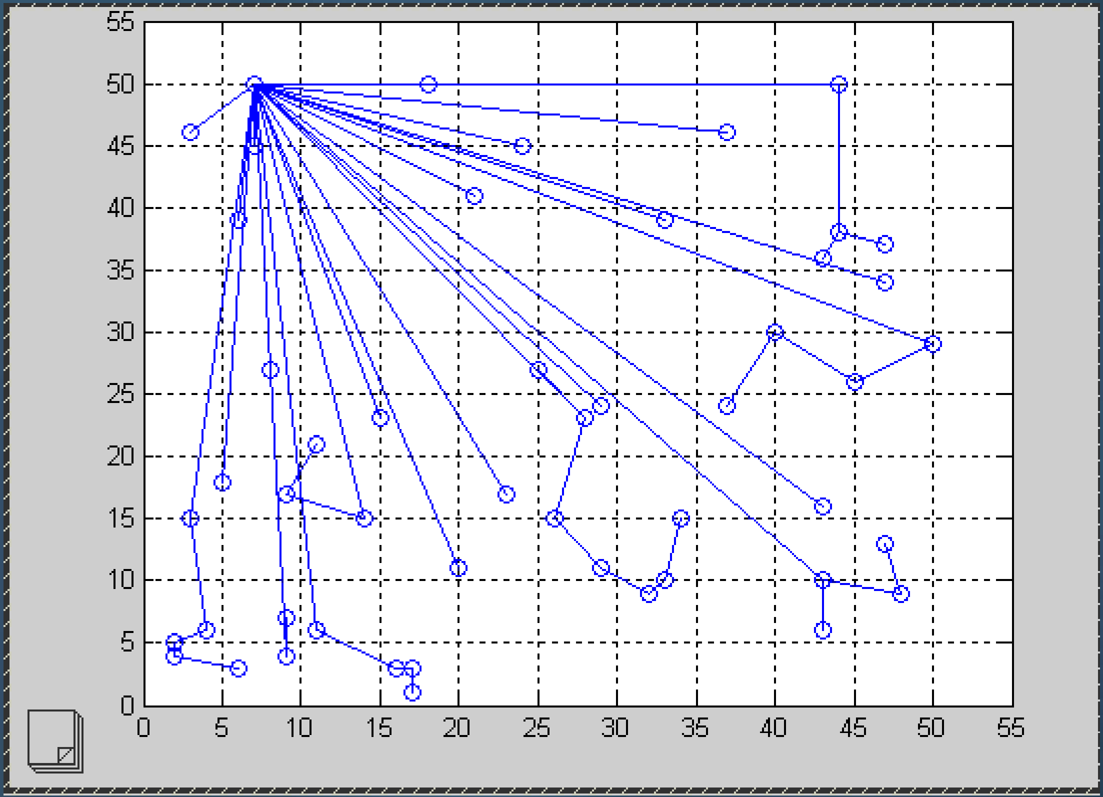
Total Wire length: 53
Maximum Radius: 11
Total Runtime: 0.936 ms

Total Wire length: 28
Maximum Radius: 17
Total Runtime: 0.926 ms

Bounded Radius Bounded Cost

Demo with medium point set

- Now we perform BPRIM with a medium set of nodes at ε = 0.5

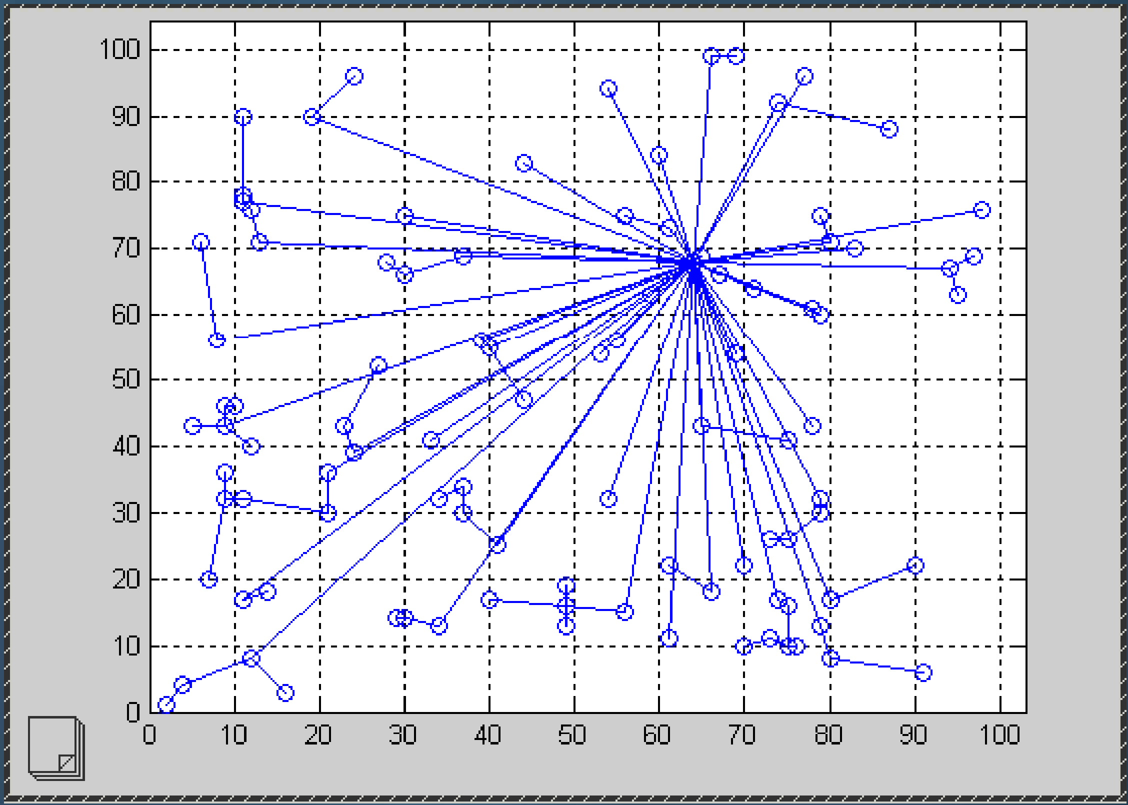


- Results:
  - Grid size: 50 x 50
  - Number of nodes: 50
  - Total Wire length: 1065
  - Maximum Radius: 90
  - Total Runtime: 11.404 ms

Bounded Radius Bounded Cost

Demo with large point set

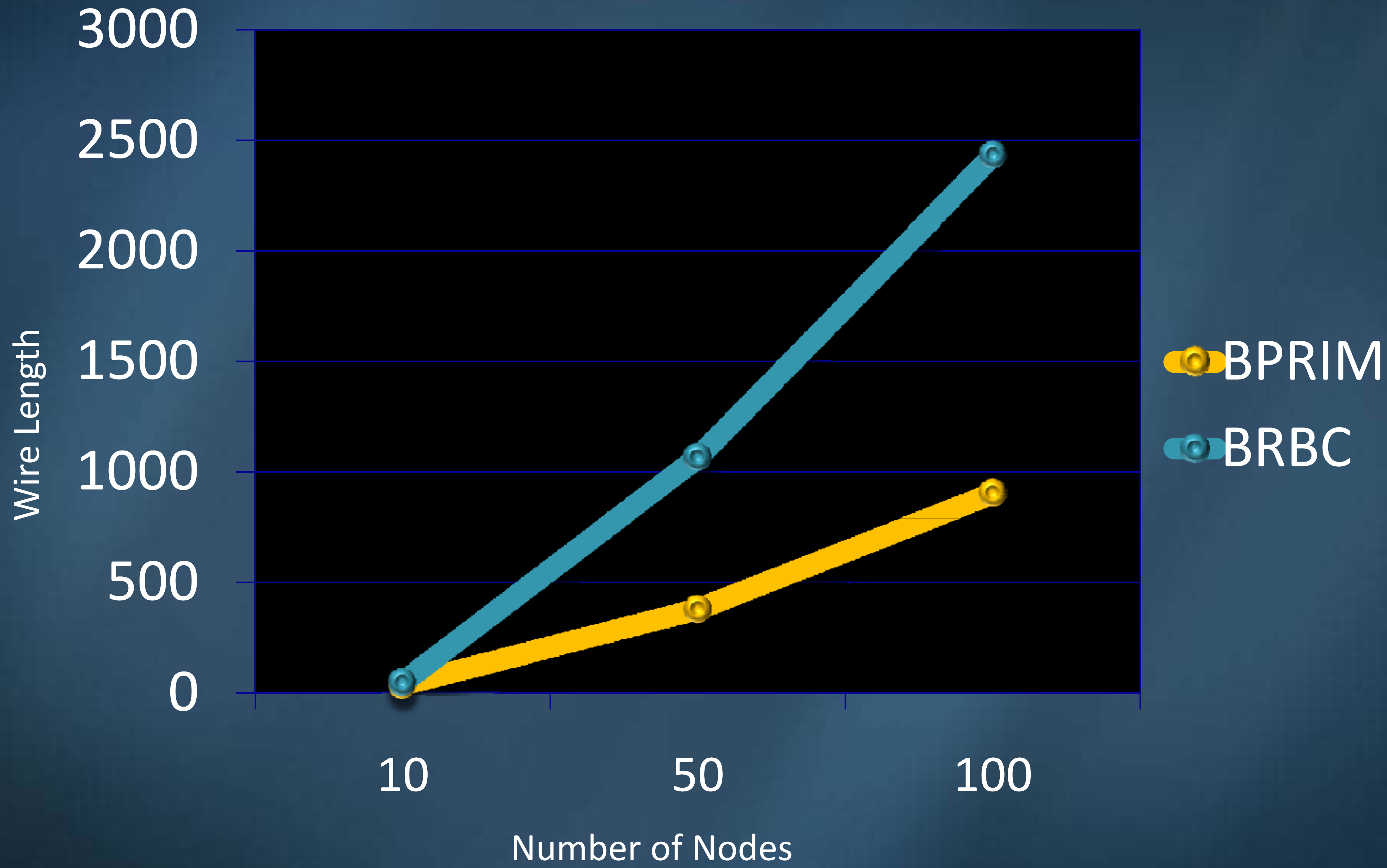
- Lastly, we perform BPRIM with a large set of nodes at ε = 0.5



- Results:
  - Grid size: 100 x 100
  - Number of nodes: 100
  - Total Wire length: 2431
  - Maximum Radius: 129
  - Total Runtime: 78.215 ms

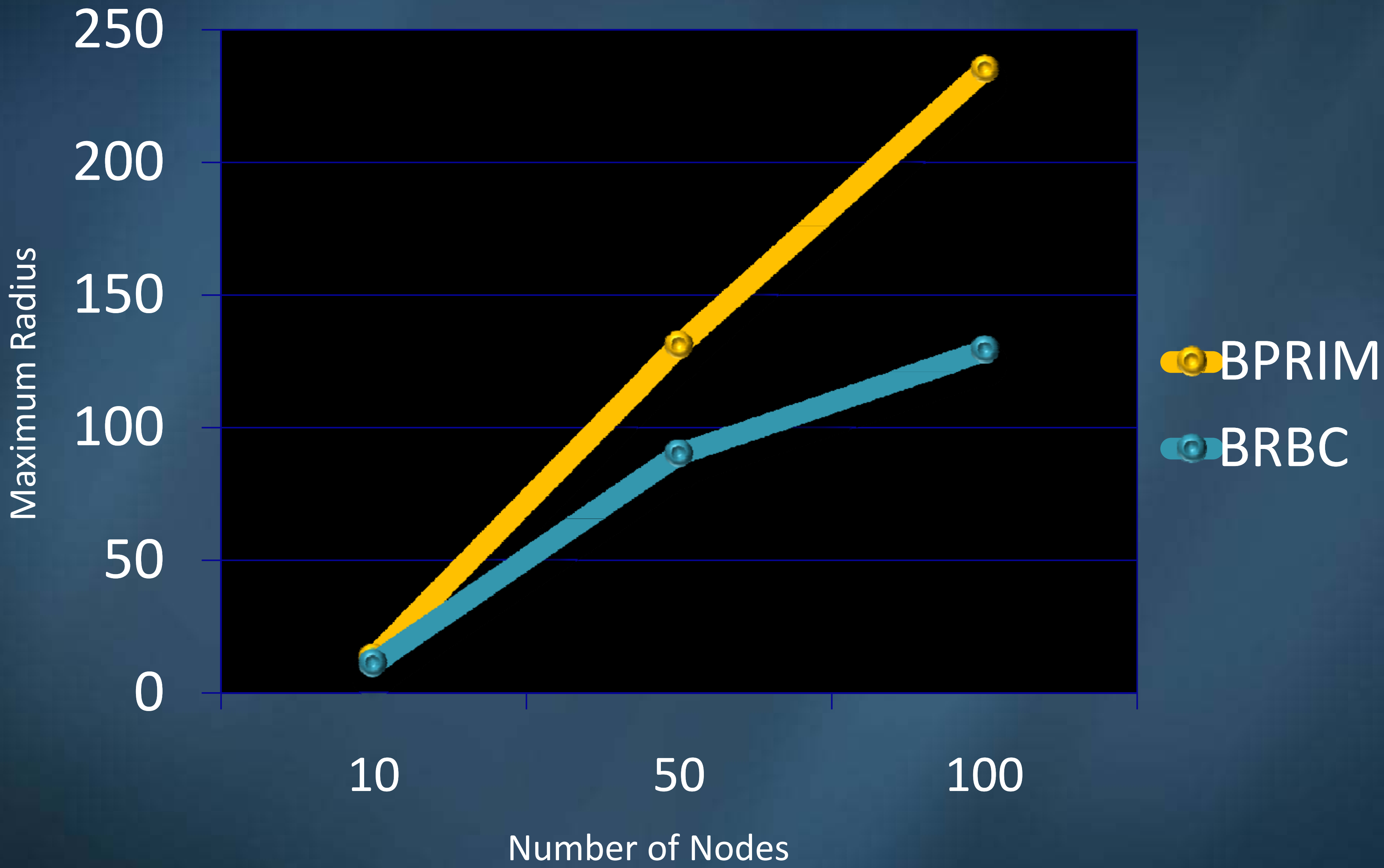
BPRIM vs. BRBC

Wire Length



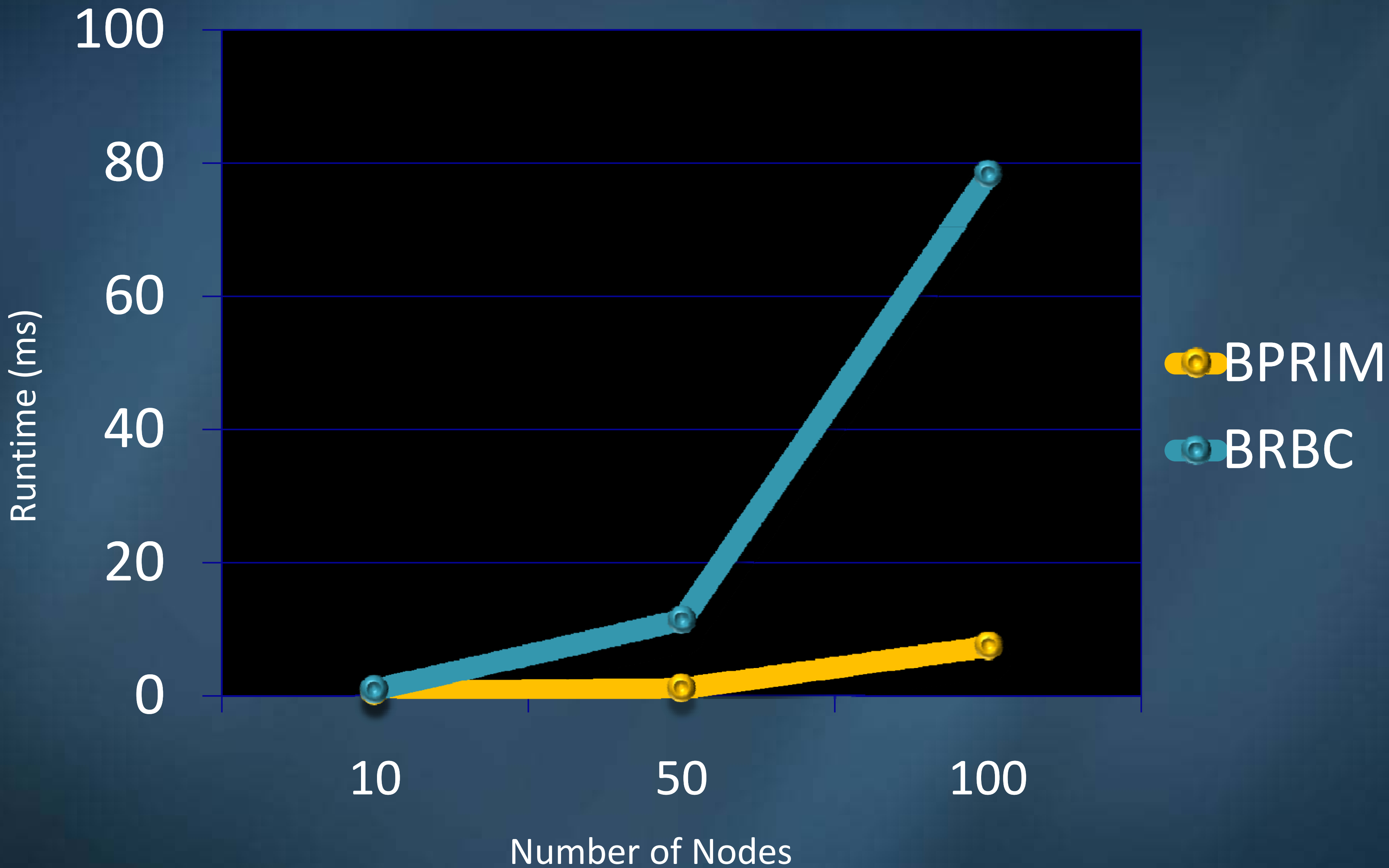
BPRIM vs. BRBC

Maximum Radius



BPRIM vs. BRBC

Run Time



Conclusions & Comparisons

- BRBC is definitely worth the extra effort on circuits with a small number of nodes. It gives a minor radius benefit at a small cost to wirelength.
- BPRIM is preferable for large circuits to maintain a reasonable wirelength. Radius can be managed by reducing ε.
- For BRBC, runtime increase dramatically as the number of nodes increases.

Conclusions & Comparisons

	BPRIM	BRBC
Wirelength	☺	
Radius		☺
Run Time	☺	

Questions?

Sources

- J. Cong, A.B. Kahng, G. Robins, M. Sarrafzadeh, and C.K. Wong, "Provably good performance-driven global routing", IEEE Trans. on Computer-Aided Design, 11(6), pp 739-752, 1992.
- Lim, Sung Kyu, "Steiner Routing" Lecture Slides
  http://users.ece.gatech.edu/limsk/course/ece6133/slides/steiner.pdf
- Lim, Sung Kyu, "Practical Problems in VLSI Physical Design Automation"
  http://users.ece.gatech.edu/limsk/book/