Mincut Placement with FM Partitioning featuring Terminal Propagation

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Project Overview

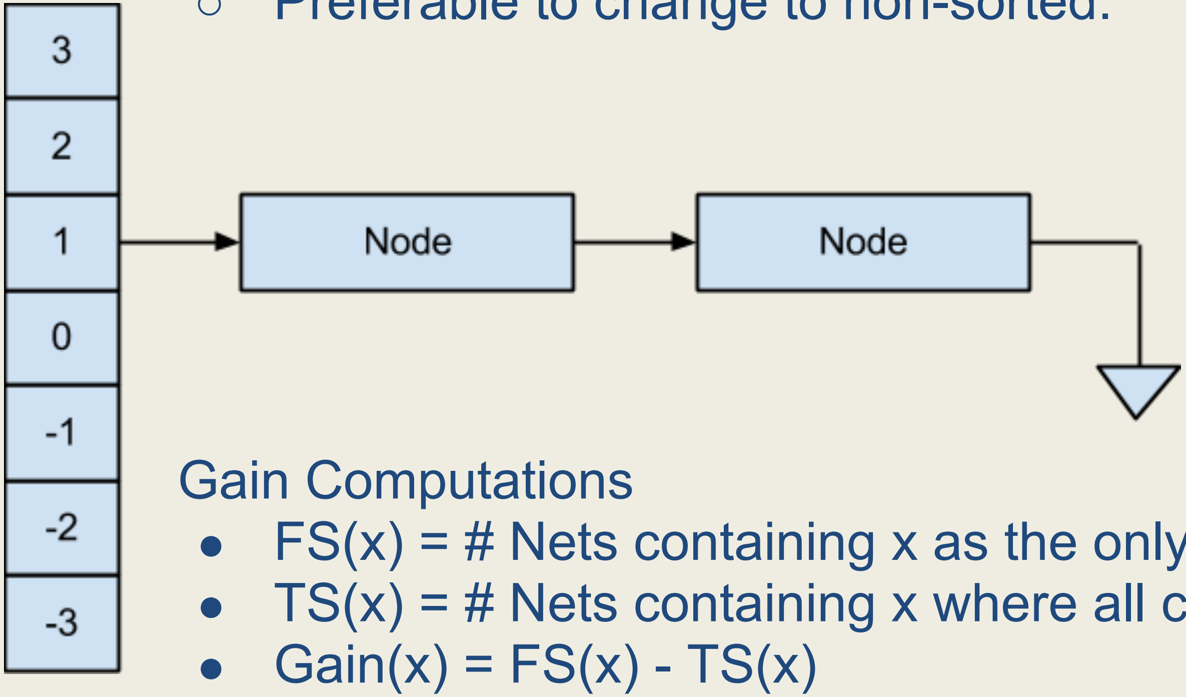
- Perform Mincut Placement using the FM Algorithm to perform partitioning.

- Goals:
  - Minimize wire length for placement
  - Minimize cut size between partitions

- Implementation Evaluation Metrics:
  - Wirelength with and without Terminal Propagation
  - Runtime with and without TP
  - Effect of TP window "Dead Zone" on result

FM Algorithm

- Node and Net information stored in a C++ map (binary tree structure)
- Buckets implemented as a C++ vector of sorted, singly-linked lists.
    - Preferable to change to non-sorted.



Gain Computations

- FS(x) = # Nets containing x as the only cell in partition 1
- TS(x) = # Nets containing x where all cells are in partition 1.
- Gain(x) = FS(x) - TS(x)

FM Algorithm

Area Constraints: 50/50 +/- 5% by default

The 3 FM bipartition methods are very similar, but have important distinctions

- Bipartition whole design
  - Continues run until there is a pass with 0 gain.
- Bipartition subset (no TP)
  - Continues run until there is a pass with 0 gain.
  - Ignores nodes not in the current subset.
- Bipartition subset with TP
  - Continues run until there is a pass with 0 gain OR the gain for a pass is less than or equal to the netGain for a pass.
  - Ignores nodes not in the current subset or the propagated terminals

FM Standalone Results

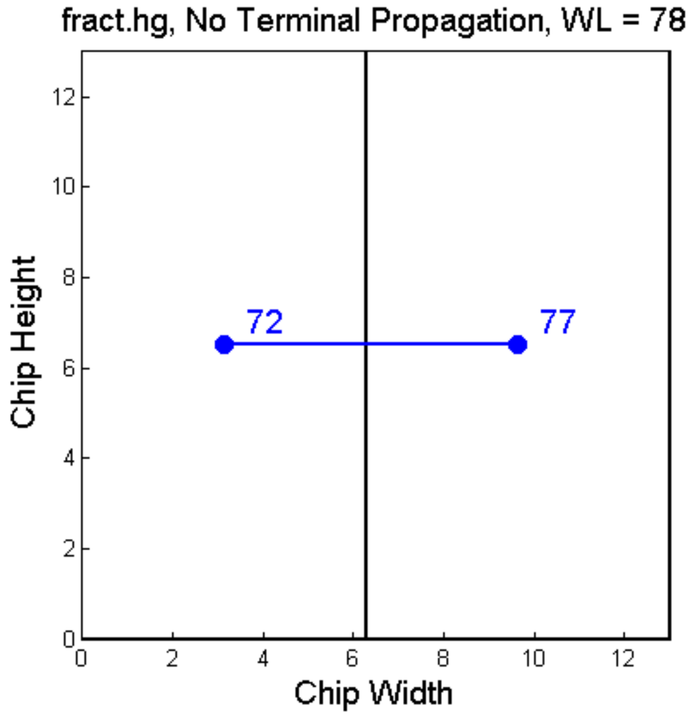
Netlist	Nodes	Nets	Max Degree
fract	149	148	7
ibm01	12753	14112	39
industry2	12638	13420	12
ibm10	69430	75197	137
ibm18	210613	201921	97

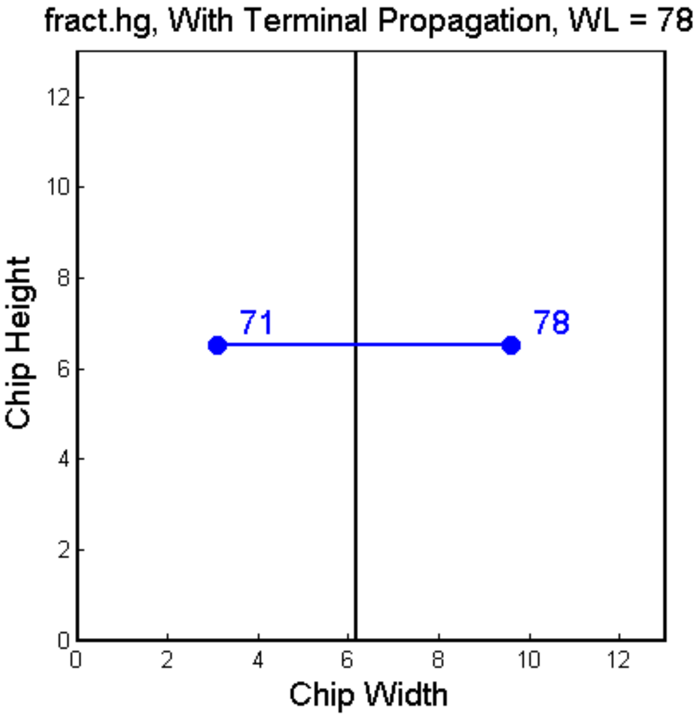
Netlist	Runs	Avg # Passes	Avg Initial Cutsize	Avg Final Cutsize	Avg Gain
fract	20	4.5	99.1	12.1	87
ibm01	10	11.7	9184.5	1376.6	7807.9
industry2	10	18.6	8090.4	620.9	7469.5
ibm10	3	24.33	50705.67	6637.67	44068
ibm18	1	29	139237	34502	104735

Placement Assumptions

- Placement done by Mincut placement, using Breadth First Recursive Bisection.
    - Done with and without terminal propagation (TP).
    - When terminal propagation was used, the default "Dead Zone Window," or A, was 0.3.
    - I.e. 30% of the partition dimension being split.
- Partition area treated the same as cell count, corresponding to the following.
    - Cells are soft, to some extent.
    - Recursion only goes so deep: down to some maximum number of cells per partition. Thus there will be room for an ILP or other floorplan solver to fit the cells to the area.

Placement Algorithm: Recursive Bisection (1)

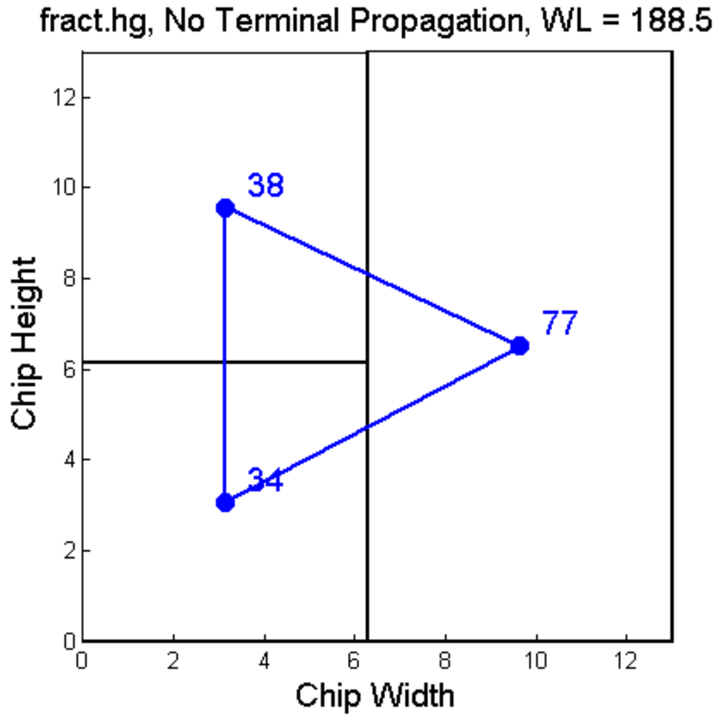

fract.hg, No Terminal Propagation, WL = 78

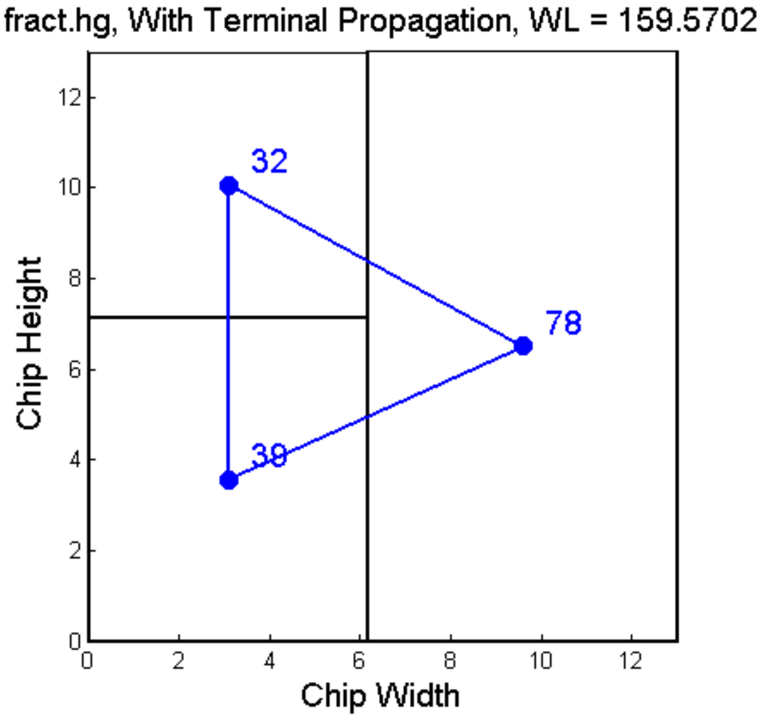

fract.hg, With Terminal Propagation, WL = 78

Recursive bisection makes a breadthwise traversal of the existing partitions (i.e. as nodes in a binary tree).

The dots in the figures are node clusters, with their number shown. Wire Length (WL) is measured as the sum of the half perimeter bounding boxes (HPBB).

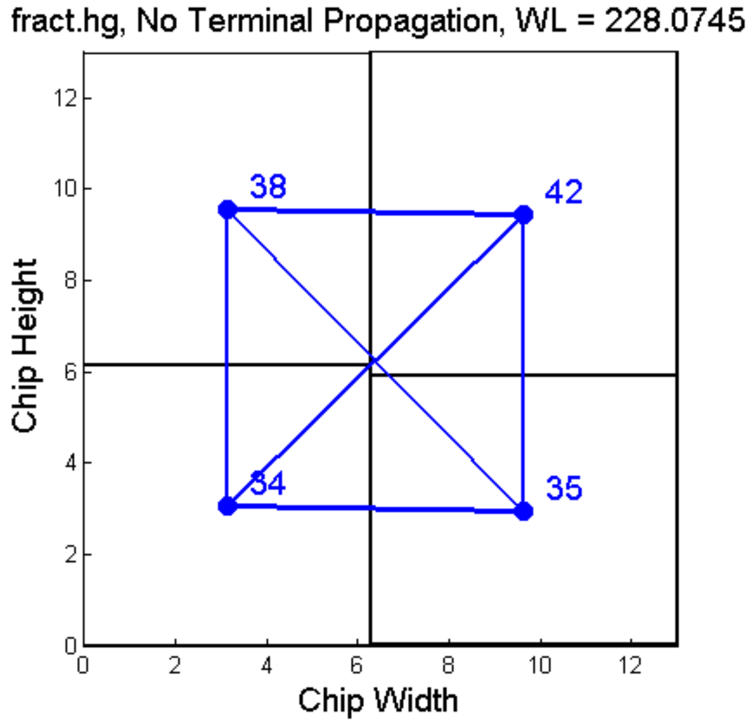
Recursive Bisection (2)

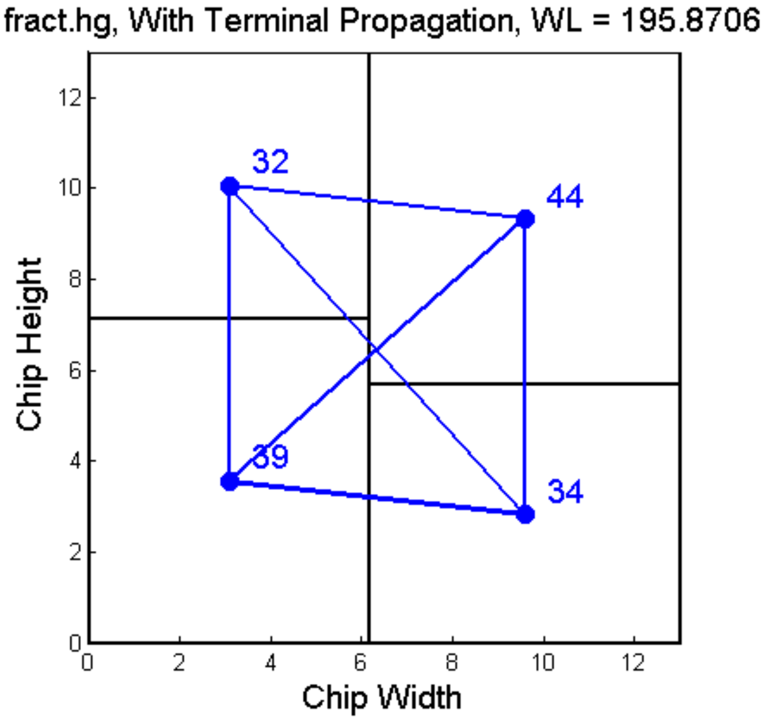




Here a 0.45 to 0.55 area balance is being used,by the FM partitioner.

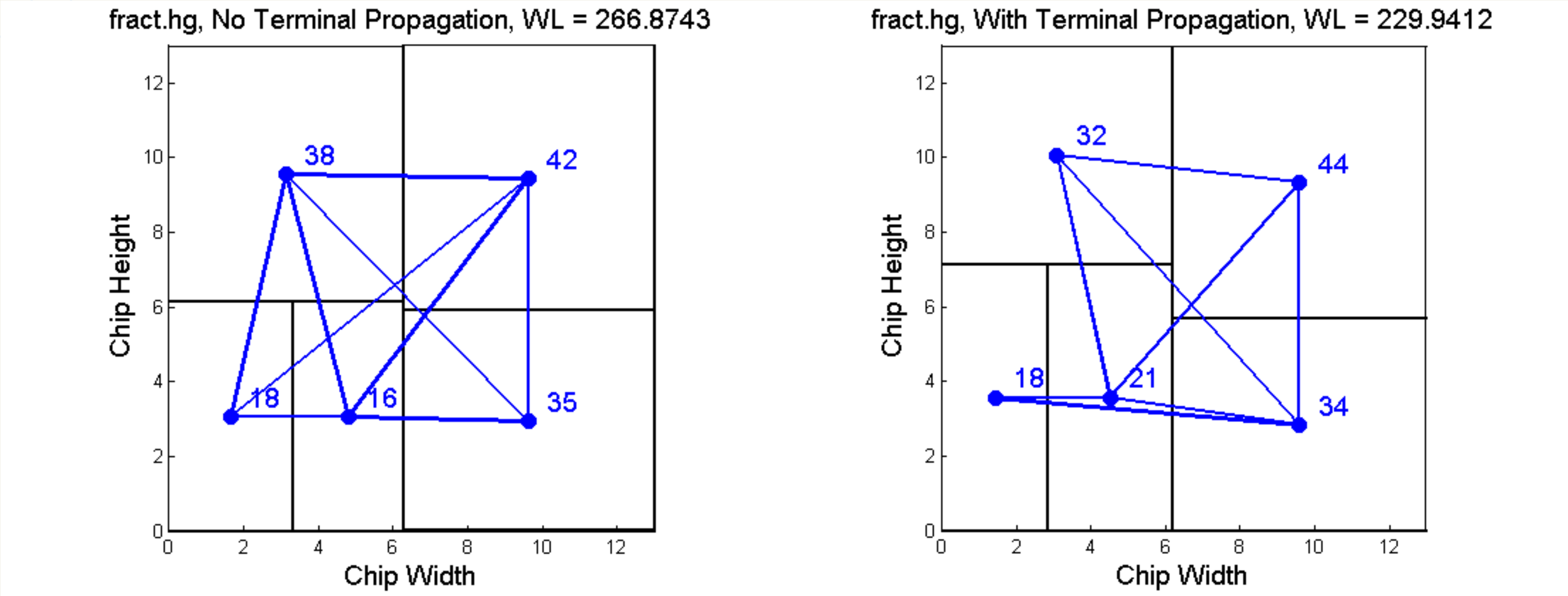
Recursive Bisection (3)


fract.hg, No Terminal Propagation, WL = 228.0745


fract.hg, With Terminal Propagation, WL = 195.8706

The area balance is enforced as much as possible, but sometimes it cannot be.
35 / 77 ~ 0.43

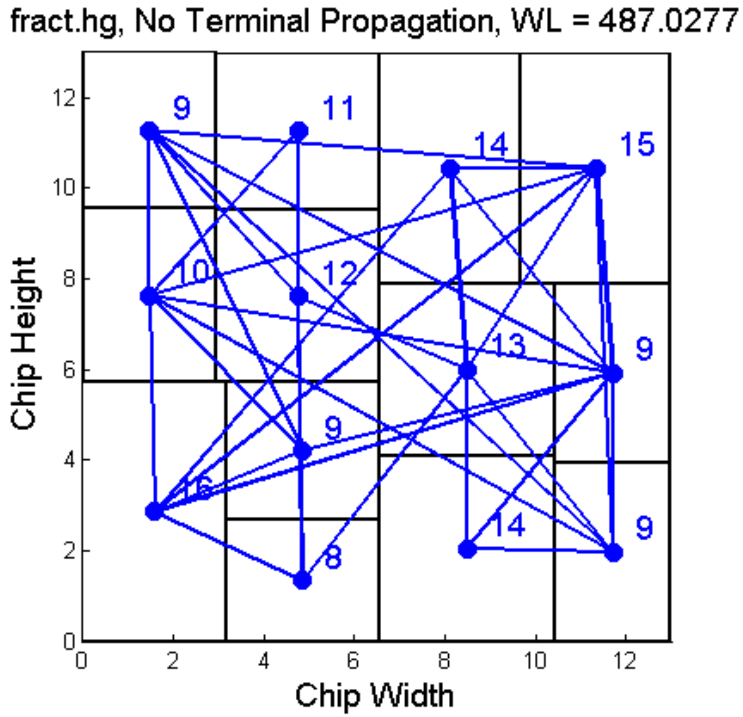
Recursive Bisection (4)

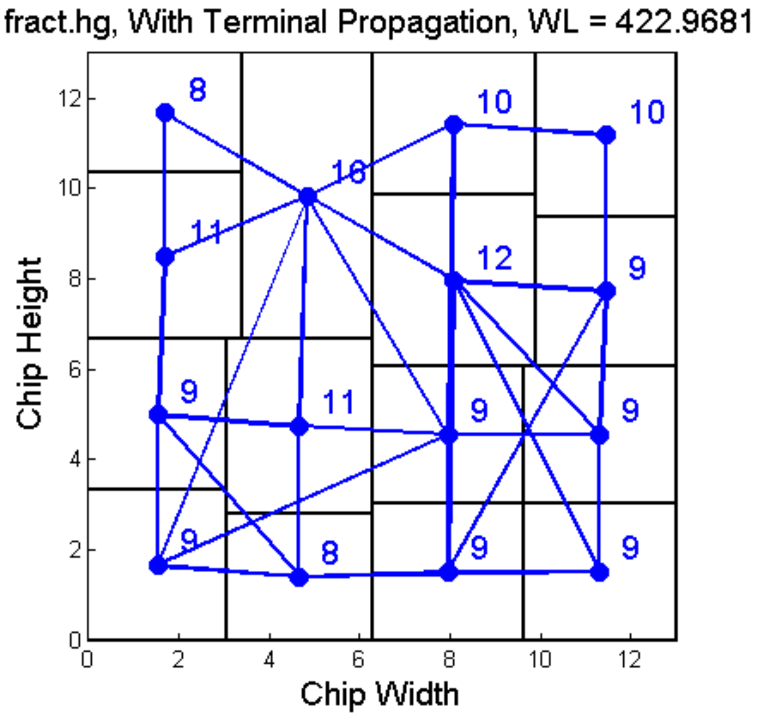


Without TP, the 18 cell cluster has connection(s) at the 42 cell cluster, farthest away.

With TP, the corresponding cluster does not have the same distant connection(s).

Effect of TP (1)

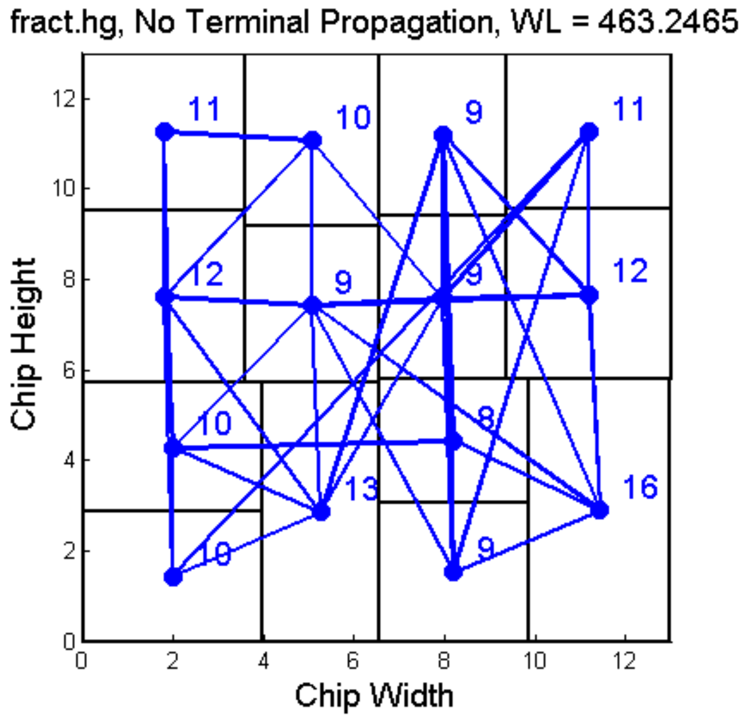




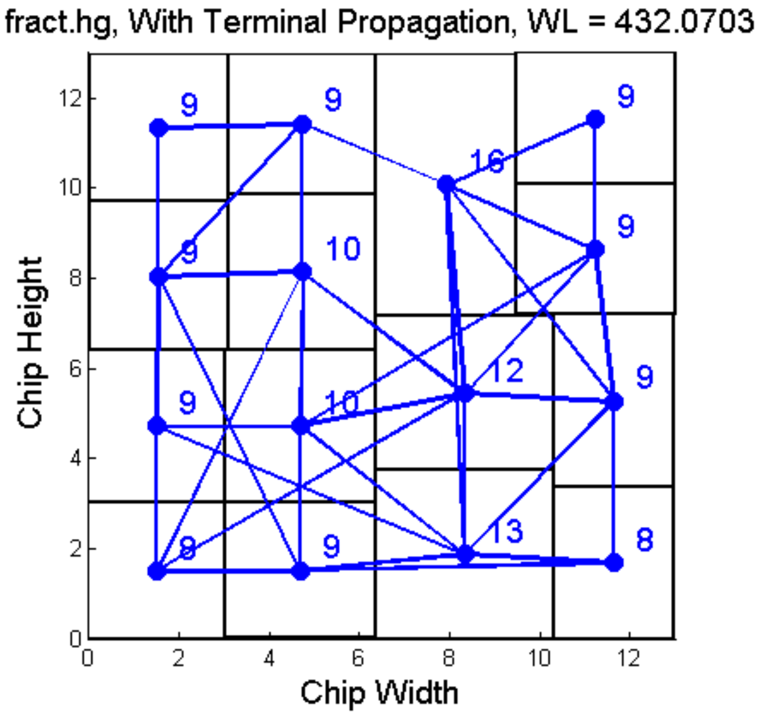
fract.hgr circuit used here, partitioning down to a maximum cell count of 16.

(0.45, 0.55) are constraints used by FM partitioner.

fract.hgr, Effect of TP (2)



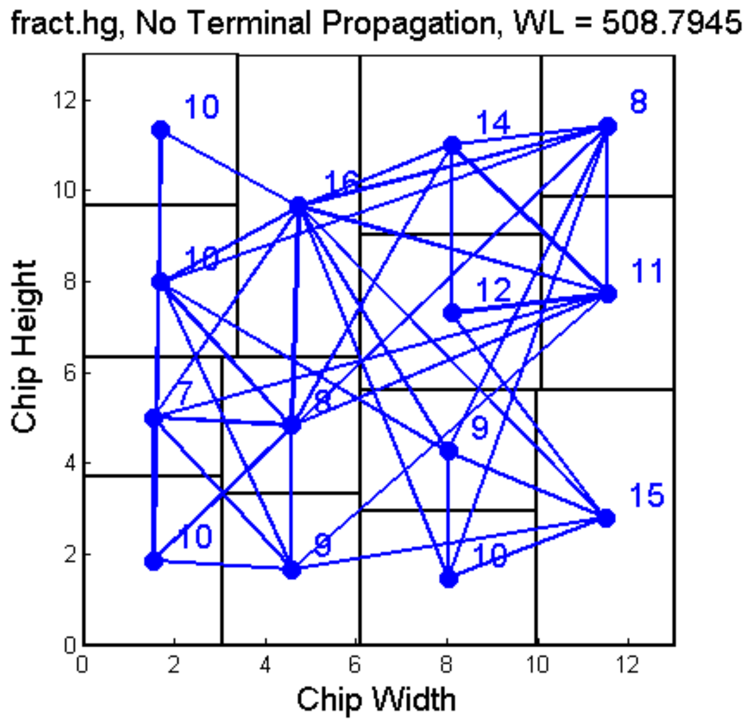
fract.hg, No Terminal Propagation, WL = 463.2465

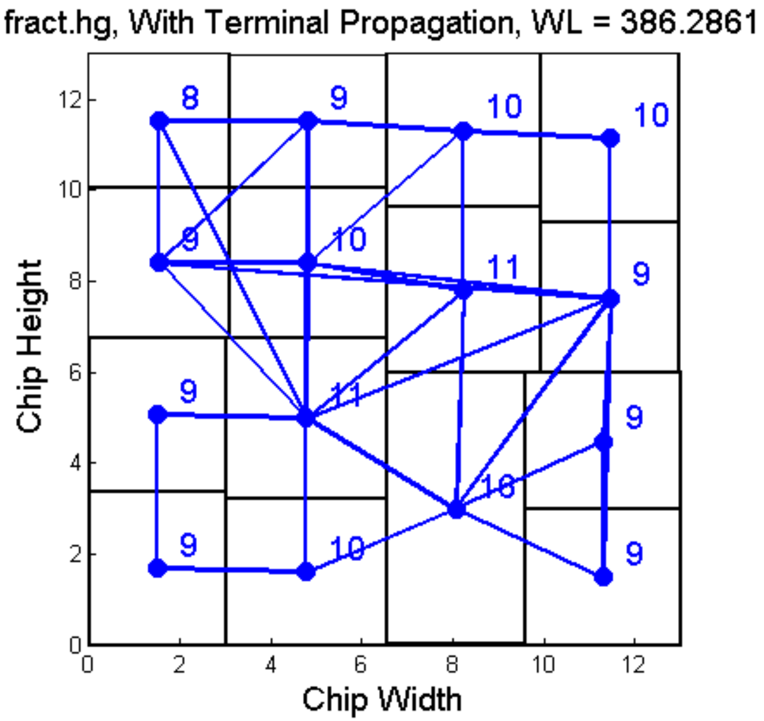


fract.hg, With Terminal Propagation, WL = 432.0703

Notice overall appearance of connections, for each case.

fract.hgr, Effect of TP (3)

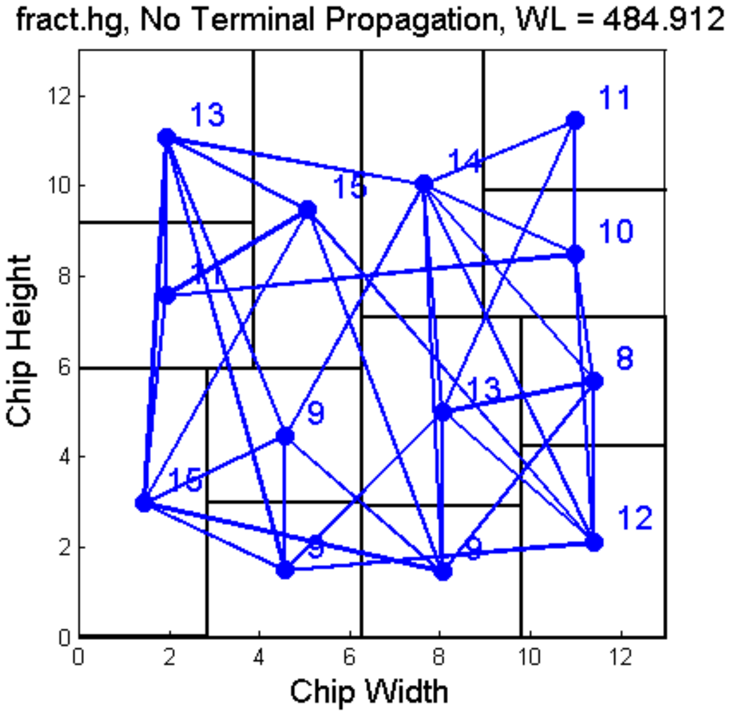


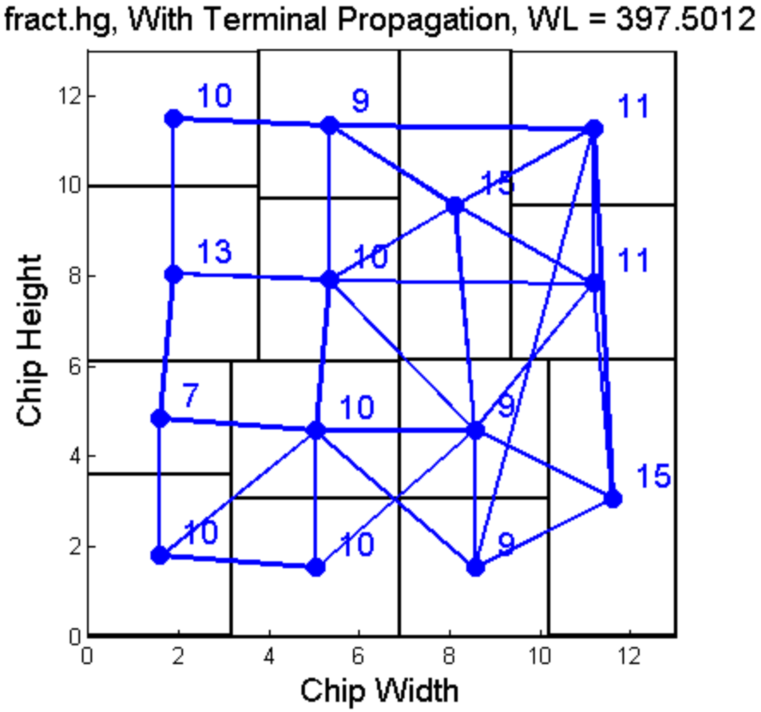


The drawn connections are meaningful. They are from the MSTs of the net, which is a good approximation of the wirelength for routing.

Recall however that the shown wirelength is for the sum of the HPBBs.

fract.hgr, Effect of TP (4)


fract.hg, No Terminal Propagation, WL = 484.912


fract.hg, With Terminal Propagation, WL = 397.5012

Note the difference in wire length, measured by HPBB.

Benchmarks

Netlist	Nodes	Nets	Max Degree	Max Cells	Square Area
fract	149	148	7	16	169
ibm01	12753	14112	39	512	12769
industry2	12638	13420	12	512	12769
ibm10	69430	75197	137	2048	69696
ibm18	210613	201921	97	4096	210681

Max Cells was decided, to keep the resulting partition areas large, so that limited cell softness, or even cell hardness, would not be a problem for the floorplanner. Giving floorplanner "room."

Square area is the minimum square area needed, assuming cells are hard 1 x 1 (not an assumption we used). This is a number to shoot for.

Wire Length Results

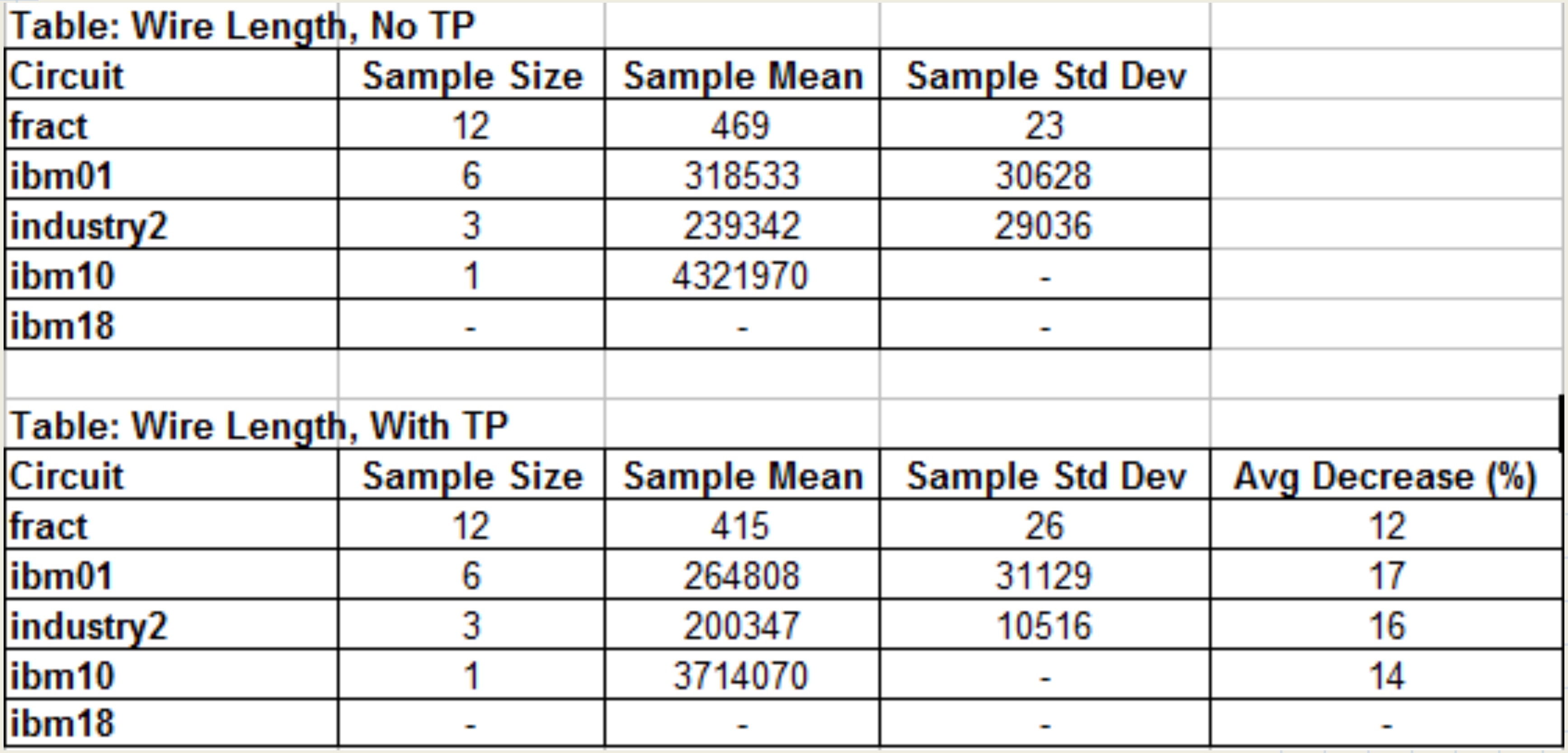


Table: Wire Length, No TP

Circuit	Sample Size	Sample Mean	Sample Std Dev
fract	12	469	23
ibm01	6	318533	30628
industry2	3	239342	29036
ibm10	1	4321970	-
ibm18	-	-	-

Table: Wire Length, With TP

Circuit	Sample Size	Sample Mean	Sample Std Dev	Avg Decrease (%)
fract	12	415	26	12
ibm01	6	264808	31129	17
industry2	3	200347	10516	16
ibm10	1	3714070	-	14
ibm18	-	-	-	-

Notice wire length improvement.

Run Time Results *

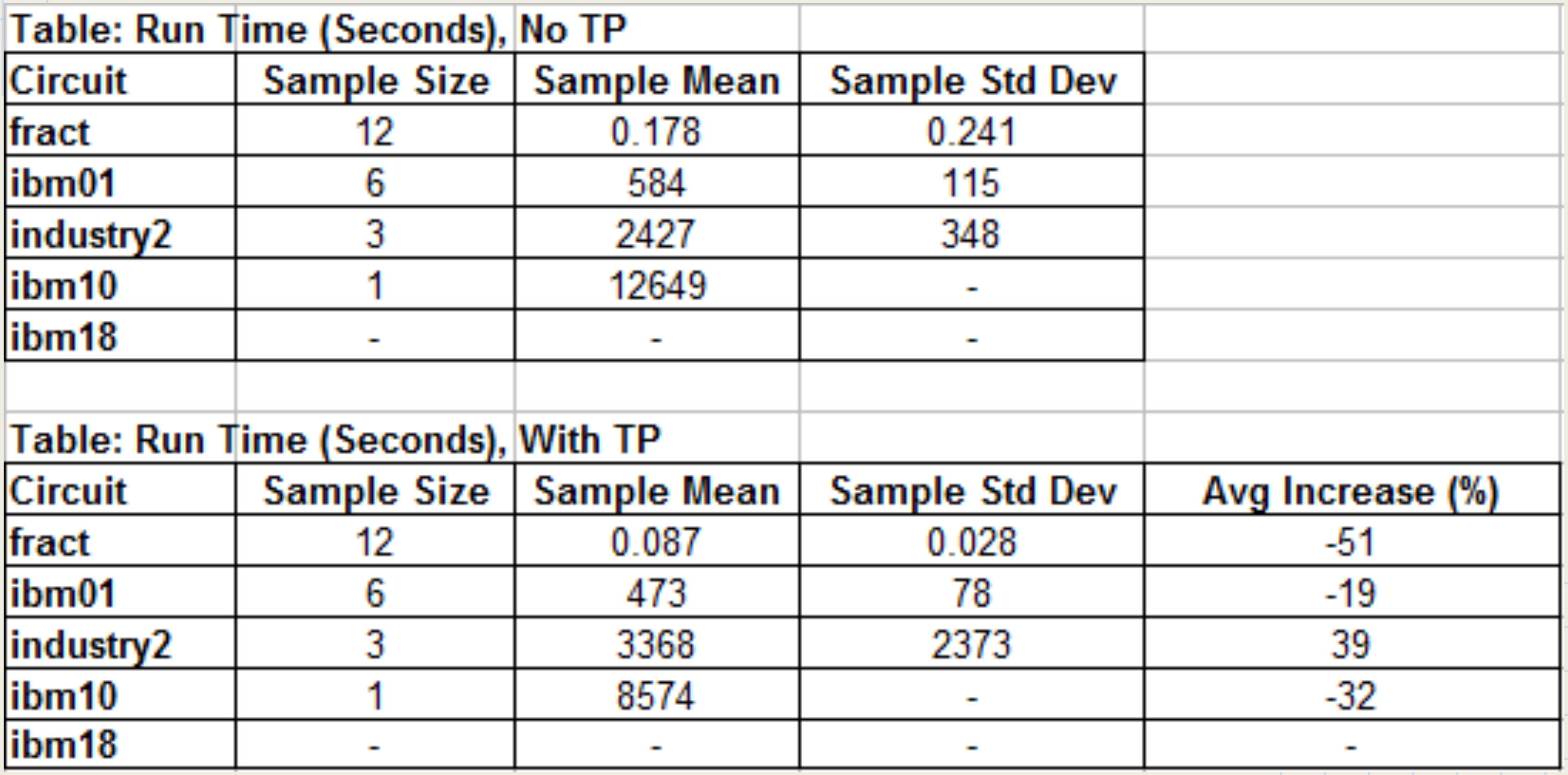


Table: Run Time (Seconds), No TP

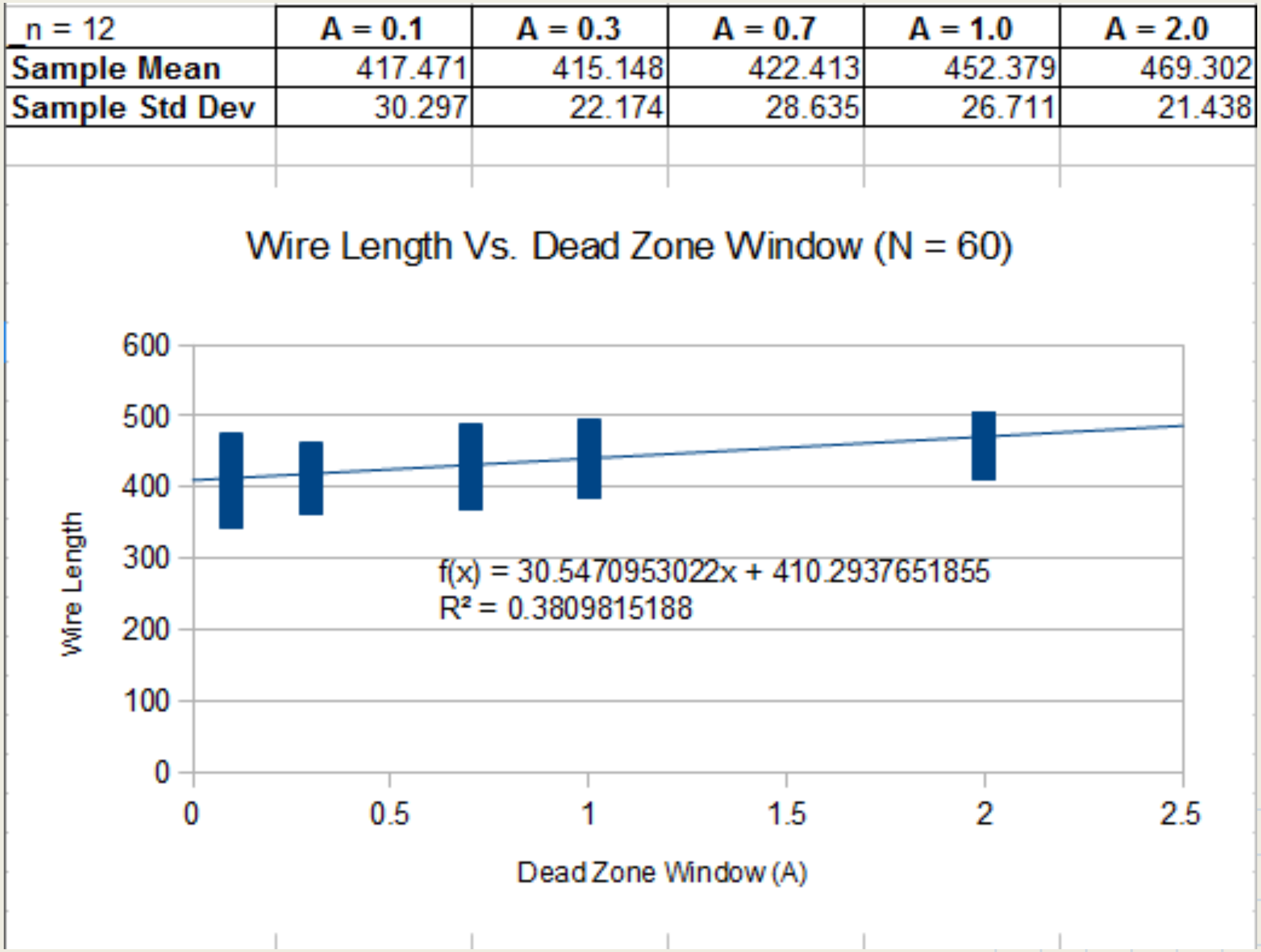
Circuit	Sample Size	Sample Mean	Sample Std Dev
fract	12	0.178	0.241
ibm01	6	584	115
industry2	3	2427	348
ibm10	1	12649	-
ibm18	-	-	-

Table: Run Time (Seconds), With TP

Circuit	Sample Size	Sample Mean	Sample Std Dev	Avg Increase (%)
fract	12	0.087	0.028	-51
ibm01	6	473	78	-19
industry2	3	3368	2373	39
ibm10	1	8574	-	-32
ibm18	-	-	-	-

* Some results are for different machines. These are preliminary results, which suggest a general trend only. The general trend is the opposite of what was expected.

Effect of Dead Zone Window (A)



n = 12	A = 0.1	A = 0.3	A = 0.7	A = 1.0	A = 2.0
Sample Mean	417.471	415.148	422.413	452.379	469.302
Sample Std Dev	30.297	22.174	28.635	26.711	21.438

Conclusion

- Terminal Propagation has positive impact on wirelength.

- To explain runtime results for non-TP vs. TP, more investigation is needed.

- The best "Dead Zone Window" for terminal propagation is ~0.3, which is similar to what was used in the text book example.