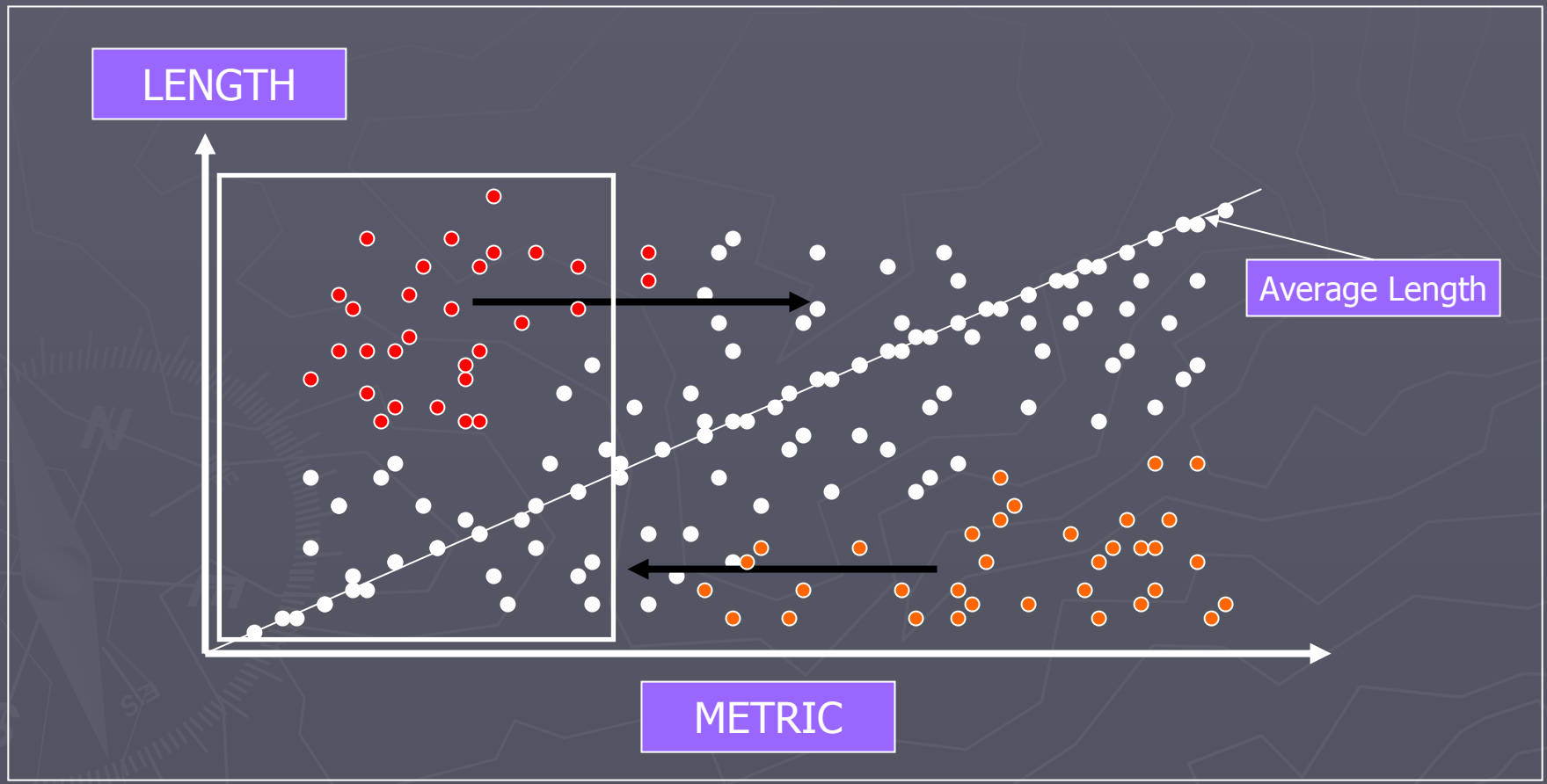
Heuristic Classification Tree for identifying the tightly clustered connections in the netlist

Pranav Anbalagan and Jeff Davis
Georgia Institute of Technology

Objective

- Is it possible to predict the length of the wires individually?
- If so, is it possible to improve upon the current methodologies?

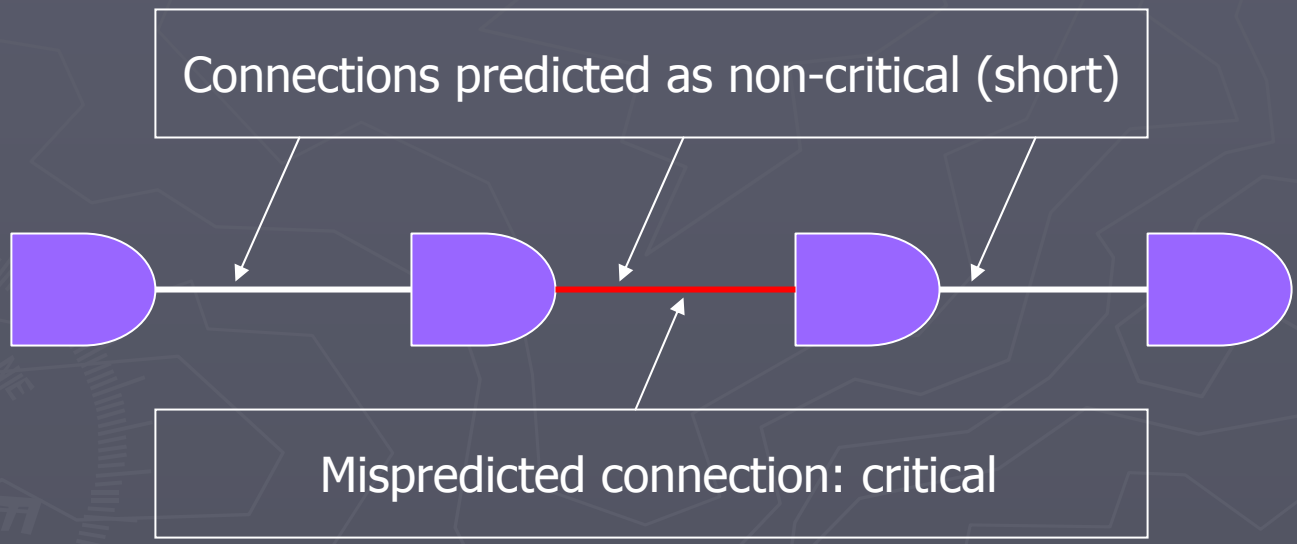
Objective



Motivation

- Accuracy is of paramount importance to develop effective and novel applications that take advantage of length prediction models
  - Implications of faulty model = Less effective applications
- Applications
  - Technology extrapolation
  - Area, Power, Delay, Routing congestion estimation
  - Placement efficiency: Runtime and wire length improvement
  - Physical driven synthesis

Implication of misprediction



Outline

- Objectives and Motivation
- Is it possible to predict the length of the wires individually?
- If so, is it possible to improve upon the current methodologies?

Predictability of wires

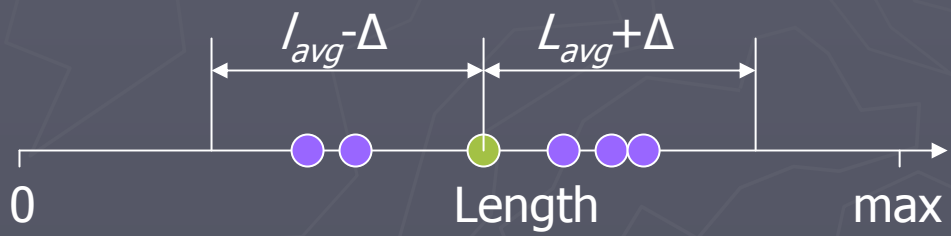
Are there wires that have consistently similar lengths in placements optimized using several placement tools?

- What fraction of wires have similar lengths?
- What are the net degrees of these wires?
- What is the length distribution of these wires?

Predictable wire has repeatable wire length

- Place a netlist using several tools
- Extract length of a wire n from the p different placements
- Calculate average of length of the wire from the p placements
- Wire is said to have repeatable length
  - If $l_{avg,n}-\Delta \leq l_{act,n,p} \leq l_{avg,n}-\Delta$ for $\forall$ p

● : Actual Length values $l_{act,n,p}$
● : Average Length value $l_{avg,n}$

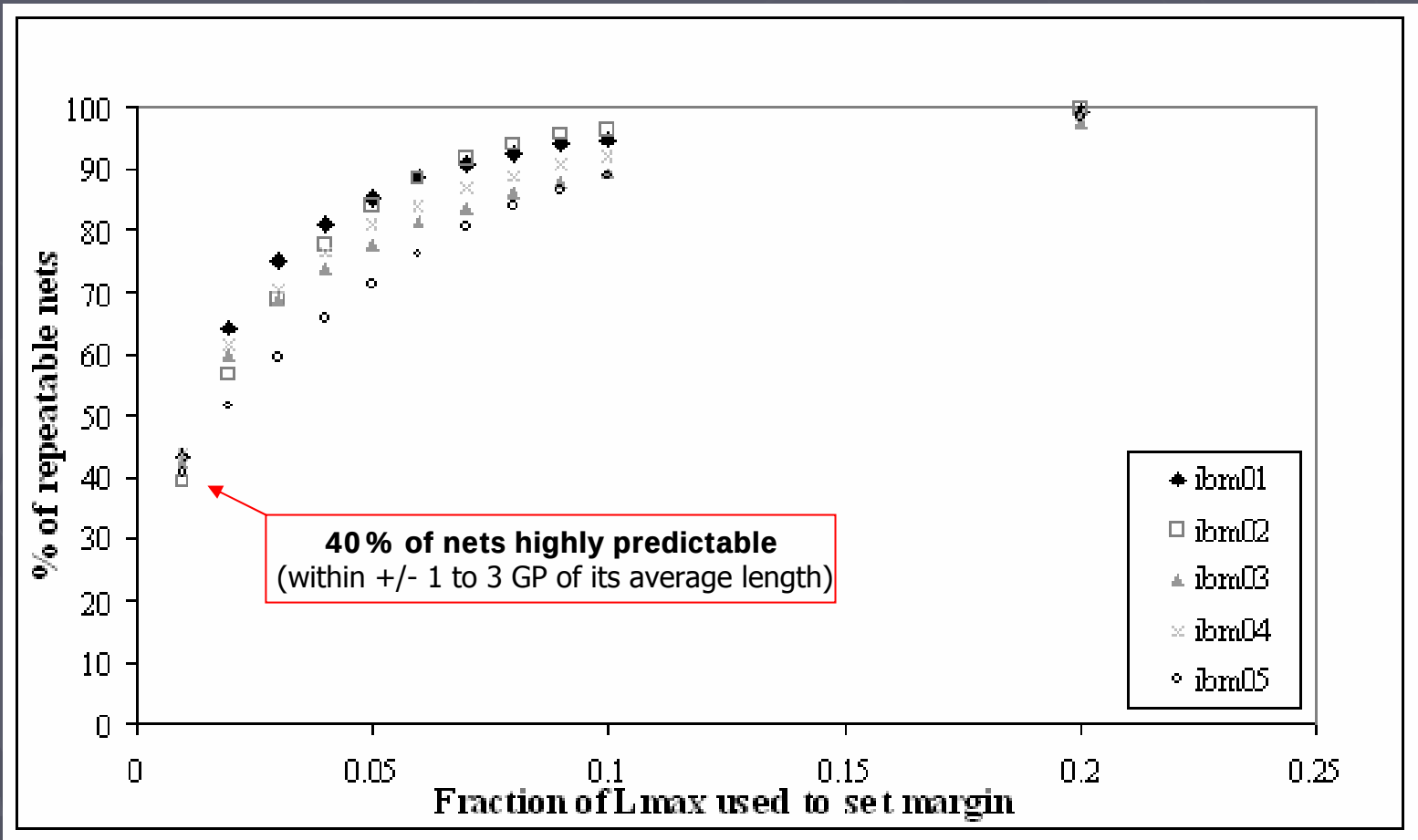


$\Delta = \delta * L_{max}$

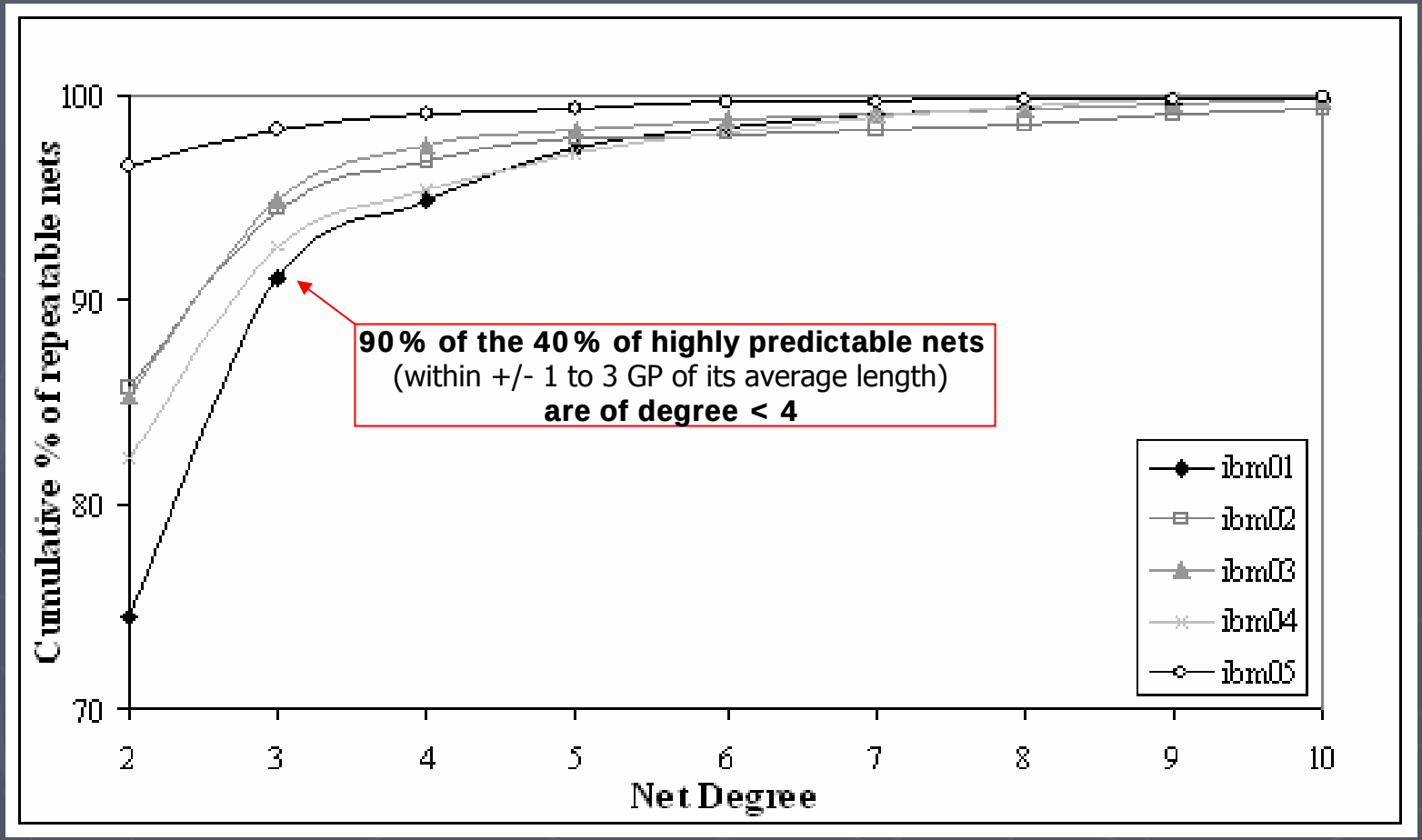
$L_{max} = \max(l_{act,n,p}) \ \forall$ n,p

$0.01 \leq \delta \leq 0.20$

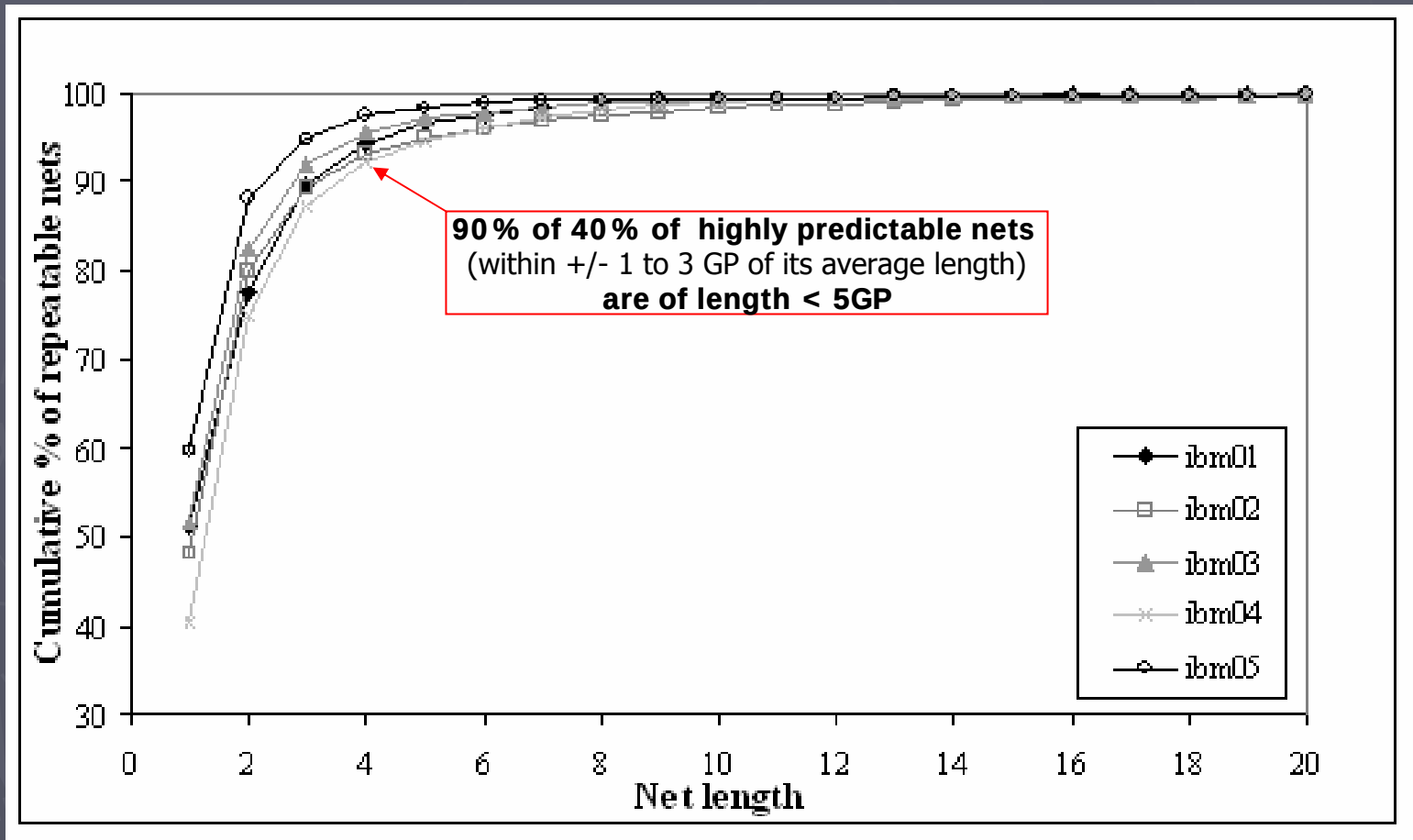
What fraction of nets have similar lengths?



What are the net degrees of these wires?



What is the length distribution of these wires?



Predictability of wires

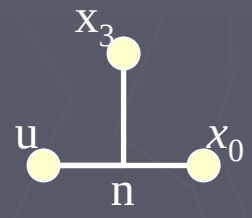
- 40% of nets have similar lengths
- 90% of them are of nets with degree < 4
- 90% of them are of nets with length < 5

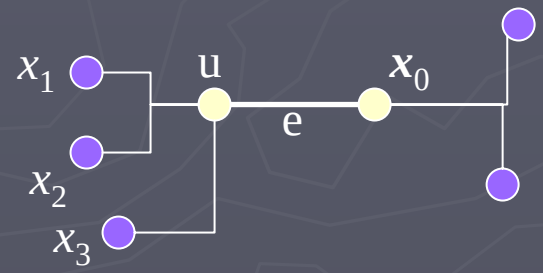
Outline

- Objectives and Motivation
- Is it possible to predict the length of the wires individually?
- If so, is it possible to improve upon the current methodologies?

Current model

- Mutual Contraction
  - Hu and Marek-Sadowska
  - Local neighborhood based metric
  - Predicts order of connections from short to long





$$w'(e) = \frac{2}{(d(n)-1)d(n)}$$

$$w_r(u,x_0) = \frac{w'(u,x_0)}{\sum_{x_i} w'(u,x_i)}$$

$$mc(u,v) = w_r(u,v)w_r(v,u)$$

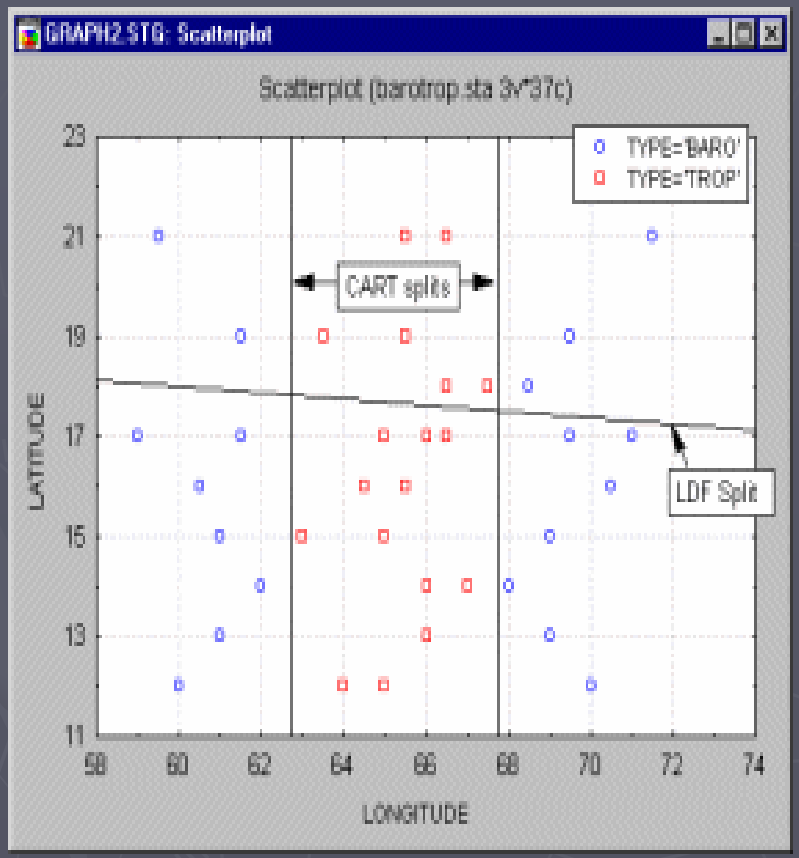
Model development

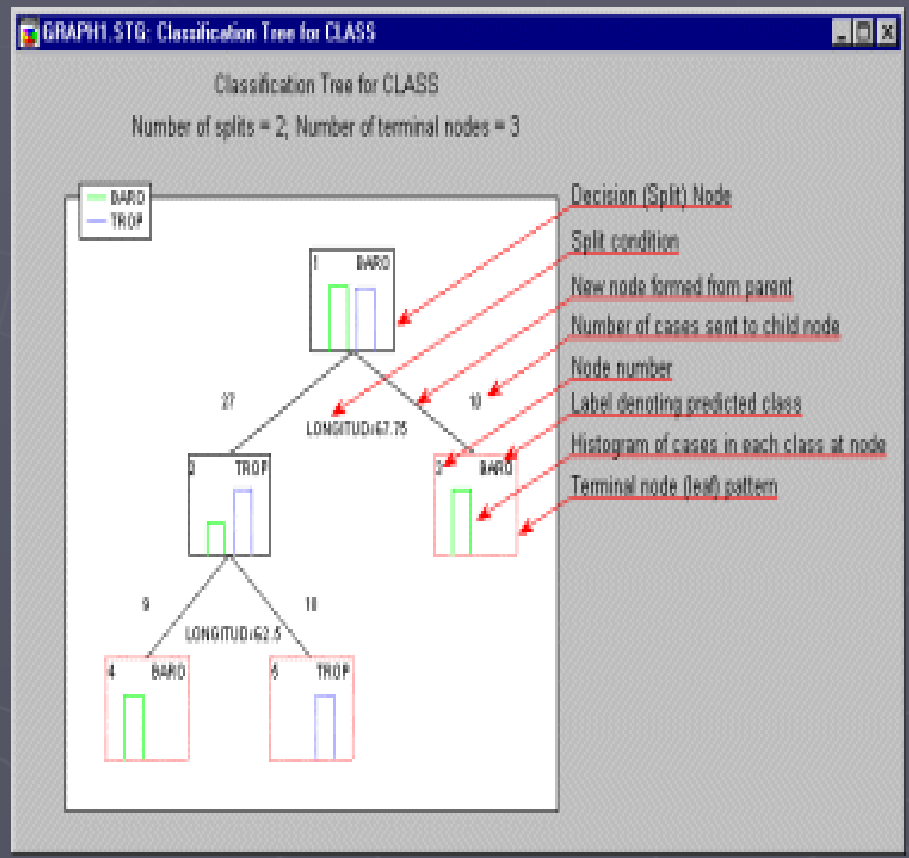
Why model complex placement process using a single, simple metric?

What if there are several metrics/properties that make the wires reach certain length consistently?

What could be a possible framework to combine several properties or metrics?

Classification and regression tree framework





* source: http://www.statsoft.com/textbook/stclatre.html

Model development

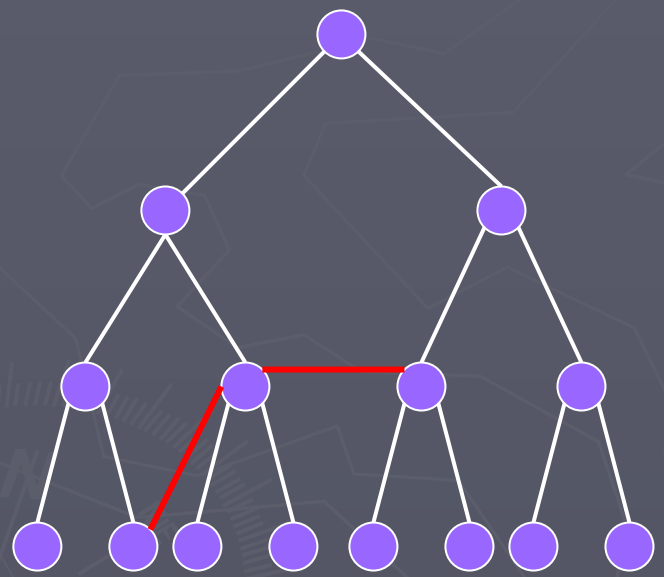
Motivation for choice of attributes

Identify attributes

Build model – heuristic classification splits

Evaluate model

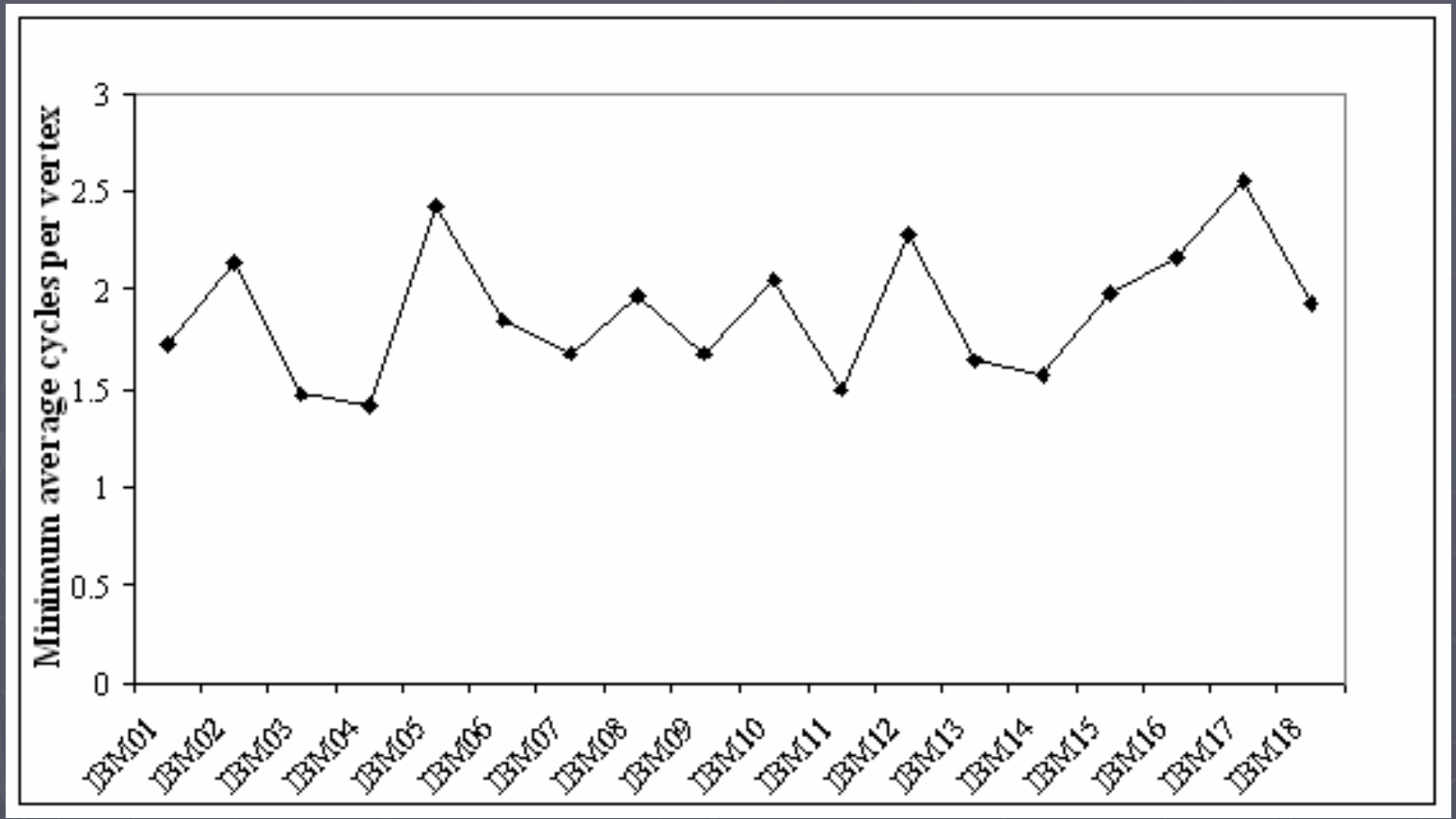
Lower bound on number of cycles in a graph



min(C)/V = 2/15 = 0.1333

- Graph
  - # of vertices, V
  - # of Edges in Graph, Eg
  - # of Edges in Tree, Et
  - Et = V-1
  - # of Cycles in Graph, C
  - min(C)= max(0, Eg-Et)
  - Minimum number of cycles per vertex = min(C)/V

Minimum number of average cycles per vertex



Model development

Motivation for choice of attributes

Identify attributes

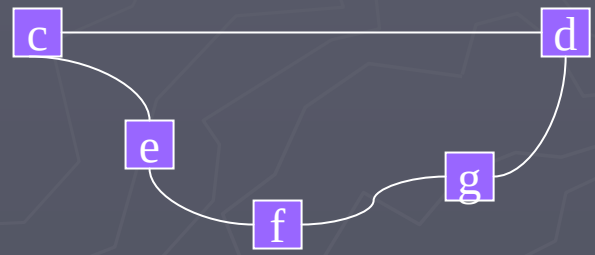
Build model – heuristic classification splits

Evaluate model

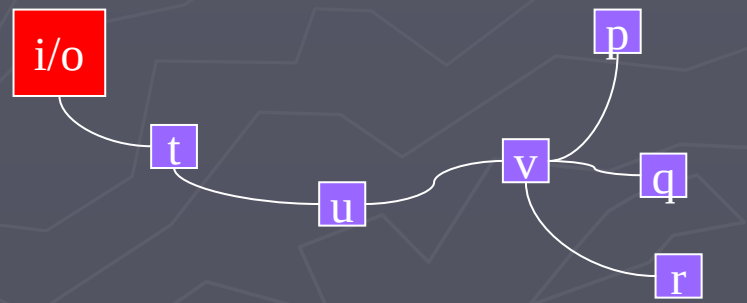
Identified Attributes

- Direct path
  - Number of paths
  - Minimum (degree of the connection's net)

- Indirect path
  - Rank, function of (number of connections in indirect path, degree of connection's net in indirect path)



- Floating Chain
  - 2 pin net chain connected to I/O pad



Model development

Motivation for choice of attributes

↓

Identify attributes

↓

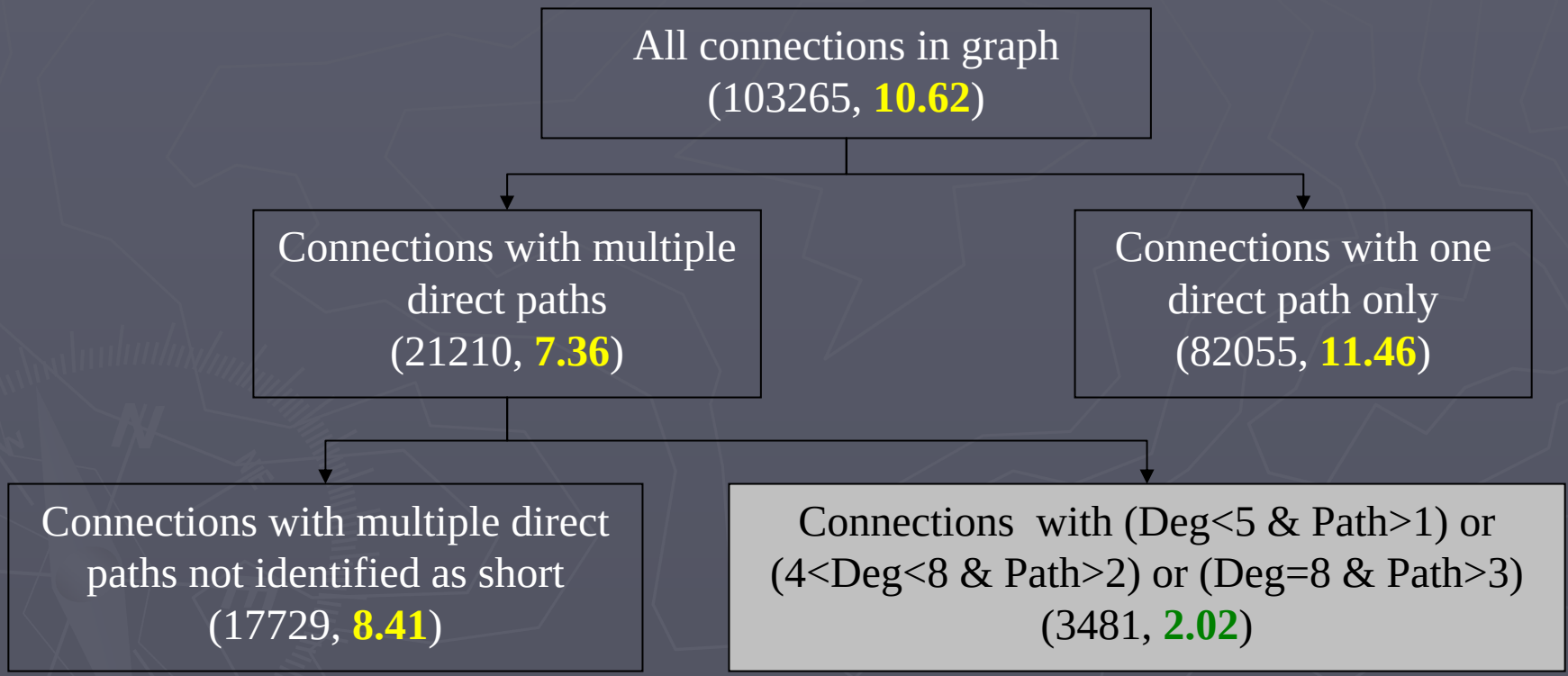
Build model – heuristic classification splits based on ibm01

Evaluate model using ibm02 –ibm18

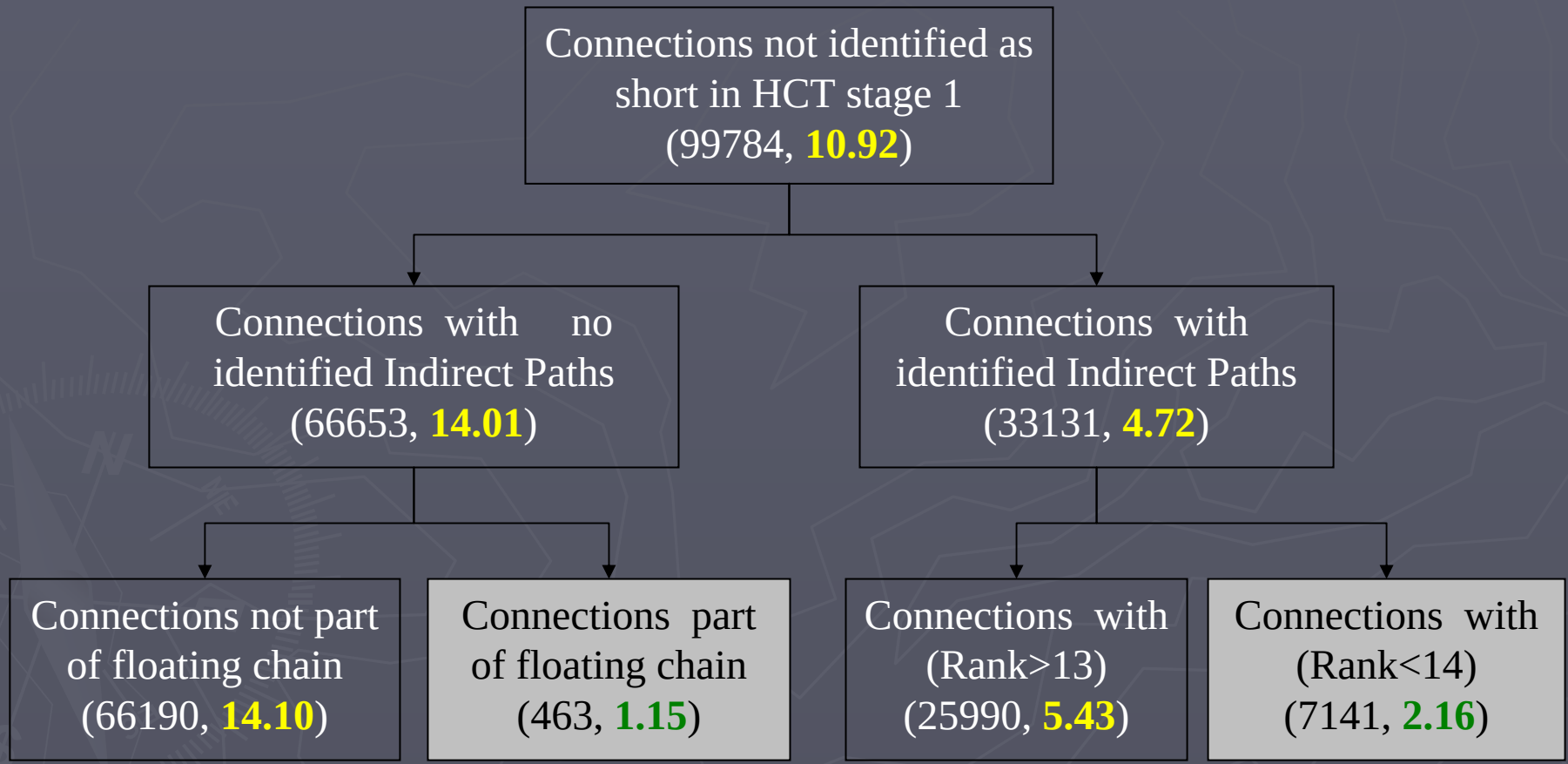
Multiple direct path based shorter connection identification

Min (Deg)	Number of Paths					
	2	3	4	5	6	7
2	1.49	1.76	1.24	1	1	0
3	2.01	1.62	1.66	1.19	1	1
4	2.52	2.05	2.01	2	1	1.4
5	3.2	2.26	2.15	1.56	1	1
6	4.08	2.06	2.97	2.29	2	1
7	3.61	2.76	2.51	2.25	2.43	1.75
8	5.33	4.5	2.59	0	2	0
9	5.69	5.27	5.55	2	0	0
10	10.25	5.37	3.91	0	0	0

HCT stage 1


All connections in graph
(103265, 10.62)
Connections with multiple direct paths
(21210, 7.36)
Connections with one direct path only
(82055, 11.46)
Connections with multiple direct paths not identified as short
(17729, 8.41)
Connections with (Deg<5 & Path>1) or (4<Deg<8 & Path>2) or (Deg=8 & Path>3)
(3481, 2.02)

HCT stage 2


Connections not identified as short in HCT stage 1 (99784, 10.92)
Connections with no identified Indirect Paths (66653, 14.01)
Connections with identified Indirect Paths (33131, 4.72)
Connections not part of floating chain (66190, 14.10)
Connections part of floating chain (463, 1.15)
Connections with (Rank>13) (25990, 5.43)
Connections with (Rank<14) (7141, 2.16)

Model development

Motivation for choice of attributes

↓

Identify attributes

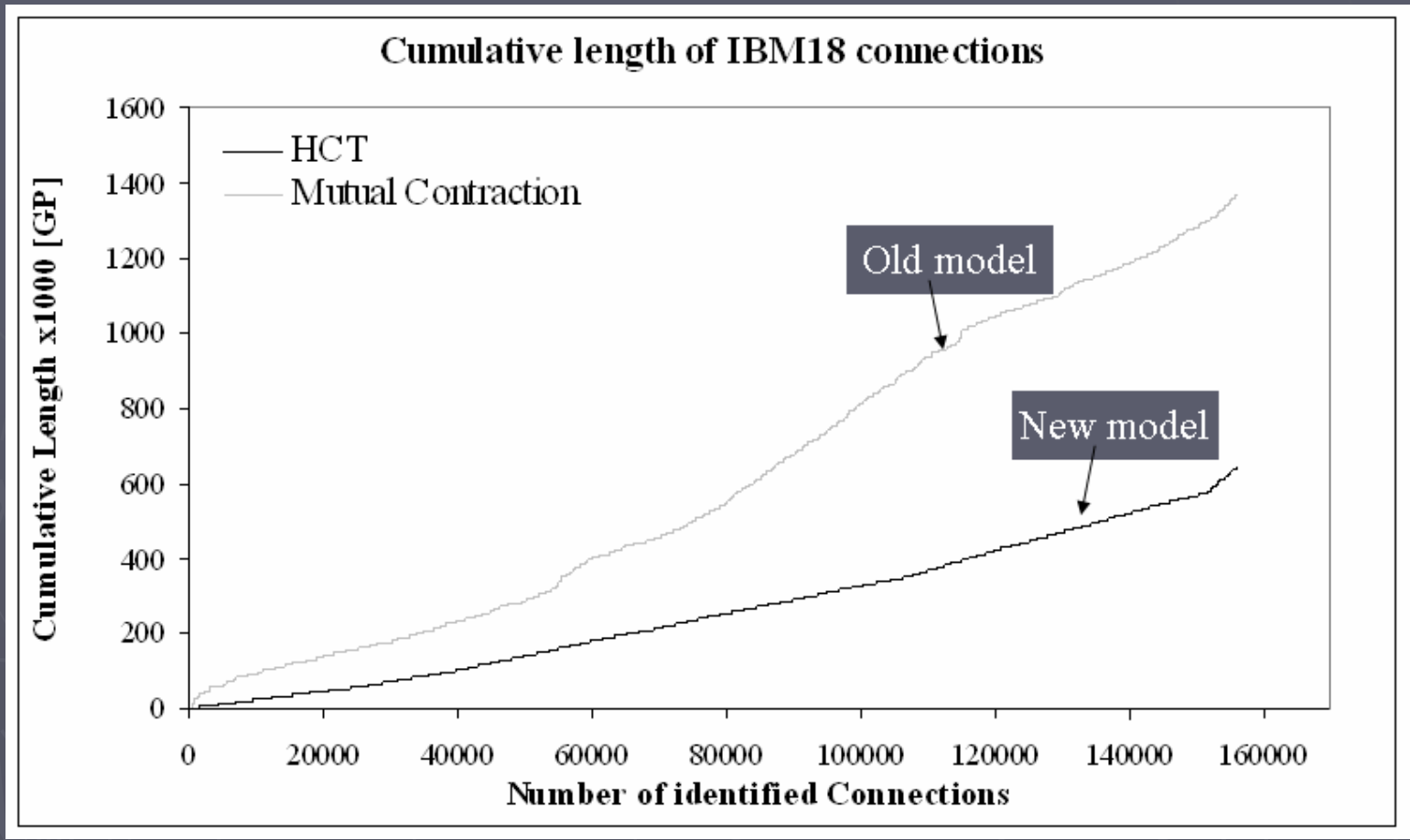
↓

Build model – heuristic classification splits based on ibm01

↓

Evaluate model using ibm02-ibm18 in terms of cumulative length, violation

HCT vs. MC : cumulative length

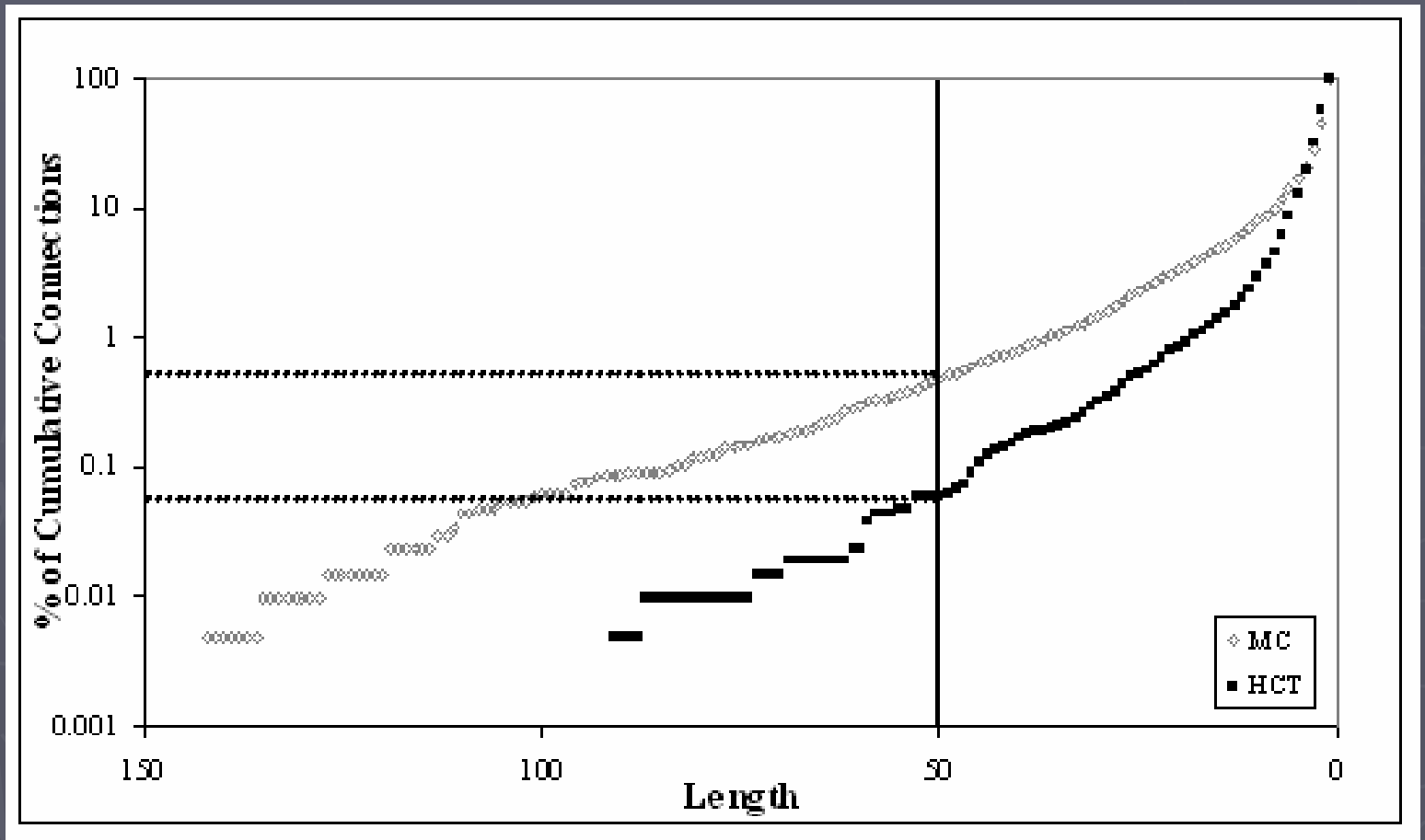


Mutual Contraction: B. Hu and M. Marek-Sadowska, "Wire length prediction based clustering and its application in placement," in *ACM/IEEE Design Automation Conference,* 2003, pp. 800-805

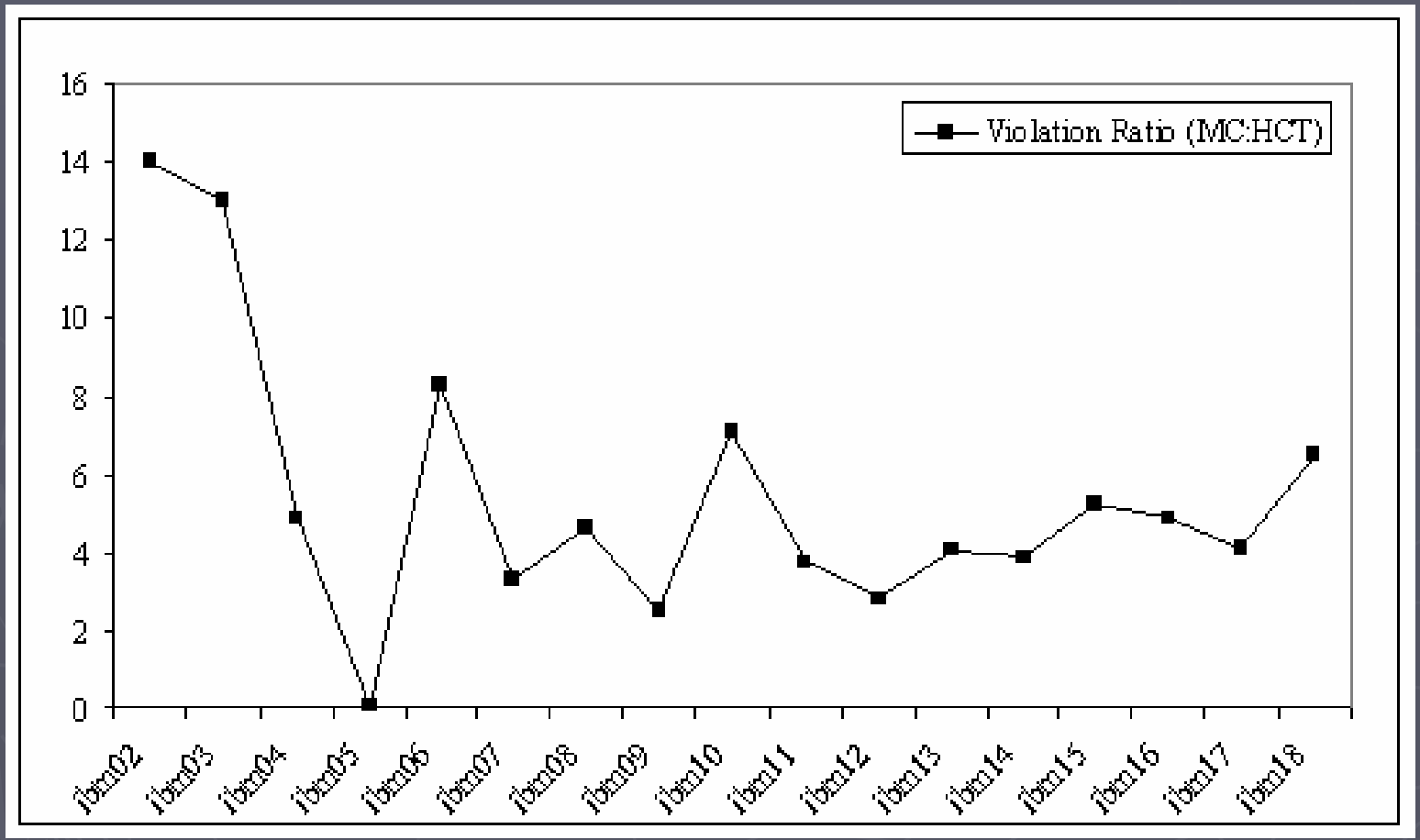
HCT vs. MC : placement tool

Circuit	% Difference in cumulative length with respect to MC results from SA		
	HCT-SA	HCT-Dragon	HCT-Capo
IBM02	-14.47	-12.25	-12.32
IBM03	-25.19	-18.43	-16.09
IBM04	-30.76	*-16.02*	*-24.08*
IBM05	47.36	*35.65*	*31.51*
IBM06	-33.80	-26.24	-38.45
IBM07	-68.59	-56.06	-64.80
IBM08	-60.39	-55.87	-64.72
IBM09	-24.13	-0.61	-6.36
IBM10	-100.47	-92.36	-87.39
IBM11	-60.57	-49.06	-51.21
IBM12	-9.45	*-13.85*	*1.26*
IBM13	-39.65	-33.93	-43.92
IBM14	-64.25	-45.16	-66.14
IBM15	-96.06	-74.18	-92.38
IBM16	-96.34	-69.19	-86.31
IBM17	-56.84	*-28.38*	*-37.05*
IBM18	-125.82	-86.81	-96.62
Average	**-50.64**	**-38.23**	**-44.63**

HCT vs. MC : Number of misprediction vs. short definition



HCT vs. MC : Major violation ratio



Conclusion

- Individual net length prediction possible for 40% of the nets!
  - 90% of the highly predictable nets are of length<5 and degree<4
- Multiple properties can be combined to improve prediction using classification tree frameworks!
  - Cumulative length at least 38% less for short connections identified by HCT when compared to MC independent of placement tool!
  - Major Violations in HCT is $1/5^{th}$ that of MC on average!