Fast estimation of the partitioning Rent characteristic using a recursive partitioning model

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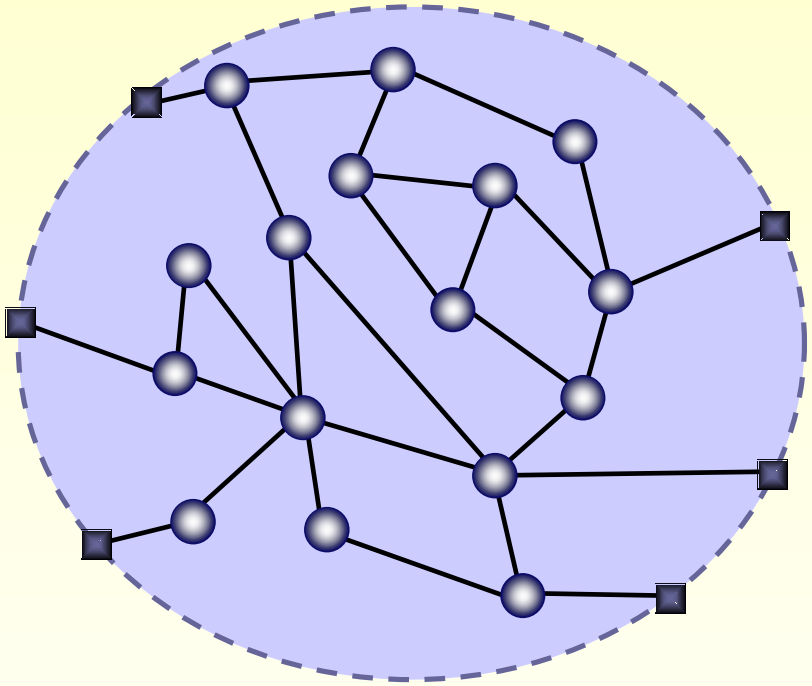
Presentation outline

- Rent's rule vs. the Rent characteristic
- Recursive (bi-)partitioning equations
- Cut probability models
- Validation and application for fast estimation of the Rent characteristic
- Conclusions & future work

The circuit graph



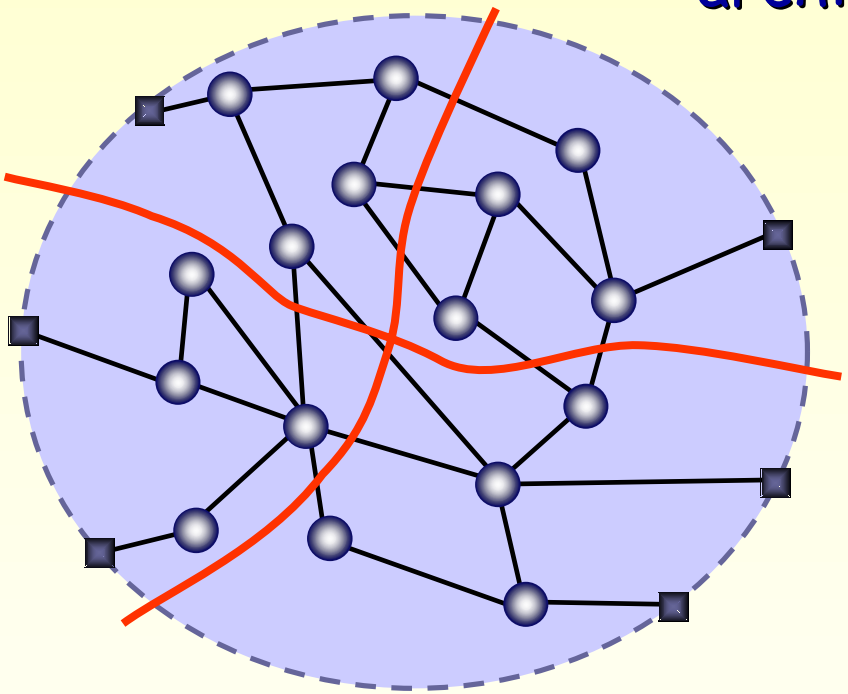
Circuit **netlist**, consists of:

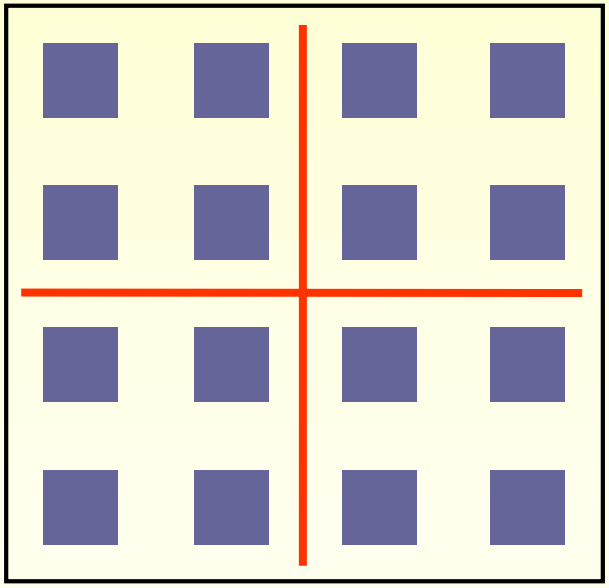
- G_c gates
- N_c connections between gates (*internal nets*)
- T_{ext} Connections to circuit's exterior (*external nets* or *pins*)

Only two-terminal connections considered !

Donath-based prediction of placement wire lengths

Perform recursive partitioning of circuit and architecture

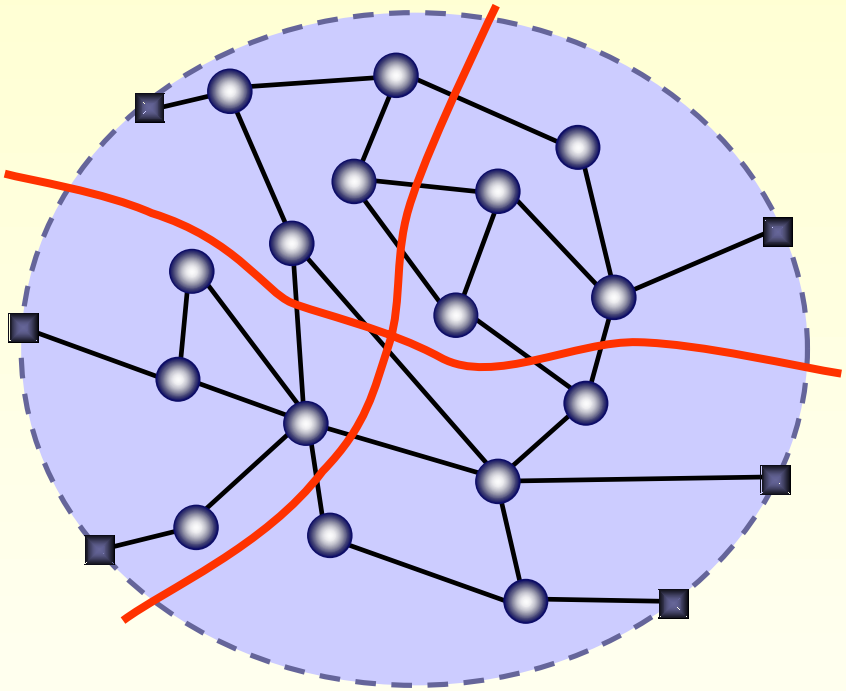




circuit

architecture

Donath-based prediction of placement wire lengths



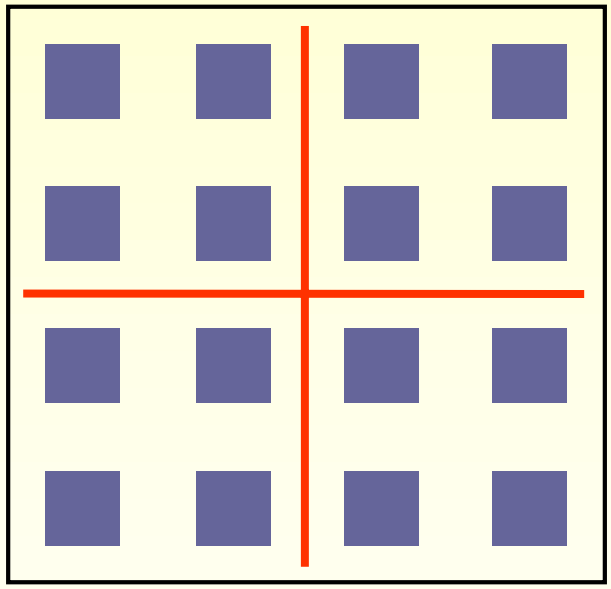
circuit

At each level:

calculate number of cut nets …

Donath-based prediction of placement wire lengths

... and their length distribution from the architecture site functions



architecture

Recursive circuit partitioning ... modeled by Rent's rule??

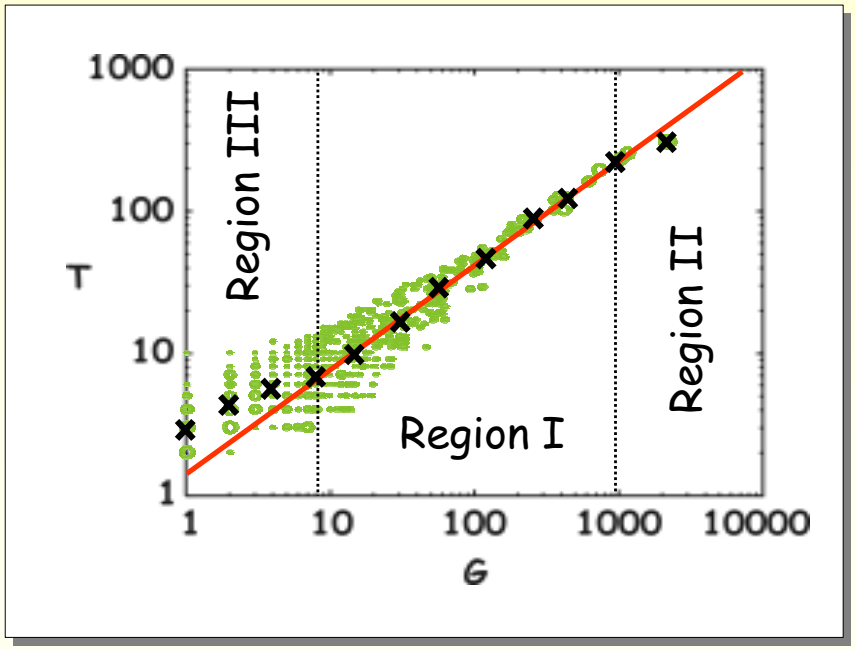
For a particular circuit netlist:

- Perform complete recursive circuit partitioning
- Find average data points for T vs. G (=Rent characteristic)
- Fit power law to region I:

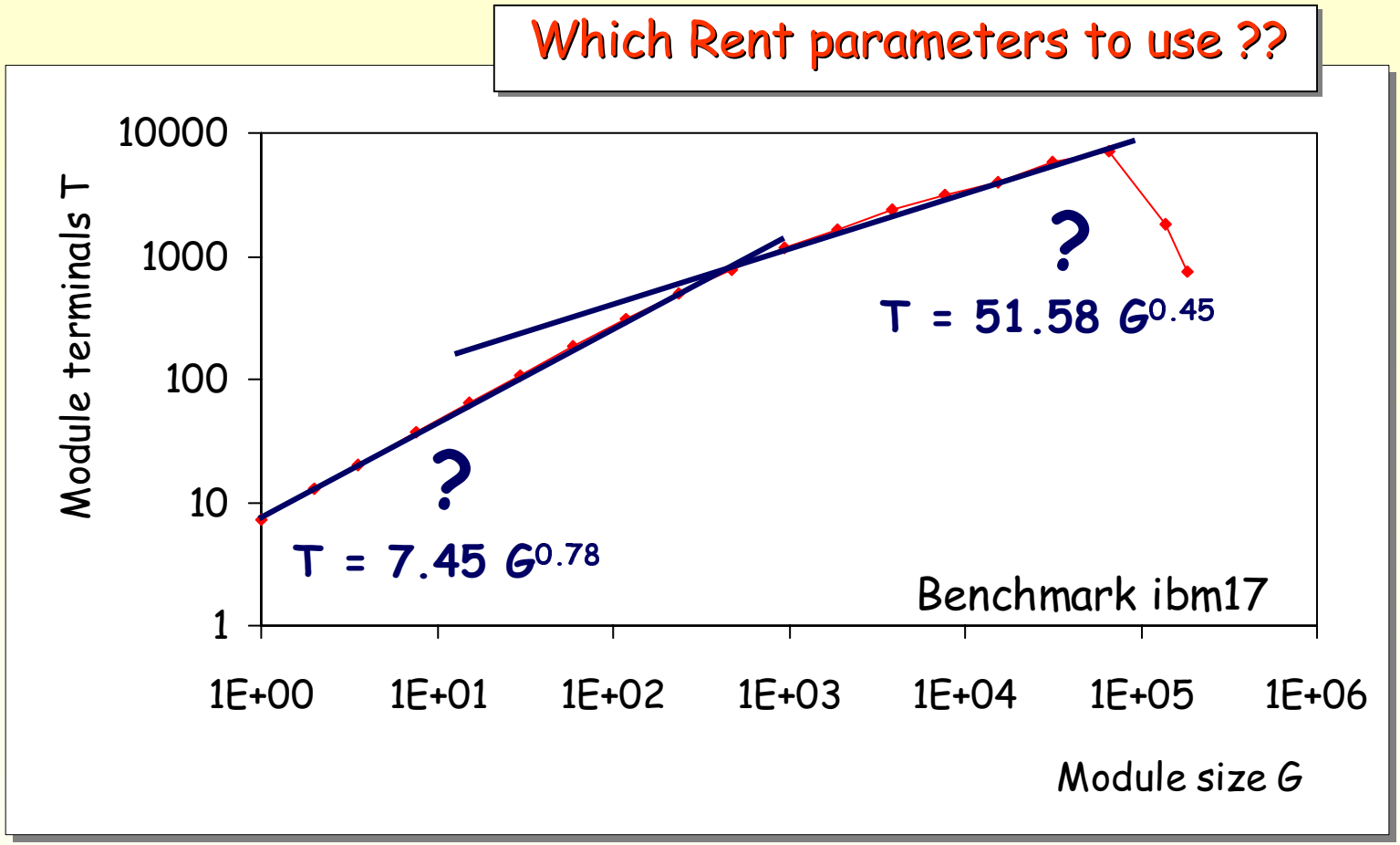
$$T = tG^p$$

p: Rent exponent

t: Rent coefficient



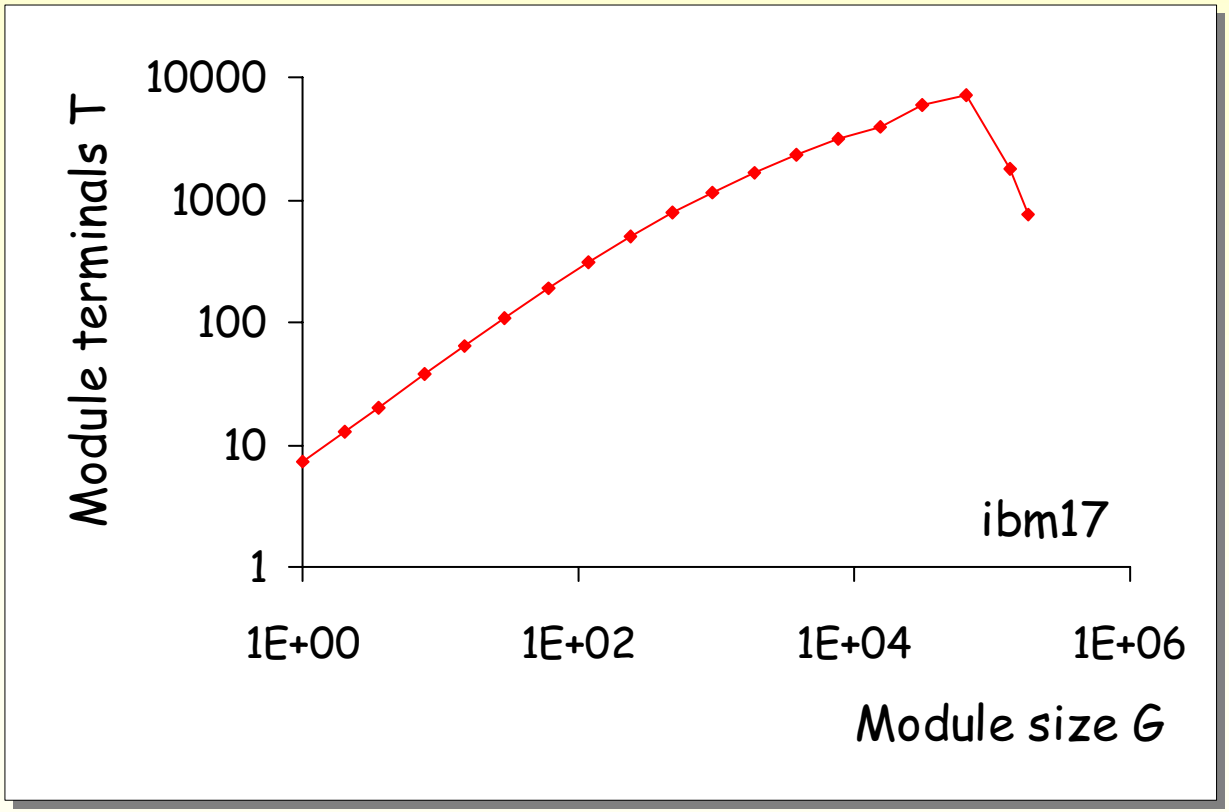
Recursive circuit partitioning ... modeled by Rent's rule??



Rent's rule vs. the Rent characteristic

Rent's rule is not a very accurate model, so ...

.... use the Rent characteristic instead of Rent's rule!

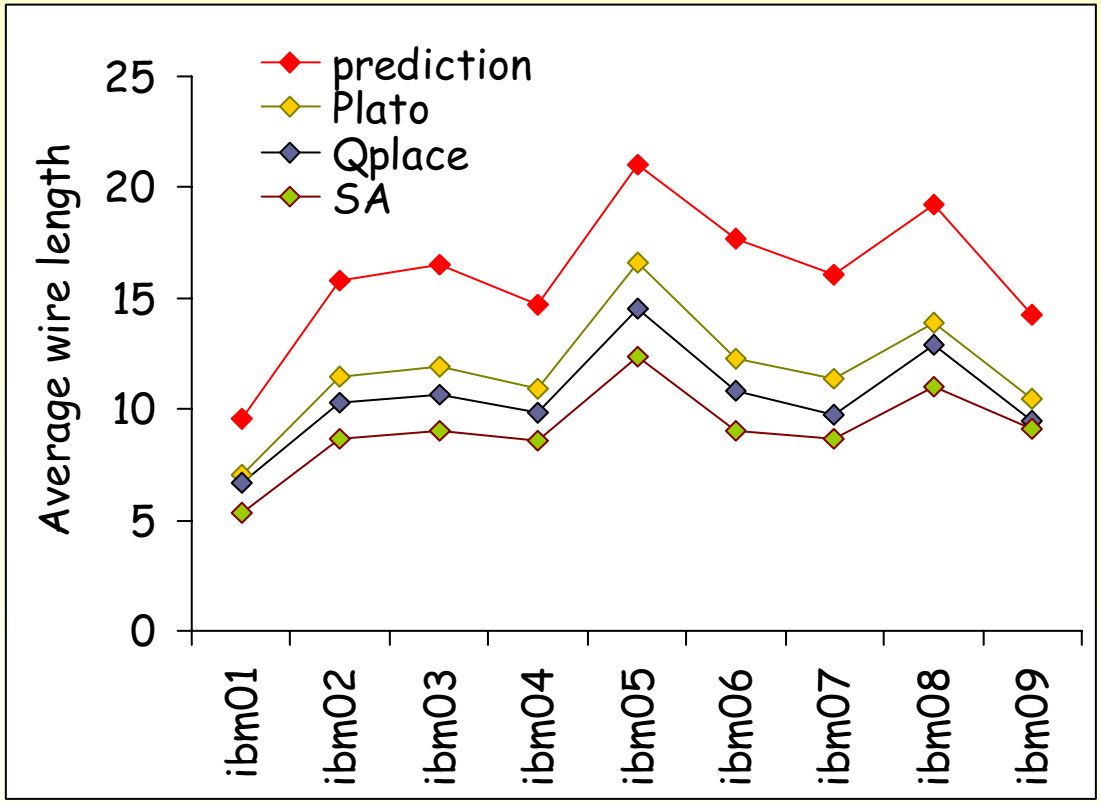


Last year's results ...

Prediction of average wire lengths, based on Donath's technique, but ...

using the Rent characteristic instead of Rent's rule

Overestimation, but very good correlation !



Rent's rule vs. the Rent characteristic

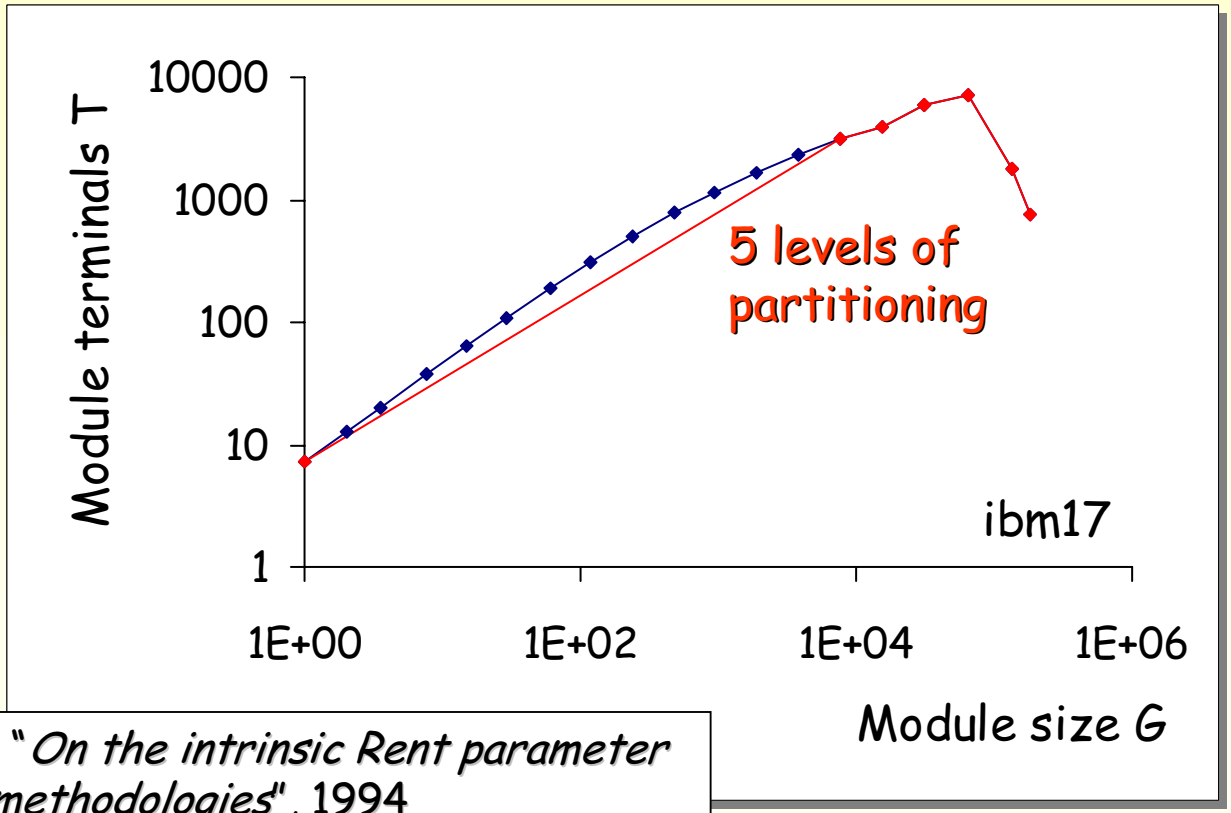
Problem: full recursive partitioning takes a lot of time

Solution I*:

perform only limited number of partitioning levels and interpolate ...

... becomes very inaccurate if too few levels

... doesn't help much if many levels



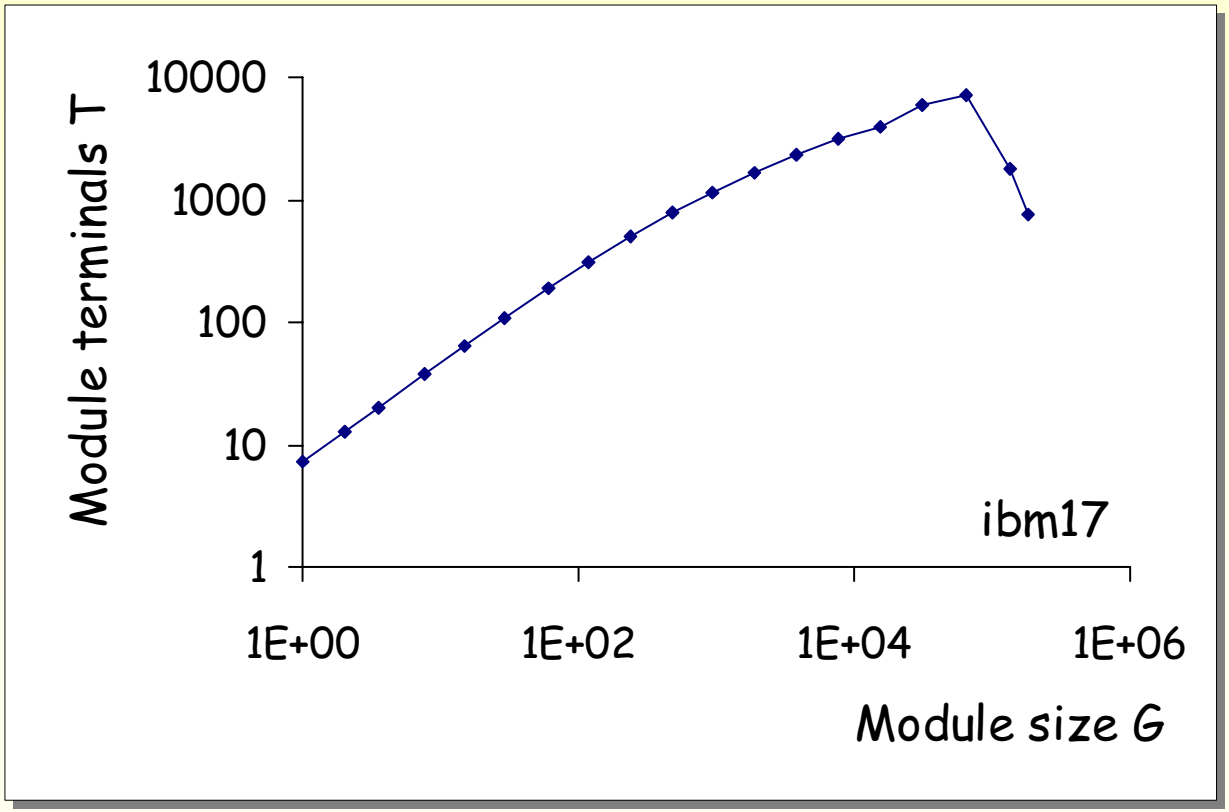
* suggested in, e.g. Hagen et al., "*On the intrinsic Rent parameter and spectra-based partitioning methodologies*", 1994

Rent's rule vs. the Rent characteristic

Problem: recursive partitioning takes a lot of time

Solution II:

find a better model than Rent's rule ??



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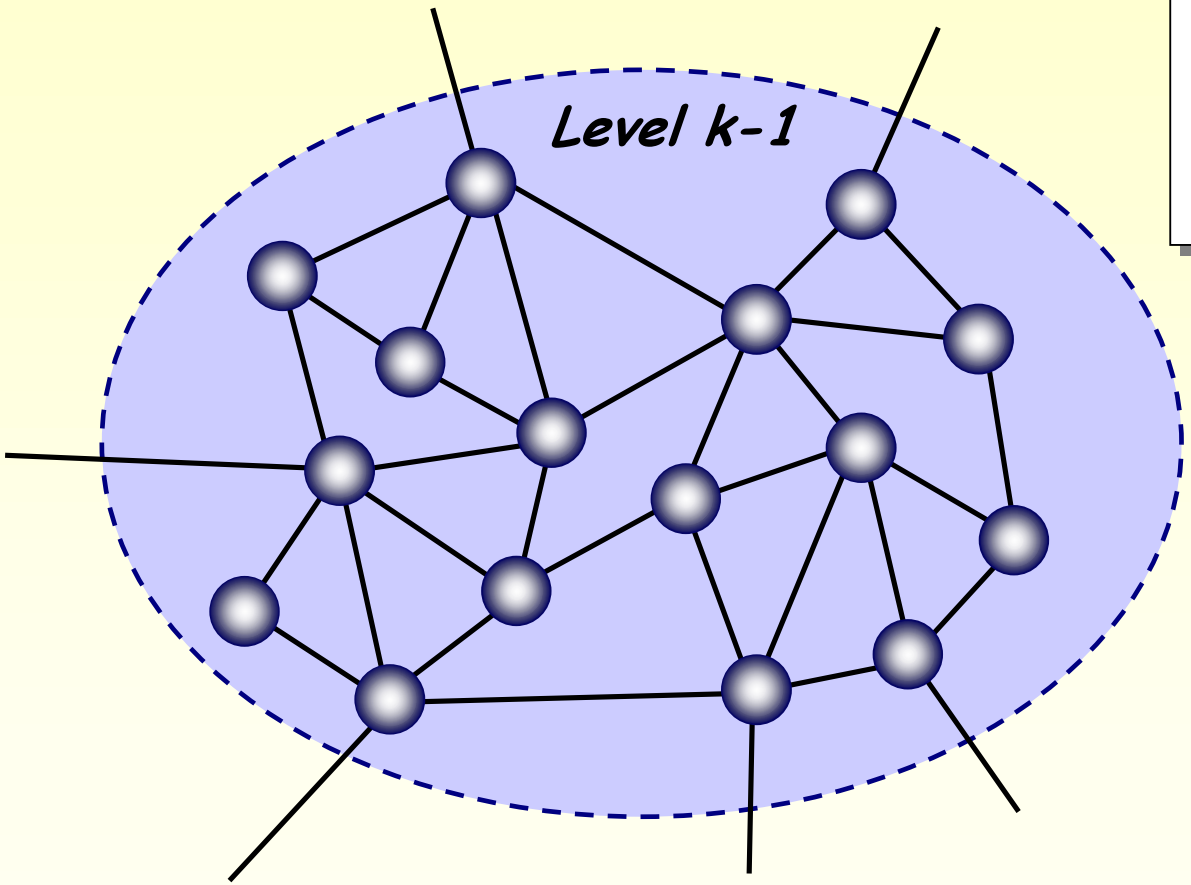
Verplaetse's recursive (bi-)partitioning equations

Hierarchy levels

k = 0 ...*H*, with:

level 0 = entire circuit,

level H = single gate



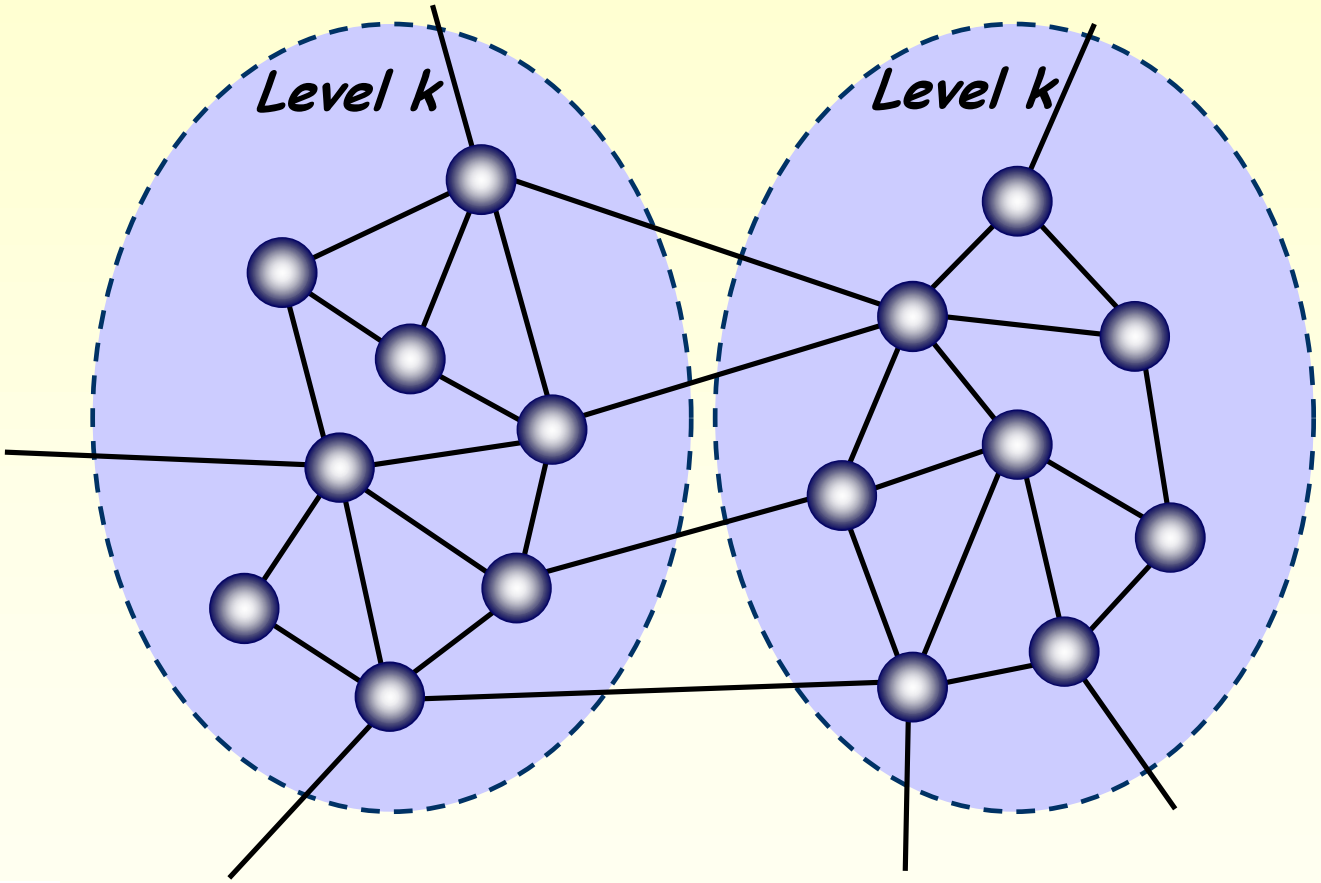
G_{k-1} = 16

T_{k-1} = 6

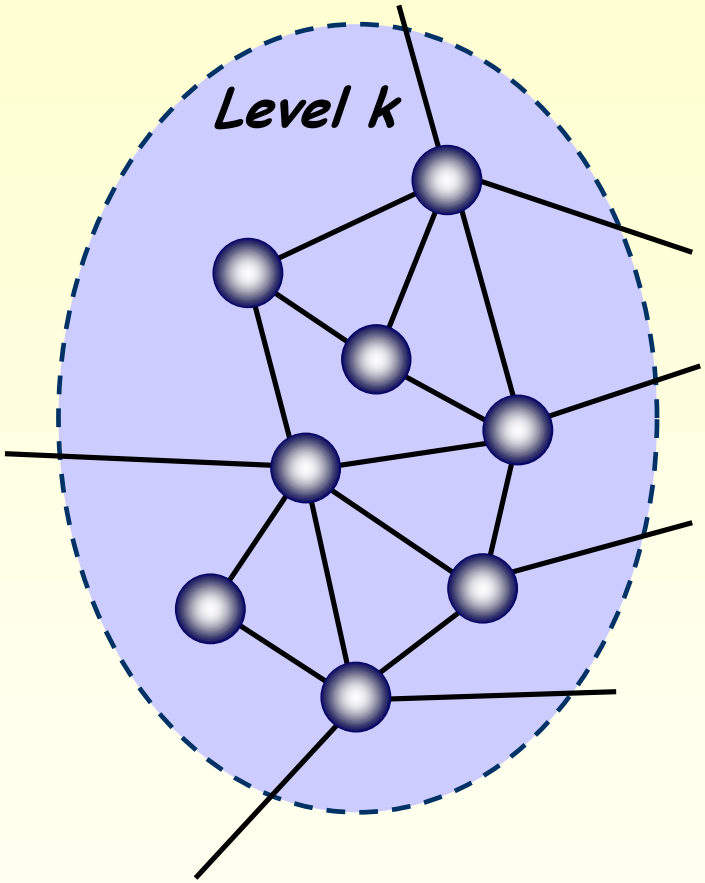
N_{k-1} = 30

Verplaetse's recursive (bi-)partitioning equations

Partition in two equal parts (balanced)



Verplaetse's recursive bipartitioning model



Define:

α_{k-1} : fraction of N_{k-1} that is cut (=*cut probability*)

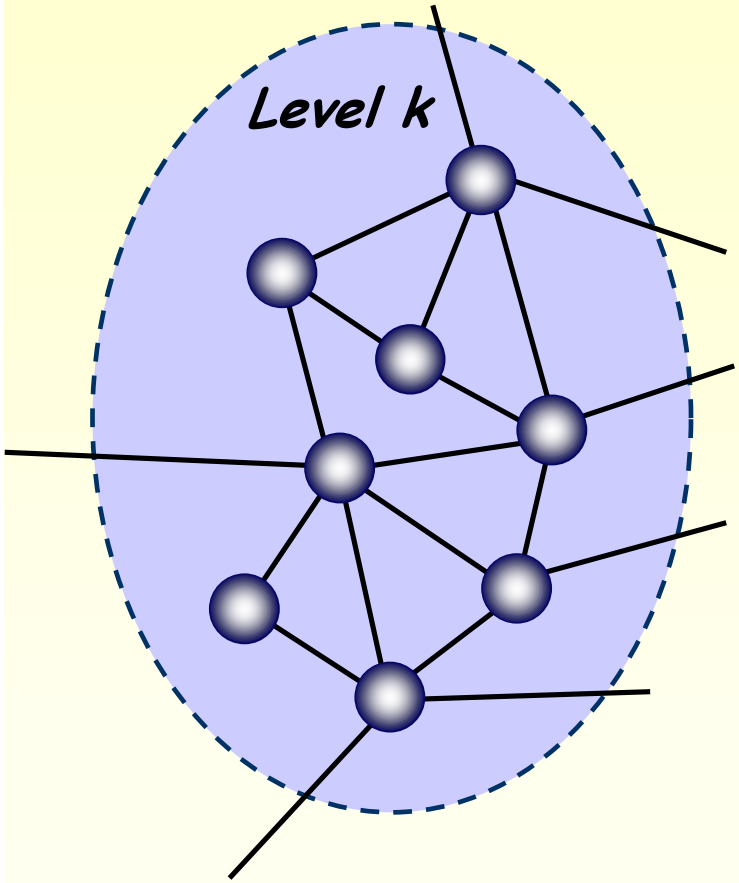
Recursive partitioning equations:

$$G_k = \frac{G_{k-1}}{2}$$

$$T_k = \frac{T_{k-1}}{2} + \alpha_{k-1} N_{k-1}$$

$$N_k = \frac{1 - \alpha_{k-1}}{2} N_{k-1}$$

Verplaetse's recursive bipartitioning model



Define:

α_{k-1} : fraction of N_{k-1} that is cut (=*cut probability*)

New problem: find expression for α_{k-1} instead of expression for T_{k-1} ??

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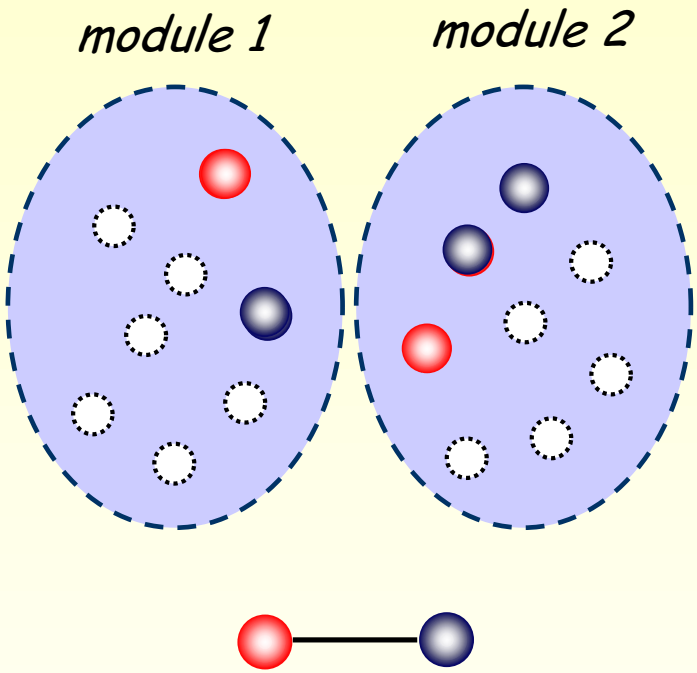
Cut probabilities for random partitioning

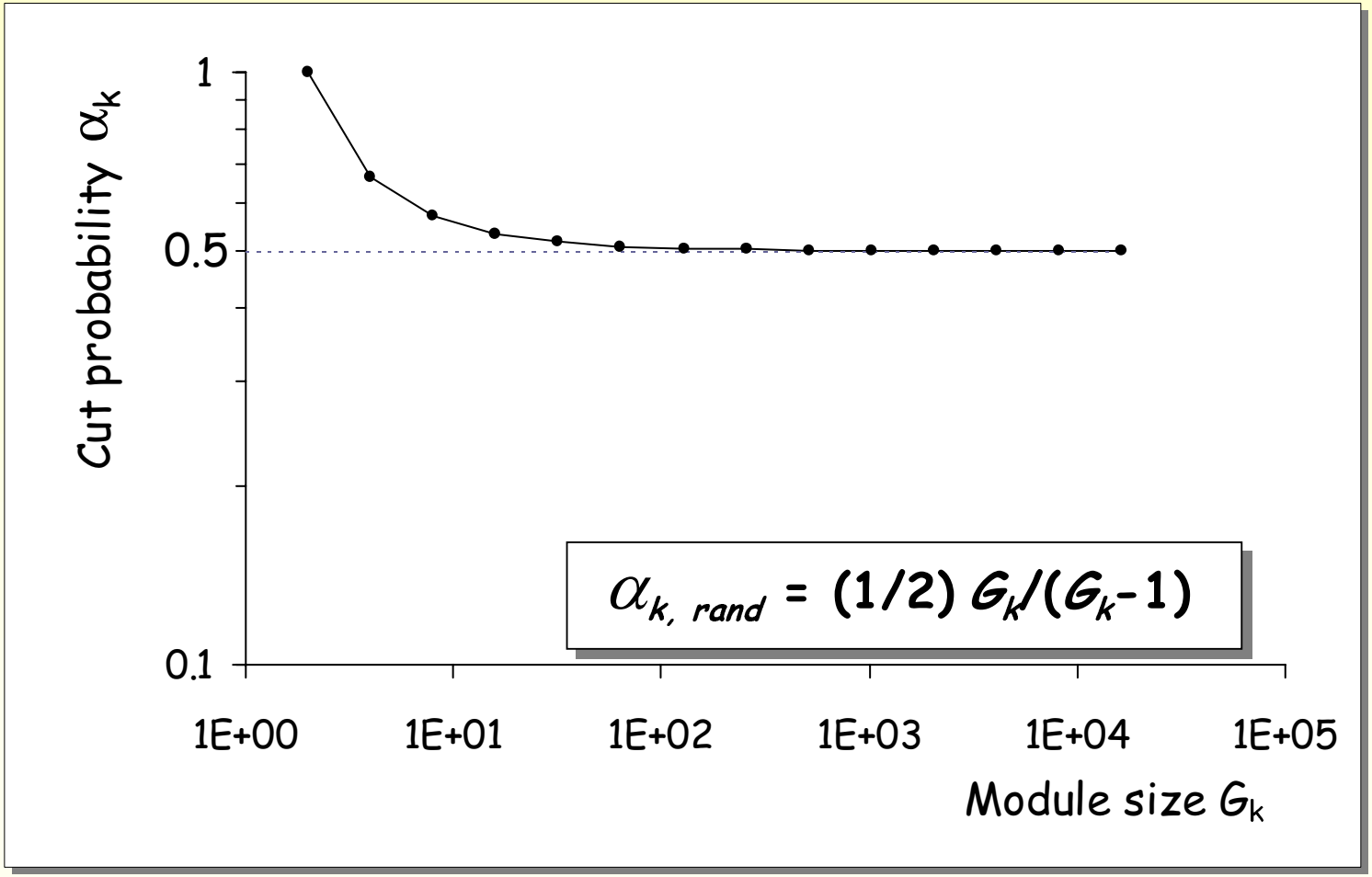


Random bipartitioning of a two-terminal net = randomly assigning both connected gates to two modules

4 possible assignments, net is cut for two of them:

$$P_{cut} = (1/2)\, G_k/(G_k-1) = \alpha_{k,\,rand}$$

Cut probabilities for random partitioning



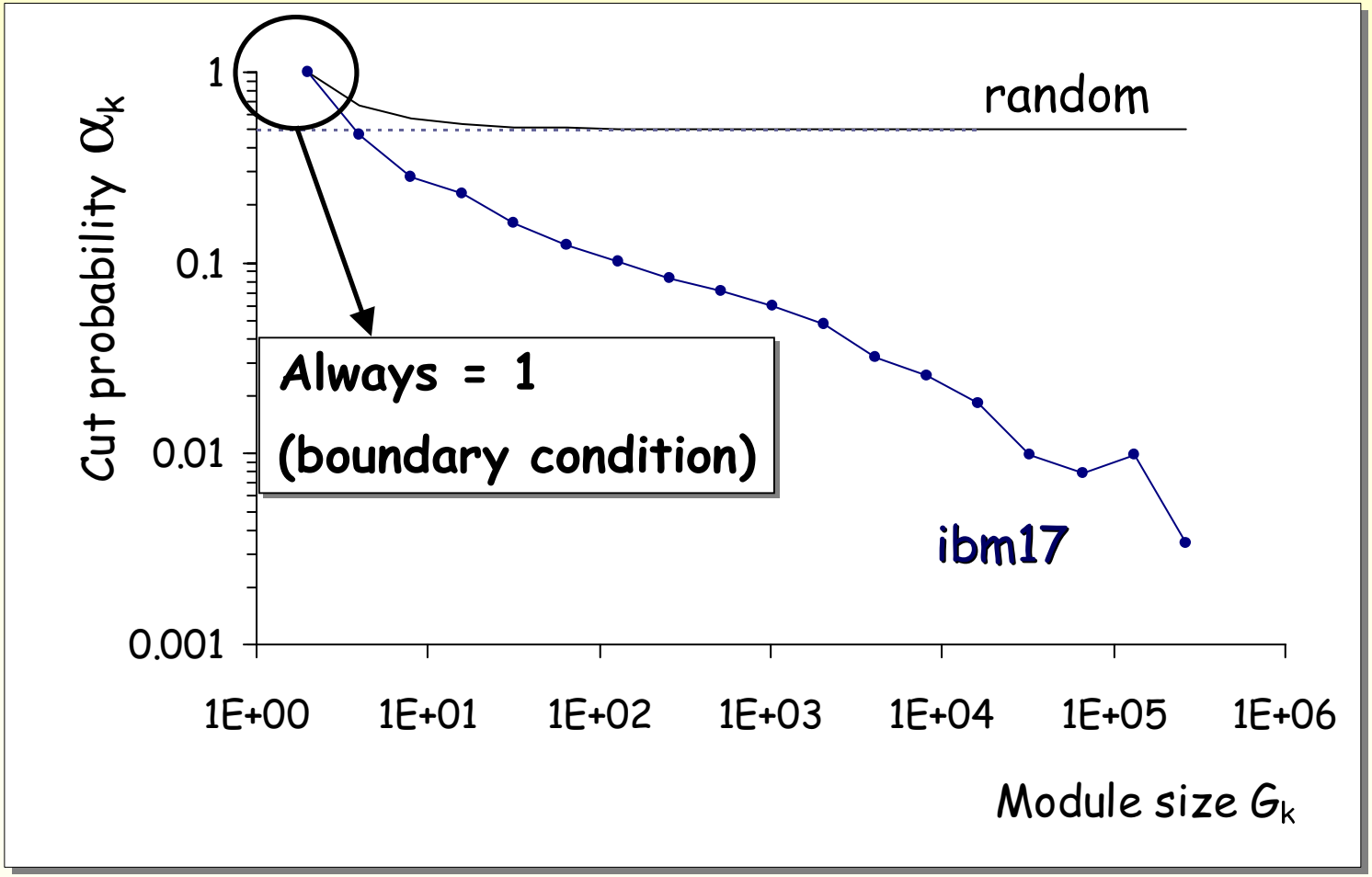
Cut probabilities for optimal circuit partitioning

Measured values of α_k ??

Must perform some manipulations on Rent characteristic because:

- circuit size not equal to 2^H
- partitionings not perfectly balanced

Cut probabilities for optimal circuit partitioning



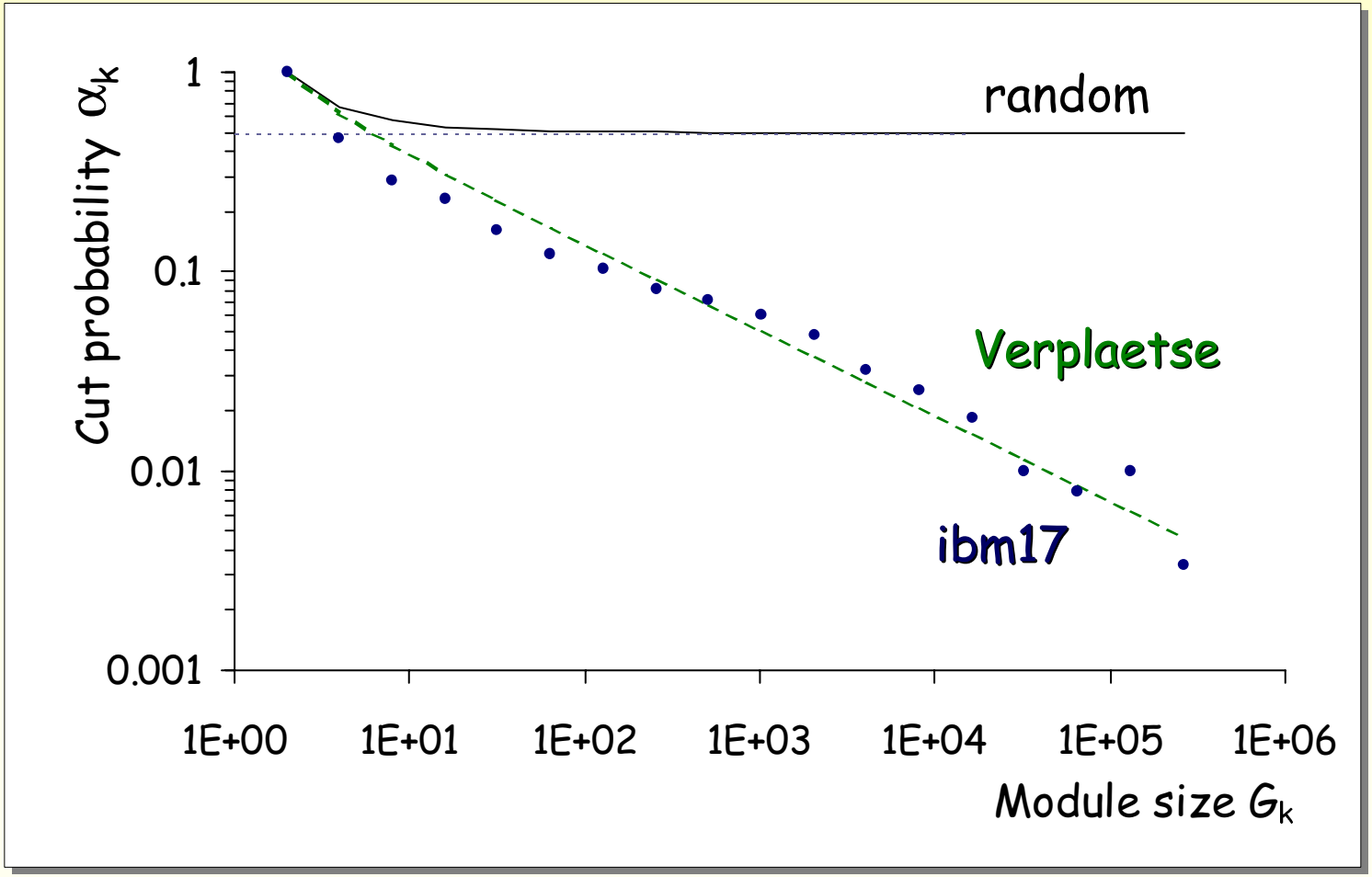
Cut probabilities for optimal circuit partitioning

Verplaetse's model for α_k :

$$\alpha_k = \frac{\tau}{2} + \frac{1 - \tau/2}{(G_k - 1)^{\varepsilon}}$$

With τ and ε parameters to be fitted

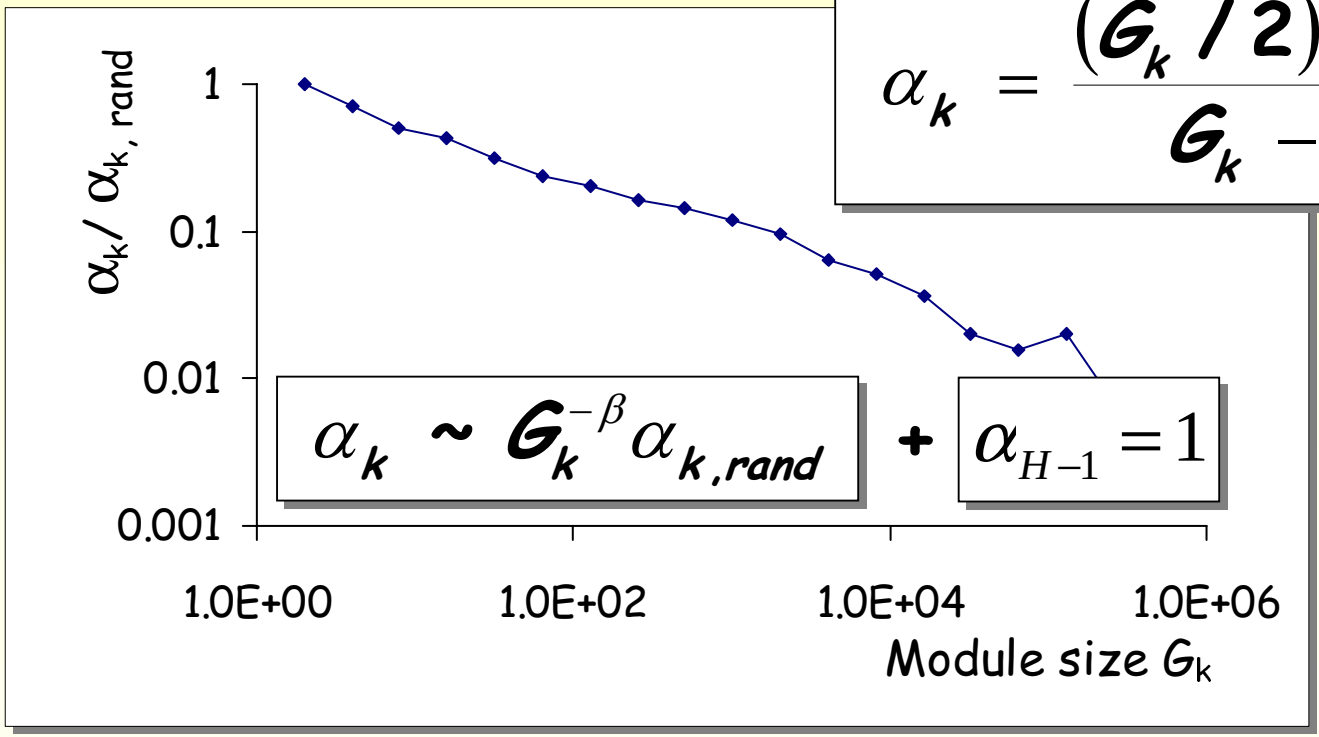
Cut probabilities for optimal circuit partitioning



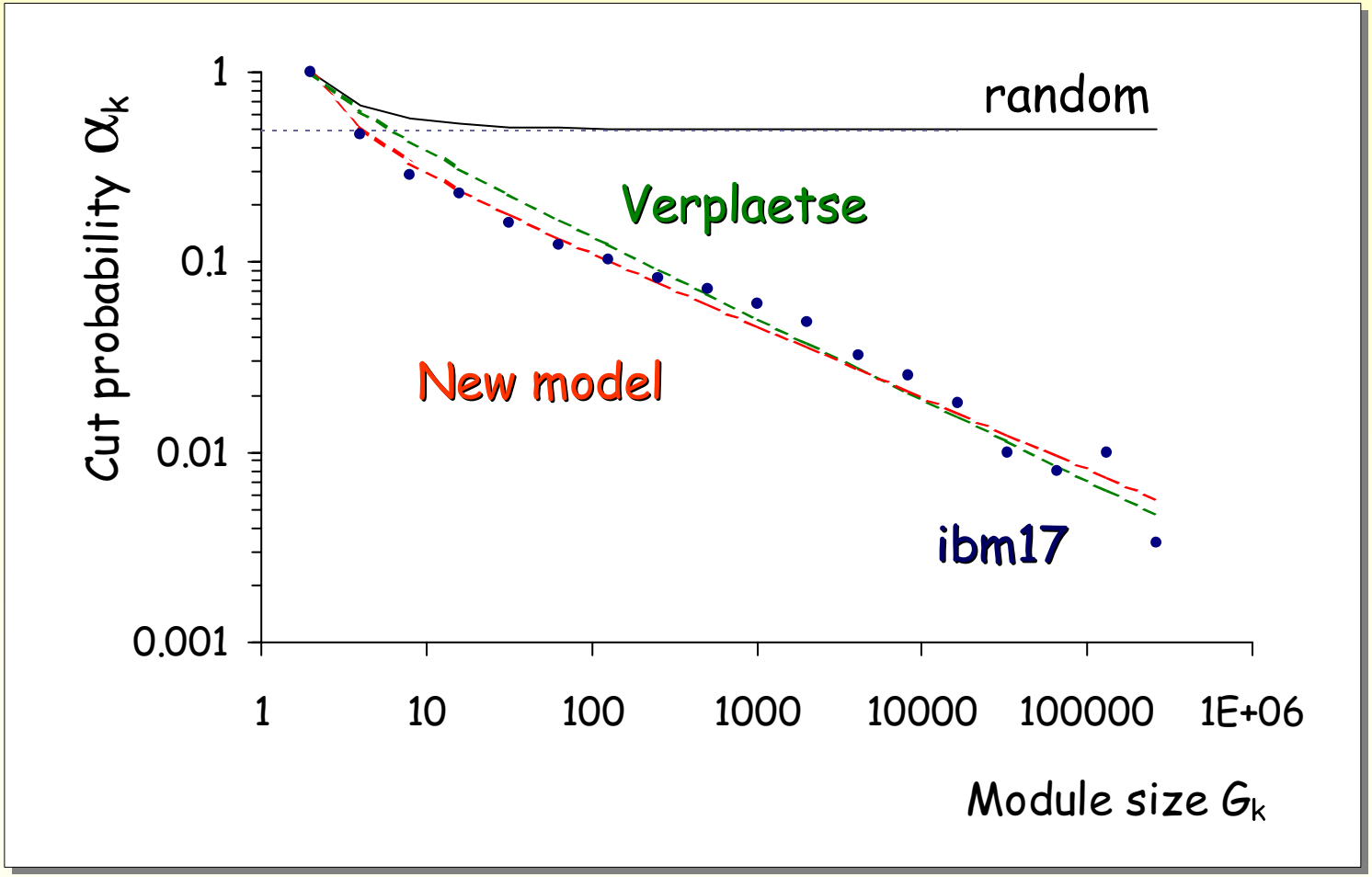
Cut probabilities for optimal circuit partitioning

New model for α_k : based on observed relationship between α_k and $\alpha_{k,rand}$

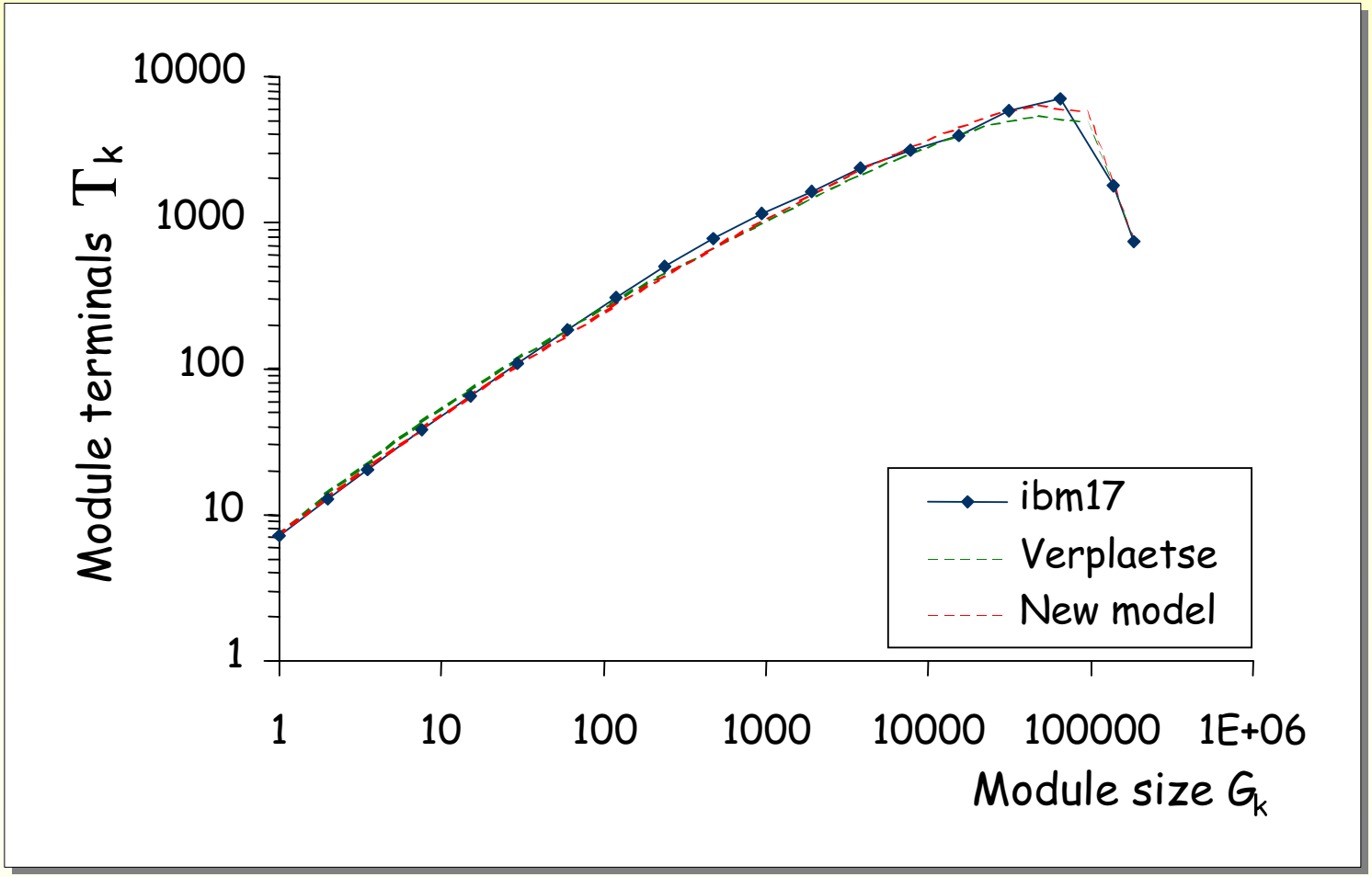
$$\alpha_k = \frac{(G_k / 2)^{-(\beta-1)}}{G_k - 1}$$



Cut probabilities for optimal circuit partitioning



Cut probabilities for optimal circuit partitioning



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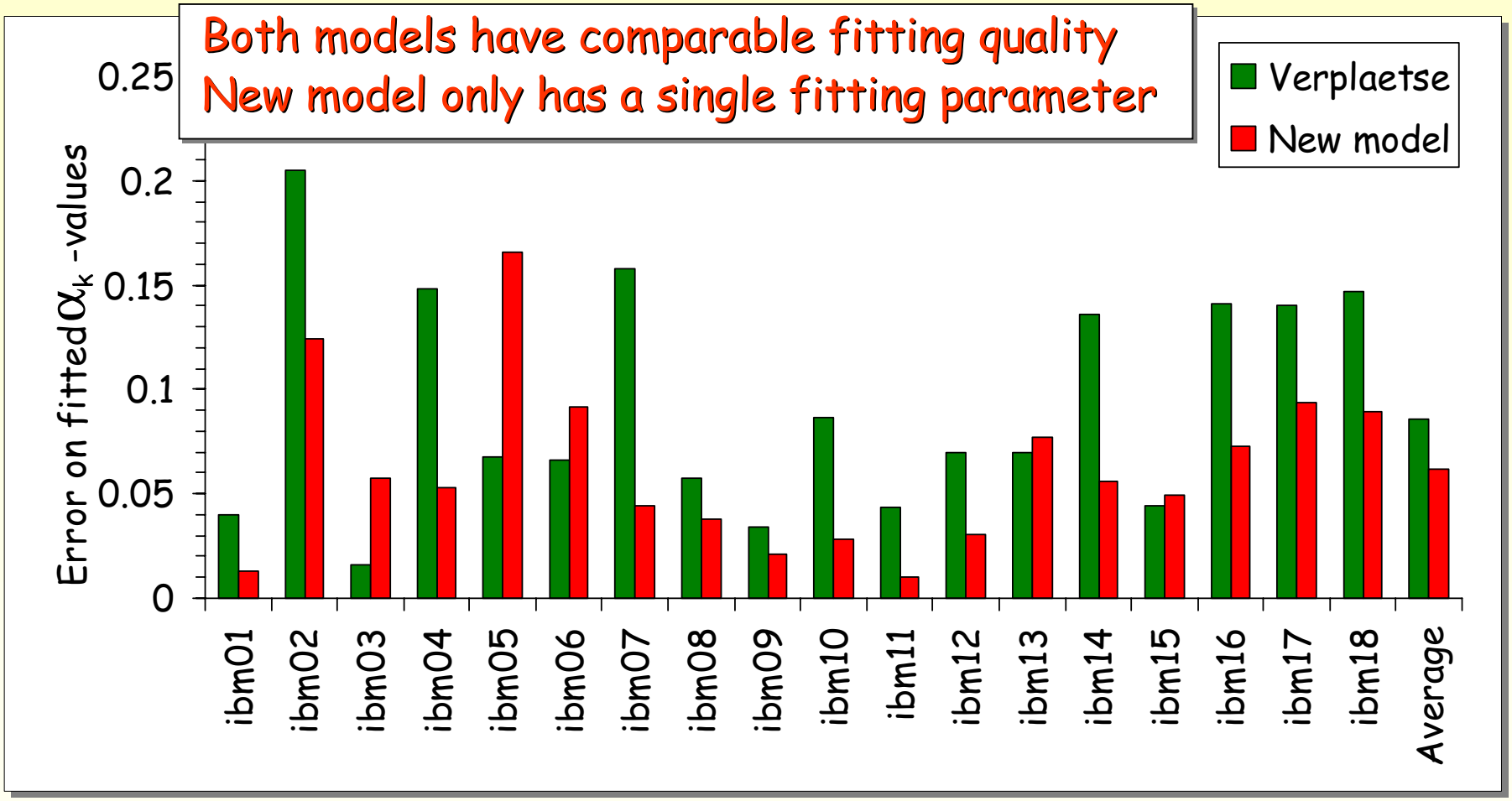
Cut probabilities for optimal circuit partitioning



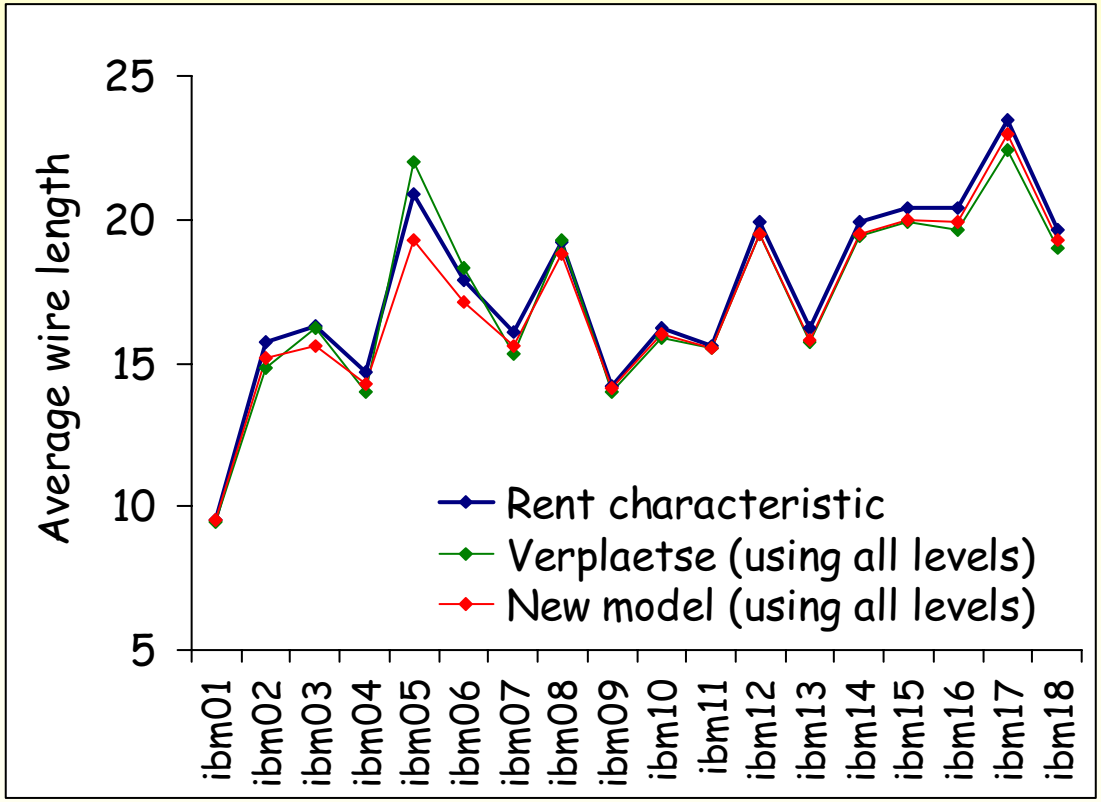
Update of last year's results ...

Prediction of average wire lengths, based on Donath's technique, but ...

using the new partitioning model instead of the Rent characteristic (Rc)

Correlation coefficients:

- Verplaetse vs. Rc: 0.988
- New model vs. Rc: 0.995

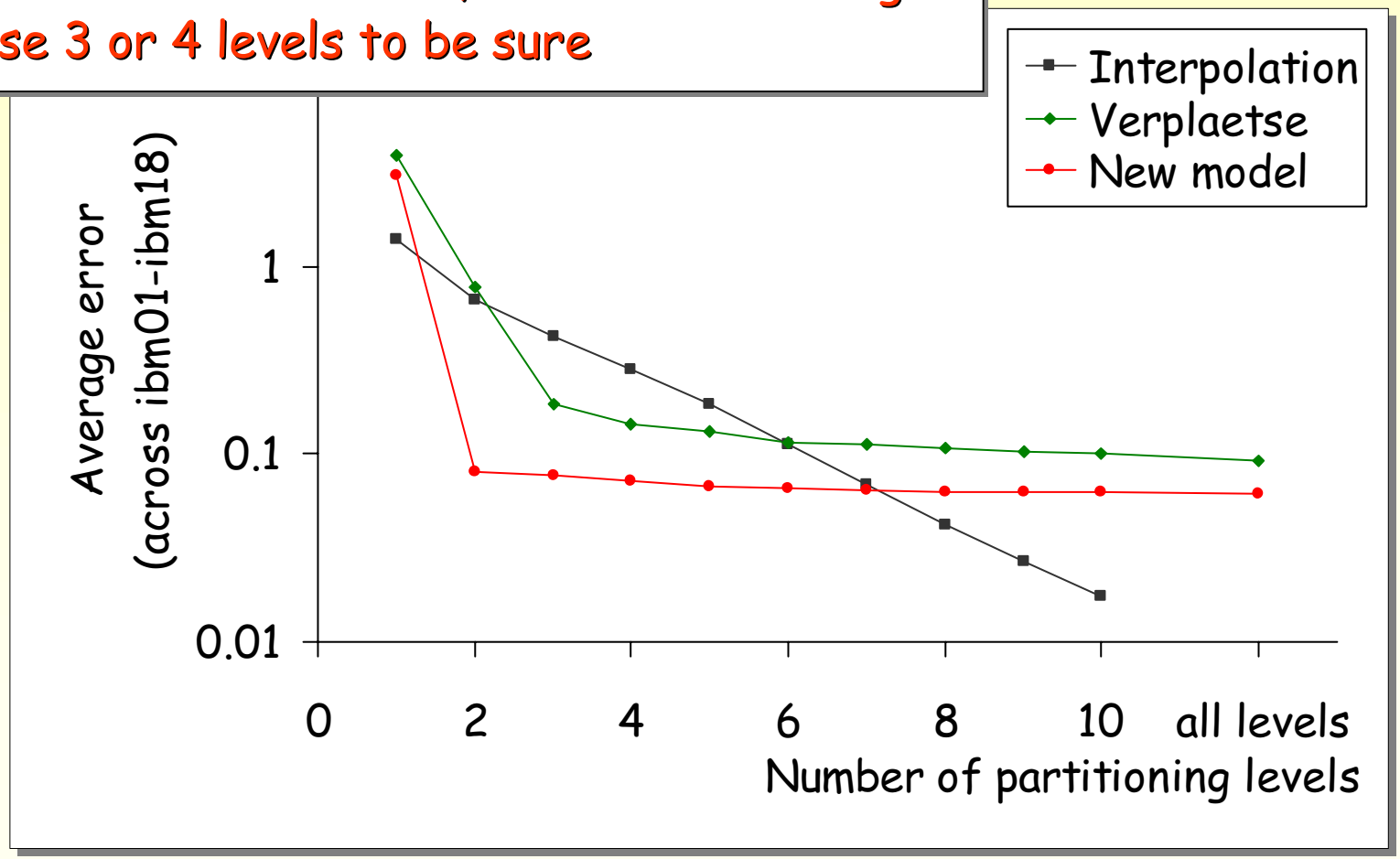


Fast estimation of the Rent characteristic

Can models for α_k be applied to obtain accurate estimations of the entire Rent characteristic based on a few partitioning levels only??

Fast estimation of the Rent characteristic

New model converges faster:
for most benchmarks, two levels is enough
use 3 or 4 levels to be sure



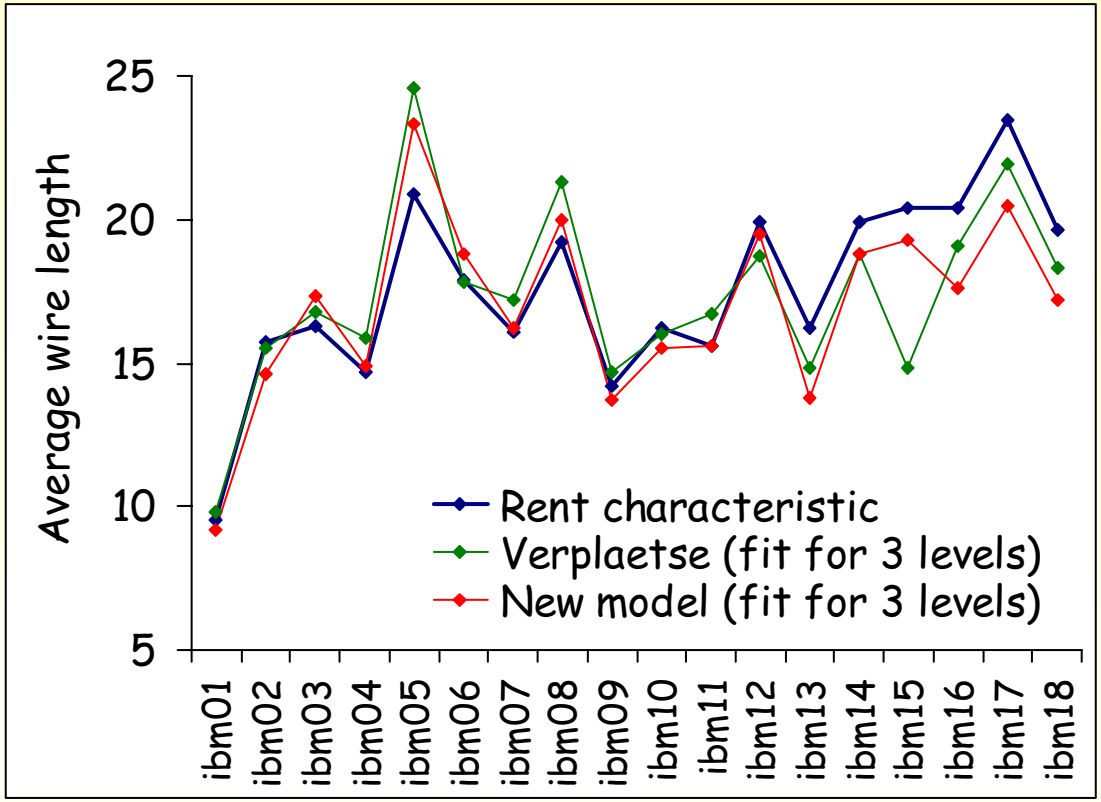
Update of last year's results ...

Prediction of average wire lengths, based on Donath's technique, but ...

using the new partitioning model, fit for 3 levels of partitioning

Correlation coefficients:

- Verplaetse vs. Rc: 0.902
- New model vs. Rc: 0.824



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Conclusions

- Adaptation of Verplaetse's recursive partitioning equations and cut probability model
- Application of this model for fast estimation of entire partitioning Rent characteristic

Future work

- Extension to multi-terminal nets
- Try to find theoretical foundations for cut probability model
- Is it possible to estimate cut probabilities from circuit graph *without* performing partitioning??