Forest Rescoring

Faster Decoding with Integrated Language Models

Liang Huang
Penn University of Pennsylvania

David Chiang
ISI Information Sciences Institute USC School of Engineering

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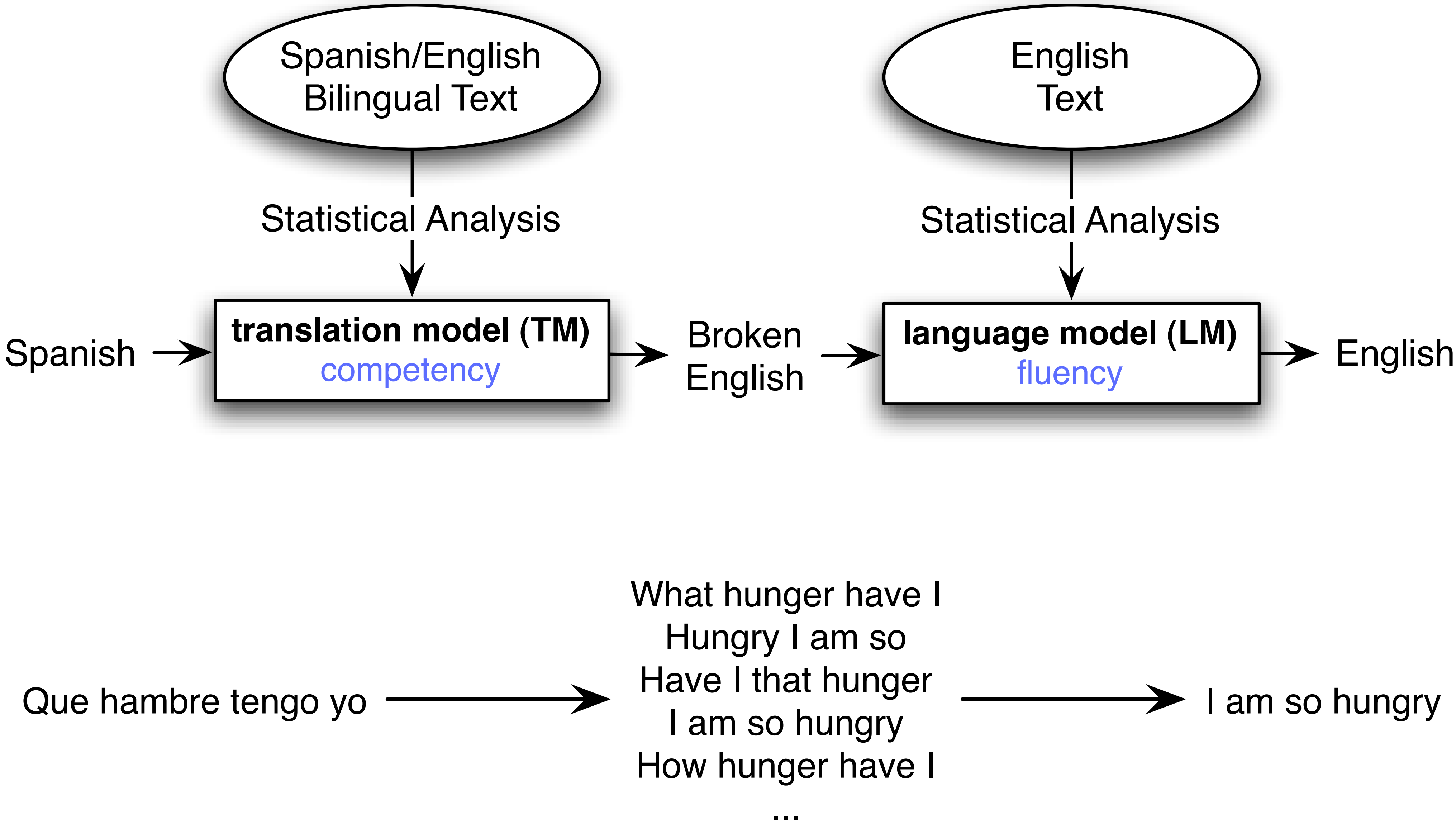
Statistical Machine Translation



(Knight and Koehn, 2003)

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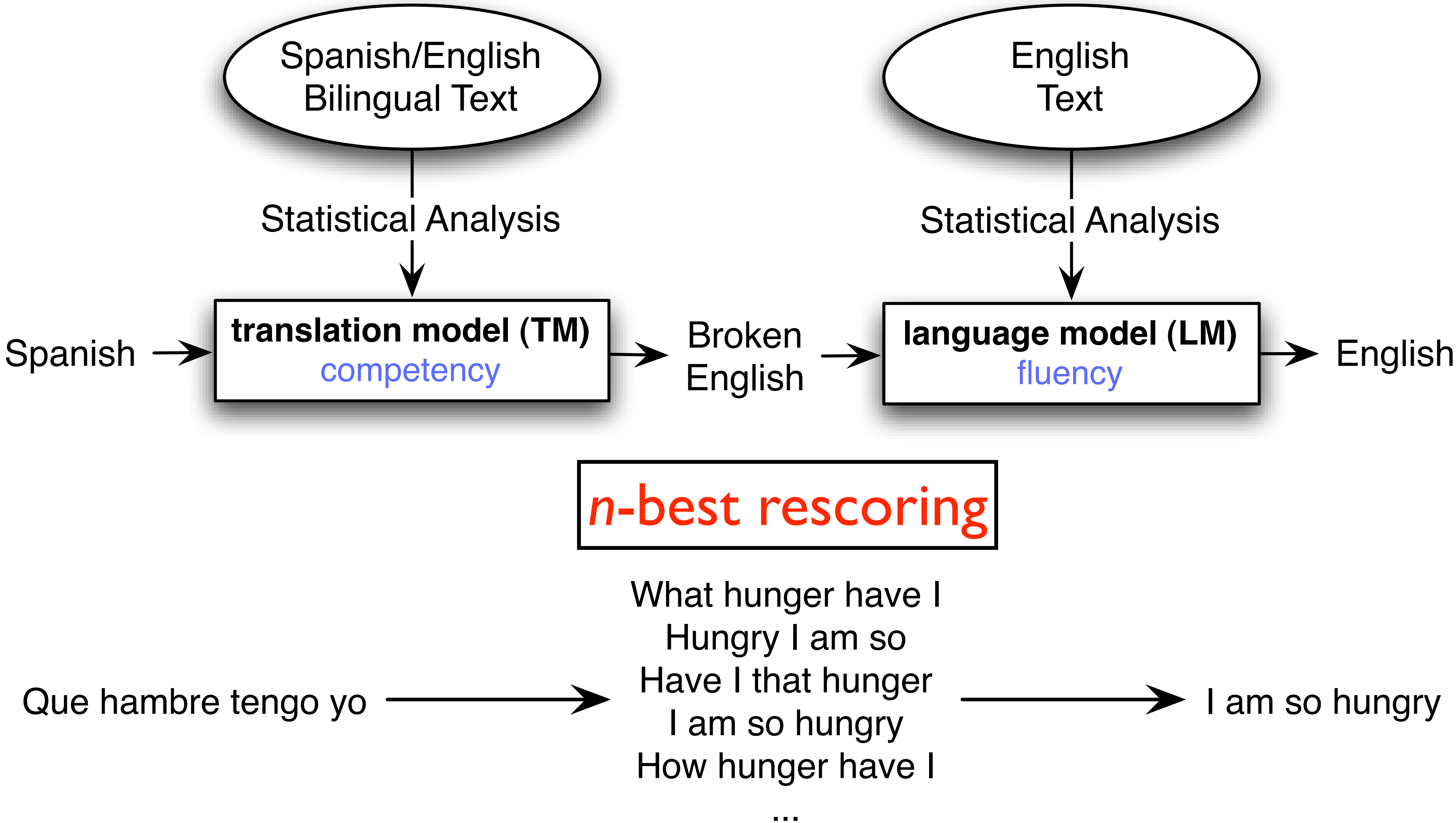

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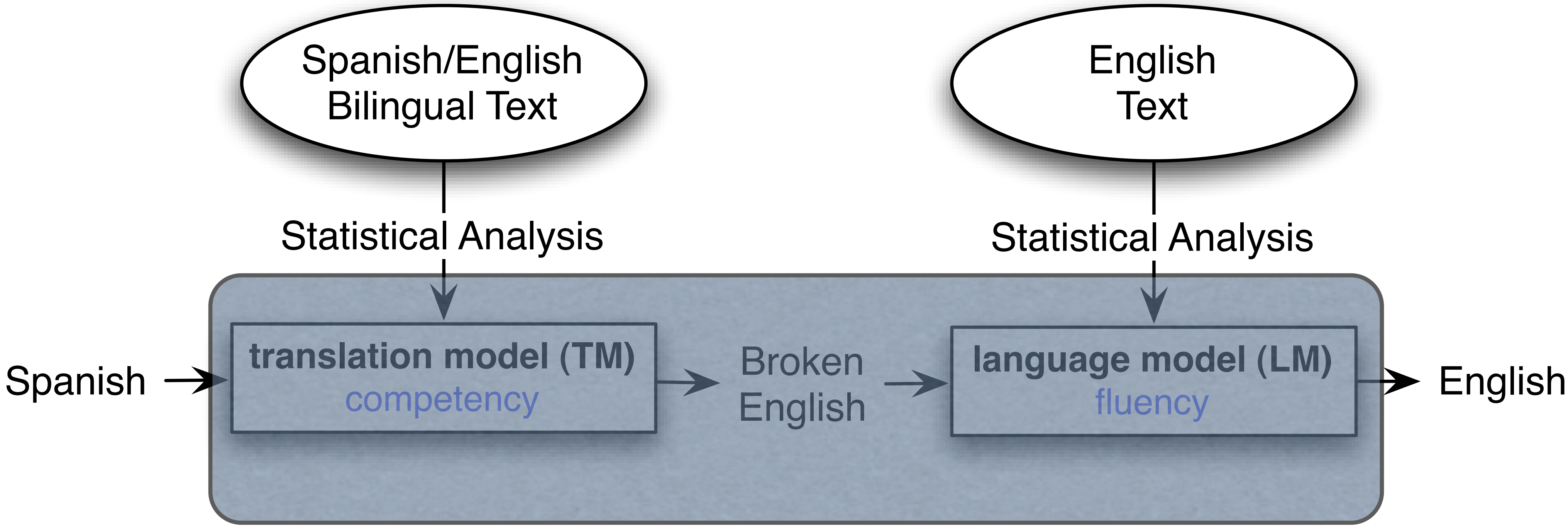

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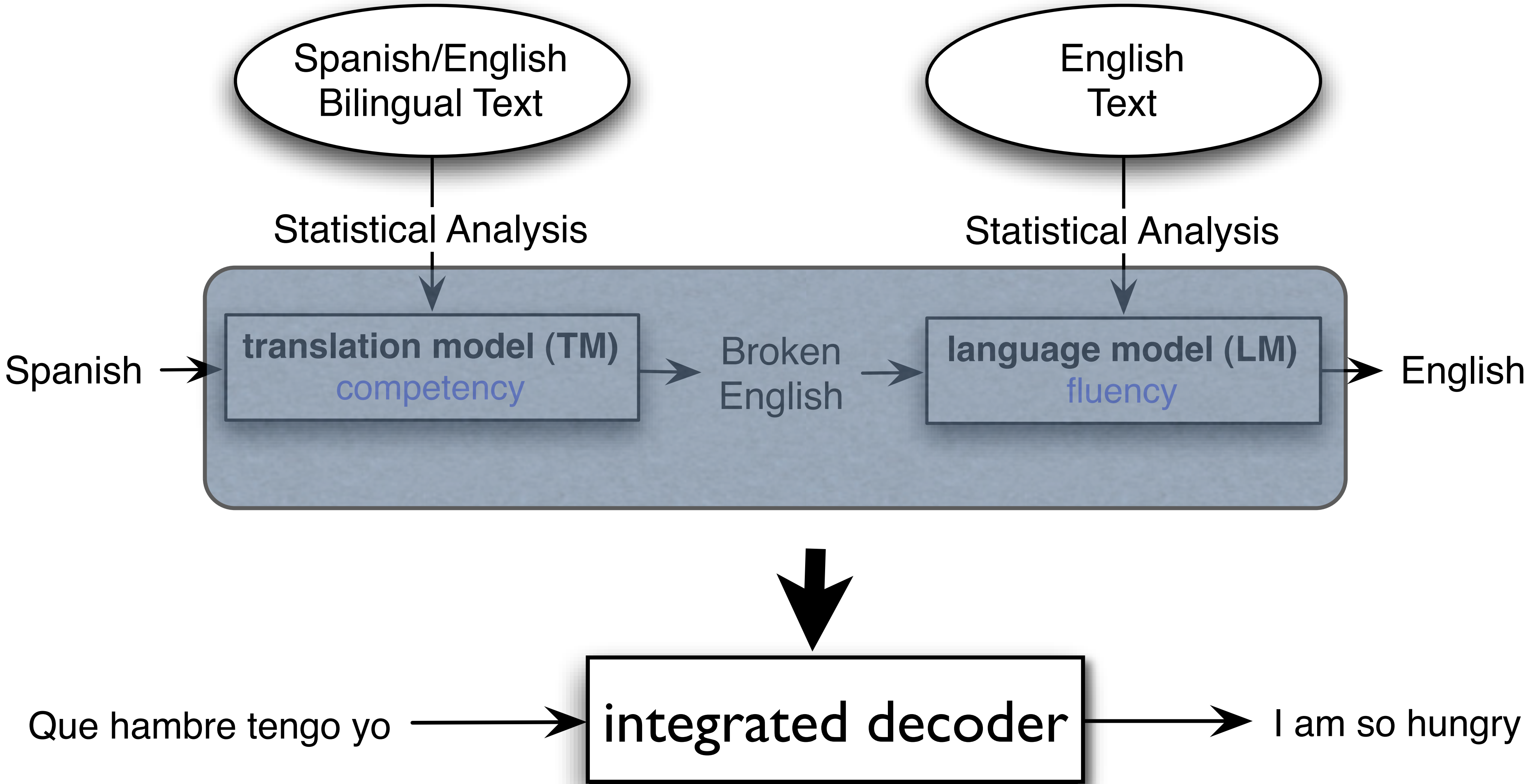

computationally challenging! ☹

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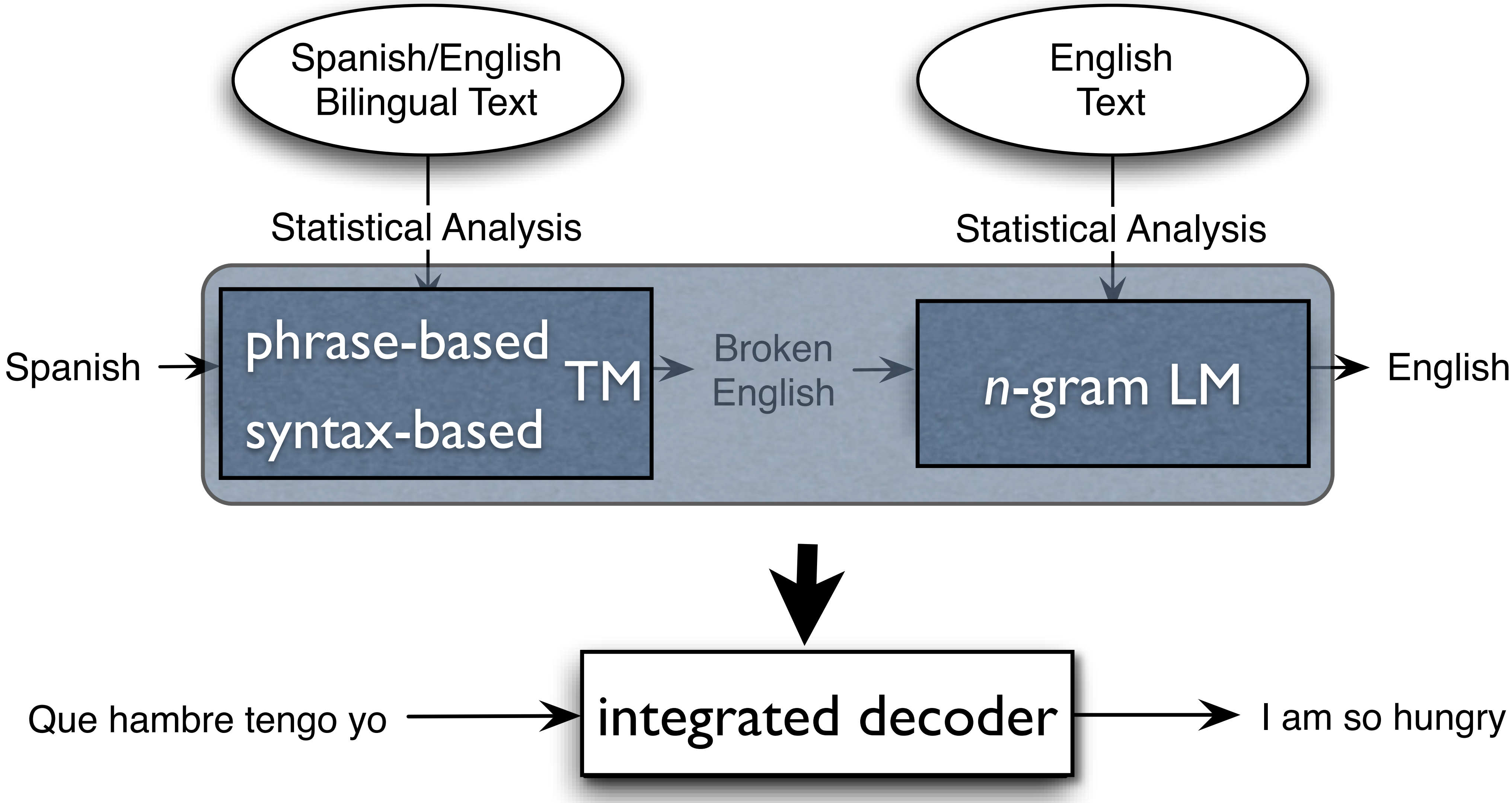

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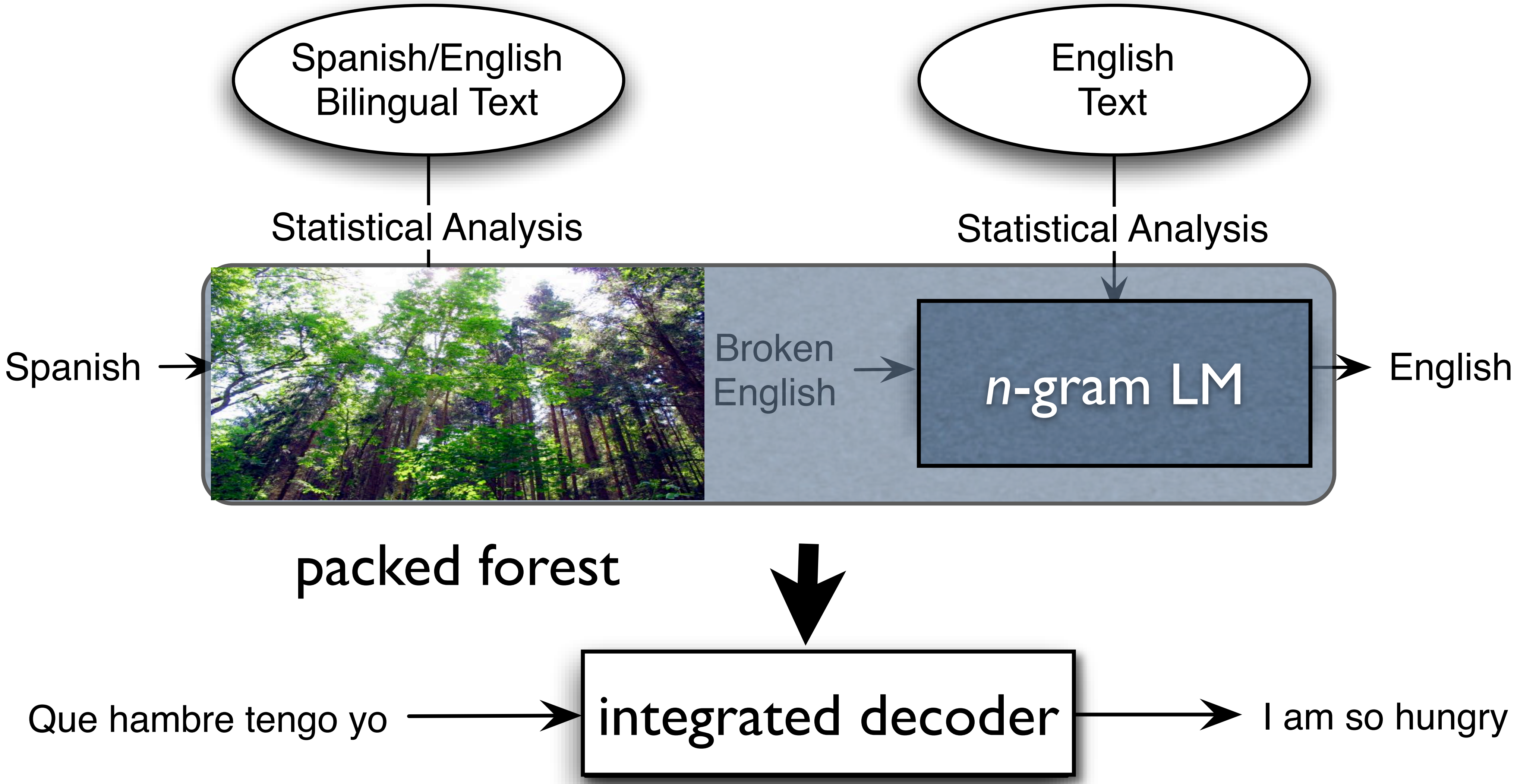

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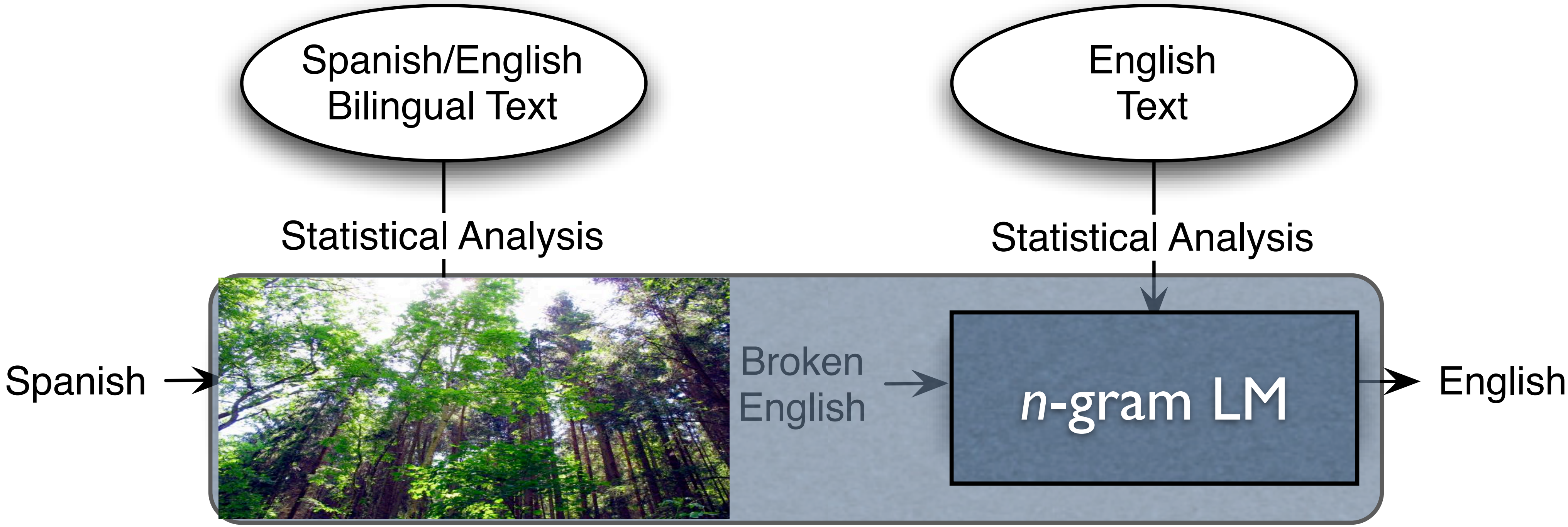

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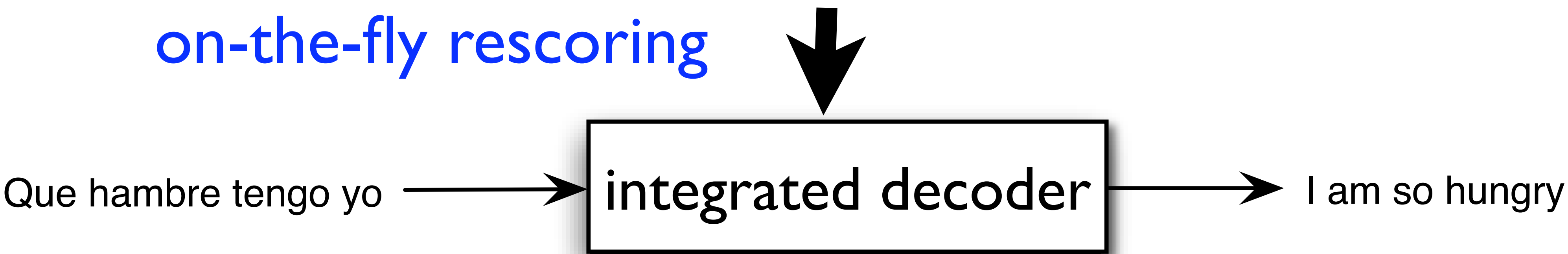

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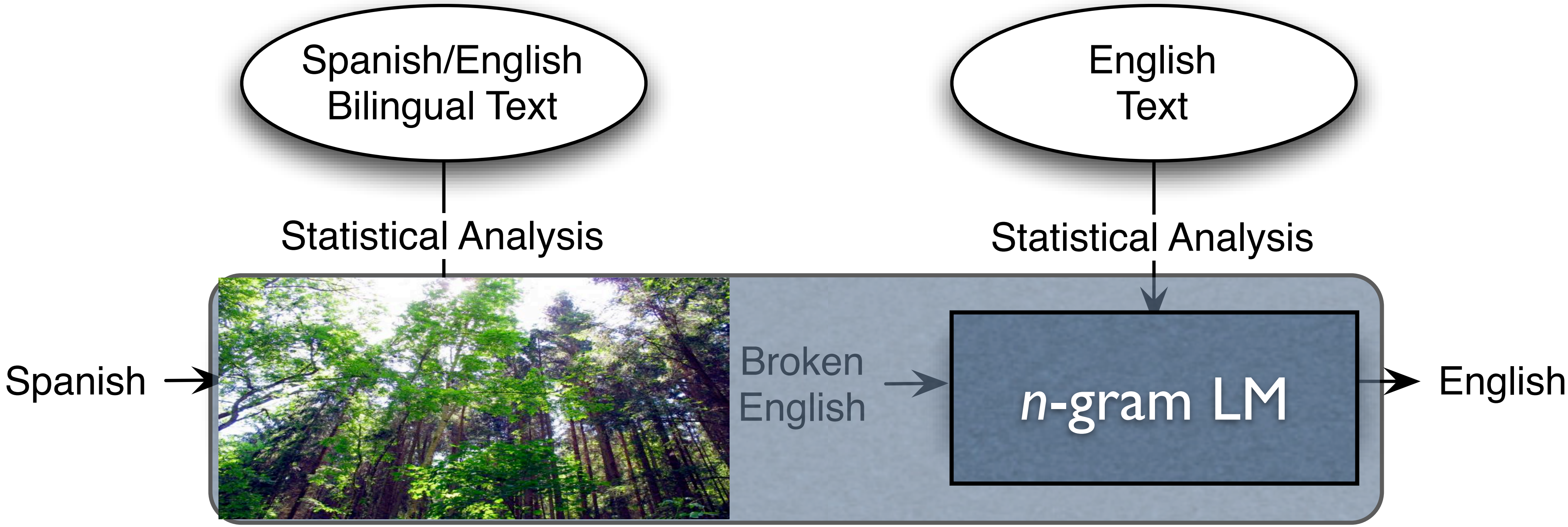


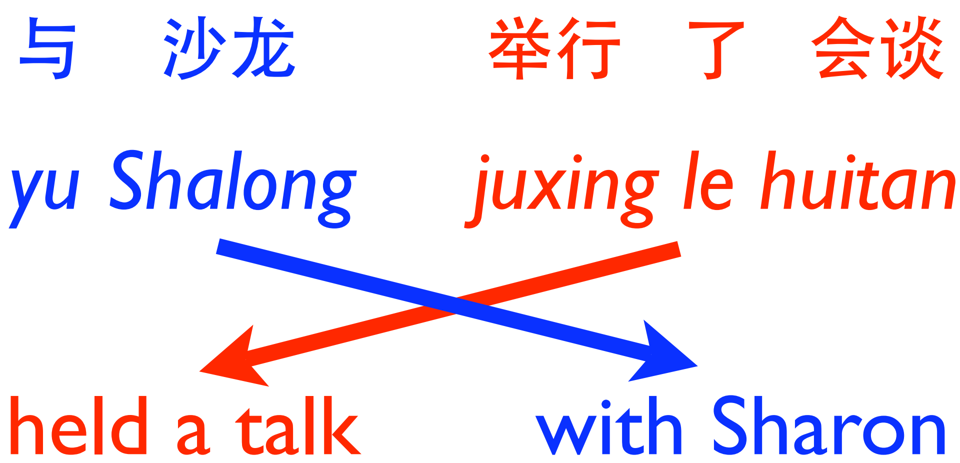
on-the-fly rescoring

significant speed-up: 10~30 times faster! ☺

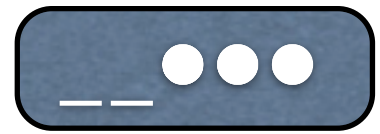
The Forest Framework

unifying phrase- and syntax-based decoding

Phrase-based Decoding

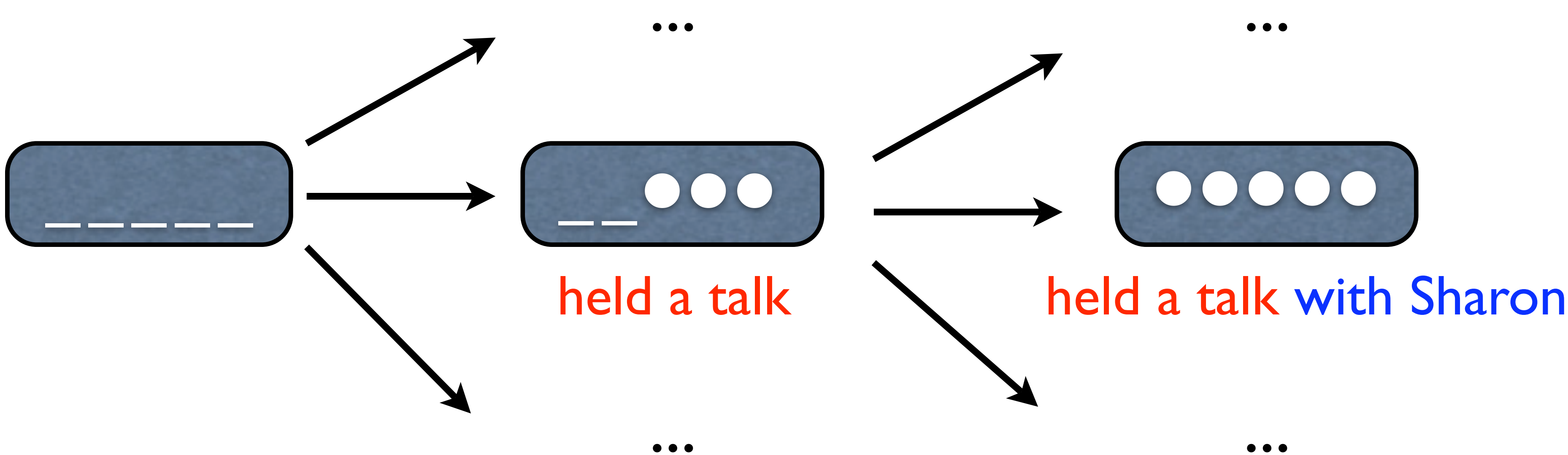


source-side: coverage vector



held a talk

target-side: grow hypotheses strictly left-to-right



Syntax-based Translation

- synchronous context-free grammars (SCFGs)
  - context-free grammar in two dimensions
  - generating pairs of strings/trees simultaneously
  - co-indexed nonterminal further rewritten as a unit

$$
\begin{array}{lcll}
\mathbf{VP} & \rightarrow & \mathbf{PP}^{(1)}\ \mathbf{VP}^{(2)}, & \mathbf{VP}^{(2)}\ \mathbf{PP}^{(1)} \\
\mathbf{VP} & \rightarrow & \textit{juxing le huitan}, & \textbf{held a meeting} \\
\mathbf{PP} & \rightarrow & \textit{yu Shalong}, & \textbf{with Sharon}
\end{array}
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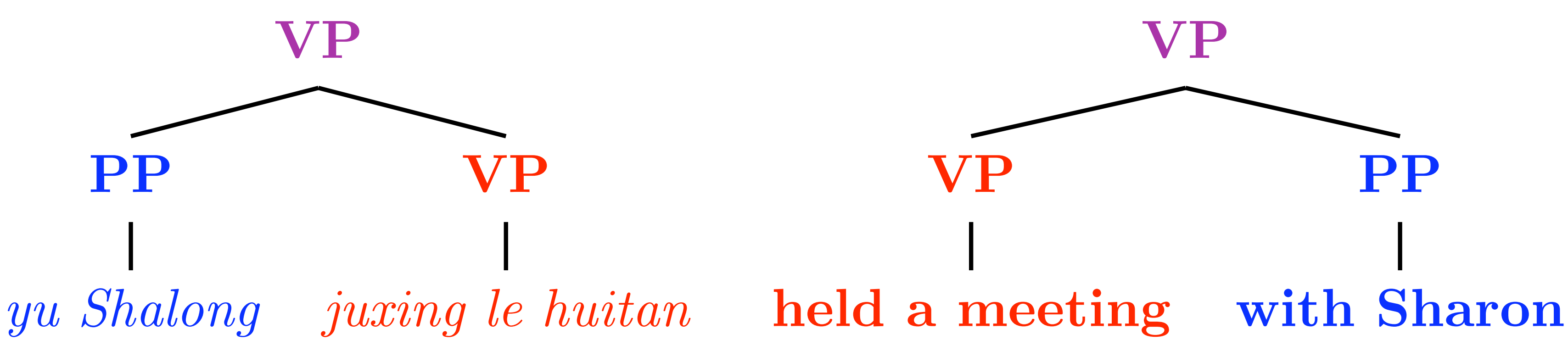

Translation as Parsing

- translation with SCFGs => monolingual parsing
- parse the source input with the source projection
  - build the corresponding target sub-strings in parallel

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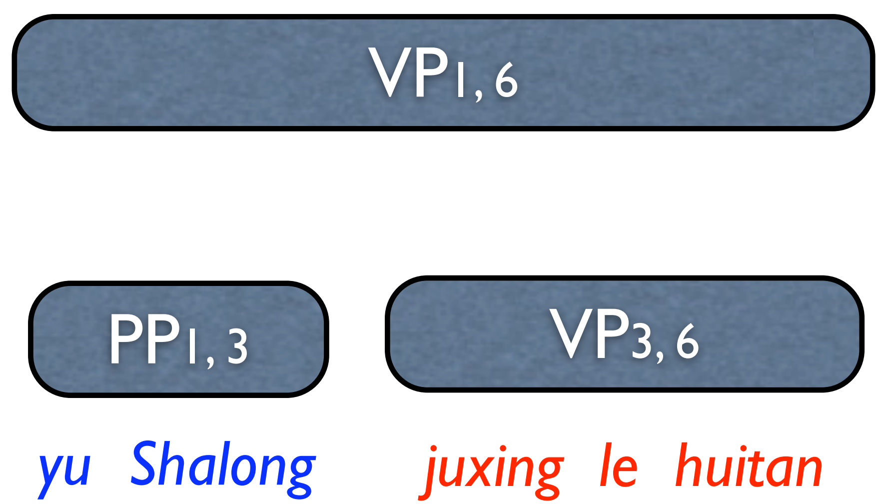

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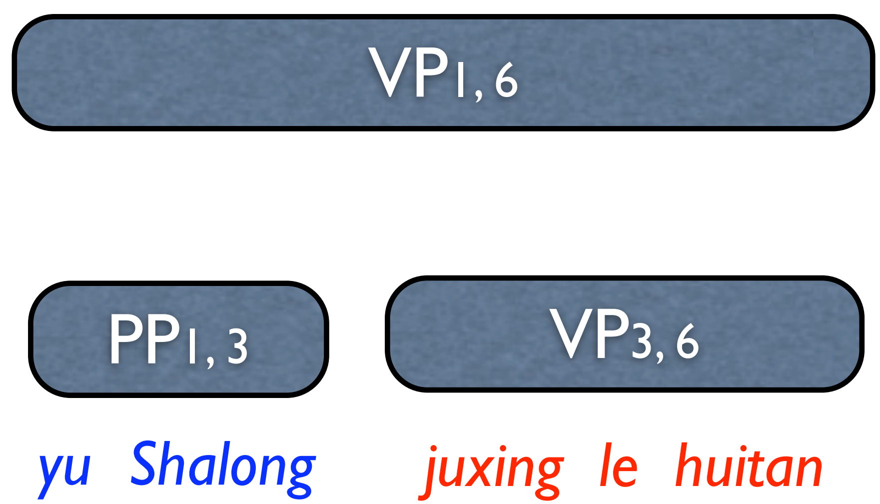

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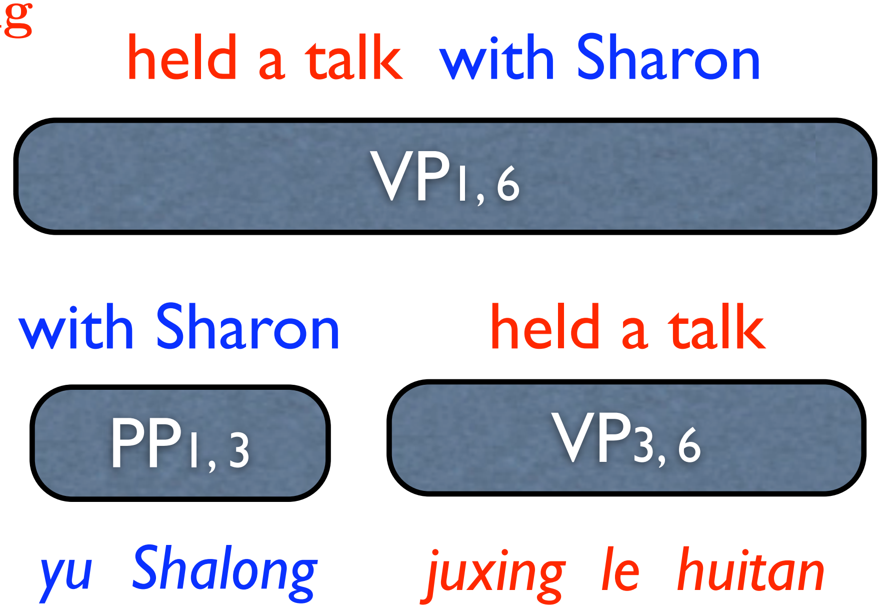
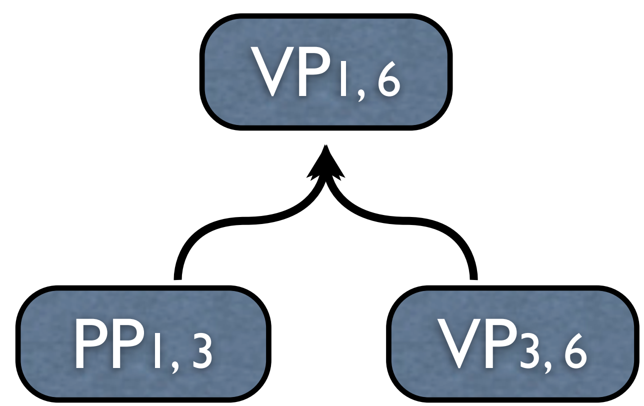


Packed Forest

- a compact representation of all translations
- has a structure of hypergraph (graph is a special case)

phrase-based: graph

syntax-based: hypergraph



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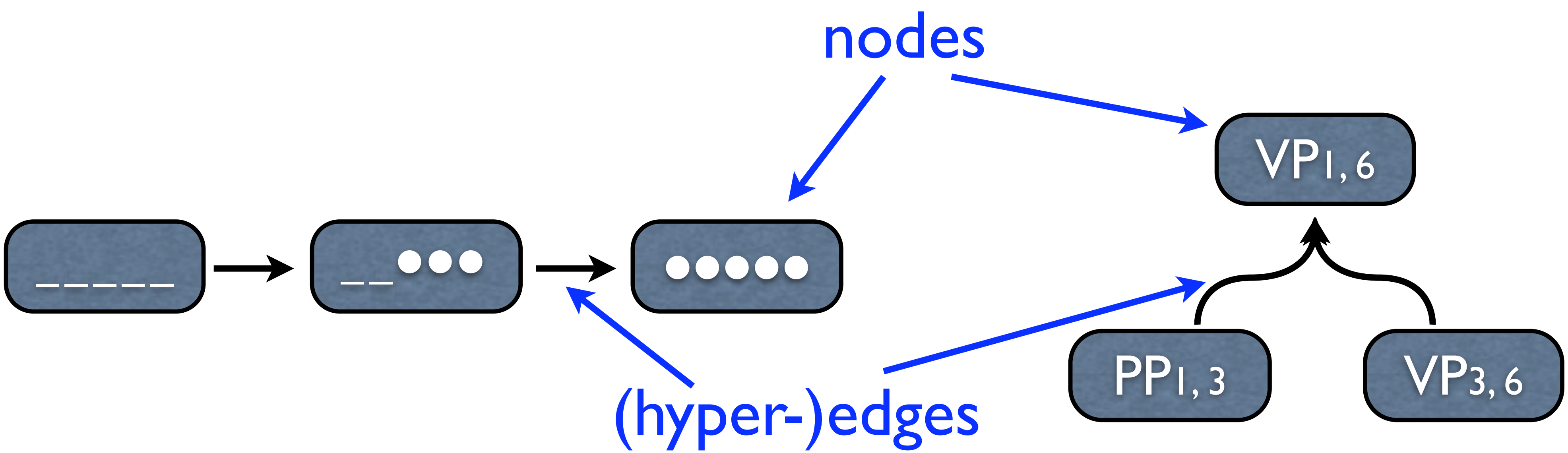
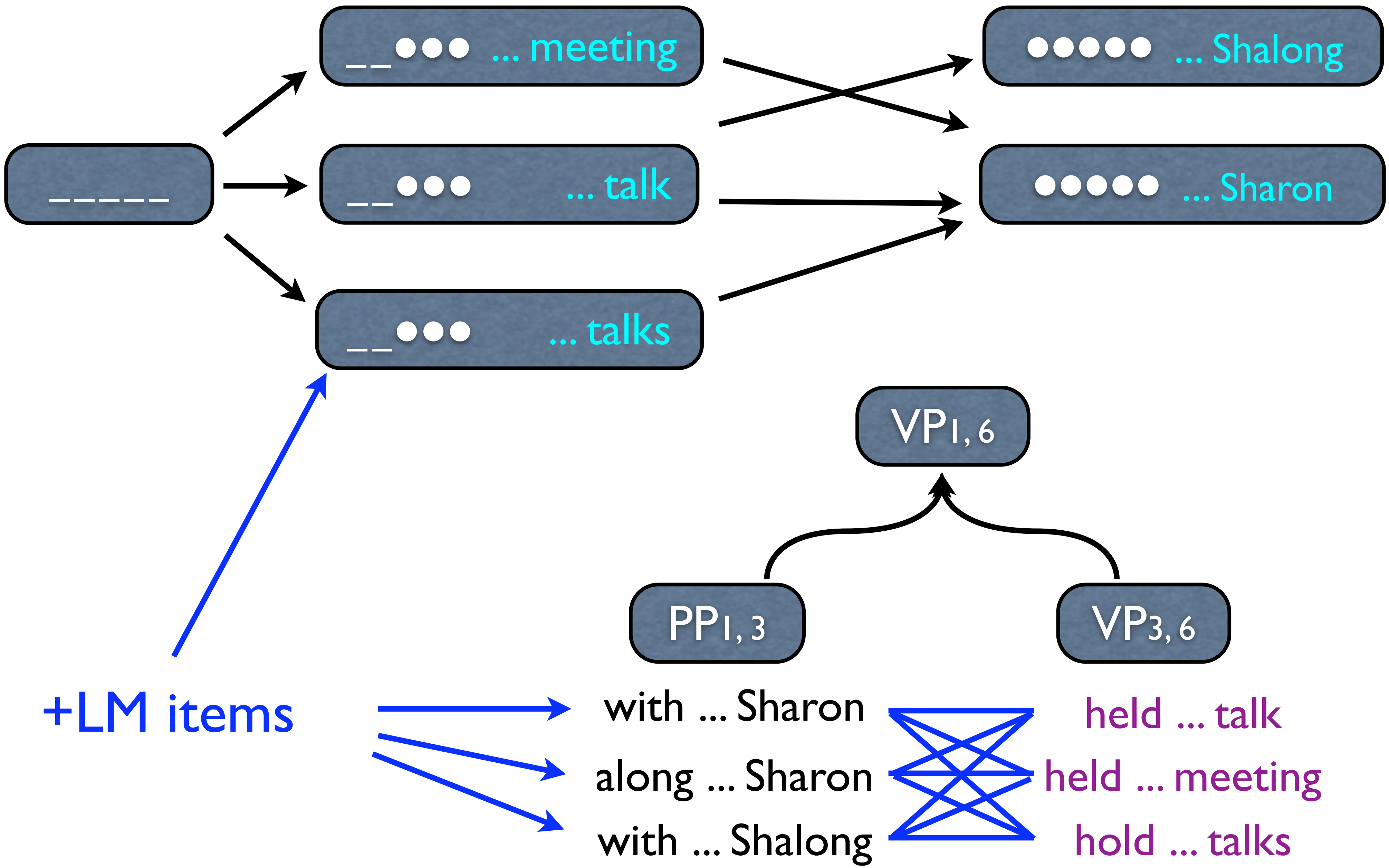


Adding a Bigram Model



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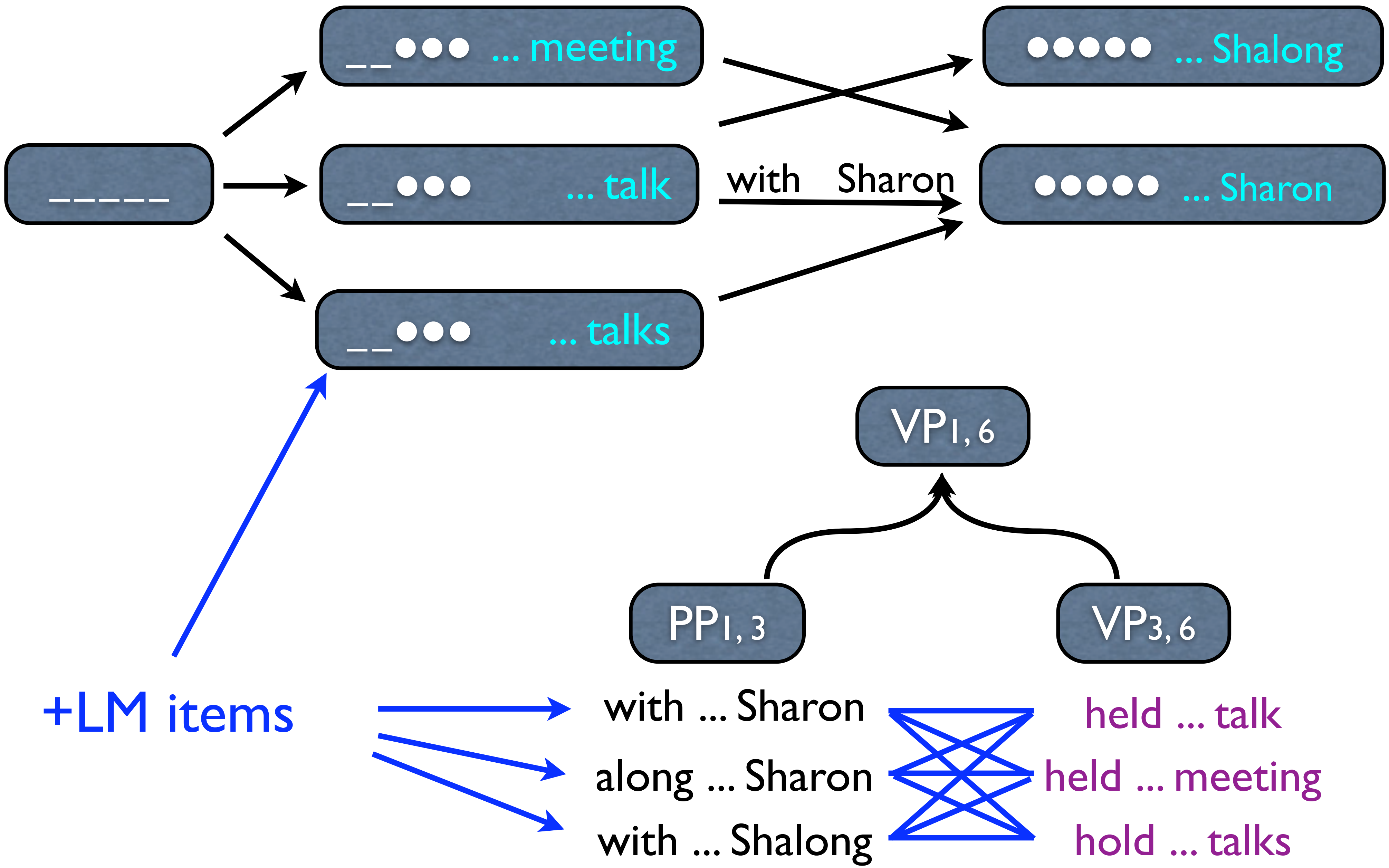

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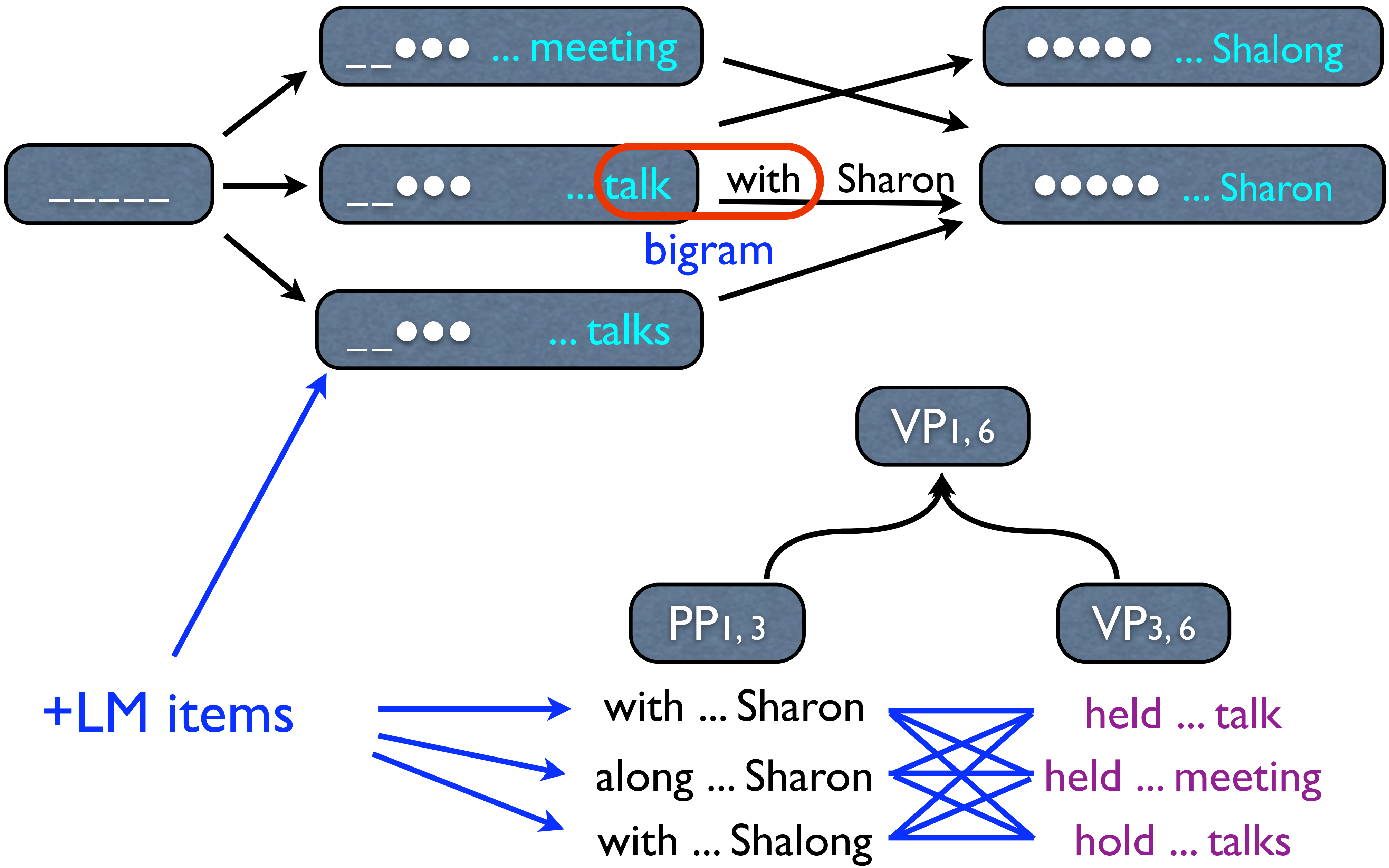

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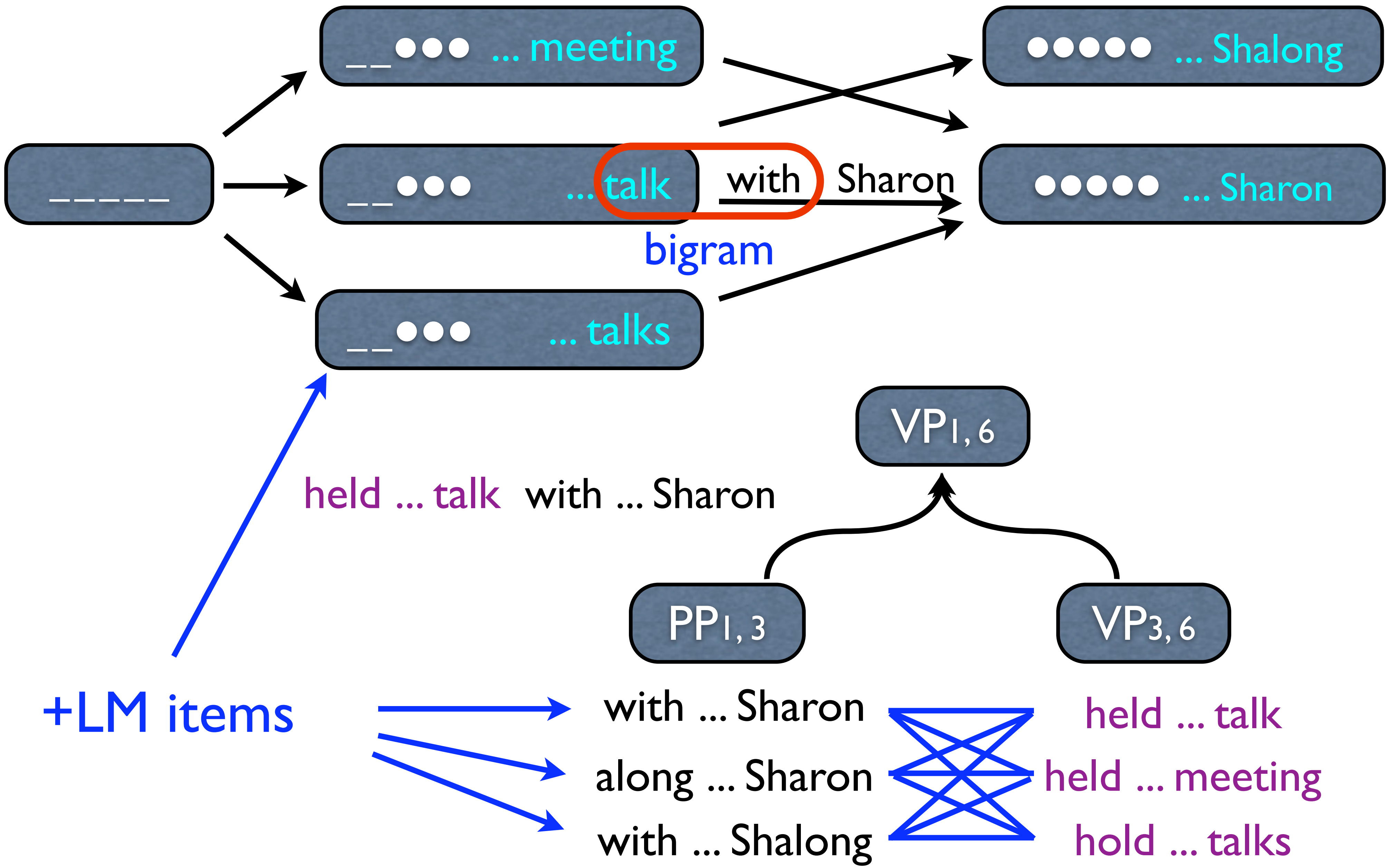

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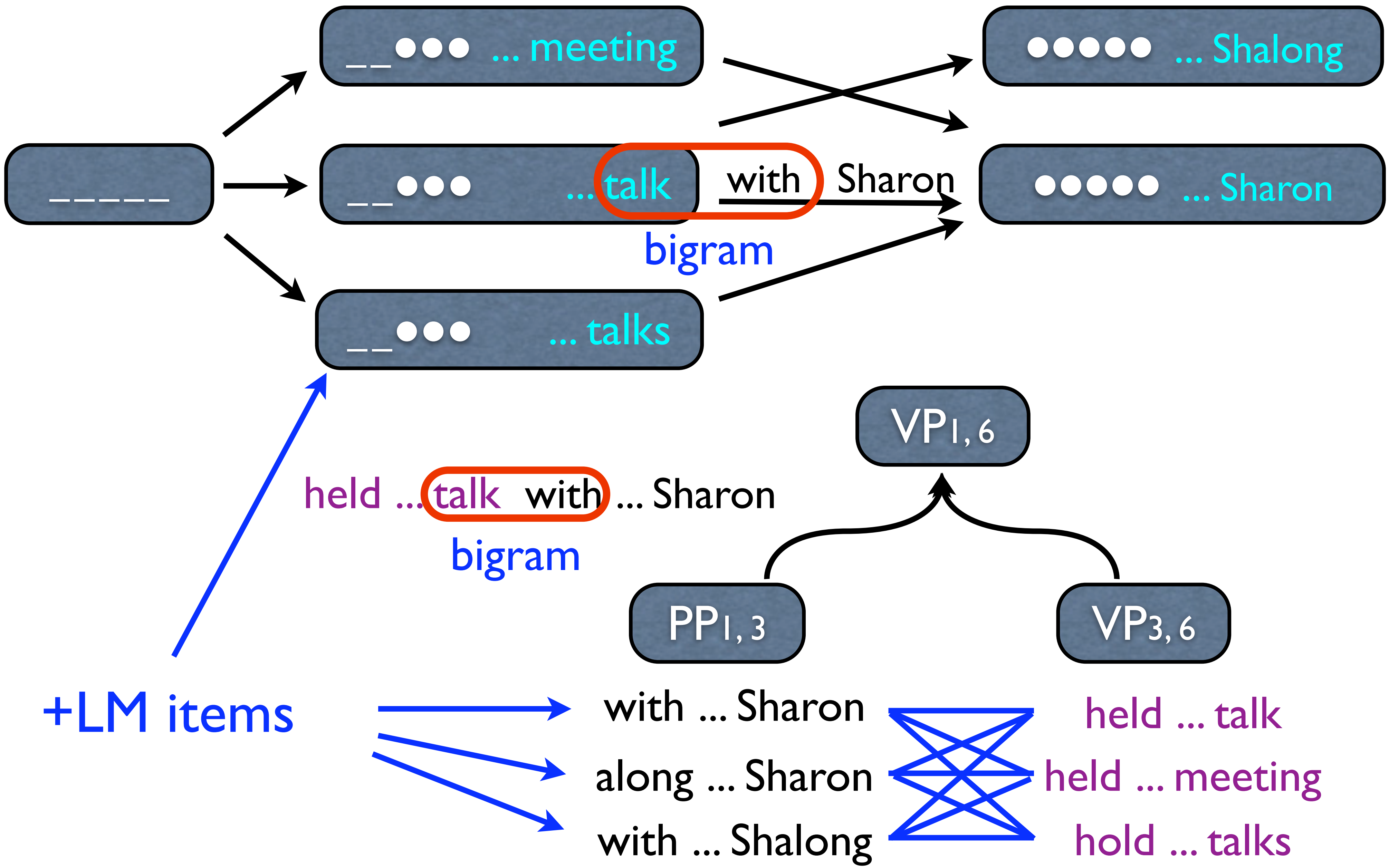

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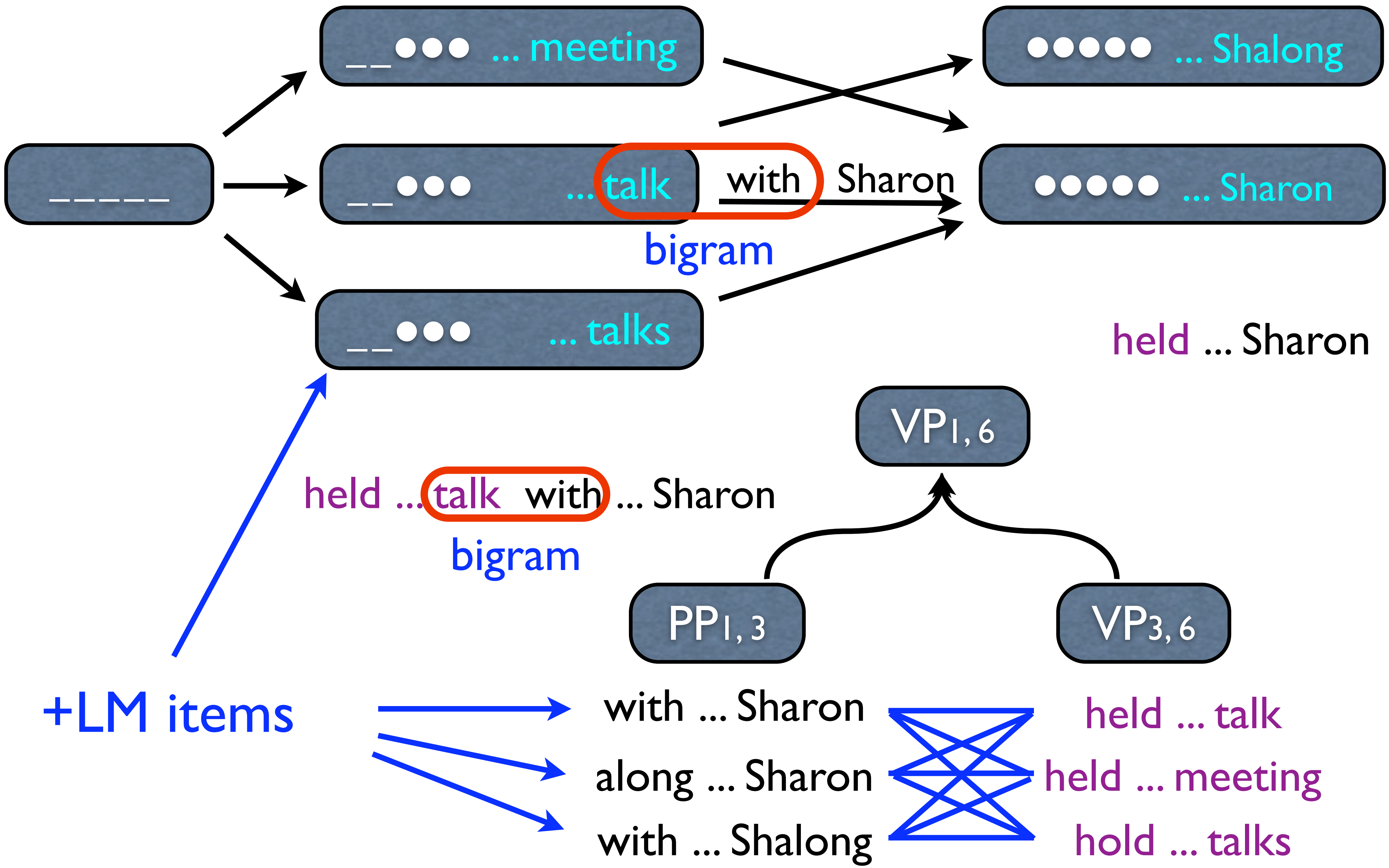

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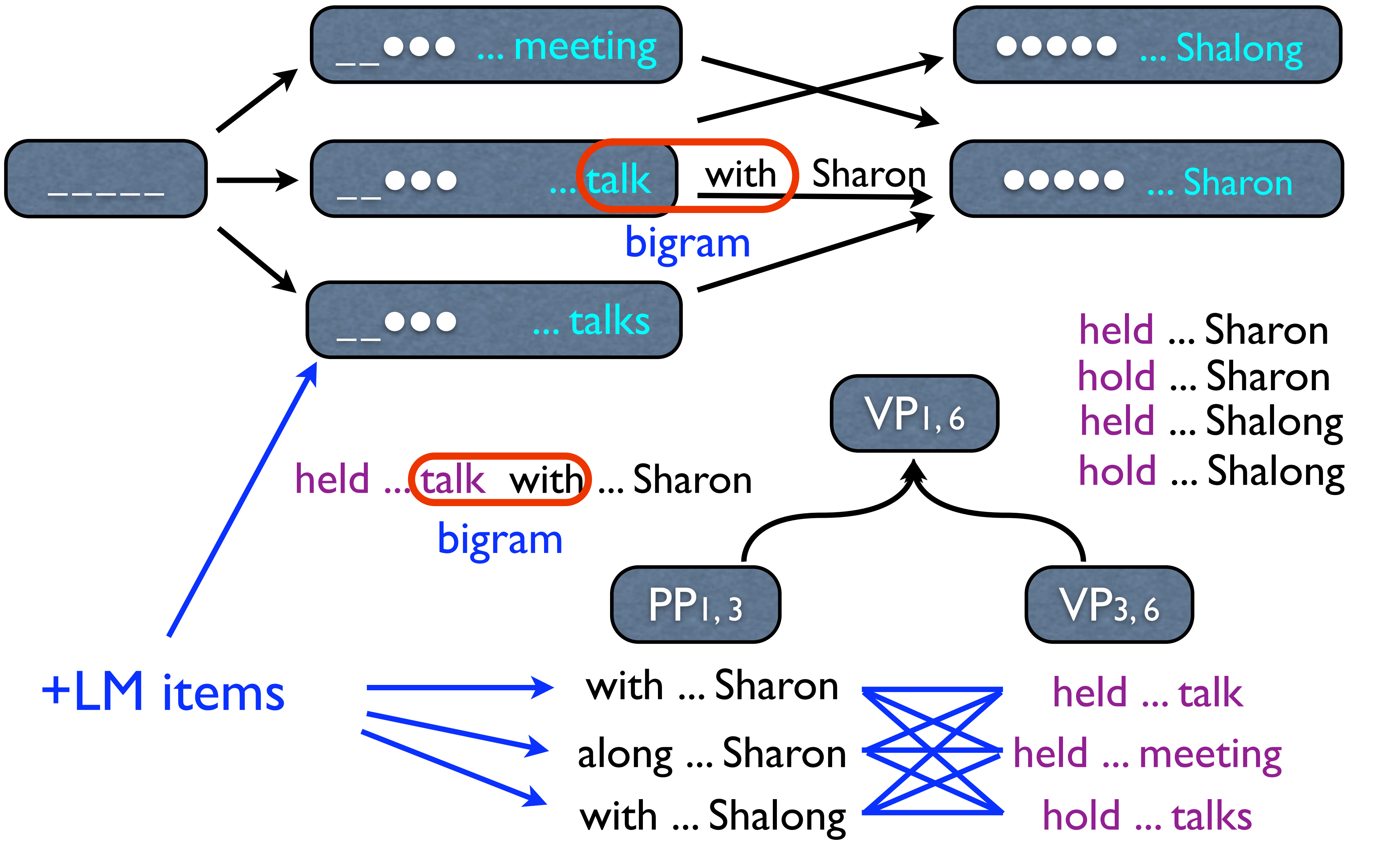
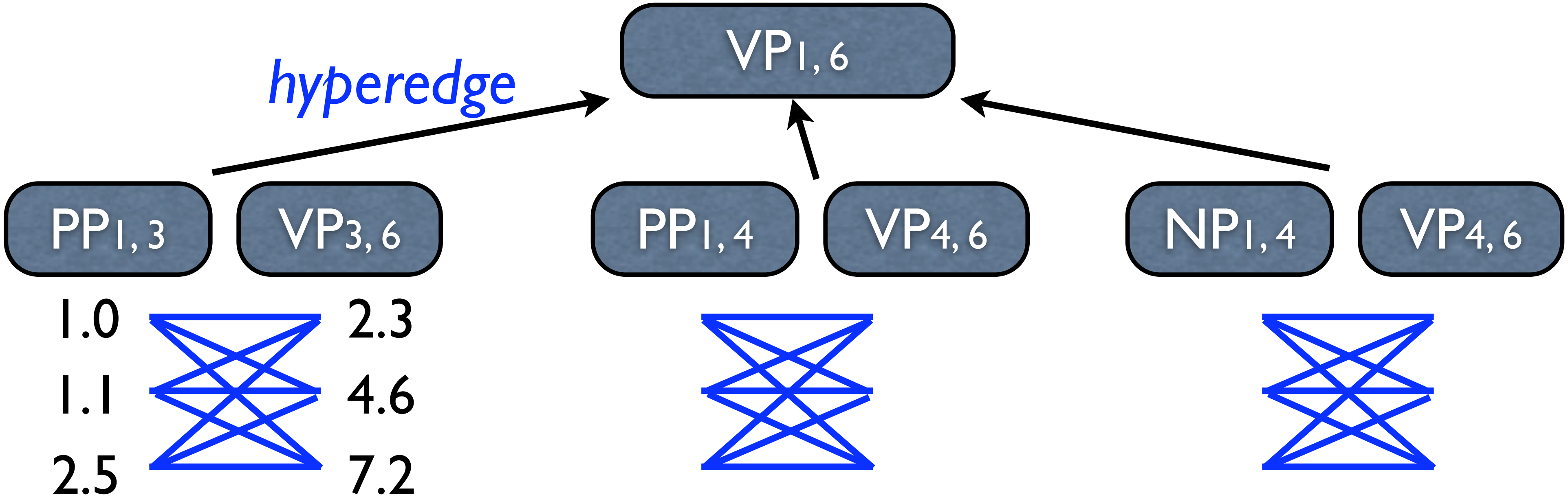
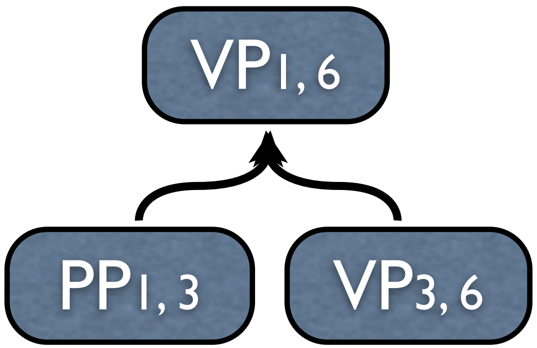


Conventional Beam Search



- beam search: only keep top-*k* +LM items at each node
- but there are many ways to derive each node
- can we avoid enumerating all combinations?
  - best-first enumeration?

Cube Pruning



monotonic grid?

		$(\mathrm{PP}_{1,3}^{\text{with} \star \text{Sharon}})$	$(\mathrm{PP}_{1,3}^{\text{along} \star \text{Sharon}})$	$(\mathrm{PP}_{1,3}^{\text{with} \star \text{Shalong}})$
		1.0	3.0	8.0
$(\mathrm{VP}_{3,6}^{\text{held} \star \text{meeting}})$	1.0	2.0	4.0	9.0
$(\mathrm{VP}_{3,6}^{\text{held} \star \text{talk}})$	1.1	2.1	4.1	9.1
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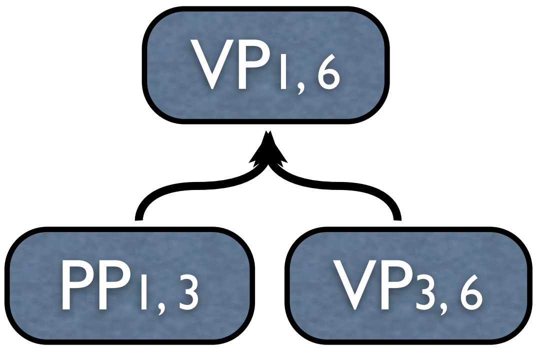

non-monotonic grid
due to LM combo costs

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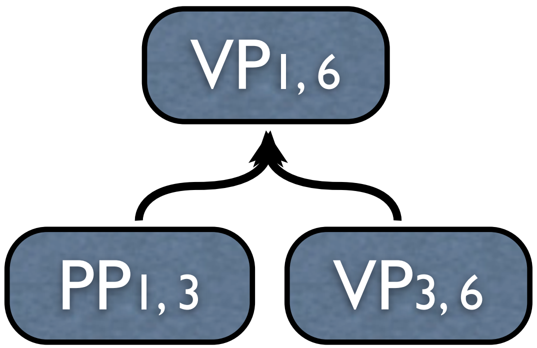

bigram (meeting, with)

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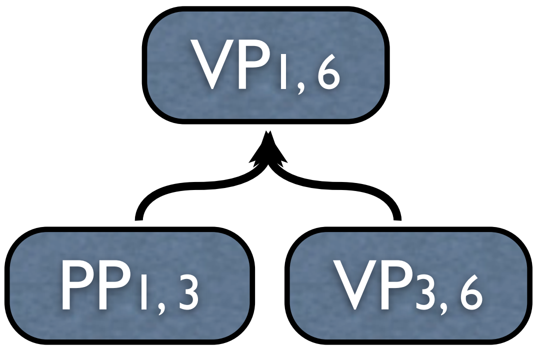

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Cube Pruning

k-best parsing
(Huang and Chiang, 2005)

- a priority queue of candidates
- extract the best candidate

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items are popped out-of-order

solution: keep a buffer of pop-ups

2.5 2.4 5.1

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finally re-sort the buffer and return inorder:

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Across Hyperedges

k-best parsing
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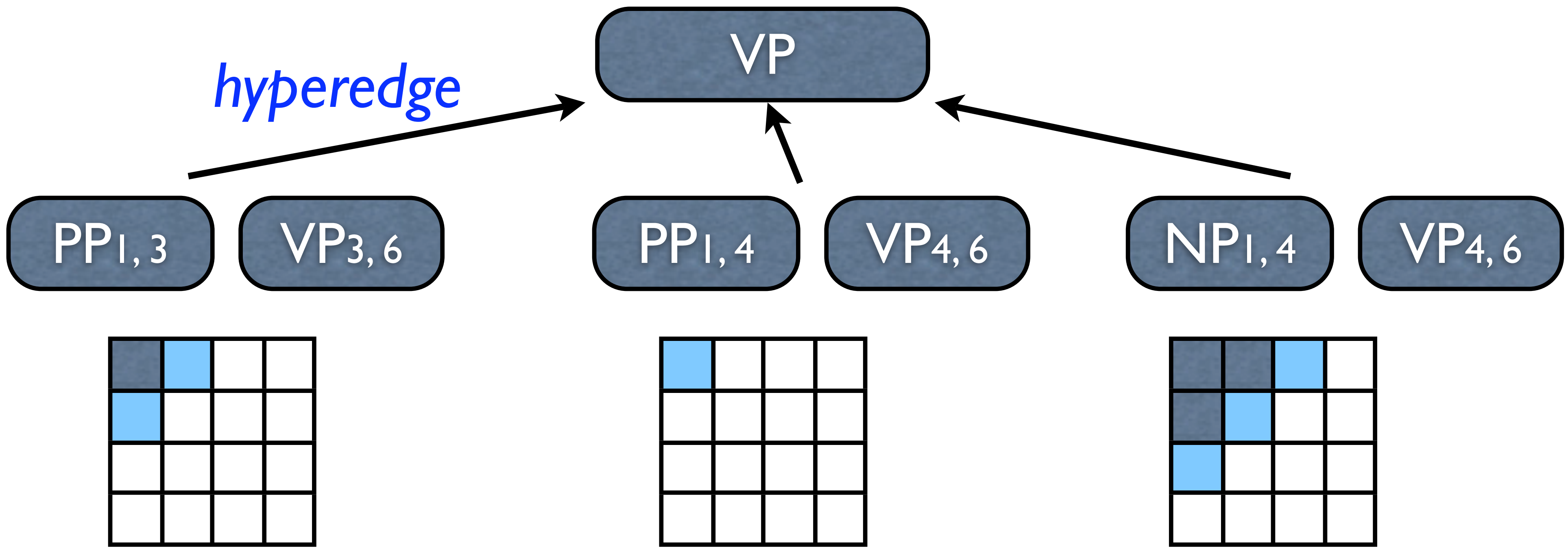
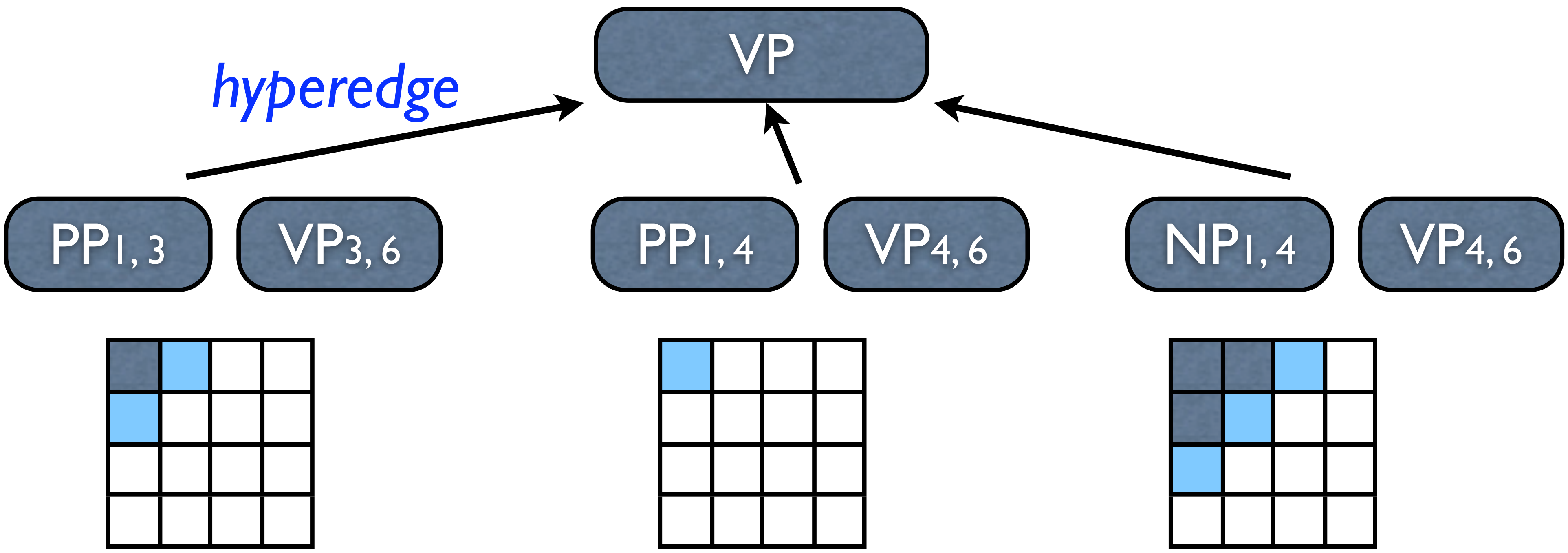


process all hyperedges simultaneously!
significant savings of computation

Across Hyperedges

k-best parsing
(Huang and Chiang, 2005)

on-the-fly rescoring at each node,
instead of only at the root node



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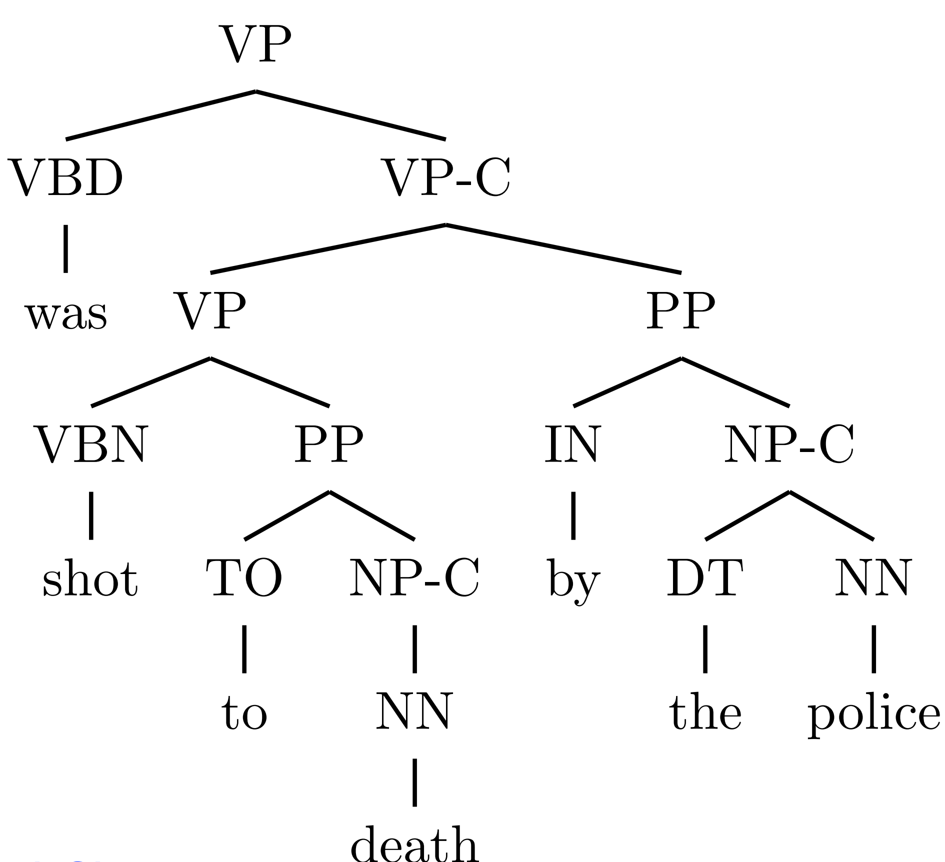
Cube Growing

- an even faster variant of cube pruning
- motivation
  - why do we have a fixed beam of size *k* at each node?
    - why don't we on-the-fly figure out the minimum *k*?
- cube growing uses
  - lazy *k*-best parsing (Huang and Chiang, 2005, Algorithm 3)
  - on-demand computation
- but harder to implement

Syntax-based Experiments

Tree-to-String System

- syntax-directed, English to Chinese (Huang, Knight, Joshi, 2006)
- first parse input, and then recursively transfer



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(Galley et al., 2004; Eisner, 2003)

search space
still a hypergraph

tested on 140 sentences
slightly better BLEU scores
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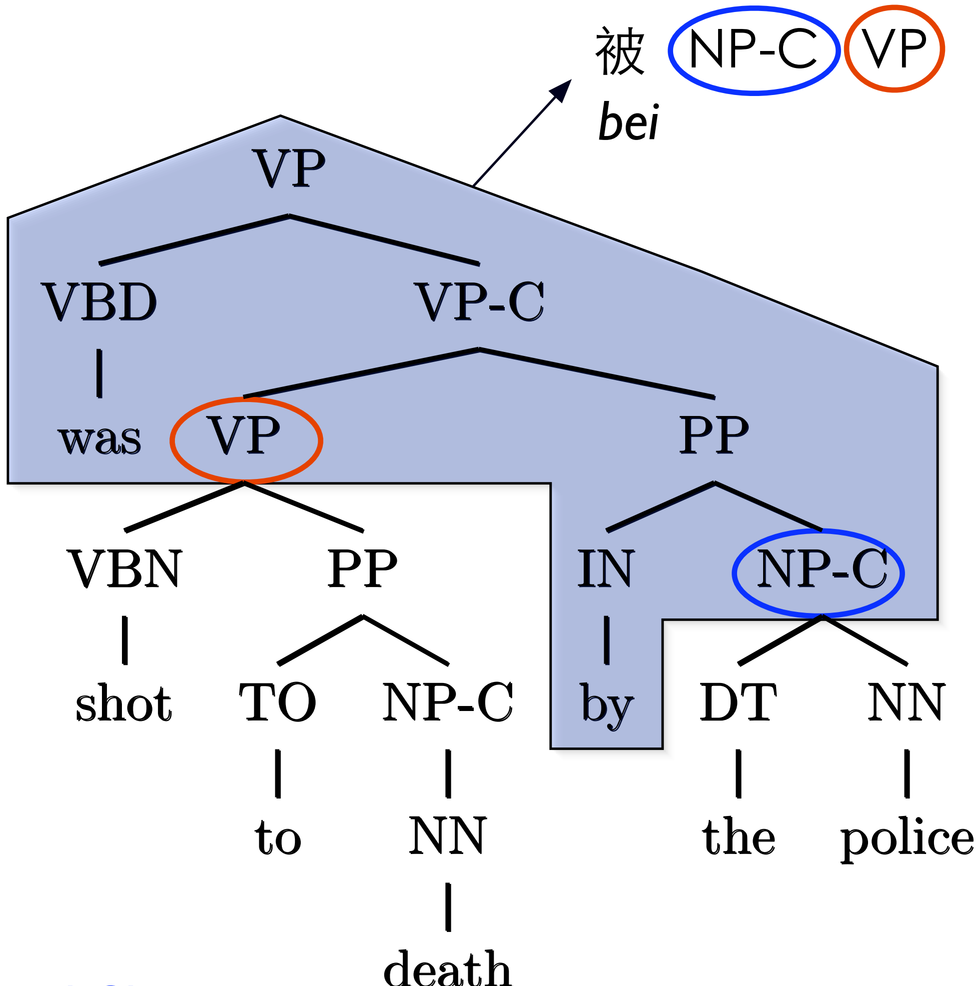

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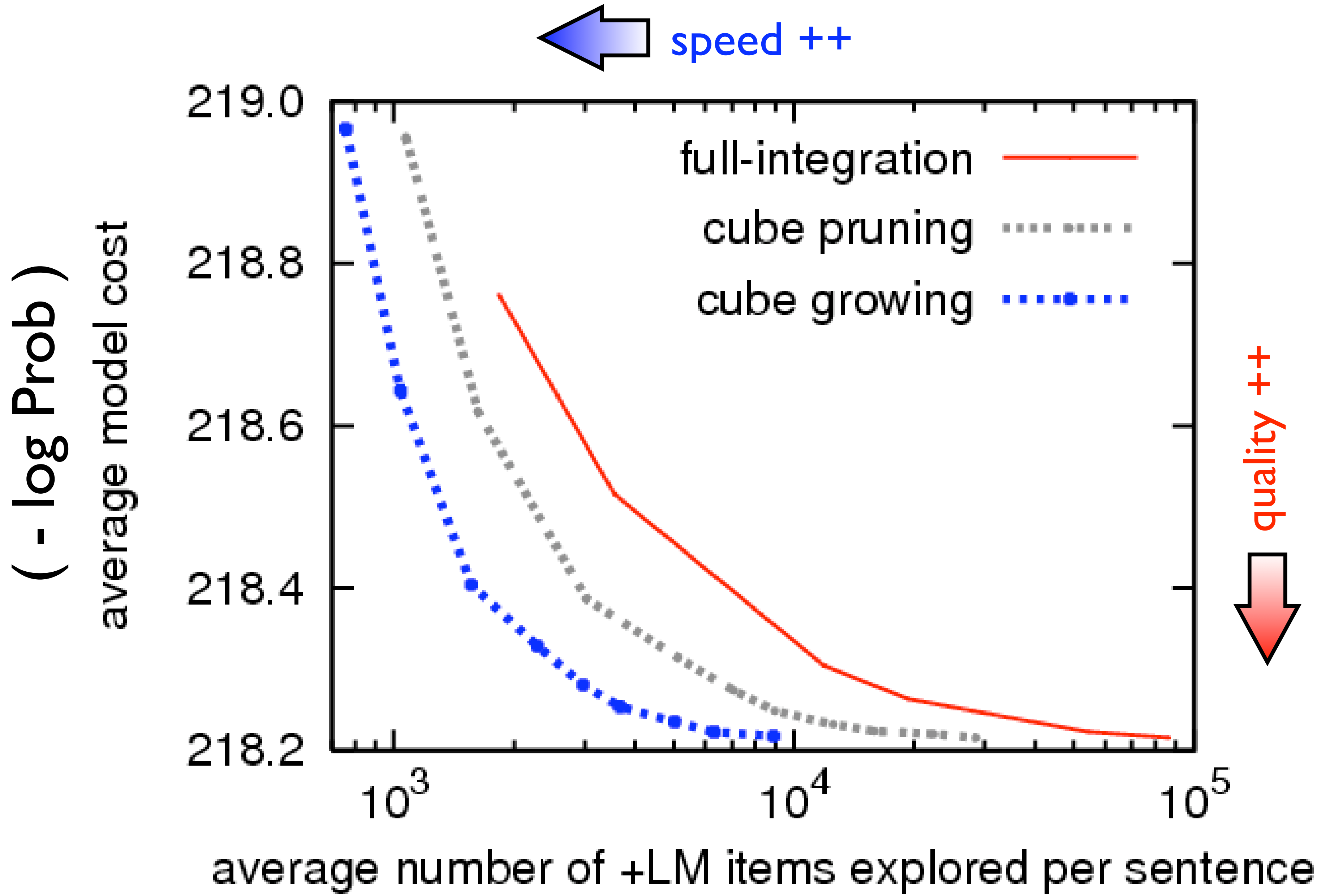

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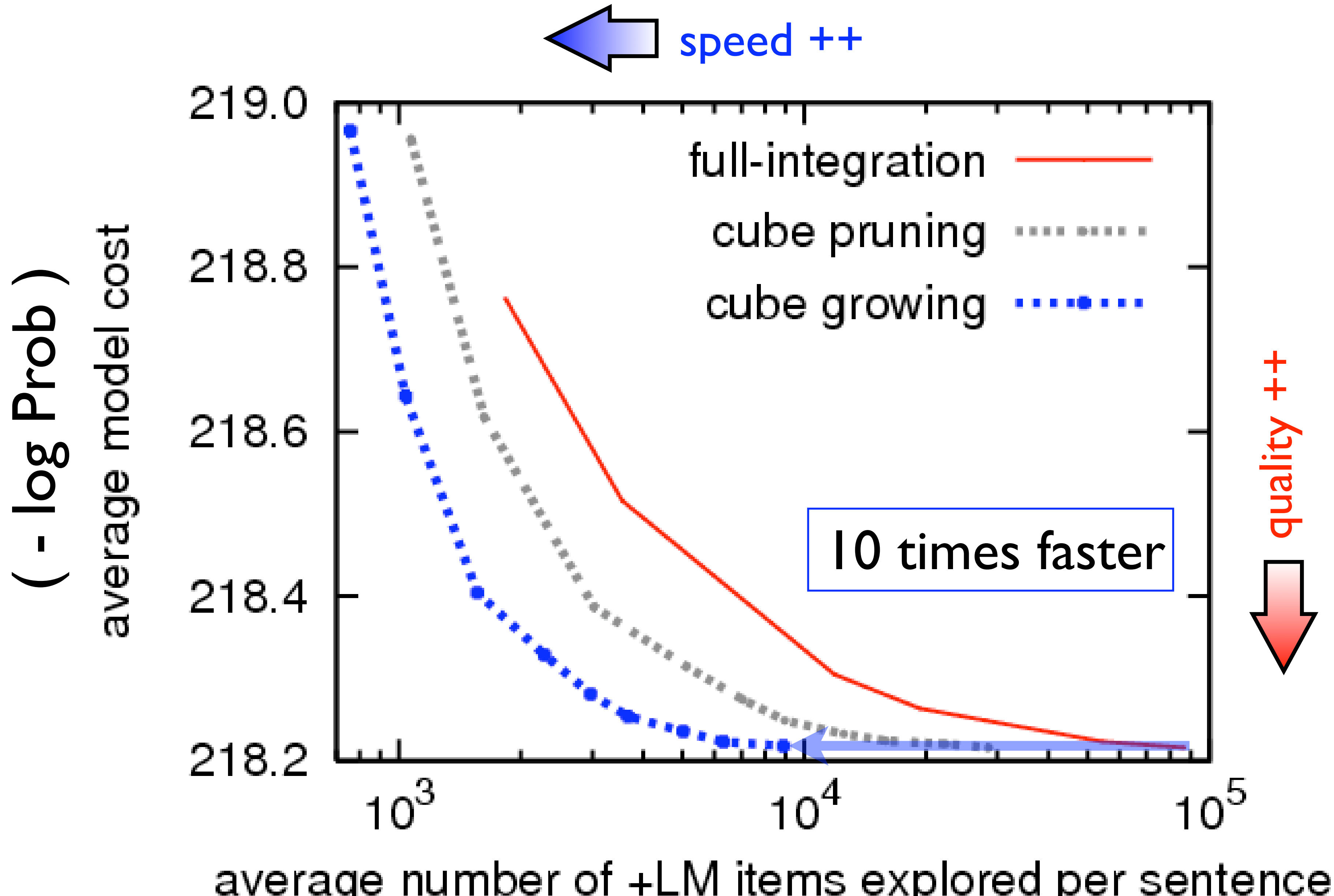

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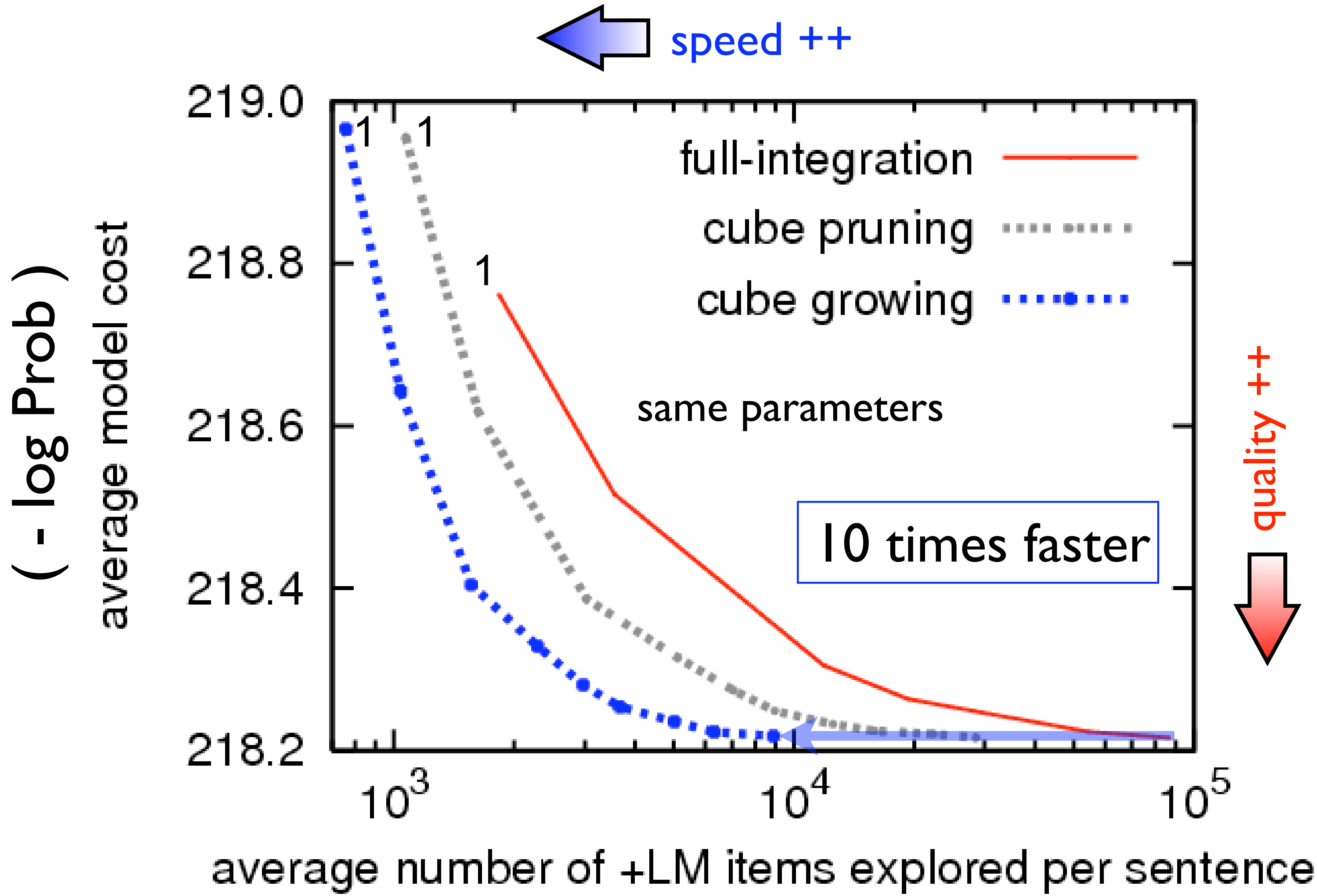

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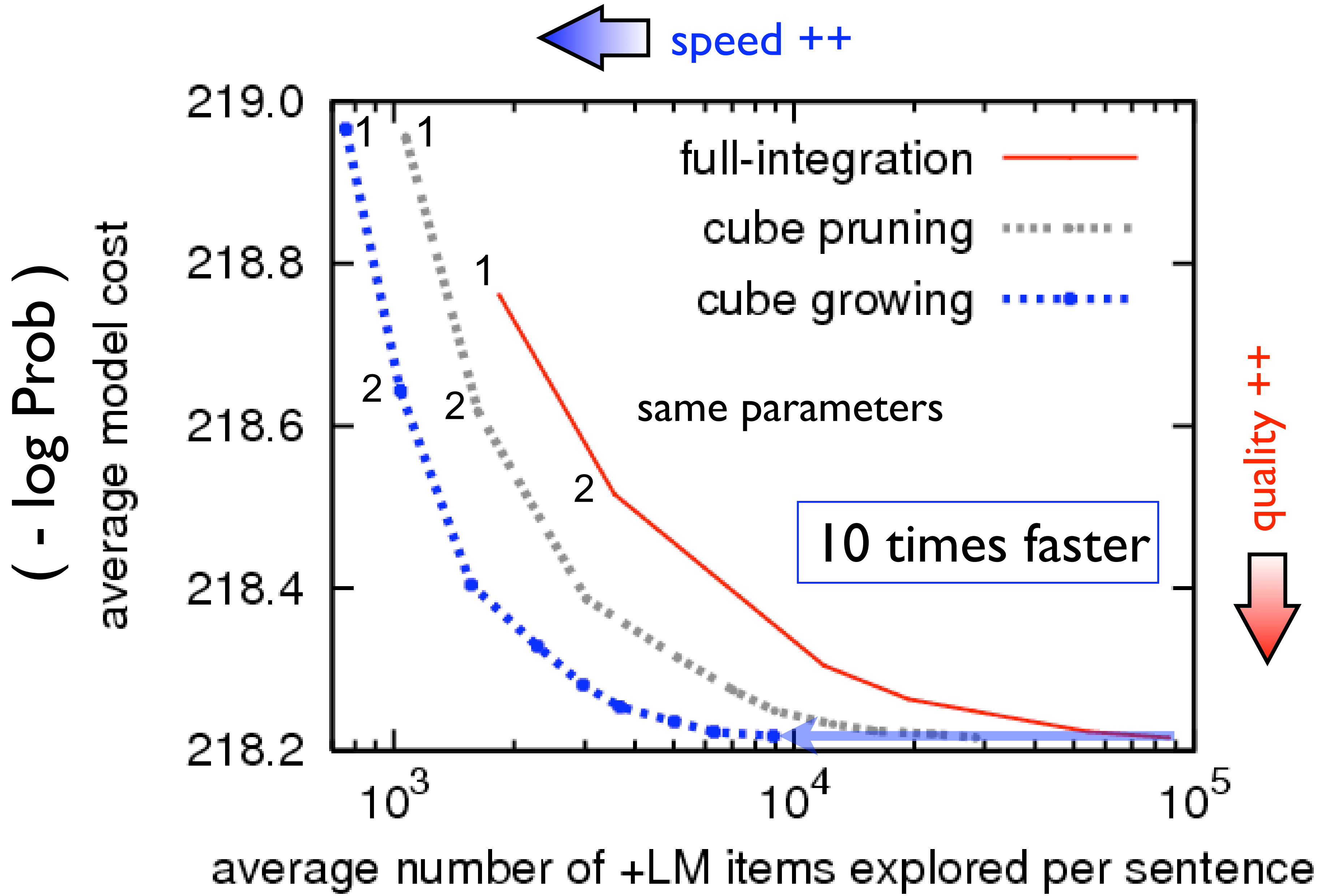

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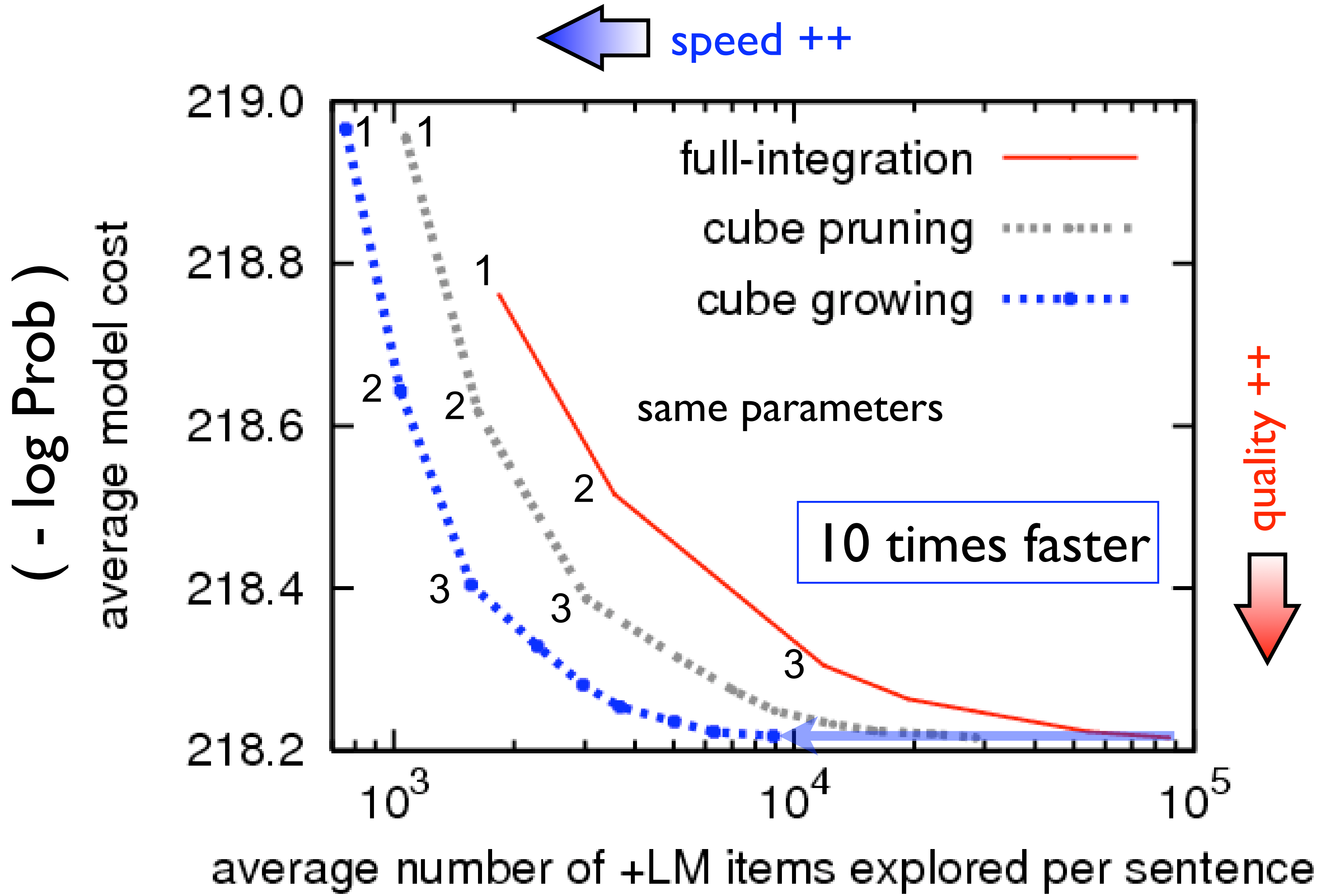
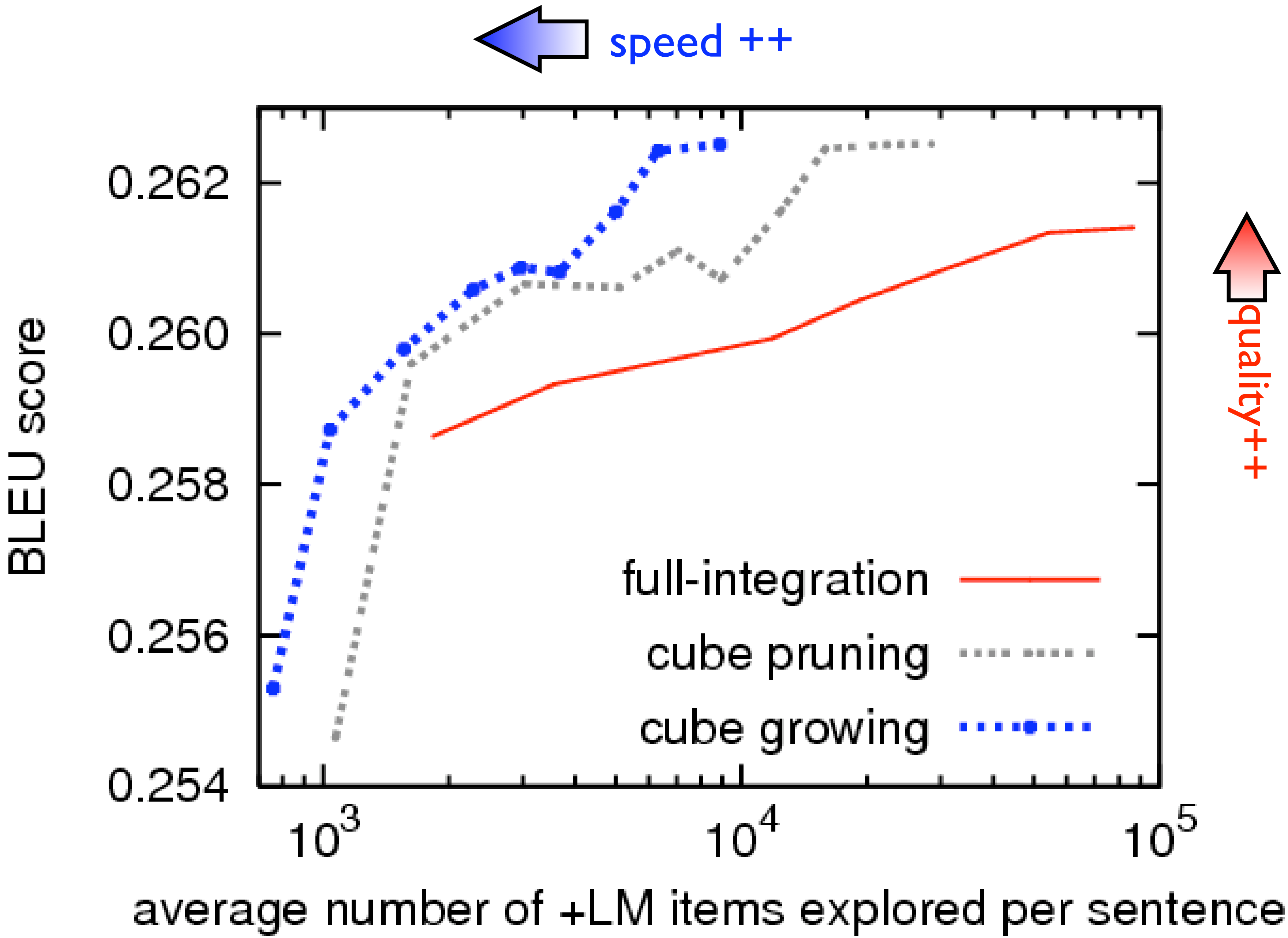


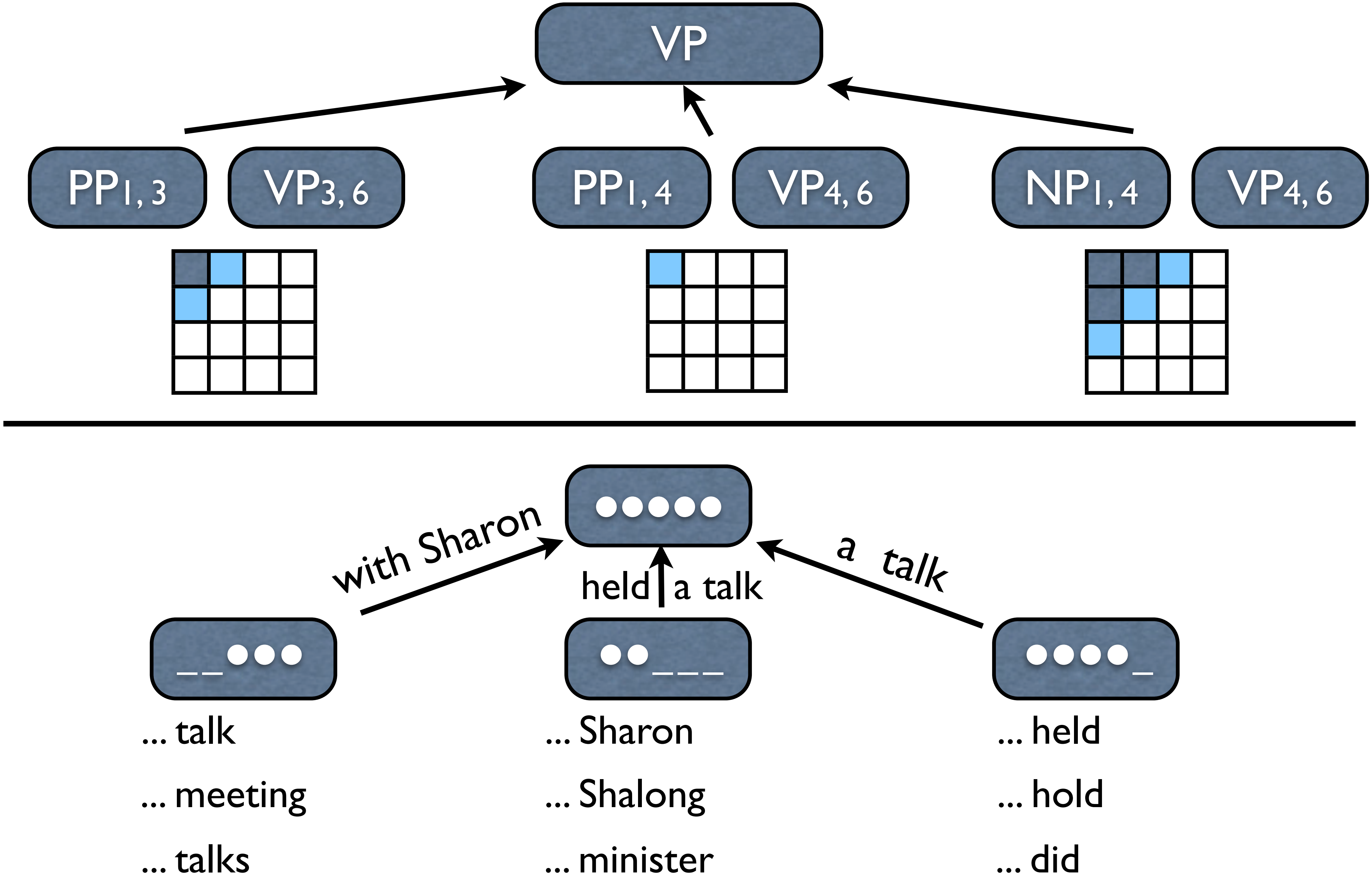
Speed vs. Translation Accuracy



Cube-Pruning for

Phrase-based Decoding

Syntax vs. Phrase-based



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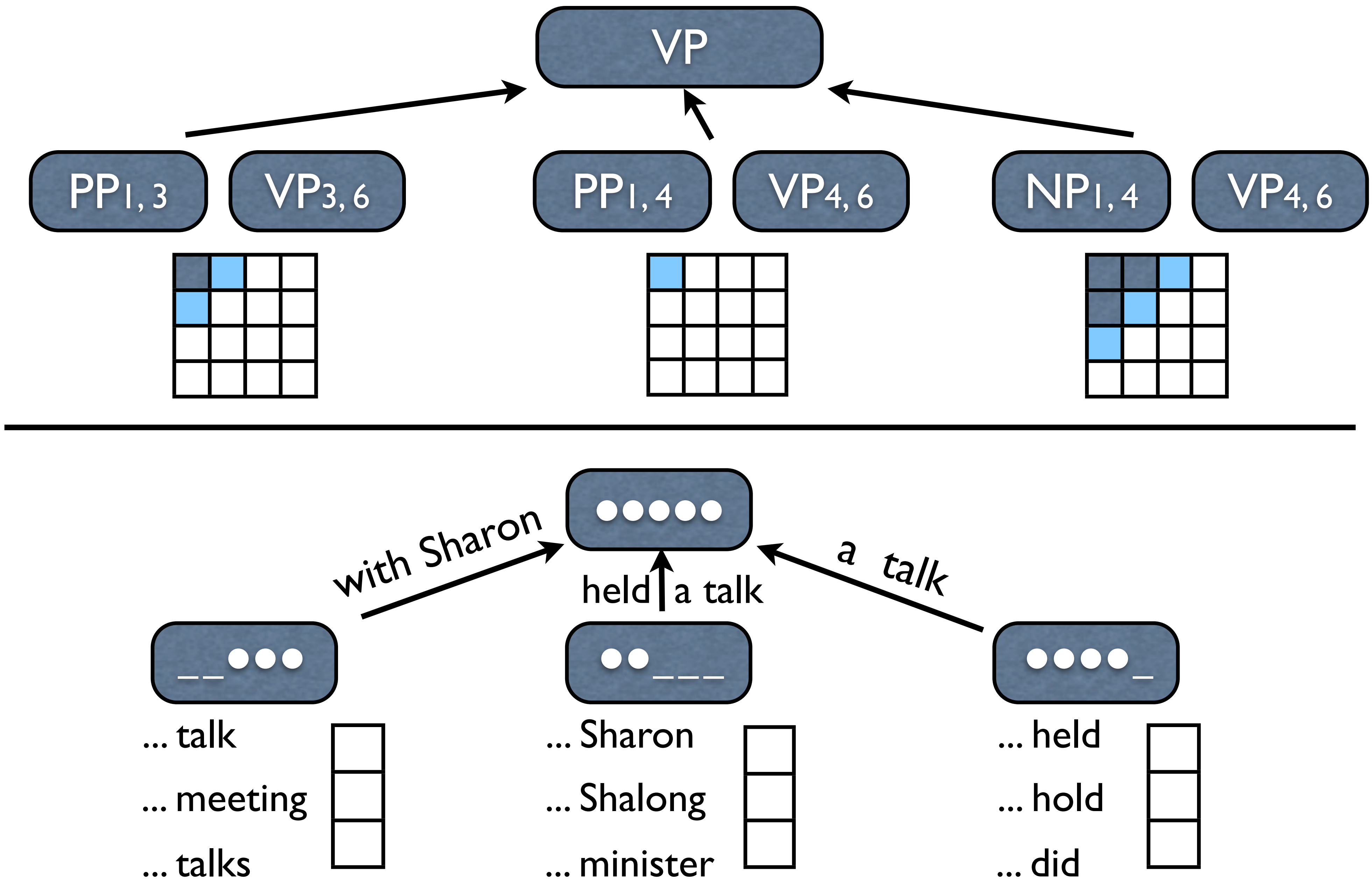
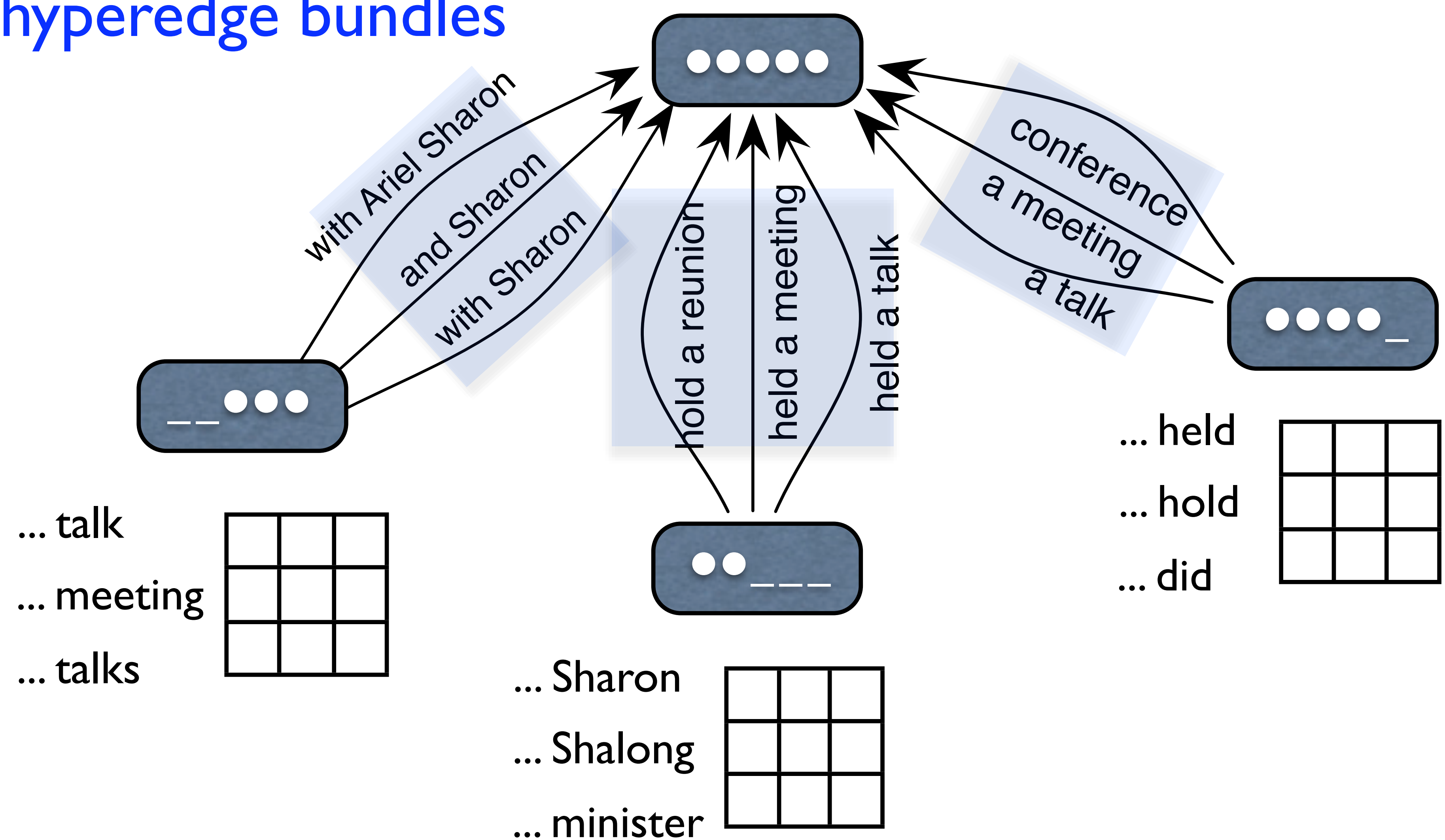


Alternative Phrase-Pairs

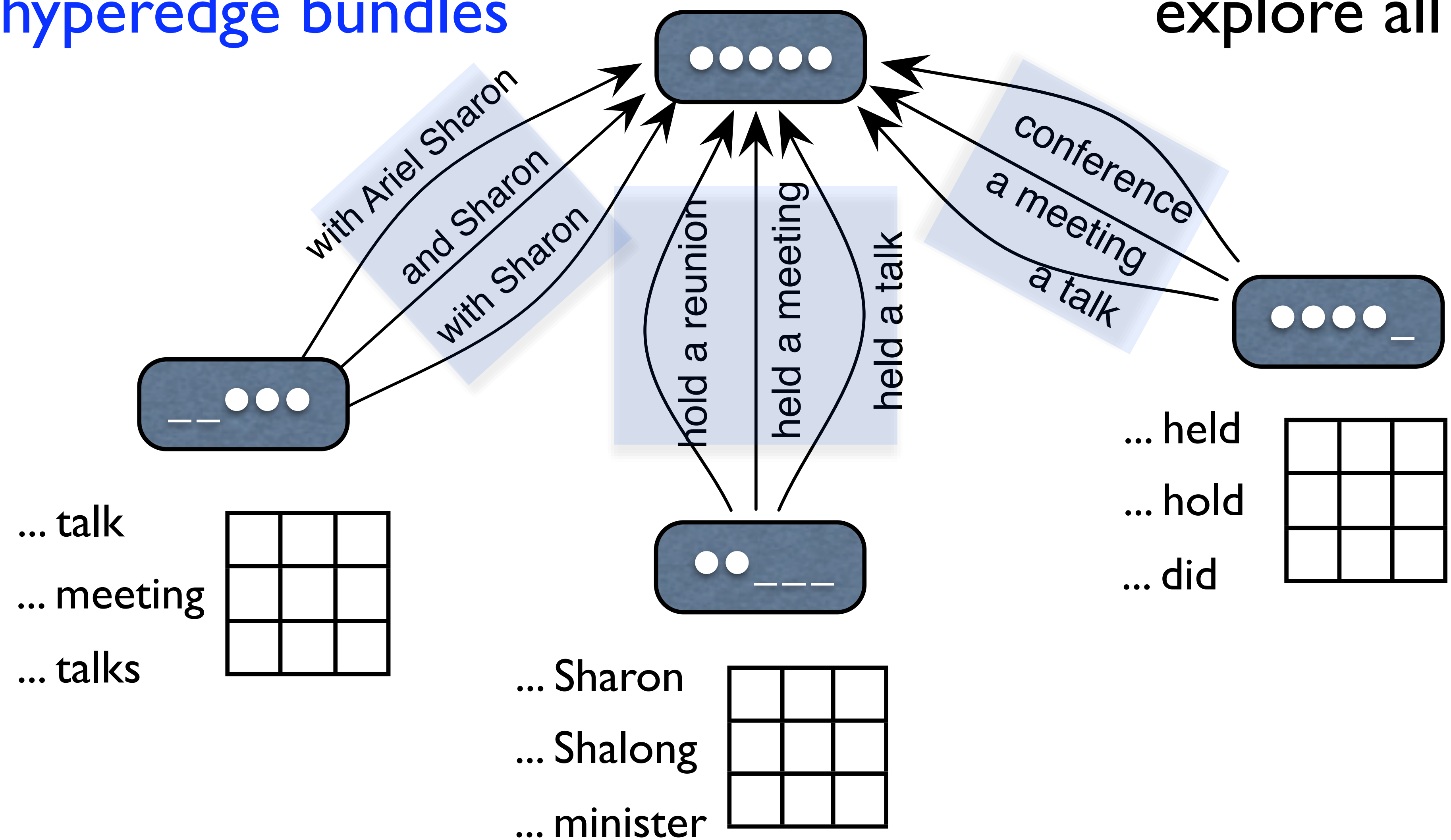
grouping into
hyperedge bundles



Alternative Phrase-Pairs

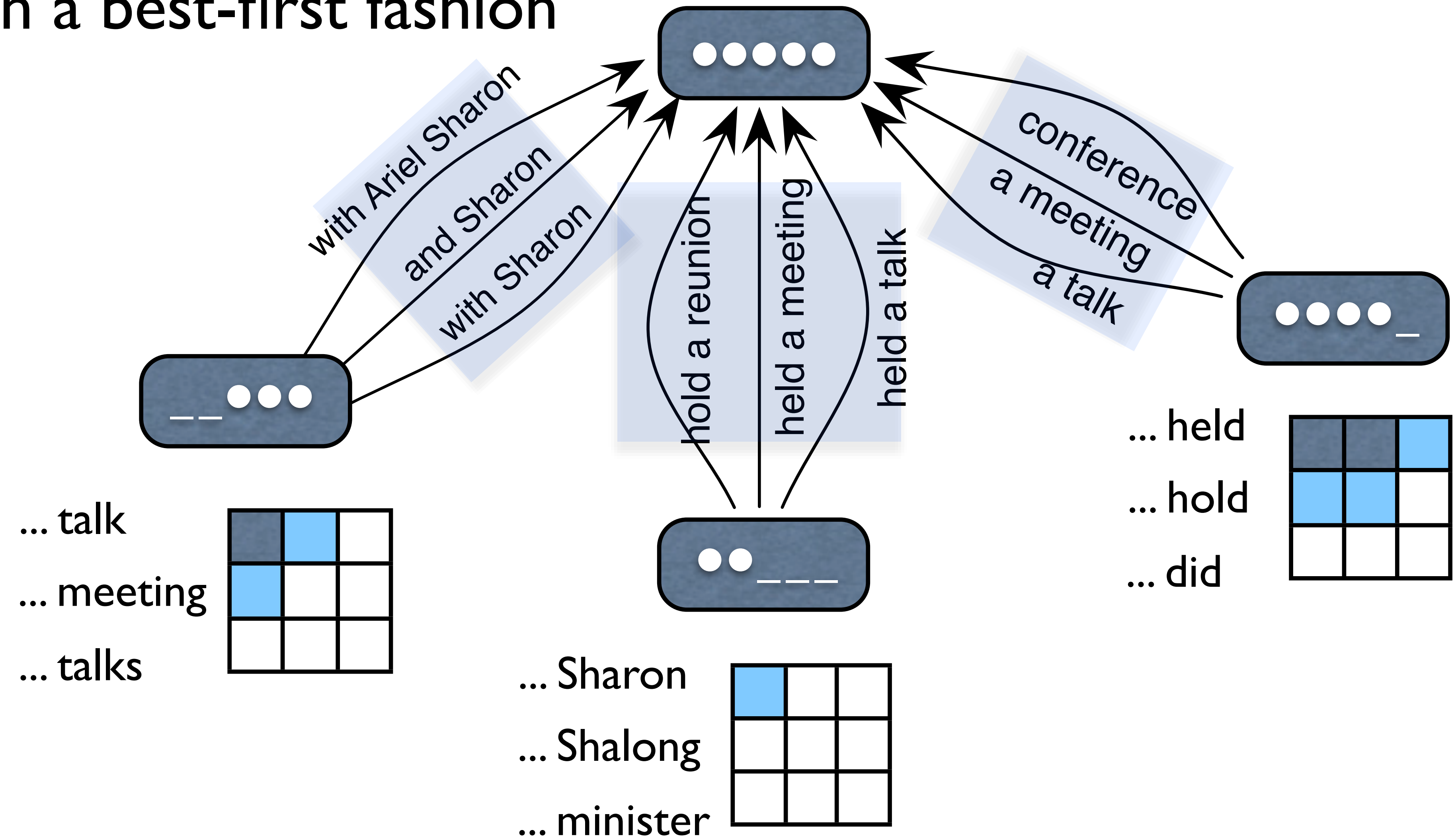
grouping into
hyperedge bundles

Pharaoh would
explore all cells



Cube Pruning

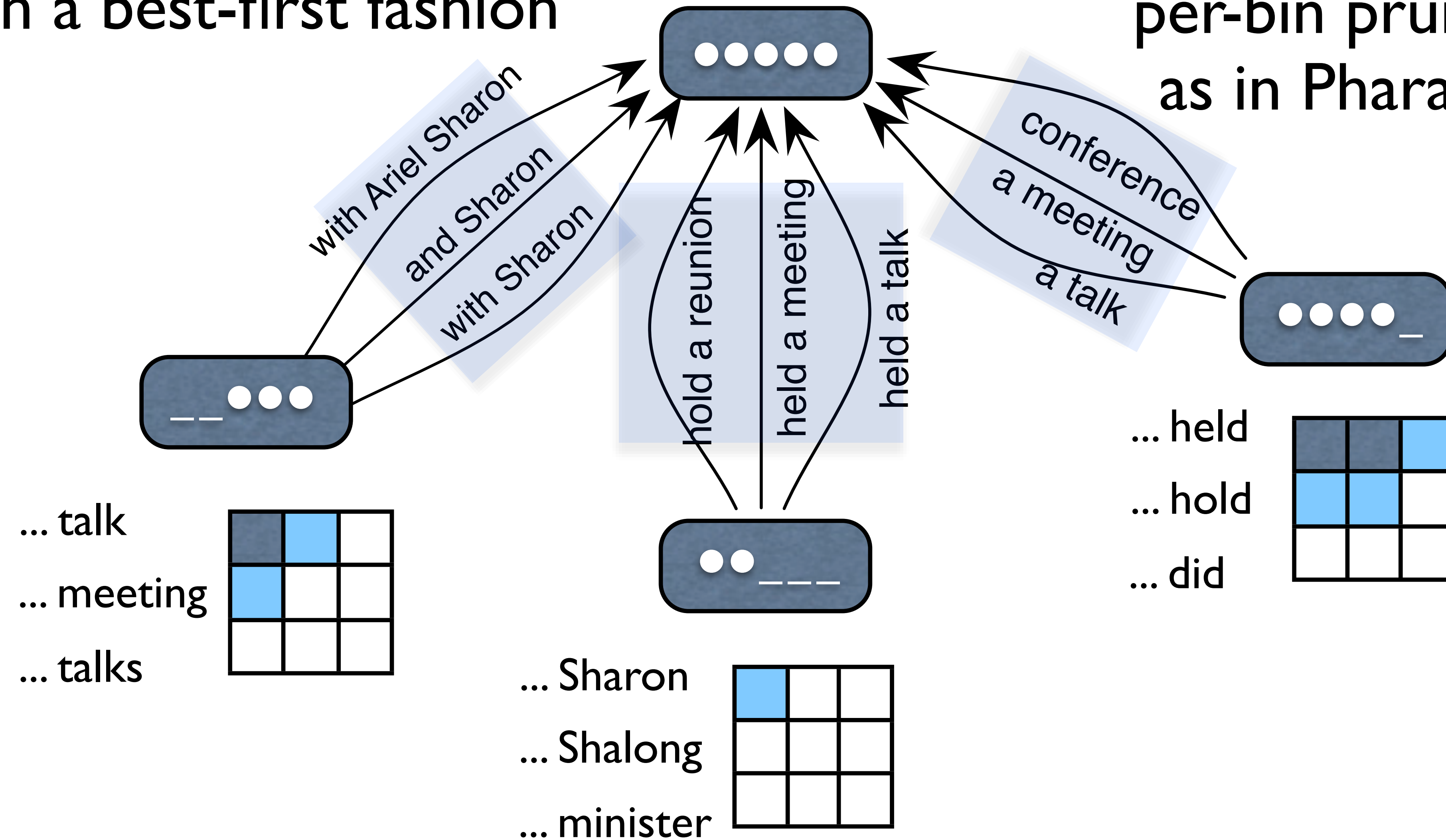
but we explore the grids
in a best-first fashion



Cube Pruning

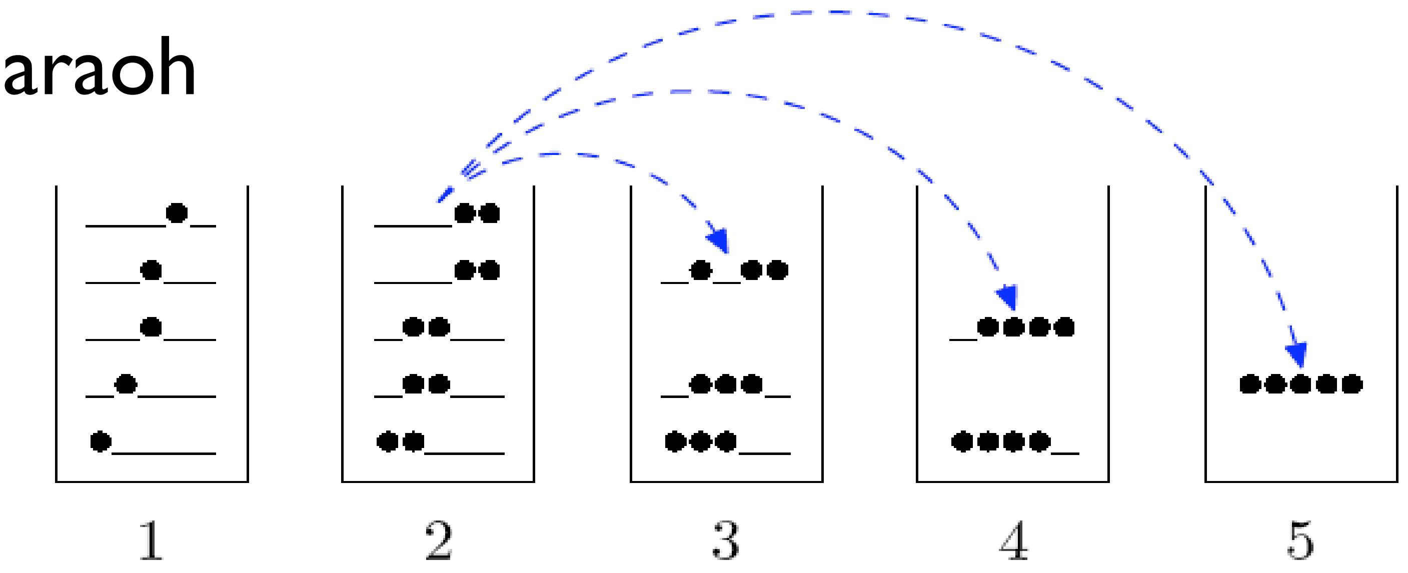
but we explore the grids in a best-first fashion

in practice we use per-bin pruning as in Pharaoh



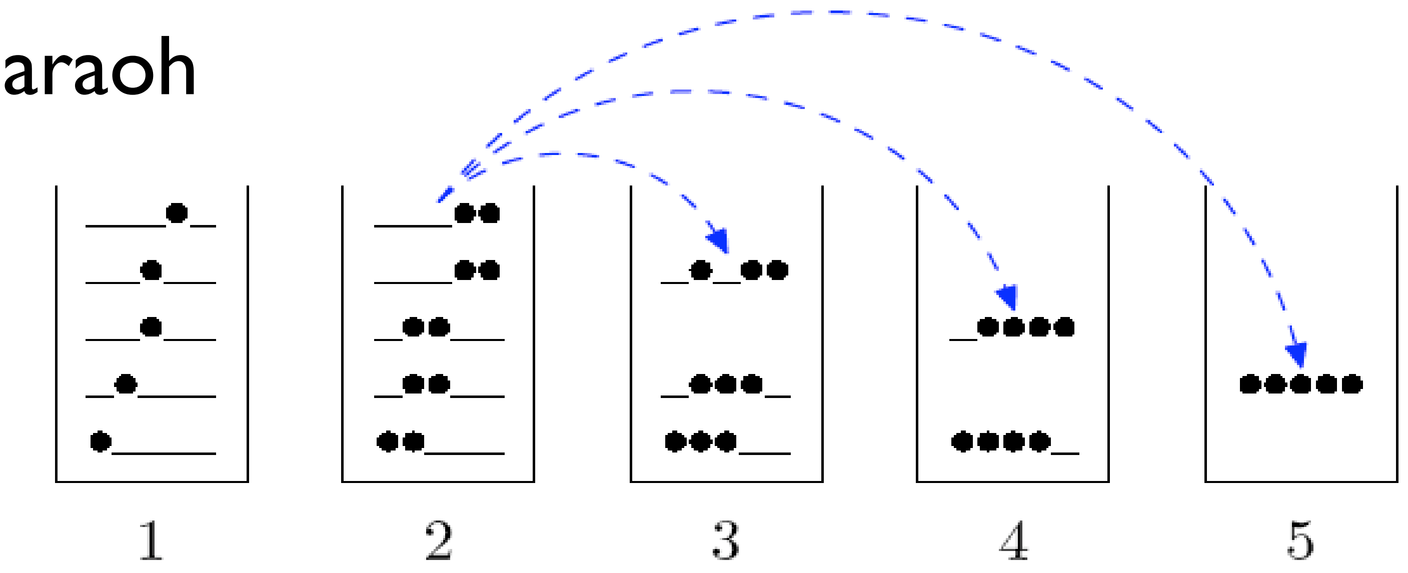
In Practice: per-bin Pruning

Pharaoh

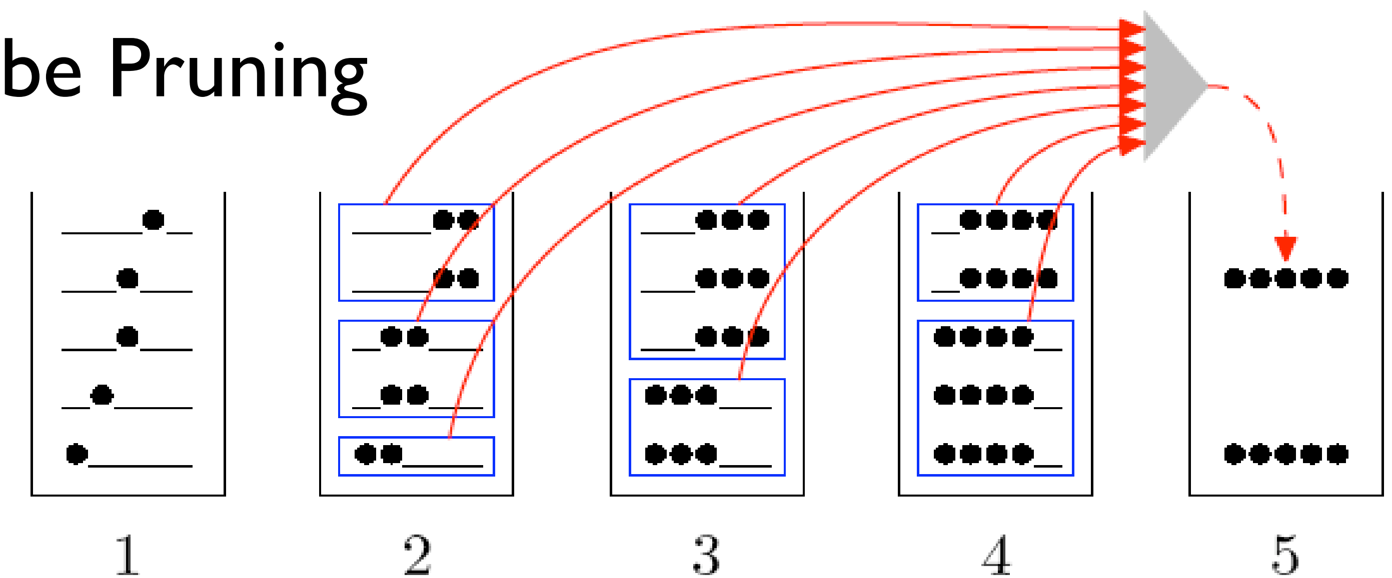


In Practice: per-bin Pruning

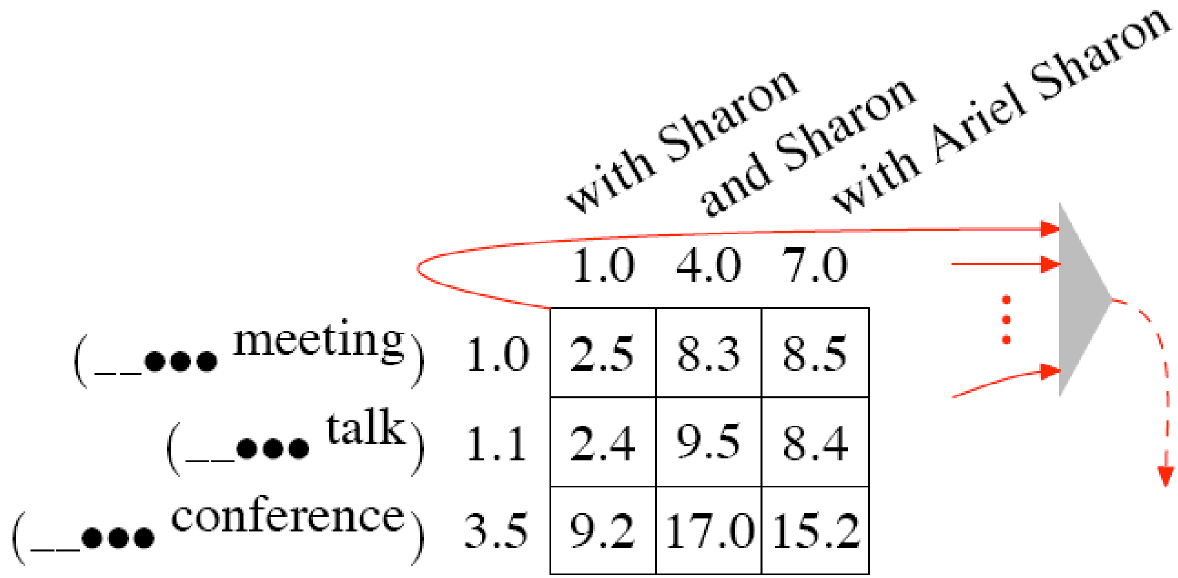
Pharaoh



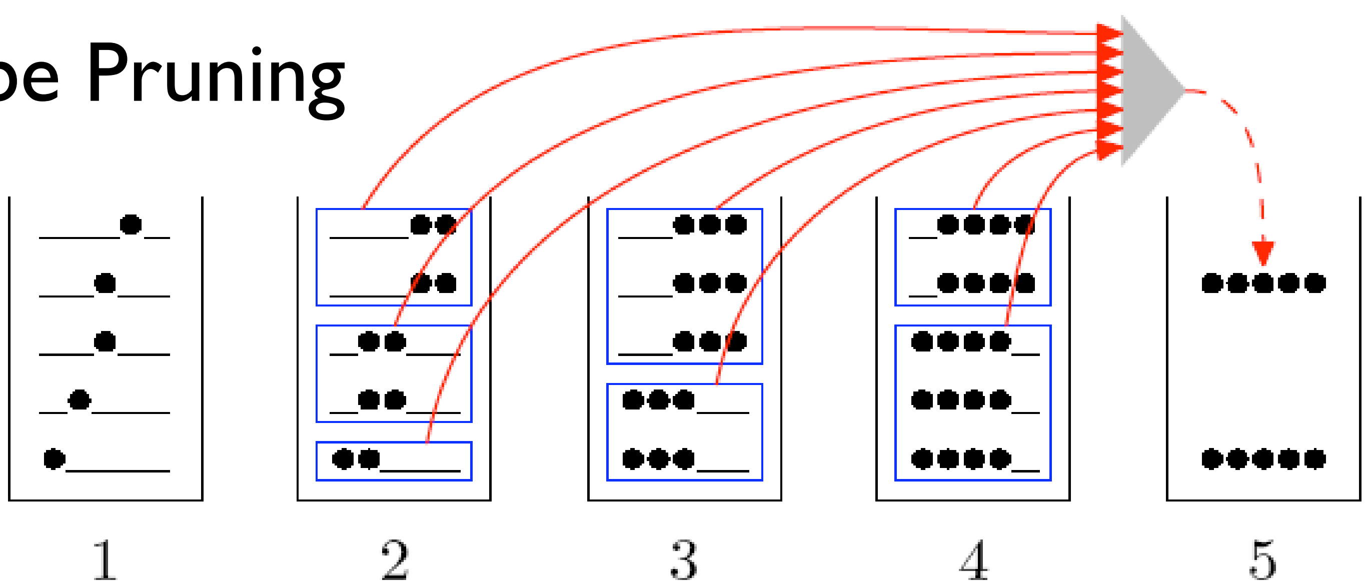
Cube Pruning



In Practice: per-bin Pruning

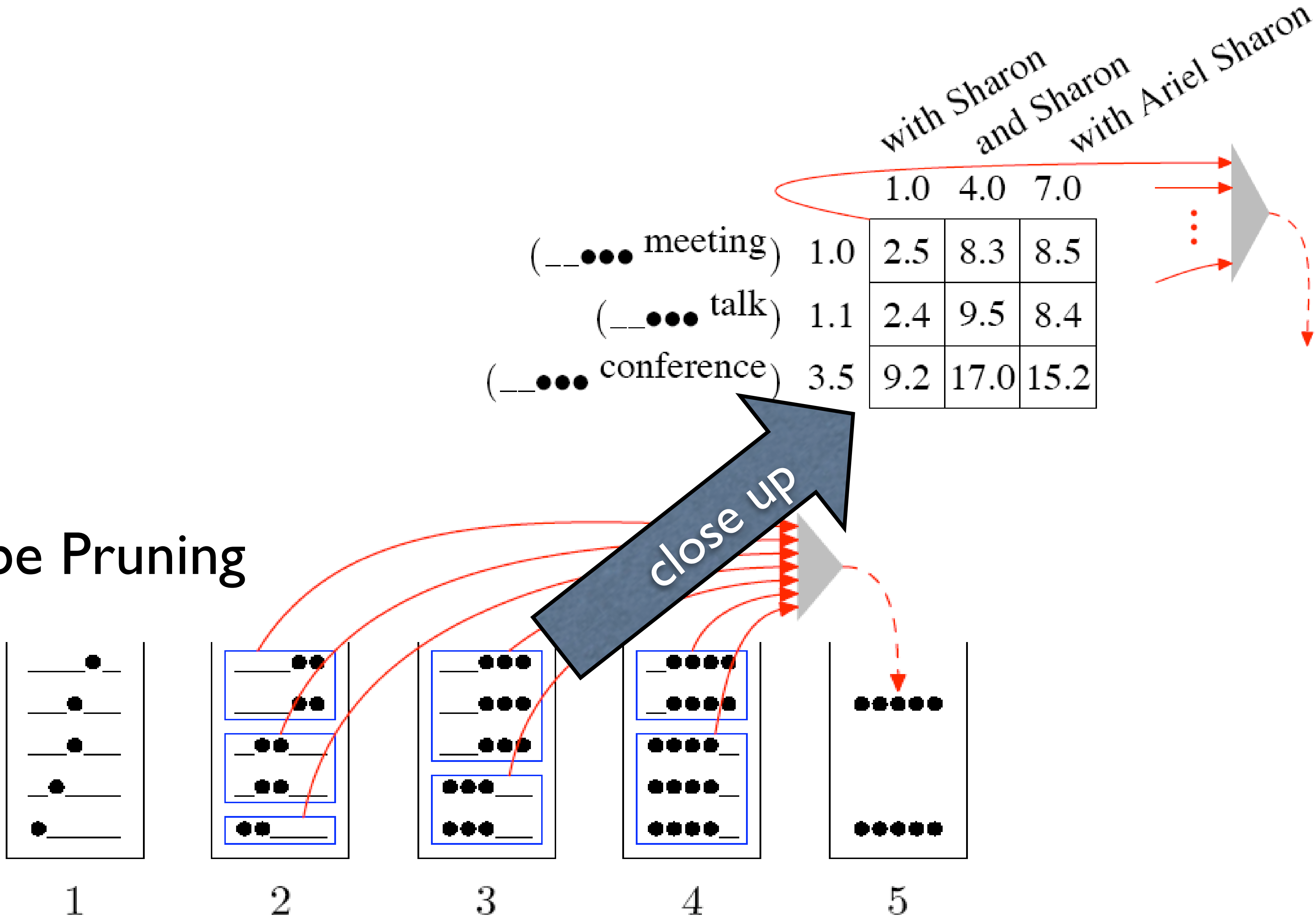


Cube Pruning

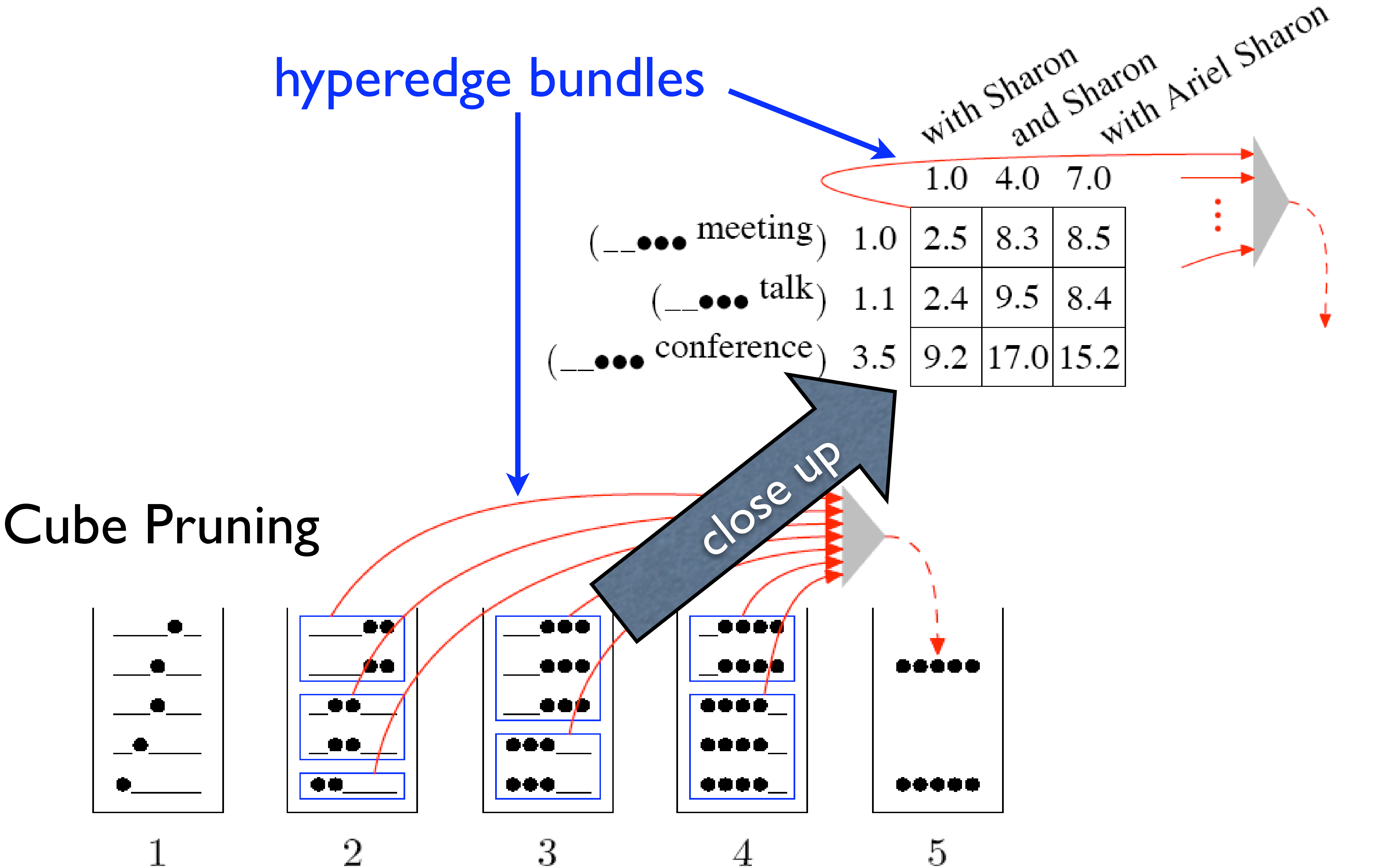


In Practice: per-bin Pruning

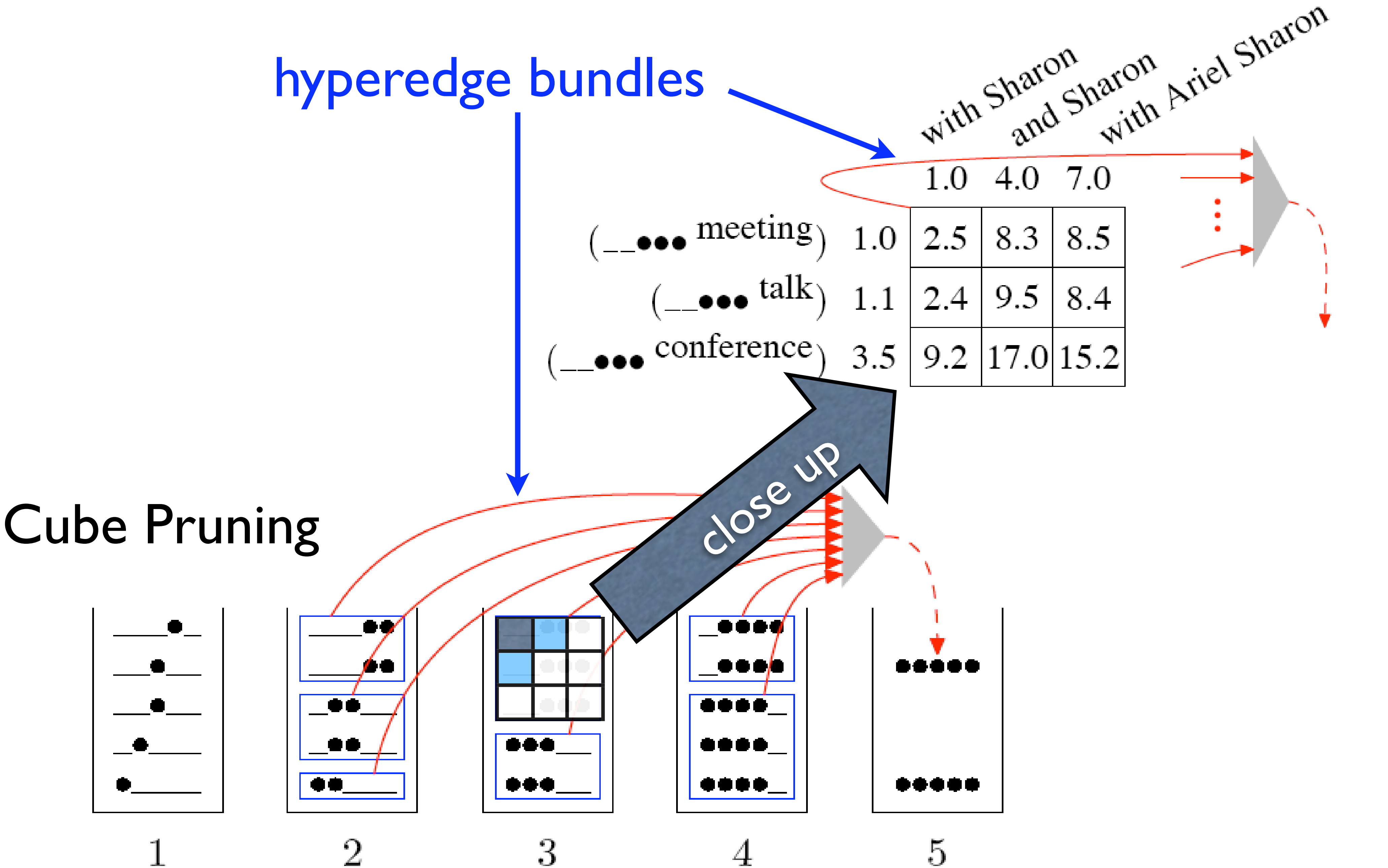
Cube Pruning



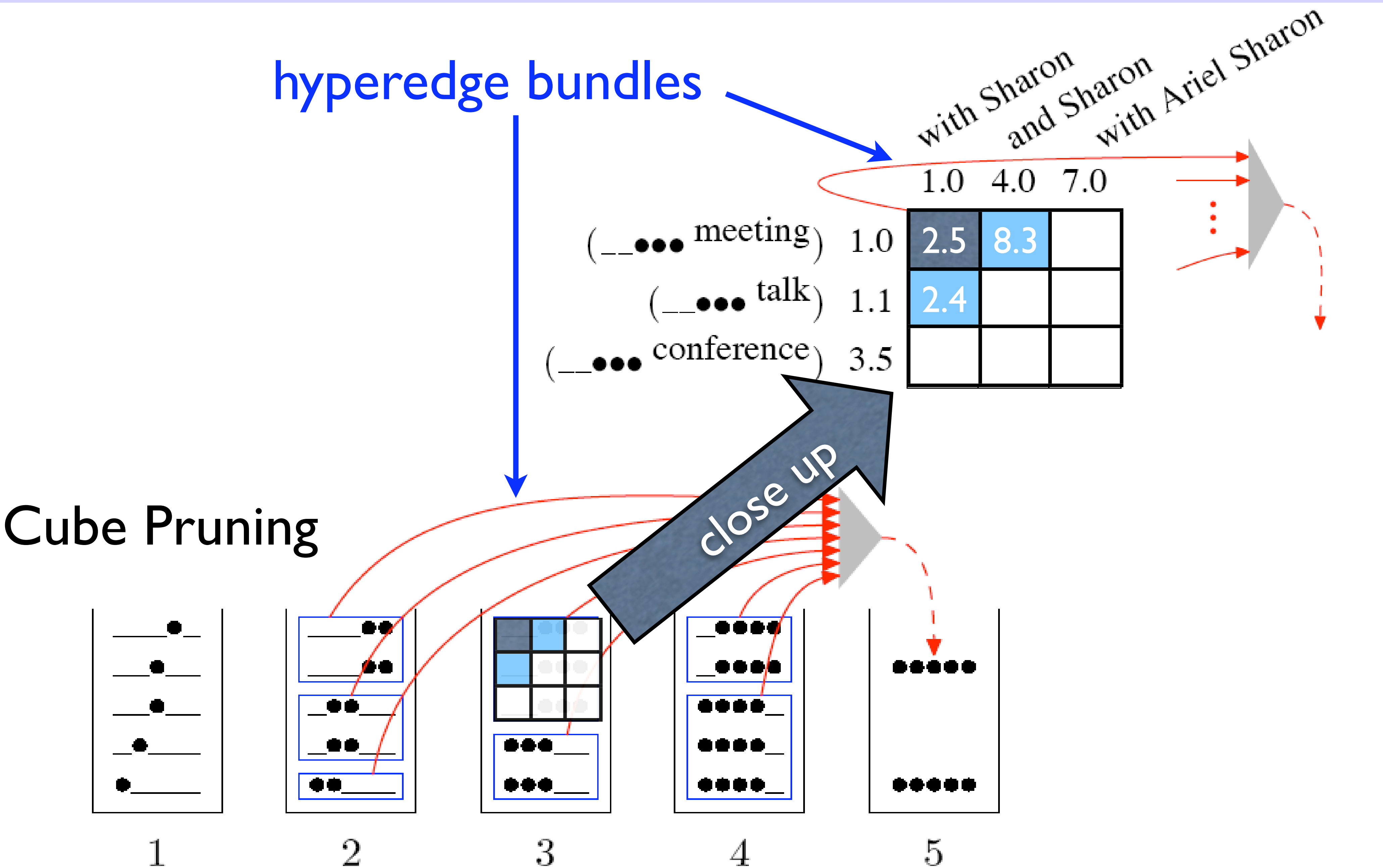
In Practice: per-bin Pruning



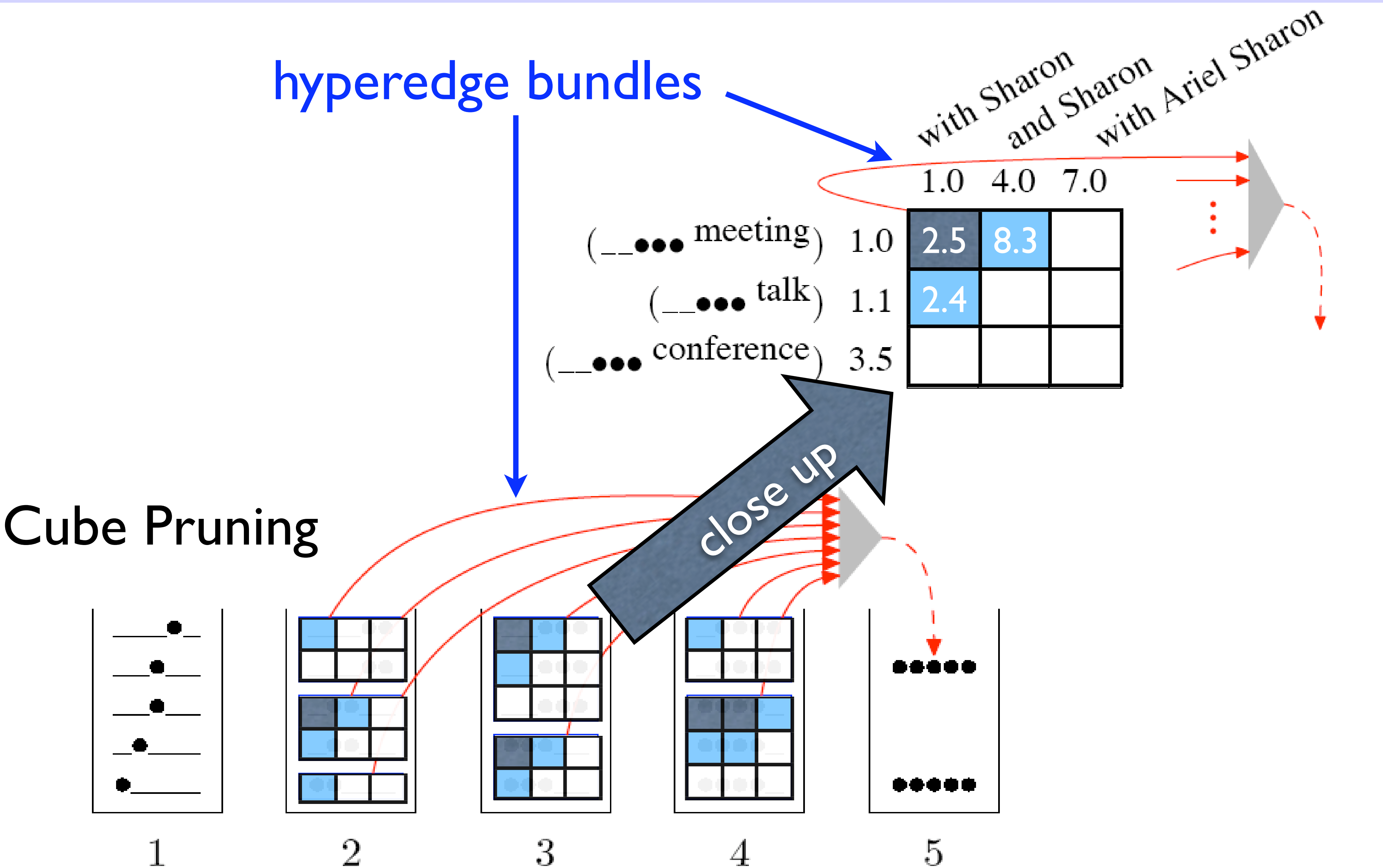
In Practice: per-bin Pruning



In Practice: per-bin Pruning

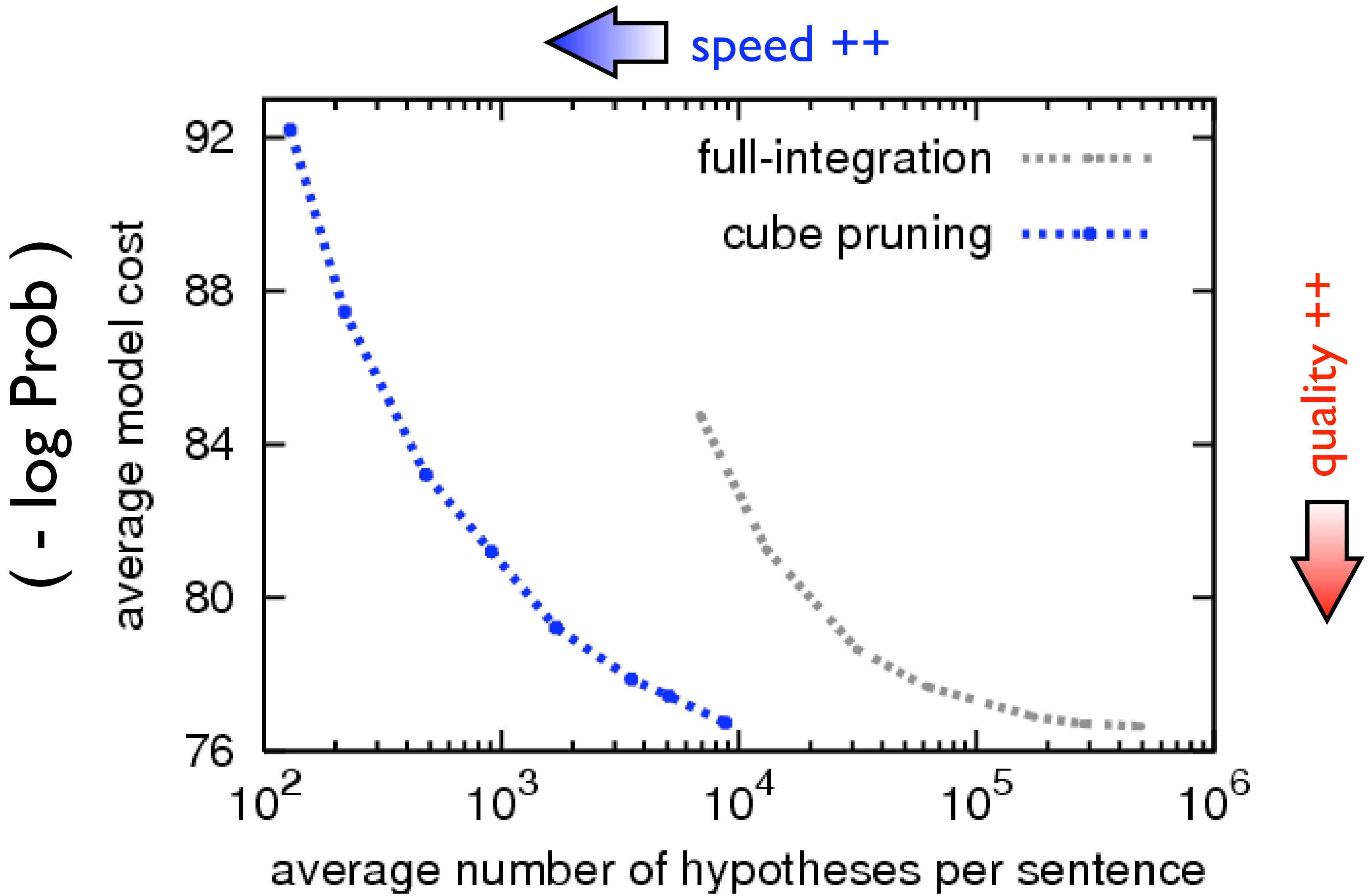


In Practice: per-bin Pruning



Speed vs. Search Quality

tested on our faithful clone of Pharaoh



Speed vs. Search Quality

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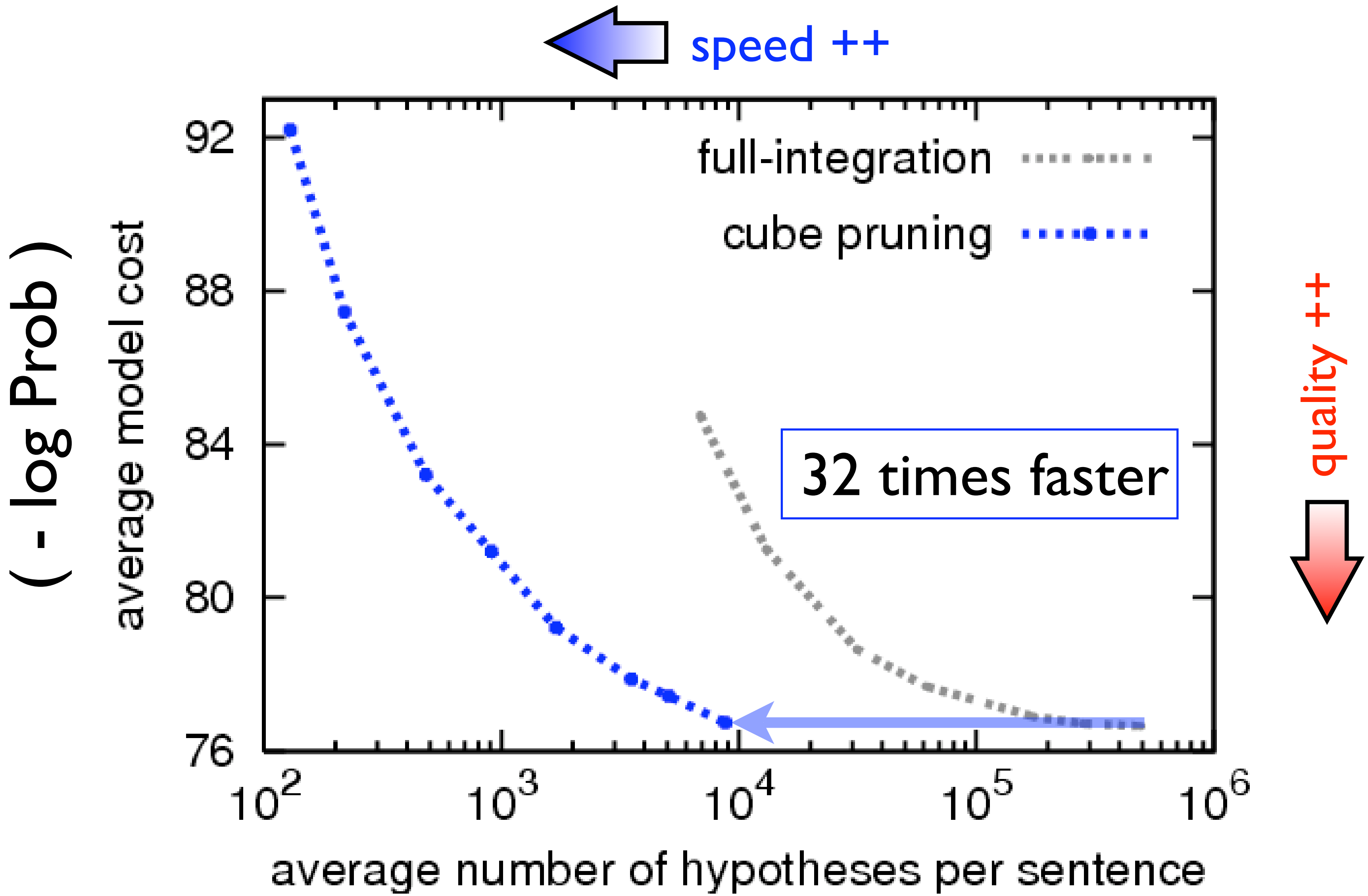

Speed vs. Search Quality

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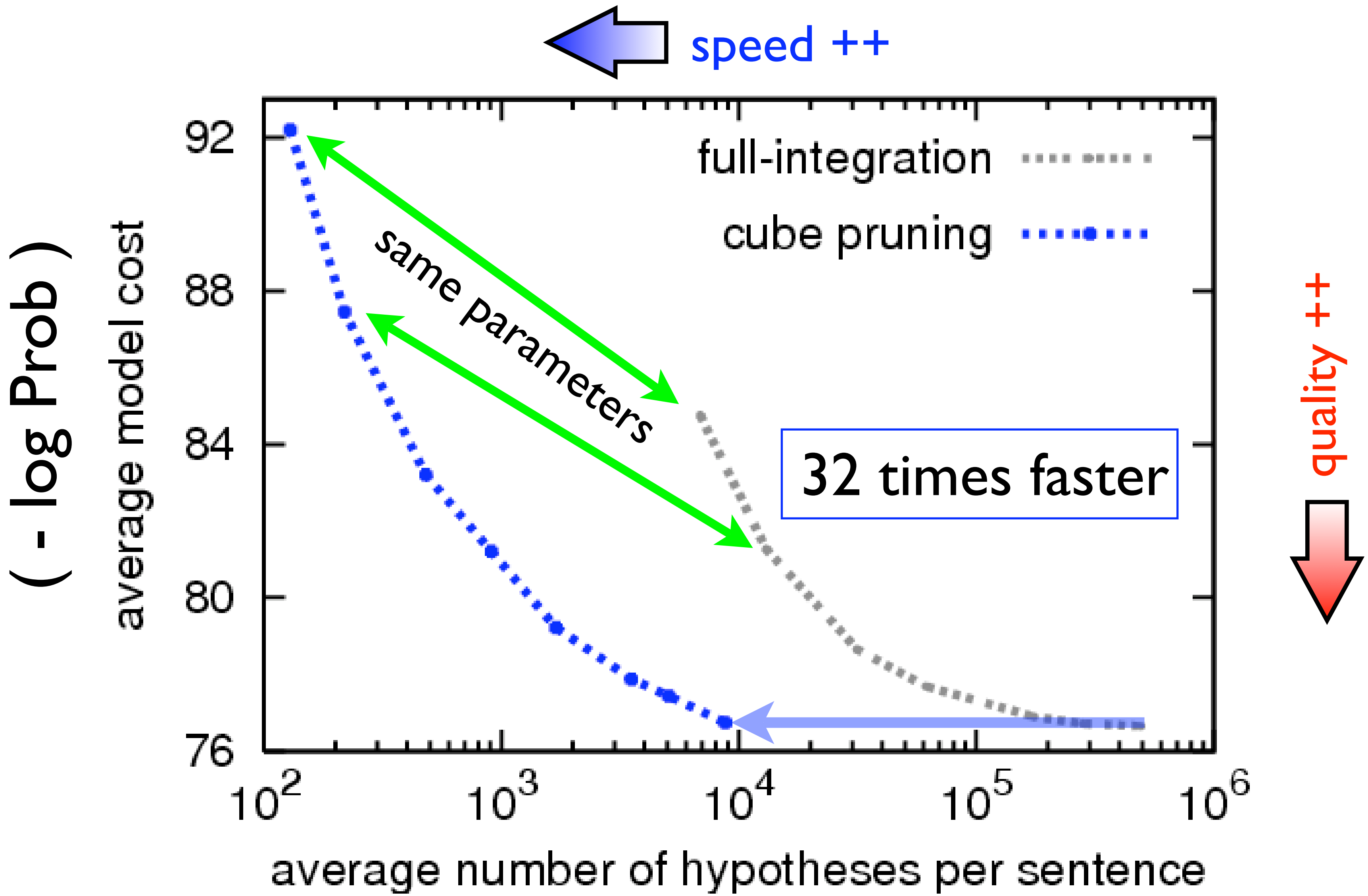
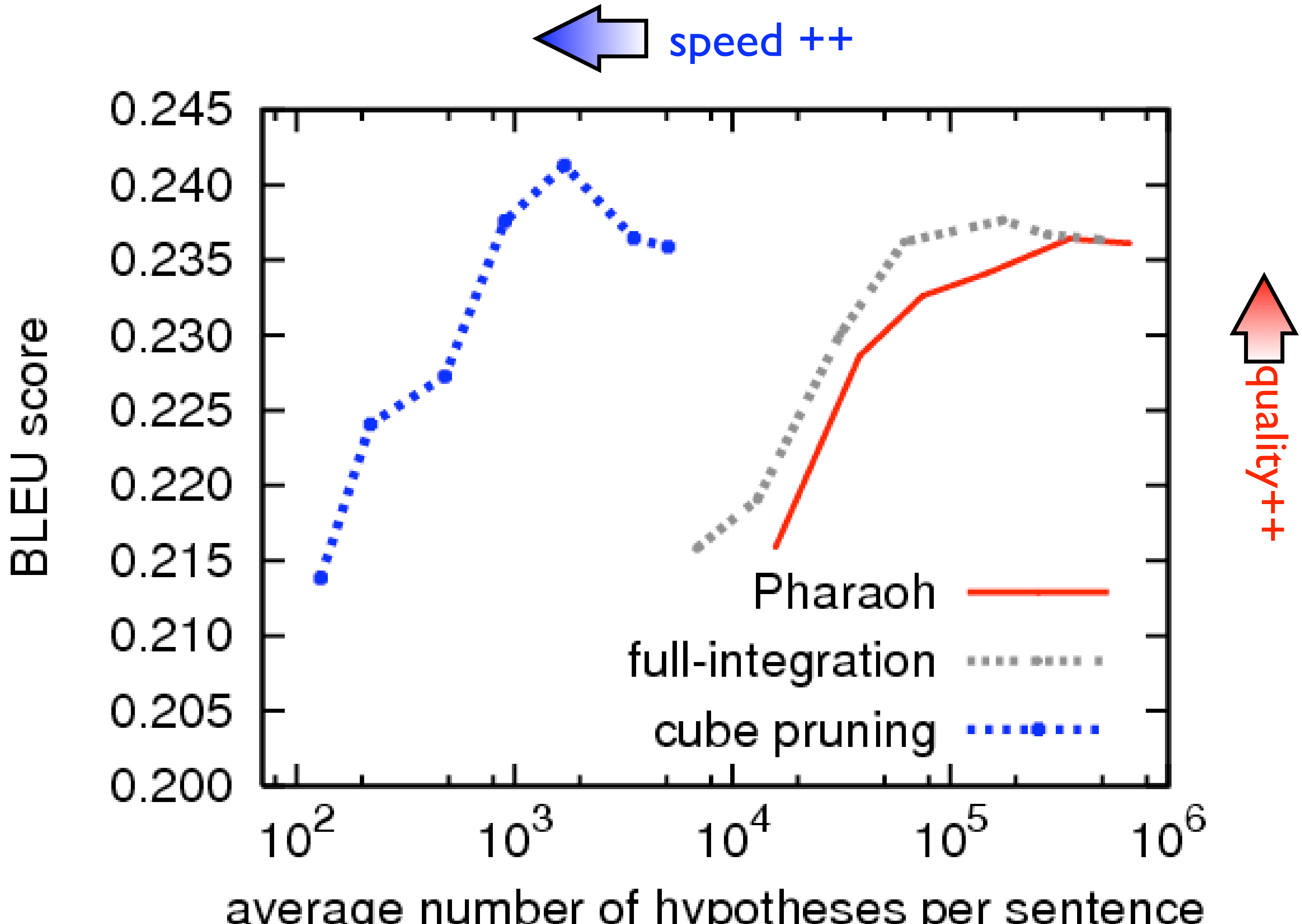
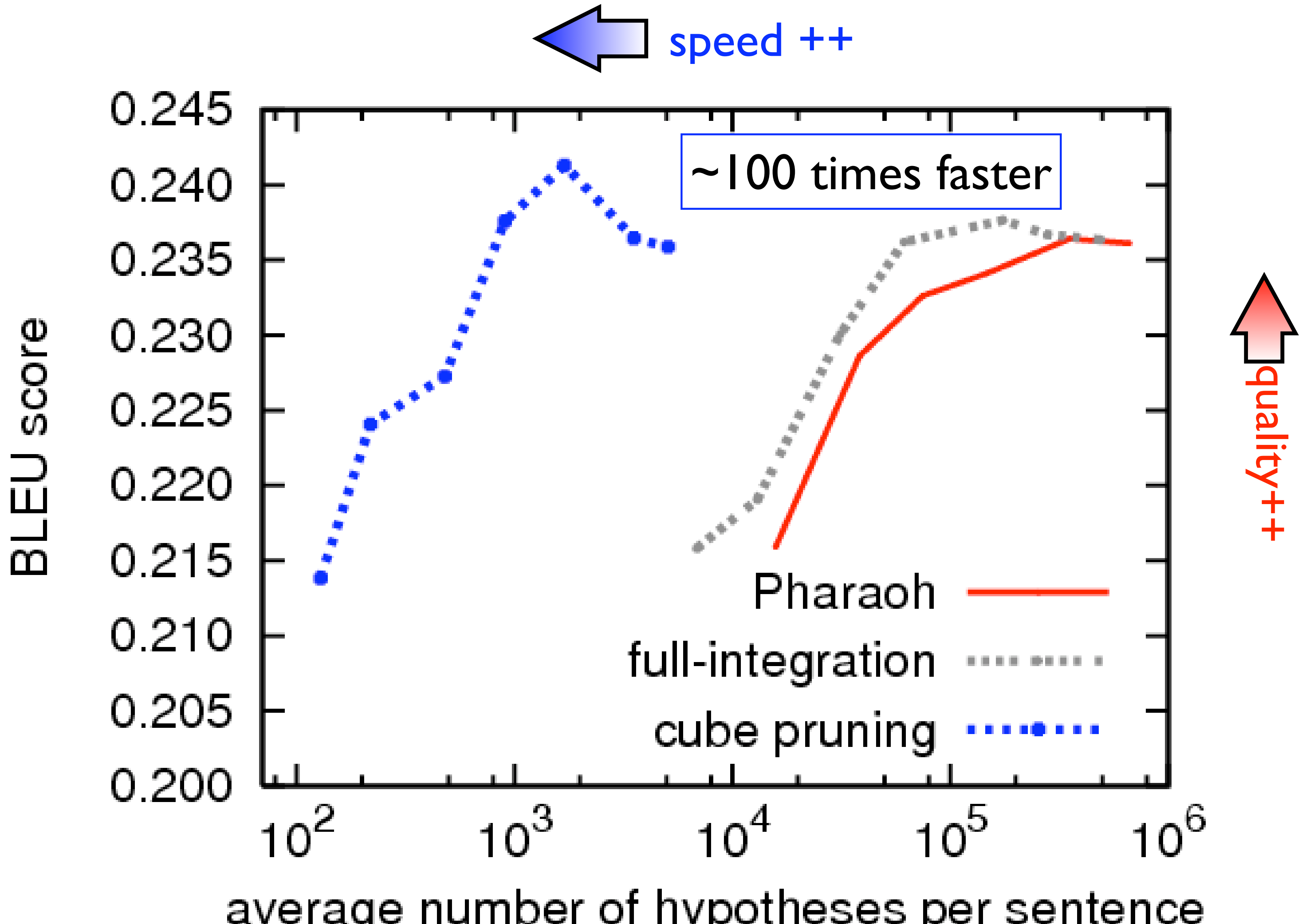


Speed vs. Translation Accuracy



Speed vs. Translation Accuracy



Conclusions

- forest-rescoring: cube pruning and cube growing
  - on-the-fly rescoring using *k*-best parsing
  - applicable to both phrase- and syntax-based systems
  - significant speed-up against conventional beam search
- general technique for reducing search spaces
  - effectiveness depends on scale of non-monotonicity
- future work
  - forest-reranking: parsing with non-local features

Thanks!

try out Cubit

a cube pruning decoder for phrase-based translation

www.cis.upenn.edu/~lhuang3/cubit/