# Energy Efficient Hybrid Wakeup Logic

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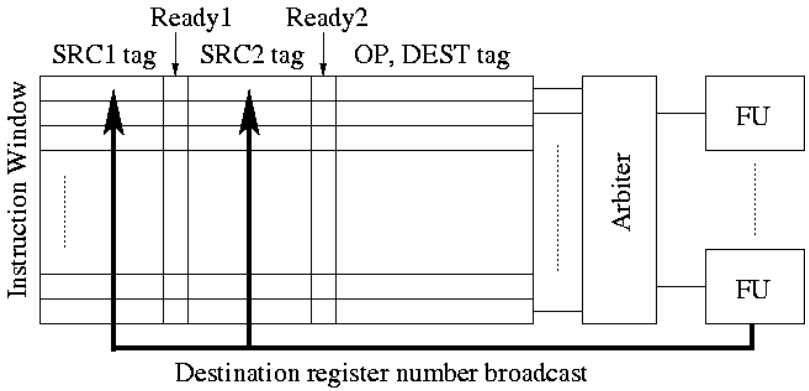
# Introduction

- Instruction window : major energy consumer
  - Wakeup logic checks many entries



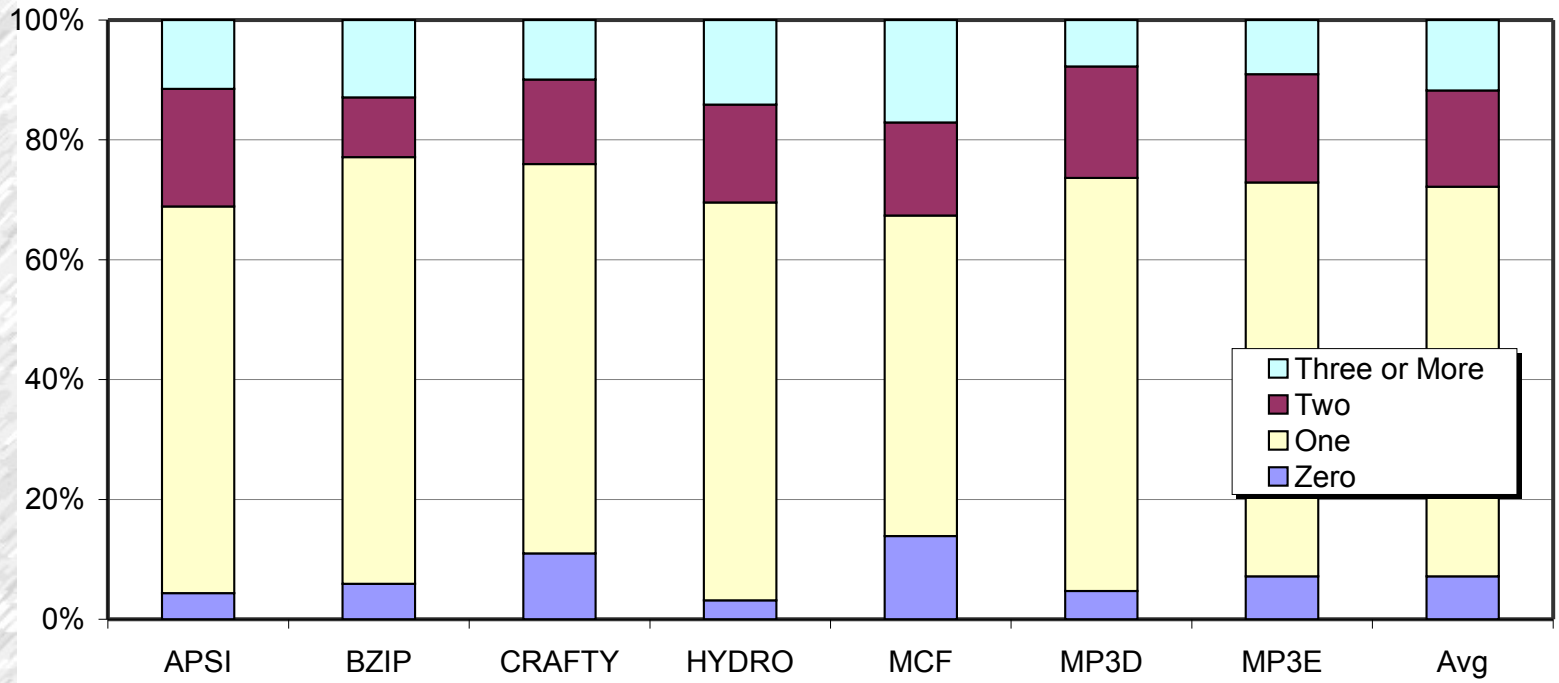

- Schemes to reduce unnecessary operations:
  - Gating empty entries*
  - Gating ready entries*

  Comparisons reduced to 25%
- Exploiting a different fact:
  - Dependence tree is narrow (small fan-out)

  Comparisons reduced to 1%

[*] Folegnani and Gonzalez, ISCA 2001

# Rationale: Number of Dependents



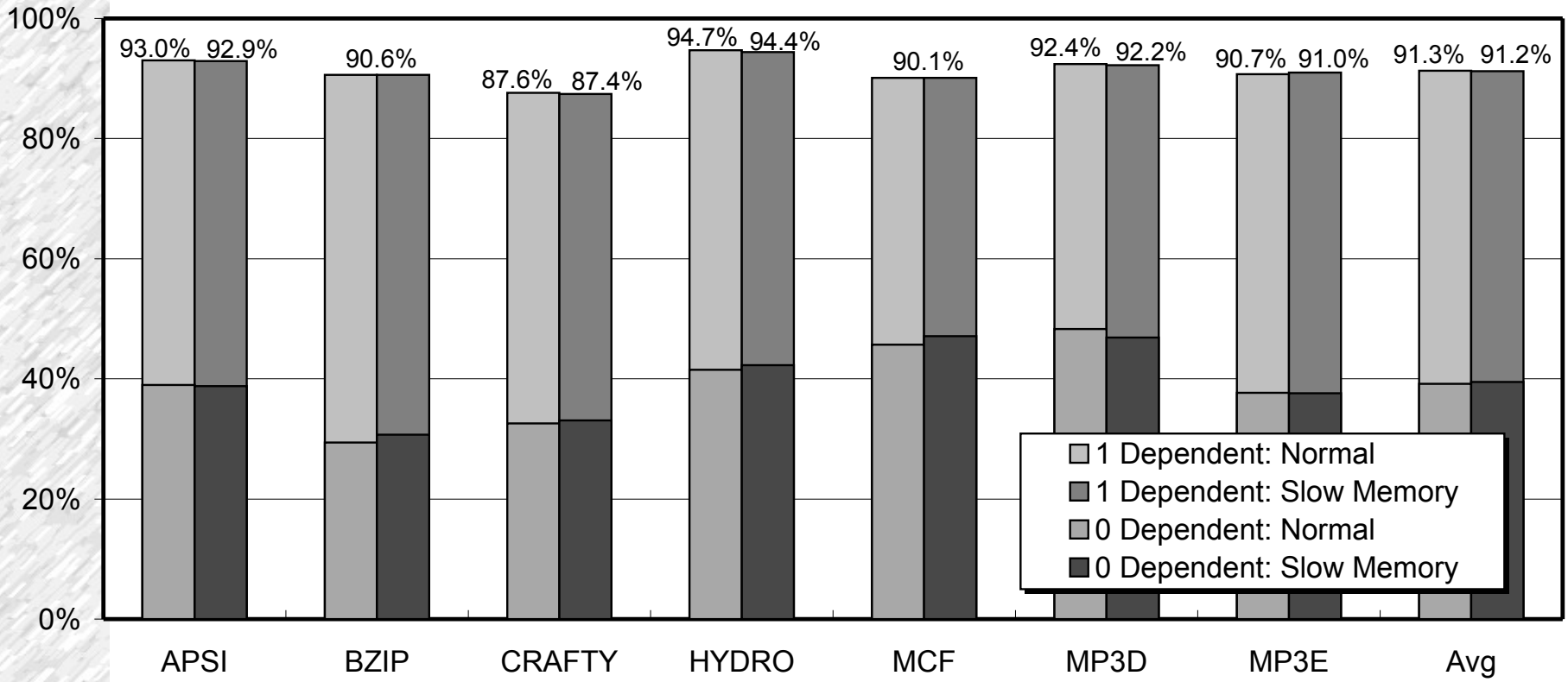

- Many instructions have 1 or less dependent
  - Not counting instructions without destination register (branch, store)
  - Close-by dependent is what matters – even fewer

# Experimental Setup

| Processor | |
|---|---|
| 1GHz 6-issue OOO core<br>I-window: 96 entries<br>Int/FP/LS units: 5/4/2<br>LSQ: 16/16 | BR: 1 unit (8 cycle min penalty)<br>RAS: 32 entries<br>BTB: 4 way 2048 entries<br>Predictor: GAp (10,8) |
| **Caches** | **Bus & Memory** |
| L1: 32KB 2-way LRU 32B<br>1,3ns (occupancy/latency)<br>L2: 512MB 8-way PLRU 64B<br>4,12ns (occupancy/latency)<br>I-Cache: 32KB 2-way LRU | FSB: 128-bit 333MHz<br>DRAM: 2-channel Rambus<br>Bandwidth: 3.2GB/s<br>Memory RT: 108ns |

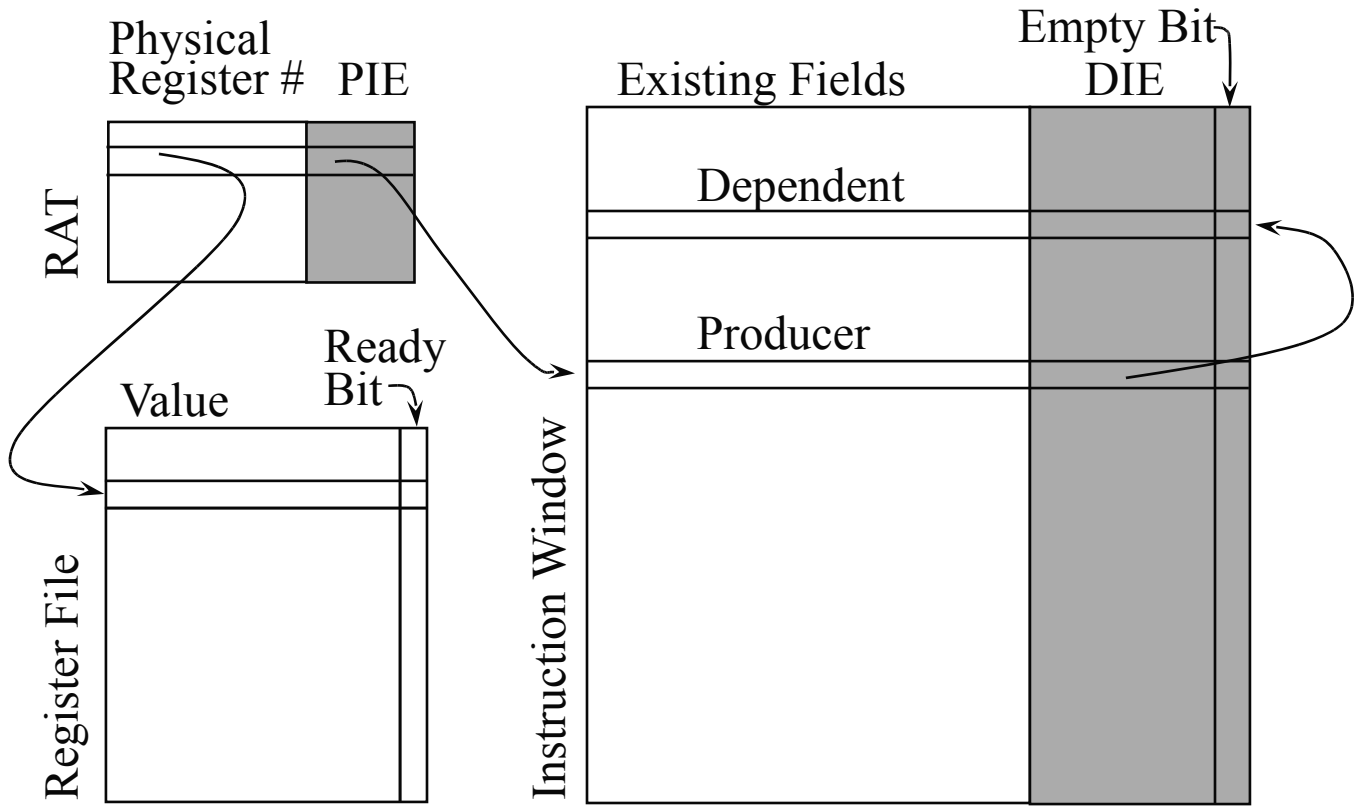
# Number of Close-by Dependents

- Distant dependents do not need wake-up

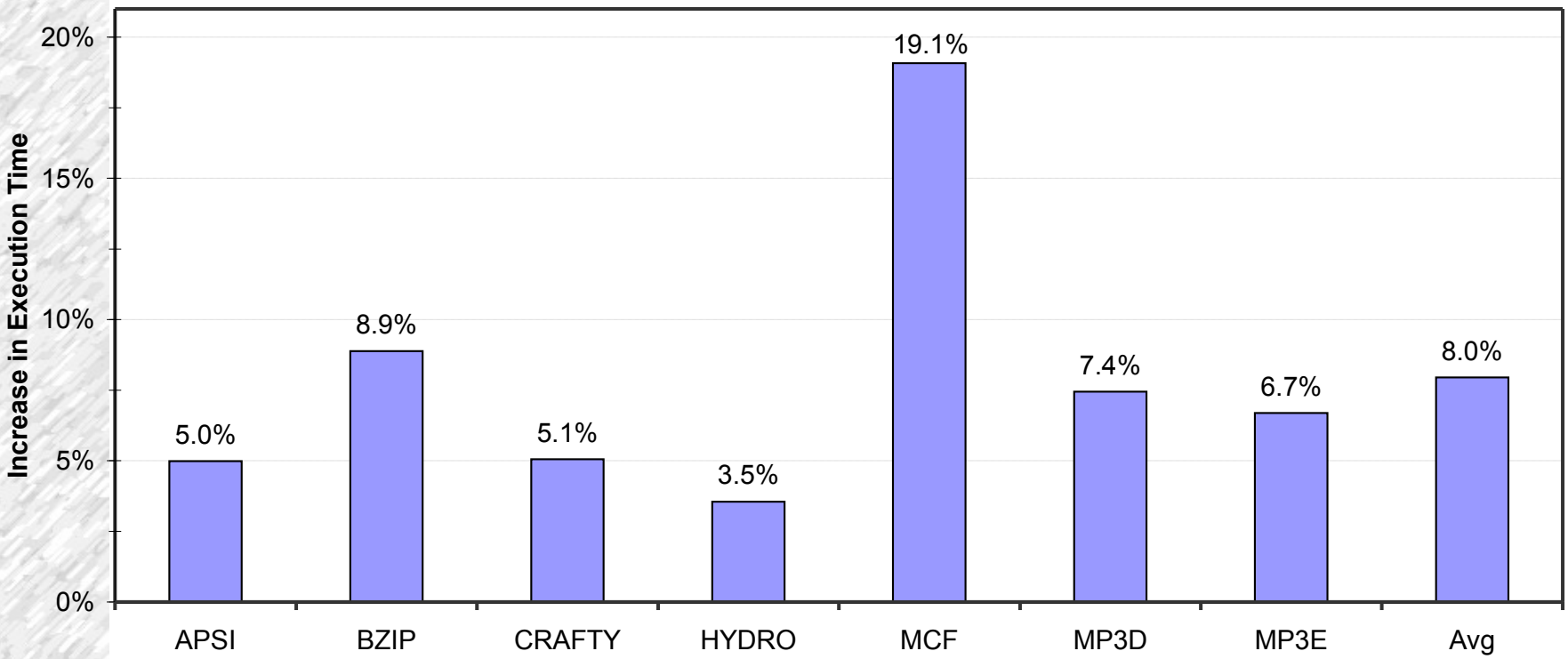



# Tracking the Dependents

- Renaming logic already does some of the job



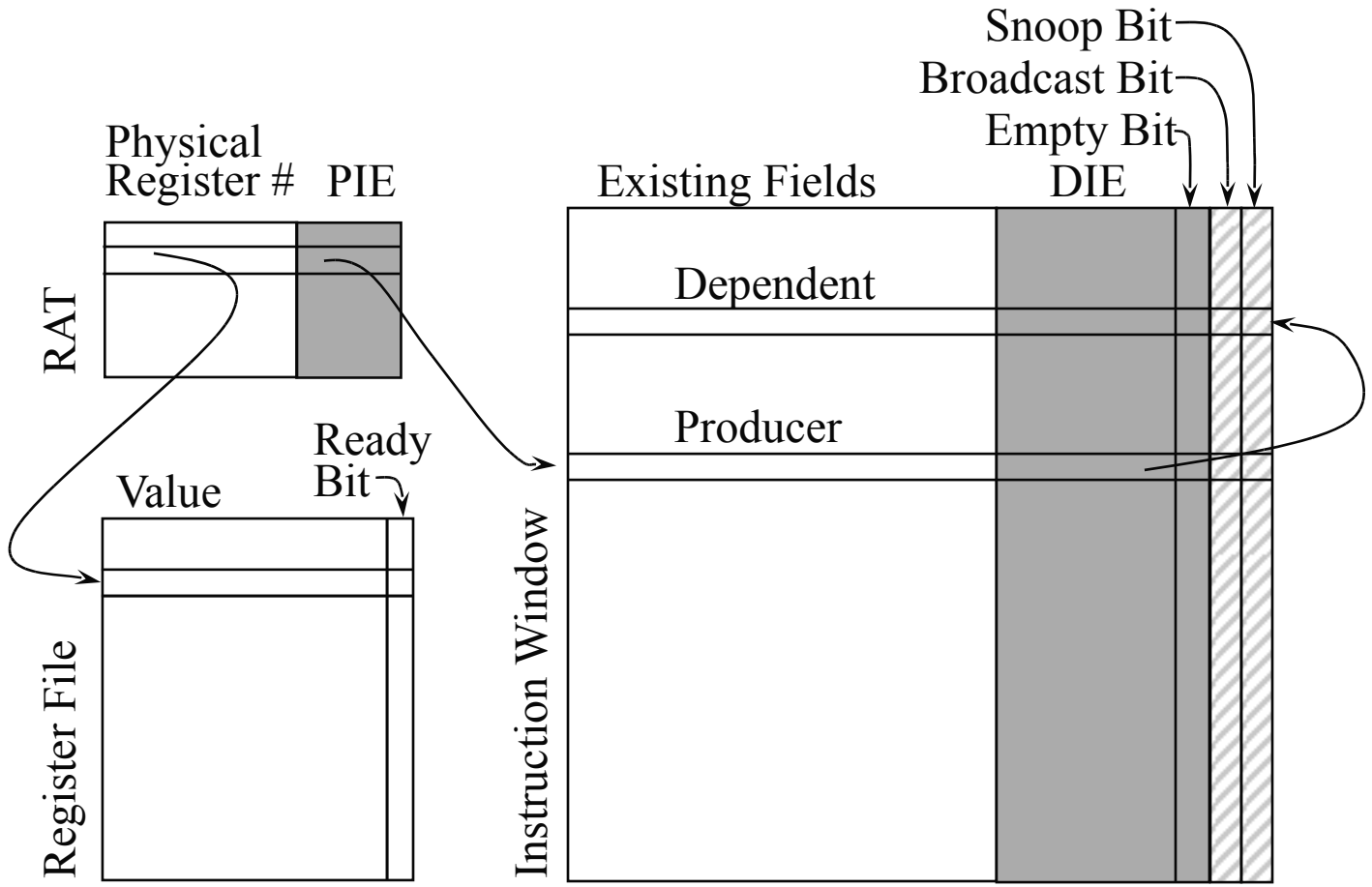
# Slowdown of Indexing-Only Wakeup




Stalling due to lack of indexing pointer results in large slowdown

# Waking Up More Than One Instruction

- Revert to broadcast – a hybrid approach



# Reduction in Tag Comparison

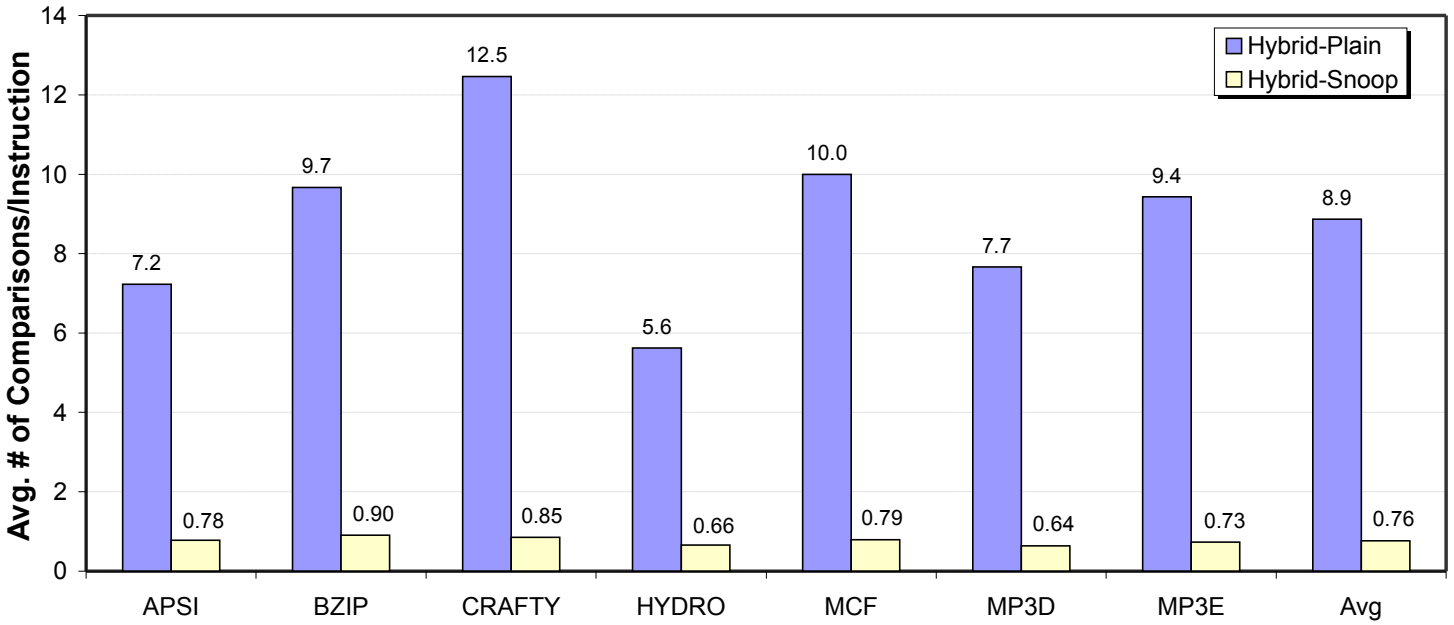
- Hybrid-Plain: $\frac{1}{N_{entry}} * P_{\text{single}} + 1 * P_{\text{more}}$
- Hybrid-Snoop: $\frac{1}{N_{entry}} * P_{\text{single}} + \frac{N_{snoop}}{N_{entry}} * P_{\text{more}}$

$N_{entry}$: # of I-win entries

$N_{Snoop}$: # of entries with snoop bit set

$P_{single}$: Prob(instr. having 1 CBD)

$P_{more}$: Prob(instr. having more CBDs)



# Other Issues in Paper

- Handling branch misprediction
  - Checkpoint the PIE field
  - Tolerating dangling pointers in the DIE field
- Applicability to other window organizations
  - Distributed windows: attach window ID
  - Compacting windows: not compatible
- Waking up two dependents: a special case
- Stalling several cycles before reverting to broadcast

  e.g. Stalling 1 cycle when DIE is not empty
  - reduces 45% broadcasts
  - 2.1% performance degradation

# Summary

Reducing wakeup comparisons

- By exploiting small "fan-out" of producer instructions:
  - 91.3% instructions have 0 or 1 close-by dependent
- Using indexing to handle common case
- Large reductions:
  - 8.9 comparisons/instruction (hybrid-plain)
  - 0.8 comparisons/instrunction (hybrid-snoop)
  - compare to 23.7 if gating ready and empty entries

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