Detailed Performance Characterization of TPC-D on a 4-CPU Pentium Pro NT Server Running Microsoft SQL

Qiang Cao, Josep Torrellas
Josep Larriba

University of Illinois at Urbana-Champaign

Youjip Won, Bob Knighten

Intel Corporation

** Performance tests and ratings are measured using specific computer systems and/or components and reflect the approximate performance of Intel products as measured by those tests. Any difference in system hardware or software design or configuration may affect actual performance. Buyers should consult other sources of information to evaluate the performance of systems or components they are considering purchasing. For more information on performance tests and on the performance of Intel products, reference www.intel.com/procs/perf/limits.htm or call (U.S.) 1-800-628-8686 or 1-916-356-3104

Outline

- System setup
- Monitoring tools
- CPI
- Cache
- Branch misprediction
- Input/output activity
- Future work

System setup

- 4-CPU Intel-based SMP
- 200 MHz Intel Pentium Pro
- 8K 4-way L1 instruction cache, 8K 2-way data cache
- 512K unified L2 cache
- 512M Physical Memory
- Two 40-bit hardware performance counters

Monitoring tools

- Emon

  Application-level performance monitor, based on hardware counters, counts events, including instructions retired, L1/L2 misses

- Perfmon

  Windows NT utility using NT software counters, measuring I/O, CPU utilization

Workloads

- TPC-D

  Scale Factor = 1

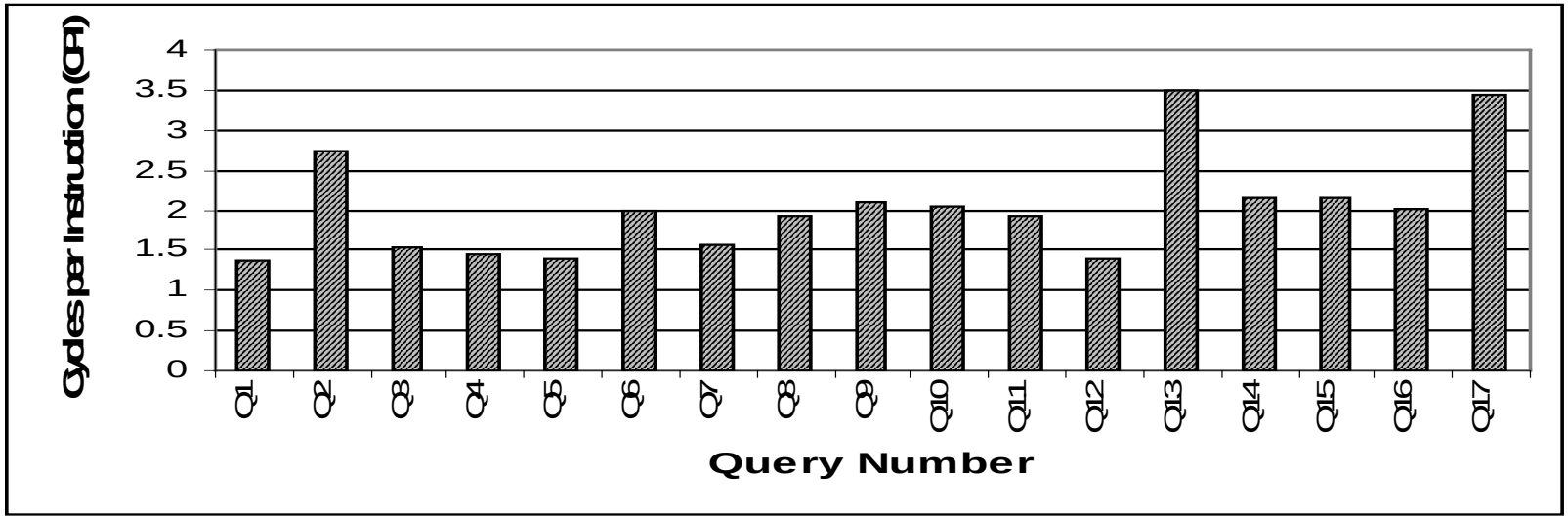
  17 read-only queries

  Multiple warm-up runs precede each experimental run

- DBMS

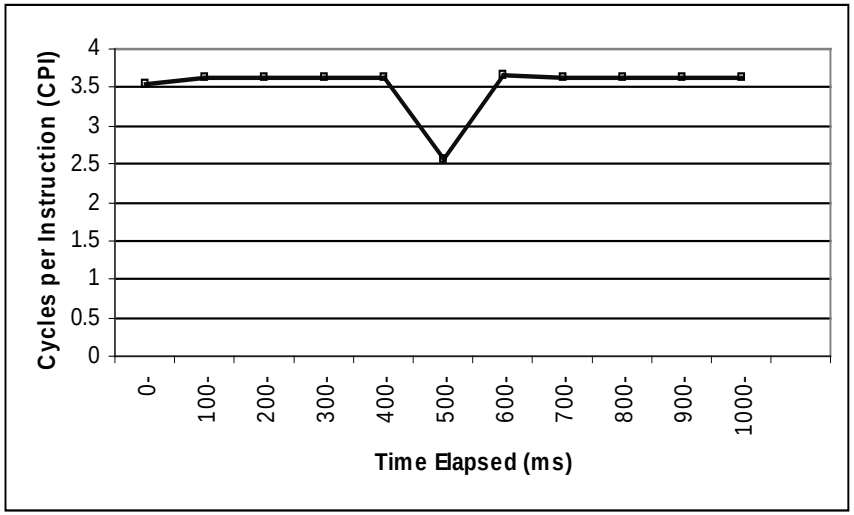
  Microsoft SQL Server

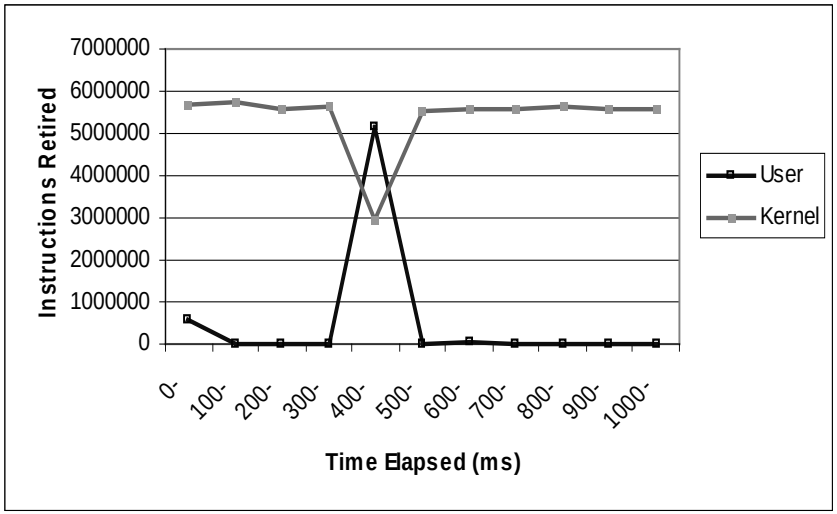
CPI



- CPI ranges from 1.4 of Q1 to 3.5 of Q13
- Short queries like Q2, Q13 and Q17 tend to have higher CPI

CPI(cont)

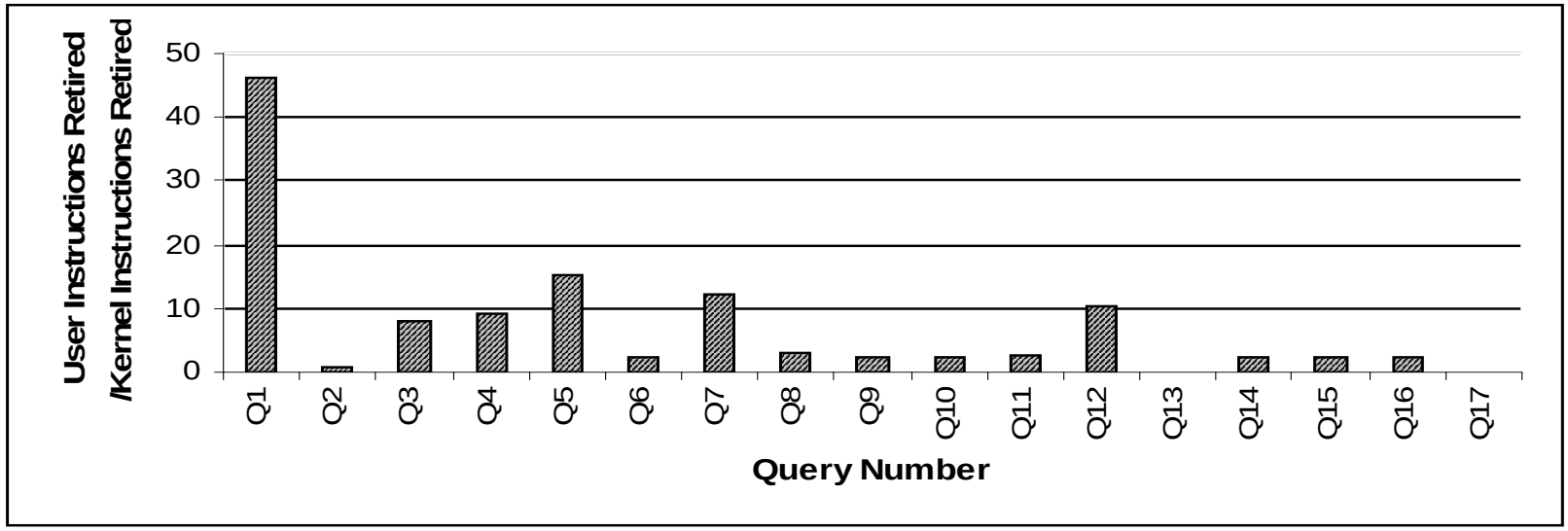




Variation with time of CPI(left) and user/kernel instructions retired (right) for Q13

- Higher CPI when kernel instructions dominate

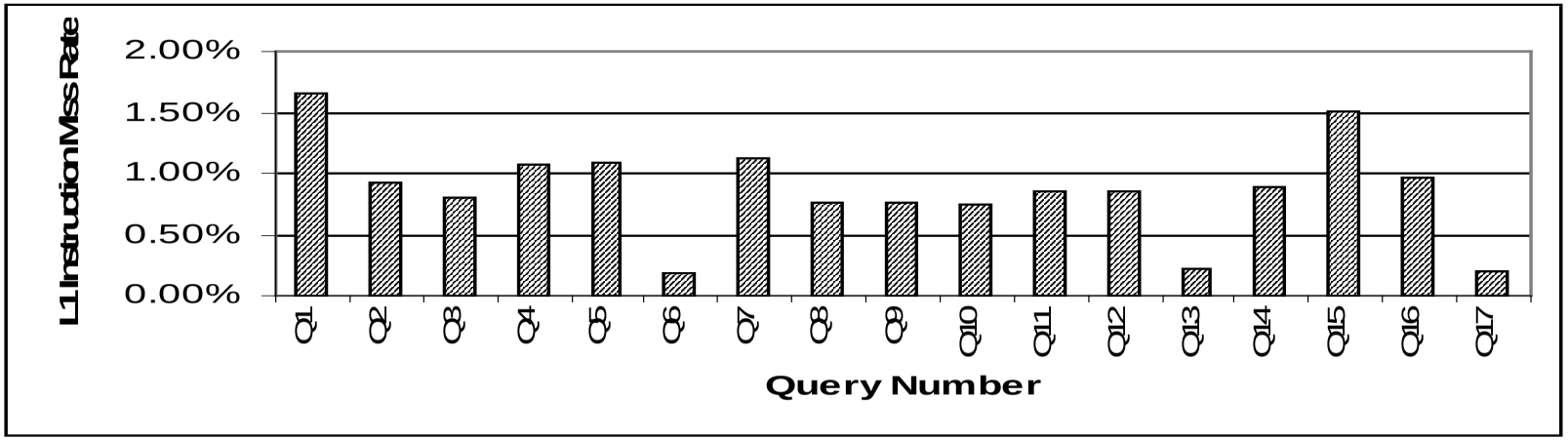
CPI(cont)

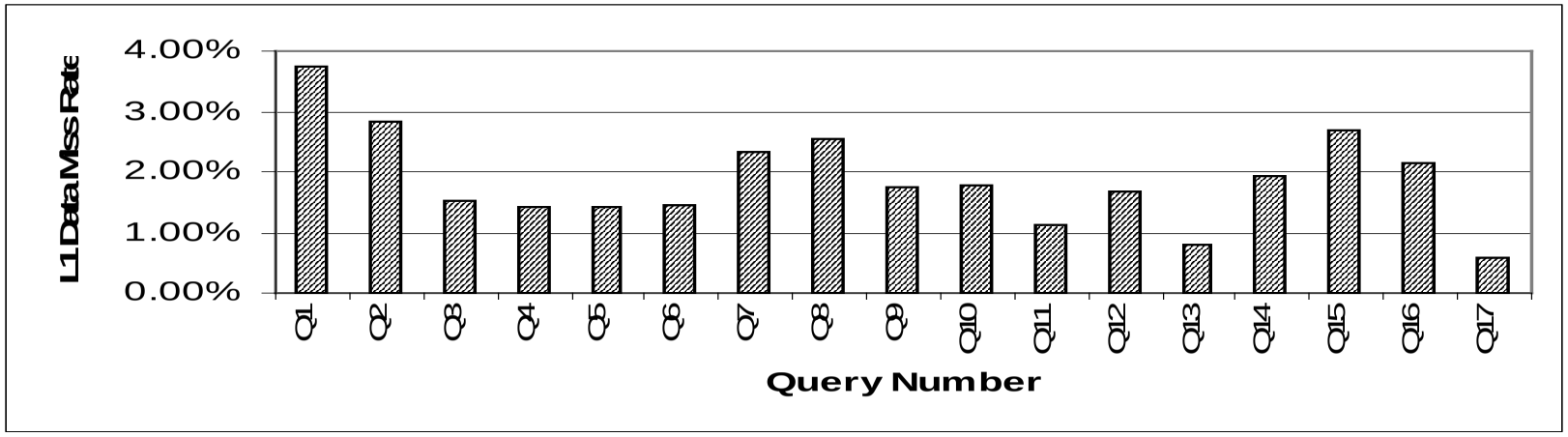


Ratio of instructions retired in user mode to kernel mode

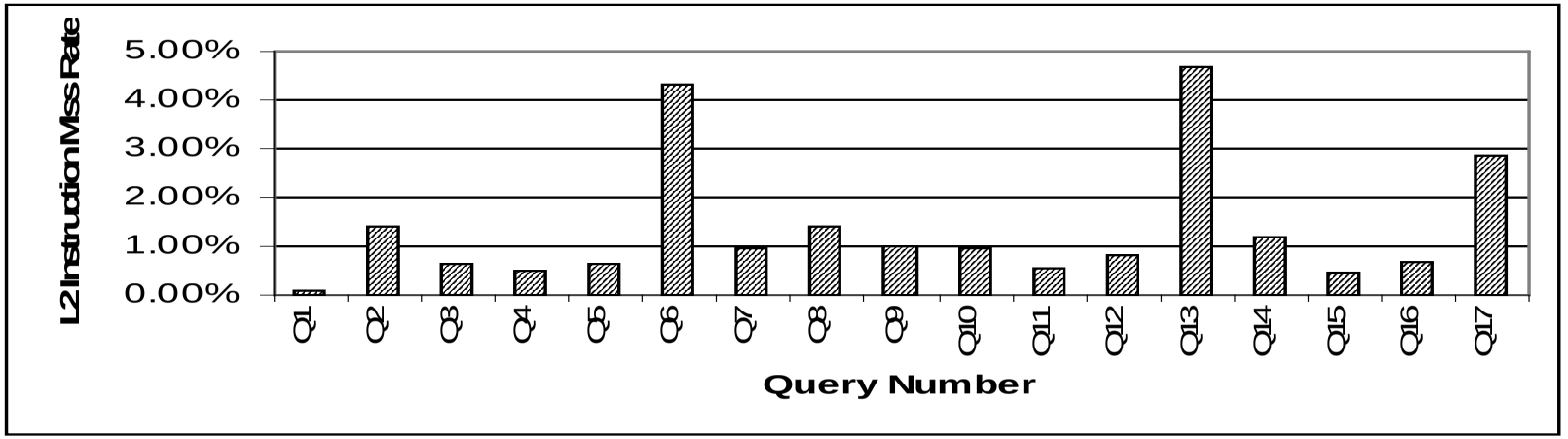
- Lower user/kernel ratio $\Rightarrow$ higher CPI

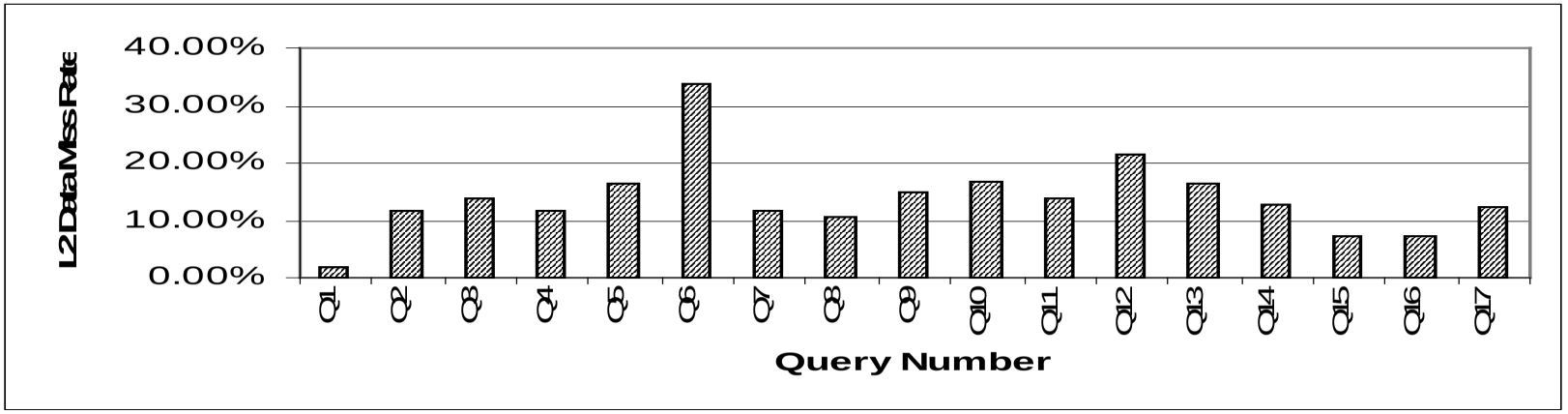
Cache(L1)


L1 Instruction Miss Rate
2.00%
1.50%
1.00%
0.50%
0.00%
Q1
Q2
Q3
Q4
Q5
Q6
Q7
Q8
Q9
Q10
Q11
Q12
Q13
Q14
Q15
Q16
Q17
Query Number


L1 Data Miss Rate
4.00%
3.00%
2.00%
1.00%
0.00%
Q1
Q2
Q3
Q4
Q5
Q6
Q7
Q8
Q9
Q10
Q11
Q12
Q13
Q14
Q15
Q16
Q17
Query Number

Cache(L2)


L2InstructionMssRate
5.00%
4.00%
3.00%
2.00%
1.00%
0.00%
Q1
Q2
Q8
Q4
Q5
Q6
Q7
Q8
Q9
Q10
Q11
Q12
Q13
Q14
Q15
Q16
Q17
Query Number


L2DataMssRate
40.00%
30.00%
20.00%
10.00%
0.00%
Q1
Q2
Q8
Q4
Q5
Q6
Q7
Q8
Q9
Q10
Q11
Q12
Q13
Q14
Q15
Q16
Q17
Query Number

Cache(cont)

- Instruction miss rates are lower than the data miss rates in both L1 and L2
- L1 instruction and data caches are effective in holding the footprint of the data and instructions
- L1 instruction/data miss rates and L2 instruction miss rate are lower than those of TPC-C

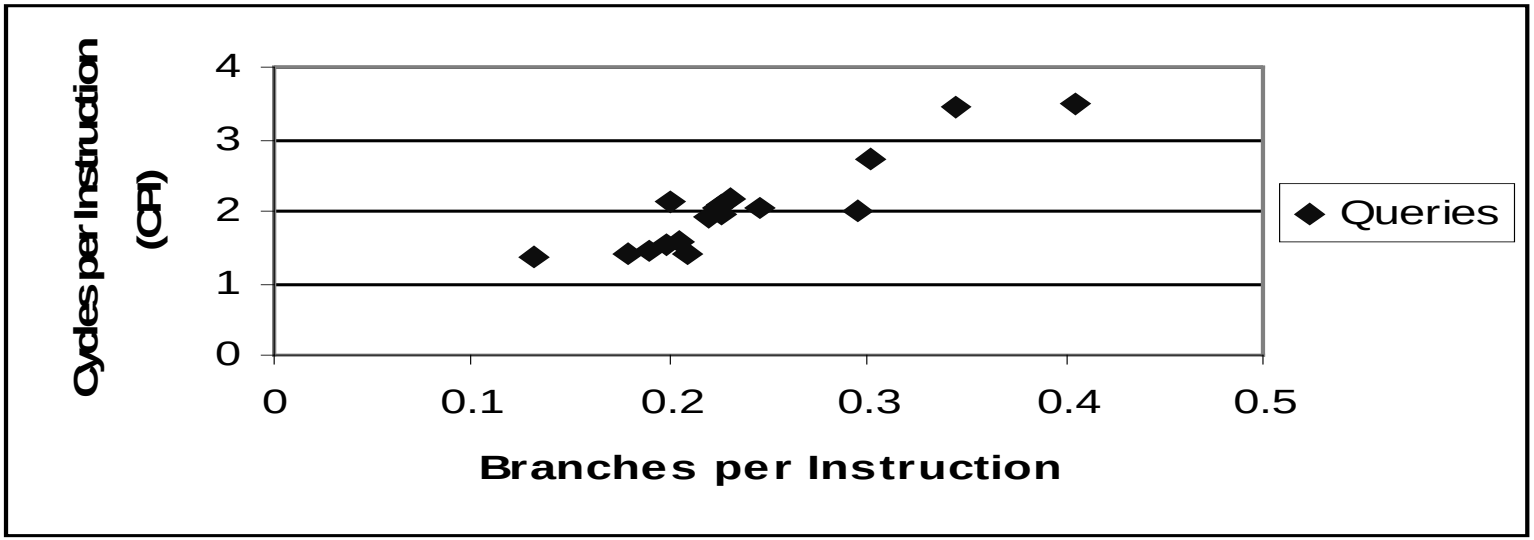
Branch misprediction

Query	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
Misprediction Ratio	3.94%	2.13%	3.75%	1.47%	1.88%	2.79%	2.76%	1.50%	2.50%
BTB Miss Ratio	33.9%	18.5%	29.9%	28.9%	26.6%	27.6%	26.2%	22.8%	20.0%
Branch Inst./Retired Inst.	13.1%	30.1%	19.7%	18.9%	17.8%	29.4%	20.4%	22.6%	22.6%

Query	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17
Misprediction Ratio	1.77%	1.67%	2.12%	0.53%	2.27%	3.27%	2.83%	0.41%
BTB Miss Ratio	18.9%	18.7%	29.8%	4.12%	19.5%	28.1%	19.4%	3.86%
Branch Inst./Retired Inst.	24.5%	21.9%	20.9%	40.5%	23.1%	20.1%	22.4%	34.4%

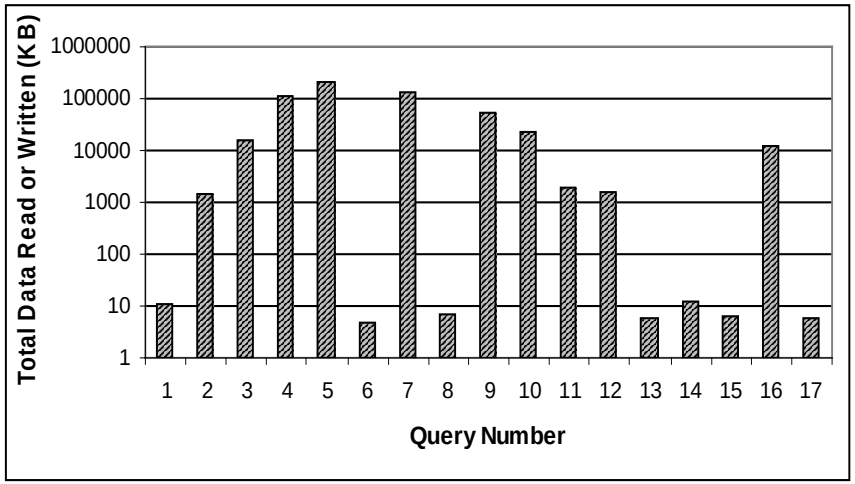
- Lower branch misprediction ratio and BTB miss ratio than TPC-C

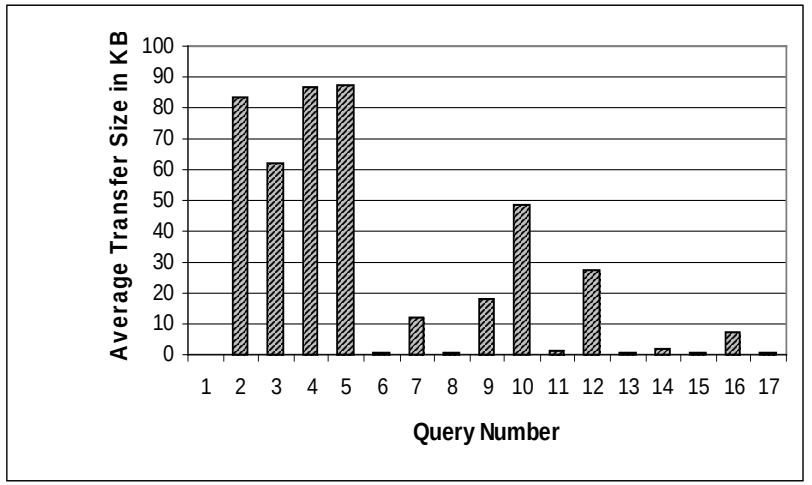
Branch misprediction(cont)



- Correlation between the branches per instruction and the CPI; more branches per instruction ⇒ higher CPI

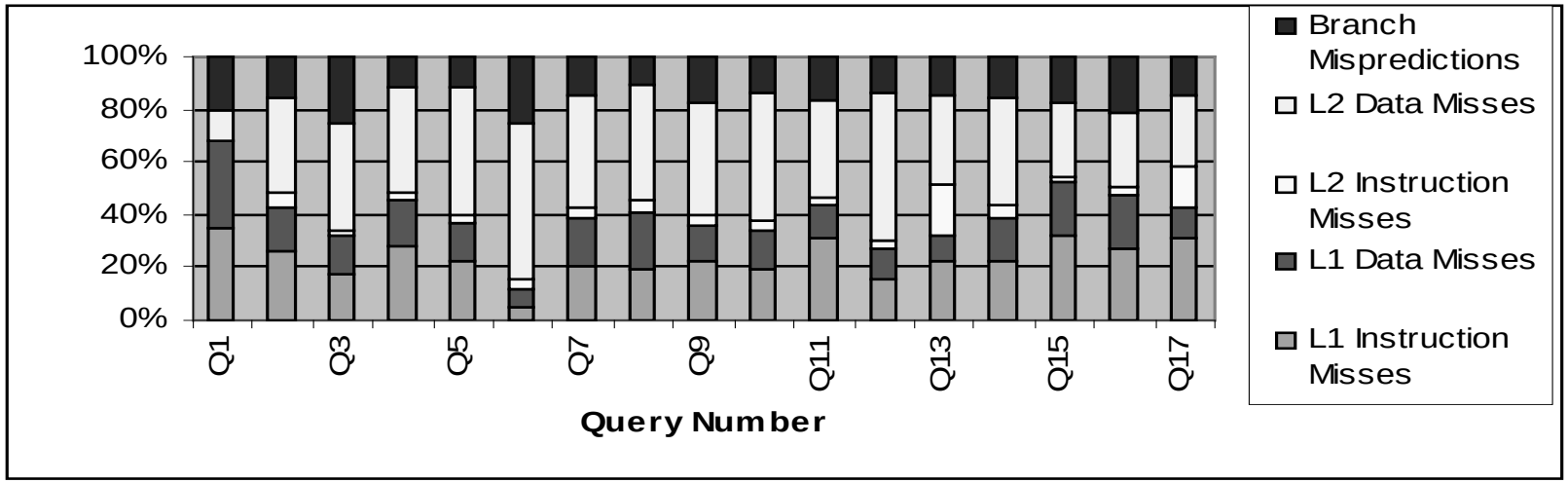
Input/Output activity





- Besides the amount of data read/written, the average I/O-transfer size determines the execution time

Relative effect of stall factors



- L2 instruction miss penalty is relatively small in all queries
- L2 data misses are the dominant factor for most of the queries

Conclusions

- There is a correlation between the branch instruction ratio and CPI
- TPC-D queries tend to have lower L1/L2 miss rates and branch misprediction ratio than TPC-C
- I/O-transfer size is an important factor in the execution time
- L2 data misses affect CPI significantly

Future work

- Large data size > 10G
- Different hardware parameters (e.g. cache size, memory size)