

Machine Problem 2

ECE/CSC 506: Architecture of Parallel Computers

Fall 2015

Coherence Protocols

Xiaoqiang Shao

200067547

1. Comparing performance with different cache sizes.

MSI:

MSI 256KB	Reads	112661	110830	114938	113428
	ReadMisses	5775	5805	5771	5813
	Writes	11942	11710	12383	12108
	WriteMisses	39	41	42	39
	Total Missrate	4.67%	4.77%	4.57%	4.66%
	WriteBacks	254	235	278	234
	C2C trans	0	0	0	0
	Mem Trans	6745	6740	6774	6761
	Interventions	68	47	81	63
	Invalidations	2014	2034	2008	2020
	Flushes	113	92	120	88
	BusRdX	716	700	725	714
MSI 512KB	Reads	112661	110830	114938	113428
	ReadMisses	5757	5792	5756	5796
	Writes	11942	11710	12383	12108
	WriteMisses	39	41	42	39
	Total Missrate	4.65%	4.76%	4.55%	4.65%
	WriteBacks	190	170	205	171
	C2C trans	0	0	0	0
	Mem Trans	6663	6662	6686	6681
	Interventions	71	47	82	63
	Invalidations	2014	2034	2008	2020
	Flushes	116	92	121	88
	BusRdX	716	700	725	714
MSI 1M	Reads	112661	110830	114938	113428
	ReadMisses	5752	5781	5752	5790
	Writes	11942	11710	12383	12108
	WriteMisses	39	41	42	39
	Total Missrate	4.65%	4.75%	4.55%	4.64%
	WriteBacks	170	155	186	157
	C2C trans	0	0	0	0
	Mem Trans	6638	6636	6663	6661
	Interventions	71	48	82	64
	Invalidations	2014	2034	2008	2020
	Flushes	116	93	121	89
	BusRdX	716	700	725	714
MSI 2M	Reads	112661	110830	114938	113428
	ReadMisses	5750	5779	5751	5789
	Writes	11942	11710	12383	12108

	WriteMisses	39	41	42	39
	Total Missrate	4.65%	4.75%	4.55%	4.64%
	WriteBacks	166	143	176	152
	C2C trans	0	0	0	0
	Mem Trans	6632	6622	6652	6655
	Interventions	71	48	82	64
	Invalidations	2014	2034	2008	2020
	Flushes	116	93	121	89
	BusRdX	716	700	725	714

MESI:

MESI 256KB	Reads	112661	110830	114938	113428
	ReadMisses	5775	5805	5771	5813
	Writes	11942	11710	12383	12108
	WriteMisses	39	41	42	39
	Total Missrate	4.67%	4.77%	4.57%	4.66%
	WriteBacks	254	235	278	234
	C2C trans	4405	4441	4406	4411
	Mem Trans	1663	1640	1685	1675
	Interventions	1468	1432	1469	1479
	Invalidations	2014	2034	2008	2020
	Flushes	113	92	120	88
	BusRdX	39	41	42	39
MESI 512KB	Reads	112661	110830	114938	113428
	ReadMisses	5757	5792	5756	5796
	Writes	11942	11710	12383	12108
	WriteMisses	39	41	42	39
	Total Missrate	4.65%	4.76%	4.55%	4.65%
	WriteBacks	190	170	205	171
	C2C trans	4392	4431	4396	4400
	Mem Trans	1594	1572	1607	1606
	Interventions	1466	1429	1465	1474
	Invalidations	2014	2034	2008	2020
	Flushes	116	92	121	88
	BusRdX	39	41	42	39
MESI 1MB	Reads	112661	110830	114938	113428
	ReadMisses	5752	5781	5752	5790
	Writes	11942	11710	12383	12108

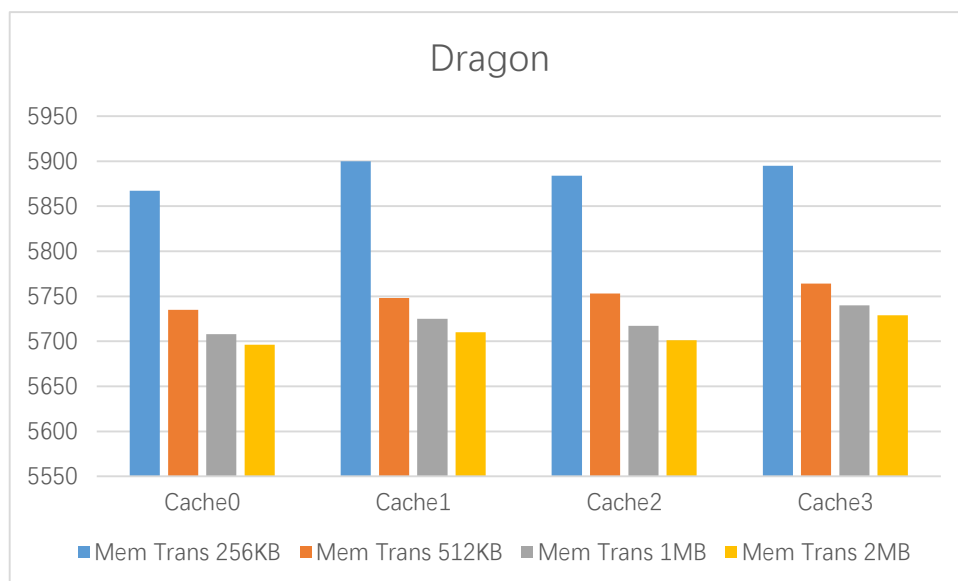
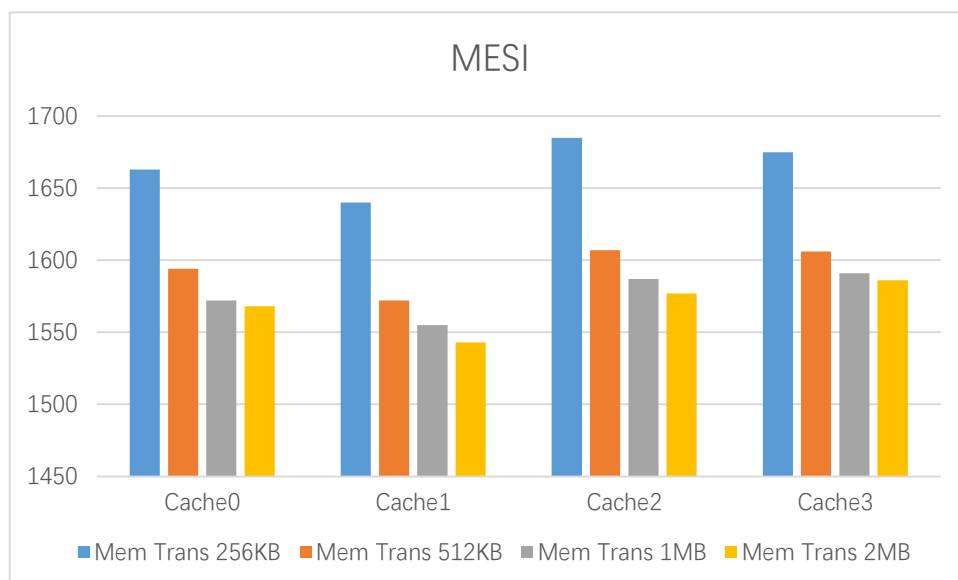
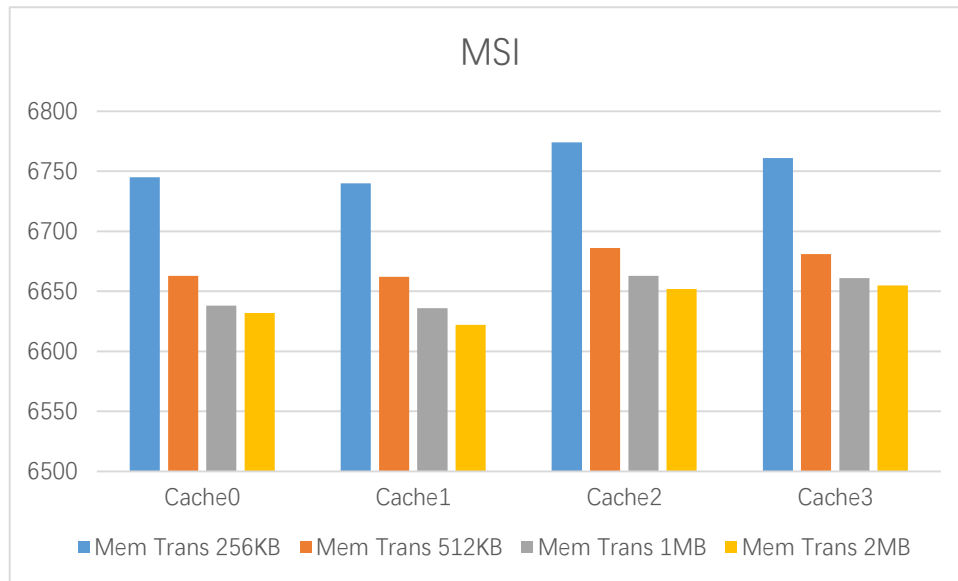
	WriteMisses	39	41	42	39
	Total Missrate	4.65%	4.75%	4.55%	4.64%
	WriteBacks	170	155	186	157
	C2C trans	4389	4422	4393	4395
	Mem Trans	1572	1555	1587	1591
	Interventions	1464	1428	1464	1474
	Invalidations	2014	2034	2008	2020
	Flushes	116	93	121	89
	BusRdX	39	41	42	39
MESI 2MB	Reads	112661	110830	114938	113428
	ReadMisses	5750	5779	5751	5789
	Writes	11942	11710	12383	12108
	WriteMisses	39	41	42	39
	Total Missrate	4.65%	4.75%	4.55%	4.64%
	WriteBacks	166	143	176	152
	C2C trans	4387	4420	4392	4394
	Mem Trans	1568	1543	1577	1586
	Interventions	1464	1428	1464	1474
	Invalidations	2014	2034	2008	2020
	Flushes	116	93	121	89
	BusRdX	39	41	42	39

Dragon:

Dragon 256KB	Reads	112661	110830	114938	113428
	ReadMisses	5635	5646	5644	5652
	Writes	11942	11710	12383	12108
	WriteMisses	3	2	2	0
	Total Missrate	4.52%	4.61%	4.43%	4.50%
	WriteBacks	229	252	238	243
	C2C trans	0	0	0	0
	Mem Trans	5867	5900	5884	5895
	Interventions	1405	1396	1398	1430
	Invalidations	0	0	0	0
	Flushes	3	9	6	9
	BusRdX	0	0	0	0
Dragon 512KB	Reads	112661	110830	114938	113428
	ReadMisses	5601	5610	5610	5617

	Writes	11942	11710	12383	12108
	WriteMisses	3	2	2	0
	Total Missrate	4.50%	4.58%	4.41%	4.47%
	WriteBacks	131	136	141	147
	C2C trans	0	0	0	0
	Mem Trans	5735	5748	5753	5764
	Interventions	1400	1388	1389	1418
	Invalidations	0	0	0	0
	Flushes	3	9	6	6
	BusRdX	0	0	0	0
Dragon 1MB	C2C trans	112661	110830	114938	113428
	ReadMisses	5595	5604	5604	5611
	Writes	11942	11710	12383	12108
	WriteMisses	3	2	2	0
	Total Missrate	4.49%	4.57%	4.40%	4.47%
	WriteBacks	110	119	111	129
	C2C trans	0	0	0	0
	Mem Trans	5708	5725	5717	5740
	Interventions	1398	1387	1387	1417
	Invalidations	0	0	0	0
	Flushes	3	9	6	6
	BusRdX	0	0	0	0
Dragon 2MB	C2C trans	112661	110830	114938	113428
	ReadMisses	5591	5603	5601	5608
	Writes	11942	11710	12383	12108
	WriteMisses	3	2	2	0
	Total Missrate	4.49%	4.57%	4.40%	4.47%
	WriteBacks	102	105	98	121
	C2C trans	0	0	0	0
	Mem Trans	5696	5710	5701	5729
	Interventions	1396	1387	1387	1416
	Invalidations	0	0	0	0
	Flushes	3	9	6	6
	BusRdX	0	0	0	0

Observation and potential reason:



From this comparison we can find that as cache size increases doubly, the memory transaction decreases but not as fast as how cache size increases.

This reason is because the larger the cache size is, the higher the possibility that the next operation will be a hit.

However, twice as large cache doesn't mean twice the performance because the miss rate almost didn't change, and a large cache also takes much memory transactions to fill up first.

Among the three protocols, MESI has the minimum memory transactions.

2. Comparing performance with different associate numbers.

MSI:

MSI4	Reads	112661	110830	114938	113428
	ReadMisses	5768	5797	5762	5803
	Writes	11942	11710	12383	12108
	WriteMisses	39	41	42	39
	Total Missrate	4.66%	4.76%	4.56%	4.65%
	WriteBacks	239	211	239	224
	C2C trans	0	0	0	0
	Mem Trans	6723	6708	6726	6741
	Interventions	69	47	81	63
	Invalidations	2014	2034	2008	2020
	Flushes	114	92	120	88
	BusRdX	716	700	725	714
MSI8	Reads	112661	110830	114938	113428
	ReadMisses	5752	5781	5752	5790
	Writes	11942	11710	12383	12108
	WriteMisses	39	41	42	39
	Total Missrate	4.65%	4.75%	4.55%	4.64%
	WriteBacks	170	155	186	157
	C2C trans	0	0	0	0
	Mem Trans	6638	6636	6663	6661
	Interventions	71	48	82	64
	Invalidations	2014	2034	2008	2020
	Flushes	116	93	121	89
	BusRdX	716	700	725	714
MSI16	Reads	112661	110830	114938	113428
	ReadMisses	5741	5772	5741	5780
	Writes	11942	11710	12383	12108
	WriteMisses	39	41	42	39

	Total Missrate	4.64%	4.74%	4.54%	4.64%
	WriteBacks	120	101	130	98
	C2C trans	0	0	0	0
	Mem Trans	6577	6573	6596	6592
	Interventions	71	48	83	64
	Invalidations	2014	2034	2008	2020
	Flushes	116	93	122	89
	BusRdX	716	700	725	714

MESI:

MESI4	Reads	112661	110830	114938	113428
	ReadMisses	5768	5797	5762	5803
	Writes	11942	11710	12383	12108
	WriteMisses	39	41	42	39
	Total Missrate	4.66%	4.76%	4.56%	4.65%
	WriteBacks	239	211	239	224
	C2C trans	4402	4434	4401	4401
	Mem Trans	1644	1615	1642	1665
	Interventions	1465	1431	1465	1480
	Invalidations	2014	2034	2008	2020
	Flushes	114	92	120	88
	BusRdX	39	41	42	39
MESI8	Reads	112661	110830	114938	113428
	ReadMisses	5752	5781	5752	5790
	Writes	11942	11710	12383	12108
	WriteMisses	39	41	42	39
	Total Missrate	4.65%	4.75%	4.55%	4.64%
	WriteBacks	170	155	186	157
	C2C trans	4389	4422	4393	4395
	Mem Trans	1572	1555	1587	1591
	Interventions	1464	1428	1464	1474
	Invalidations	2014	2034	2008	2020
	Flushes	116	93	121	89
	BusRdX	39	41	42	39
MESI16	Reads	112661	110830	114938	113428
	ReadMisses	5741	5772	5741	5780
	Writes	11942	11710	12383	12108
	WriteMisses	39	41	42	39
	Total Missrate	4.64%	4.74%	4.54%	4.64%
	WriteBacks	120	101	130	98

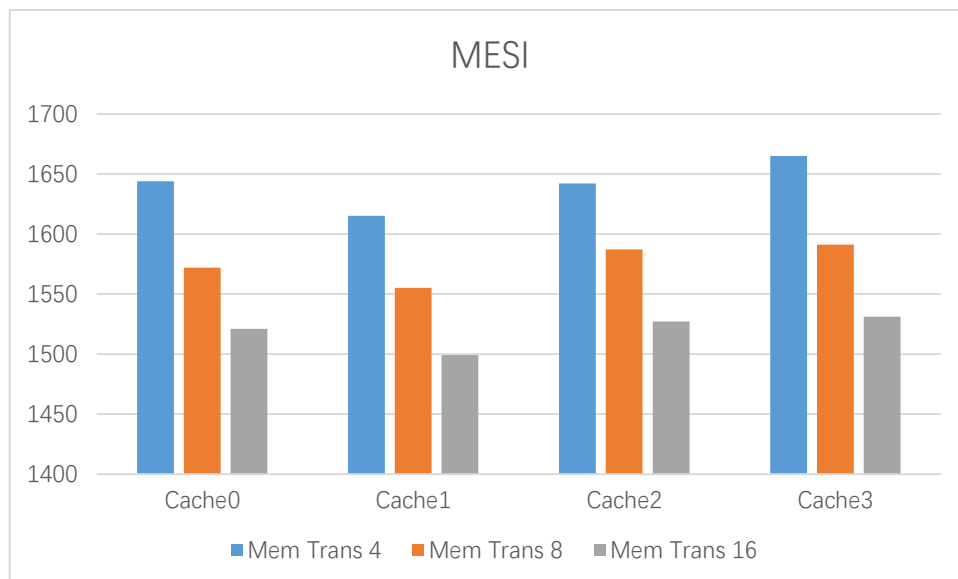
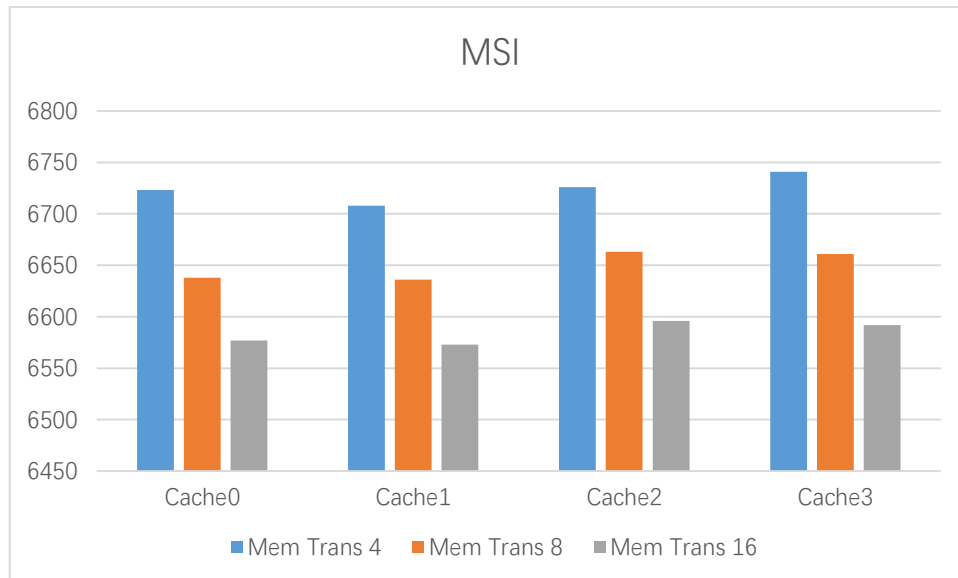
	C2C trans	4379	4415	4386	4386
	Mem Trans	1521	1499	1527	1531
	Interventions	1463	1426	1461	1473
	Invalidations	2014	2034	2008	2020
	Flushes	116	93	122	89
	BusRdX	39	41	42	39

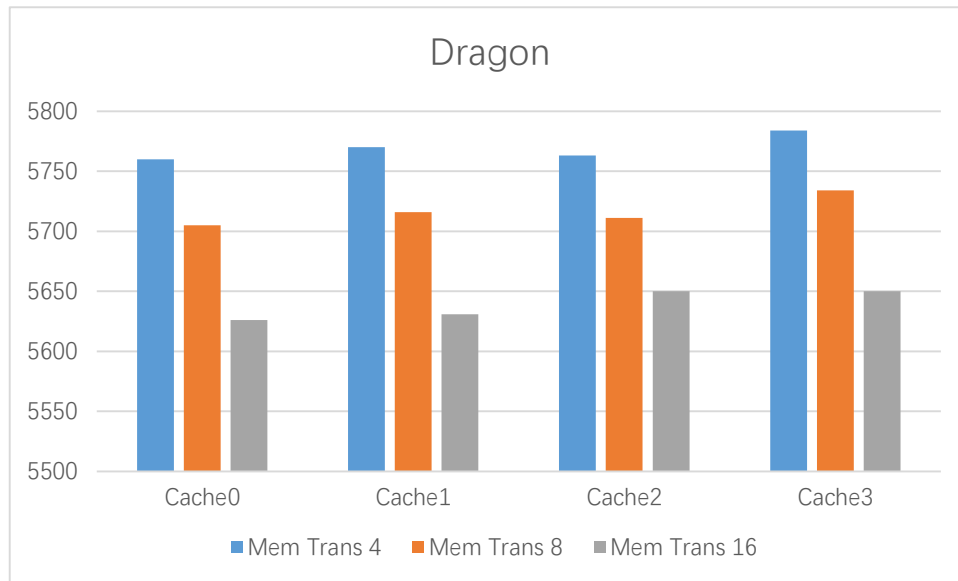
Dragon:

Dragon4	Reads	112661	110830	114938	113428
	ReadMisses	5609	5619	5619	5626
	Writes	11942	11710	12383	12108
	WriteMisses	3	2	2	0
	Total Missrate	4.50%	4.59%	4.41%	4.48%
	WriteBacks	148	149	142	158
	C2C trans	0	0	0	0
	Mem Trans	5760	5770	5763	5784
	Interventions	1400	1392	1388	1424
	Invalidations	0	0	0	0
	Flushes	3	9	6	6
	BusRdX	0	0	0	0
Dragon8	Reads	112661	110830	114938	113428
	ReadMisses	5595	5604	5604	5611
	Writes	11942	11710	12383	12108
	WriteMisses	3	2	2	0
	Total Missrate	4.49%	4.57%	4.40%	4.47%
	WriteBacks	107	110	105	123
	C2C trans	0	0	0	0
	Mem Trans	5705	5716	5711	5734
	Interventions	1398	1387	1387	1417
	Invalidations	0	0	0	0
	Flushes	3	9	6	6
	BusRdX	0	0	0	0
Dragon16	Reads	112661	110830	114938	113428
	ReadMisses	5576	5586	5586	5593
	Writes	11942	11710	12383	12108
	WriteMisses	3	2	2	0
	Total Missrate	4.48%	4.56%	4.39%	4.46%
	WriteBacks	47	43	62	57
	C2C trans	0	0	0	0
	Mem Trans	5626	5631	5650	5650

	Interventions	1395	1382	1383	1411
	Invalidations	0	0	0	0
	Flushes	3	9	6	6
	BusRdX	0	0	0	0

Observations and potential reasons:





From the comparison we can find that as associate number increases, the memory transactions also decrease. However, similarly the decreasing rate is also lower than the increasing rate.

The reason may be the higher associativity, each set has more blocks, so there's less chance of a conflict between two addresses. But higher associativity also requires more hardware, so we can't make it too large as well.

Among the three protocols, still MESI has the minimum memory transactions.

3. Comparing performance with different block sizes

MSI:

MSI64	Reads	112661	110830	114938	113428
	ReadMisses	5752	5781	5752	5790
	Writes	11942	11710	12383	12108
	WriteMisses	39	41	42	39
	Total Missrate	4.65%	4.75%	4.55%	4.64%
	WriteBacks	170	155	186	157
	C2C trans	0	0	0	0
	Mem Trans	6638	6636	6663	6661
	Interventions	71	48	82	64
	Invalidations	2014	2034	2008	2020
	Flushes	116	93	121	89
	BusRdX	716	700	725	714
MSI128	Reads	112661	110830	114938	113428
	ReadMisses	5340	5386	5341	5384
	Writes	11942	11710	12383	12108

	WriteMisses	39	40	42	39
	Total Missrate	4.32%	4.43%	4.23%	4.32%
	WriteBacks	275	250	283	269
	C2C trans	0	0	0	0
	Mem Trans	6344	6347	6369	6386
	Interventions	119	84	127	110
	Invalidations	2066	2089	2053	2068
	Flushes	164	129	166	135
	BusRdX	729	711	745	733
MSI256	Reads	112661	110830	114938	113428
	ReadMisses	5023	5070	5004	5084
	Writes	11942	11710	12383	12108
	WriteMisses	39	40	42	39
	Total Missrate	4.06%	4.17%	3.96%	4.08%
	WriteBacks	363	342	383	332
	C2C trans	0	0	0	0
	Mem Trans	6137	6147	6167	6159
	Interventions	166	133	192	145
	Invalidations	2132	2157	2107	2148
	Flushes	211	178	231	170
	BusRdX	751	735	780	743

MESI:

MESI64	Reads	112661	110830	114938	113428
	ReadMisses	5752	5781	5752	5790
	Writes	11942	11710	12383	12108
	WriteMisses	39	41	42	39
	Total Missrate	4.65%	4.75%	4.55%	4.64%
	WriteBacks	170	155	186	157
	C2C trans	4389	4422	4393	4395
	Mem Trans	1572	1555	1587	1591
	Interventions	1464	1428	1464	1474
	Invalidations	2014	2034	2008	2020
	Flushes	116	93	121	89
	BusRdX	39	41	42	39
MESI128	Reads	112661	110830	114938	113428
	ReadMisses	5340	5386	5341	5384
	Writes	11942	11710	12383	12108
	WriteMisses	39	40	42	39
	Total Missrate	4.32%	4.43%	4.23%	4.32%

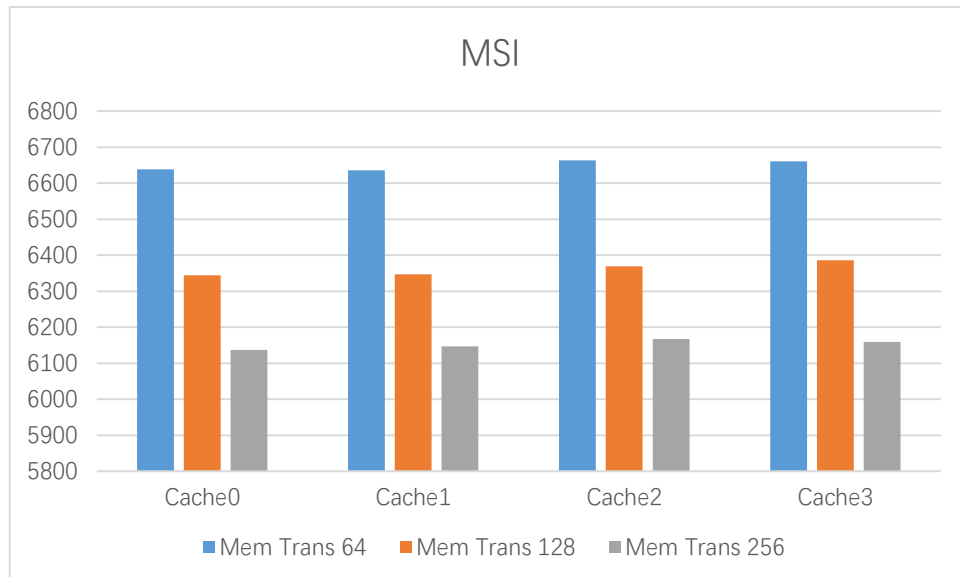
	WriteBacks	275	250	283	269
	C2C trans	4124	4155	4115	4125
	Mem Trans	1530	1521	1551	1567
	Interventions	1367	1337	1377	1385
	Invalidations	2066	2089	2053	2068
	Flushes	164	129	166	135
	BusRdX	39	40	42	39
MESI256	Reads	112661	110830	114938	113428
	ReadMisses	5023	5070	5004	5084
	Writes	11942	11710	12383	12108
	WriteMisses	39	40	42	39
	Total Missrate	4.06%	4.17%	3.96%	4.08%
	WriteBacks	363	342	383	332
	C2C trans	3938	3943	3903	3939
	Mem Trans	1487	1509	1526	1516
	Interventions	1283	1284	1321	1309
	Invalidations	2132	2157	2107	2148
	Flushes	211	178	231	170
	BusRdX	39	40	42	39

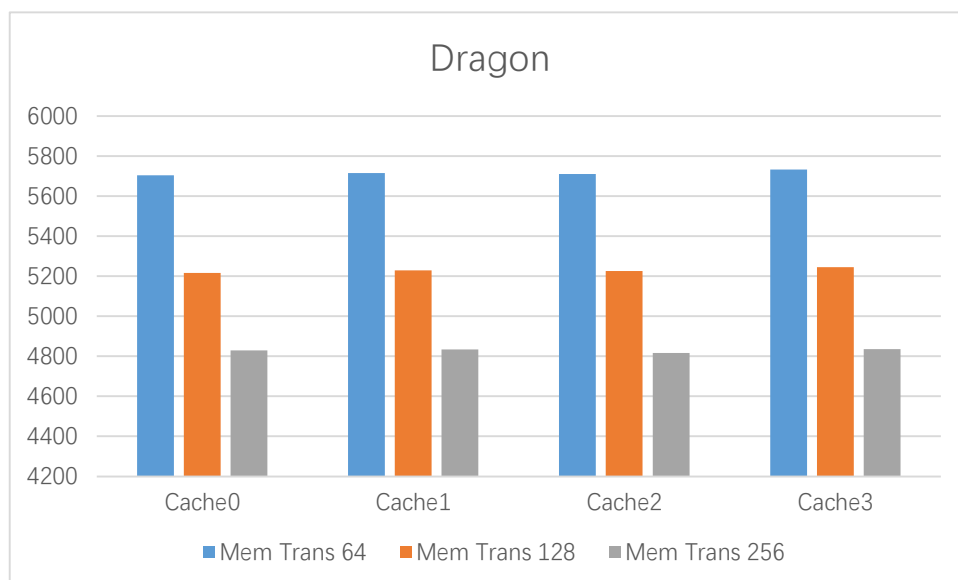
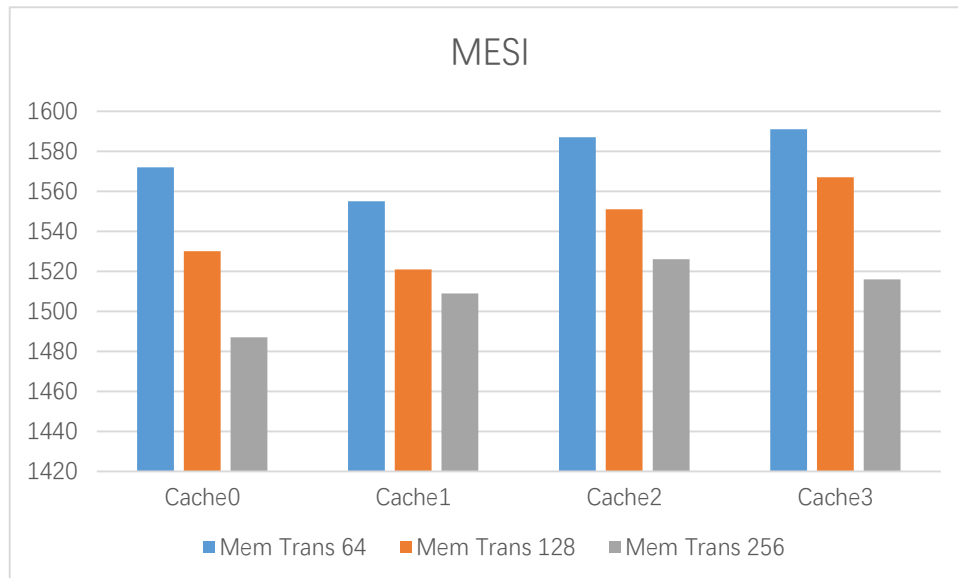
Dragon:

Dragon64	Reads	112661	110830	114938	113428
	ReadMisses	5595	5604	5604	5611
	Writes	11942	11710	12383	12108
	WriteMisses	300.00%	200.00%	200.00%	0.00%
	Total Missrate	0.0449	0.0457	0.044	0.0447
	WriteBacks	107	110	105	123
	C2C trans	0	0	0	0
	Mem Trans	5705	5716	5711	5734
	Interventions	1398	1387	1387	1417
	Invalidations	0	0	0	0
	Flushes	3	9	6	6
	BusRdX	0	0	0	0
Dragon128	Reads	112661	110830	114938	113428
	ReadMisses	5069	5080	5080	5086
	Writes	11942	11710	12383	12108
	WriteMisses	300.00%	100.00%	200.00%	0.00%
	Total Missrate	0.0407	0.0415	0.0399	0.0405
	WriteBacks	145	149	145	160
	C2C trans	0	0	0	0

	Mem Trans	5217	5230	5227	5246
	Interventions	1256	1266	1257	1287
	Invalidations	0	0	0	0
	Flushes	3	9	6	9
	BusRdX	0	0	0	0
Dragon256	Reads	112661	110830	114938	113428
	ReadMisses	4628	4633	4630	4640
	Writes	11942	11710	12383	12108
	WriteMisses	300.00%	100.00%	200.00%	0.00%
	Total Missrate	0.0372	0.0378	0.0364	0.037
	WriteBacks	198	200	185	196
	C2C trans	0	0	0	0
	Mem Trans	4829	4834	4817	4836
	Interventions	1125	1175	1143	1176
	Invalidations	0	0	0	0
	Flushes	3	11	9	9
	BusRdX	0	0	0	0

Observations and potential reasons:





From this comparison we can find that the larger the block size is, the better the performance of cache is, but the performance is also not growing in the same speed as block size increases.

The reason may be that larger block size takes better advantage of spatial locality so the miss rate is lower and the performance is better. But if blocks are too large, there are fewer blocks available, and more potential conflicts misses will happen, so we can't make block size too large as well.

Among the three protocols, still MESI has the minimum memory transactions and its performance is the best.

4. Conclusion

For cache, cache size, associativity and block size all have an impact on the performance. And the larger the cache size is, the larger the associativity is, the larger the block size is, the better the performance is. However, this is not necessarily true when the numbers grow too large.

For different cache coherence protocols, they all have similar miss rates, but MESI have the minimum memory transactions. From this perspective, it has the best performance.