Assignment- 5 Parallel Sorting

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Problem Statement

Implementing a parallel sorting algorithm such that each partition of the array is sorted in parallel. Considering two different schemes for deciding whether to sort in parallel.

1. A cutoff (defaults to, say, 1000) which will update according to the first argument in the command line when running. To experiment and come up with a good value for this cutoff. If there are fewer elements to sort than the cutoff, then system sort should be used instead.
2. Recursion depth or the number of available threads. Using this determination, you might decide on an ideal number (*t*) of separate threads (stick to powers of 2) and arrange for that number of partitions to be parallelized (by preventing recursion after the depth of *lg t* is reached).
3. An appropriate combination of these.

Method of experimentation

1. To find the right number of threads or depth of recursion for maximum efficiency with least sorting time.
2. To find the best cut off limit for any array size.

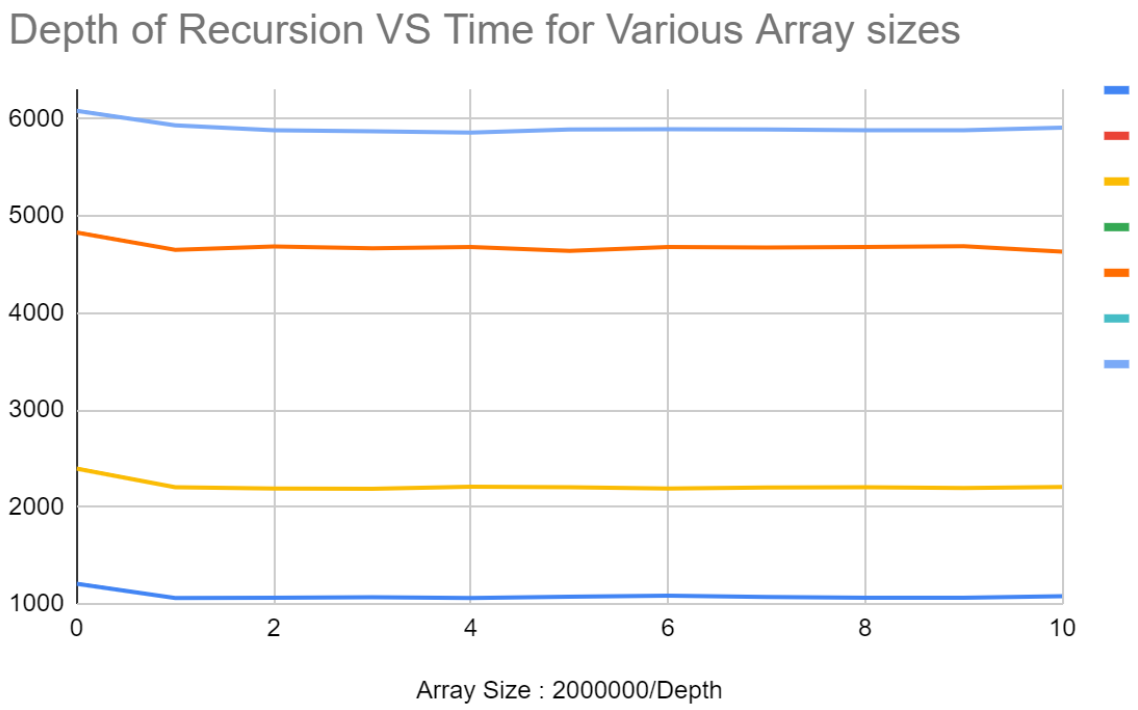
All the experiments were done on a windows machine with a x86 CPU of 8 cores at base clock of 3.2 GHZ and 16 GB of memory.

Finding the most optimal number of threads/depth of recursion for parallel sorting

By making changes to the thread pool count and the number of times recursive parallel sorting calls, I limited the number of threads created while keeping the cutoff constant at the value 1 so it doesn't affect our results. Below are the observations for various array sizes.

Array Size : 2000000		Array Size : 4000000		Array Size : 8000000		Array Size : 10000000	
Depth	Time	Depth	Time	Depth	Time	Depth	Time
0	1207	0	2396	0	4831	0	6086
1	1061	1	2203	1	4652	1	5938
2	1063	2	2190	2	4688	2	5885

3	1068	3	2186	3	4667	3	5876
4	1060	4	2209	4	4681	4	5861
5	1075	5	2202	5	4641	5	5893
6	1084	6	2190	6	4682	6	5896
7	1070	7	2200	7	4676	7	5895
8	1064	8	2203	8	4681	8	5887
9	1064	9	2195	9	4690	9	5887
10	1080	10	2206	10	4634	10	5913



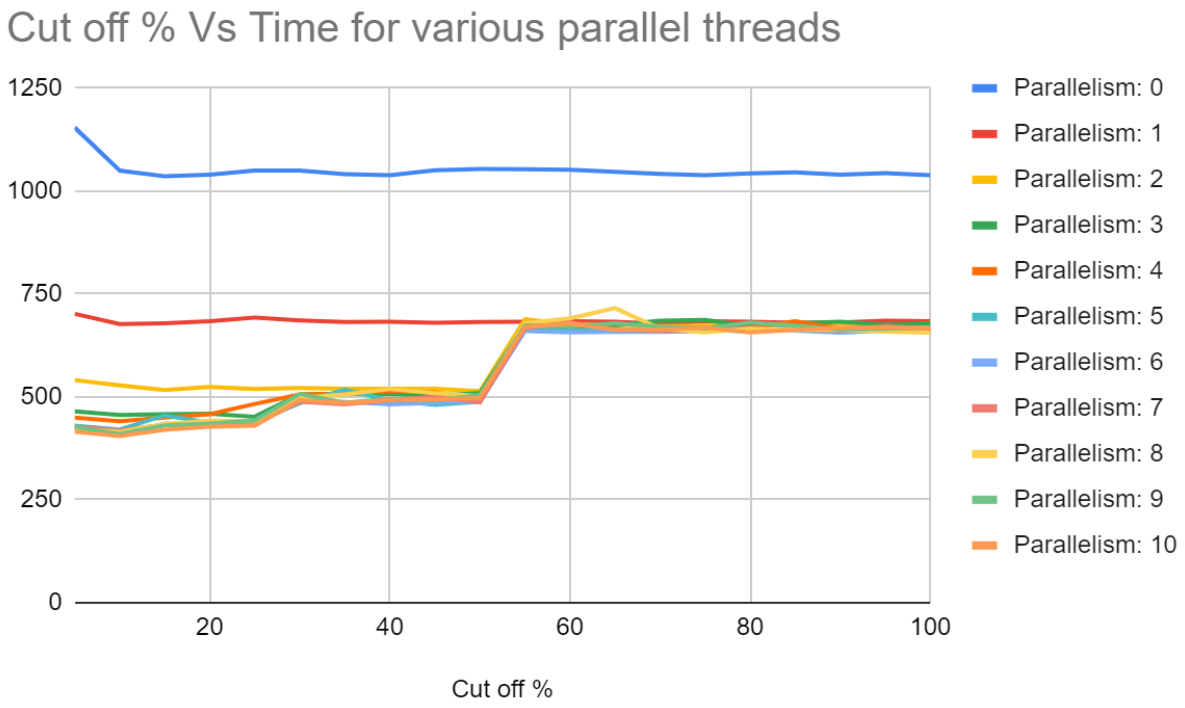
We can observe from the obtained data and the subsequent graph that the least time taken for sorting is around **4 recursive depth or 16 threads.** Any more threads doesn't seem to have any significant impact and might even consume more time in creation and processing of the threads itself.

Finding the most optimal cut off percentage for any array size for parallel sorting

By making changes to the cut off value and for each level of recursion and also for each size of the array, I obtained the following values and subsequent graphs for different array sizes.

Array Size : 2,000,000

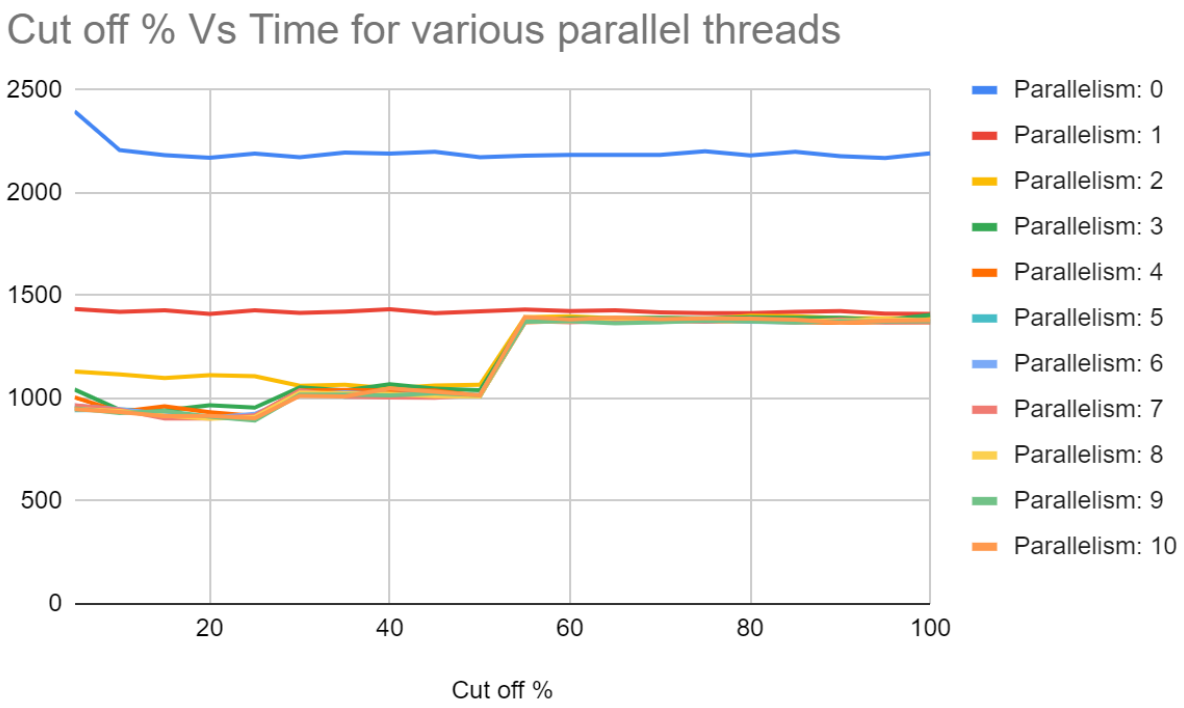
Cut off %	Parallelism: 0	Parallelism: 1	Parallelism: 2	Parallelism: 3	Parallelism: 4	Parallelism: 5	Parallelism: 6	Parallelism: 7	Parallelism: 8	Parallelism: 9	Parallelism: 10
5	1155	702	541	465	450	430	428	428	422	427	416
10	1050	677	528	456	441	421	407	418	415	410	405
15	1036	679	517	458	450	455	435	433	434	431	420
20	1040	684	524	459	458	437	431	433	442	435	428
25	1050	693	519	452	483	438	440	436	441	443	430
30	1050	686	522	506	506	485	496	488	498	507	492
35	1041	682	520	508	507	518	488	482	506	486	485
40	1039	683	520	507	514	492	482	492	519	496	493
45	1051	680	520	503	511	481	486	501	509	492	494
50	1054	682	514	509	493	488	489	487	502	504	497
55	1053	683	689	677	664	663	660	667	679	674	670
60	1052	684	677	669	663	662	657	681	691	672	678
65	1047	683	676	674	662	662	658	665	716	679	663
70	1042	678	672	685	661	661	658	660	666	671	663
75	1039	684	673	687	664	664	660	661	657	667	669
80	1043	683	677	672	669	659	667	662	666	681	657
85	1046	680	670	679	684	669	661	665	663	673	663
90	1040	681	679	683	666	664	656	661	663	664	668
95	1044	685	667	676	664	665	661	672	659	666	669
100	1039	684	680	679	660	663	657	665	656	668	667



Array Size: 4,000,000

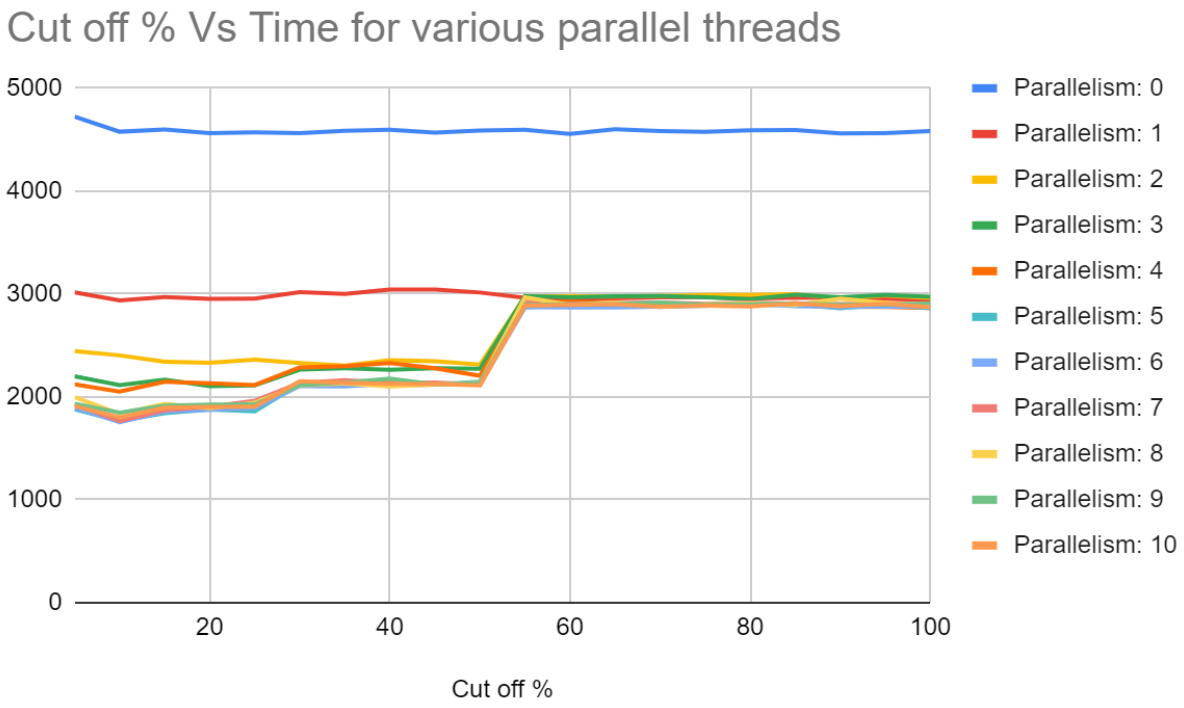
Cut off %	Parallelism: 0	Parallelism: 1	Parallelism: 2	Parallelism: 3	Parallelism: 4	Parallelism: 5	Parallelism: 6	Parallelism: 7	Parallelism: 8	Parallelism: 9	Parallelism: 10
5	2397	1435	1131	1043	1005	942	965	966	949	952	947
10	2208	1421	1117	945	935	944	948	945	939	929	934
15	2183	1429	1099	941	961	924	924	902	916	939	914
20	2171	1411	1113	967	933	908	906	902	901	911	915
25	2191	1428	1108	955	915	898	925	917	910	892	903
30	2174	1416	1061	1053	1038	1029	1016	1039	1028	1018	1012
35	2196	1422	1066	1039	1041	1008	1030	1008	1024	1018	1009
40	2191	1434	1049	1069	1039	1012	1019	1005	1022	1014	1049
45	2200	1415	1063	1047	1038	1011	1025	1003	1011	1025	1032
50	2174	1423	1066	1040	1011	1011	1016	1016	1010	1016	1015
55	2181	1432	1395	1384	1371	1382	1374	1377	1375	1373	1396
60	2185	1425	1399	1390	1377	1376	1373	1370	1376	1375	1385

65	2185	1428	1390	1389	1370	1385	1376	1377	1390	1366	1393
70	2185	1418	1392	1392	1379	1388	1372	1376	1379	1370	1386
75	2203	1415	1386	1389	1376	1373	1384	1374	1380	1378	1389
80	2182	1415	1402	1394	1376	1389	1373	1381	1380	1374	1388
85	2200	1421	1399	1392	1370	1373	1370	1370	1379	1369	1383
90	2179	1425	1391	1392	1368	1377	1376	1385	1378	1376	1368
95	2170	1412	1390	1381	1370	1376	1372	1369	1387	1374	1378
100	2192	1411	1391	1406	1371	1374	1378	1371	1379	1376	1381



Array Size:8,000,000

Cut off %	Parallelism: 0	Parallelism: 1	Parallelism: 2	Parallelism: 3	Parallelism: 4	Parallelism: 5	Parallelism: 6	Parallelism: 7	Parallelism: 8	Parallelism: 9	Parallelism: 10
5	4725	3017	2445	2200	2122	1879	1893	1930	1998	1934	1912
10	4578	2938	2404	2115	2051	1766	1754	1764	1837	1847	1800
15	4600	2970	2343	2167	2148	1842	1858	1871	1932	1916	1895
20	4565	2953	2333	2104	2132	1877	1876	1904	1891	1925	1902
25	4571	2955	2363	2113	2116	1861	1892	1963	1944	1928	1905
30	4565	3019	2329	2266	2287	2126	2106	2136	2113	2116	2153
35	4588	3001	2304	2280	2298	2134	2101	2164	2129	2140	2137
40	4597	3045	2356	2264	2329	2111	2129	2138	2102	2179	2127
45	4569	3043	2348	2278	2278	2120	2130	2139	2121	2122	2125
50	4589	3015	2314	2274	2206	2147	2120	2119	2137	2132	2113
55	4597	2963	2976	2980	2910	2872	2872	2915	2968	2895	2887
60	4556	2953	2979	2969	2925	2889	2869	2904	2894	2900	2894
65	4602	2959	2977	2979	2909	2900	2869	2911	2919	2903	2901
70	4583	2968	2982	2982	2908	2874	2878	2918	2881	2917	2878
75	4577	2971	2991	2968	2892	2894	2884	2906	2901	2895	2887
80	4592	2959	2991	2950	2895	2891	2907	2919	2910	2899	2881
85	4594	2962	2998	2994	2909	2898	2883	2905	2893	2910	2907
90	4561	2965	2957	2968	2878	2863	2875	2902	2955	2896	2883
95	4564	2954	2985	2991	2874	2898	2877	2906	2915	2898	2904
100	4583	2944	2960	2974	2864	2862	2876	2898	2886	2907	2872



From the above output values and the graphs we can observe that the least time taken for various arrays and parallelism(depth of recursion) is **25% of the total array size.**

Conclusion

From the above observations we can conclude that:

1. The depth of recursion is only effective till **4 recursive depth or 16 threads**.
2. The optimal cut off point for various array sizes and threads is around **25% of the total array size.**

Output:

Array Size:2,000,000

Parallelism: 0

cutoff:100000 10times Time:1214ms

cutoff:200000 10times Time:1028ms

cutoff:300000 10times Time:1038ms

cutoff:400000 10times Time:1022ms
cutoff:500000 10times Time:1003ms
cutoff:600000 10times Time:1005ms
cutoff:700000 10times Time:1003ms
cutoff:800000 10times Time:1011ms
cutoff:900000 10times Time:1004ms
cutoff:1000000 10times Time:1015ms
cutoff:1100000 10times Time:1005ms
cutoff:1200000 10times Time:1009ms
cutoff:1300000 10times Time:1002ms
cutoff:1400000 10times Time:1016ms
cutoff:1500000 10times Time:1009ms
cutoff:1600000 10times Time:1011ms
cutoff:1700000 10times Time:1014ms
cutoff:1800000 10times Time:1013ms
cutoff:1900000 10times Time:1005ms
cutoff:2000000 10times Time:1011ms
Parallelism: 1
cutoff:100000 10times Time:686ms
cutoff:200000 10times Time:669ms
cutoff:300000 10times Time:659ms
cutoff:400000 10times Time:661ms
cutoff:500000 10times Time:657ms
cutoff:600000 10times Time:664ms
cutoff:700000 10times Time:659ms
cutoff:800000 10times Time:665ms
cutoff:900000 10times Time:659ms
cutoff:1000000 10times Time:661ms
cutoff:1100000 10times Time:661ms

cutoff:1200000 10times Time:668ms
cutoff:1300000 10times Time:662ms
cutoff:1400000 10times Time:662ms
cutoff:1500000 10times Time:665ms
cutoff:1600000 10times Time:668ms
cutoff:1700000 10times Time:665ms
cutoff:1800000 10times Time:664ms
cutoff:1900000 10times Time:662ms
cutoff:2000000 10times Time:663ms
Parallelism: 2
cutoff:100000 10times Time:515ms
cutoff:200000 10times Time:508ms
cutoff:300000 10times Time:501ms
cutoff:400000 10times Time:495ms
cutoff:500000 10times Time:498ms
cutoff:600000 10times Time:504ms
cutoff:700000 10times Time:505ms
cutoff:800000 10times Time:500ms
cutoff:900000 10times Time:498ms
cutoff:1000000 10times Time:499ms
cutoff:1100000 10times Time:666ms
cutoff:1200000 10times Time:665ms
cutoff:1300000 10times Time:664ms
cutoff:1400000 10times Time:665ms
cutoff:1500000 10times Time:666ms
cutoff:1600000 10times Time:667ms
cutoff:1700000 10times Time:663ms
cutoff:1800000 10times Time:666ms
cutoff:1900000 10times Time:664ms

cutoff:2000000 10times Time:671ms

Parallelism: 3

cutoff:100000 10times Time:445ms

cutoff:200000 10times Time:438ms

cutoff:300000 10times Time:455ms

cutoff:400000 10times Time:448ms

cutoff:500000 10times Time:441ms

cutoff:600000 10times Time:499ms

cutoff:700000 10times Time:500ms

cutoff:800000 10times Time:506ms

cutoff:900000 10times Time:498ms

cutoff:1000000 10times Time:495ms

cutoff:1100000 10times Time:668ms

cutoff:1200000 10times Time:668ms

cutoff:1300000 10times Time:664ms

cutoff:1400000 10times Time:665ms

cutoff:1500000 10times Time:666ms

cutoff:1600000 10times Time:663ms

cutoff:1700000 10times Time:664ms

cutoff:1800000 10times Time:664ms

cutoff:1900000 10times Time:663ms

cutoff:2000000 10times Time:667ms

Parallelism: 4

cutoff:100000 10times Time:438ms

cutoff:200000 10times Time:426ms

cutoff:300000 10times Time:443ms

cutoff:400000 10times Time:437ms

cutoff:500000 10times Time:441ms

cutoff:600000 10times Time:499ms

cutoff:700000 10times Time:497ms
cutoff:800000 10times Time:503ms
cutoff:900000 10times Time:499ms
cutoff:1000000 10times Time:482ms
cutoff:1100000 10times Time:638ms
cutoff:1200000 10times Time:650ms
cutoff:1300000 10times Time:648ms
cutoff:1400000 10times Time:645ms
cutoff:1500000 10times Time:656ms
cutoff:1600000 10times Time:648ms
cutoff:1700000 10times Time:654ms
cutoff:1800000 10times Time:649ms
cutoff:1900000 10times Time:647ms
cutoff:2000000 10times Time:650ms
Parallelism: 5
cutoff:100000 10times Time:412ms
cutoff:200000 10times Time:399ms
cutoff:300000 10times Time:416ms
cutoff:400000 10times Time:407ms
cutoff:500000 10times Time:411ms
cutoff:600000 10times Time:477ms
cutoff:700000 10times Time:477ms
cutoff:800000 10times Time:473ms
cutoff:900000 10times Time:476ms
cutoff:1000000 10times Time:479ms
cutoff:1100000 10times Time:656ms
cutoff:1200000 10times Time:650ms
cutoff:1300000 10times Time:649ms
cutoff:1400000 10times Time:658ms

cutoff:1500000 10times Time:659ms
cutoff:1600000 10times Time:650ms
cutoff:1700000 10times Time:649ms
cutoff:1800000 10times Time:655ms
cutoff:1900000 10times Time:662ms
cutoff:2000000 10times Time:648ms
Parallelism: 6
cutoff:100000 10times Time:415ms
cutoff:200000 10times Time:400ms
cutoff:300000 10times Time:418ms
cutoff:400000 10times Time:415ms
cutoff:500000 10times Time:414ms
cutoff:600000 10times Time:477ms
cutoff:700000 10times Time:478ms
cutoff:800000 10times Time:474ms
cutoff:900000 10times Time:480ms
cutoff:1000000 10times Time:486ms
cutoff:1100000 10times Time:648ms
cutoff:1200000 10times Time:647ms
cutoff:1300000 10times Time:646ms
cutoff:1400000 10times Time:648ms
cutoff:1500000 10times Time:651ms
cutoff:1600000 10times Time:653ms
cutoff:1700000 10times Time:647ms
cutoff:1800000 10times Time:650ms
cutoff:1900000 10times Time:649ms
cutoff:2000000 10times Time:650ms
Parallelism: 7
cutoff:100000 10times Time:412ms

cutoff:200000 10times Time:401ms
cutoff:300000 10times Time:415ms
cutoff:400000 10times Time:416ms
cutoff:500000 10times Time:423ms
cutoff:600000 10times Time:478ms
cutoff:700000 10times Time:475ms
cutoff:800000 10times Time:482ms
cutoff:900000 10times Time:486ms
cutoff:1000000 10times Time:483ms
cutoff:1100000 10times Time:647ms
cutoff:1200000 10times Time:646ms
cutoff:1300000 10times Time:646ms
cutoff:1400000 10times Time:649ms
cutoff:1500000 10times Time:647ms
cutoff:1600000 10times Time:649ms
cutoff:1700000 10times Time:648ms
cutoff:1800000 10times Time:652ms
cutoff:1900000 10times Time:652ms
cutoff:2000000 10times Time:651ms
Parallelism: 8
cutoff:100000 10times Time:415ms
cutoff:200000 10times Time:402ms
cutoff:300000 10times Time:413ms
cutoff:400000 10times Time:419ms
cutoff:500000 10times Time:415ms
cutoff:600000 10times Time:478ms
cutoff:700000 10times Time:474ms
cutoff:800000 10times Time:476ms
cutoff:900000 10times Time:477ms

cutoff:1000000 10times Time:482ms
cutoff:1100000 10times Time:648ms
cutoff:1200000 10times Time:653ms
cutoff:1300000 10times Time:645ms
cutoff:1400000 10times Time:650ms
cutoff:1500000 10times Time:652ms
cutoff:1600000 10times Time:650ms
cutoff:1700000 10times Time:644ms
cutoff:1800000 10times Time:642ms
cutoff:1900000 10times Time:658ms
cutoff:2000000 10times Time:652ms
Parallelism: 9
cutoff:100000 10times Time:411ms
cutoff:200000 10times Time:398ms
cutoff:300000 10times Time:422ms
cutoff:400000 10times Time:421ms
cutoff:500000 10times Time:412ms
cutoff:600000 10times Time:478ms
cutoff:700000 10times Time:476ms
cutoff:800000 10times Time:475ms
cutoff:900000 10times Time:481ms
cutoff:1000000 10times Time:475ms
cutoff:1100000 10times Time:650ms
cutoff:1200000 10times Time:645ms
cutoff:1300000 10times Time:651ms
cutoff:1400000 10times Time:650ms
cutoff:1500000 10times Time:654ms
cutoff:1600000 10times Time:649ms
cutoff:1700000 10times Time:655ms

cutoff:1800000 10times Time:657ms

cutoff:1900000 10times Time:655ms

cutoff:2000000 10times Time:653ms

Parallelism: 10

cutoff:100000 10times Time:409ms

cutoff:200000 10times Time:396ms

cutoff:300000 10times Time:415ms

cutoff:400000 10times Time:414ms

cutoff:500000 10times Time:409ms

cutoff:600000 10times Time:475ms

cutoff:700000 10times Time:476ms

cutoff:800000 10times Time:479ms

cutoff:900000 10times Time:474ms

cutoff:1000000 10times Time:475ms

cutoff:1100000 10times Time:650ms

cutoff:1200000 10times Time:652ms

cutoff:1300000 10times Time:647ms

cutoff:1400000 10times Time:657ms

cutoff:1500000 10times Time:655ms

cutoff:1600000 10times Time:647ms

cutoff:1700000 10times Time:643ms

cutoff:1800000 10times Time:653ms

cutoff:1900000 10times Time:650ms

cutoff:2000000 10times Time:647ms

Process finished with exit code 0

Array Size:4,000,000

Parallelism: 0

cutoff:200000 10times Time:2376ms
cutoff:400000 10times Time:2246ms
cutoff:600000 10times Time:2239ms
cutoff:800000 10times Time:2211ms
cutoff:1000000 10times Time:2233ms
cutoff:1200000 10times Time:2227ms
cutoff:1400000 10times Time:2215ms
cutoff:1600000 10times Time:2217ms
cutoff:1800000 10times Time:2204ms
cutoff:2000000 10times Time:2210ms
cutoff:2200000 10times Time:2224ms
cutoff:2400000 10times Time:2236ms
cutoff:2600000 10times Time:2248ms
cutoff:2800000 10times Time:2241ms
cutoff:3000000 10times Time:2209ms
cutoff:3200000 10times Time:2237ms
cutoff:3400000 10times Time:2243ms
cutoff:3600000 10times Time:2215ms
cutoff:3800000 10times Time:2211ms
cutoff:4000000 10times Time:2249ms
Parallelism: 1
cutoff:200000 10times Time:1437ms
cutoff:400000 10times Time:1424ms
cutoff:600000 10times Time:1405ms
cutoff:800000 10times Time:1420ms
cutoff:1000000 10times Time:1410ms
cutoff:1200000 10times Time:1418ms
cutoff:1400000 10times Time:1422ms
cutoff:1600000 10times Time:1421ms

cutoff:1800000 10times Time:1410ms
cutoff:2000000 10times Time:1413ms
cutoff:2200000 10times Time:1427ms
cutoff:2400000 10times Time:1448ms
cutoff:2600000 10times Time:1435ms
cutoff:2800000 10times Time:1432ms
cutoff:3000000 10times Time:1431ms
cutoff:3200000 10times Time:1432ms
cutoff:3400000 10times Time:1421ms
cutoff:3600000 10times Time:1427ms
cutoff:3800000 10times Time:1436ms
cutoff:4000000 10times Time:1418ms
Parallelism: 2
cutoff:200000 10times Time:1104ms
cutoff:400000 10times Time:1084ms
cutoff:600000 10times Time:1072ms
cutoff:800000 10times Time:1070ms
cutoff:1000000 10times Time:1057ms
cutoff:1200000 10times Time:1085ms
cutoff:1400000 10times Time:1042ms
cutoff:1600000 10times Time:1042ms
cutoff:1800000 10times Time:1054ms
cutoff:2000000 10times Time:1077ms
cutoff:2200000 10times Time:1411ms
cutoff:2400000 10times Time:1409ms
cutoff:2600000 10times Time:1400ms
cutoff:2800000 10times Time:1420ms
cutoff:3000000 10times Time:1417ms
cutoff:3200000 10times Time:1414ms

cutoff:3400000 10times Time:1415ms

cutoff:3600000 10times Time:1396ms

cutoff:3800000 10times Time:1417ms

cutoff:4000000 10times Time:1407ms

Parallelism: 3

cutoff:200000 10times Time:980ms

cutoff:400000 10times Time:950ms

cutoff:600000 10times Time:938ms

cutoff:800000 10times Time:913ms

cutoff:1000000 10times Time:936ms

cutoff:1200000 10times Time:1034ms

cutoff:1400000 10times Time:1042ms

cutoff:1600000 10times Time:1032ms

cutoff:1800000 10times Time:1075ms

cutoff:2000000 10times Time:1025ms

cutoff:2200000 10times Time:1391ms

cutoff:2400000 10times Time:1397ms

cutoff:2600000 10times Time:1398ms

cutoff:2800000 10times Time:1409ms

cutoff:3000000 10times Time:1404ms

cutoff:3200000 10times Time:1408ms

cutoff:3400000 10times Time:1412ms

cutoff:3600000 10times Time:1402ms

cutoff:3800000 10times Time:1403ms

cutoff:4000000 10times Time:1402ms

Parallelism: 4

cutoff:200000 10times Time:977ms

cutoff:400000 10times Time:944ms

cutoff:600000 10times Time:947ms

cutoff:800000 10times Time:908ms

cutoff:1000000 10times Time:914ms

cutoff:1200000 10times Time:1042ms

cutoff:1400000 10times Time:1028ms

cutoff:1600000 10times Time:1043ms

cutoff:1800000 10times Time:1038ms

cutoff:2000000 10times Time:1045ms

cutoff:2200000 10times Time:1387ms

cutoff:2400000 10times Time:1394ms

cutoff:2600000 10times Time:1383ms

cutoff:2800000 10times Time:1380ms

cutoff:3000000 10times Time:1387ms

cutoff:3200000 10times Time:1402ms

cutoff:3400000 10times Time:1376ms

cutoff:3600000 10times Time:1383ms

cutoff:3800000 10times Time:1386ms

cutoff:4000000 10times Time:1378ms

Parallelism: 5

cutoff:200000 10times Time:949ms

cutoff:400000 10times Time:869ms

cutoff:600000 10times Time:913ms

cutoff:800000 10times Time:912ms

cutoff:1000000 10times Time:908ms

cutoff:1200000 10times Time:1046ms

cutoff:1400000 10times Time:1052ms

cutoff:1600000 10times Time:1029ms

cutoff:1800000 10times Time:1021ms

cutoff:2000000 10times Time:1037ms

cutoff:2200000 10times Time:1408ms

cutoff:2400000 10times Time:1390ms
cutoff:2600000 10times Time:1400ms
cutoff:2800000 10times Time:1385ms
cutoff:3000000 10times Time:1429ms
cutoff:3200000 10times Time:1388ms
cutoff:3400000 10times Time:1402ms
cutoff:3600000 10times Time:1395ms
cutoff:3800000 10times Time:1392ms
cutoff:4000000 10times Time:1421ms
Parallelism: 6
cutoff:200000 10times Time:891ms
cutoff:400000 10times Time:863ms
cutoff:600000 10times Time:892ms
cutoff:800000 10times Time:932ms
cutoff:1000000 10times Time:892ms
cutoff:1200000 10times Time:1014ms
cutoff:1400000 10times Time:1034ms
cutoff:1600000 10times Time:1027ms
cutoff:1800000 10times Time:1041ms
cutoff:2000000 10times Time:1035ms
cutoff:2200000 10times Time:1417ms
cutoff:2400000 10times Time:1426ms
cutoff:2600000 10times Time:1387ms
cutoff:2800000 10times Time:1408ms
cutoff:3000000 10times Time:1392ms
cutoff:3200000 10times Time:1399ms
cutoff:3400000 10times Time:1404ms
cutoff:3600000 10times Time:1402ms
cutoff:3800000 10times Time:1430ms

cutoff:4000000 10times Time:1400ms

Parallelism: 7

cutoff:200000 10times Time:903ms

cutoff:400000 10times Time:874ms

cutoff:600000 10times Time:899ms

cutoff:800000 10times Time:909ms

cutoff:1000000 10times Time:900ms

cutoff:1200000 10times Time:1020ms

cutoff:1400000 10times Time:1032ms

cutoff:1600000 10times Time:1041ms

cutoff:1800000 10times Time:1037ms

cutoff:2000000 10times Time:1034ms

cutoff:2200000 10times Time:1409ms

cutoff:2400000 10times Time:1416ms

cutoff:2600000 10times Time:1395ms

cutoff:2800000 10times Time:1390ms

cutoff:3000000 10times Time:1413ms

cutoff:3200000 10times Time:1386ms

cutoff:3400000 10times Time:1397ms

cutoff:3600000 10times Time:1398ms

cutoff:3800000 10times Time:1406ms

cutoff:4000000 10times Time:1396ms

Parallelism: 8

cutoff:200000 10times Time:881ms

cutoff:400000 10times Time:851ms

cutoff:600000 10times Time:898ms

cutoff:800000 10times Time:901ms

cutoff:1000000 10times Time:900ms

cutoff:1200000 10times Time:1012ms

cutoff:1400000 10times Time:1037ms
cutoff:1600000 10times Time:1033ms
cutoff:1800000 10times Time:1038ms
cutoff:2000000 10times Time:1038ms
cutoff:2200000 10times Time:1397ms
cutoff:2400000 10times Time:1396ms
cutoff:2600000 10times Time:1397ms
cutoff:2800000 10times Time:1379ms
cutoff:3000000 10times Time:1424ms
cutoff:3200000 10times Time:1400ms
cutoff:3400000 10times Time:1396ms
cutoff:3600000 10times Time:1394ms
cutoff:3800000 10times Time:1401ms
cutoff:4000000 10times Time:1387ms
Parallelism: 9
cutoff:200000 10times Time:897ms
cutoff:400000 10times Time:844ms
cutoff:600000 10times Time:911ms
cutoff:800000 10times Time:925ms
cutoff:1000000 10times Time:910ms
cutoff:1200000 10times Time:1034ms
cutoff:1400000 10times Time:1054ms
cutoff:1600000 10times Time:1033ms
cutoff:1800000 10times Time:1024ms
cutoff:2000000 10times Time:1035ms
cutoff:2200000 10times Time:1393ms
cutoff:2400000 10times Time:1406ms
cutoff:2600000 10times Time:1391ms
cutoff:2800000 10times Time:1411ms

cutoff:3000000 10times Time:1407ms
cutoff:3200000 10times Time:1387ms
cutoff:3400000 10times Time:1392ms
cutoff:3600000 10times Time:1400ms
cutoff:3800000 10times Time:1413ms
cutoff:4000000 10times Time:1403ms
Parallelism: 10
cutoff:200000 10times Time:871ms
cutoff:400000 10times Time:849ms
cutoff:600000 10times Time:907ms
cutoff:800000 10times Time:910ms
cutoff:1000000 10times Time:897ms
cutoff:1200000 10times Time:1047ms
cutoff:1400000 10times Time:1024ms
cutoff:1600000 10times Time:1065ms
cutoff:1800000 10times Time:1033ms
cutoff:2000000 10times Time:1037ms
cutoff:2200000 10times Time:1400ms
cutoff:2400000 10times Time:1404ms
cutoff:2600000 10times Time:1413ms
cutoff:2800000 10times Time:1414ms
cutoff:3000000 10times Time:1408ms
cutoff:3200000 10times Time:1390ms
cutoff:3400000 10times Time:1400ms
cutoff:3600000 10times Time:1387ms
cutoff:3800000 10times Time:1427ms
cutoff:4000000 10times Time:1390ms

Process finished with exit code 0

Array Size:4,000,000

Parallelism: 0

cutoff:400000 10times Time:5027ms

cutoff:800000 10times Time:4822ms

cutoff:1200000 10times Time:4807ms

cutoff:1600000 10times Time:4822ms

cutoff:2000000 10times Time:4753ms

cutoff:2400000 10times Time:4750ms

cutoff:2800000 10times Time:4761ms

cutoff:3200000 10times Time:4773ms

cutoff:3600000 10times Time:4730ms

cutoff:4000000 10times Time:4754ms

cutoff:4400000 10times Time:4724ms

cutoff:4800000 10times Time:4758ms

cutoff:5200000 10times Time:4762ms

cutoff:5600000 10times Time:4760ms

cutoff:6000000 10times Time:4761ms

cutoff:6400000 10times Time:4782ms

cutoff:6800000 10times Time:4744ms

cutoff:7200000 10times Time:4730ms

cutoff:7600000 10times Time:4762ms

cutoff:8000000 10times Time:4719ms

Parallelism: 1

cutoff:400000 10times Time:3079ms

cutoff:800000 10times Time:3001ms

cutoff:1200000 10times Time:2999ms

cutoff:1600000 10times Time:3007ms

cutoff:2000000 10times Time:3027ms
cutoff:2400000 10times Time:3067ms
cutoff:2800000 10times Time:3098ms
cutoff:3200000 10times Time:3090ms
cutoff:3600000 10times Time:3068ms
cutoff:4000000 10times Time:3110ms
cutoff:4400000 10times Time:3032ms
cutoff:4800000 10times Time:3045ms
cutoff:5200000 10times Time:3040ms
cutoff:5600000 10times Time:3010ms
cutoff:6000000 10times Time:3031ms
cutoff:6400000 10times Time:3043ms
cutoff:6800000 10times Time:3032ms
cutoff:7200000 10times Time:3000ms
cutoff:7600000 10times Time:3027ms
cutoff:8000000 10times Time:3015ms
Parallelism: 2
cutoff:400000 10times Time:2695ms
cutoff:800000 10times Time:2371ms
cutoff:1200000 10times Time:2358ms
cutoff:1600000 10times Time:2334ms
cutoff:2000000 10times Time:2320ms
cutoff:2400000 10times Time:2306ms
cutoff:2800000 10times Time:2293ms
cutoff:3200000 10times Time:2243ms
cutoff:3600000 10times Time:2218ms
cutoff:4000000 10times Time:2231ms
cutoff:4400000 10times Time:3031ms
cutoff:4800000 10times Time:3057ms

cutoff:5200000 10times Time:3033ms
cutoff:5600000 10times Time:3012ms
cutoff:6000000 10times Time:3022ms
cutoff:6400000 10times Time:3043ms
cutoff:6800000 10times Time:2993ms
cutoff:7200000 10times Time:3031ms
cutoff:7600000 10times Time:3025ms
cutoff:8000000 10times Time:3015ms
Parallelism: 3
cutoff:400000 10times Time:1966ms
cutoff:800000 10times Time:1895ms
cutoff:1200000 10times Time:1958ms
cutoff:1600000 10times Time:1986ms
cutoff:2000000 10times Time:1974ms
cutoff:2400000 10times Time:2217ms
cutoff:2800000 10times Time:2220ms
cutoff:3200000 10times Time:2192ms
cutoff:3600000 10times Time:2233ms
cutoff:4000000 10times Time:2190ms
cutoff:4400000 10times Time:2979ms
cutoff:4800000 10times Time:2977ms
cutoff:5200000 10times Time:2966ms
cutoff:5600000 10times Time:2969ms
cutoff:6000000 10times Time:2985ms
cutoff:6400000 10times Time:3010ms
cutoff:6800000 10times Time:2979ms
cutoff:7200000 10times Time:2967ms
cutoff:7600000 10times Time:2975ms
cutoff:8000000 10times Time:2974ms

Parallelism: 4

cutoff:400000	10times Time:1989ms
cutoff:800000	10times Time:1806ms
cutoff:1200000	10times Time:1935ms
cutoff:1600000	10times Time:1974ms
cutoff:2000000	10times Time:2005ms
cutoff:2400000	10times Time:2197ms
cutoff:2800000	10times Time:2218ms
cutoff:3200000	10times Time:2172ms
cutoff:3600000	10times Time:2239ms
cutoff:4000000	10times Time:2138ms
cutoff:4400000	10times Time:2958ms
cutoff:4800000	10times Time:2947ms
cutoff:5200000	10times Time:2932ms
cutoff:5600000	10times Time:2936ms
cutoff:6000000	10times Time:3007ms
cutoff:6400000	10times Time:2963ms
cutoff:6800000	10times Time:2961ms
cutoff:7200000	10times Time:2979ms
cutoff:7600000	10times Time:2951ms
cutoff:8000000	10times Time:2953ms

Parallelism: 5

cutoff:400000	10times Time:1882ms
cutoff:800000	10times Time:1786ms
cutoff:1200000	10times Time:1943ms
cutoff:1600000	10times Time:1966ms
cutoff:2000000	10times Time:1949ms
cutoff:2400000	10times Time:2166ms
cutoff:2800000	10times Time:2171ms

cutoff:3200000 10times Time:2133ms
cutoff:3600000 10times Time:2161ms
cutoff:4000000 10times Time:2152ms
cutoff:4400000 10times Time:2944ms
cutoff:4800000 10times Time:2979ms
cutoff:5200000 10times Time:2978ms
cutoff:5600000 10times Time:2959ms
cutoff:6000000 10times Time:2969ms
cutoff:6400000 10times Time:2946ms
cutoff:6800000 10times Time:2948ms
cutoff:7200000 10times Time:2963ms
cutoff:7600000 10times Time:2950ms
cutoff:8000000 10times Time:2999ms
Parallelism: 6
cutoff:400000 10times Time:1937ms
cutoff:800000 10times Time:1769ms
cutoff:1200000 10times Time:1938ms
cutoff:1600000 10times Time:1959ms
cutoff:2000000 10times Time:1909ms
cutoff:2400000 10times Time:2179ms
cutoff:2800000 10times Time:2172ms
cutoff:3200000 10times Time:2147ms
cutoff:3600000 10times Time:2165ms
cutoff:4000000 10times Time:2141ms
cutoff:4400000 10times Time:2992ms
cutoff:4800000 10times Time:2983ms
cutoff:5200000 10times Time:2962ms
cutoff:5600000 10times Time:2992ms
cutoff:6000000 10times Time:2961ms

cutoff:6400000 10times Time:2965ms

cutoff:6800000 10times Time:3008ms

cutoff:7200000 10times Time:3012ms

cutoff:7600000 10times Time:2982ms

cutoff:8000000 10times Time:2986ms

Parallelism: 7

cutoff:400000 10times Time:1949ms

cutoff:800000 10times Time:1784ms

cutoff:1200000 10times Time:1892ms

cutoff:1600000 10times Time:1919ms

cutoff:2000000 10times Time:1955ms

cutoff:2400000 10times Time:2180ms

cutoff:2800000 10times Time:2164ms

cutoff:3200000 10times Time:2113ms

cutoff:3600000 10times Time:2179ms

cutoff:4000000 10times Time:2132ms

cutoff:4400000 10times Time:2960ms

cutoff:4800000 10times Time:2969ms

cutoff:5200000 10times Time:2941ms

cutoff:5600000 10times Time:2965ms

cutoff:6000000 10times Time:2961ms

cutoff:6400000 10times Time:2983ms

cutoff:6800000 10times Time:2979ms

cutoff:7200000 10times Time:2946ms

cutoff:7600000 10times Time:2937ms

cutoff:8000000 10times Time:2932ms

Parallelism: 8

cutoff:400000 10times Time:1933ms

cutoff:800000 10times Time:1781ms

cutoff:1200000 10times Time:2005ms
cutoff:1600000 10times Time:1927ms
cutoff:2000000 10times Time:1907ms
cutoff:2400000 10times Time:2196ms
cutoff:2800000 10times Time:2181ms
cutoff:3200000 10times Time:2141ms
cutoff:3600000 10times Time:2180ms
cutoff:4000000 10times Time:2172ms
cutoff:4400000 10times Time:2942ms
cutoff:4800000 10times Time:2969ms
cutoff:5200000 10times Time:2975ms
cutoff:5600000 10times Time:2979ms
cutoff:6000000 10times Time:2952ms
cutoff:6400000 10times Time:2962ms
cutoff:6800000 10times Time:2933ms
cutoff:7200000 10times Time:2951ms
cutoff:7600000 10times Time:2960ms
cutoff:8000000 10times Time:2964ms
Parallelism: 9
cutoff:400000 10times Time:1952ms
cutoff:800000 10times Time:1800ms
cutoff:1200000 10times Time:1806ms
cutoff:1600000 10times Time:1785ms
cutoff:2000000 10times Time:1791ms
cutoff:2400000 10times Time:2129ms
cutoff:2800000 10times Time:2104ms
cutoff:3200000 10times Time:2114ms
cutoff:3600000 10times Time:2120ms
cutoff:4000000 10times Time:2137ms

cutoff:4400000 10times Time:2962ms
cutoff:4800000 10times Time:2973ms
cutoff:5200000 10times Time:2945ms
cutoff:5600000 10times Time:2967ms
cutoff:6000000 10times Time:2962ms
cutoff:6400000 10times Time:2975ms
cutoff:6800000 10times Time:2946ms
cutoff:7200000 10times Time:2934ms
cutoff:7600000 10times Time:2943ms
cutoff:8000000 10times Time:2949ms
Parallelism: 10
cutoff:400000 10times Time:1908ms
cutoff:800000 10times Time:1787ms
cutoff:1200000 10times Time:1791ms
cutoff:1600000 10times Time:1792ms
cutoff:2000000 10times Time:1789ms
cutoff:2400000 10times Time:2126ms
cutoff:2800000 10times Time:2142ms
cutoff:3200000 10times Time:2120ms
cutoff:3600000 10times Time:2131ms
cutoff:4000000 10times Time:2106ms
cutoff:4400000 10times Time:2949ms
cutoff:4800000 10times Time:2944ms
cutoff:5200000 10times Time:2973ms
cutoff:5600000 10times Time:2944ms
cutoff:6000000 10times Time:2968ms
cutoff:6400000 10times Time:2919ms
cutoff:6800000 10times Time:2949ms
cutoff:7200000 10times Time:2962ms

cutoff : 7600000 10times Time:2954ms

cutoff : 8000000 10times Time:2957ms

Process finished with exit code 0