Program Structures and Algorithms

Spring 2023(SEC – 01)

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**ASSIGNMENT:** 5

**Task:** To implement a parallel sorting algorithm such that each partition of the array is sorted in parallel. We need to consider two different schemes for deciding whether to sort in parallel.

1. A cutoff which will be updated 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 you should use the system sort 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.
3. An appropriate combination of these.

Prepare a report that shows the results of your experiments and draws conclusions about the efficacy of this method of parallelizing sort. Your experiments should involve sorting arrays of sufficient size for the parallel sort to make a difference. You should run with many different array sizes and different cutoff schemes.

**Relationship Conclusion:**

It is evident from all the values obtained and the graphs plotted that as the size of the array increases the total time taken for Parallel sorting also increases. They are in direct relation to one another. So, performance degrades as data size is increased. Here, the array size taken is between 1 million and 3 million at gaps of 0.5 million. Overall, 1 million sized array takes the least time and 3 million the most.

Secondly, with an increase in the number of threads, the time taken and the performance does get better up until T=4. However, after that even an increased number of threads does not have a significant impact. It might end up taking more time or remaining in a waiting loop thereby adverse effect on our values.

The values for cutoff are varied from 20,000 to 2 million at intervals of 20,000. The general trend I observed was that the values are higher and when the value is between 1/4th and ½ of the array size, the performance time goes down.

Overall, parallel sorting can be useful provided the parameters are used properly.

**Evidence to support that conclusion:**

**ParSort.java**

**Text

Description automatically generated**

**Text

Description automatically generated**

**Main.java**

A screenshot of a computer

Description automatically generated with medium confidence

Text

Description automatically generated

A screenshot of a computer

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Description automatically generated**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Array size ：1500000 | |  |  |  |  |  |
| Cutoff | T=2 | T=4 | T=8 | T=16 | T=32 | T=64 |
| 20000 | 860 | 631 | 572 | 785 | 658 | 545 |
| 40000 | 486 | 443 | 451 | 934 | 533 | 475 |
| 60000 | 423 | 422 | 407 | 741 | 429 | 410 |
| 80000 | 412 | 417 | 404 | 567 | 414 | 421 |
| 100000 | 455 | 416 | 396 | 506 | 398 | 408 |
| 120000 | 412 | 399 | 400 | 467 | 397 | 411 |
| 140000 | 412 | 414 | 397 | 440 | 400 | 403 |
| 160000 | 420 | 447 | 412 | 453 | 399 | 412 |
| 180000 | 406 | 552 | 409 | 494 | 402 | 439 |
| 200000 | 412 | 434 | 425 | 492 | 415 | 426 |
| 220000 | 408 | 457 | 414 | 490 | 403 | 405 |
| 240000 | 412 | 436 | 400 | 536 | 440 | 405 |
| 260000 | 408 | 457 | 413 | 597 | 416 | 415 |
| 280000 | 464 | 678 | 406 | 441 | 436 | 410 |
| 300000 | 425 | 520 | 426 | 442 | 406 | 414 |
| 320000 | 537 | 518 | 407 | 451 | 419 | 406 |
| 340000 | 439 | 555 | 442 | 416 | 428 | 402 |
| 360000 | 419 | 688 | 462 | 422 | 407 | 405 |
| 380000 | 408 | 413 | 422 | 424 | 399 | 396 |
| 400000 | 407 | 407 | 423 | 402 | 410 | 421 |
| 420000 | 411 | 411 | 410 | 407 | 415 | 404 |
| 440000 | 452 | 403 | 405 | 438 | 413 | 397 |
| 460000 | 406 | 401 | 406 | 457 | 414 | 401 |
| 480000 | 410 | 401 | 404 | 439 | 419 | 401 |
| 500000 | 432 | 402 | 400 | 420 | 421 | 398 |
| 520000 | 413 | 401 | 398 | 415 | 410 | 407 |
| 540000 | 412 | 401 | 406 | 413 | 416 | 404 |
| 560000 | 415 | 401 | 405 | 474 | 435 | 402 |
| 580000 | 408 | 404 | 404 | 439 | 434 | 399 |
| 600000 | 409 | 406 | 408 | 450 | 418 | 415 |
| 620000 | 414 | 405 | 411 | 447 | 399 | 427 |
| 640000 | 412 | 473 | 434 | 410 | 412 | 418 |
| 660000 | 413 | 454 | 421 | 420 | 414 | 400 |
| 680000 | 415 | 410 | 565 | 415 | 421 | 401 |
| 700000 | 411 | 402 | 495 | 454 | 418 | 398 |
| 720000 | 405 | 413 | 582 | 449 | 411 | 411 |
| 740000 | 411 | 398 | 529 | 410 | 411 | 407 |
| 760000 | 561 | 549 | 694 | 557 | 554 | 563 |
| 780000 | 551 | 551 | 678 | 564 | 554 | 571 |
| 800000 | 551 | 563 | 775 | 554 | 560 | 570 |
| 820000 | 576 | 557 | 608 | 575 | 554 | 551 |
| 840000 | 561 | 551 | 599 | 584 | 549 | 558 |
| 860000 | 549 | 567 | 593 | 596 | 551 | 577 |
| 880000 | 554 | 558 | 605 | 589 | 561 | 553 |
| 900000 | 550 | 570 | 584 | 584 | 556 | 575 |
| 920000 | 551 | 567 | 573 | 698 | 552 | 562 |
| 940000 | 563 | 563 | 607 | 607 | 552 | 557 |
| 960000 | 551 | 549 | 673 | 639 | 553 | 553 |
| 980000 | 551 | 569 | 638 | 610 | 562 | 548 |
| 1000000 | 551 | 567 | 588 | 624 | 553 | 550 |
| 1020000 | 553 | 555 | 586 | 639 | 555 | 551 |
| 1040000 | 552 | 557 | 596 | 606 | 559 | 557 |
| 1060000 | 551 | 552 | 623 | 588 | 556 | 572 |
| 1080000 | 562 | 555 | 589 | 577 | 553 | 587 |
| 1100000 | 574 | 550 | 587 | 575 | 554 | 579 |
| 1120000 | 558 | 587 | 582 | 580 | 552 | 558 |
| 1140000 | 555 | 556 | 582 | 574 | 552 | 560 |
| 1160000 | 572 | 556 | 592 | 606 | 551 | 556 |
| 1180000 | 561 | 692 | 607 | 609 | 546 | 563 |
| 1200000 | 551 | 587 | 581 | 603 | 566 | 554 |
| 1220000 | 554 | 577 | 570 | 597 | 559 | 565 |
| 1240000 | 588 | 585 | 560 | 600 | 557 | 563 |
| 1260000 | 748 | 554 | 556 | 578 | 559 | 559 |
| 1280000 | 689 | 556 | 627 | 608 | 573 | 561 |
| 1300000 | 563 | 555 | 573 | 606 | 554 | 579 |
| 1320000 | 570 | 547 | 615 | 577 | 560 | 574 |
| 1340000 | 569 | 552 | 587 | 591 | 565 | 554 |
| 1360000 | 555 | 558 | 580 | 580 | 582 | 562 |
| 1380000 | 549 | 565 | 590 | 574 | 567 | 579 |
| 1400000 | 562 | 598 | 577 | 579 | 584 | 554 |
| 1420000 | 551 | 552 | 575 | 572 | 562 | 551 |
| 1440000 | 567 | 588 | 554 | 569 | 557 | 551 |
| 1460000 | 609 | 578 | 569 | 565 | 558 | 558 |
| 1480000 | 605 | 697 | 587 | 585 | 560 | 547 |
| 1500000 | 555 | 632 | 582 | 577 | 554 | 560 |
| 1520000 | 893 | 1088 | 907 | 1101 | 878 | 865 |
| 1540000 | 881 | 891 | 909 | 995 | 873 | 871 |
| 1560000 | 885 | 876 | 901 | 902 | 883 | 870 |
| 1580000 | 884 | 883 | 909 | 907 | 878 | 884 |
| 1600000 | 889 | 876 | 925 | 936 | 875 | 881 |
| 1620000 | 883 | 877 | 902 | 914 | 876 | 870 |
| 1640000 | 883 | 883 | 912 | 909 | 872 | 871 |
| 1660000 | 882 | 871 | 904 | 902 | 879 | 875 |
| 1680000 | 877 | 911 | 908 | 917 | 895 | 879 |
| 1700000 | 894 | 875 | 893 | 909 | 878 | 883 |
| 1720000 | 876 | 876 | 893 | 894 | 873 | 886 |
| 1740000 | 884 | 883 | 905 | 1008 | 882 | 871 |
| 1760000 | 885 | 887 | 926 | 913 | 880 | 896 |
| 1780000 | 881 | 979 | 919 | 904 | 872 | 881 |
| 1800000 | 887 | 883 | 921 | 900 | 872 | 873 |
| 1820000 | 907 | 879 | 971 | 895 | 875 | 879 |
| 1840000 | 900 | 881 | 1004 | 1112 | 880 | 875 |
| 1860000 | 912 | 875 | 1040 | 912 | 884 | 877 |
| 1880000 | 893 | 870 | 963 | 884 | 898 | 871 |
| 1900000 | 899 | 884 | 966 | 871 | 877 | 883 |
| 1920000 | 917 | 879 | 977 | 871 | 874 | 877 |
| 1940000 | 887 | 871 | 942 | 868 | 871 | 878 |
| 1960000 | 886 | 870 | 1029 | 869 | 873 | 876 |
| 1980000 | 899 | 898 | 1102 | 898 | 874 | 874 |
| 2000000 | 1057 | 995 | 949 | 916 | 870 | 875 |
| Array size ：2000000 | |  |  |  |  |  |
| Cutoff | T=2 | T=4 | T=8 | T=16 | T=32 | T=64 |
| 20000 | 810 | 871 | 824 | 976 | 1075 | 698 |
| 40000 | 592 | 793 | 803 | 824 | 1045 | 643 |
| 60000 | 573 | 795 | 898 | 852 | 906 | 604 |
| 80000 | 546 | 797 | 803 | 741 | 862 | 589 |
| 100000 | 556 | 760 | 783 | 650 | 899 | 589 |
| 120000 | 548 | 772 | 850 | 835 | 1475 | 582 |
| 140000 | 542 | 646 | 921 | 1093 | 959 | 578 |
| 160000 | 539 | 585 | 1045 | 1042 | 730 | 578 |
| 180000 | 558 | 680 | 763 | 896 | 697 | 579 |
| 200000 | 547 | 616 | 815 | 735 | 691 | 586 |
| 220000 | 536 | 546 | 741 | 682 | 659 | 569 |
| 240000 | 532 | 539 | 673 | 743 | 664 | 593 |
| 260000 | 554 | 569 | 676 | 922 | 673 | 598 |
| 280000 | 574 | 565 | 646 | 937 | 660 | 596 |
| 300000 | 541 | 561 | 645 | 876 | 656 | 583 |
| 320000 | 553 | 586 | 677 | 920 | 675 | 586 |
| 340000 | 546 | 565 | 639 | 897 | 657 | 588 |
| 360000 | 592 | 564 | 646 | 886 | 661 | 583 |
| 380000 | 550 | 567 | 633 | 813 | 657 | 582 |
| 400000 | 569 | 575 | 734 | 785 | 684 | 655 |
| 420000 | 561 | 622 | 656 | 782 | 731 | 807 |
| 440000 | 545 | 584 | 638 | 849 | 701 | 603 |
| 460000 | 585 | 588 | 632 | 763 | 843 | 599 |
| 480000 | 564 | 624 | 659 | 693 | 729 | 583 |
| 500000 | 581 | 591 | 665 | 845 | 691 | 587 |
| 520000 | 547 | 610 | 659 | 817 | 854 | 580 |
| 540000 | 545 | 647 | 657 | 769 | 792 | 713 |
| 560000 | 542 | 554 | 658 | 1296 | 733 | 834 |
| 580000 | 533 | 550 | 726 | 953 | 663 | 796 |
| 600000 | 566 | 731 | 870 | 855 | 671 | 860 |
| 620000 | 550 | 746 | 1103 | 882 | 698 | 826 |
| 640000 | 567 | 686 | 1410 | 994 | 662 | 729 |
| 660000 | 561 | 554 | 835 | 827 | 680 | 633 |
| 680000 | 562 | 541 | 704 | 734 | 683 | 712 |
| 700000 | 577 | 545 | 692 | 708 | 689 | 671 |
| 720000 | 576 | 550 | 828 | 693 | 706 | 707 |
| 740000 | 816 | 549 | 790 | 692 | 685 | 736 |
| 760000 | 644 | 537 | 791 | 683 | 663 | 605 |
| 780000 | 737 | 540 | 726 | 873 | 699 | 859 |
| 800000 | 698 | 559 | 718 | 945 | 787 | 752 |
| 820000 | 629 | 552 | 728 | 828 | 754 | 654 |
| 840000 | 676 | 548 | 730 | 761 | 696 | 635 |
| 860000 | 670 | 536 | 824 | 681 | 663 | 816 |
| 880000 | 646 | 538 | 776 | 748 | 661 | 799 |
| 900000 | 679 | 558 | 758 | 766 | 671 | 717 |
| 920000 | 632 | 562 | 690 | 795 | 816 | 804 |
| 940000 | 746 | 550 | 639 | 735 | 953 | 777 |
| 960000 | 666 | 561 | 641 | 689 | 788 | 736 |
| 980000 | 665 | 562 | 624 | 670 | 716 | 787 |
| 1000000 | 729 | 565 | 652 | 683 | 667 | 812 |
| 1020000 | 888 | 756 | 870 | 906 | 932 | 849 |
| 1040000 | 808 | 744 | 837 | 952 | 880 | 851 |
| 1060000 | 795 | 743 | 816 | 916 | 892 | 861 |
| 1080000 | 805 | 749 | 812 | 934 | 891 | 835 |
| 1100000 | 783 | 756 | 793 | 926 | 864 | 846 |
| 1120000 | 828 | 754 | 788 | 882 | 867 | 868 |
| 1140000 | 947 | 743 | 802 | 909 | 853 | 815 |
| 1160000 | 813 | 741 | 805 | 937 | 994 | 863 |
| 1180000 | 829 | 745 | 807 | 934 | 974 | 825 |
| 1200000 | 849 | 745 | 795 | 949 | 1185 | 807 |
| 1220000 | 841 | 758 | 807 | 934 | 1305 | 793 |
| 1240000 | 903 | 746 | 815 | 1240 | 1269 | 806 |
| 1260000 | 957 | 771 | 821 | 1100 | 1276 | 797 |
| 1280000 | 951 | 791 | 805 | 890 | 1484 | 758 |
| 1300000 | 813 | 820 | 798 | 879 | 1858 | 768 |
| 1320000 | 788 | 802 | 792 | 899 | 1389 | 779 |
| 1340000 | 826 | 806 | 802 | 945 | 1428 | 833 |
| 1360000 | 794 | 806 | 789 | 942 | 1177 | 785 |
| 1380000 | 773 | 802 | 1244 | 904 | 963 | 791 |
| 1400000 | 796 | 830 | 1117 | 894 | 998 | 800 |
| 1420000 | 781 | 858 | 1101 | 1000 | 1024 | 779 |
| 1440000 | 757 | 878 | 944 | 906 | 913 | 769 |
| 1460000 | 754 | 864 | 942 | 898 | 867 | 762 |
| 1480000 | 765 | 861 | 869 | 942 | 871 | 750 |
| 1500000 | 748 | 856 | 906 | 900 | 934 | 754 |
| 1520000 | 747 | 818 | 1045 | 910 | 1094 | 753 |
| 1540000 | 771 | 824 | 1034 | 892 | 1119 | 746 |
| 1560000 | 756 | 810 | 1068 | 942 | 1220 | 750 |
| 1580000 | 781 | 812 | 935 | 972 | 1248 | 758 |
| 1600000 | 789 | 900 | 898 | 898 | 1233 | 753 |
| 1620000 | 780 | 885 | 888 | 880 | 1279 | 752 |
| 1640000 | 776 | 886 | 1221 | 942 | 1152 | 750 |
| 1660000 | 766 | 863 | 1089 | 1034 | 1150 | 800 |
| 1680000 | 751 | 876 | 887 | 1035 | 901 | 823 |
| 1700000 | 748 | 894 | 1006 | 920 | 869 | 895 |
| 1720000 | 750 | 868 | 927 | 931 | 841 | 855 |
| 1740000 | 752 | 855 | 953 | 912 | 834 | 810 |
| 1760000 | 747 | 893 | 944 | 1019 | 1135 | 796 |
| 1780000 | 807 | 893 | 903 | 1077 | 878 | 789 |
| 1800000 | 822 | 852 | 1112 | 928 | 862 | 788 |
| 1820000 | 786 | 863 | 985 | 929 | 831 | 868 |
| 1840000 | 768 | 873 | 920 | 894 | 808 | 807 |
| 1860000 | 780 | 862 | 912 | 891 | 791 | 829 |
| 1880000 | 753 | 864 | 897 | 996 | 789 | 1057 |
| 1900000 | 748 | 865 | 876 | 983 | 868 | 987 |
| 1920000 | 744 | 872 | 864 | 928 | 821 | 902 |
| 1940000 | 748 | 866 | 883 | 908 | 799 | 882 |
| 1960000 | 744 | 876 | 852 | 897 | 785 | 820 |
| 1980000 | 786 | 884 | 847 | 1061 | 778 | 804 |
| 2000000 | 789 | 861 | 844 | 1153 | 773 | 795 |
| Array size ：2500000 | |  |  |  |  |  |
| Cutoff | T=2 | T=4 | T=8 | T=16 | T=32 | T=64 |
| 20000 | 829 | 825 | 833 | 834 | 1327 | 896 |
| 40000 | 801 | 774 | 771 | 773 | 914 | 761 |
| 60000 | 828 | 758 | 789 | 768 | 789 | 766 |
| 80000 | 780 | 748 | 762 | 749 | 739 | 736 |
| 100000 | 838 | 749 | 767 | 743 | 769 | 735 |
| 120000 | 977 | 760 | 754 | 759 | 771 | 753 |
| 140000 | 820 | 758 | 750 | 747 | 745 | 751 |
| 160000 | 768 | 738 | 748 | 742 | 787 | 746 |
| 180000 | 791 | 734 | 743 | 735 | 755 | 778 |
| 200000 | 776 | 739 | 753 | 737 | 734 | 730 |
| 220000 | 762 | 748 | 744 | 742 | 749 | 741 |
| 240000 | 762 | 736 | 740 | 747 | 758 | 729 |
| 260000 | 767 | 734 | 744 | 752 | 746 | 737 |
| 280000 | 745 | 732 | 731 | 753 | 751 | 723 |
| 300000 | 776 | 726 | 762 | 748 | 735 | 744 |
| 320000 | 791 | 781 | 768 | 845 | 763 | 756 |
| 340000 | 799 | 774 | 774 | 797 | 812 | 753 |
| 360000 | 793 | 752 | 777 | 770 | 770 | 750 |
| 380000 | 869 | 756 | 770 | 772 | 988 | 757 |
| 400000 | 821 | 749 | 772 | 764 | 907 | 749 |
| 420000 | 787 | 759 | 775 | 767 | 782 | 771 |
| 440000 | 777 | 749 | 769 | 768 | 849 | 752 |
| 460000 | 772 | 752 | 765 | 762 | 853 | 751 |
| 480000 | 784 | 769 | 773 | 766 | 945 | 767 |
| 500000 | 768 | 767 | 770 | 766 | 829 | 750 |
| 520000 | 792 | 772 | 767 | 764 | 797 | 757 |
| 540000 | 772 | 769 | 770 | 756 | 771 | 767 |
| 560000 | 768 | 757 | 777 | 767 | 772 | 763 |
| 580000 | 769 | 756 | 763 | 769 | 875 | 761 |
| 600000 | 783 | 764 | 760 | 777 | 1002 | 751 |
| 620000 | 776 | 758 | 759 | 767 | 807 | 752 |
| 640000 | 775 | 763 | 753 | 768 | 805 | 755 |
| 660000 | 779 | 801 | 779 | 786 | 819 | 765 |
| 680000 | 773 | 779 | 774 | 777 | 786 | 775 |
| 700000 | 773 | 771 | 765 | 794 | 769 | 763 |
| 720000 | 769 | 781 | 787 | 791 | 761 | 763 |
| 740000 | 771 | 776 | 779 | 784 | 791 | 756 |
| 760000 | 773 | 787 | 768 | 940 | 812 | 762 |
| 780000 | 772 | 898 | 769 | 909 | 817 | 756 |
| 800000 | 771 | 1002 | 856 | 821 | 800 | 762 |
| 820000 | 789 | 869 | 859 | 821 | 783 | 763 |
| 840000 | 768 | 804 | 886 | 781 | 802 | 758 |
| 860000 | 770 | 791 | 878 | 770 | 803 | 757 |
| 880000 | 768 | 808 | 819 | 778 | 815 | 756 |
| 900000 | 775 | 816 | 837 | 785 | 794 | 755 |
| 920000 | 784 | 762 | 874 | 775 | 783 | 766 |
| 940000 | 778 | 764 | 823 | 770 | 768 | 767 |
| 960000 | 773 | 765 | 780 | 761 | 772 | 759 |
| 980000 | 765 | 764 | 782 | 771 | 770 | 759 |
| 1000000 | 764 | 767 | 781 | 770 | 769 | 758 |
| 1020000 | 848 | 776 | 774 | 764 | 774 | 758 |
| 1040000 | 917 | 808 | 773 | 767 | 788 | 757 |
| 1060000 | 907 | 1031 | 774 | 762 | 863 | 757 |
| 1080000 | 797 | 892 | 783 | 767 | 807 | 752 |
| 1100000 | 772 | 811 | 783 | 762 | 783 | 753 |
| 1120000 | 775 | 781 | 798 | 762 | 778 | 756 |
| 1140000 | 792 | 778 | 798 | 765 | 809 | 759 |
| 1160000 | 809 | 778 | 790 | 769 | 892 | 761 |
| 1180000 | 788 | 786 | 778 | 774 | 822 | 753 |
| 1200000 | 813 | 769 | 773 | 768 | 792 | 750 |
| 1220000 | 809 | 770 | 776 | 765 | 795 | 755 |
| 1240000 | 850 | 772 | 778 | 765 | 771 | 751 |
| 1260000 | 1058 | 1067 | 1013 | 1000 | 1015 | 990 |
| 1280000 | 1013 | 1071 | 1008 | 986 | 1003 | 948 |
| 1300000 | 1000 | 999 | 1230 | 985 | 996 | 945 |
| 1320000 | 995 | 1035 | 1226 | 975 | 1000 | 948 |
| 1340000 | 991 | 998 | 1122 | 976 | 1074 | 956 |
| 1360000 | 998 | 992 | 1113 | 1006 | 1046 | 937 |
| 1380000 | 991 | 1059 | 1067 | 1051 | 1030 | 959 |
| 1400000 | 983 | 1042 | 1059 | 1027 | 1005 | 945 |
| 1420000 | 981 | 1026 | 1030 | 1028 | 995 | 949 |
| 1440000 | 988 | 1013 | 1015 | 1045 | 1003 | 954 |
| 1460000 | 987 | 1025 | 1008 | 1022 | 989 | 947 |
| 1480000 | 980 | 1004 | 1001 | 1033 | 992 | 956 |
| 1500000 | 982 | 1006 | 1010 | 1252 | 1008 | 951 |
| 1520000 | 980 | 1000 | 1034 | 1128 | 1293 | 955 |
| 1540000 | 980 | 993 | 1021 | 1206 | 1174 | 971 |
| 1560000 | 988 | 996 | 1025 | 1474 | 1194 | 971 |
| 1580000 | 987 | 1006 | 1018 | 1358 | 1098 | 965 |
| 1600000 | 990 | 1009 | 1016 | 1287 | 1044 | 964 |
| 1620000 | 1016 | 1085 | 1008 | 1223 | 1034 | 963 |
| 1640000 | 1038 | 1045 | 1283 | 1038 | 1026 | 969 |
| 1660000 | 1008 | 1010 | 1112 | 1014 | 1009 | 974 |
| 1680000 | 985 | 1012 | 1041 | 1011 | 1014 | 983 |
| 1700000 | 982 | 991 | 1057 | 1291 | 995 | 982 |
| 1720000 | 987 | 994 | 1013 | 1148 | 1007 | 963 |
| 1740000 | 999 | 987 | 1026 | 1055 | 1068 | 971 |
| 1760000 | 989 | 1052 | 996 | 1010 | 1052 | 981 |
| 1780000 | 991 | 1040 | 992 | 1009 | 1044 | 980 |
| 1800000 | 995 | 1008 | 993 | 1008 | 1036 | 978 |
| 1820000 | 977 | 1020 | 999 | 1007 | 1156 | 973 |
| 1840000 | 985 | 986 | 986 | 1103 | 1052 | 967 |
| 1860000 | 996 | 992 | 991 | 1023 | 1027 | 972 |
| 1880000 | 983 | 985 | 1020 | 1005 | 999 | 955 |
| 1900000 | 979 | 975 | 1122 | 1016 | 983 | 962 |
| 1920000 | 978 | 971 | 1141 | 1078 | 1014 | 951 |
| 1940000 | 974 | 1006 | 1061 | 1026 | 981 | 945 |
| 1960000 | 985 | 980 | 1028 | 1035 | 982 | 957 |
| 1980000 | 971 | 990 | 1025 | 1007 | 991 | 947 |
| 2000000 | 961 | 984 | 992 | 1020 | 981 | 943 |
| Array size ：3000000 | |  |  |  |  |  |
| Cutoff | T=2 | T=4 | T=8 | T=16 | T=32 | T=64 |
| 20000 | 1102 | 1084 | 1239 | 1061 | 1125 | 1181 |
| 40000 | 1021 | 998 | 1061 | 1000 | 1033 | 1085 |
| 60000 | 940 | 961 | 962 | 950 | 978 | 1018 |
| 80000 | 934 | 943 | 968 | 949 | 953 | 1011 |
| 100000 | 896 | 918 | 967 | 910 | 964 | 981 |
| 120000 | 886 | 927 | 944 | 946 | 973 | 1002 |
| 140000 | 885 | 936 | 930 | 954 | 970 | 1015 |
| 160000 | 897 | 930 | 918 | 941 | 946 | 973 |
| 180000 | 896 | 929 | 919 | 952 | 943 | 981 |
| 200000 | 884 | 936 | 943 | 948 | 949 | 962 |
| 220000 | 881 | 949 | 1002 | 1007 | 1036 | 1063 |
| 240000 | 875 | 969 | 1039 | 984 | 1068 | 1175 |
| 260000 | 900 | 927 | 1022 | 1044 | 1069 | 1055 |
| 280000 | 1007 | 981 | 943 | 959 | 967 | 1392 |
| 300000 | 887 | 1033 | 979 | 1003 | 1023 | 1378 |
| 320000 | 878 | 967 | 1002 | 992 | 1077 | 1226 |
| 340000 | 882 | 919 | 988 | 1042 | 1032 | 967 |
| 360000 | 889 | 922 | 948 | 993 | 983 | 971 |
| 380000 | 936 | 967 | 973 | 985 | 983 | 1021 |
| 400000 | 972 | 958 | 980 | 1033 | 1026 | 987 |
| 420000 | 922 | 925 | 947 | 1022 | 1065 | 991 |
| 440000 | 915 | 934 | 1003 | 949 | 977 | 1212 |
| 460000 | 907 | 950 | 1026 | 990 | 1016 | 1102 |
| 480000 | 915 | 938 | 1039 | 990 | 991 | 1051 |
| 500000 | 917 | 924 | 1096 | 974 | 997 | 981 |
| 520000 | 907 | 925 | 1024 | 1021 | 1090 | 976 |
| 540000 | 906 | 945 | 1051 | 948 | 1036 | 1104 |
| 560000 | 906 | 944 | 1048 | 934 | 1037 | 1028 |
| 580000 | 921 | 935 | 1025 | 981 | 1067 | 1005 |
| 600000 | 907 | 950 | 1033 | 994 | 1018 | 1075 |
| 620000 | 908 | 1339 | 989 | 964 | 1063 | 1212 |
| 640000 | 921 | 1233 | 978 | 1009 | 1009 | 1437 |
| 660000 | 915 | 942 | 1007 | 1019 | 976 | 1197 |
| 680000 | 925 | 1097 | 1041 | 1004 | 1005 | 1442 |
| 700000 | 922 | 1200 | 1079 | 1064 | 1032 | 1216 |
| 720000 | 920 | 1030 | 974 | 962 | 1076 | 1164 |
| 740000 | 927 | 940 | 1068 | 992 | 1039 | 1253 |
| 760000 | 934 | 966 | 1034 | 979 | 978 | 1039 |
| 780000 | 935 | 948 | 1070 | 1017 | 991 | 1108 |
| 800000 | 960 | 974 | 1035 | 1022 | 1018 | 1476 |
| 820000 | 956 | 936 | 1009 | 1018 | 1024 | 1246 |
| 840000 | 958 | 964 | 1014 | 1025 | 1050 | 1195 |
| 860000 | 1186 | 1017 | 999 | 958 | 1041 | 1190 |
| 880000 | 1013 | 1039 | 967 | 981 | 1003 | 1188 |
| 900000 | 946 | 1024 | 956 | 1001 | 1026 | 1150 |
| 920000 | 945 | 949 | 994 | 1001 | 1017 | 1258 |
| 940000 | 962 | 940 | 954 | 1017 | 1017 | 1343 |
| 960000 | 973 | 937 | 994 | 982 | 1047 | 1337 |
| 980000 | 961 | 946 | 992 | 1033 | 1117 | 1721 |
| 1000000 | 943 | 936 | 988 | 1038 | 1061 | 1446 |
| 1020000 | 1111 | 939 | 1007 | 968 | 1049 | 1405 |
| 1040000 | 1121 | 1014 | 974 | 977 | 1020 | 1359 |
| 1060000 | 973 | 948 | 965 | 992 | 1026 | 1258 |
| 1080000 | 976 | 941 | 964 | 987 | 976 | 1301 |
| 1100000 | 982 | 942 | 984 | 976 | 982 | 1287 |
| 1120000 | 940 | 1033 | 958 | 990 | 1006 | 1562 |
| 1140000 | 956 | 981 | 1004 | 984 | 1048 | 1380 |
| 1160000 | 940 | 963 | 1006 | 980 | 1023 | 1417 |
| 1180000 | 931 | 955 | 1025 | 1068 | 1019 | 1287 |
| 1200000 | 931 | 968 | 950 | 968 | 1045 | 1660 |
| 1220000 | 931 | 935 | 953 | 989 | 1068 | 1550 |
| 1240000 | 938 | 936 | 959 | 990 | 971 | 1491 |
| 1260000 | 938 | 937 | 977 | 996 | 979 | 1357 |
| 1280000 | 930 | 931 | 968 | 1024 | 977 | 1424 |
| 1300000 | 931 | 930 | 992 | 1005 | 1028 | 1398 |
| 1320000 | 932 | 935 | 989 | 989 | 1003 | 1365 |
| 1340000 | 934 | 1048 | 1025 | 1004 | 978 | 1284 |
| 1360000 | 938 | 1021 | 989 | 977 | 983 | 1352 |
| 1380000 | 930 | 995 | 1007 | 982 | 984 | 1344 |
| 1400000 | 930 | 957 | 1000 | 995 | 965 | 1340 |
| 1420000 | 945 | 956 | 993 | 981 | 989 | 1323 |
| 1440000 | 929 | 988 | 984 | 1024 | 1013 | 1279 |
| 1460000 | 926 | 952 | 1176 | 1017 | 1040 | 1594 |
| 1480000 | 931 | 998 | 1051 | 1021 | 1018 | 1825 |
| 1500000 | 926 | 938 | 1046 | 1076 | 972 | 1776 |
| 1520000 | 1239 | 1274 | 1335 | 1298 | 1304 | 2208 |
| 1540000 | 1250 | 1205 | 1240 | 1238 | 1231 | 2005 |
| 1560000 | 1204 | 1197 | 1223 | 1266 | 1233 | 1791 |
| 1580000 | 1201 | 1200 | 1219 | 1261 | 1265 | 1731 |
| 1600000 | 1198 | 1211 | 1229 | 1263 | 1276 | 2087 |
| 1620000 | 1195 | 1223 | 1222 | 1242 | 1273 | 2006 |
| 1640000 | 1200 | 1296 | 1234 | 1248 | 1270 | 1615 |
| 1660000 | 1201 | 1290 | 1257 | 1270 | 1322 | 1584 |
| 1680000 | 1205 | 1254 | 1257 | 1260 | 1259 | 1798 |
| 1700000 | 1205 | 1299 | 1299 | 1263 | 1367 | 1710 |
| 1720000 | 1205 | 1264 | 1339 | 1276 | 1275 | 2081 |
| 1740000 | 1194 | 1258 | 1354 | 1286 | 1576 | 2257 |
| 1760000 | 1198 | 1259 | 1316 | 1277 | 1433 | 1712 |
| 1780000 | 1210 | 1246 | 1286 | 1264 | 1427 | 1638 |
| 1800000 | 1210 | 1247 | 1248 | 1253 | 1331 | 1567 |
| 1820000 | 1227 | 1238 | 1238 | 1244 | 1317 | 1536 |
| 1840000 | 1202 | 1272 | 1250 | 1247 | 1306 | 1563 |
| 1860000 | 1209 | 1272 | 1282 | 1269 | 1248 | 1603 |
| 1880000 | 1205 | 1231 | 1224 | 1257 | 1238 | 1771 |
| 1900000 | 1200 | 1217 | 1230 | 1237 | 1268 | 1640 |
| 1920000 | 1246 | 1273 | 1229 | 1261 | 1249 | 1584 |
| 1940000 | 1224 | 1256 | 1237 | 1268 | 1245 | 1519 |
| 1960000 | 1305 | 1223 | 1237 | 1240 | 1254 | 1688 |
| 1980000 | 1225 | 1226 | 1219 | 1237 | 1372 | 1562 |
| 2000000 | 1218 | 1206 | 1221 | 1269 | 1291 | 1600 |

**Graphical Representation:**

In each of the graphs below we see the Cutoff is on the X-axis and Time taken in milliseconds is on the Y-Axis.

**For Array size ：1000000**

**For Array size ：1500000**

**For Array size ：2000000**

**For Array size ：2500000**

**For Array size ：3000000**

**Unit Test Screenshots:** This assignment involved no Unit Tests