VIET NAM
NATIONAL
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HO CHI MINH CITY

Faculty of Information Technology

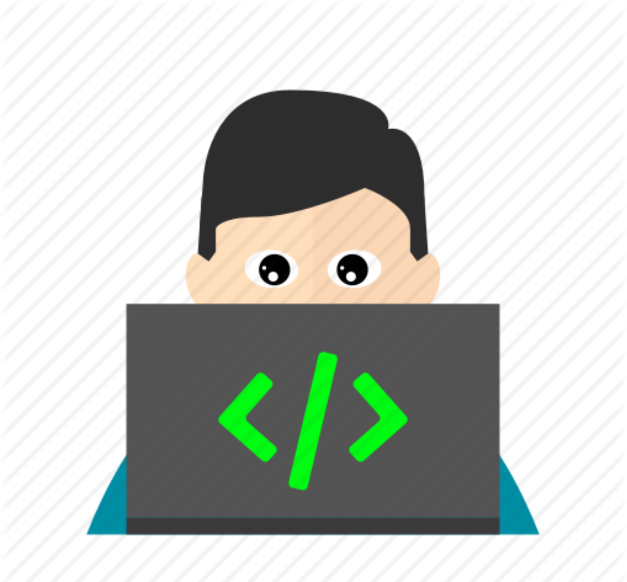
*Môn học : **Lập trình song song trên GPU***
Lớp CQ2016/2 – Học kỳ I/2019-2020
*GV: **Trần Trung Kiên***

TỐI ƯU HÓA RADIX SORT TRÊN GPU

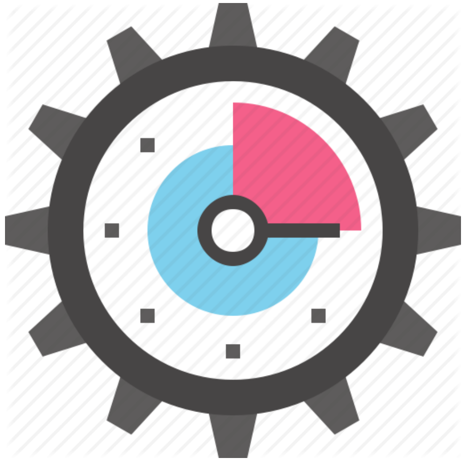
<Báo cáo đồ án cuối kỳ ngày 10-01-2020>

***Nhóm 04:** Đặng Phương Nam – Lê Minh Nghĩa*

NỘI DUNG CHÍNH



4 phiên bản baseline



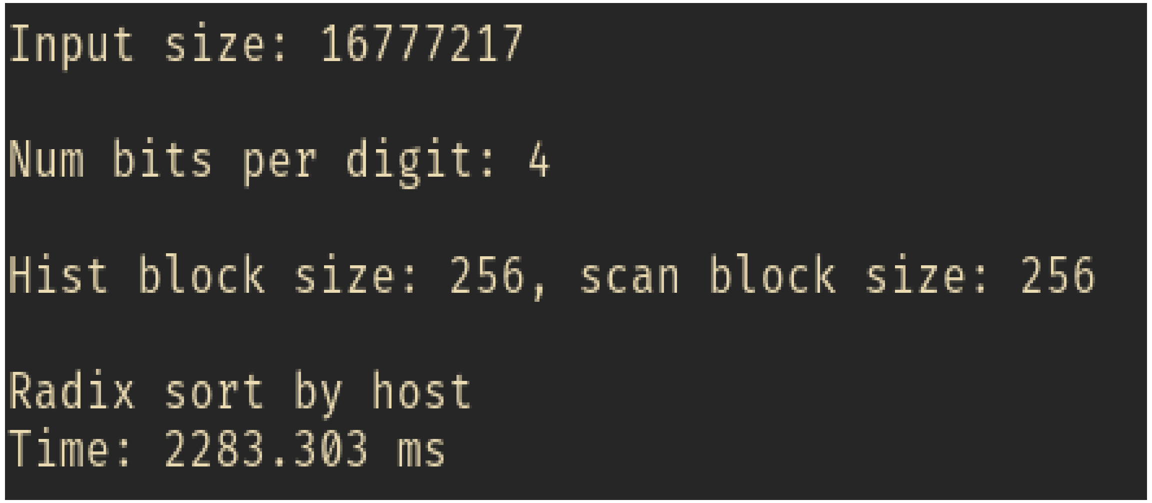
Quá trình tối ưu hóa

Chạy phiên bản tốt nhất

nBits = 4, hist block size = 256 và scan block size = 256

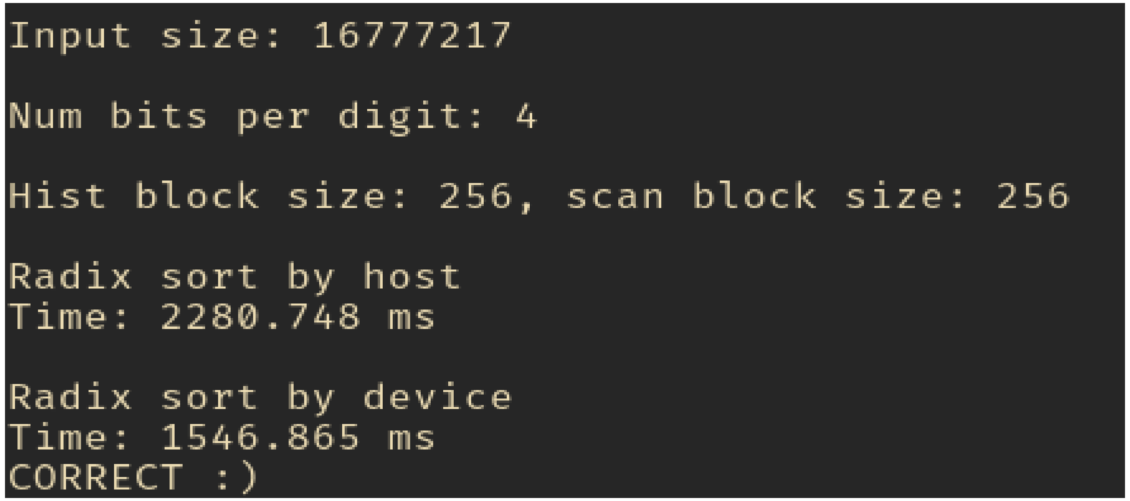
Version	Description	Run Time (ms)
baseline01	Cài đặt tuần tự thuật toán Radix Sort tuần tự.	2283.303
baseline02	Cài đặt song song 2 bước histogram và scan của thuật toán Radix Sort tuần tự.	1546.865
baseline03	Cài đặt song song thuật toán Radix Sort với k = 1 bit.	584.170
baseline04	Cài đặt tuần tự ý tưởng thuật toán Radix Sort song song trong bài báo của NVIDIA.	2779.344
thrust	Thuật toán sort song song trong trong thư viện Thrust.	80.575

4 PHIÊN BẢN BASE LINE



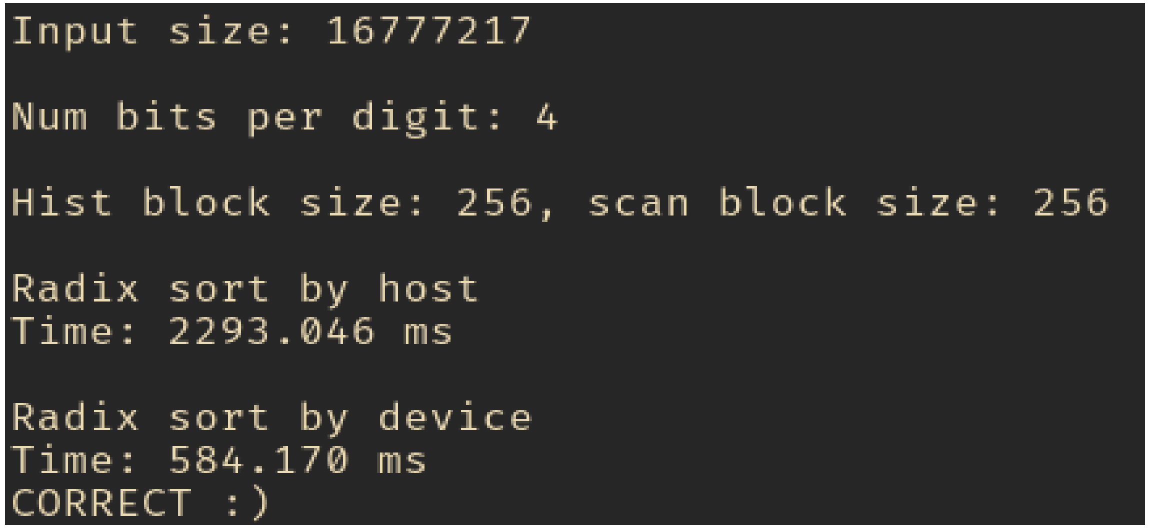
```
Input size: 16777217

Num bits per digit: 4

Hist block size: 256, scan block size: 256

Radix sort by host
Time: 2283.303 ms
```

Baseline01



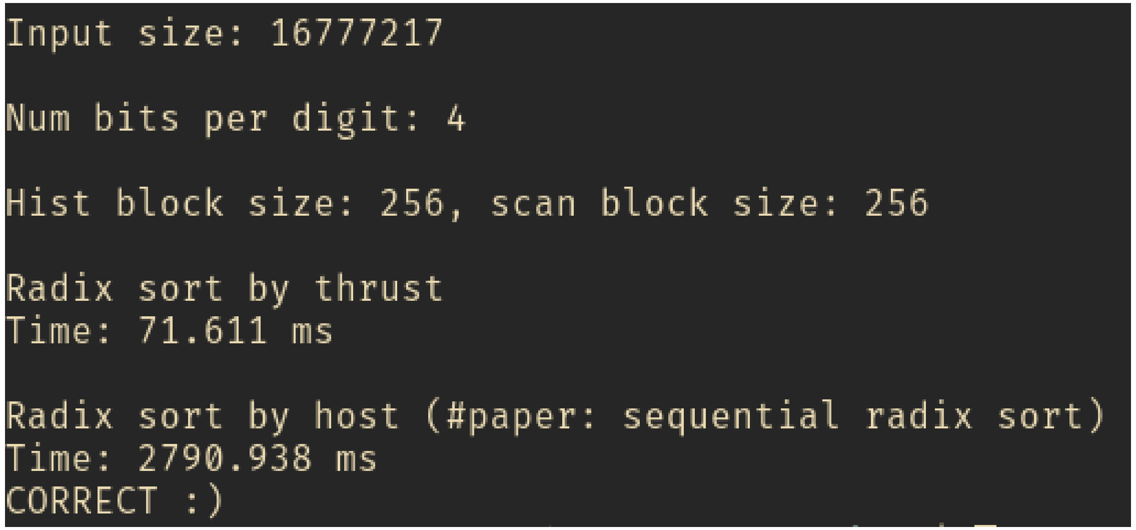
```
Input size: 16777217

Num bits per digit: 4

Hist block size: 256, scan block size: 256

Radix sort by host
Time: 2280.748 ms

Radix sort by device
Time: 1546.865 ms
CORRECT :)
```

Baseline02



```
Input size: 16777217

Num bits per digit: 4

Hist block size: 256, scan block size: 256

Radix sort by host
Time: 2293.046 ms

Radix sort by device
Time: 584.170 ms
CORRECT :)
```

Baseline03



```
Input size: 16777217

Num bits per digit: 4

Hist block size: 256, scan block size: 256

Radix sort by thrust
Time: 71.611 ms

Radix sort by host (#paper: sequential radix sort)
Time: 2790.938 ms
CORRECT :)
```

Baseline04

nBits = 4, hist block size = 256 và scan block size = 256

Version	Description	Run Time # Step 1 (ms/loop)	Run Time # Step 2 (ms/loop)	Run Time # Step 3 (ms/loop)	Run Time Total (ms)
baseline04-v1	Cài đặt tuần tự ý tưởng thuật toán Radix Sort song song trong bài báo của NVIDIA.	135.680	5.601	201.208	2772.958
baseline04-v2	Cài đặt song song bước tính local histogram và exclusive scan trên mảng một chiều gồm các các cột nối với nhau.	2.802	0.883	224.110	1866.060
baseline04-v3	Cài đặt song song bước scatter dữ liệu xuống mảng output, với in-block-sort dùng work-inefficient scan.	2.671	0.868	49.173	470.487
baseline04-v4	Cài đặt song song bước scatter dữ liệu xuống mảng output, với in-block-sort dùng work-inefficient scan (mỗi thread xử lý 2 phần tử).	2.678	0.872	45.780	442.680

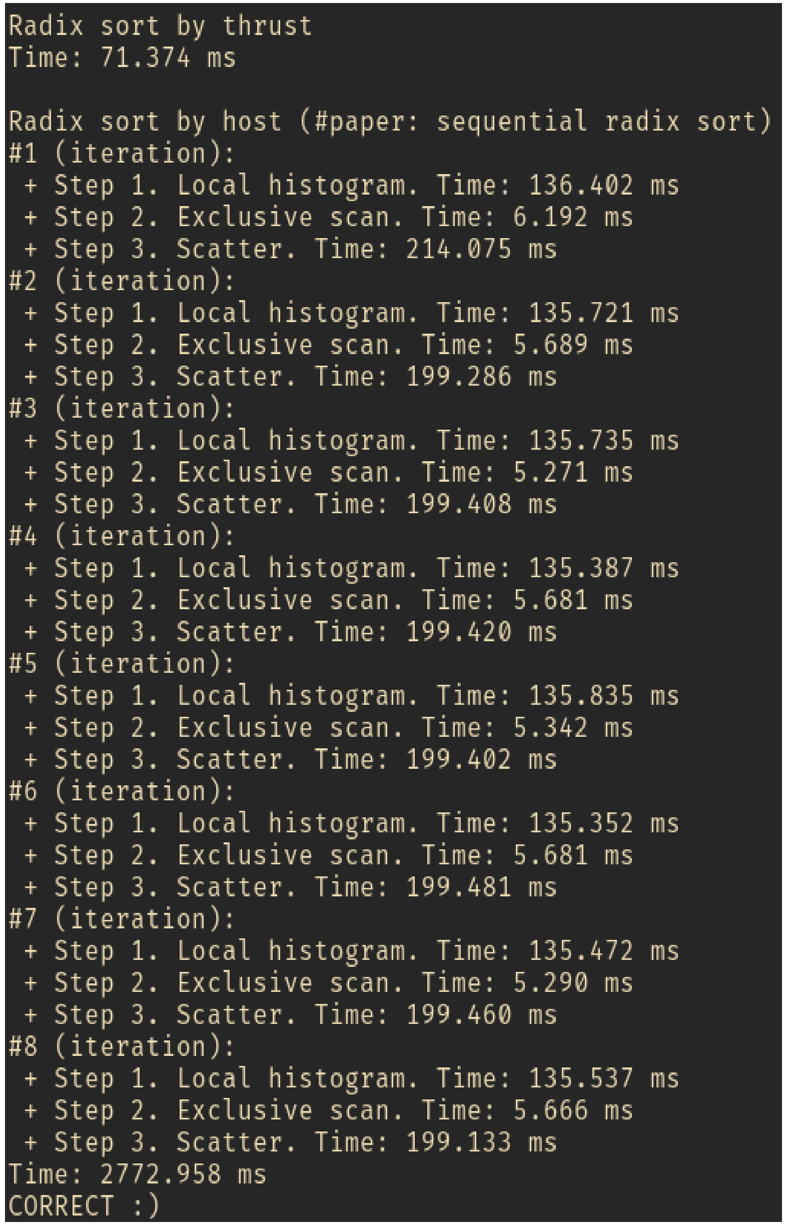
QUÁ TRÌNH TỐI ƯU HÓA CHO PHIÊN BẢN BASELINE04

nBits = 4, hist block size = 256 và scan block size = 256

Version	Description	Run Time # Step 1 (ms/loop)	Run Time # Step 2 (ms/loop)	Run Time # Step 3 (ms/loop)	Run Time Total (ms)
baseline04-v5	Cài đặt song song bước scatter dữ liệu xuống mảng output, với in-block-sort dùng work-efficient scan (mỗi thread xử lý 2 phần tử).	2.798	0.867	48.805	466.951
baseline04-v6	Cài đặt song song bước scatter dữ liệu xuống mảng output, với in-block-sort dùng warp shuffles scan.	2.671	0.867	22.801	258.824
baseline04-v7	Cài đặt song song bước scatter dữ liệu xuống mảng output, với in-block-sort dùng warp shuffles scan. (mỗi thread xử lý 2 phần tử).	2.673	0.868	20.783	243.245
thrust	Thuật toán sort song song trong trong thư viện Thrust.				72.695

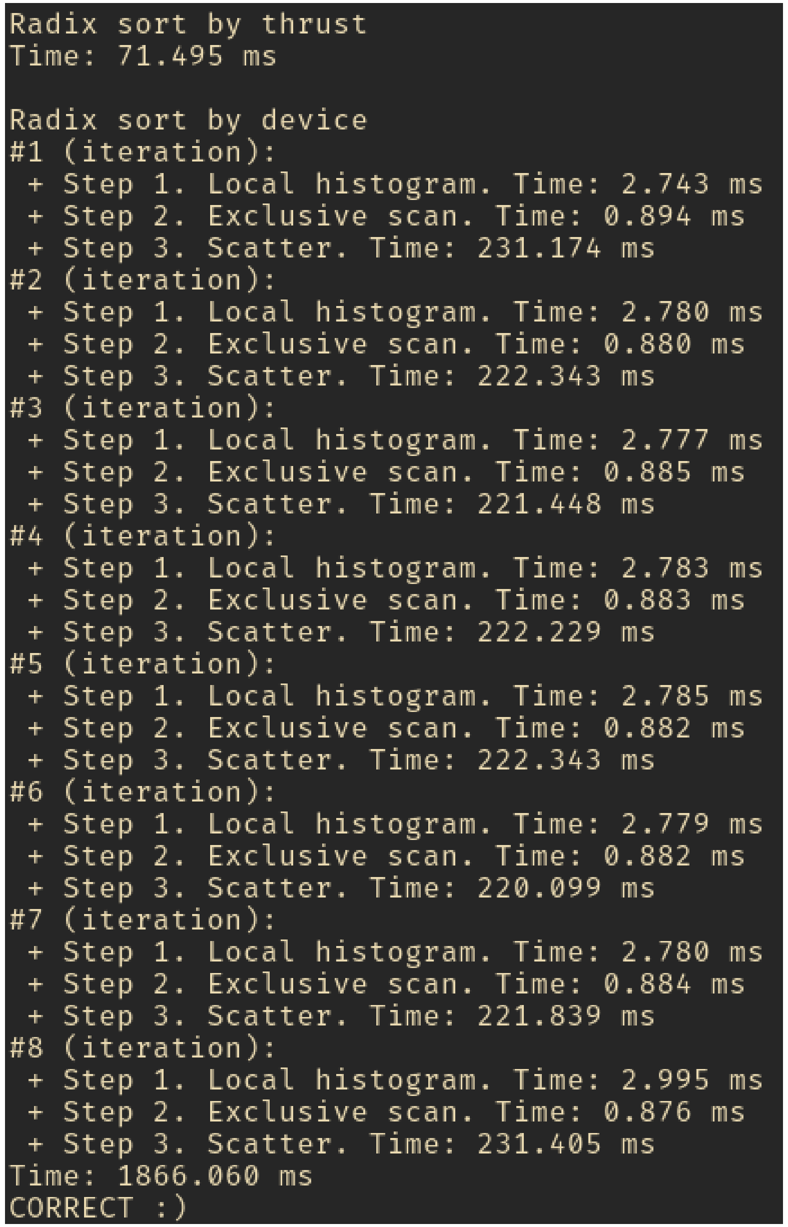
Phiên bản tốt nhất mà nhóm cài đặt được là phiên bản baseline04-v7.

QUÁ TRÌNH TỐI ƯU HÓA CHO PHIÊN BẢN BASELINE04



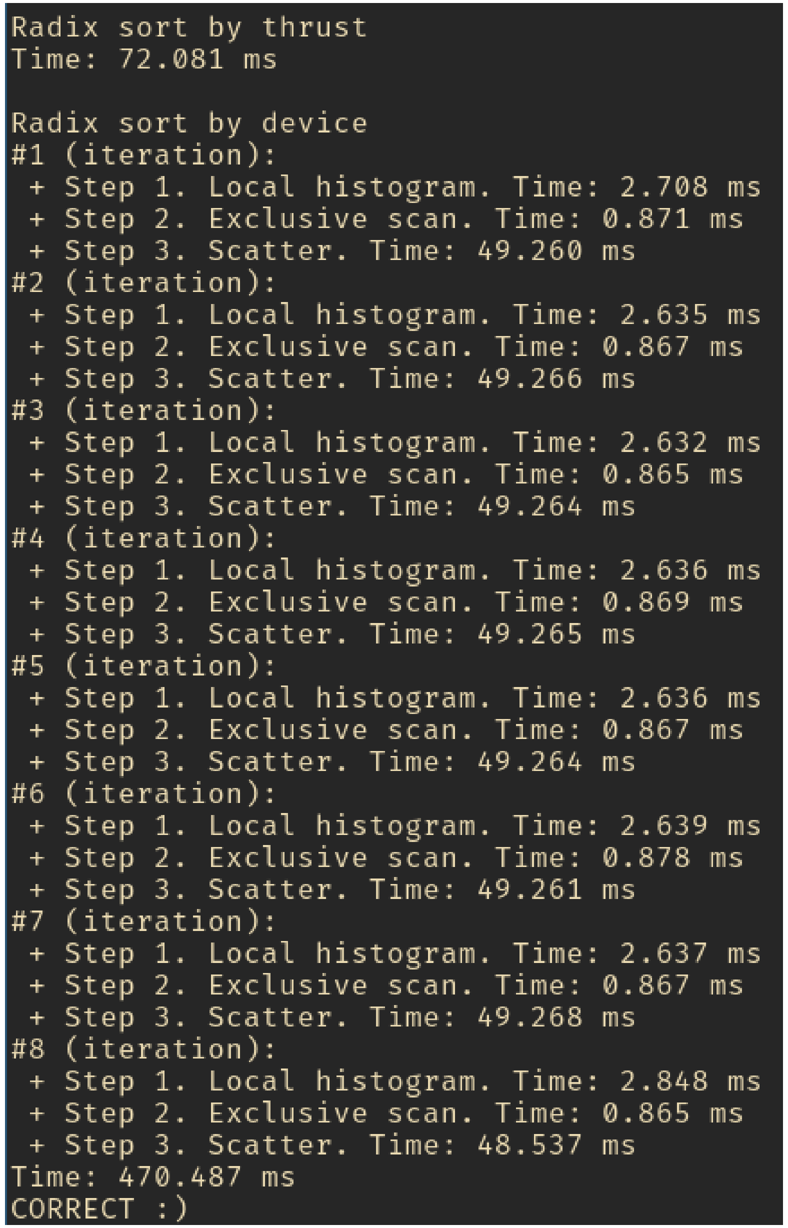
```
Radix sort by thrust
Time: 71.374 ms

Radix sort by host (#paper: sequential radix sort)
#1 (iteration):
 + Step 1. Local histogram. Time: 136.402 ms
 + Step 2. Exclusive scan. Time: 6.192 ms
 + Step 3. Scatter. Time: 214.075 ms
#2 (iteration):
 + Step 1. Local histogram. Time: 135.721 ms
 + Step 2. Exclusive scan. Time: 5.689 ms
 + Step 3. Scatter. Time: 199.286 ms
#3 (iteration):
 + Step 1. Local histogram. Time: 135.735 ms
 + Step 2. Exclusive scan. Time: 5.271 ms
 + Step 3. Scatter. Time: 199.408 ms
#4 (iteration):
 + Step 1. Local histogram. Time: 135.387 ms
 + Step 2. Exclusive scan. Time: 5.681 ms
 + Step 3. Scatter. Time: 199.420 ms
#5 (iteration):
 + Step 1. Local histogram. Time: 135.835 ms
 + Step 2. Exclusive scan. Time: 5.342 ms
 + Step 3. Scatter. Time: 199.402 ms
#6 (iteration):
 + Step 1. Local histogram. Time: 135.352 ms
 + Step 2. Exclusive scan. Time: 5.681 ms
 + Step 3. Scatter. Time: 199.481 ms
#7 (iteration):
 + Step 1. Local histogram. Time: 135.472 ms
 + Step 2. Exclusive scan. Time: 5.290 ms
 + Step 3. Scatter. Time: 199.460 ms
#8 (iteration):
 + Step 1. Local histogram. Time: 135.537 ms
 + Step 2. Exclusive scan. Time: 5.666 ms
 + Step 3. Scatter. Time: 199.133 ms
Time: 2772.958 ms
CORRECT :)
```

Baseline04-v1



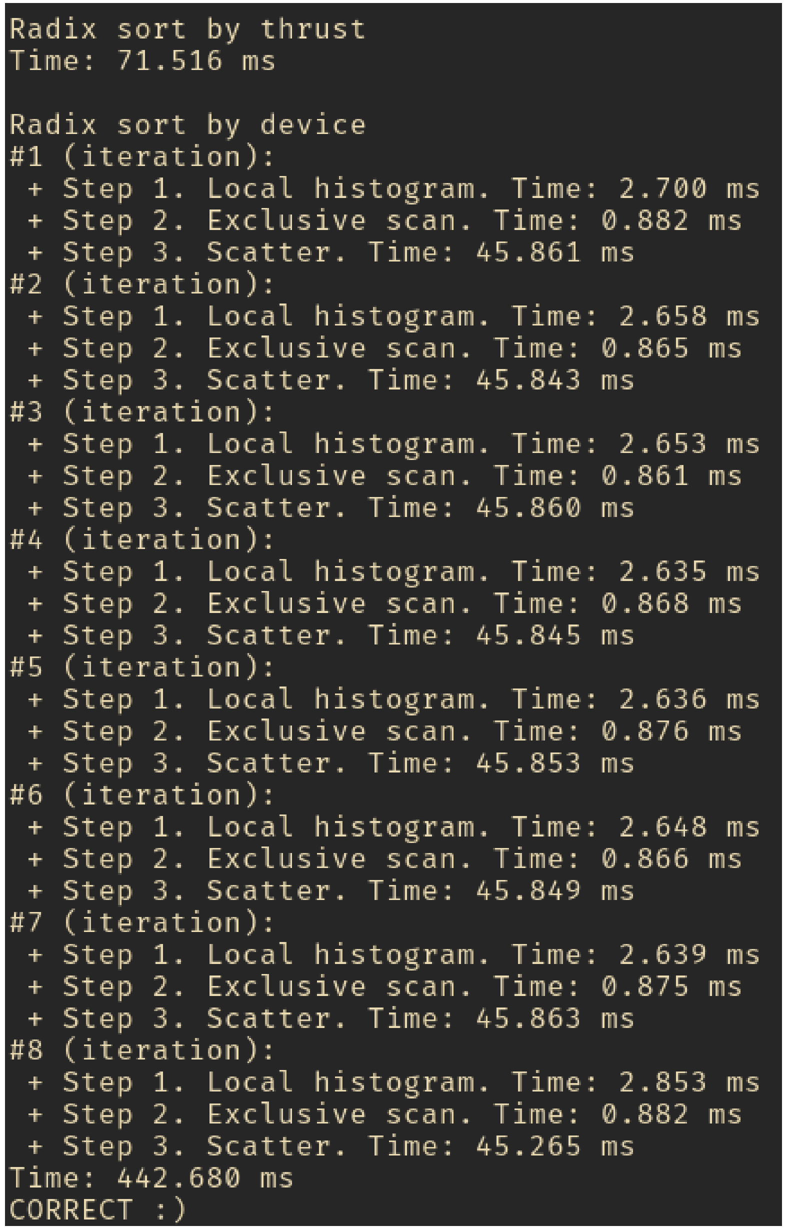
```
Radix sort by thrust
Time: 71.495 ms

Radix sort by device
#1 (iteration):
 + Step 1. Local histogram. Time: 2.743 ms
 + Step 2. Exclusive scan. Time: 0.894 ms
 + Step 3. Scatter. Time: 231.174 ms
#2 (iteration):
 + Step 1. Local histogram. Time: 2.780 ms
 + Step 2. Exclusive scan. Time: 0.880 ms
 + Step 3. Scatter. Time: 222.343 ms
#3 (iteration):
 + Step 1. Local histogram. Time: 2.777 ms
 + Step 2. Exclusive scan. Time: 0.885 ms
 + Step 3. Scatter. Time: 221.448 ms
#4 (iteration):
 + Step 1. Local histogram. Time: 2.783 ms
 + Step 2. Exclusive scan. Time: 0.883 ms
 + Step 3. Scatter. Time: 222.229 ms
#5 (iteration):
 + Step 1. Local histogram. Time: 2.785 ms
 + Step 2. Exclusive scan. Time: 0.882 ms
 + Step 3. Scatter. Time: 222.343 ms
#6 (iteration):
 + Step 1. Local histogram. Time: 2.779 ms
 + Step 2. Exclusive scan. Time: 0.882 ms
 + Step 3. Scatter. Time: 220.099 ms
#7 (iteration):
 + Step 1. Local histogram. Time: 2.780 ms
 + Step 2. Exclusive scan. Time: 0.884 ms
 + Step 3. Scatter. Time: 221.839 ms
#8 (iteration):
 + Step 1. Local histogram. Time: 2.995 ms
 + Step 2. Exclusive scan. Time: 0.876 ms
 + Step 3. Scatter. Time: 231.405 ms
Time: 1866.060 ms
CORRECT :)
```

Baseline04-v2



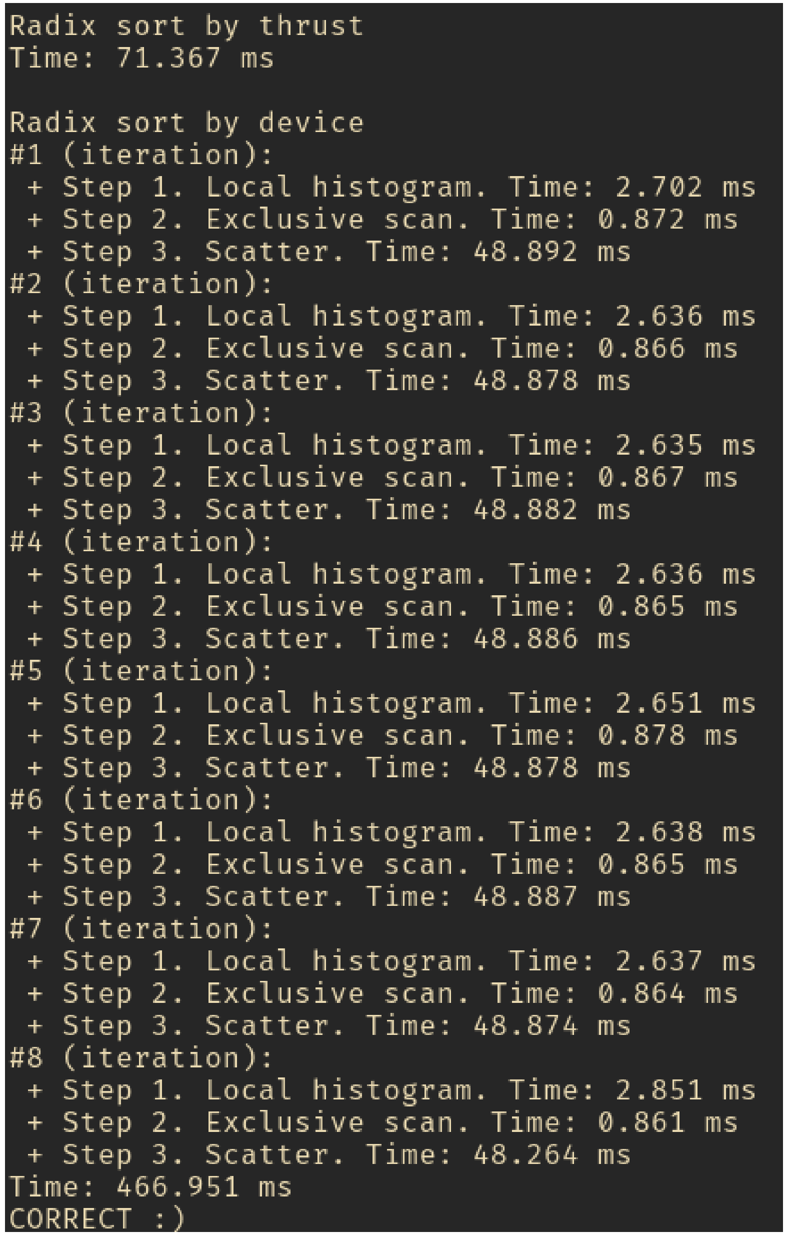
```
Radix sort by thrust
Time: 72.081 ms

Radix sort by device
#1 (iteration):
 + Step 1. Local histogram. Time: 2.708 ms
 + Step 2. Exclusive scan. Time: 0.871 ms
 + Step 3. Scatter. Time: 49.260 ms
#2 (iteration):
 + Step 1. Local histogram. Time: 2.635 ms
 + Step 2. Exclusive scan. Time: 0.867 ms
 + Step 3. Scatter. Time: 49.266 ms
#3 (iteration):
 + Step 1. Local histogram. Time: 2.632 ms
 + Step 2. Exclusive scan. Time: 0.865 ms
 + Step 3. Scatter. Time: 49.264 ms
#4 (iteration):
 + Step 1. Local histogram. Time: 2.636 ms
 + Step 2. Exclusive scan. Time: 0.869 ms
 + Step 3. Scatter. Time: 49.265 ms
#5 (iteration):
 + Step 1. Local histogram. Time: 2.636 ms
 + Step 2. Exclusive scan. Time: 0.867 ms
 + Step 3. Scatter. Time: 49.264 ms
#6 (iteration):
 + Step 1. Local histogram. Time: 2.639 ms
 + Step 2. Exclusive scan. Time: 0.878 ms
 + Step 3. Scatter. Time: 49.261 ms
#7 (iteration):
 + Step 1. Local histogram. Time: 2.637 ms
 + Step 2. Exclusive scan. Time: 0.867 ms
 + Step 3. Scatter. Time: 49.268 ms
#8 (iteration):
 + Step 1. Local histogram. Time: 2.848 ms
 + Step 2. Exclusive scan. Time: 0.865 ms
 + Step 3. Scatter. Time: 48.537 ms
Time: 470.487 ms
CORRECT :)
```

Baseline04-v3



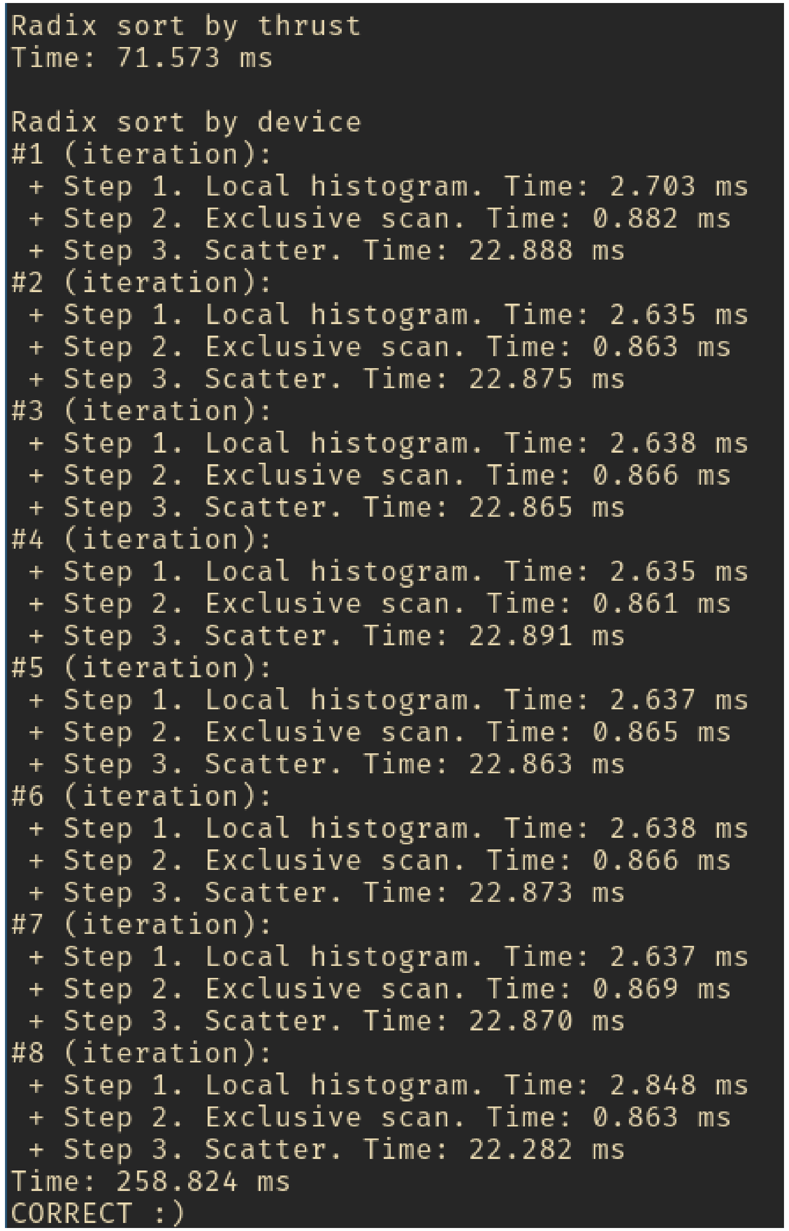
```
Radix sort by thrust
Time: 71.516 ms

Radix sort by device
#1 (iteration):
 + Step 1. Local histogram. Time: 2.700 ms
 + Step 2. Exclusive scan. Time: 0.882 ms
 + Step 3. Scatter. Time: 45.861 ms
#2 (iteration):
 + Step 1. Local histogram. Time: 2.658 ms
 + Step 2. Exclusive scan. Time: 0.865 ms
 + Step 3. Scatter. Time: 45.843 ms
#3 (iteration):
 + Step 1. Local histogram. Time: 2.653 ms
 + Step 2. Exclusive scan. Time: 0.861 ms
 + Step 3. Scatter. Time: 45.860 ms
#4 (iteration):
 + Step 1. Local histogram. Time: 2.635 ms
 + Step 2. Exclusive scan. Time: 0.868 ms
 + Step 3. Scatter. Time: 45.845 ms
#5 (iteration):
 + Step 1. Local histogram. Time: 2.636 ms
 + Step 2. Exclusive scan. Time: 0.876 ms
 + Step 3. Scatter. Time: 45.853 ms
#6 (iteration):
 + Step 1. Local histogram. Time: 2.648 ms
 + Step 2. Exclusive scan. Time: 0.866 ms
 + Step 3. Scatter. Time: 45.849 ms
#7 (iteration):
 + Step 1. Local histogram. Time: 2.639 ms
 + Step 2. Exclusive scan. Time: 0.875 ms
 + Step 3. Scatter. Time: 45.863 ms
#8 (iteration):
 + Step 1. Local histogram. Time: 2.853 ms
 + Step 2. Exclusive scan. Time: 0.882 ms
 + Step 3. Scatter. Time: 45.265 ms
Time: 442.680 ms
CORRECT :)
```

Baseline04-v4



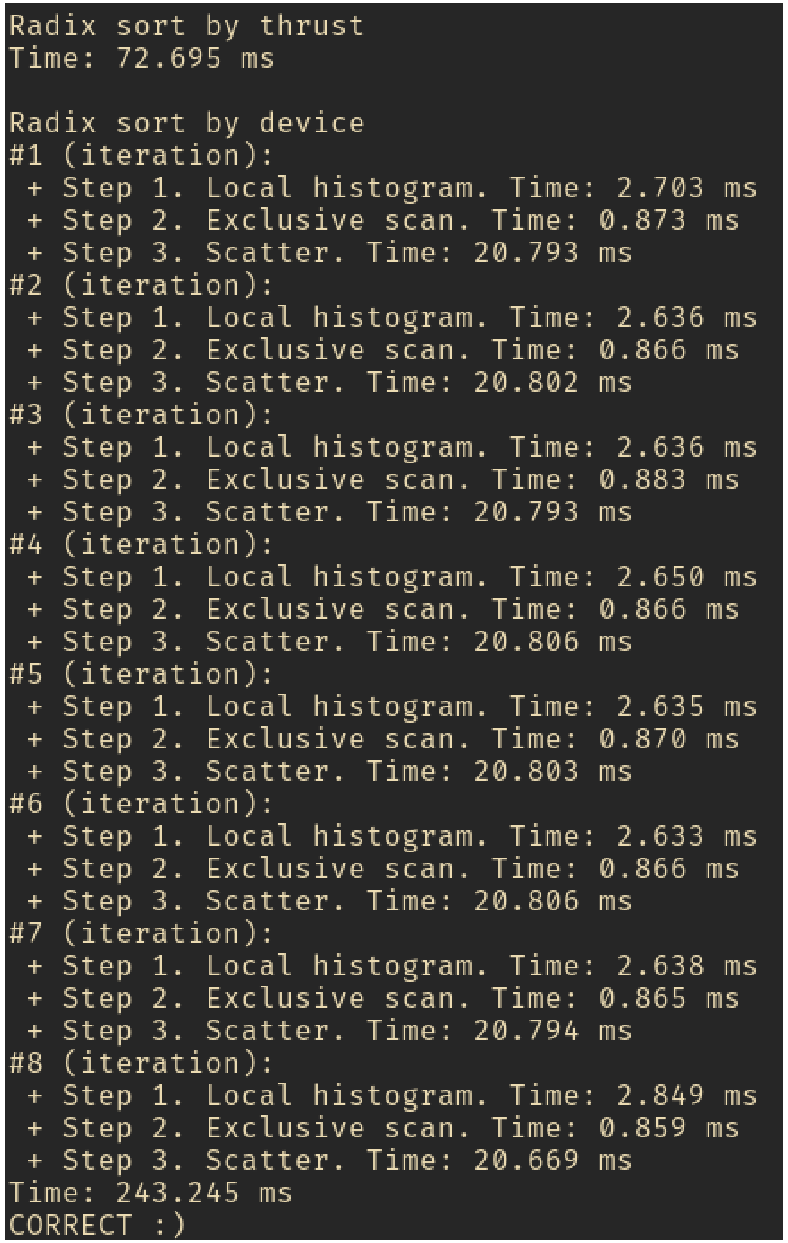
```
Radix sort by thrust
Time: 71.367 ms

Radix sort by device
#1 (iteration):
 + Step 1. Local histogram. Time: 2.702 ms
 + Step 2. Exclusive scan. Time: 0.872 ms
 + Step 3. Scatter. Time: 48.892 ms
#2 (iteration):
 + Step 1. Local histogram. Time: 2.636 ms
 + Step 2. Exclusive scan. Time: 0.866 ms
 + Step 3. Scatter. Time: 48.878 ms
#3 (iteration):
 + Step 1. Local histogram. Time: 2.635 ms
 + Step 2. Exclusive scan. Time: 0.867 ms
 + Step 3. Scatter. Time: 48.882 ms
#4 (iteration):
 + Step 1. Local histogram. Time: 2.636 ms
 + Step 2. Exclusive scan. Time: 0.865 ms
 + Step 3. Scatter. Time: 48.886 ms
#5 (iteration):
 + Step 1. Local histogram. Time: 2.651 ms
 + Step 2. Exclusive scan. Time: 0.878 ms
 + Step 3. Scatter. Time: 48.878 ms
#6 (iteration):
 + Step 1. Local histogram. Time: 2.638 ms
 + Step 2. Exclusive scan. Time: 0.865 ms
 + Step 3. Scatter. Time: 48.887 ms
#7 (iteration):
 + Step 1. Local histogram. Time: 2.637 ms
 + Step 2. Exclusive scan. Time: 0.864 ms
 + Step 3. Scatter. Time: 48.874 ms
#8 (iteration):
 + Step 1. Local histogram. Time: 2.851 ms
 + Step 2. Exclusive scan. Time: 0.861 ms
 + Step 3. Scatter. Time: 48.264 ms
Time: 466.951 ms
CORRECT :)
```

Baseline04-v5



```
Radix sort by thrust
Time: 71.573 ms

Radix sort by device
#1 (iteration):
 + Step 1. Local histogram. Time: 2.703 ms
 + Step 2. Exclusive scan. Time: 0.882 ms
 + Step 3. Scatter. Time: 22.888 ms
#2 (iteration):
 + Step 1. Local histogram. Time: 2.635 ms
 + Step 2. Exclusive scan. Time: 0.863 ms
 + Step 3. Scatter. Time: 22.875 ms
#3 (iteration):
 + Step 1. Local histogram. Time: 2.638 ms
 + Step 2. Exclusive scan. Time: 0.866 ms
 + Step 3. Scatter. Time: 22.865 ms
#4 (iteration):
 + Step 1. Local histogram. Time: 2.635 ms
 + Step 2. Exclusive scan. Time: 0.861 ms
 + Step 3. Scatter. Time: 22.891 ms
#5 (iteration):
 + Step 1. Local histogram. Time: 2.637 ms
 + Step 2. Exclusive scan. Time: 0.865 ms
 + Step 3. Scatter. Time: 22.863 ms
#6 (iteration):
 + Step 1. Local histogram. Time: 2.638 ms
 + Step 2. Exclusive scan. Time: 0.866 ms
 + Step 3. Scatter. Time: 22.873 ms
#7 (iteration):
 + Step 1. Local histogram. Time: 2.637 ms
 + Step 2. Exclusive scan. Time: 0.869 ms
 + Step 3. Scatter. Time: 22.870 ms
#8 (iteration):
 + Step 1. Local histogram. Time: 2.848 ms
 + Step 2. Exclusive scan. Time: 0.863 ms
 + Step 3. Scatter. Time: 22.282 ms
Time: 258.824 ms
CORRECT :)
```

Baseline04-v6



```
Radix sort by thrust
Time: 72.695 ms

Radix sort by device
#1 (iteration):
 + Step 1. Local histogram. Time: 2.703 ms
 + Step 2. Exclusive scan. Time: 0.873 ms
 + Step 3. Scatter. Time: 20.793 ms
#2 (iteration):
 + Step 1. Local histogram. Time: 2.636 ms
 + Step 2. Exclusive scan. Time: 0.866 ms
 + Step 3. Scatter. Time: 20.802 ms
#3 (iteration):
 + Step 1. Local histogram. Time: 2.636 ms
 + Step 2. Exclusive scan. Time: 0.883 ms
 + Step 3. Scatter. Time: 20.793 ms
#4 (iteration):
 + Step 1. Local histogram. Time: 2.650 ms
 + Step 2. Exclusive scan. Time: 0.866 ms
 + Step 3. Scatter. Time: 20.806 ms
#5 (iteration):
 + Step 1. Local histogram. Time: 2.635 ms
 + Step 2. Exclusive scan. Time: 0.870 ms
 + Step 3. Scatter. Time: 20.803 ms
#6 (iteration):
 + Step 1. Local histogram. Time: 2.633 ms
 + Step 2. Exclusive scan. Time: 0.866 ms
 + Step 3. Scatter. Time: 20.806 ms
#7 (iteration):
 + Step 1. Local histogram. Time: 2.638 ms
 + Step 2. Exclusive scan. Time: 0.865 ms
 + Step 3. Scatter. Time: 20.794 ms
#8 (iteration):
 + Step 1. Local histogram. Time: 2.849 ms
 + Step 2. Exclusive scan. Time: 0.859 ms
 + Step 3. Scatter. Time: 20.669 ms
Time: 243.245 ms
CORRECT :)
```

Baseline04-v7

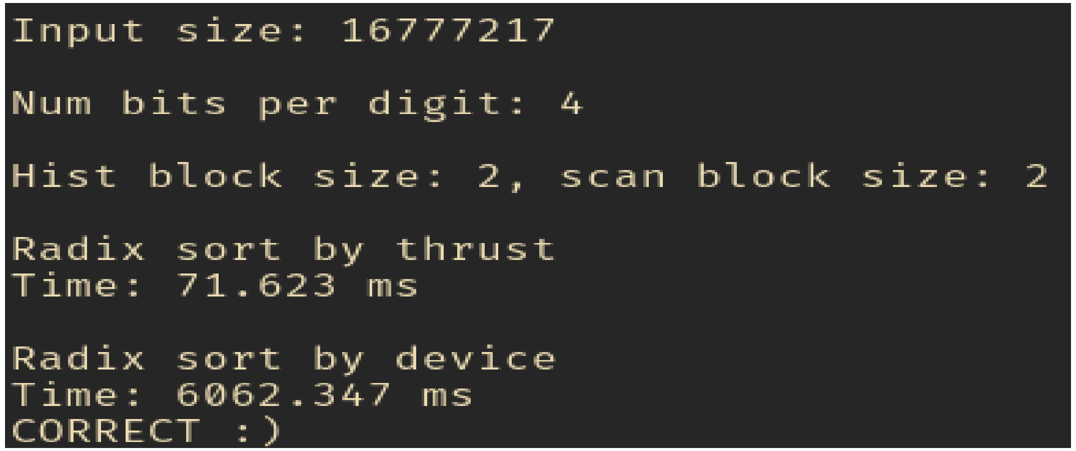
Phiên bản baseline04-v7 với nBits = 4

Hist block size	Scan block size	Run Time (ms)
2	2	6062.347
2	4	4408.337
2	16	2994.594
2	256	2761.198
4	2	4108.598
4	4	3062.705
4	16	2463.188
4	256	2341.852

Hist block size	Scan block size	Run Time (ms)
16	2	2068.141
16	4	1959.383
16	16	1368.400
16	256	1149.069
256	2	381.797
256	4	309.685
256	16	256.146
256	256	242.113

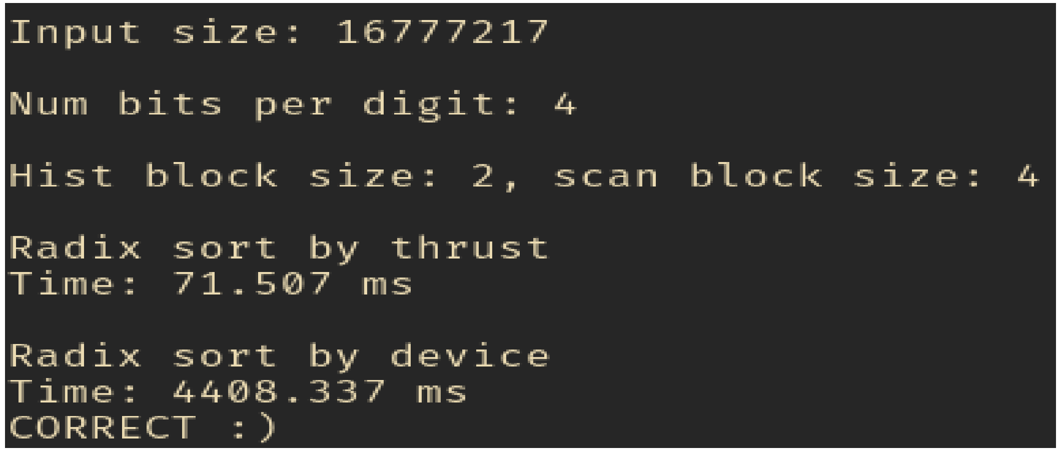
CHẠY PHIÊN BẢN TỐT NHẤT – BLOCK SIZE KHÁC NHAU

Phiên bản baseline04-v7 với nBits = 4 và hist block size = 2



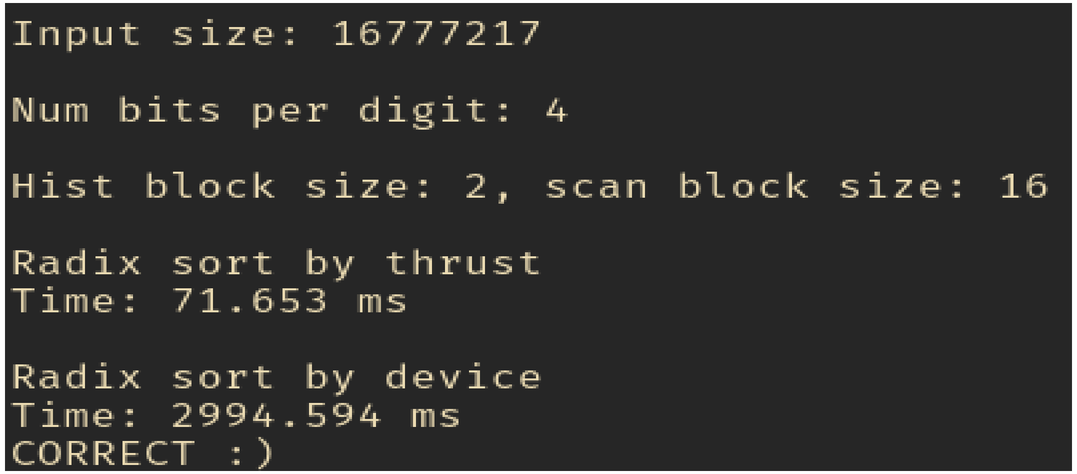
```
Input size: 16777217

Num bits per digit: 4

Hist block size: 2, scan block size: 2

Radix sort by thrust
Time: 71.623 ms

Radix sort by device
Time: 6062.347 ms
CORRECT :)
```

Scan block size = 2



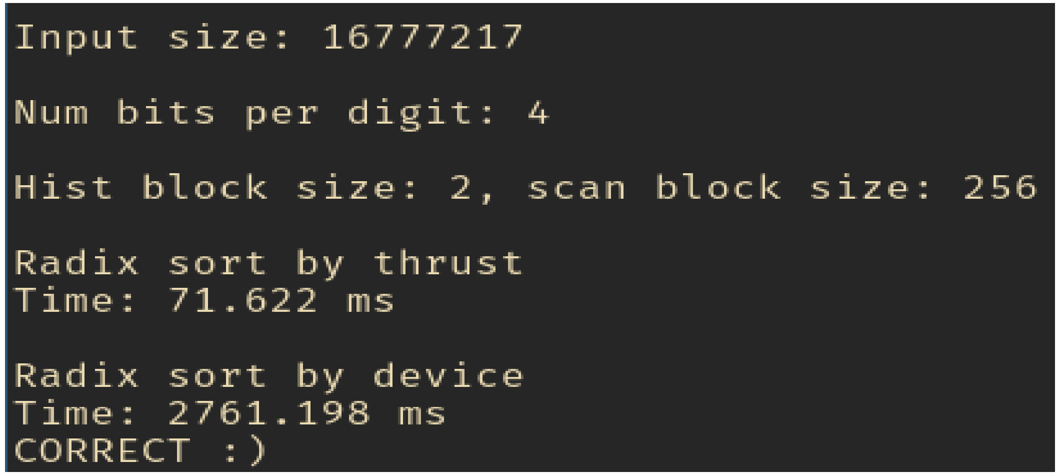
```
Input size: 16777217

Num bits per digit: 4

Hist block size: 2, scan block size: 4

Radix sort by thrust
Time: 71.507 ms

Radix sort by device
Time: 4408.337 ms
CORRECT :)
```

Scan block size = 4



```
Input size: 16777217

Num bits per digit: 4

Hist block size: 2, scan block size: 16

Radix sort by thrust
Time: 71.653 ms

Radix sort by device
Time: 2994.594 ms
CORRECT :)
```

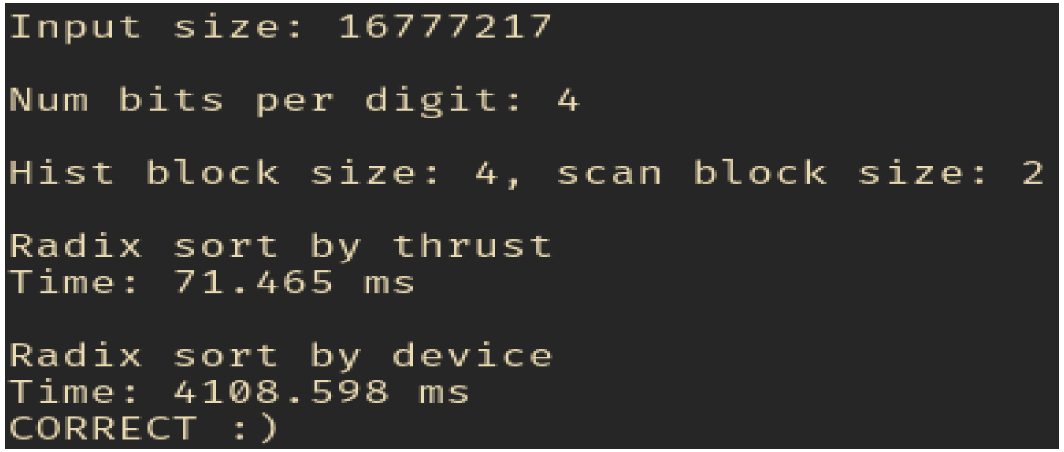
Scan block size = 16



```
Input size: 16777217

Num bits per digit: 4

Hist block size: 2, scan block size: 256

Radix sort by thrust
Time: 71.622 ms

Radix sort by device
Time: 2761.198 ms
CORRECT :)
```

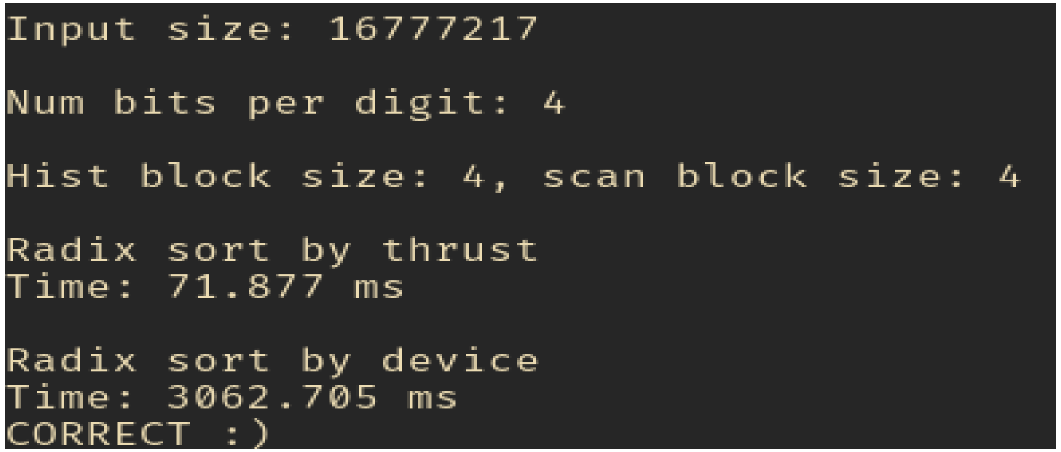
Scan block size = 256

Phiên bản baseline04-v7 với nBits = 4 và hist block size = 4



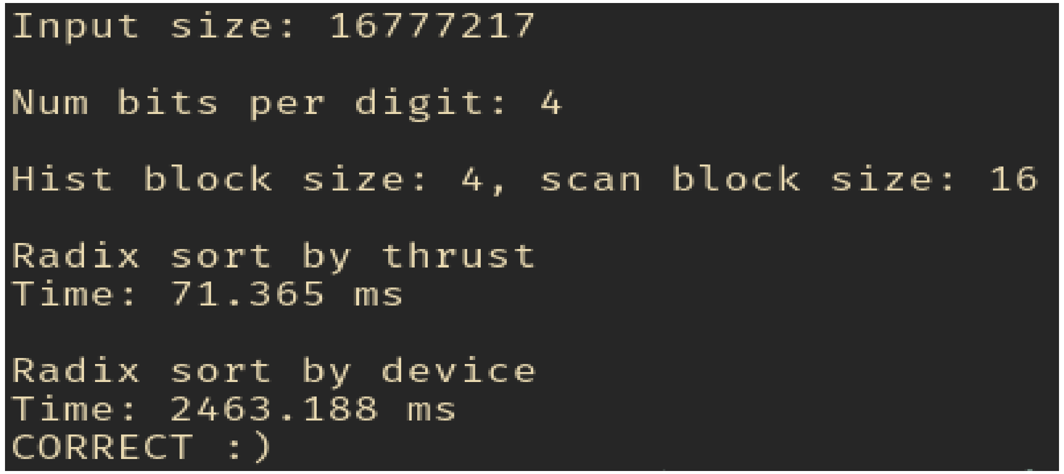
```
Input size: 16777217

Num bits per digit: 4

Hist block size: 4, scan block size: 2

Radix sort by thrust
Time: 71.465 ms

Radix sort by device
Time: 4108.598 ms
CORRECT :)
```

Scan block size = 2



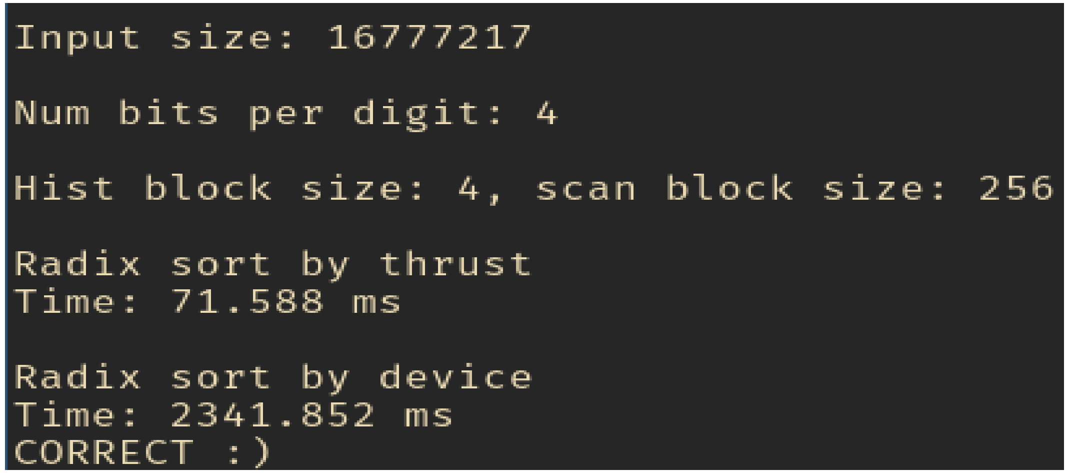
```
Input size: 16777217

Num bits per digit: 4

Hist block size: 4, scan block size: 4

Radix sort by thrust
Time: 71.877 ms

Radix sort by device
Time: 3062.705 ms
CORRECT :)
```

Scan block size = 4



```
Input size: 16777217

Num bits per digit: 4

Hist block size: 4, scan block size: 16

Radix sort by thrust
Time: 71.365 ms

Radix sort by device
Time: 2463.188 ms
CORRECT :)
```

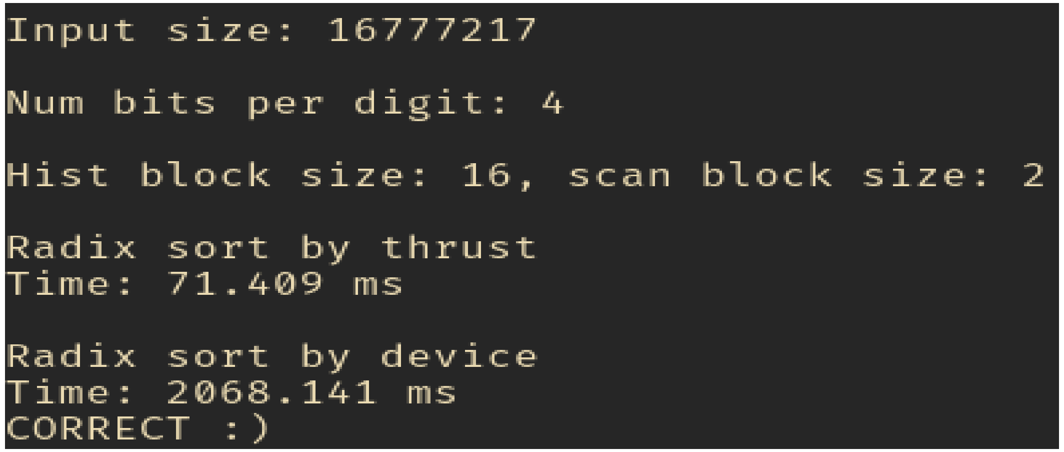
Scan block size = 16



```
Input size: 16777217

Num bits per digit: 4

Hist block size: 4, scan block size: 256

Radix sort by thrust
Time: 71.588 ms

Radix sort by device
Time: 2341.852 ms
CORRECT :)
```

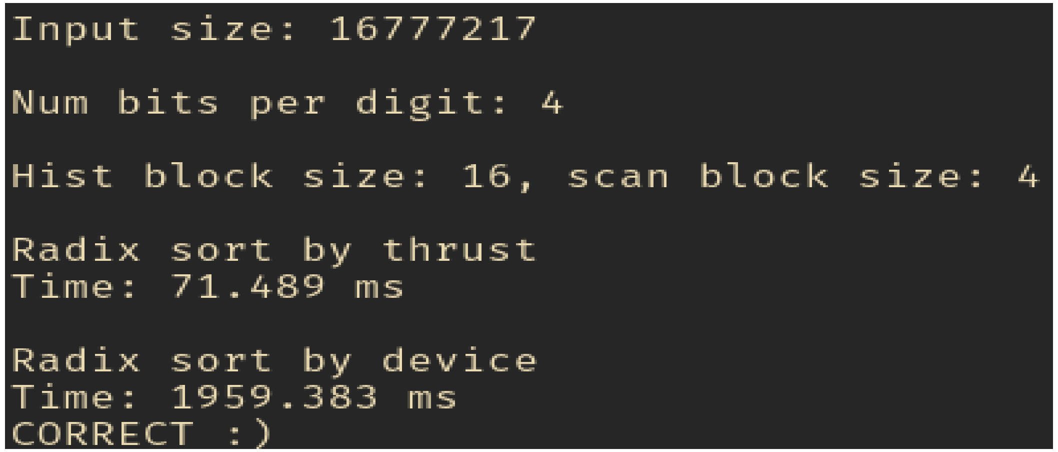
Scan block size = 256

Phiên bản baseline04-v7 với nBits = 4 và hist block size = 16



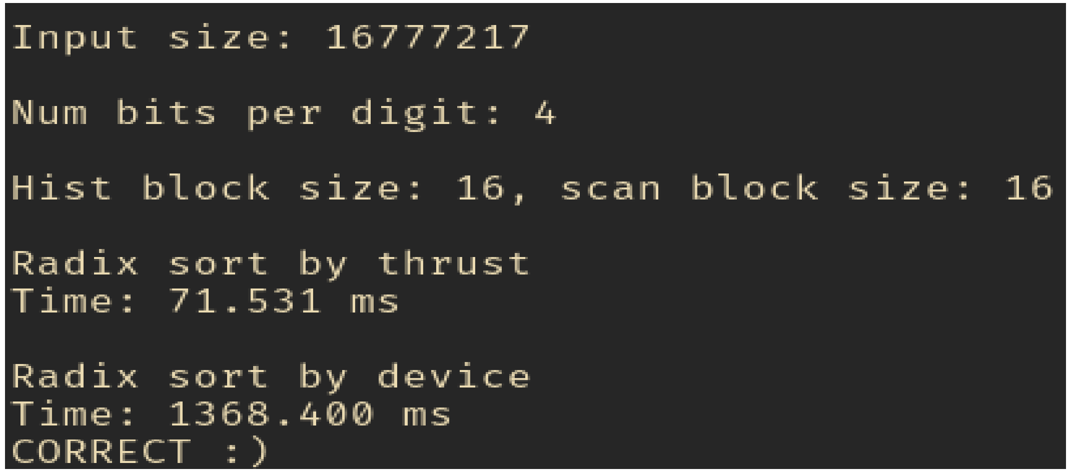
```
Input size: 16777217

Num bits per digit: 4

Hist block size: 16, scan block size: 2

Radix sort by thrust
Time: 71.409 ms

Radix sort by device
Time: 2068.141 ms
CORRECT :)
```

Scan block size = 2



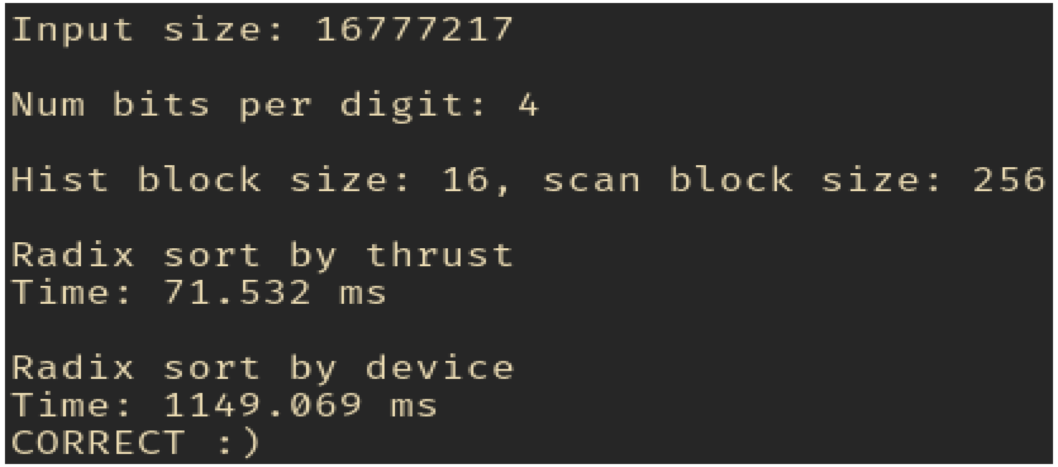
```
Input size: 16777217

Num bits per digit: 4

Hist block size: 16, scan block size: 4

Radix sort by thrust
Time: 71.489 ms

Radix sort by device
Time: 1959.383 ms
CORRECT :)
```

Scan block size = 4



```
Input size: 16777217

Num bits per digit: 4

Hist block size: 16, scan block size: 16

Radix sort by thrust
Time: 71.531 ms

Radix sort by device
Time: 1368.400 ms
CORRECT :)
```

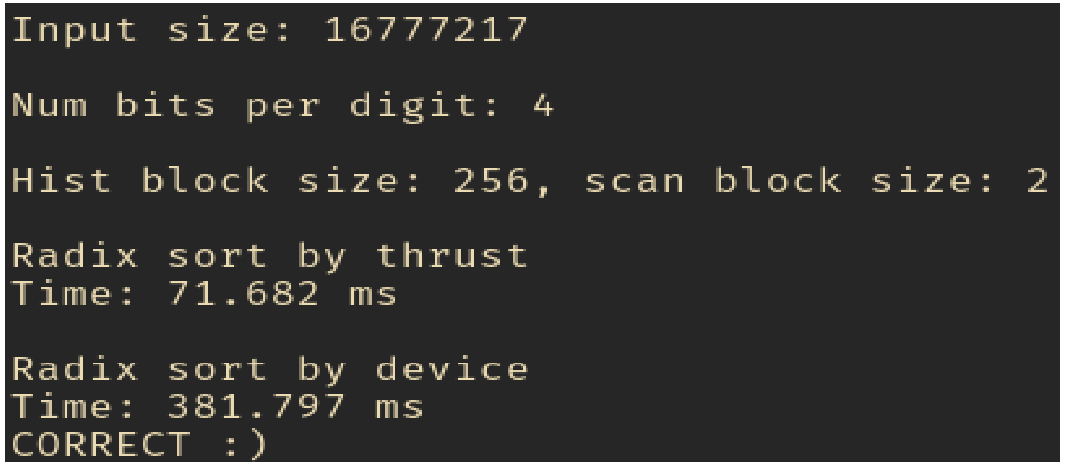
Scan block size = 16



```
Input size: 16777217

Num bits per digit: 4

Hist block size: 16, scan block size: 256

Radix sort by thrust
Time: 71.532 ms

Radix sort by device
Time: 1149.069 ms
CORRECT :)
```

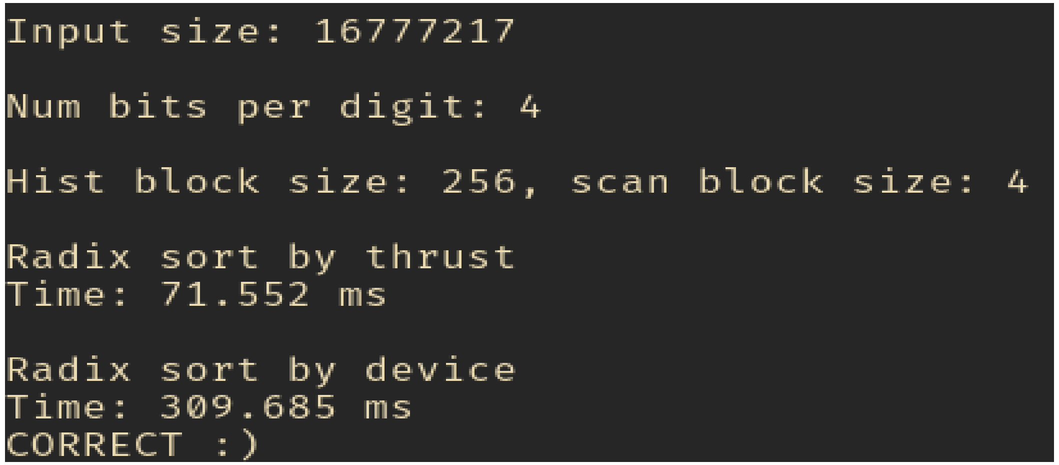
Scan block size = 256

Phiên bản baseline04-v7 với nBits = 4 và hist block size = 256



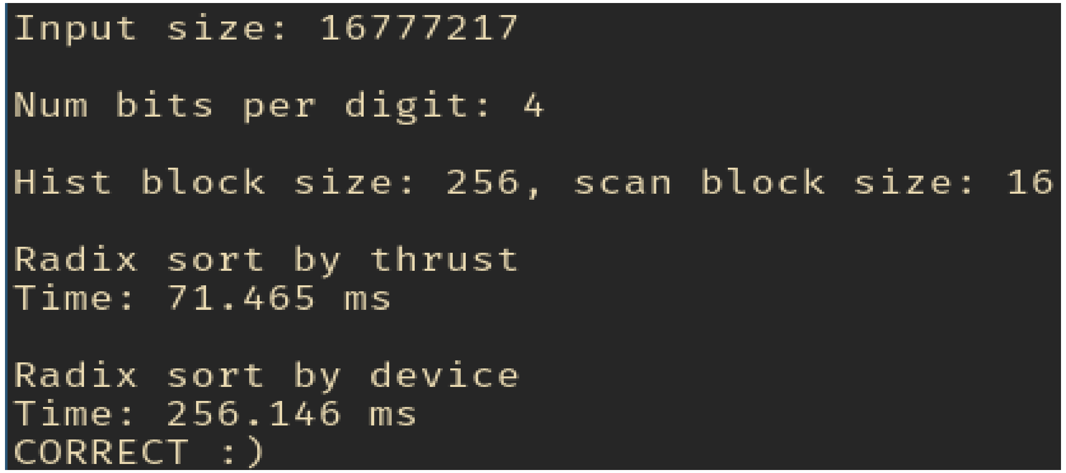
```
Input size: 16777217

Num bits per digit: 4

Hist block size: 256, scan block size: 2

Radix sort by thrust
Time: 71.682 ms

Radix sort by device
Time: 381.797 ms
CORRECT :)
```

Scan block size = 2



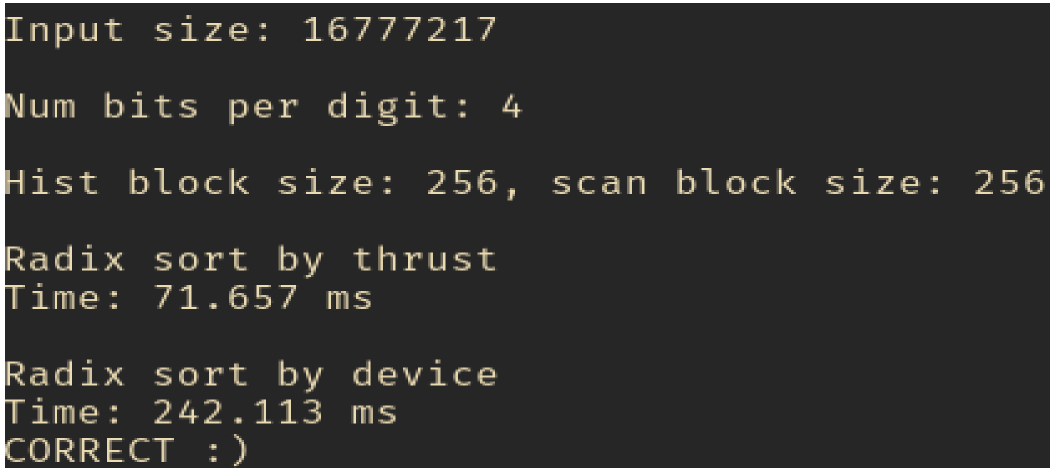
```
Input size: 16777217

Num bits per digit: 4

Hist block size: 256, scan block size: 4

Radix sort by thrust
Time: 71.552 ms

Radix sort by device
Time: 309.685 ms
CORRECT :)
```

Scan block size = 4



```
Input size: 16777217

Num bits per digit: 4

Hist block size: 256, scan block size: 16

Radix sort by thrust
Time: 71.465 ms

Radix sort by device
Time: 256.146 ms
CORRECT :)
```

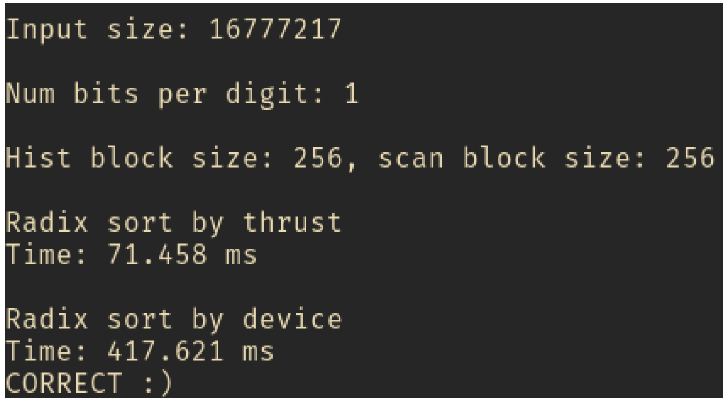
Scan block size = 16



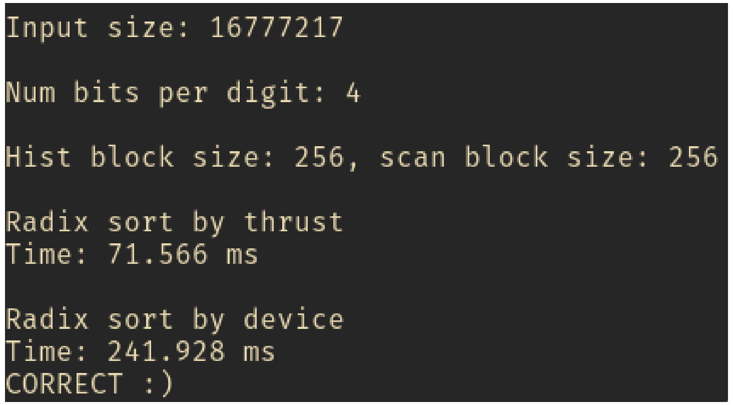
```
Input size: 16777217

Num bits per digit: 4

Hist block size: 256, scan block size: 256

Radix sort by thrust
Time: 71.657 ms

Radix sort by device
Time: 242.113 ms
CORRECT :)
```

Scan block size = 256

Phiên bản baseline04-v7 với hist block size = 256 và scan block size = 256

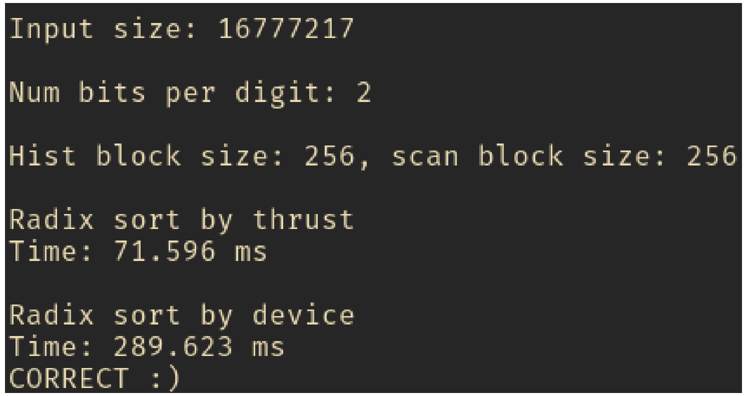


```
Input size: 16777217

Num bits per digit: 1

Hist block size: 256, scan block size: 256

Radix sort by thrust
Time: 71.458 ms

Radix sort by device
Time: 417.621 ms
CORRECT :)
```

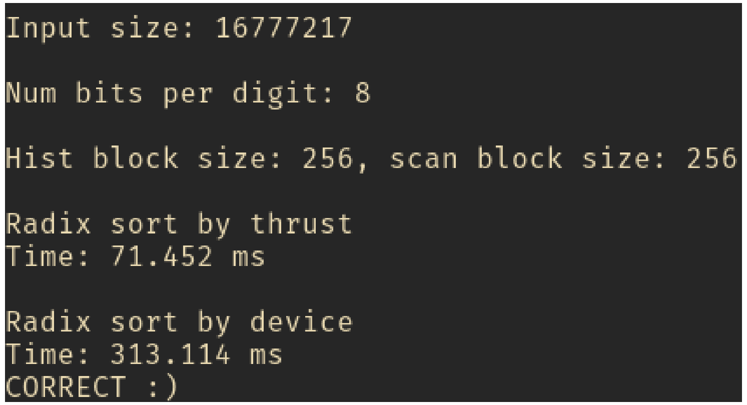


```
Input size: 16777217

Num bits per digit: 4

Hist block size: 256, scan block size: 256

Radix sort by thrust
Time: 71.566 ms

Radix sort by device
Time: 241.928 ms
CORRECT :)
```

nBits	Run Time (ms)
1	417.621
2	289.623
4	241.928
8	414.114



```
Input size: 16777217

Num bits per digit: 2

Hist block size: 256, scan block size: 256

Radix sort by thrust
Time: 71.596 ms

Radix sort by device
Time: 289.623 ms
CORRECT :)
```

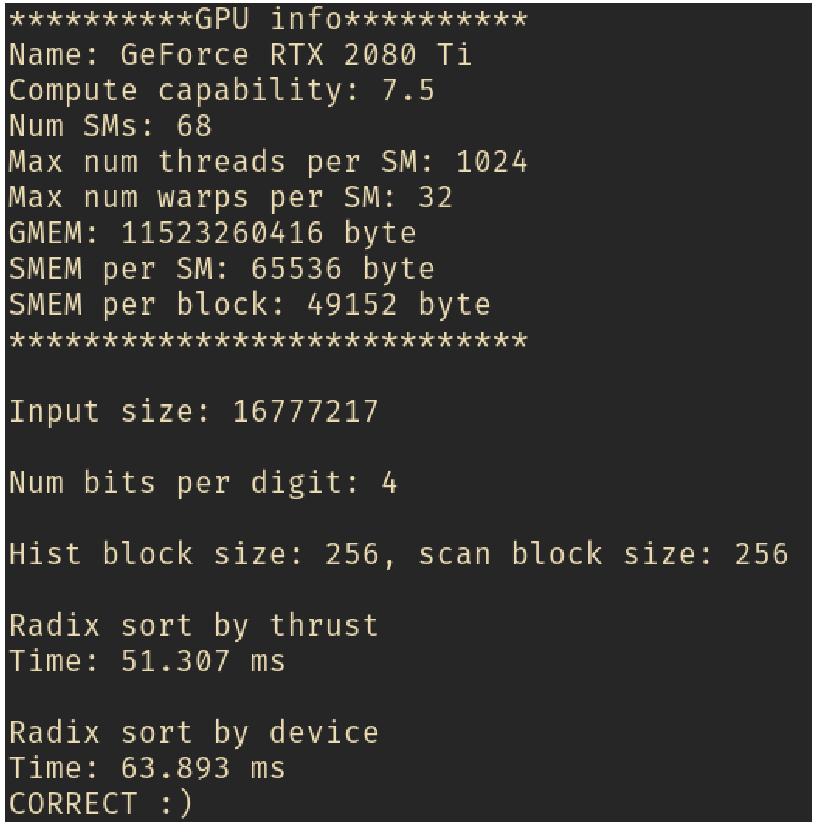


```
Input size: 16777217

Num bits per digit: 8

Hist block size: 256, scan block size: 256

Radix sort by thrust
Time: 71.452 ms

Radix sort by device
Time: 313.114 ms
CORRECT :)
```

CHẠY PHIÊN BẢN TỐT NHẤT – NBITS KHÁC NHAU

Phiên bản baseline04-v7
nBits = 4, hist block size = 256 và scan block size = 256

	Run Time (ms)
basline04-v7	63.893
thrush	51.307



```
**********GPU info***********
Name: GeForce RTX 2080 Ti
Compute capability: 7.5
Num SMs: 68
Max num threads per SM: 1024
Max num warps per SM: 32
GMEM: 11523260416 byte
SMEM per SM: 65536 byte
SMEM per block: 49152 byte
****************************

Input size: 16777217

Num bits per digit: 4

Hist block size: 256, scan block size: 256

Radix sort by thrust
Time: 51.307 ms

Radix sort by device
Time: 63.893 ms
CORRECT :)
```

CHẠY PHIÊN BẢN TỐT NHẤT – GPU CÓ 68 SM

- Work-efficient:

  Adam O'Donovan, Parallel Prefix Sum on the GPU (Scan), slides 13 – 17.

  http://users.umiacs.umd.edu/~ramani/cmsc828e_gpusci/ScanTalk.pdf

- Warp shuffles scan:

  Prof. Mike Giles, Oxford University Mathematical Institute, Lecture 4: warp shuffles, and reduction / scan operations, slides 26 – 28.

  https://people.maths.ox.ac.uk/gilesm/cuda/lecs/lec4.pdf

TÀI LIỆU THAM KHẢO

THANK YOU FOR WATCHING