Sorting Using Hadoop MapReduce Chan-Ching Hsu

Purpose

The goal is to write a program using MapReduce that can sort a large data set quickly. Sorting is a common task on large data sets, and the input is a standard data set.

Dataset

The name of the data file ends with the number of records in the input, for example "gensort-out-500K" has 500 thousand input records. Since each record is 100 bytes, this file takes about 50MB.

Each dataset is made up of multiple lines, one line per record. Each record has a key of 10 characters, followed by a space, followed by a payload (which in turn has a sequence number plus some other data). The final output is going to be sorted by key, and the output is going to include the payload for the key. Example of the input data:

```
77779999444488885555CCCC77775555555BBBB666644446666
                                 CCCCFFFF777799995555FFFF11112222999988884444DDDDFFFF
uI^EYm8s=|
FFFF111100000000000066668888BBB3333333AAAA1111CC
                                 7777AAAABBBBBBB22224444444499995555BBBB11118888DDDD
                                 AAAA88883333BBBB8888888884444777722227777999900002222
}-Wz1;TD-
Ofssx}~[oB
                                 FFFF999977774444AAAA7777EEEEDDDDAAAAAAAA99998888BBBB
z4VCN@a#"
                                 DDDDBBBB1111FFFF2222DDDDFFFFBBBBFFFF6666444477778888
                                 22226666CCCC66662222FFFF0000EEEE11118888444455559999
                                 0000AAAA8888FFFF0000888800000000222255551111FFFFEEEE
```

Algorithm description

The first Mapper reads in an input data with *TextInputFormat* and outputs with *SequenceFileOutputFormat* with compression. There is no reducer actually implemented for the first Mapper since we just want to convert the input into another format (*TextInputFormat*). In the second MapReduce job, we essentially apply *TotalOrderPartitioner* to partition with *RandomSampler* to attempt to evenly distribute keys among Reducers; *RandomSampler* uniformly samples keys for partitioning keys into desired groups among which keys are in order. For example, the keys assigned to the i-th group will be less than the groups after i.

When reading input in *SequenceFile*, one should use *ByteWritable* to identify a key for the Mapper. Using other class, such as *Text* or *LongWritable* will result in exception.

The run time on of the program running on the largest dataset was roughly 295 seconds on Cystorm.

Example output

gensort-out-50M

output file list

```
chsu@n0 lab 4]$ hdfs dfs -ls /scr/cchsu/lab4/output
ound 9 items
                3 cchsu 419x
                                              0 2017-02-09 17:48 /scr/cchsu/lab4/output/_SUCCESS
                                   561305900 2017-02-09 17:48 /scr/cchsu/lab4/output/part-r-00000 571102200 2017-02-09 17:48 /scr/cchsu/lab4/output/part-r-00001
rw-rw-r--
rw-rw-r--
                  cchsu 419x
                                   610220700 2017-02-09 17:48 /scr/cchsu/lab4/output/part-r-00002
rw-rw-r--
                3 cchsu 419x
                                   611212900 2017-02-09 17:48 /scr/cchsu/lab4/output/part-r-00003
                  cchsu 419x
rw-rw-r--
                                   613859800 2017-02-09 17:48 /scr/cchsu/lab4/output/part-r-00004 564000200 2017-02-09 17:48 /scr/cchsu/lab4/output/part-r-00005 596407000 2017-02-09 17:48 /scr/cchsu/lab4/output/part-r-00006
                  cchsu 419x
                  cchsu 419x
                                   871891300 2017-02-09 17:48 /scr/cchsu/lab4/output/part-r-00007
                3 cchsu 419x
```

part-r-00000 and part-r-00001

```
chsu@n0 lab_4]$ hdfs dfs -cat /scr/cchsu/lab4/outpu
   "O!uve
                                                    77778888000022224444DDDDDDDDEEEE0000000CCCC7777DDDD
                                                   5555AAAA9999EEEE888822229999CCCCDDDD6666555544442222
  !&S3/]]
                 000000000000000000000000002145D78
                                                   8888BBBDDDD1111CCCC55556666BBBB1111EEEEDDDD22229999
                 00000000000000000000000019072E3
                                                    33332222FFFFBBBB0000FFFFAAAA666655553333DDDD33333
   ,=U#,9
                                                   8888AAAA11114444FFFF77773333EEEE44440000FFFF99999999
  &&!epOj
                 00000000000000000000000001CBB42E
                                                   2222BBBB2222FFFFFFFFFFFCCCC55556666666777700003333
                 00000000000000000000000001FBD93E
                                                   'AJ:hL:
                 (VcS$Pz
   >MS1.E
                                                   5555DDDD111199998888EEEEBBBB55555551111BBBBC
                 000000000000000000000000001B8132
                                                    5555EEEE888899994444FFFF1111CCCCEEEE1111EEEE6666FFFF
[cchsu@n0 lab_4]$ hdfs dfs -cat /scr/cchsu/lab4/output/part-r-00000 | tail -n 10
r^q6/($sZP 00000000000000000000000777761 55555555555DDDD777755559999
                                                   5555555555DDDD777755559999AAAA000099995555EEEE6666
                                                   5555FFFF3333AAAA2222444477772222DDDD00000C
                 00000000000000000000000000131BFAC
 q6G1Z~&]
^q86A*)gd
                 000000000000000000000000002552351
                                                   0000DDDD7777333311116666BBBB111111113333555577776666
 q::**n*u
                                                   99999999999FFFF999900008888AAAA1111DDDD9999BBBB1111
 `q;@"|8Zg
                 000000000000000000000000028C028A
000000000000000000000000001A0563C
                                                   DDDD222277770000AAAA222229999BBBB777788884444FFFF777
                                                   4444AAAA88885555000011116666CCCC4444BBBB0000
 `q;|,SIBq
                                                   2222BBBBDDDDDDD6666DDDDDDD8888CCCC9999333344441111
                 000000000000000000000000011845C0
 'a<e?M0Y)
                                                    33330000BBBB9999AAAA66663333EEEE8888777788883333EEEE
^q?v3+Nu4
                                                    9999555588888888888882222BBBB9999AAAAFFFF777744446666
 qCrfg*f[
^qCro=9Dm
                 00000000000000000000000002A26E2B
                                                   BBBBAAAABBBB3333EEEE99999AAAAEEEE66669999AAAAFFFF4444
qE*~z4Q)
                                                    7777333322223333EEEE55556666BBBBEEEE6666AAAAAAAAFFFF
                                                    5555666600001111AAAA1111BBBB1111FFFF111144440000FFFE
                 00000000000000000000000000280DB12
                                                   88887777AAAA22227777222266669999FFFF6666AAAA00004444
777788886666888855552222666622225555BBBB666655554444
 `qEq-'jJ(
 `aFNS) cHb
                 000000000000000000000000018068CB
 `qJ;Ge4T.
                                                   222244442222111122223333BBBB2222FFFF3333DDDDDDDDD3333
                                                   BBBBDDDD555533333333CCCCBBBB0000BBBBEEEEAAAA1111FFFF
 `aJDSr::c
                                                   EEEE0000000044440000000044441111BBBB33338888BBBB8888
 qK'.wsp,
                                                    11114444444DDDD0000FFFFAAAAEEEE4444AAAAEEEE44441111
^qLE[5#05
                 000000000000000000000000002DD27B1
                                                    777799990000EEEEDDDD999911119999999AAAA888811116666
cat: Unable to write to output stream.
00000000000000000000000000BA4DBE
                                                   8888AAAA0000333336666AAAA11117777DDDDAAAA0000BBBB3333
03dpMvJ7~
                                                   CCCCBBBBEEEE3333BBBB2222CCCC66667777BBBB000099992222
3333333377776666AAAA2222555533339998888DDDDAAAA6666
22226666DDDD66667777BBBB9999111100002222EEEE99990000
Q3eu516&c
Q3f%7I}qN
                 000000000000000000000000019F29A1
                 0000000000000000000000000034BB6F
03fe#HL&0
                                                   FFFF9999AAAADDDD5555EEEE1111333311111111AAAA8888BBBB
                 000000000000000000000000002656B06
Q3fyQu';3
                 0000000000000000000000000007EC068
Q3k /-bPT
Q31q!#VT^
                                                   55551111555500008888BBBB0000AAAAEEEE88883333AAAA7
Q3m(DupiP
                 22223333888833334444AAAA4444555544447777FFFFDDDD9999
503nfvA6yy
                                                   BBBB11113333DDDD0000BBBB3333EEEECCCCBBBB2222C
                 00000000000000000000000000094BE53
```

```
hdfs dfs -cat /scr/cchsu/lab4/ou
000000000000000000000000001BE8935
                                                  HACTPALA T-00002 | HEAR H 10
44447777AAAADDDD111199996666000066669999888855552222
BBBB7777AAAA0000FFFF77776666BBB6666999911112222BBB
                 000000000000000000000000002F1E5E6
.
Q3o=`Lri_
                                                   444455553333AAAA9999888899995555555555888888886666
5Q3oD{_}m_
5Q3oJVUz%e
                 0000000000000000000000000010F8A4A
                                                   55553333FFFF3333AAAA222233333334444CCCC44443333777
                                                   AAAA2222222AAAACCCC33332222222555566664444FFFF4444
                 00000000000000000000000001A6C42B
O3oisUB<2
                 1111999988882222FFFF99993333BBBBDDDDFFFF7777FFFF2222
                                                   999922229999EEEE5555EEEE22222221111CCCC555533336666
Q3q^Dp0=
Q3rtA4wta
                 00000000000000000000000001017FFF
                                                   03vx\-60I
                 0000000000000000000000000009B789D
Q3zF}IH@.
                 00000000000000000000000001803BDB
                                                   EEEE00005555DDDD111144444444111133332222888844444444
at: Unable to write to output stream.
cchsu@n0 lab_4]$ hdfs dfs -cat /scr/cchsu/lab4/output/part-r-00002 | tail -n 10
                                                   CCCC7777BBBB3333AAAA7777DDDD3333CCCCEEEE7777BBBB5555
EEEE44445555CCC77771111FFFFDDD4444888BBBB33339999
                 *CQRagstQ
*CU%jrq;u
                 00000000000000000000000001C742A8
                                                   DDDD4444DDDDDDD1111000066663333333BBBB99998888777
                 00000000000000000000000000007C32BA
*CW@MmUnB
                                                   0000DDDD44440000777711112222000011112222222DDDD5555
*CZ'6/100
                 00000000000000000000000000390D5C
                                                   BBBB99996666DDDD0000FFFF66668888EEEE0000BBBBAAAA9999
*C[d&K4 R
*C[n2~Z%&
                 222299992222BBBBAAAA2222222BBBB5555888800009999AAAA
  ^xfMTUI
                                                   6666CCCC222277774444BBBB5555777755552222333399996666
*C /JDN&f
                 000000000000000000000000000AD07E1
                                                   EEEE00000AAAA888811116666FFFFBBBB11115555999966666666
                                                   66664444777700006666DDDDBBBB666699990000FFFF88884444
                 0000000000000000000000000146489B
*CaW6r8iC
                                                   0000AAAA222211114444FFFF5555CCCC2222222EEEE8888CCC
*CcVf9('+
                 000000000000000000000000019FB693
00000000000000000000000000004ABEB
                                                   DDDD0000BBBB888844442222000011114444FFFF111133334444
A*Cg~F8ZPN
                 0000000000000000000000000170A4D5
                                                   AAAACCCC2222CCCCAAAA22222FFFFDDDD44443333FFFFBBBB2222
                                                  55552227777555522233337777EEEEFFFF666611112222BBBB
AAAADDDD111116666EEEEAAAA77772222FFFFCCCFFFF11119999
                 000000000000000000000000002EFD5E6
4*Cj[Z)k:q
\*Cj^Qp{+H
\*Ckc6`$^S
                                                   0000EEEEBBBB88886666DDDD5555EEEE999900008888DDDD
                                                      7AAAA6666FFFF6666EEEE66661111AAAAEEEE0000AAAA999
                 00000000000000000000000002F8A9B2
                                                   DDDD5555BBBB99996666CCCC9999FFFFEEEE11117777EEEEFFFF
                                                   1111777744445555999933331111DDDDBBBBEEEE888877775555
*Cmu6E7 U
                 0000000000000000000000001A3FE3C
                                                   CCCC55559999FFFFFFFF2222000077773333CCCCCCC88881111
*Cn<%Ub9C
                 0000000000000000000000000190BD80
cat: Unable to write to output stream.
cchsu@n0 lab 4]$ hdfs dfs -cat /scr/cchsu/lab4/output/part-r-00003 | tail -n 10
                                                   7777FFFFEEEE7777777DDDD8888DDDD6666BBBB444455559999
                 000000000000000000000000027E54E3
                                                   DDDDEEEE2222DDDD7777BBBB9999FFFF88887777BBBB3333C
dOr~]vWo9
dOuUW Mf!
                 0000000000000000000000000000073284
                 000000000000000000000000005DCF44
d0v1RsQ"X
                                                   CCCCBBBBFFFFCCCC3333DDDD9999999FFFF333399994444DDDD
                 FFFF999977774444DDDD3333CCCCEEEE66668888AAAADDDDBBBB
d0y4sc}qP
                                                   DDDD4444888899992222BBBBCCCC77775555AAAADDDD3333AAAA
d0z,gy8<6
                 0000000000000000000000001F6900D
dOzPco^+|
                 FFFF666688883333CCCCDDDD3333DDDDCCCCAAAA0000DDDDFFFF
dP!"mWhPl
                 9999FFFF6666BBBB5555DDDD00005555AAAA1111777722224444
                00000000000000000000000002B4DF7D
000000000000000000000000000269B16A
                                                   FFFF8888CCCCEEEE00006666EEEE66665555888822224444AAAA
dP!K[V45z
                                                   FFFF5555444499991111DDDD77772222DDDD9999DDD99997
```

part-r-00004 and part-r-00005

```
dP'RXP',<
                                                    FFFFBBBB000066668888DDDD555577770000BBBBEEEEDDDD111
dP(G|`@dh
dP2;MC R-
                                                    BBBB99992222FFFFEEEE5555EEEE000033338888BBBB00001111
LdP4cQJ]|W
                  00000000000000000000000001214C4E
                                                   CCCC00003333CCCCCCCCCCC9999BBBB00002222DDDD66663333
LdP5%CQe'M
                                                   222222233334444DDDDDDDDDDDDDDCCCC7777AAAACCCC0000EEEE
                                                   2222DDDD8888FFFFAAAABBBBDDDDEEEE7777FFFFFFFCCCC8888
                  0000000000000000000000000064D4B7
dP6iwApM*
dP7grbNaO
                                                   AAAA99997777DDDDEEEE00006666BBBB3333DDDD99996666000
dP=iA'Jse
                                                   BBBB0000999966665555666666688883333888888883333DDDI
dP>+N,;>`
                  000000000000000000000000140A875
                                                   6666CCCCBBBBEEEE22228888EEEEAAAA0000CCCCFFFF11112222
LdP>Bw*:3(
                 00000000000000000000000000097DBC0
                                                   CCCCBBBB4444CCCCCCCCAAAAFFFFCCCC44442222555544441111
cat: Unable to write to output stream.
[cchsu@n0 lab_4]$ hdfs dfs -cat /scr/cchsu/lab4/output/part-r-00004 | tail -n 10
                                                   0000FFFFDDDD88889999000066661111EEEE8888CCCC9999AAAA
                 00000000000000000000000009957E9
                                                   999988884444EEEEBBBBEEEE222255557777CCCC11111111EEEE
                                                   9999BBBBEEEEAAAA444CCCC8888FFFFAAAA444DDDCCCC0000
XCVda2P0Vd
XCVfP70-w/
                 0000000000000000000000000097DD8C
XCVfi!PGJk
                                                   5555AAAA4444CCCCCCCC7777555577772222BBBB33335555CCC
                 0000000000000000000000000009452C3
XCVg_F{SDF
                                                    11118888777777772222BBBB4444DDDD9999DDDD7777DDDDFFFE
CVi+N<wy&
                                                    0000DDDD44442222FFFFEEEE33337777AAAA0000CCCC1111BBBB
XCVi:cgzKs
                                                    00008888DDDDDDDD6666EEEE3333FFFFDDDDAAAABBBB11111111
XCVkk'A+hr
                 55559999FFFFFFF8888444433334444AAAA88887777CCCC000
                 0000000000000000000000000047F9E2
                                                   CCCC333377778888111144449999AAAA9999999922227777FFFF
XCVko:Ef&
CVmK=*1J$
                                                    FFFFDDDDFFFFBBBB55553333FFFF00006666FFFFFFFF3333FFF
XCVpP2d_:B
                 00000000000000000000000001CEF9FB
                                                   BBBB11119999DDD3333EEEE0000BBBB88888888000022224444
XCVq2?65}V
                                                   DDDDEEEEFFFF666611119999EEEE88886666BBBB7777222277774444777774444AAAA5555444433334444BBBB9997777BBBB8888
                 000000000000000000000000015EE09A
                 00000000000000000000000000164A4C7
XCVa}}X:67
                                                    0000DDDD3333AAAAEEEE33334444FFFFBBBB55550000BBBB4444
                  000000000000000000000000002C5246B
(CVrA>80>s
                                                    555544442222AAAABBBB6666999977774444DDDD111112222DDD
CVtRP>py?
                  0000000000000000000000000009E337
                                                   DDDD222244448888BBBEEEE000099990000EEEE111144448888
XCVu)j([3}
                 000000000000000000000000024B53E2
                                                   CCCC55557777666611111111888866665555222200007777FFFF
                                                   4444DDDD5555FFFF999966660000CCCC8888CCCCAAAAFFFF2222
XCVx*,:;EY
cat: Unable to write to output stream.
[cchsu@n0 lab_4]$ hdfs dfs -cat /scr/cchsu/lab4/output/part-r-00005 | tail -n 10
                  0000000000000000000000000249BAB7
                                                   8888AAAADDDDEEEE55556666666FFFF111155559999CCCC8888
                                                   EEEE1111666644446666444477779999444499995555FFFF0000
c(J>Iv n'H
                 000000000000000000000000001D9EF43
                                                   22223333FFFF9999CCCCBBBB44448888DDDDEEEEFFFFAAAACCC
c(J>y#Y=0Z
                 00000000000000000000000001340373
                                                    4444EEEE1111AAAAFFFF8888AAAABBBB00002222EEEE1111BBBB
c(JATY6#8K
                                                    BBBBAAAA00004444AAAA666611119999EEEE44448888EEEE3333
                                                   111100001111EEEE888844445555333311117777DDDD33334444
FFFFCCCC333311110000CCCCBBBB22226666000055559999BBBB
                  000000000000000000000000000000E7DFEB
                 000000000000000000000000000945FB6
c(JJJN6J0Q
c(JKb\XE1f
                 0000000000000000000000000099CB71
                                                   44441111AAAACCCCFFFFAAAA222233334444DDDDAAAA55556666
                  0000000000000000000000001F82369
                                                   9999EEEEEEECCCC11117777BBBB1111FFFF111111119999EEEE
```

part-r-00006 and part-r-00007

```
5555AAAA9999DDDDAAAA22225555EEEEFFFF8888111155550000
                  000000000000000000000000000002C5E6DD
                                                     00005555FFFF222222233337777EEEE77771111BBBBEEEEAAAA
(JMO97II.r
                                                     DDDD222299999994444DDDD777733330000111144442222EEEE
(JMZ,M;3#
                  00000000000000000000000005EBB74
(JNS5=Em
                                                     AAAA1111666644447777BBBB999944440000EEEE99995555DDDI
                                                      4444EEEEFFFFBBBB6666CCCC555599991111CCCC66666666CCC
                                                     111177777777FFFF3333222222227777EEEE0000EEEE9999CCCCDDDD222244444443333FFFF22220000AAAABBBB22224444999
(JRd$]YW
                  000000000000000000000000024836D8
(JS&I.?40
                  0000000000000000000000000025D5071
                                                     AAAA22222225555666633331111777744449999DDDD55556666
                  0000000000000000000000001528FAA
                                                     BBBBEEEEFFFFAAAA7777BBBB99992222CCCC777700005555777
(JT (4+~H7
                                                     EEEE5555666644440000EEEE1111444499995555AAAA99998888
c(JT>yZg4#
at: Unable to write to output stream.
cchsu@n0 lab_4]$ hdfs dfs -cat /scr/cchsu/lab4/output/part-r-00006 | tail -n 10
                                                     BBBB333366667777DDDDD000055559997777EEEEEEEEEEEEEEE
666655557777AAAA4444EEEEDDDD2222FFFF5555CCCBBBBEEEE
                  HJdd^7bl*
nHJghQHP3m
                  000000000000000000000000002A6CB2A
                                                     00000000EEEE00009999DDDD555599994444FFFF2222DDDD777
nHJj-,1b:G
nHJo9-OdH/
                  0000000000000000000000000244EE39
                                                     11114444EEEE11118888EEEEDDDDBBBB6666DDDD77774444EEEE
                  0000000000000000000000000002E2F720
                                                     222233338888BBBB000088882222EEEEDDDD5555CCCC66661111
nHJqct"ceL
nHJrcG7'2P
                                                      1111AAAABBBBBBB77779999AAAABBBBCCCCEEEEEEEBBBBDDD
                  333322220000FFFFEEEEBBBB7777CCCC222244443333FFFF5555
                                                     CCCCAAAAFFFFBBBBFFFF2222AAAA55552222CCCC999900003333
nHJti#oiK"
                  0000000000000000000000000013ACA2E
                                                     6666444422228888FFFF000088880000BBBB444422224444000
                  00000000000000000000000001537DBF
nHJu$2H) 6h
                  00000000000000000000000001E253FF
                                                     33331111FFFFAAAA777788885555DDDDBBBBAAAACCCC00000000
nHJx-LMTg+
[cchsu@n0 lab_4]$ hdfs dfs -cat /scr/cchsu/lab4/output/part-r-00007 | head -n 10
                                                     11116666DDDDDDD3333FFFF888822226666888844447777AAAA
                  00000000000000000000000002A75ACD
                  FFFF333322227777DDDDDDDDDAAAADDDDAAAABBBBEEEE111155556666444400001111EEEEBBBB333399994444444FFFFBBBB999
nHJzZ)?BJc
nHJ{'%x#^O
                                                     8888BBBB44448888EEEEAAAA8888AAAAEEEEBBBBBBBB3333AAAA
nHJ| epTT<
                  00000000000000000000000000024B20D
HK"T5WAS#
                  22226666BBBB4444777755558888EEEE22228888AAAAAAAA1111
                                                     2222FFFF44443333EEEE00001111DDDD1111FFFFBBBB1111AAAF
                                                     DDDD222233331111777755552222111133333CCCC222211118888
HK&lpM{EZ
nHK't.Rv=3
                  00000000000000000000000001079F47
                                                     CCCC555511115555999944446666FFFFFFFAAAADDDD33338888
nHK) ?X%YH/
                  00000000000000000000000000000000BDA0B
                                                     111188882222CCCC55559999BBBBEEEE55556666111111114444
                  000000000000000000000000002AD18FE
nHK0oOtgu{
                                                     FFFF55550000EEEE0000BBBBAAAACCCC6666666EEEE77773333
cat: Unable to write to output stream.
[cchsu@n0 lab 4]$ hdfs dfs -cat /scr/cchsu/lab4/output/part-r-00007 | tail -n 10
                                                     33337777222255556666DDDDAAAA999944445555555BBBBAAAA
                                                     BBBBEEEE2222222BBBBAAAA55551111FFFF99995555FFFF7
 ~~ruROgur
 ~~g!ST.~~7
                                                     11114444FFFFBBBB11113333000000008888AAAA9999EEEE777
                                                     2222DDDDDDD77771111EEEECCCC7777BBBB4444888811111111
                  000000000000000000000000006BE930
 ~~s/Pq,-E
                                                     6666BBBB1111EEEEEEEE5555CCCCDDDD5555555BBBBBBBBDDD
 ~sf&V`wv
                                                      99991111DDDD222211110000FFFFEEEEFFFF33337777CCCC2222
  yKO1:qE
                  CCCC11114444888822226666BBBB888855557777EEEEBBBB000
  yA.
zbA_ 1
o^FEg
                  00000000000000000000000007F9F4F
                                                     BBBBCCCC666655559999FFFF8888AAAA11116666AAAABBBB0000
                                                     4444CCCCBBBB9999222288885555888CCCCFFFF000011111111
777711118888AAAAAAAA22221111BBBB00002222BBBBCCCC222
                  0000000000000000000000001E06130
```

Resource

 https://hadoop.apache.org/docs/r2.4.1/api/org/apache/hadoop/mapred/ Partitioner.html

Template Code

Chapter 9 MapReduce Features: Total Sort, Hadoop – The Definitive Guide