Frits Hoogland - Hotsos Symposium 2013

ABOUT MULTIBLOCK READS

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Who am I?

- Frits Hoogland
  - Working with Oracle products since 1996

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Agenda

- Full scan implementation
  - Version 10 and earlier versus version 11 and later

- Direct path read slots

- ‘autotune’ / adaptive direct path reads

What is this presentation about?

- Multiblock reads can behave different after 10.2
- This could lead to different behavior of applications using the database.

- I assume the audience to have basic understanding about:
  - Oracle execution plans
  - Oracle SQL/10046 extended traces
  - General execution behavior of the RDBMS engine
  - C language in general

Row source operations

- Multiblock reads are an optimised method to read database blocks from disk for a database process.

  – Mainly used for the:
    - ‘TABLE ACCESS FULL’
    - ‘FAST FULL INDEX SCAN’
    - ‘BITMAP FULL SCAN’
  – rowsource operations.

Row source operations

- For much of other segment access rowsource actions, like:
  - ‘INDEX UNIQUE SCAN’
  - ‘INDEX RANGE SCAN’
  - ‘INDEX FULL SCAN’
  - ‘TABLE ACCESS BY INDEX ROWID’
- single block reads are mostly used.
- The order in which individual blocks are read is important.

db file multiblock read count

- Multiblock reads are done up to DB_FILE_MULTIBLOCK_READ_COUNT blocks.
  - If MBRC is unset, default is ‘maximum IO size that can be efficiently performed’.
  - Most operating systems allow a single IO operation up to 1 MB.
  - “Autotuned” (set to 0) seems to calculate its value by using the parameters ‘sessions’ and ‘db_cache_size’.
  - I prefer to set it manually.

My test environment

- Mac OSX Mountain Lion, VM Ware fusion

  - VM: OL6u3 x64
    - Database version 10.2.0.1 and 11.2.0.3
    - ASM GI 11.2.0.3

  - Sample tables:
    - T1 - 21504 blocks - 176M - 1’000’000 rows
      - PK index - 2304 blocks / 19M
    - T2 - 21504 blocks - 176M - 1’000’000 rows

First test

- 10.2.0.1 instance:
  - sga_target = 600M
  - Effective buffercache size = 450M
  - Freshly started

First test

```
TS@v10201 > select /*+ index(t t1_pk_ix) */ count(id), sum(scattered) from t1 t;

 COUNT(ID) SUM(SCATTERED)
---------- --------------
   1000000     9999500000

-----------------------------------------------------------------------------------
| Id  | Operation                           | Name     |  Rows  |  Bytes | Cost (%CPU) |
-----------------------------------------------------------------------------------
|   0 | SELECT STATEMENT                    |          |      1 |      5 | 23234   (1) |
|   1 |  SORT AGGREGATE                     |          |      1 |      5 |             |
|   2 |   TABLE ACCESS BY INDEX ROWID       | T1       |   1000K |  4884K | 23234   (1) |
|   3 |    INDEX FULL SCAN                  | T1_PK_IX |   1000K |        |  2253   (2) |
-----------------------------------------------------------------------------------
```

First test

- How would you expect Oracle 10.2.0.1 to execute this?
  - In other words:
  - What would be the result of a SQL trace with waits? *

* If all blocks need to be read from disk (ie. not cached)

First test

- My guess would be:
  - Index root bock (1 block)
  - None, one or more branch blocks (1 block)
  - Index leaf block, fetch values (1 block)
  - Table block via index rowid, fetch value(s) (1/1+ block)
  - Index values, block value(s), etc.

First test

- That should look like something like this:

```
WAIT #8: nam='db file sequential read' ela= 326 file#=5 block#=43028 blocks=1
WAIT #8: nam='db file sequential read' ela= 197 file#=5 block#=43719 blocks=1
WAIT #8: nam='db file sequential read' ela= 227 file#=5 block#=43029 blocks=1
WAIT #8: nam='db file sequential read' ela= 125 file#=5 block#=20 blocks=1
WAIT #8: nam='db file sequential read' ela= 109 file#=5 block#=21 blocks=1
WAIT #8: nam='db file sequential read' ela= 242 file#=5 block#=22 blocks=1
WAIT #8: nam='db file sequential read' ela= 98 file#=5 block#=23 blocks=1
WAIT #8: nam='db file sequential read' ela= 76 file#=5 block#=24 blocks=1
WAIT #8: nam='db file sequential read' ela= 77 file#=5 block#=25 blocks=1
WAIT #8: nam='db file sequential read' ela= 77 file#=5 block#=26 blocks=1
WAIT #8: nam='db file sequential read' ela= 105 file#=5 block#=27 blocks=1
WAIT #8: nam='db file sequential read' ela= 82 file#=5 block#=28 blocks=1
WAIT #8: nam='db file sequential read' ela= 71 file#=5 block#=29 blocks=1
WAIT #8: nam='db file sequential read' ela= 93 file#=5 block#=43030 blocks=1
...
```

First test

- Instead, I get:

```
WAIT #4: nam='db file scattered read' ela= 361 file#=5 block#=43025 blocks=8
WAIT #4: nam='db file scattered read' ela= 220 file#=5 block#=43713 blocks=8
WAIT #4: nam='db file scattered read' ela= 205 file#=5 block#=17 blocks=8
WAIT #4: nam='db file scattered read' ela= 219 file#=5 block#=25 blocks=8
WAIT #4: nam='db file scattered read' ela= 192 file#=5 block#=33 blocks=8
WAIT #4: nam='db file scattered read' ela= 141 file#=5 block#=41 blocks=8
WAIT #4: nam='db file scattered read' ela= 123 file#=5 block#=49 blocks=8
WAIT #4: nam='db file scattered read' ela= 190 file#=5 block#=57 blocks=8
WAIT #4: nam='db file scattered read' ela= 231 file#=5 block#=43033 blocks=8
WAIT #4: nam='db file scattered read' ela= 113 file#=5 block#=65 blocks=8
...
```

First test

- Sets of 8 blocks are read for rowsources which really need a single block.
- Reason:
  - This is an empty cache.
  - Oracle reads multiple blocks to get the cache filled.
  - ‘cache warming’
    - Statistic (‘physical reads cache prefetch’)
- Needed to tune the BC down to 50M and pre-warm it with another table to get single block reads again (!!)

db_file_multiblock_read_count

- MBRC is the **maximum** amount of blocks read in one IO.
- Buffered MBRC cannot cross extent borders.
- Concepts guide on full table scans: (11.2 version)
  - A scan of table data in which the database sequentially reads all rows from a table and filters out those that do not meet the selection criteria. All data blocks under the high water mark are scanned.

Full scan - Oracle 10.2

- Let’s look at an Oracle 10.2.0.1 database
  - SGA_TARGET 600M
  - Table TS.T2 size 21504 blks / 176M

Full scan - Oracle 10.2

```
TS@v10201 > set autot on exp stat
TS@v10201 > select count(*) from t2;

  COUNT(*)
----------
   1000000

Execution Plan
----------------------------------------------------------
Plan hash value: 3724264953

-------------------------------------------------------------------------
| Id  | Operation           | Name | Rows  | Cost (%CPU)| Time     |
-------------------------------------------------------------------------
|   0 | SELECT STATEMENT    |      |     1 |  3674   (1)| 00:00:45 |
|   1 |  SORT AGGREGATE     |      |     1 |            |          |
|   2 |   TABLE ACCESS FULL| T2   |  1007K|  3674   (1)| 00:00:45 |
-------------------------------------------------------------------------
```

Full scan - Oracle 10.2

```
Statistics
----------------------------------------------------------
        212  recursive calls
          0  db block gets
      20976  consistent gets
      20942  physical reads
          0  redo size
        515  bytes sent via SQL*Net to client
        469  bytes received via SQL*Net from client
          2  SQL*Net roundtrips to/from client
          4  sorts (memory)
          0  sorts (disk)
          1  rows processed
```

Full scan - Oracle 10.2

```
SYS@v10201 AS SYSDBA>
select object_id, object_name, owner from dba_objects where object_name = 'T2';

 OBJECT_ID OBJECT_NAME                                        OWNER
---------- ---------------------------------------- ------------------
     10237 T2                                       TS


SYS@v10201 AS SYSDBA> select * from x$kcboqh where obj# = 10237;

ADDR                   INDX    INST_ID      TS#     OBJ#   NUM_BUF HEADER
---------------- -------- ---------- ------- ------- ---------- ----------------
FFFFFD7FFD5C6FA8      335          1       5   10237      20942 000000038FBCF840
```

Full scan - Oracle 10.2

```
TS@v10201 > select count(*) from t2;

Statistics
----------------------------------------------------------
          0  recursive calls
          0  db block gets
      20953  consistent gets
          0  physical reads
          0  redo size
        515  bytes sent via SQL*Net to client
        469  bytes received via SQL*Net from client
          2  SQL*Net roundtrips to/from client
          0  sorts (memory)
          0  sorts (disk)
          1  rows processed
```

Full scan - Oracle 11.2

- Now look at an Oracle 11.2.0.3 database
  - SGA_TARGET 600M
  - Table TS.T2 size 21504 blks / 176M

Full scan - Oracle 11.2

```
TS@v11203 > select count(*) from t2;

  COUNT(*)
----------
   1000000


Execution Plan
----------------------------------------------------------
Plan hash value: 3724264953

-------------------------------------------------------------------------------
| Id  | Operation          | Name | Rows  | Cost (%CPU)| Time     |
-------------------------------------------------------------------------------
|   0 | SELECT STATEMENT   |      |     1 |  3672   (1)| 00:00:45 |
|   1 |  SORT AGGREGATE    |      |     1 |            |          |
|   2 |   TABLE ACCESS FULL| T2   |  1000K|  3672   (1)| 00:00:45 |
-------------------------------------------------------------------------------
```

Full scan - Oracle 11.2

```
Statistics
----------------------------------------------------------
        217  recursive calls
          0  db block gets
      20970  consistent gets
      20942  physical reads
          0  redo size
        526  bytes sent via SQL*Net to client
        523  bytes received via SQL*Net from client
          2  SQL*Net roundtrips to/from client
          4  sorts (memory)
          0  sorts (disk)
          1  rows processed
```

Full scan - Oracle 11.2

```
SYS@v11203 AS SYSDBA>
select object_id, object_name, owner from dba_objects where object_name = 'T2';

 OBJECT_ID OBJECT_NAME                                                    OWNER
---------- ------------------------------------------------------------ ------------
     66614 T2                                                           TS


SYS@v11203 AS SYSDBA> select * from x$kcboqh where obj# = 66614;

ADDR                   INDX   INST_ID     TS#       OBJ#    NUM_BUF HEADER
---------------- ------- -------- ------ ---------- ---------- ----------------
FFFFFD7FFC541B18      43        1      5      66614          1 000000039043E470
```

Full scan - Oracle 11.2

```
TS@v11203 > select count(*) from t2;

Statistics
----------------------------------------------------------
          0  recursive calls
          0  db block gets
      20945  consistent gets
      20941  physical reads
          0  redo size
        526  bytes sent via SQL*Net to client
        523  bytes received via SQL*Net from client
          2  SQL*Net roundtrips to/from client
          0  sorts (memory)
          0  sorts (disk)
          1  rows processed
```

Full scan 10.2 vs. 11.2

- Why does version 10 caches all the blocks read,
- And version 11 only 1 of them??

- Let’s do an extended SQL trace
  - AKA 10046 level 8 trace.

Full scan 10.2 vs. 11.2

Relevant part of 10046/8 trace file of version 10.2.0.1:

```
WAIT #1: nam='db file sequential read' ela= 32941 file#=5 block#=19 blocks=1
WAIT #1: nam='db file scattered read' ela= 4003 file#=5 block#=20 blocks=5
WAIT #1: nam='db file scattered read' ela= 6048 file#=5 block#=25 blocks=8
WAIT #1: nam='db file scattered read' ela= 1155 file#=5 block#=34 blocks=7
WAIT #1: nam='db file scattered read' ela= 860 file#=5 block#=41 blocks=8
WAIT #1: nam='db file scattered read' ela= 837 file#=5 block#=50 blocks=7
WAIT #1: nam='db file scattered read' ela= 1009 file#=5 block#=57 blocks=8
WAIT #1: nam='db file scattered read' ela= 890 file#=5 block#=66 blocks=7
WAIT #1: nam='db file scattered read' ela= 837 file#=5 block#=73 blocks=8
WAIT #1: nam='db file scattered read' ela= 10461 file#=5 block#=82 blocks=7
WAIT #1: nam='db file scattered read' ela= 623 file#=5 block#=89 blocks=8
WAIT #1: nam='db file scattered read' ela= 1077 file#=5 block#=98 blocks=7
WAIT #1: nam='db file scattered read' ela= 49146 file#=5 block#=105 blocks=8
WAIT #1: nam='db file scattered read' ela= 719 file#=5 block#=114 blocks=7
WAIT #1: nam='db file scattered read' ela= 1093 file#=5 block#=121 blocks=8
WAIT #1: nam='db file scattered read' ela= 1293 file#=5 block#=130 blocks=7
WAIT #1: nam='db file scattered read' ela= 2103 file#=5 block#=137 blocks=8
WAIT #1: nam='db file scattered read' ela= 42206 file#=5 block#=147 blocks=126
```

Full scan 10.2 vs. 11.2

Relevant part of 10046/8 trace file of version 11.2.0.3:

```
WAIT #140120507194664: nam='db file sequential read' ela= 12607 file#=5
block#=43394 blocks=1 obj#=14033 tim=1329685383169372
nam='direct path read' ela= 50599 file number=5 first dba=43395 block cnt=13
nam='direct path read' ela= 21483 file number=5 first dba=43425 block cnt=15
nam='direct path read' ela= 10766 file number=5 first dba=43441 block cnt=15
nam='direct path read' ela= 12915 file number=5 first dba=43457 block cnt=15
nam='direct path read' ela= 12583 file number=5 first dba=43473 block cnt=15
nam='direct path read' ela= 11899 file number=5 first dba=43489 block cnt=15
nam='direct path read' ela= 10010 file number=5 first dba=43505 block cnt=15
nam='direct path read' ela= 160237 file number=5 first dba=43522 block cnt=126
nam='direct path read' ela= 25561 file number=5 first dba=43650 block cnt=126
nam='direct path read' ela= 121507 file number=5 first dba=43778 block cnt=126
nam='direct path read' ela= 25253 file number=5 first dba=43906 block cnt=126
```

First single block read

- The segment header is read separately
  - Single block, read into SGA

- The header block is listed in dba_segments

```
select owner, segment_name, header_file, header_block
from dba_segments where segment_name like 'T2';

OWNER          SEGMENT_NAME           HEADER_FILE HEADER_BLOCK
----------     --------------------- ----------- ------------
TS             T2                     5           130
```

Full scan 10.2 vs. 11.2

- A full scan uses direct path reads in the v11 case.
  - Noticeable by ‘direct path read’ event
  - Direct path reads go to PGA
  - Which means the blocks read are not cached

Full scan 10.2 vs. 11.2

- Do all full scans in version 11 always use direct path?

- Direct path reads are considered
  - if #blocks of the segment > 5*_small_table_threshold

- PS: MOS note 787373.1
- “How does Oracle load data into the buffer cache for table scans ?”
- Mentions _small_table_threshold being the limit
  - Note INCORRECT!

Direct path read

Small table threshold of my Oracle 11 instance:

```
NAME                           VALUE
------------------------------ ------------------------------
_small_table_threshold         245
```

This means objects up to 245*5=1225 blocks will be read into buffercache / SGA.

Let’s create a table with a size just below 1225 blocks:

```
TS@v11203 > create table t1_small as select * from t1 where id <= 47000;

TS@v11203 > exec dbms_stats.gather_table_stats(null,‘T1_SMALL’);
```

Direct path read

```
SYS@v11203 AS SYSDBA>

select segment_name, blocks, bytes
from dba_segments where segment_name = 'T1_SMALL';

SEGMENT_NAME                                BLOCKS      BYTES
------------------------------------------- ---------- ----------
T1_SMALL                                    1024        8388608

SQL@v11203 AS SYSDBA> alter system flush buffer_cache;
```

Direct path read

```
TS@v11203 > set autot trace exp stat
TS@v11203 > select count(*) from t1_small;


Execution Plan
----------------------------------------------------------
Plan hash value: 1277318887

-----------------------------------------------------------------------------
| Id  | Operation          | Name      | Rows  | Cost (%CPU)| Time     |
-----------------------------------------------------------------------------
|   0 | SELECT STATEMENT   |           |     1 |   176   (1)| 00:00:03 |
|   1 |  SORT AGGREGATE    |           |     1 |            |          |
|   2 |   TABLE ACCESS FULL| T1_SMALL  | 47000 |   176   (1)| 00:00:03 |
-----------------------------------------------------------------------------
```

Direct path read

```
Statistics
----------------------------------------------------------
          0  recursive calls
          0  db block gets
        983  consistent gets
        979  physical reads
          0  redo size
        527  bytes sent via SQL*Net to client
        523  bytes received via SQL*Net from client
          2  SQL*Net roundtrips to/from client
          0  sorts (memory)
          0  sorts (disk)
          1  rows processed
```

Direct path read

```
SYS@v11203 AS SYSDBA>
select object_id, object_name, owner
from dba_objects where object_name = 'T1_SMALL';

 OBJECT_ID OBJECT_NAME                                                    OWNER
---------- ------------------------------------------------------------ -------------
     66729 T1_SMALL                                                     TS
```

```
SYS@v11203 AS SYSDBA> select * from x$kcboqh where obj# = 66729;

ADDR             INDX    INST_ID TS#    OBJ#    NUM_BUF    HEADER
---------------- ------ ------- ------ ------- ---------- ----------------
FFFFFD7FFC6E1EF0 0      1       5      66729   979        0000000390437840
```

Direct path read

Ah, now the full scan is buffered!

Another scan will reuse the cached blocks now:

```
TS@v11203 > select count(*) from t1_small;

...

Statistics
----------------------------------------------------------
          0  recursive calls
          0  db block gets
        983  consistent gets
          0  physical reads
```

Direct path read

- What type of wait event will be used for a full scan:
  - Oracle version 11.2
  - If segment is *smaller* than 5 * _small_table_threshold

Direct path read

Well, try it:

```
TS@v11203 > alter session set events ‘10046 trace name context forever, level 8’;
TS@v11203 > select count(*) from t1_small;
...
TS@v11203 > alter session set events ‘10046 trace name context off’;
```

It shows:

```
WAIT #140358956326184: nam='db file sequential read' ela= 38476 file#=5
block#=88706 blocks=1 obj#=14047 tim=1330369985672633
nam='db file scattered read' ela= 116037 file#=5 block#=88707 blocks=5
nam='db file scattered read' ela= 56675 file#=5 block#=88712 blocks=8
nam='db file scattered read' ela= 11195 file#=5 block#=88721 blocks=7
nam='db file scattered read' ela= 132928 file#=5 block#=88728 blocks=8
nam='db file scattered read' ela= 18692 file#=5 block#=88737 blocks=7
nam='db file scattered read' ela= 87817 file#=5 block#=88744 blocks=8
```

Oracle 11 multiblock IO

- In version 11 of the Oracle database
  - Multiblocks reads use both wait events:
    - db file scattered read
    - direct path read
  - Which are two different codepath's

Implementation

- Buffered multiblock reads
  - Buffered multiblock reads == ‘db file scattered read’
  - Up to version 10 the ONLY option for non-PQ multiblock reads
  - Starting from version 11, a possible multiblock read option

Buffered multiblock reads

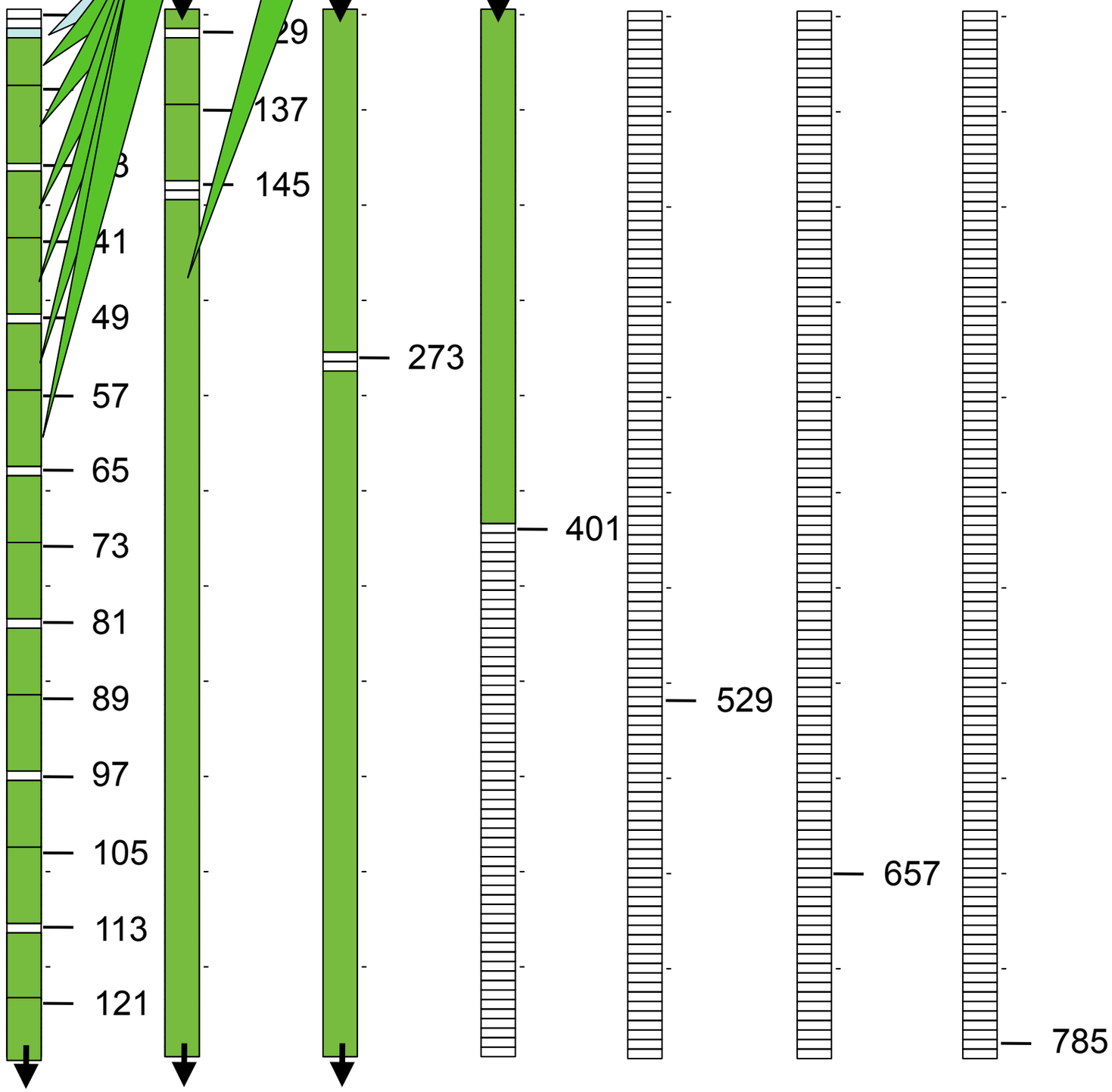
```
SYS@v10201 AS SYSDBA> select segment_name, extent_id, block_id, blocks, bytes
from dba_extents where segment_name = 'T2' and owner = 'TS' order by extent_id;

SEGMENT_NAME                                EXTENT_ID  BLOCKS     BYTES
------------------------------------------- ---------- --------- ----------
T2                                                  0         8      65536
...
T2                                                 15         8      65536
T2                                                 16       128    1048576
...
T2                                                 78       128    1048576
T2                                                 79      1024    8388608
...
T2                                                 91      1024    8388608
```

Buffered multiblock reads

Version 10 multiblock reads:

```
WAIT #2: nam='db file sequential read' ela= 12292 file#=5 block#=19 blocks=1
WAIT #2: nam='db file scattered read' ela= 179162 file#=5 block#=20 blocks=5
WAIT #2: nam='db file scattered read' ela= 47597 file#=5 block#=25 blocks=8
WAIT #2: nam='db file scattered read' ela= 5206 file#=5 block#=34 blocks=7
WAIT #2: nam='db file scattered read' ela= 94101 file#=5 block#=41 blocks=8
WAIT #2: nam='db file scattered read' ela= 512 file#=5 block#=50 blocks=7
WAIT #2: nam='db file scattered read' ela= 87657 file#=5 block#=57 blocks=8
WAIT #2: nam='db file scattered read' ela= 27488 file#=5 block#=66 blocks=7
WAIT #2: nam='db file scattered read' ela= 24316 file#=5 block#=73 blocks=8
WAIT #2: nam='db file scattered read' ela= 55251 file#=5 block#=82 blocks=7
WAIT #2: nam='db file scattered read' ela= 641 file#=5 block#=89 blocks=8
WAIT #2: nam='db file scattered read' ela= 455 file#=5 block#=98 blocks=7
WAIT #2: nam='db file scattered read' ela= 43826 file#=5 block#=105 blocks=8
WAIT #2: nam='db file scattered read' ela= 32685 file#=5 block#=114 blocks=7
WAIT #2: nam='db file scattered read' ela= 60212 file#=5 block#=121 blocks=8
WAIT #2: nam='db file scattered read' ela= 37735 file#=5 block#=130 blocks=7
WAIT #2: nam='db file scattered read' ela= 59565 file#=5 block#=137 blocks=8
(ps: edited for clarity)
```

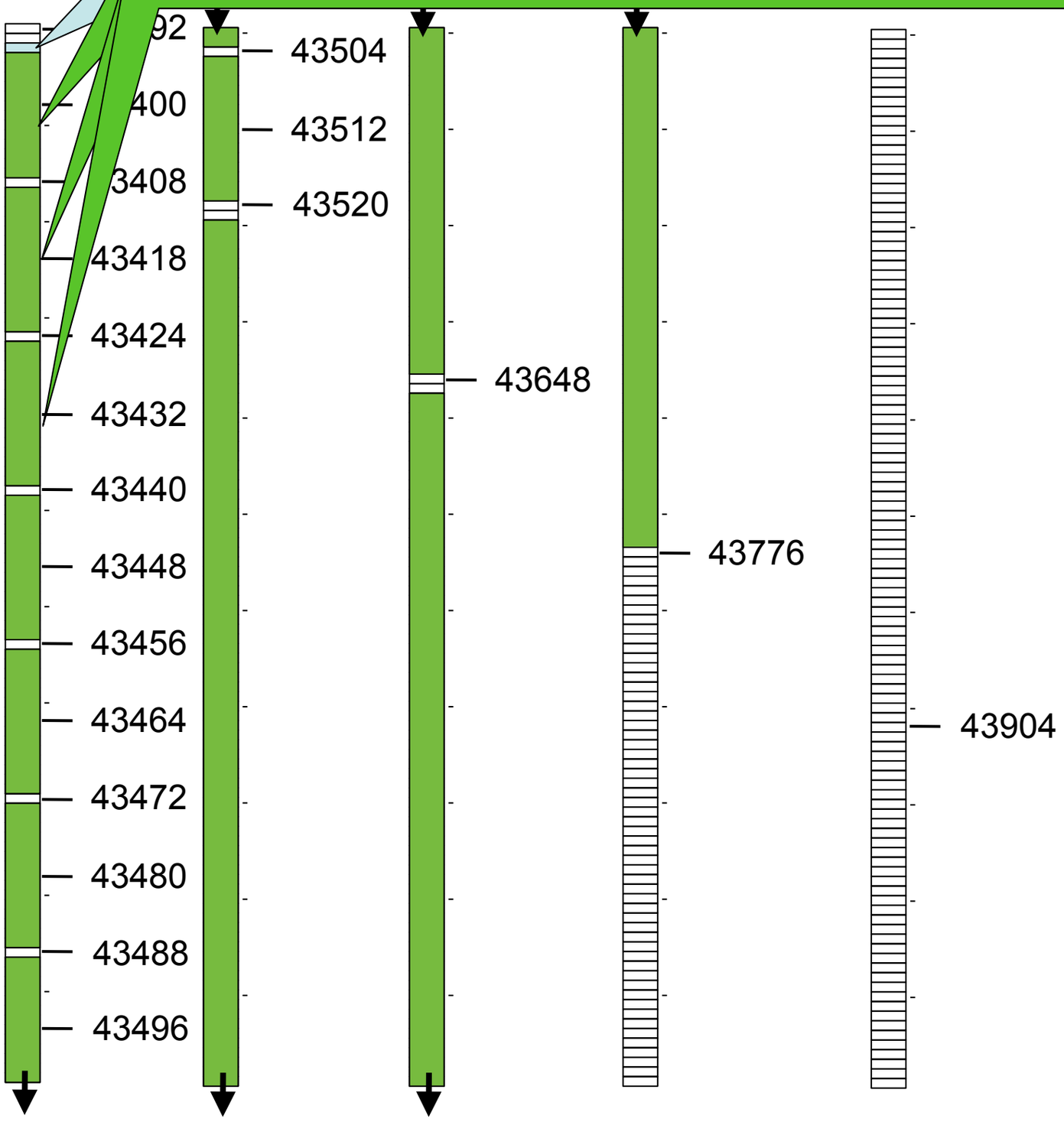
nam='db file scattered read' ela= 87657 file#=5 block#=147 blocks=126



Non buffered multiblock reads

```
WAIT #140120507194664: nam='db file sequential read' ela= 12607 file#=5
block#=43394 blocks=1 obj#=14033 tim=132968538316937 2

nam='direct path read' ela= 50599 file number=5 first dba=43395 block cnt=13
nam='direct path read' ela= 21483 file number=5 first dba=43425 block cnt=15
nam='direct path read' ela= 10766 file number=5 first dba=43441 block cnt=15
nam='direct path read' ela= 12915 file number=5 first dba=43457 block cnt=15
nam='direct path read' ela= 12583 file number=5 first dba=43473 block cnt=15
nam='direct path read' ela= 11899 file number=5 first dba=43489 block cnt=15
nam='direct path read' ela= 10010 file number=5 first dba=43505 block cnt=15
nam='direct path read' ela= 160237 file number=5 first dba=43522 block cnt=126
nam='direct path read' ela= 25561 file number=5 first dba=43650 block cnt=126
nam='direct path read' ela= 121507 file number=5 first dba=43778 block cnt=126
nam='direct path read' ela= 25253 file number=5 first dba=43906 block cnt=126
```

nam='direct path read' ela= 21483 file number=5 first dba=43425 block cnt=15



ASSM

- Automatic segment space management
  - Tablespace property
  - Default since Oracle 10.2
- Uses L 1/2/3 bitmap blocks for space management

- With extent size of
  - 8 blocks: 1 BMB as first block of every other extent
  - 128 blocks: 2 BMB as first blocks in all extents
  - 1024 blocks: 4 BMB as first blocks in all extents

Multiblock implementation

- Conclusion:
  - Buffered reads scan up to:
    - Non data (space admin. bitmap) block
    - Extent border
    - Block already in cache (from TOP, didn't test this)
  - Direct path/non buffered reads scan up to:
    - Non data (space admin. bitmap) block
    - Block already in cache (from TOP, didn't test this)

Waits and implementation

- ‘Wait’ or wait event
  - Part of the formula:
    - Elapsed time = CPU time + Wait time

- Inside the Oracle database it is meant to record the time spent in a specific part of the oracle database code not running on CPU.

- Let’s look at the implementation of some of the wait events for multiblock reads!

strace

- Linux tool for tracing (viewing) system calls
  - Solaris/AIX: truss, HPUX: tusc.

- Very, **very**, useful to understand what is happening
- Much people are using it for years
- **STRACE LIES!** (at least on linux)

strace lies

- Strace doesn't show io_getevents() if:
  - timeout struct set to {0,0} ('zero')
  - does not succeed in reaping min_nr IO's

- This strace omission is not documented

strace lies

- This is best seen with system's IO capability severely throttled (1 IOPS)
- See http://fritshoogland.wordpress.com/2012/12/15/throttling-io-with-linux/

- Cgroups
  - Control groups
  - Linux feature
  - Fully available with OL6

strace lies

- Strace output
  - Version 11.2.0.3 (reason shown later)
  - IO throttled to 1 IOPS
  - Full table scan doing count(*) on t2
  - With 10046 at level 8
    - To show where waits are occuring
  - Start of FTS, up to first reap of IO

strace lies

```
io_submit(139801394388992, 1, {{0x7f260a8b3450, 0, 0, 0, 257}}) = 1

io_submit(139801394388992, 1, {{0x7f260a8b31f8, 0, 0, 0, 257}}) = 1

io_getevents(139801394388992, 1, 128, {{0x7f260a8b3450, 0x7f260a8b3450, 106496,
0}}, {600, 0}) = 1

write(8, "WAIT #139801362351208: nam='dire"..., 133) = 133


* edited for clarity
```

strace lies

- Profile the same using ‘gdb’

- Set breakpoints at functions:
  - io_submit, io_getevents_0_4
  - kslwtbctx, kslwtectx
- Let gdb continue after breakpoint

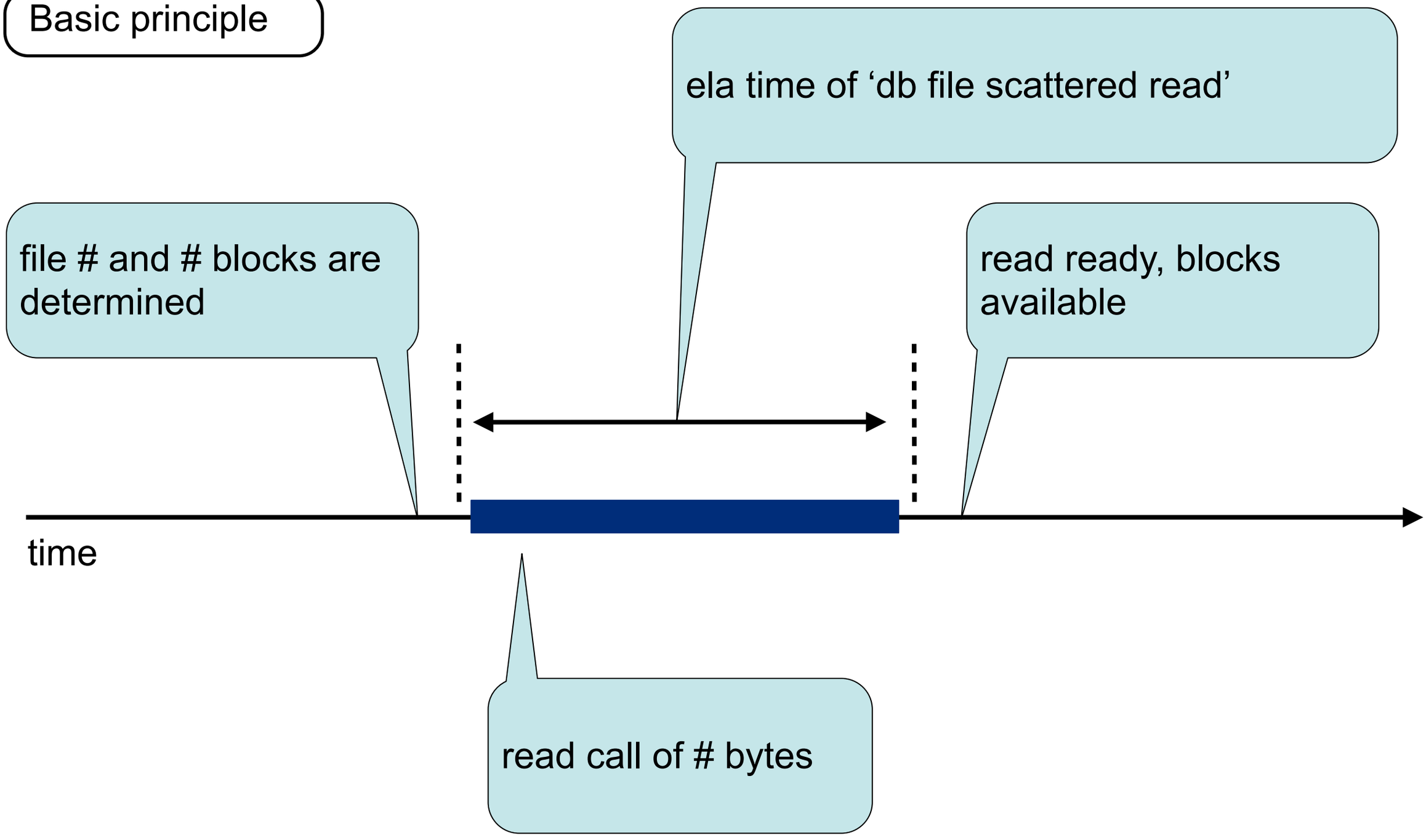
- The symbol table is preserved in the oracle binary
- Making it able to set breakpoints at functions

strace lies

```
#0  io_submit (ctx=0x7f46fe708000, nr=1, iocbs=0x7fff24547ce0) at io_submit.c:23

#0  io_submit (ctx=0x7f46fe708000, nr=1, iocbs=0x7fff24547ce0) at io_submit.c:23

Breakpoint 3, io_getevents_0_4 (ctx=0x7f46fe708000, min_nr=2, nr=128,
events=0x7fff24550348, timeout=0x7fff24551350) at io_getevents.c:46

Breakpoint 3, io_getevents_0_4 (ctx=0x7f46fe708000, min_nr=2, nr=128,
events=0x7fff24553428, timeout=0x7fff24554430) at io_getevents.c:46

Breakpoint 3, io_getevents_0_4 (ctx=0x7f46fe708000, min_nr=2, nr=128,
events=0x7fff24550148, timeout=0x7fff24551150) at io_getevents.c:46

Breakpoint 3, io_getevents_0_4 (ctx=0x7f46fe708000, min_nr=2, nr=128,
events=0x7fff24553228, timeout=0x7fff24554230) at io_getevents.c:46

#0  0x0000000008f9a652 in kslwtbctx ()

Breakpoint 3, io_getevents_0_4 (ctx=0x7f46fe708000, min_nr=1, nr=128,
events=0x7fff24550138, timeout=0x7fff24551140) at io_getevents.c:46

#0  0x0000000008fa1334 in kslwtectx ()


* edited for clarity
```

db file scattered read

Basic principle



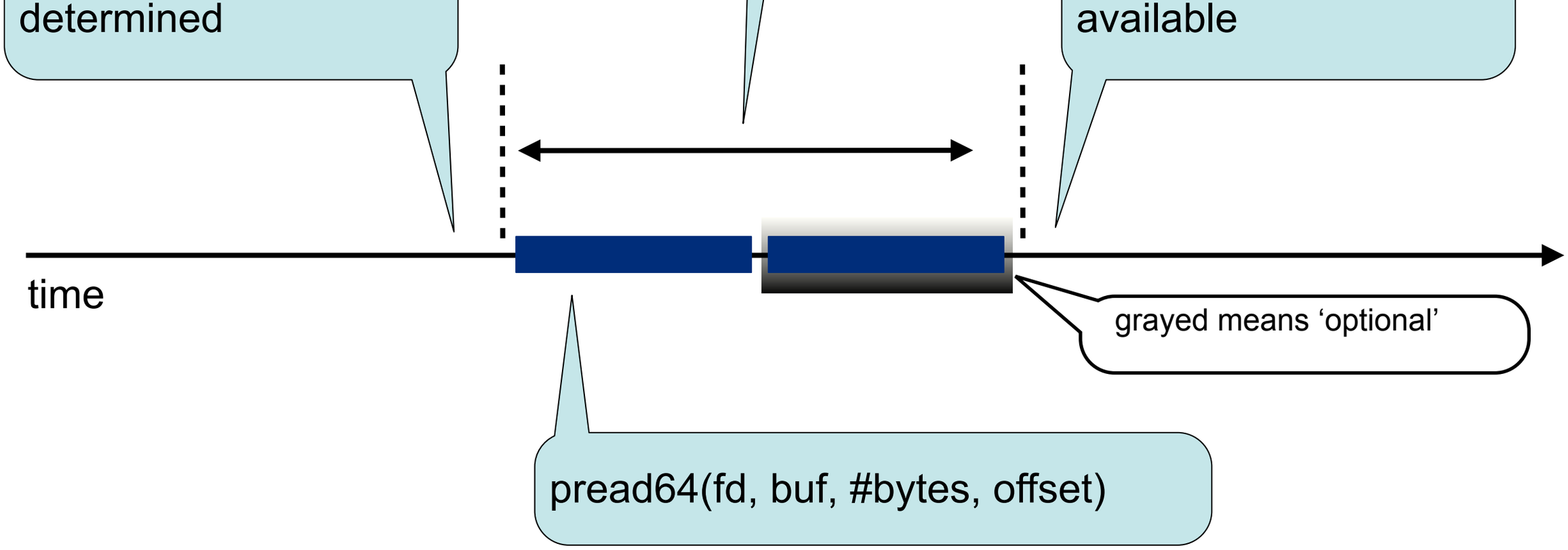
db file scattered read

Implementation
synchronous IO
10.2.0.1/11.2.0.1/11.2.0.3

ela time of ‘db file scattered read’

file # and # blocks are determined

read ready, blocks available



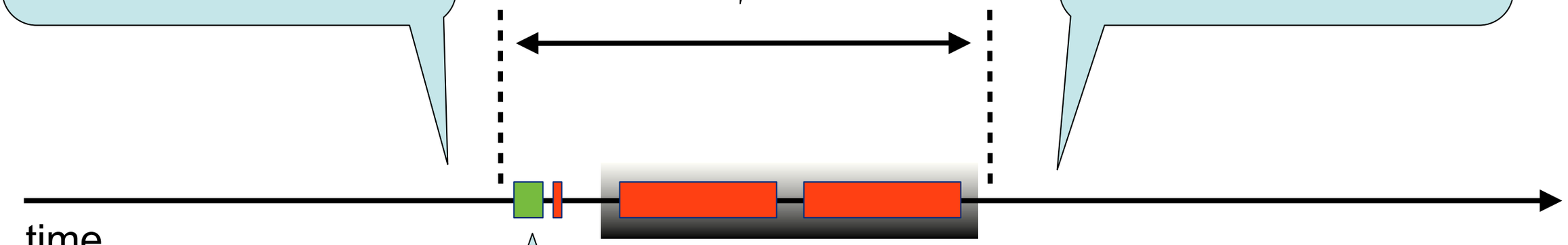
db file scattered read

Implementation
asynchronous IO
10.2.0.1

ela time of ‘db file scattered read’

file # and # blocks are determined

read ready, blocks available



io_submit(aio_ctx, #cb, {iocb})

io_getevents(aio_ctx, min_nr, nr, io_event, timeout)

db file scattered read

Implementation
asynchronous IO
11.2.0.1

ela time of ‘db file scattered read’

file # and # blocks are determined

read ready, blocks available

io_submit(aio_ctx, #cb, {iocb})

io_getevents(aio_ctx, min_nr, nr, io_event, timeout)

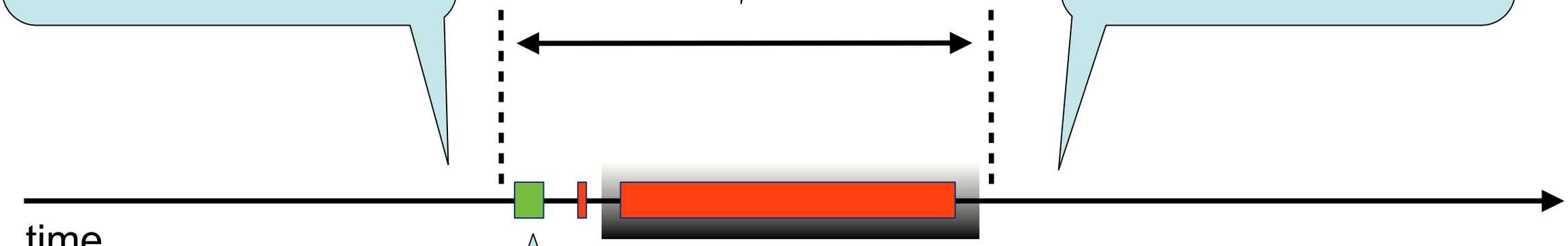
db file scattered read

Implementation
asynchronous IO
11.2.0.3

ela time of ‘db file scattered read’

file # and # blocks are determined

read ready, blocks available



io_submit(aio_ctx, #cb, {iocb})

io_getevents(aio_ctx, min_nr, nr, io_event, timeout)

direct path read - 11g

- Time spent on waiting for reading blocks for putting them into the PGA
- Reports wait time of the request that gets reaped with a timed io_getevents() call.
- Multiple IO requests can be submitted with AIO
- At start, Oracle tries to keep 2 IO's in flight
- Wait time is only reported if 'waiting' occurs
  - Waiting means: not ALL IO's can be reaped immediately after submitting

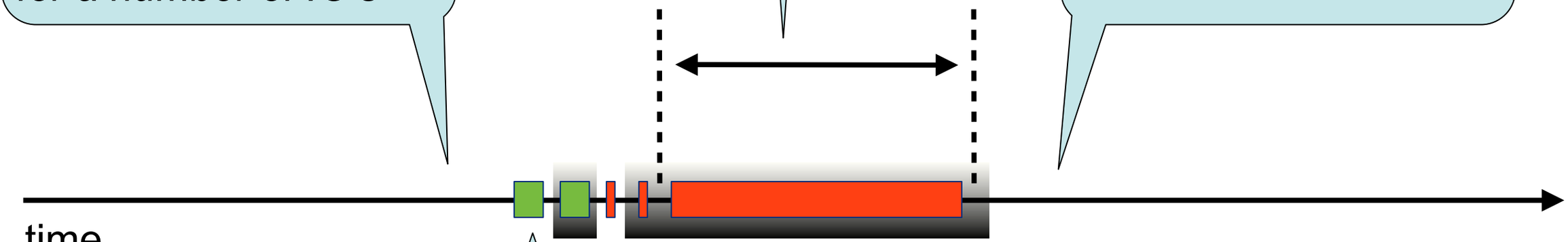
direct path read 11g

Implementation
asynchronous IO
11.2.0.1

ela time of ‘direct path read’*

file # and # blocks are determined
for a number of IO’s

read ready, blocks available



io_submit(aio_ctx, #cb, {iocb})

io_getevents(aio_ctx, min_nr, nr, io_event, timeout)

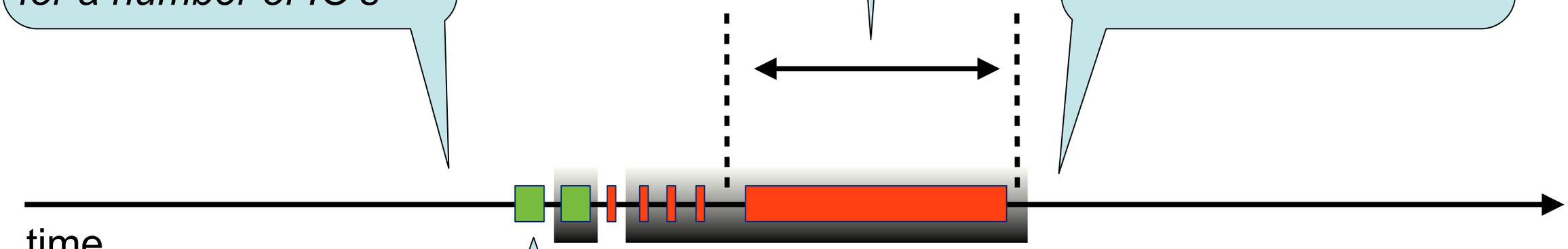
direct path read 11g

Implementation
asynchronous IO
11.2.0.3

ela time of ‘direct path read’*

file # and # blocks are determined
for a number of IO’s

read ready, blocks available



io_submit(aio_ctx, #cb, {iocb})

io_getevents(aio_ctx, min_nr, nr, io_event, timeout)

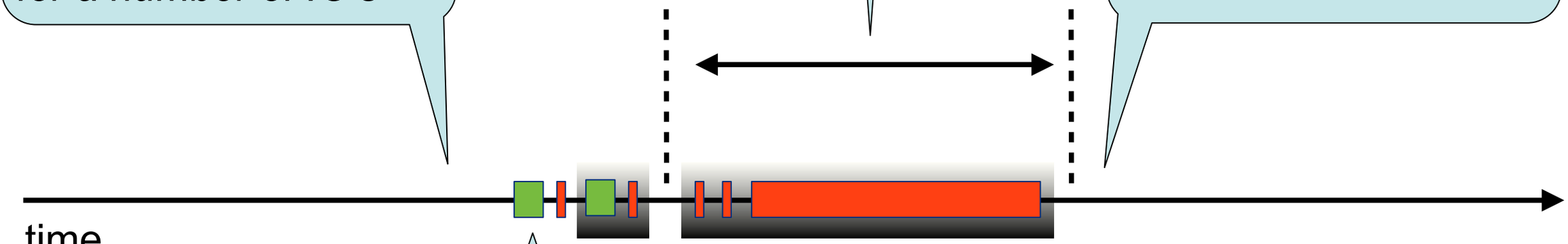
direct path read

Implementation
asynchronous IO
10.2.0.1

ela time of ‘direct path read’

file # and # blocks are determined
for a number of IO’s

read ready, blocks available



io_submit(aio_ctx, #cb, {iocb})

io_getevents(aio_ctx, min_nr, nr, io_event, timeout)

direct path read

Implementation
synchronous IO
10.2.0.1/11.2.0.1/11.2.0.3

file # and # blocks are determined
~~*for a number of IO's*~~

ela time of 'direct path read'

read ready, blocks available

pread64(fd, buf, #bytes, offset)

kfk: async disk IO

- Only seen with ‘direct path read’ waits and ASM
- Always seen in version 11.2.0.1
- Gone with 11.2.0.2+

- Not normally seen in version 11.2.0.2+

- KFK = Kernel File ASM code layer

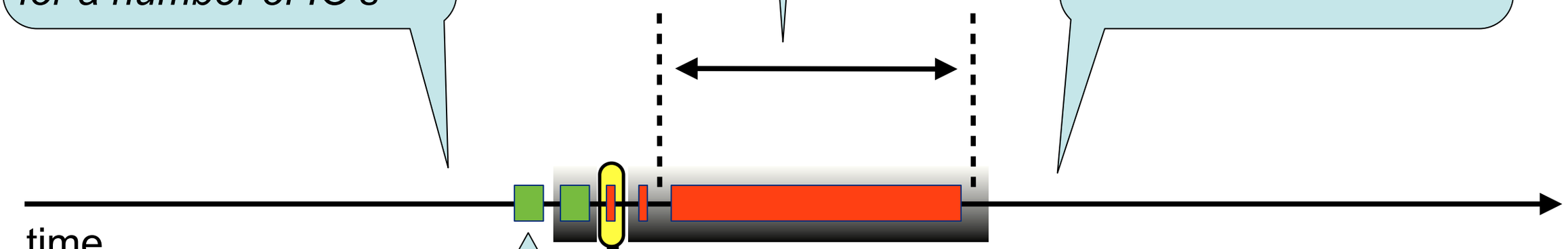
kfk: async disk io

Implementation
asynchronous IO
11.2.0.1

ela time of ‘direct path read’*

file # and # blocks are determined
for a number of IO’s

read ready, blocks available



io_submit(aio_ctx, #cb, {iocb})

io_getevents(aio_ctx, min_nr, nr, io_event, timeout)

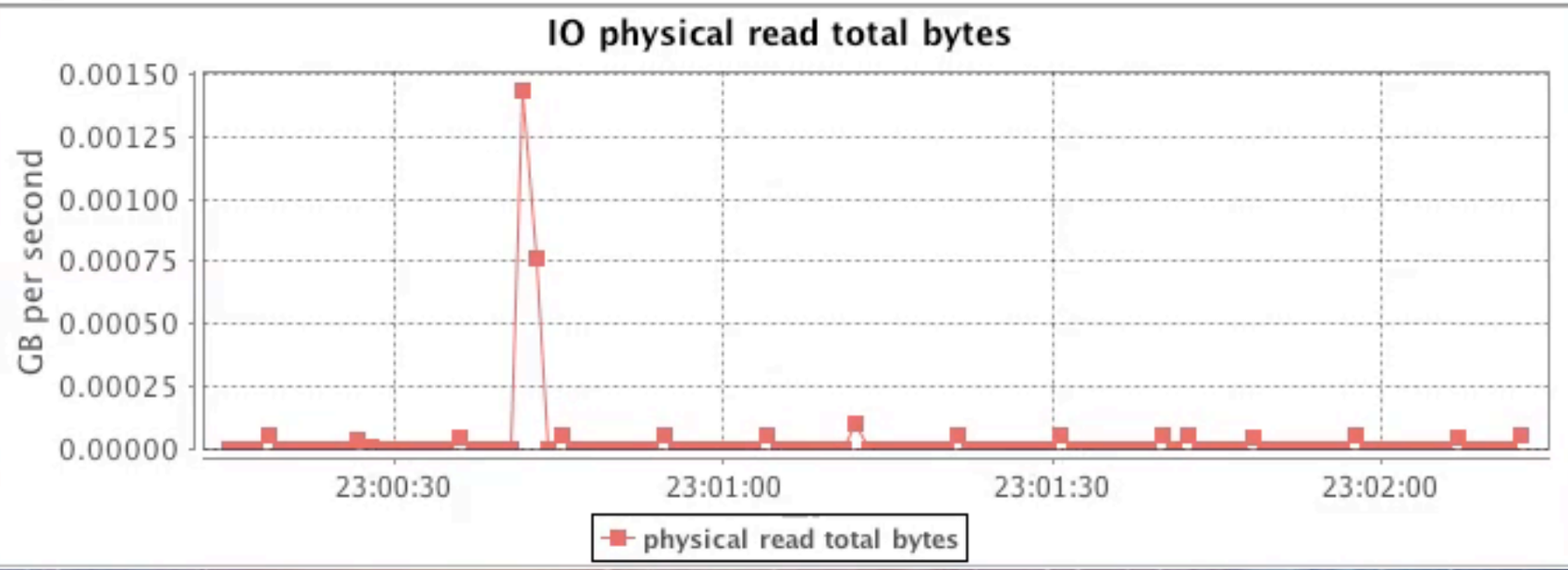
kfk: async disk io

IO Slots

Discussion with Kerry Osborne about IO's on Exadata

IO physical read total bytes [Database]

File



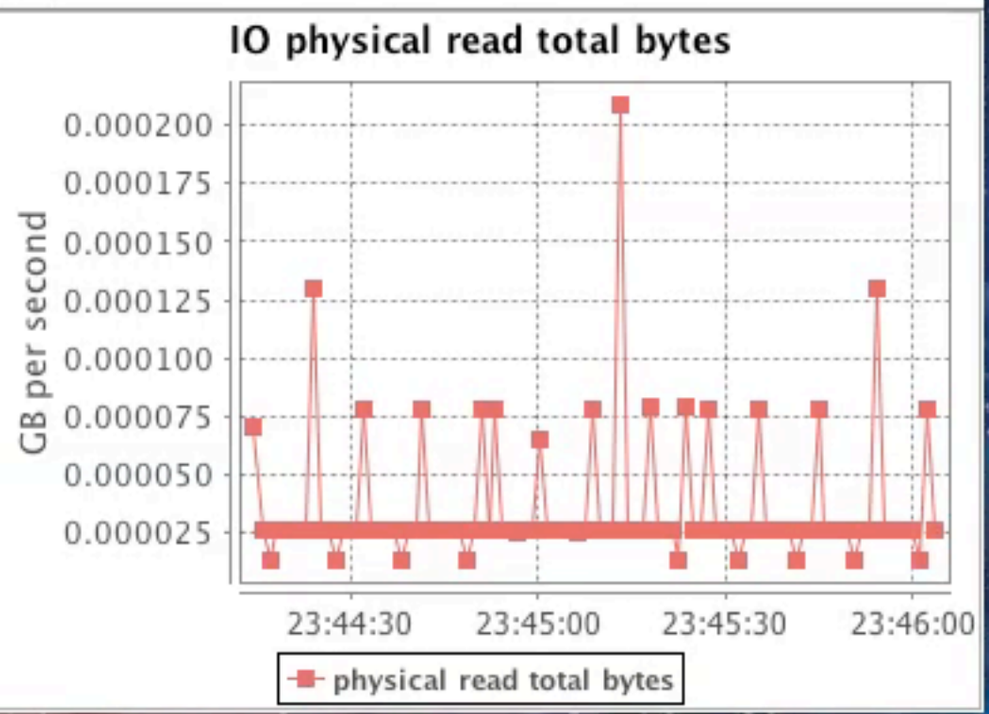
1. oracle@dm01db01.jdf.prod:/home/oracle ORACLE_SID=t11201 ORACLE_HOME=/u01/app/oracle/product/11.2.0/dbhome_1 (ssh)

oracle@dm01db01.jdf.prod... | java | oracle@dm01db01.jdf.prod...

```
SQL> exit
Disconnected from Oracle Database 11g Enterprise Edition Release 11.2.0.1.0 - 64bit Production
With the Partitioning, Real Application Clusters, Automatic Storage Management, OLAP,
Data Mining and Real Application Testing options
[oracle@dm01db01 [t11201] ~]$ rsqlplus cg/cg

SQL*Plus: Release 11.2.0.1.0 Production on Tue Nov 22 23:00:47 2011

Copyright (c) 1982, 2009, Oracle.  All rights reserved.


Connected to:
Oracle Database 11g Enterprise Edition Release 11.2.0.1.0 - 64bit Production
With the Partitioning, Real Application Clusters, Automatic Storage Management, OLAP,
Data Mining and Real Application Testing options

SQL> alter session set cell_offload_processing=false;

Session altered.

(reverse-i-search)`cou': select count(*) from cg_var;
```

IO physical read total bytes [Database]

File



1. oracle@dm01db01.jdf.prod:/home/oracle ORACLE_SID=vxone1 ORACLE_HOME=/u01/app/oracle/product/11.2.0.2/dbhome_1 (ssh)

oracle@dm01db01.jdf.prod... | java | oracle@dm01db01.jdf.prod...

```
Disconnected from Oracle Database 11g Enterprise Edition Release 11.2.0.2.0 - 64bit Production
With the Partitioning, Real Application Clusters, Automatic Storage Management, OLAP,
Data Mining and Real Application Testing options
[oracle@dm01db01 [vxone1] ~]$ rsqlplus cg/cg

SQL*Plus: Release 11.2.0.2.0 Production on Tue Nov 22 23:45:33 2011

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Connected to:
Oracle Database 11g Enterprise Edition Release 11.2.0.2.0 - 64bit Production
With the Partitioning, Real Application Clusters, Automatic Storage Management, OLAP,
Data Mining and Real Application Testing options

SQL> alter session set cell_offload_processing=false;

Session altered.

(reverse-i-search)`': 
```

IO Slots

- Jonathan Lewis pointed me to ‘total number of slots’
  - v$sysstat
  - v$sesstat
- Global or per session number of slots

- ‘Slots are a unit of I/O and this factor controls the number of outstanding I/Os’
  - Comment with event 10353

IO Slots

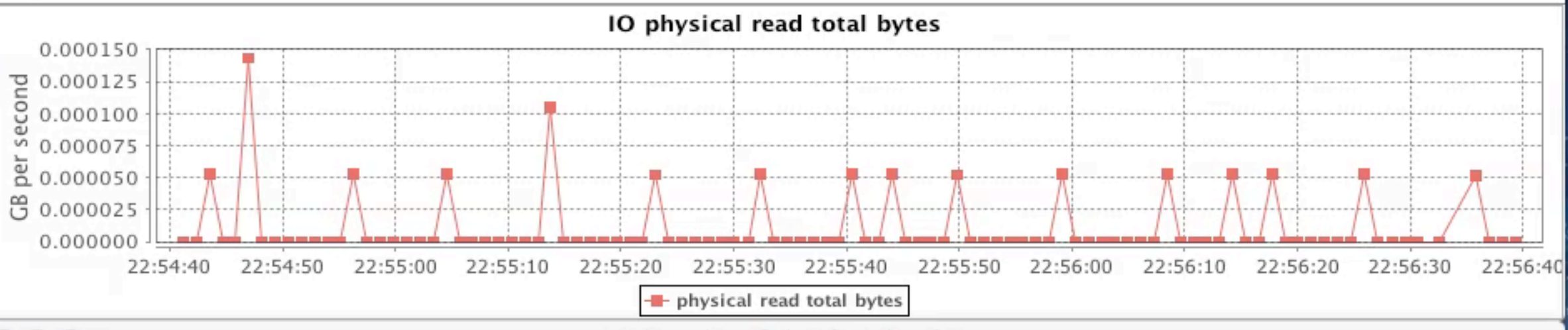
- ‘total number of slots’
  - Is **NOT** cumulative!
- So you won’t capture this statistic when taking delta’s from v$sysstat/v$sesstat!

IO Slots

- Let’s look at the throughput statistics again
  - But together with number of slots

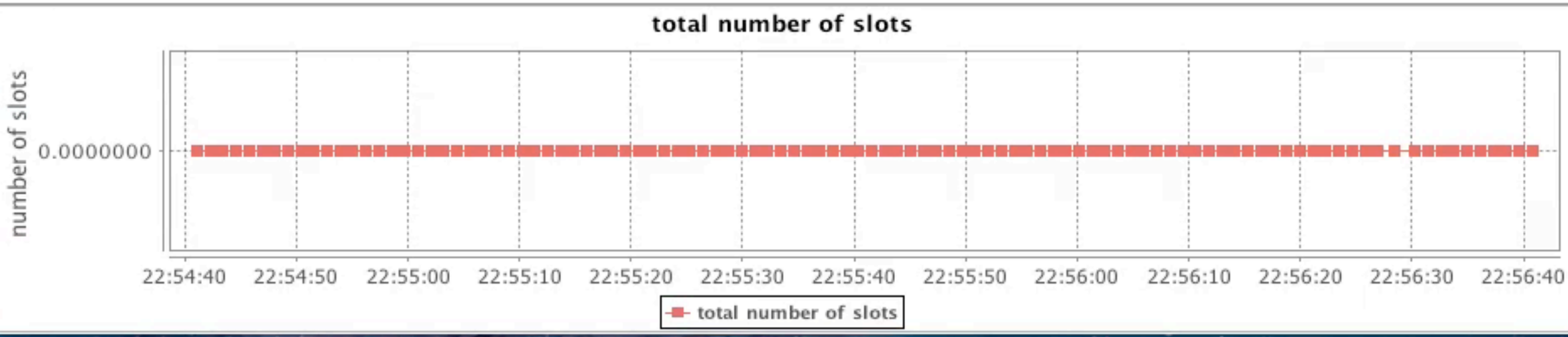
IO physical read total bytes [Database]

File



total number of slots [Database]

File



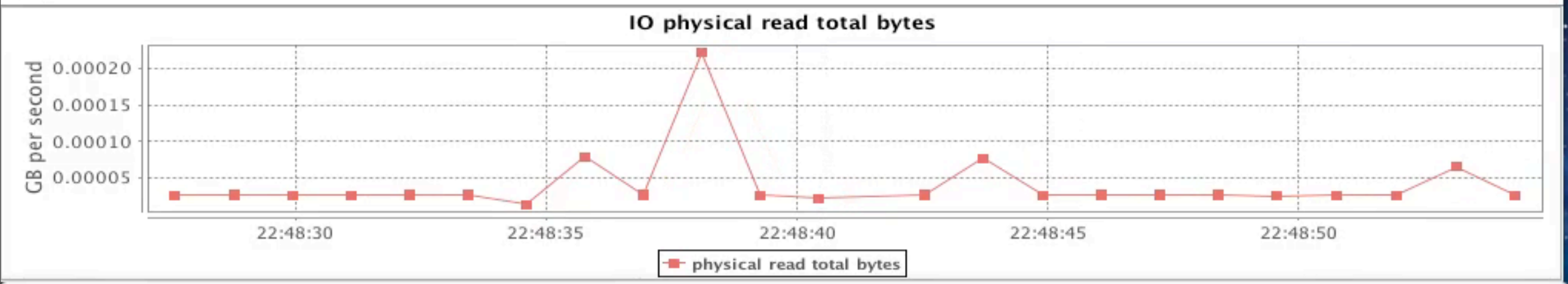
1. oracle@dm01db01.jdf.prod:/home/oracle ORACLE_SID=t11201 ORACLE_HOME=/u01/app/oracle/product/11.2.0/dbh...

oracle@sol10.local:/expor... | oracle@sol10.local:/expor... | oracle@dm01db01.jdf.pro... | java | oracle@dm01db01.jdf.pro...

```
[oracle@dm01db01 [t11201] ~]$ rsqlplus cg/cg

SQL*Plus: Release 11.2.0.1.0 Production on Wed Nov 23 22:52:45 2011

Copyright (c) 1982, 2009, Oracle.  All rights reserved.


Connected to:
Oracle Database 11g Enterprise Edition Release 11.2.0.1.0 - 64bit Production
With the Partitioning, Real Application Clusters, Automatic Storage Management, OLAP,
Data Mining and Real Application Testing options

(reverse-i-search)`': alter session set cell_offload_processing=false;
```

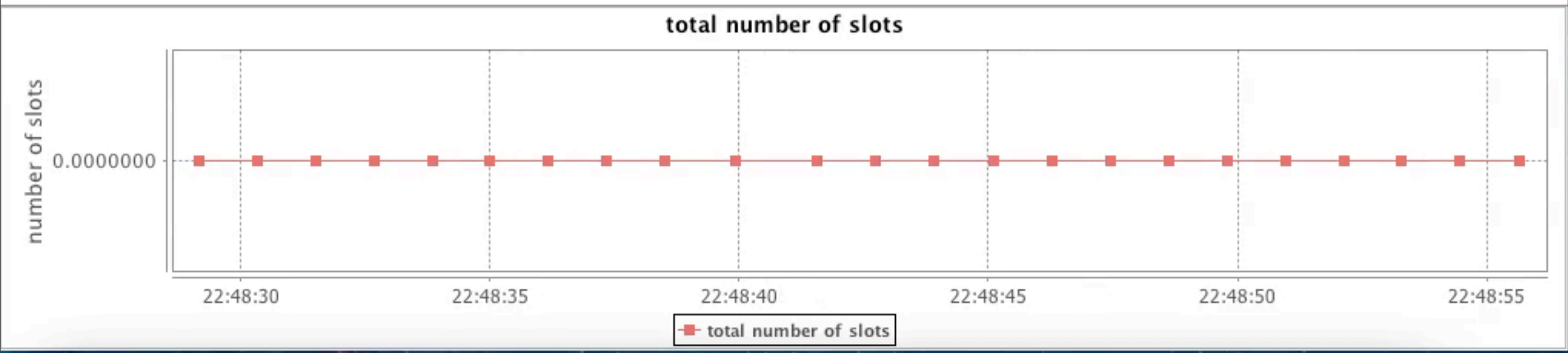
IO physical read total bytes [Database]

File



total number of slots [Database]

File



1. oracle@dm01db01.jdf.prod:/home/oracle ORACLE_SID=vxone1 ORACLE_HOME=/u01/app/oracle/product/11.2.0.2/d...

oracle@sol10.local:/expor... | oracle@sol10.local:/expor... | oracle@dm01db01.jdf.pro... | java | oracle@dm01db01.jdf.pro...

```
Copyright (c) 1982, 2010, Oracle.  All rights reserved.

ERROR:
ORA-28002: the password will expire within 7 days



Connected to:
Oracle Database 11g Enterprise Edition Release 11.2.0.2.0 - 64bit Production
With the Partitioning, Real Application Clusters, Automatic Storage Management, OLAP,
Data Mining and Real Application Testing options

(reverse-i-search)`': 
```

IO Slots

- IO Slots is a mechanism to take advantage of storage bandwidth using AIO
- With version 11 direct path reads can be used by both PQ slaves as well as non PQ foregrounds
  - IO Slots are not used with buffered reads

- Each outstanding asynchronous IO request is tracked using what is called a ‘slot’
- Default and minimal number of slots: 2

‘autotune’

- The direct path code changed with version 11
- Second observation:
  - The database foreground measures direct path IO effectiveness
  - It measures time, wait time and throughput
  - The oracle process has the ability to add more asynchronous IO slots
  - Only does so starting from 11.2.0.2
    - Although the mechanism is there in 11.2.0.1

‘autotune’

- Introducing event 10365
  - “turn on debug information for adaptive direct reads”

- Set to 1 to get debug information
  - alter session set events ‘10365 trace name context forever, level 1’

‘autotune’

```
kcbldrsini: Timestamp 61180 ms
kcbldrsini: Current idx 16
kcbldrsini: Initializing kcbldrps
kcbldrsini: Slave idx 17
kcbldrsini: Number slots 2
kcbldrsini: Number of slots per session 2

*** 2011-11-28 22:58:48.808
kcblsinc:Timing time 1693472, wait time 1291416, ratio 76 st 248752270 cur 250445744
kcblsinc: Timing curidx 17 session idx 17
kcblsinc: Timestamp 64180 ms
kcblsinc: Current idx 17
kcblsinc: Slave idx 17
kcblsinc: Number slots 2
kcblsinc: Number of slots per session 2
kcblsinc: Previous throughput 8378 state 2
kcblsinc: adaptive direct read mode 1, adaptive direct write mode 0
```

‘autotune’

```
*** 2011-11-28 22:58:54.988
kcblsinc:Timing time 2962717, wait time 2923226, ratio 98 st 253662983 cur 256625702
kcblsinc: Timing curidx 19 session idx 19
kcblsinc: Timestamp 70270 ms
kcblsinc: Current idx 19
kcblsinc: Slave idx 19
kcblsinc: Number slots 2
kcblsinc: Number of slots per session 2
kcblsinc: Previous throughput 11210 state 1
kcblsinc: adaptive direct read mode 1, adaptive direct write mode 0
kcblsinc: Adding extra slos 1

*** 2011-11-28 22:58:58.999
kcblsinc:Timing time 4011239, wait time 3528563, ratio 87 st 256625785 cur 260637026
kcblsinc: Timing curidx 20 session idx 20
kcblsinc: Timestamp 74170 ms
kcblsinc: Current idx 20
kcblsinc: Slave idx 20
kcblsinc: Number slots 3
kcblsinc: Number of slots per session 3
kcblsinc: Previous throughput 12299 state 2
```

‘autotune’

- Looking at the 10365 trace, the reason 11.2.0.1 does not ‘autotune’ could be guessed....

‘autotune’

```
*** 2011-11-28 22:54:18.361
kcblsinc:Timing time 3092929, wait time 0, ratio 0 st 4271872759 cur 4274965690
kcblsinc: Timing curidx 65 session idx 65
kcblsinc: Timestamp 192430 ms
kcblsinc: Current idx 65
kcblsinc: Slave idx 65
kcblsinc: Number slots 2
kcblsinc: Number of slots per session 2
kcblsinc: Previous throughput 20655 state 2
kcblsinc: adaptive direct read mode 1, adaptive direct write mode 0

*** 2011-11-28 22:54:21.306
kcblsinc:Timing time 2944852, wait time 0, ratio 0 st 4274965762 cur 4277910616
kcblsinc: Timing curidx 66 session idx 66
kcblsinc: Timestamp 195430 ms
kcblsinc: Current idx 66
kcblsinc: Slave idx 66
kcblsinc: Number slots 2
kcblsinc: Number of slots per session 2
kcblsinc: Previous throughput 20746 state 1
kcblsinc: adaptive direct read mode 1, adaptive direct write mode 0
```

IO slots

11.2.0.3
FAST IO

slots starts with 2

kcblsinc ()

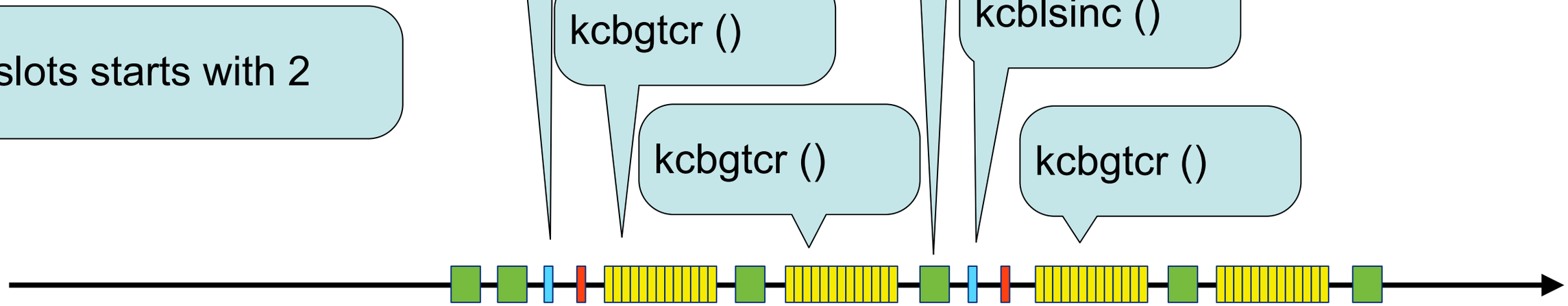
kcbgtcr ()

kcbgtcr ()

io_submit(aio_ctx,1 , {iocb})

kcblsinc ()

kcbgtcr ()



time

io_submit(aio_ctx,1 , {iocb})

io_submit(aio_ctx,1 , {iocb})

io_getevents(aio_ctx, 2, 128, io_event, {0, 0})
OK!

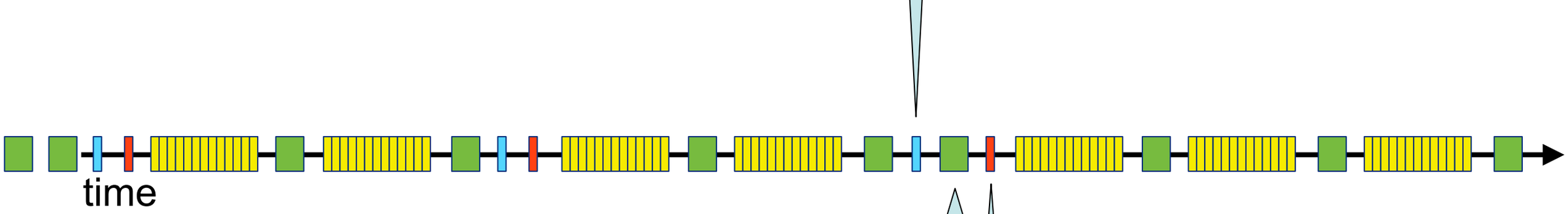
io_submit(aio_ctx,1 , {iocb})

io_getevents(aio_ctx, 2, 128, io_event, {0, 0}) OK!

IO slots

11.2.0.3
FAST IO

kcblsinc ()
+1 ‘slos’



io_submit(aio_ctx,1 , {iocb})

io_getevents(aio_ctx, *3*, 128, io_event, {0, 0})
OK!

Time and waits

- Waits implementation
  - Most are system call instrumentation
    - db file sequential read
  - ‘direct path read’ is different.
    - Only shows up if not all IO can be reaped immediately
    - The wait only occurs if process is truly waiting
    - With AIO, a process has the ability to keep on processing without waiting on IO
    - Wait time is not physical IO latency

Conclusion

- In Oracle version 10.2 and earlier non-PX reads use:
  - db file sequential read / db file scattered read events
  - Read blocks go to buffercache.

- Starting from Oracle version 11 reads could do both
  - buffered reads
  - unbuffered or direct path reads

Conclusion

- Direct path read is decision in IO codepath of full scan.
  - NOT an optimiser decision(!)

- In Oracle version 11, a read is done buffered, unless database decides to do a direct path read

- Direct path read decision is influenced by
  - Type of read (FTS or FFIS)
  - Size of segment (> 5 * _small_table_threshold)
  - Number of blocks cached (< ~ 50%)

Conclusion

- By default, (AIO) direct path read uses two slots.
  - ‘autotune’ scales up in steps.
  - I’ve witnessed it scale up to 32 slots.

- Direct path code has an ‘autotune’ function, which can add IO slots.
  - In order to be able to use more bandwidth
  - Direct path ‘autotune’ works for PX reads too!

- ‘autotune’ does not kick in with Oracle version 11.2.0.1

Thank you for attending!

Questions?

Thanks, Links, etc.

- Tanel Poder
- Jason Arneil
- Klaas-Jan Jongsma
- Doug Burns
- Cary Millsap
- http://afatkulin.blogspot.com/2009/01/11g-adaptive-direct-path-reads-what-is.html
- http://dioncho.wordpress.com/2009/07/21/disabling-direct-path-read-for-the-serial-full-table-scan-11g/
- http://www.oracle.com/pls/db112/homepage
- http://hoopercharles.wordpress.com/2010/04/10/auto-tuned-db_file_multiblock_read_count-parameter/
- http://fritshoogland.wordpress.com/2012/04/26/getting-to-know-oracle-wait-events-in-linux/