Analysing and Troubleshooting Parallel Execution

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WHO AM I

- Independent consultant
  - In-house workshops
    - Cost-Based Optimizer
    - Performance By Design
  - Performance Troubleshooting
- Oracle ACE Director
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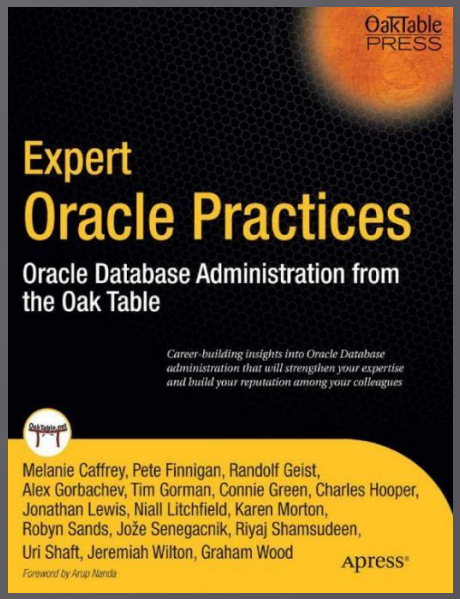
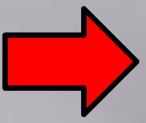


AGENDA



- Parallel Execution introduction
- Major challenges
  - Parallel unfriendly examples
  - Distribution skew examples
- How to measure distribution of work
- How to systematically analyze distribution

INTRODUCTION

- Oracle Database Enterprise Edition includes the powerful Parallel Execution feature that allows spreading the processing of a single SQL statement execution across multiple worker processes

- The feature is fully integrated into the Cost Based Optimizer as well as the execution runtime engine and automatically distributes the work across the so called Parallel Workers

INTRODUCTION

- Simple generic parallelization example

  Task: Compute sum of 8 numbers

  1+8+7+9+6+2+6+3= ???

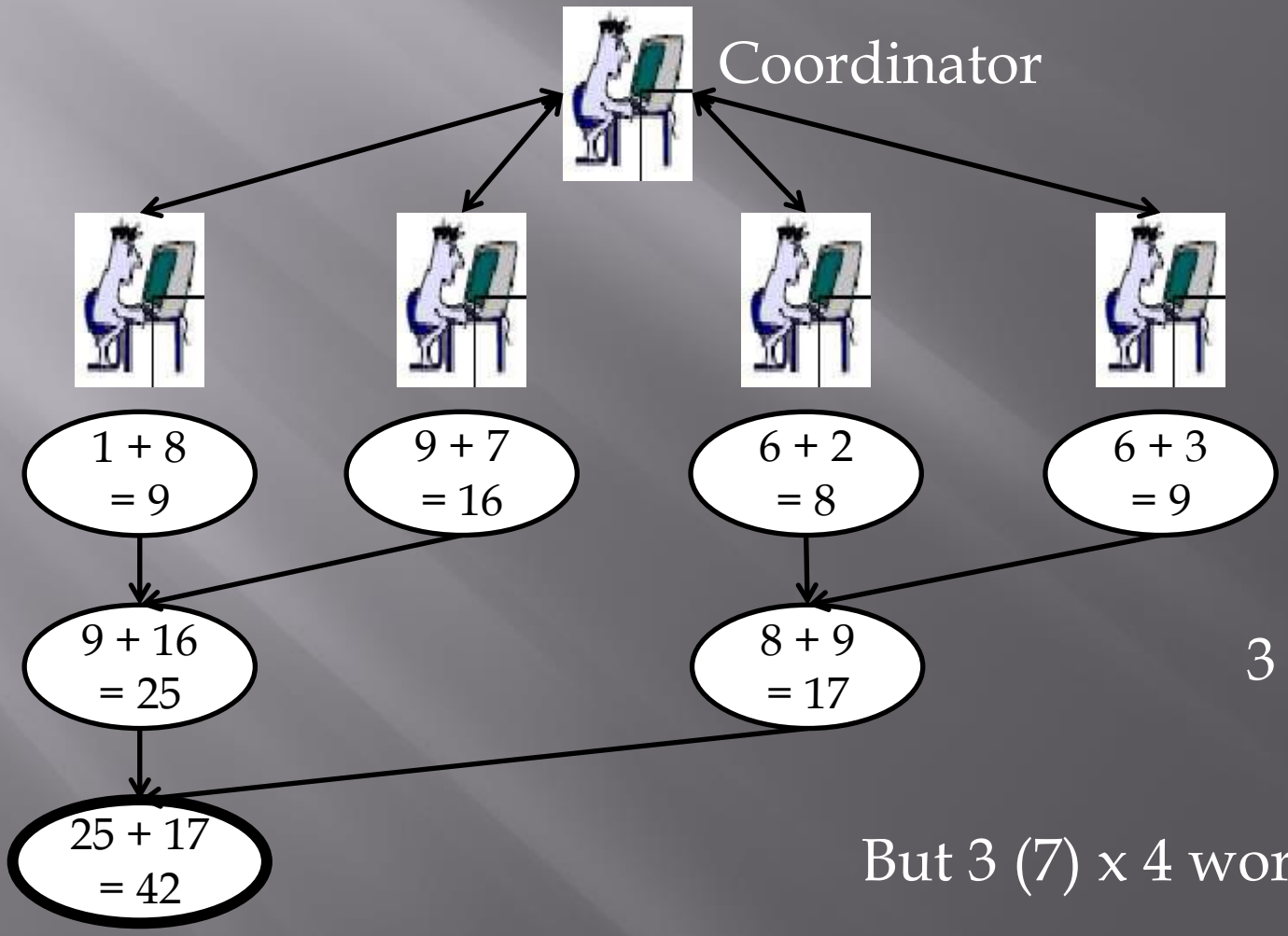
  1+8=9, 9+7=16, 16+9=25,...

  n=8 numbers, 7 computation steps required

  Serial execution: 7 time units

INTRODUCTION

Simple generic parallelization example



4 workers

3 (7) time units

But 3 (7) x 4 workers assigned

INTRODUCTION

- Simple generic parallelization example
  - Possibly additional startup cost:
    Find available /instruct / coordinate workers
  - Major challenge: Divide task into chunks that can be efficiently and independently processed by workers
  - Overall execution time in parallel can be lower than serial execution
  - But potentially more worker units required than serial execution

INTRODUCTION

- Simple generic parallelization example
  - Number of worker units assigned matters
    - Too few can be bad
    - Too many can be bad, too
  - Communication between worker units required – data needs to be (re-) distributed (overhead!)
  - Major challenge: Keep all workers busy all the time
  - Parallelization might require different approach

INTRODUCTION

- Parallel Execution doesn't mean "work smarter"
- You're actually willing to accept to "work harder"
- Could also be called:
  "Brute force" approach

INTRODUCTION

So with Parallel Execution there might be the problem that it doesn't work "hard enough"

INTRODUCTION

Two major challenges

Can the given task be divided into sub-tasks that can efficiently and independently be processed by the workers? (“Parallel Unfriendly”)

Can all assigned workers be kept busy all the time?

INTRODUCTION

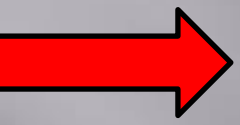
- Parallel Execution can only reduce runtime as expected if all workers are kept busy
- Possibly only a few or a single worker will be active and have to do all the work
- In this case Parallel Execution can actually be **slower** than serial execution
- There is a need to **measure** how busy the workers are kept

INTRODUCTION

- Note that this measure doesn't tell you anything about the efficiency of the actual operation / execution plan
- But an otherwise efficient Parallel Execution plan can only scale if the expected number of workers is kept busy ideally all the time
- Note that it says "can scale" – if your system cannot scale the required resources (like I/O) you just end up with more workers waiting

INTRODUCTION

Other reasons why Oracle Parallel Execution might not reduce runtime as expected:



- Parallel DML/DDL gotchas
- "Downgrade" at execution time (less workers assigned than expected)
- Overhead of Parallel Execution implementation
- Limitations of Parallel Execution implementation

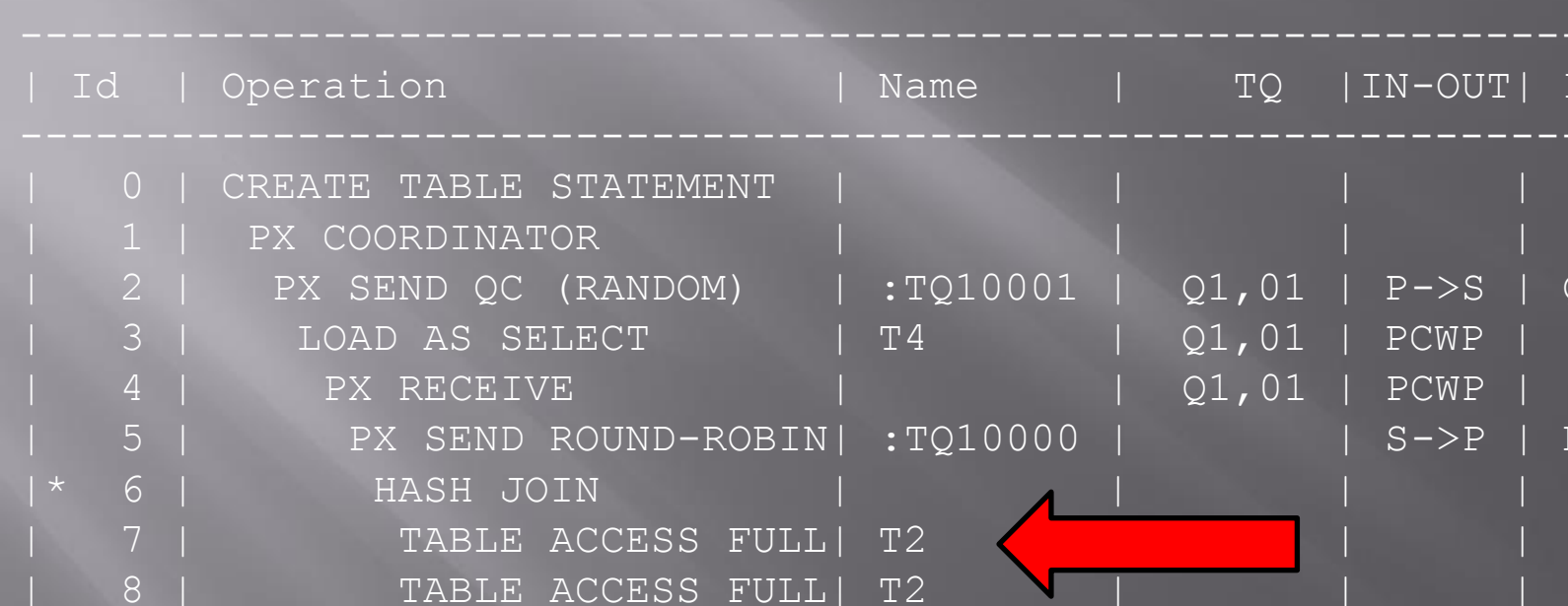
PARALLEL DML/DDL

Parallel DML / DDL gotchas

- DML / DDL part can run parallel or serial
- Query part can run parallel or serial

PARALLEL DDL / DML PLANS

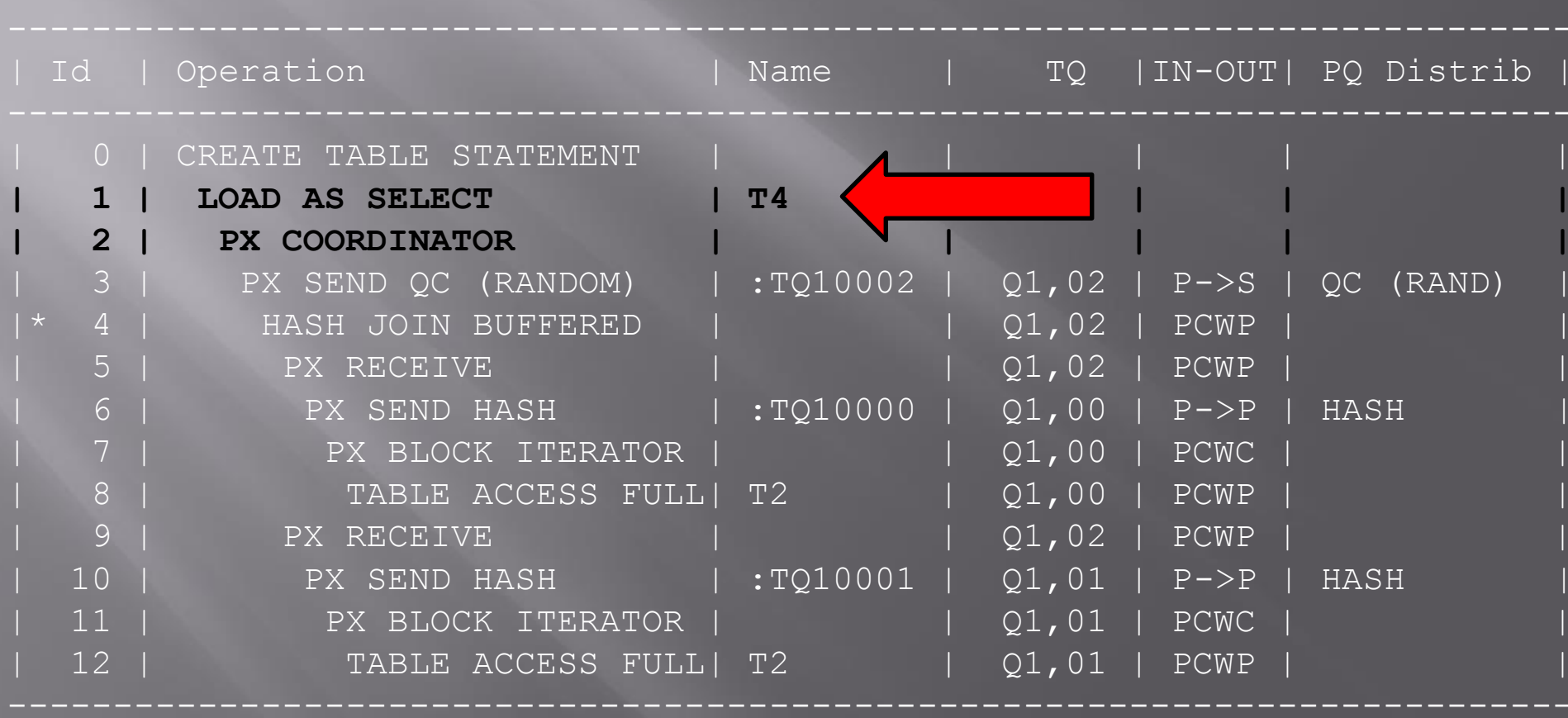
Parallel CTAS but serial query



```
-------------------------------------------------------------------------------
| Id  | Operation                | Name     |    TQ  |IN-OUT| PQ Distrib |
-------------------------------------------------------------------------------
|   0 | CREATE TABLE STATEMENT   |          |        |      |            |
|   1 |  PX COORDINATOR          |          |        |      |            |
|   2 |   PX SEND QC (RANDOM)    | :TQ10001 |  Q1,01 | P->S | QC (RAND)  |
|   3 |    LOAD AS SELECT        | T4       |  Q1,01 | PCWP |            |
|   4 |     PX RECEIVE           |          |  Q1,01 | PCWP |            |
|   5 |      PX SEND ROUND-ROBIN| :TQ10000 |        | S->P | RND-ROBIN  |
|*  6 |       HASH JOIN          |          |        |      |            |
|   7 |        TABLE ACCESS FULL| T2       |        |      |            |
|   8 |        TABLE ACCESS FULL| T2       |        |      |            |
-------------------------------------------------------------------------------
```

PARALLEL DDL / DML PLANS

Serial CTAS but parallel query



Id	Operation	Name	TQ	IN-OUT	PQ Distrib
0	CREATE TABLE STATEMENT				
1	**LOAD AS SELECT**	**T4**			
2	**PX COORDINATOR**				
3	PX SEND QC (RANDOM)	:TQ10002	Q1,02	P->S	QC (RAND)
* 4	HASH JOIN BUFFERED		Q1,02	PCWP	
5	PX RECEIVE		Q1,02	PCWP	
6	PX SEND HASH	:TQ10000	Q1,00	P->P	HASH
7	PX BLOCK ITERATOR		Q1,00	PCWC	
8	TABLE ACCESS FULL	T2	Q1,00	PCWP	
9	PX RECEIVE		Q1,02	PCWP	
10	PX SEND HASH	:TQ10001	Q1,01	P->P	HASH
11	PX BLOCK ITERATOR		Q1,01	PCWC	
12	TABLE ACCESS FULL	T2	Q1,01	PCWP	

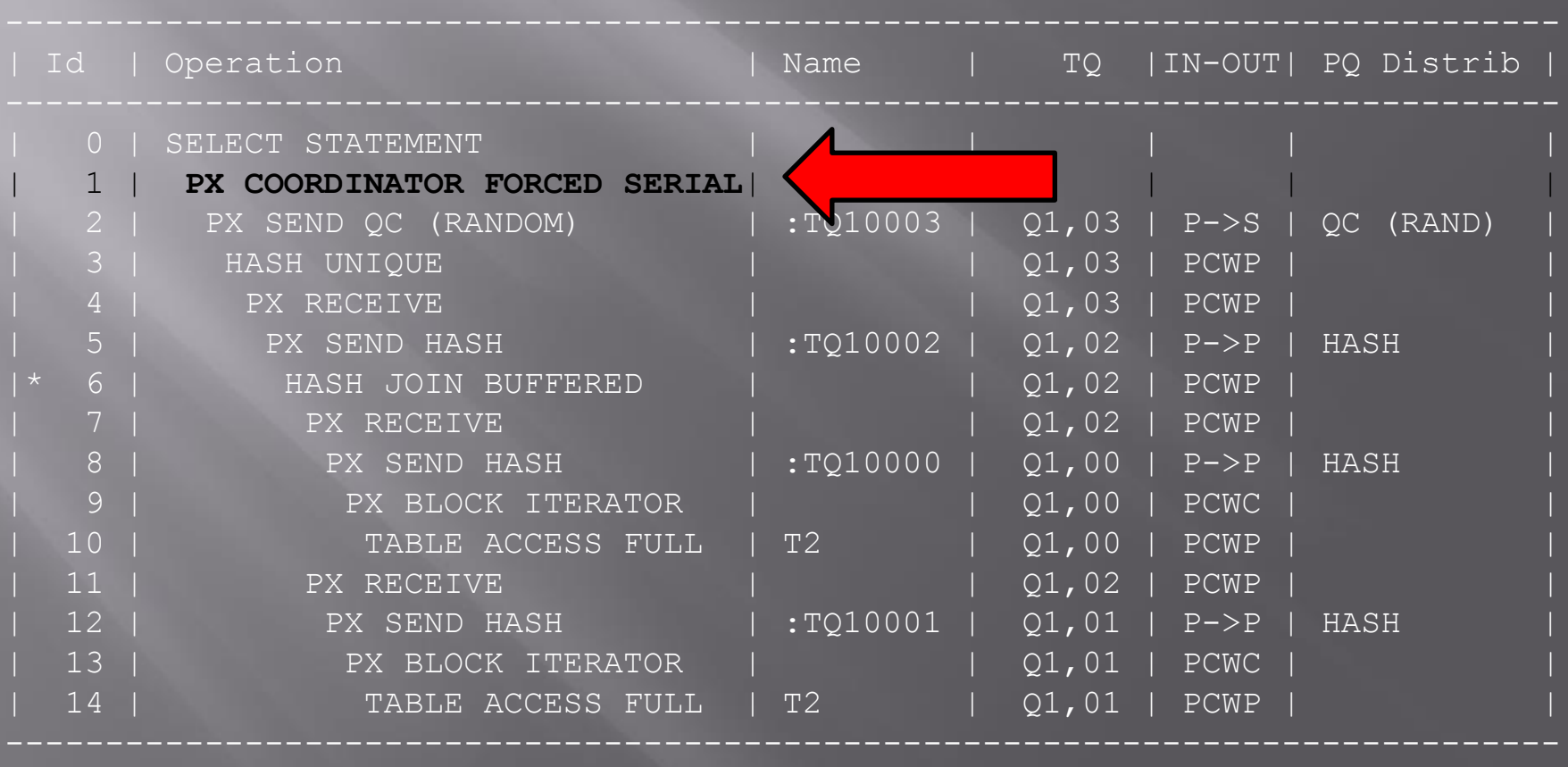
INTRODUCTION

Other reasons why Oracle Parallel Execution might not scale as expected:

- Parallel DML/DDL gotchas
- "Downgrade" at execution time (less workers assigned than expected)
- Overhead of Parallel Execution implementation
- Limitations of Parallel Execution implementation

IMPLEMENTATION LIMITATIONS

"Parallel Forced Serial" Example



Id	Operation	Name	TQ	IN-OUT	PQ Distrib
0	SELECT STATEMENT				
1	**PX COORDINATOR FORCED SERIAL**				
2	PX SEND QC (RANDOM)	:TQ10003	Q1,03	P->S	QC (RAND)
3	HASH UNIQUE		Q1,03	PCWP	
4	PX RECEIVE		Q1,03	PCWP	
5	PX SEND HASH	:TQ10002	Q1,02	P->P	HASH
* 6	HASH JOIN BUFFERED		Q1,02	PCWP	
7	PX RECEIVE		Q1,02	PCWP	
8	PX SEND HASH	:TQ10000	Q1,00	P->P	HASH
9	PX BLOCK ITERATOR		Q1,00	PCWC	
10	TABLE ACCESS FULL	T2	Q1,00	PCWP	
11	PX RECEIVE		Q1,02	PCWP	
12	PX SEND HASH	:TQ10001	Q1,01	P->P	HASH
13	PX BLOCK ITERATOR		Q1,01	PCWC	
14	TABLE ACCESS FULL	T2	Q1,01	PCWP	

CHALLENGES

Two major challenges

Can the given task be divided into sub-tasks that can efficiently and independently be processed by the workers? (“Parallel Unfriendly”)

Can all assigned workers be kept busy all the time?

PARALLEL UNFRIENDLY

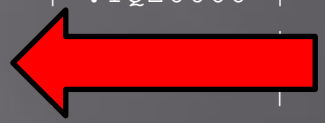
```
select median(id) from t2;
```

```
-------------------------------------------------------------------------
| Id  | Operation                | Name     |    TQ  |IN-OUT| PQ Distrib |
-------------------------------------------------------------------------
|   0 | SELECT STATEMENT         |          |        |      |            |
|   1 |  SORT GROUP BY           |          |        |      |            |
|   2 |   PX COORDINATOR         |          |        |      |            |
|   3 |    PX SEND QC (RANDOM)| :TQ10000 |  Q1,00 | P->S | QC (RAND)  |
|   4 |     PX BLOCK ITERATOR |          |  Q1,00 | PCWC |            |
|   5 |      TABLE ACCESS FULL| T2       |  Q1,00 | PCWP |            |
-------------------------------------------------------------------------
```

PARALLEL UNFRIENDLY

```
create table t3 parallel
as
select * from t2
where rownum <= 10000000;
```

```
-------------------------------------------------------------------------------
| Id  | Operation                  | Name      |    TQ  |IN-OUT| PQ Distrib |
-------------------------------------------------------------------------------
|   0 | CREATE TABLE STATEMENT     |           |        |      |            |
|   1 |  PX COORDINATOR            |           |        |      |            |
|   2 |   PX SEND QC (RANDOM)      | :TQ20001  |  Q2,01 | P->S | QC (RAND)  |
|   3 |    LOAD AS SELECT          | T3        |  Q2,01 | PCWP |            |
|   4 |     PX RECEIVE             |           |  Q2,01 | PCWP |            |
|   5 |      PX SEND ROUND-ROBIN   | :TQ20000  |        | S->P | RND-ROBIN  |
|*  6 |       COUNT STOPKEY        |           |        |      |            |
|   7 |        PX COORDINATOR      |           |        |      |            |
|   8 |         PX SEND QC (RANDOM)| :TQ10000  |  Q1,00 | P->S | QC (RAND)  |
|*  9 |          COUNT STOPKEY     |           |  Q1,00 | PCWC |            |
|  10 |           PX BLOCK ITERATOR|           |  Q1,00 | PCWC |            |
|  11 |            TABLE ACCESS FULL| T2        |  Q1,00 | PCWP |            |
-------------------------------------------------------------------------------
```



PARALLEL UNFRIENDLY

```
create table t3 parallel
as select * from (select a.*,
lag(filler, 1) over (order by id) as prev_filler
from t2 a);
```

```
-------------------------------------------------------------------------------------
| Id  | Operation                        | Name     |    TQ  |IN-OUT| PQ Distrib |
-------------------------------------------------------------------------------------
|   0 | CREATE TABLE STATEMENT           |          |        |      |            |
|   1 |  PX COORDINATOR                  |          |        |      |            |
|   2 |   PX SEND QC (RANDOM)            | :TQ20001 |  Q2,01 | P->S | QC (RAND)  |
|   3 |    LOAD AS SELECT                | T3       |  Q2,01 | PCWP |            |
|   4 |     PX RECEIVE                   |          |  Q2,01 | PCWP |            |
|   5 |      PX SEND ROUND-ROBIN         | :TQ20000 |        | S->P | RND-ROBIN  |
|   6 |       VIEW                       |          |        |      |            |
|   7 |        WINDOW BUFFER             |          |        |      |            |
|   8 |         PX COORDINATOR           |          |        |      |            |
|   9 |          PX SEND QC (ORDER)      | :TQ10001 |  Q1,01 | P->S | QC (ORDER) |
|  10 |           SORT ORDER BY          |          |  Q1,01 | PCWP |            |
|  11 |            PX RECEIVE            |          |  Q1,01 | PCWP |            |
|  12 |             PX SEND RANGE        | :TQ10000 |  Q1,00 | P->P | RANGE      |
|  13 |              PX BLOCK ITERATOR   |          |  Q1,00 | PCWC |            |
|  14 |               TABLE ACCESS FULL  | T2       |  Q1,00 | PCWP |            |
-------------------------------------------------------------------------------------
```

PARALLEL UNFRIENDLY

All these examples have one thing in common:

If the Query Coordinator (non-parallel part) needs to perform a significant part of the overall work, Parallel Execution won't reduce the runtime as expected

CHALLENGES

Two major challenges

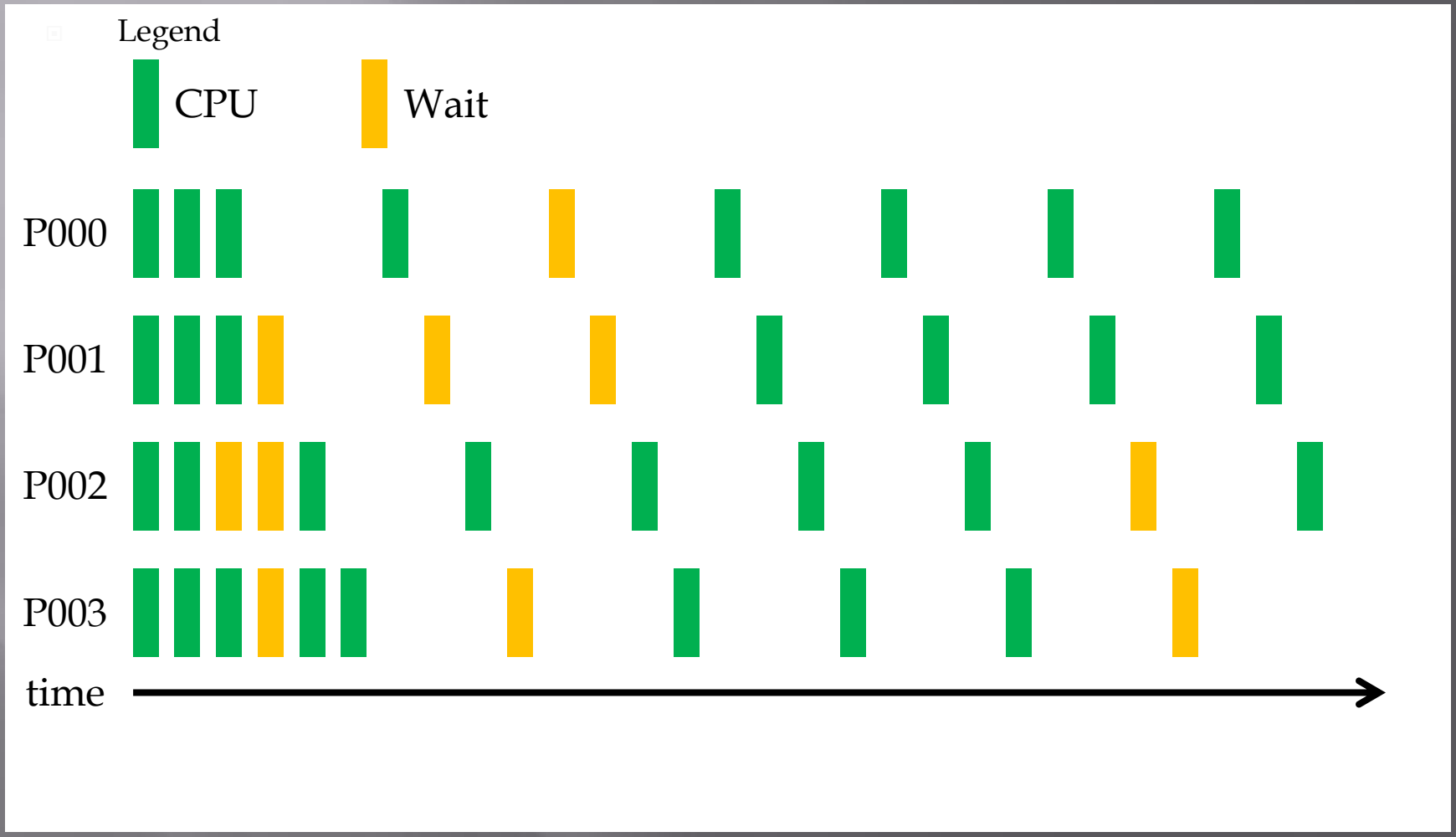
Can the given task be divided into sub-tasks that can efficiently and independently be processed by the workers? (“Parallel Unfriendly”)

Can all assigned workers be kept busy all the time?

ALL WORKERS BUSY

DATA DISTRIBUTION SKEW

TEMPORAL SKEW



AGENDA

- Parallel Execution introduction
- Major challenges
  - Parallel unfriendly examples
  - Distribution skew examples
- How to measure distribution of work
- How to systematically analyze distribution

CHALLENGES

Measure Parallel Execution work distribution

- From 11g on: Real Time SQL Monitoring
- Requires Diagnostics + Tuning Pack license
- Based on Active Session History to large degree

REAL-TIME SQL MONITORING

- Analysis of a single SQL execution
- Provides Elapsed Time and DB Time
- Shows Average Active Sessions graph
- Shows DB Time per Parallel Worker process

REAL-TIME SQL MONITORING

- ✓ Easy to identify whether all workers are kept busy all the time or not
- ✓ Easy to identify if there was a problem with work distribution
- ✓ Shows actual parallel degree used (“Parallel Downgrade”)
- ✓ Supports RAC

REAL-TIME SQL MONITORING

- ✗ Reports are not persisted and will be flushed from memory quite quickly on busy systems
- ✗ No easy identification and therefore no systematic troubleshooting which plan operations cause a work distribution problem
- ✗ Lacks some precision regarding Parallel Execution details

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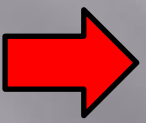

PARALLEL EXECUTION SKEW

Analyzing Data Distribution Skew

- Real-Time SQL Monitoring: Not part of report, requires custom query, only data distribution skew
- V$PQ_TQSTAT: requires to reproduce, fails for complex queries, only data distribution skew
- Extended SQL Trace: requires to reproduce, many trace files, only data distribution skew

PARALLEL EXECUTION SKEW

- One very useful approach is using Active Session History (ASH)
- ASH samples active sessions once a second
- Activity of Parallel Workers over time can easily be analyzed
- From 11g on the ASH data even contains a reference to the execution plan line, so a relation between Parallel Worker activity and execution plan line based on ASH is possible

PARALLEL EXECUTION SKEW

- Custom queries on ASH data required for detailed analysis
- XPLAN_ASH tool runs these queries for a given SQL_ID execution
- Advantage of ASH is the availability of retained historic ASH data via AWR on disk
- Information can be extracted even for SQL executions as long ago as the retention configured for AWR

PARALLEL EXECUTION SKEW

Fixing Data Distribution Skew

- Influence Parallel Distribution: Data volume estimates, PQ_DISTRIBUTE hint
- Partitioning: Partition-wise operations
- Rewrite queries
- Change application design

QUESTIONS & ANSWERS

Q & A