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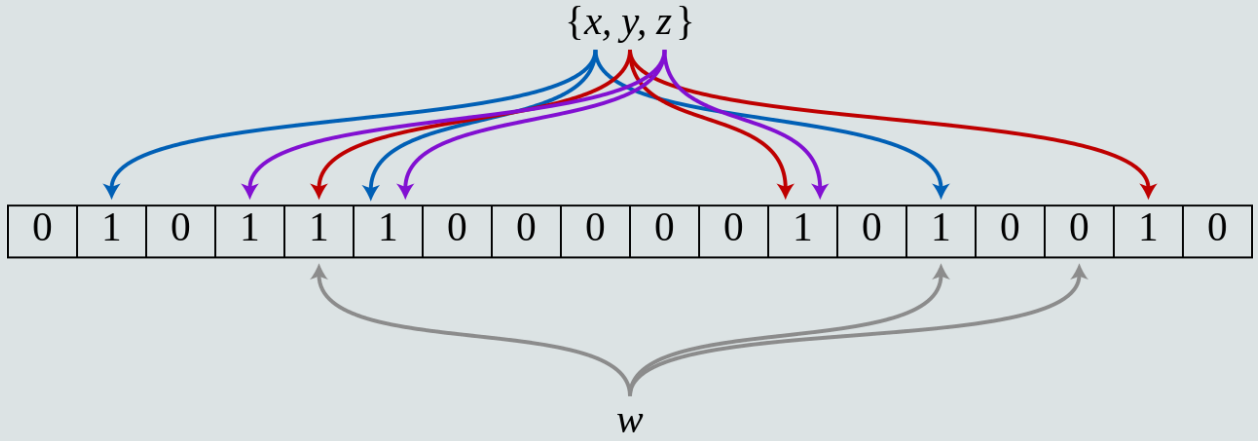
# Bloom filters

**Toon Koppelaars**

**Real World Performance team**
**Database Server Technologies**

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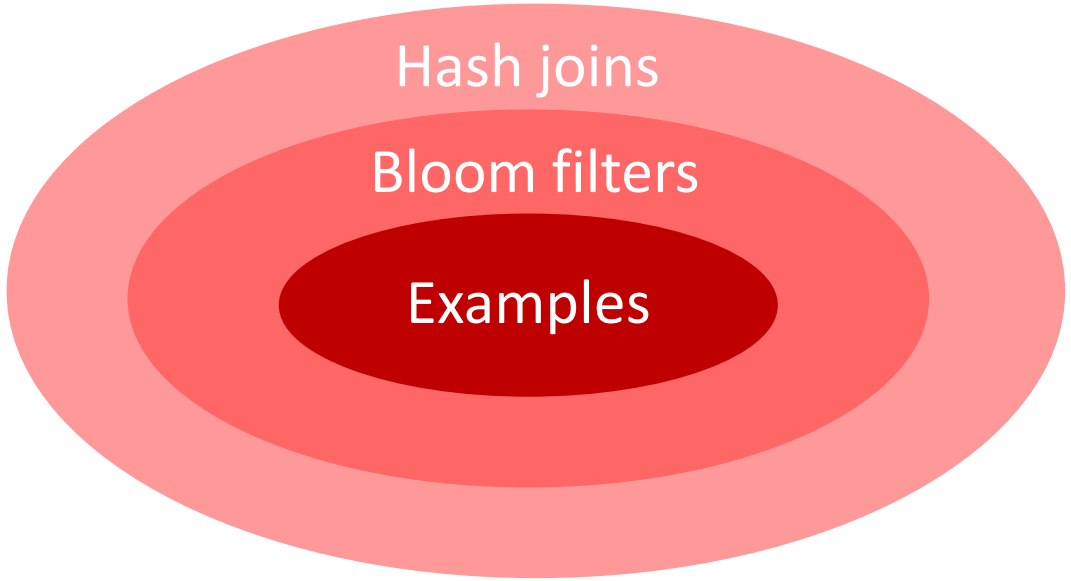
# Agenda



# Hash joins and Bloom filters

- Bloom filters (BF) introduced in 10gR2
  - Enable CBO to “filter early” in hash joins
  - Used automatically, visible in execution plan

- Implemented to speed up large parallel hash joins (DWH/BI)
  - BF’s created from dimension tables and applied to fact table during scan
  - To prevent unnecessary row-transport between parallel query slave sets

- As of 11.2.0.4 BF’s may also show up in serial plans

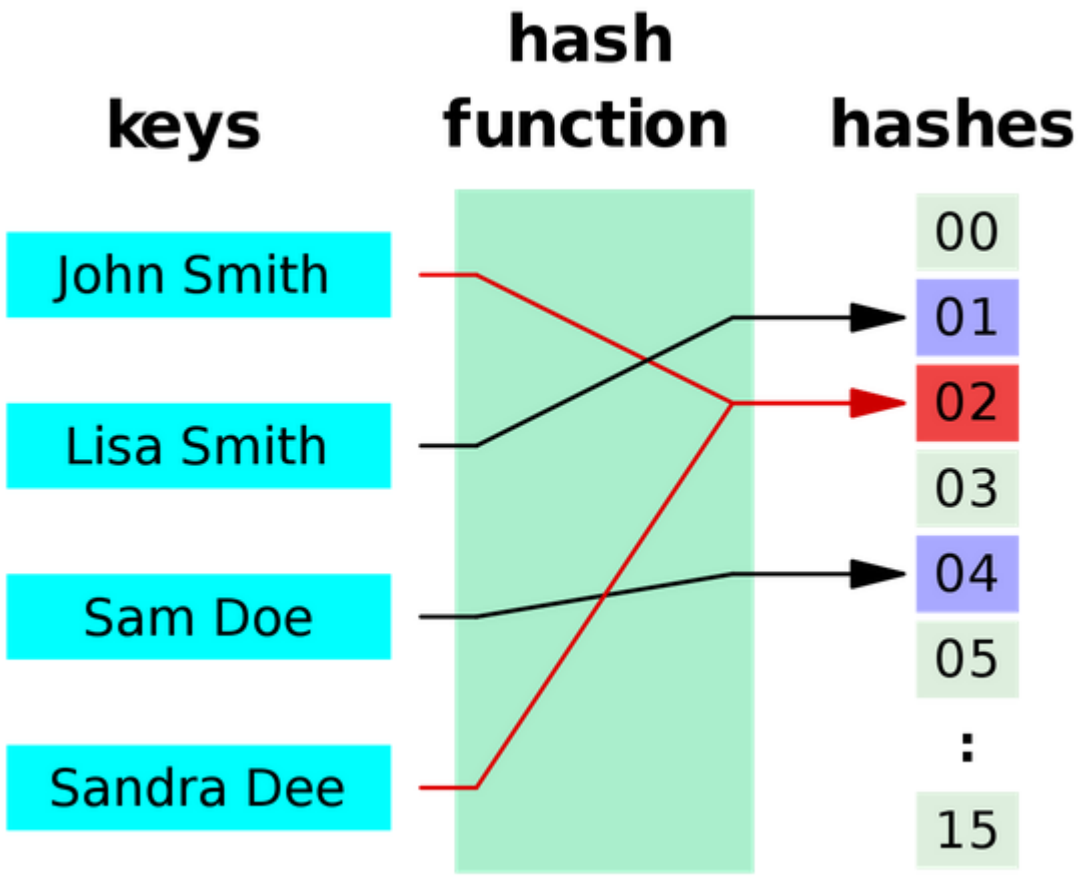
# Hash joins explained

```
select *
from emp e, dept d
where d.deptno = e.deptno
```

```
-----------------------------------
| Id  | Operation          | Name |
-----------------------------------
|   0 | SELECT STATEMENT   |      |
|*  1 |  HASH JOIN         |      |
|   2 |   TABLE ACCESS FULL| DEPT |
|   3 |   TABLE ACCESS FULL| EMP  |
-----------------------------------
Predicate Information
---------------------------------------
  1 - access("D"."DEPTNO"="E"."DEPTNO")
```

# What is a hash-function?

- Hash function takes arbitrary value as input domain
  - Digital data (byte string) of any length
- Hash function computes what's called a "hash value" for given input
  - Hash value = numerical offset in range of function
  - Range is typically [0..some-power-of-2 minus 1]
- Hash values are typically "evenly distributed" in range
  - Irrespective of distribution of input values
- Collisions can occur (#domain > #range)



# Phase 1: build hash table (DEPT)

```
select *
from emp e, dept d
where d.deptno = e.deptno
```

```
-----------------------------------
| Id  | Operation           | Name |
-----------------------------------
|   0 | SELECT STATEMENT    |      |
|*  1 |  HASH JOIN          |      |
|   2 |   TABLE ACCESS FULL | DEPT |
|   3 |   TABLE ACCESS FULL | EMP  |
-----------------------------------
Predicate Information
-----------------------------------
  1 - access("D"."DEPTNO"="E"."DEPTNO")
```

scan

| DEPTNO | DNAME | LOC |
|---|---|---|
| 1 | ACCOUNTING | NEW YORK |
| 2 | RESEARCH | DALLAS |
| 3 | SALES | CHICAGO |
| 4 | OPERATIONS | BOSTON |

Apply hash function to DEPT.DEPTNO to find in which bucket to store

Build phase


Bucketized hash-table in memory

# Phase 2: probe phase (EMP)

```
select *
from emp e, dept d
where d.deptno = e.deptno
```

```
-------------------------------------
| Id  | Operation          | Name |
-------------------------------------
|   0 | SELECT STATEMENT   |      |
|*  1 |  HASH JOIN         |      |
|   2 |   TABLE ACCESS FULL| DEPT |
|   3 |   TABLE ACCESS FULL| EMP  |
-------------------------------------
Predicate Information
---------------------------------------
  1 - access("D"."DEPTNO"="E"."DEPTNO")
```

# Phase 2: probe phase (EMP)

```
select *
from emp e, dept d
where d.deptno = e.deptno
```

```
-------------------------------------
| Id  | Operation           | Name  |
-------------------------------------
|   0 | SELECT STATEMENT    |       |
|*  1 |  HASH JOIN          |       |
|   2 |   TABLE ACCESS FULL | DEPT  |
|   3 |   TABLE ACCESS FULL | EMP   |
-------------------------------------
Predicate Information
-------------------------------------
  1 - access("D"."DEPTNO"="E"."DEPTNO")
```

scan

| EMPNO | ENAME | JOB | MGR | HIREDATE | SAL | COMM | DEPTNO |
|---|---|---|---|---|---|---|---|
| 1 | SMITH | CLERK | 7902 | 17-DEC-80 | 800 | | 2 |
| 2 | ALLEN | SALESMAN | 7698 | 20-FEB-81 | 1600 | 300 | 3 |
| 3 | WARD | SALESMAN | 7698 | 22-FEB-81 | 1250 | 500 | 4 |
| 4 | JONES | MANAGER | 7839 | 02-APR-81 | 2975 | | 5 |
| 5 | MARTIN | SALESMAN | 7698 | 28-SEP-81 | 1250 | 1400 | 6 |
| 6 | BLAKE | MANAGER | 7839 | 01-MAY-81 | 2850 | | 7 |
| 7 | CLARK | MANAGER | 7839 | 09-JUN-81 | 2450 | | 8 |
| 8 | SCOTT | ANALYST | 7566 | 19-APR-87 | 3000 | | 9 |
| 9 | KING | PRESIDENT | | 17-NOV-81 | 5000 | | 10 |
| 10 | TURNER | SALESMAN | 7698 | 08-SEP-81 | 1500 | 0 | 11 |
| 11 | ADAMS | CLERK | 7788 | 23-MAY-87 | 1100 | | 12 |
| 12 | JAMES | CLERK | 7698 | 03-DEC-81 | 950 | | 13 |
| 13 | FORD | ANALYST | 7566 | 03-DEC-81 | 3000 | | 14 |
| 14 | MILLER | CLERK | 7782 | 23-JAN-82 | 1300 | | 15 |

Apply hash function to EMP.DEPTNO to find in which bucket to probe for matching DEPT record
If match found: join and return row

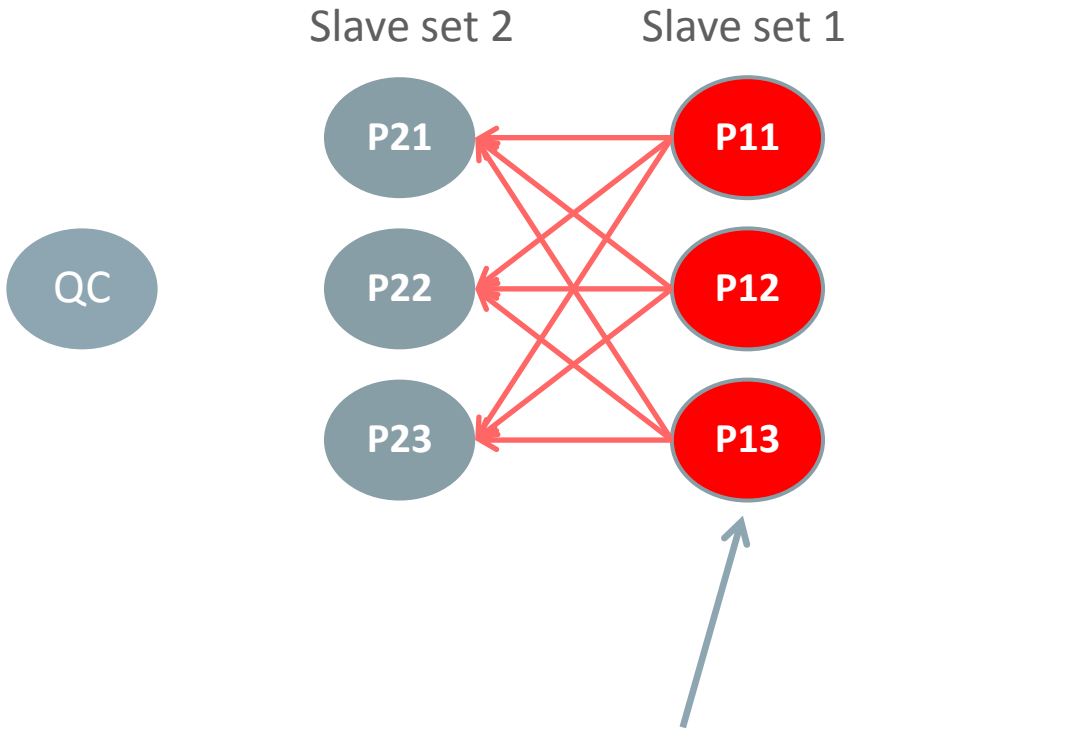
Probe phase

# Hash joins parallel execution plan

```
-------------------------------------------------------------------------------
| Id  | Operation                | Name     |    TQ  |IN-OUT| PQ Distrib |
-------------------------------------------------------------------------------
|   0 | SELECT STATEMENT         |          |        |      |            |
|   1 |  PX COORDINATOR          |          |        |      |            |
|   2 |   PX SEND QC (RANDOM)    | :TQ10002 |  Q1,02 | P->S | QC (RAND)  |
|*  3 |    HASH JOIN             |          |  Q1,02 | PCWP |            |
|   4 |     PX RECEIVE           |          |  Q1,02 | PCWP |            |
|   5 |      PX SEND HASH        | :TQ10000 |  Q1,00 | P->P | HASH       |
|   6 |       PX BLOCK ITERATOR  |          |  Q1,00 | PCWC |            |
|   7 |        TABLE ACCESS FULL | DEPT     |  Q1,00 | PCWP |            |
|   8 |     PX RECEIVE           |          |  Q1,02 | PCWP |            |
|   9 |      PX SEND HASH        | :TQ10001 |  Q1,01 | P->P | HASH       |
|  10 |       PX BLOCK ITERATOR  |          |  Q1,01 | PCWC |            |
|  11 |        TABLE ACCESS FULL | EMP      |  Q1,01 | PCWP |            |
-------------------------------------------------------------------------------
Predicate Information (identified by operation id):
---------------------------------------------------
   3 - access("D"."DEPTNO"="E"."DEPTNO")
```

# Hash joins parallel execution plan

```
-------------------------------------------------------------------------------
| Id  | Operation                | Name     |    TQ  |IN-OUT| PQ Distrib |
-------------------------------------------------------------------------------
|   0 | SELECT STATEMENT         |          |        |      |            |
|   1 |  PX COORDINATOR          |          |        |      |            |
|   2 |   PX SEND QC (RANDOM)    | :TQ10002 |  Q1,02 | P->S | QC (RAND)  |
|*  3 |    HASH JOIN             |          |  Q1,02 | PCWP |            |
|   4 |     PX RECEIVE           |          |  Q1,02 | PCWP |            |
|   5 |      PX SEND HASH        | :TQ10000 |  Q1,00 | P->P | HASH       |
|   6 |       PX BLOCK ITERATOR  |          |  Q1,00 | PCWC |            |
|   7 |        TABLE ACCESS FULL | DEPT     |  Q1,00 | PCWP |            |
|   8 |     PX RECEIVE           |          |  Q1,02 | PCWP |            |
|   9 |      PX SEND HASH        | :TQ10001 |  Q1,01 | P->P | HASH       |
|  10 |       PX BLOCK ITERATOR  |          |  Q1,01 | PCWC |            |
|  11 |        TABLE ACCESS FULL | EMP      |  Q1,01 | PCWP |            |
-------------------------------------------------------------------------------
Predicate Information (identified by operation id):
---------------------------------------------------
   3 - access("D"."DEPTNO"="E"."DEPTNO")
```

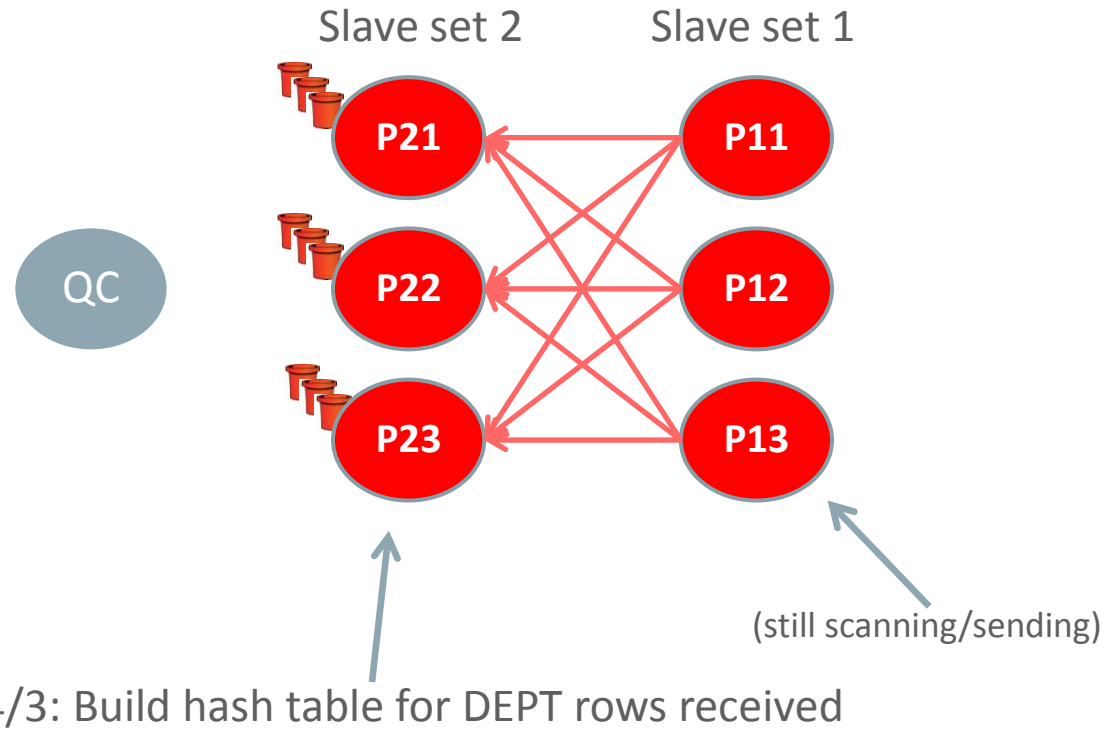



Lines 7,6,5: Scan DEPT, hash send to SS2

Hash PQ Distrib:
simply distributes rows based on
mod(hash(deptno),3)

# Hash joins parallel execution plan

```
-------------------------------------------------------------------------------
| Id  | Operation                | Name     |    TQ  |IN-OUT| PQ Distrib |
-------------------------------------------------------------------------------
|   0 | SELECT STATEMENT         |          |        |      |            |
|   1 |  PX COORDINATOR          |          |        |      |            |
|   2 |   PX SEND QC (RANDOM)    | :TQ10002 |  Q1,02 | P->S | QC (RAND)  |
|*  3 |    HASH JOIN             |          |  Q1,02 | PCWP |            |
|   4 |     PX RECEIVE           |          |  Q1,02 | PCWP |            |
|   5 |      PX SEND HASH        | :TQ10000 |  Q1,00 | P->P | HASH       |
|   6 |       PX BLOCK ITERATOR  |          |  Q1,00 | PCWC |            |
|   7 |        TABLE ACCESS FULL| DEPT     |  Q1,00 | PCWP |            |
|   8 |     PX RECEIVE           |          |  Q1,02 | PCWP |            |
|   9 |      PX SEND HASH        | :TQ10001 |  Q1,01 | P->P | HASH       |
|  10 |       PX BLOCK ITERATOR  |          |  Q1,01 | PCWC |            |
|  11 |        TABLE ACCESS FULL| EMP      |  Q1,01 | PCWP |            |
-------------------------------------------------------------------------------
Predicate Information (identified by operation id):
---------------------------------------------------
   3 - access("D"."DEPTNO"="E"."DEPTNO")
```



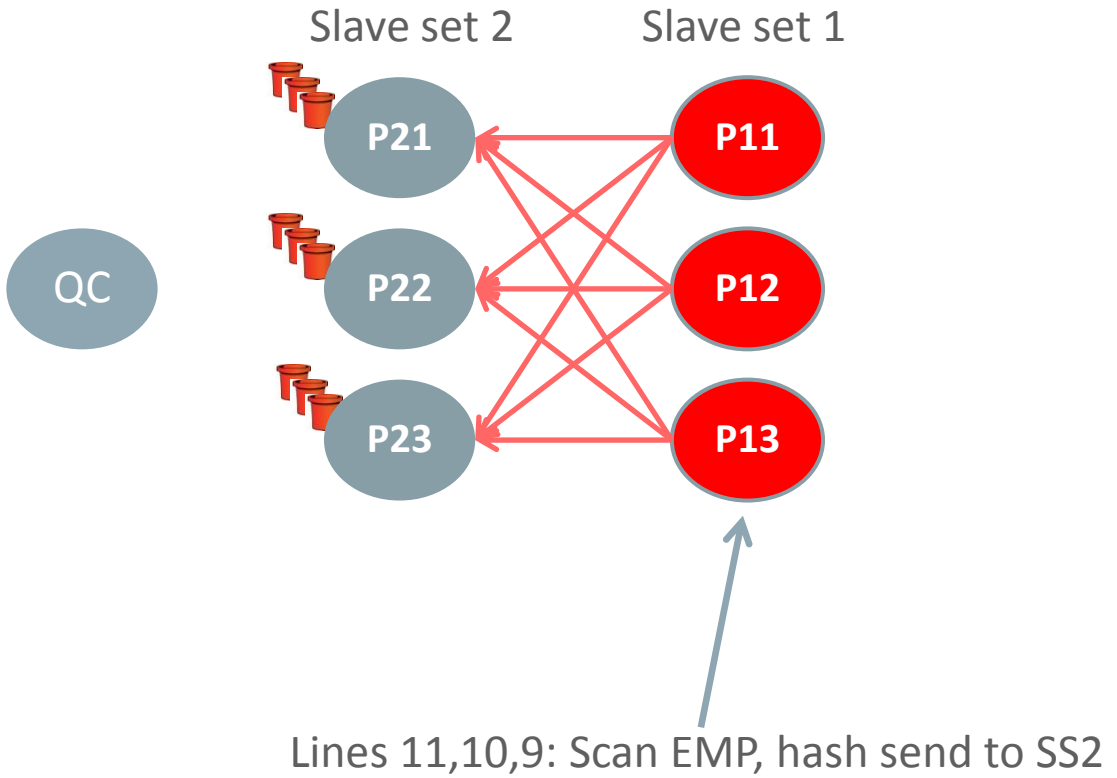
# Hash joins parallel execution plan

```
-------------------------------------------------------------------------------
| Id  | Operation                | Name     |    TQ  |IN-OUT| PQ Distrib |
-------------------------------------------------------------------------------
|   0 | SELECT STATEMENT         |          |        |      |            |
|   1 |  PX COORDINATOR          |          |        |      |            |
|   2 |   PX SEND QC (RANDOM)    | :TQ10002 |  Q1,02 | P->S | QC (RAND)  |
|*  3 |    HASH JOIN             |          |  Q1,02 | PCWP |            |
|   4 |     PX RECEIVE           |          |  Q1,02 | PCWP |            |
|   5 |      PX SEND HASH        | :TQ10000 |  Q1,00 | P->P | HASH       |
|   6 |       PX BLOCK ITERATOR  |          |  Q1,00 | PCWC |            |
|   7 |        TABLE ACCESS FULL| DEPT     |  Q1,00 | PCWP |            |
|   8 |     PX RECEIVE           |          |  Q1,02 | PCWP |            |
|   9 |      PX SEND HASH        | :TQ10001 |  Q1,01 | P->P | HASH       |
|  10 |       PX BLOCK ITERATOR  |          |  Q1,01 | PCWC |            |
|  11 |        TABLE ACCESS FULL| EMP      |  Q1,01 | PCWP |            |
-------------------------------------------------------------------------------
Predicate Information (identified by operation id):
---------------------------------------------------
   3 - access("D"."DEPTNO"="E"."DEPTNO")
```


Build phase ready

# Hash joins parallel execution plan

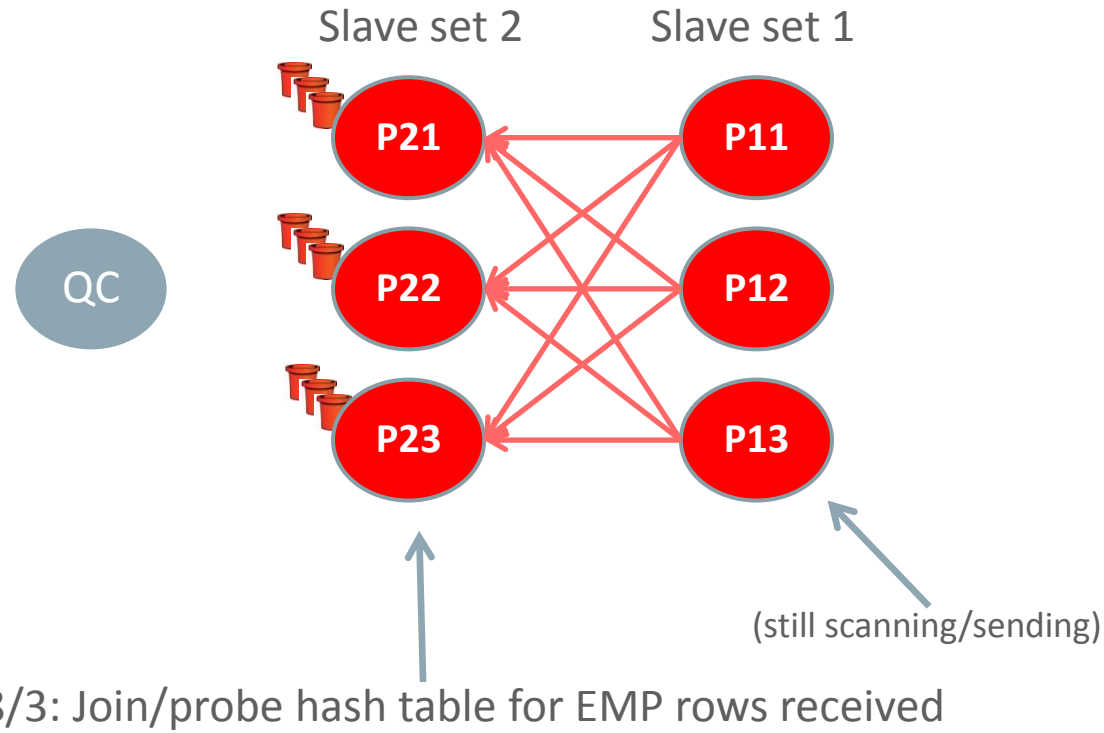
```
-------------------------------------------------------------------------------
| Id  | Operation                | Name     |    TQ  |IN-OUT| PQ Distrib |
-------------------------------------------------------------------------------
|   0 | SELECT STATEMENT         |          |        |      |            |
|   1 |  PX COORDINATOR          |          |        |      |            |
|   2 |   PX SEND QC (RANDOM)    | :TQ10002 |  Q1,02 | P->S | QC (RAND)  |
|*  3 |    HASH JOIN             |          |  Q1,02 | PCWP |            |
|   4 |     PX RECEIVE           |          |  Q1,02 | PCWP |            |
|   5 |      PX SEND HASH        | :TQ10000 |  Q1,00 | P->P | HASH       |
|   6 |       PX BLOCK ITERATOR  |          |  Q1,00 | PCWC |            |
|   7 |        TABLE ACCESS FULL | DEPT     |  Q1,00 | PCWP |            |
|   8 |     PX RECEIVE           |          |  Q1,02 | PCWP |            |
|   9 |      PX SEND HASH        | :TQ10001 |  Q1,01 | P->P | HASH       |
|  10 |       PX BLOCK ITERATOR  |          |  Q1,01 | PCWC |            |
|  11 |        TABLE ACCESS FULL | EMP      |  Q1,01 | PCWP |            |
-------------------------------------------------------------------------------
Predicate Information (identified by operation id):
---------------------------------------------------
   3 - access("D"."DEPTNO"="E"."DEPTNO")
```




Same mod(hash(deptno),3) distribution used

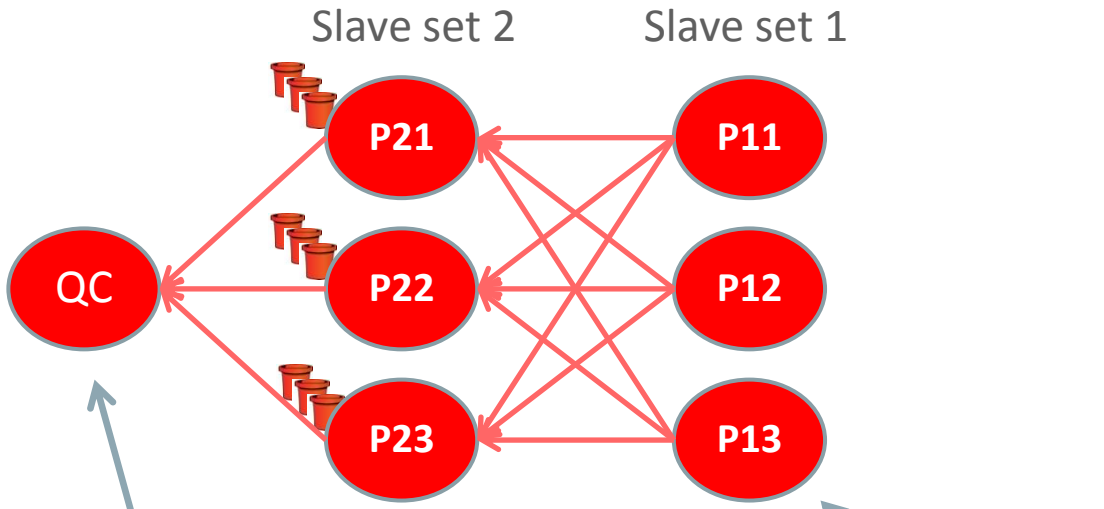
# Hash joins parallel execution plan

```
-------------------------------------------------------------------------------
| Id  | Operation                | Name     |    TQ  |IN-OUT| PQ Distrib |
-------------------------------------------------------------------------------
|   0 | SELECT STATEMENT         |          |        |      |            |
|   1 |  PX COORDINATOR          |          |        |      |            |
|   2 |   PX SEND QC (RANDOM)    | :TQ10002 |  Q1,02 | P->S | QC (RAND)  |
| * 3 |    HASH JOIN             |          |  Q1,02 | PCWP |            |
|   4 |     PX RECEIVE           |          |  Q1,02 | PCWP |            |
|   5 |      PX SEND HASH        | :TQ10000 |  Q1,00 | P->P | HASH       |
|   6 |       PX BLOCK ITERATOR  |          |  Q1,00 | PCWC |            |
|   7 |        TABLE ACCESS FULL| DEPT     |  Q1,00 | PCWP |            |
|   8 |    PX RECEIVE            |          |  Q1,02 | PCWP |            |
|   9 |      PX SEND HASH        | :TQ10001 |  Q1,01 | P->P | HASH       |
|  10 |       PX BLOCK ITERATOR  |          |  Q1,01 | PCWC |            |
|  11 |        TABLE ACCESS FULL| EMP      |  Q1,01 | PCWP |            |
-------------------------------------------------------------------------------
Predicate Information (identified by operation id):
---------------------------------------------------
   3 - access("D"."DEPTNO"="E"."DEPTNO")
```



# Hash joins parallel execution plan

```
-------------------------------------------------------------------------------
| Id  | Operation                | Name     |    TQ  |IN-OUT| PQ Distrib |
-------------------------------------------------------------------------------
|   0 | SELECT STATEMENT         |          |        |      |            |
|   1 |  PX COORDINATOR          |          |        |      |            |
|   2 |   PX SEND QC (RANDOM)    | :TQ10002 |  Q1,02 | P->S | QC (RAND)  |
|*  3 |    HASH JOIN             |          |  Q1,02 | PCWP |            |
|   4 |     PX RECEIVE           |          |  Q1,02 | PCWP |            |
|   5 |      PX SEND HASH        | :TQ10000 |  Q1,00 | P->P | HASH       |
|   6 |       PX BLOCK ITERATOR  |          |  Q1,00 | PCWC |            |
|   7 |        TABLE ACCESS FULL | DEPT     |  Q1,00 | PCWP |            |
|   8 |     PX RECEIVE           |          |  Q1,02 | PCWP |            |
|   9 |      PX SEND HASH        | :TQ10001 |  Q1,01 | P->P | HASH       |
|  10 |       PX BLOCK ITERATOR  |          |  Q1,01 | PCWC |            |
|  11 |        TABLE ACCESS FULL | EMP      |  Q1,01 | PCWP |            |
-------------------------------------------------------------------------------
Predicate Information (identified by operation id):
---------------------------------------------------
   3 - access("D"."DEPTNO"="E"."DEPTNO")
```



# Filter early

- What do we mean by “filter early”?
  - In the hierarchical execution plan tree
  - Eliminate rows as soon (early) as possible
  - Preventing their (expensive) flow through parent execution stages in plan

# Filter early: join example

Remember this plan
BF's operate in same way

```
select d.dname,e.ename
 from dept d, emp e
 where d.deptno = e.deptno
    and d.deptno between 130 and 150
```

```
-----------------------------------------------------------------------------
| Id  | Operation                             | Name    | Starts | A-Rows |
-----------------------------------------------------------------------------
|   0 | SELECT STATEMENT                      |         |      1 |     84 |
|*  1 |  HASH JOIN                            |         |      1 |     84 |
|   2 |   TABLE ACCESS BY INDEX ROWID BATCHED | DEPT    |      1 |     21 |
|*  3 |    INDEX RANGE SCAN                   | DEPT_PK |      1 |     21 |
|*  4 |   TABLE ACCESS FULL                   | EMP     |      1 |     84 | <== Filter!
-----------------------------------------------------------------------------
Predicate Information (identified by operation id):
---------------------------------------------------
  1 - access("D"."DEPTNO"="E"."DEPTNO")
  3 - access("D"."DEPTNO">=130 AND "D"."DEPTNO"<=150)
  4 - filter(("E"."DEPTNO">=130 AND "E"."DEPTNO"<=150))
```

# Bloom filter concept

# Bloom filter concept

- Memory structure representing a *set of values* (say S)
  - "representing" ➔ member values are encoded in specific manner
- Memory structure can be used to answer:
  - Is a given value x, member of set S?
- Two possible answers
  - Definitely not
  - Probably yes

Two operators on structure:
1) Add value x
2) Test membership

Conceived by Burton Howard Bloom in 1970

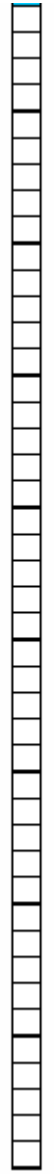
# Bloom filter concept

- BF(k,m)
  - k = number of hash functions used to encode value ($hf_1$,…,$hf_k$)
  - m = size of memory structure in bits (array of m bits)

  Hash-functions produce hash-value >=m, then moduled between 0..m-1

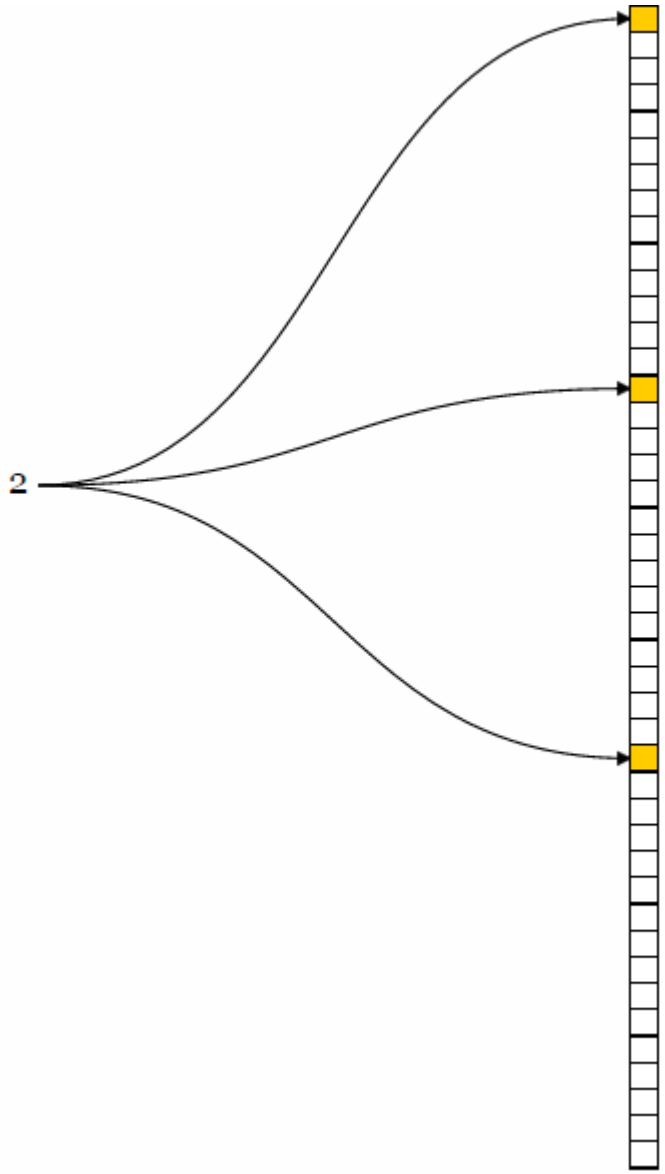
  Bit array initially filled with 0's

- Adding (encoding) a value x:
  - Apply each hash-function to value x ➔ this produces k hash-values
  - Set bit in array at each hash-value's position

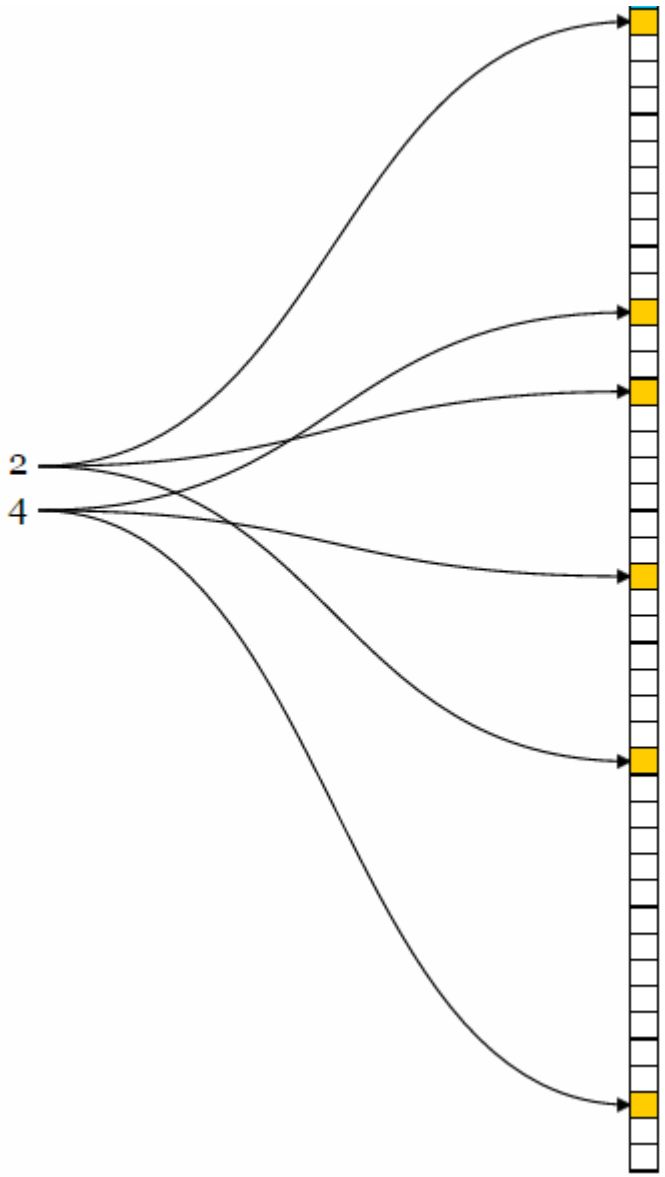


# Bloom filter: adding value 2

Assuming 3 hash functions used

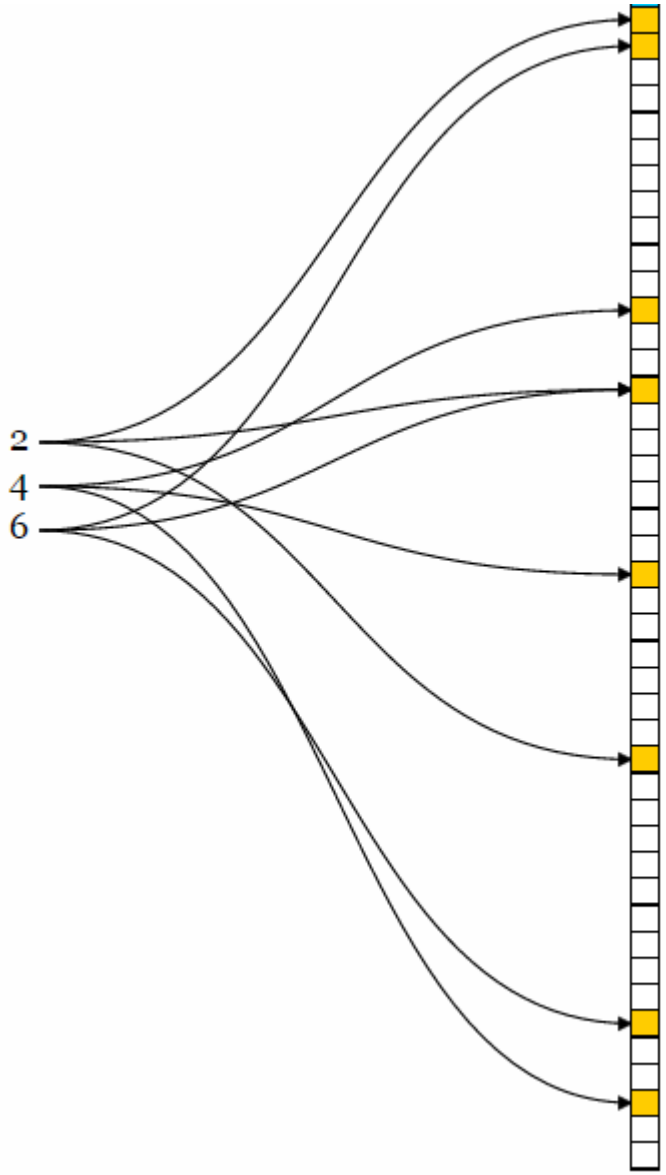


# Bloom filter: adding value 4



# Bloom filter: adding value 6

Note:
one of hashes of 6 is same as
one of hashes of 2

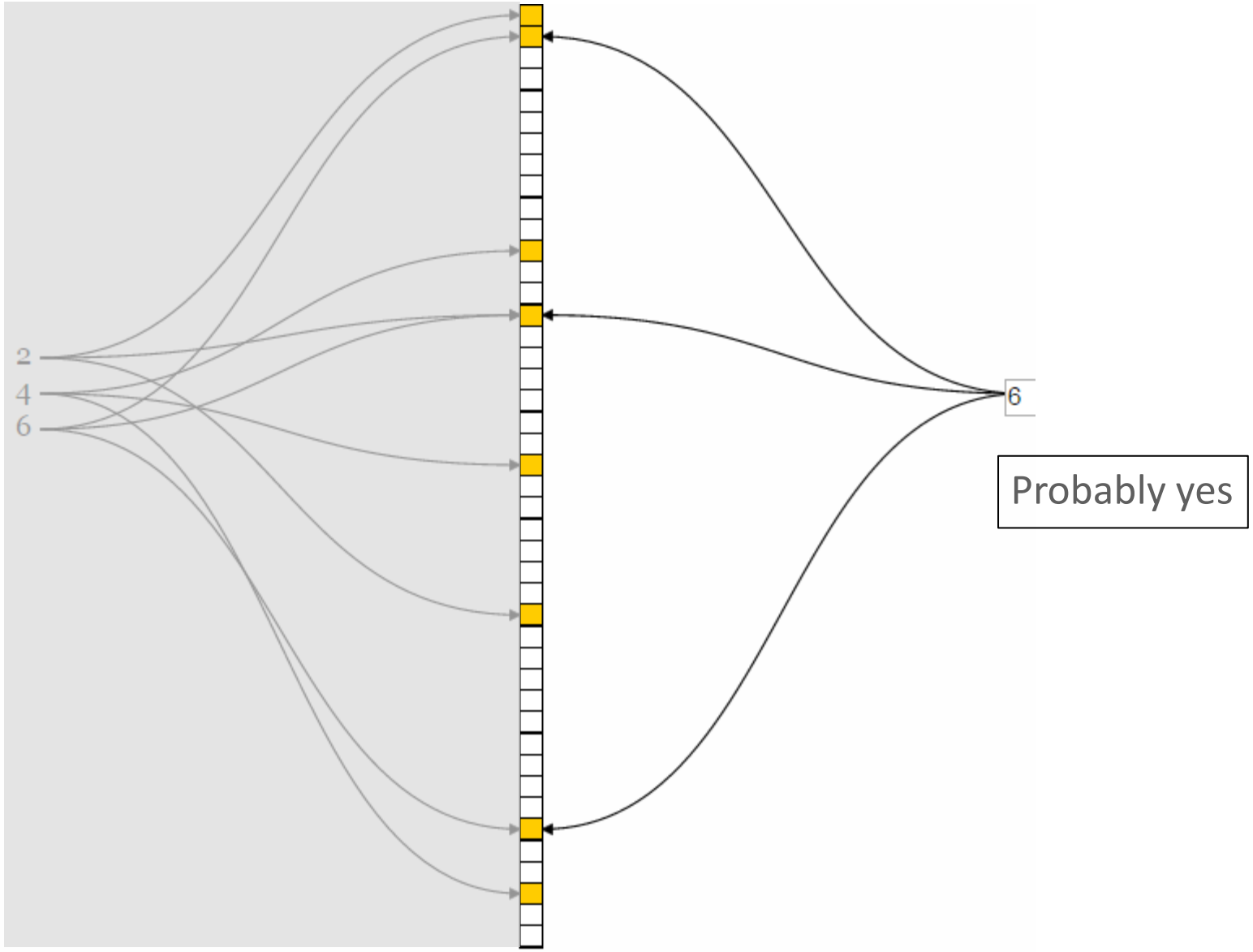


# Bloom filter: testing for membership

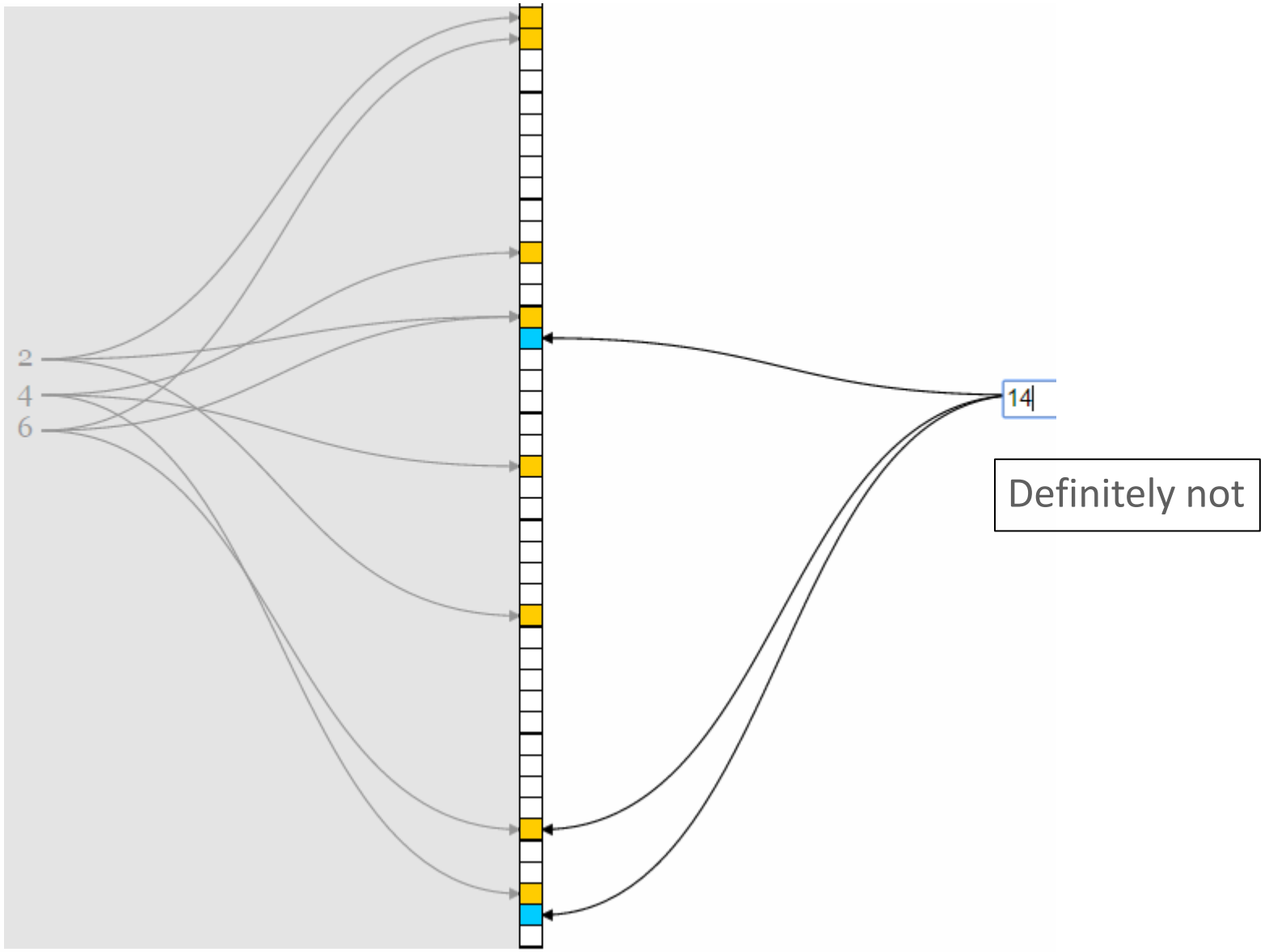
- Once bloom filter is populated with complete set, we can test for membership of any given value
  - By just applying the hash-functions to the value
  - And checking if all positions in bit-array are filled with 1
- If any not filled ➔ then *definitely not* a member of the set
- If all filled ➔ then *probably* (!) member of the set

- Two possible answers
  - Definitely not
  - Probably yes

# Testing value 6



# Testing value 14



# False positives possible

- Likelihood increases when bit-array is sized too small

- Demo: https://www.jasondavies.com/bloomfilter/

# Bloom filter sizing

- CBO uses estimated NDV to size Bloom filter (*)

- Demo: http://hur.st/bloomfilter?n=100000&p=0.01

(*) Not true anymore (folding/unfolding)

# Why use Bloom filters?

1. Memory structure is small
   - Around 9-10 bits per (distinct) element required for a 1% false positive probability
2. Add and test operators are fast
   - Cheap hash + fast bit set/test operations
3. Enable early filtering (definitely not an element of set)
   - As we'll see shortly

➔ Bloom filters are cheap to create, use and dispose of, on-the-fly

# How can Bloom filter help filter early?

- BF use-cases in hash-join are of the form:
  - In BUILD stage of execution plan: BF CREATE
  - Then during PROBE scan stage of execution plan: BF USE

# Bloom filter use cases

- Parallel join filter
- Serial subquery filter
- Multiple BF’s (rightdeep tree)
- Bloom pruning filter

# Parallel join filter

```
select d.dname,e.ename
from dept d, emp e
where d.deptno = e.deptno
    and d.loc = 'UTRECHT'
```

False positives caught in line 3

What is saved?
- Row distr. SS2 → SS1
- Bit vs byte comparisons

:BF0000 =
bit signature of join condition

```
-----------------------------------------
| Id  | Operation                | Name     |
-----------------------------------------
|   0 | SELECT STATEMENT         |          |
|   1 |  PX COORDINATOR          |          |
|   2 |   PX SEND QC (RANDOM)    | :TQ10002 |
| * 3 |    HASH JOIN             |          |
|   4 |     JOIN FILTER CREATE   | :BF0000  |
|   5 |      PX RECEIVE          |          |
|   6 |       PX SEND HASH       | :TQ10000 |
|   7 |        PX BLOCK ITERATOR |          |
| * 8 |         TABLE ACCESS FULL| DEPT     |
|   9 |     PX RECEIVE           |          |
|  10 |      PX SEND HASH        | :TQ10001 |
|  11 |       JOIN FILTER USE    | :BF0000  |
|  12 |        PX BLOCK ITERATOR |          |
| * 13 |         TABLE ACCESS FULL| EMP      |
-----------------------------------------
Predicate Information (identified by operation id):
---------------------------------------------------
   3 - access("D"."DEPTNO"="E"."DEPTNO")
   8 - filter("D"."LOC"='UTRECHT')
  13 - filter(SYS_OP_BLOOM_FILTER(:BF0000,"E"."DEPTNO"))
```

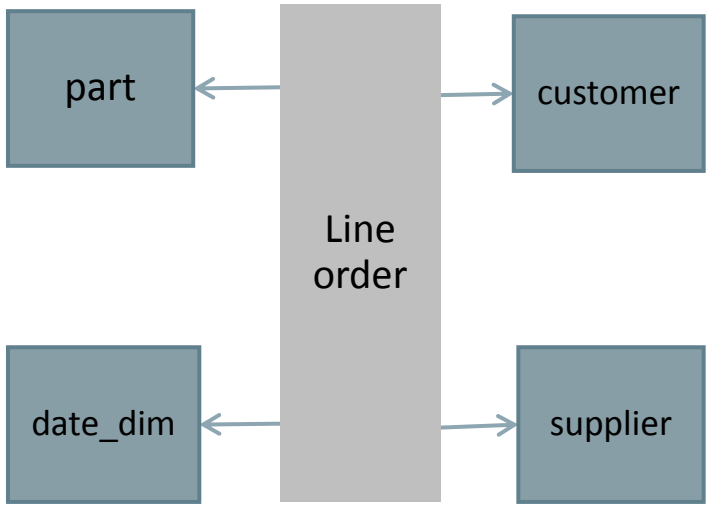
# Serial subquery filter

```
select d.dname,e.disnm
 from dept d
     ,(select deptno
             ,count(distinct ename)
                                as disnm
         from emp
    group by deptno) e
where d.loc='UTRECHT'
     and d.deptno = e.deptno
```

BF push through GB

```
-----------------------------------------------------------------------
| Id  | Operation                | Name       | Starts | A-Rows |
-----------------------------------------------------------------------
|   0 | SELECT STATEMENT         |            |      1 |     11 |
|   1 |  HASH GROUP BY           |            |      1 |     11 |
|*  2 |   HASH JOIN              |            |      1 |     44 |
|   3 |    JOIN FILTER CREATE    | :BF0000    |      1 |     11 |
|*  4 |     TABLE ACCESS FULL    | DEPT       |      1 |     11 |
|   5 |    VIEW                  | VM_NWVW_1  |      1 |     44 |
|   6 |     HASH GROUP BY        |            |      1 |     44 |
|   7 |      JOIN FILTER USE     | :BF0000    |      1 |     44 |
|*  8 |       TABLE ACCESS FULL  | EMP        |      1 |     44 |
-----------------------------------------------------------------------
Predicate Information (identified by operation id):
---------------------------------------------------
   2 - access("D"."DEPTNO"="$vm_col_2")
   4 - filter("D"."LOC"='UTRECHT')
   8 - filter(SYS_OP_BLOOM_FILTER(:BF0000,"DEPTNO"))
```

# Mutliple Bloom filters




```
-------------------------------------------------------------------------------
| Id  | Operation                          | Name        | Rows  | Bytes |
-------------------------------------------------------------------------------
|   0 | SELECT STATEMENT                   |             |    63 |  7371 |
|   1 |  PX COORDINATOR                    |             |       |       |
|   2 |   PX SEND QC (ORDER)               | :TQ10003    |    63 |  7371 |
|   3 |    SORT GROUP BY                   |             |    63 |  7371 |
|   4 |     PX RECEIVE                     |             |    63 |  7371 |
|   5 |      PX SEND RANGE                 | :TQ10002    |    63 |  7371 |
|   6 |       HASH GROUP BY                |             |    63 |  7371 |
|*  7 |        HASH JOIN                   |             |   430 | 50310 |
|   8 |         JOIN FILTER CREATE         | :BF0000     |  4013 |  133K|
|   9 |          PX RECEIVE                |             |  4013 |  133K|
|  10 |           PX SEND BROADCAST        | :TQ10000    |  4013 |  133K|
|  11 |            PX BLOCK ITERATOR       |             |  4013 |  133K|
|* 12 |             TABLE ACCESS INMEMORY FULL | SUPPLIER |  4013 |  133K|
|* 13 |         HASH JOIN                  |             | 10589 |  858K|
|  14 |          JOIN FILTER CREATE        | :BF0001     |    31 |  1023 |
|* 15 |           TABLE ACCESS INMEMORY FULL | DATE_DIM  |    31 |  1023 |
|* 16 |          HASH JOIN                 |             |  845K|    40M|
|  17 |           JOIN FILTER CREATE       | :BF0002     |  2332 | 65296 |
|  18 |            PX RECEIVE              |             |  2332 | 65296 |
|  19 |             PX SEND BROADCAST      | :TQ10001    |  2332 | 65296 |
|  20 |              PX BLOCK ITERATOR     |             |  2332 | 65296 |
|* 21 |               TABLE ACCESS INMEMORY FULL| PART   |  2332 | 65296 |
|  22 |           JOIN FILTER USE          | :BF0000     |  300M|  6294M|
|  23 |            JOIN FILTER USE         | :BF0001     |  300M|  6294M|
|  24 |             JOIN FILTER USE        | :BF0002     |  300M|  6294M|
|  25 |              PX BLOCK ITERATOR     |             |  300M|  6294M|
|* 26 |               TABLE ACCESS INMEMORY FULL| LINEORDER |  300M|  6294M|
-------------------------------------------------------------------------------
```

# Bloom pruning filter (11g)

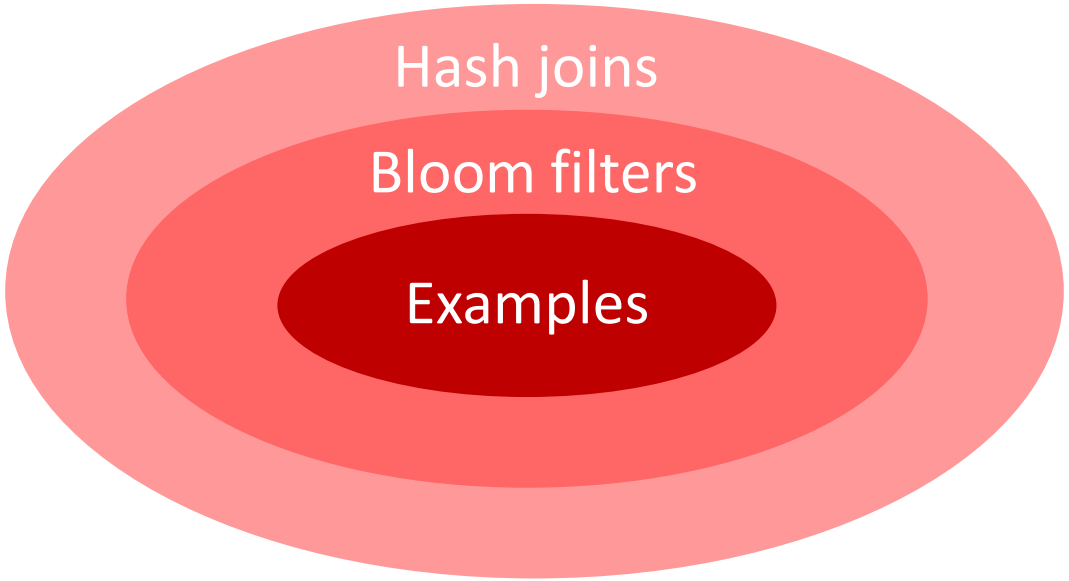
- Shows up as "*Partition* join filter create"
  - When joining from DIM to FACT and join-column is input for partitioning scheme of FACT, then
  - Partition function is applied to DIM column values to find P#'s of FACT that would hold such value
  - These P#'s are added to Bloom filter
  - Bloom filter is used when probing FACT
    - Only partitions that are in Bloom filter will be scanned

# Bloom pruning filter

```
-----------------------------------------------------------------------------
| Id  | Operation                        | Name        | Pstart| Pstop |
-----------------------------------------------------------------------------
|   0 | SELECT STATEMENT                 |             |       |       |
|   1 |  SORT AGGREGATE                  |             |       |       |
|   2 |   PX COORDINATOR                 |             |       |       |
|   3 |    PX SEND QC (RANDOM)           | :TQ10001    |       |       |
|   4 |     SORT AGGREGATE               |             |       |       |
| * 5 |      HASH JOIN                   |             |       |       |
|   6 |       BUFFER SORT                |             |       |       |
|   7 |        PART JOIN FILTER CREATE   | :BF0000     |       |       |
|   8 |         PX RECEIVE               |             |       |       |
|   9 |          PX SEND BROADCAST       | :TQ10000    |       |       |
| * 10|           TABLE ACCESS FULL      | DATE_DIM    |       |       |
|  11 |       PX BLOCK ITERATOR          |             |:BF0000|:BF0000|
| * 12|        TABLE ACCESS FULL         | STORE_SALES |:BF0000|:BF0000|
-----------------------------------------------------------------------------
```

# Final remarks

- Bloom filter can be pushed down to storage cells



# Questions?

Email: toon.koppelaars@oracle.com

Twitter: @toonkoppelaars

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