NoSQL features of Db2 (LUW) revisited

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abis

TRAINING & CONSULTING

GSE Db2 BeLux

User Group Meeting

at IBM, Brussels, 18 October 2018

NoSQL features of Db2 revisited -- agenda:

- NoSQL, BigData, analytics
  - ACID versus BASE
  - “flat” data, versus XML / JSON
  - Db2 flexibility: BLOB, hash access, APPEND ON, MQTs, ...
- Parallelism and sharding
  - cluster-based model: data distribution & replication; shared-nothing
  - the CAP theorem
  - Db2: what about clone tables, columnar tables, HADR, pureScale, ... ?
- Weakening ACID in Db2
  - SET ISOLATION = UR; NOT ENFORCED; NOT LOGGED; circular logs; ...
  - restartable programs
  - pseudo-conversation

NoSQL - what’s in a name

Wikipedia:

- A **NoSQL** or **Not Only SQL** database provides a mechanism for
  - storage/retrieval of data, modelled otherwise than in RDBMS tables
  - motivations for this approach include:
    simplicity of design,
    horizontal *scaling*,
    higher *availability*,
    faster response
- Growing industry use in *big data* and *real-time web* applications
- Many NoSQL stores *compromise consistency*
  in favour of *availability* and *partition tolerance* (“CAP theorem”)
- Most NoSQL stores lack true *ACID transactions*

Term “NoSQL” introduced 1998 by Carlo Strozzi (shell-interfaced RDBMS);
term reintroduced 2009 in the context of ***distributed* DBs** (now meaning *not relational*)

NoSQL and Big Data

- *3 Vs* (Gartner, 2001): high-**V**olume, high-**V**elocity, high-**V**ariety data
- (distributed) data *analysis* (data mining; statistical techniques)
- insight:
  - keep *all* data (sensor data, website clicks, blogs, ...)
  - in their *original* format (no ETL)
  - for potential later use (not yet decided at moment of collection)

    (pre-formatting may destroy or bias some information)
- as a consequence:
  - unstructured (or semi-structured, non-flat) data
  - less quality control/semantics during load => mainly useful for OLAP
  - interpretation & value judgement: done by ad-hoc *analysis* step(s)

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   - no DDL ?
   - no joins ?
   - NoSQL database types
2. Parallelism and sharding
   - cluster-based model:
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     shared-nothing
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Alledged problems/issues with “relational”

Some often heard arguments:

- **1. flat, tabular representation is *unnatural***
- **1b. need to *convert* to / from original (natural) representation**
- **2. data modelling (*DDL*) beforehand => too rigid / restrictive / complex**
- **2b. single column can only store *similar* data => too limiting**
- **3. often need table *joins* => too heavy / complex / non-intuitive**
- **4. may not *scale* well (*horizontal* scaling; large tables & growing)**
- **5. too low *concurrency* (simultaneous users; parallelism)**
- **...**

Problem #1 - flat data

Statement: “flat, tabular representation is *unnatural*”

Db2’s response:

- store as **XML** (already since Db2 Version 9.1 -- that is: 2006 !)
  - Suppose table “companies” has column “empl”

    storing all employees for that company

    => one such “empl” should be of data type XML and could e.g. be:

    ```
    <employees><person><name>Janssen</name><function>ANALYST</function></person>
    <person><name>Dupont</name><function>MANAGER</function></person></employees>
    ```
  - interrogate with XQuery or (even better) just **with SQL:**

```
SELECT   coname,XMLQUERY('count($E//function[.="ANALYST"])' PASSING empl AS e)
FROM     companies
WHERE    XMLEXISTS('$E/employees/person[function="ANALYST"]' PASSING empl AS e)
;
SELECT   c.coname, x.name AS employee_name, x.func AS employee_function
FROM     companies c,
         XMLTABLE('$E/employees/person' PASSING c.empl AS e
                        COLUMNS    func   VARCHAR(64) PATH 'function'
                               ,   name VARCHAR(32) PATH 'name'    ) x
;
```

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Problem #1 - flat data (cont'd)

Db2's response: (nr. 2)

- store as **JSON** (ECMA standard 2013; Db2 support since Version 10.5)
  - Suppose table "companies" has BLOB column "empl", storing all employees for that company

    => one such "empl" could have the following value:

    ```
    { employees: { person:  [  { name: "Janssen",     function: "analyst" },
                               { name: "Dupont",      function: "manager" } ]
    }                 }
    ```

  - Interrogate with scalar function `SYSTOOLS.JSON_VAL2`, or with:

    ```
    SELECT c.coname, x.value AS function
    FROM companies c,
         TABLE(SYSTOOLS.JSON_TABLE(c.empl, 'employees.person.function', 's:64')) x
    ```

  - or use the JSON-specific command line interface `db2nosql.sh` (!)

    Database has to be "enabled" (once) for using this interface with `enable(true)`

    ```
    db2nosql.bat -db MyDatabase
    nosql> db.companies.$find({})
    nosql> db.companies.$find({"employees.person.name":"Dupont"})
    ```

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Problem #1b - convert to/from flat data

Db2 indeed does not require us to convert between XML & flat data !

but XML or JSON: probably still too rigid / too limited !

- **How can we *store anything whatsoever***
- **and yet easily**
  - ***find it back* and/or**
  - ***aggregate* on it (count/sum/avg/rank/top10/...)**

"*In search of a middle ground between file system & database*"
=> one size *does not* fit all ... (Robert Greene, 2012)

Which brings us to Problem # 2 ...

Problem #2 - data modelling (*DDL*) beforehand

NoSQL wants:

- *schema-less* storage (=> dynamically add new attributes)
- but with *keys* & values (tuple store, ...) & possibly indexes

most NoSQL databases offer the possibility to work

- without a “schema”, i.e., without a predefined structure
- or with dynamically changing schema’s

BUT which *guarantees* can such a setup provide us?

Db2’s response:

- more flexible DDL changes

  (more `ALTER` support, esp. `DROP COLUMN`)
- created global temporary tables
- common table expressions (CTEs), e.g. on top of CLOB/XML/JSON

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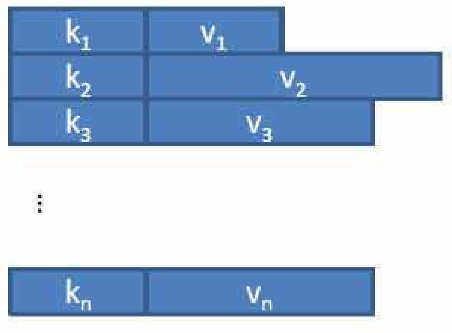
Intermezzo: NoSQL database types

- Key/Value Databases
  - *Examples*: Berkeley DB, Oracle NoSQL, Dynamo, *MapReduce*
- Document Stores
  - *Examples*: MongoDB, CouchDB, MarkLogic, *IBM Lotus Notes (Domino)*
- Columnar Databases
  - *Examples*: Google Bigtable (2006), HBase, Cassandra, *Db2 BLU*
- Graph (navigational) Data Model
  - *Examples*: Neo4j, GraphDB, InfoGrid, *IMS*
- Network DBMS
  - *Examples*: IDMS

Intermezzo: NoSQL database types (cont'd)

Key/Value Database

- data stored based on programmer-defined <u>keys</u> [hash table approach]
- system is agnostic as to the semantics of the value
- requests are expressed in terms of keys: put(key, value), get(key): value
- indexes are defined over keys



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Intermezzo: NoSQL database types (cont'd)

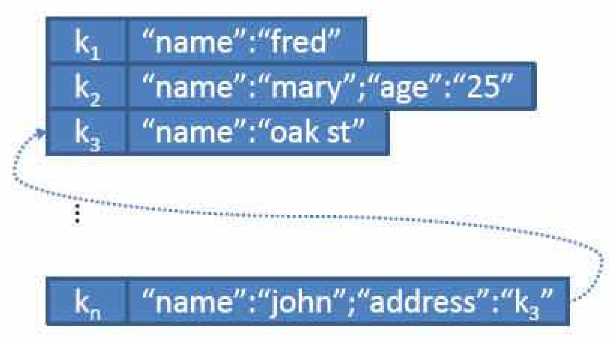
Key/Value Database - Db2's related possibilities:

- **Hash** access:
  - Db2 table(space) which is not cluster-organized, but organized "by hash"
  - allows for fastest possible (single-page) access to a single row
  - hash "key" must be the primary key
- The **BYTE**(n) and VARBYTE(n) datatypes
  - similar to CHAR(n) and VARCHAR(n)
  - but no CCSID => no text interpretation, hence no auto-conversion
- The **BLOB** datatype
- The Db2 transaction **logs**

Intermezzo: NoSQL database types (cont'd)

Document store

- documents stored with programmer-defined key [“**key-value**”]
- system is aware of the arbitrary document **structure**
- support for lists, **pointers** and nested documents
- support for key-based & secondary **indexes** (with search possibility)



k_1	“name”:“fred”
k_2	“name”:“mary”;“age”:“25”
k_3	“name”:“oak st”
⋮	
k_n	“name”:“john”;“address”:“k_3”

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Intermezzo: NoSQL database types (cont’d)

Document store - Db2’s answer:

- XML (again)
- but not quite a “document store”
  - complicated way to assign an XML Schema to an XML document ...
    - cf. SYSCAT.XSROBJECTS catalog view
    - need a stored procedure for registering new XML Schema

      ```
      CALL SYSPROC.XSR_REGISTER( 'AbisSchema' , 'AbisCourseInfo',
                                 ’http://abis.be/courses.xsd',
                                 ? , ? )
      ```
    - after that, the following allows Schema validation upon insert:

      ```
      INSERT INTO MyTable(MyXmlCourseInfo)
      VALUES ( XMLVALIDATE( ?
                  ACCORDING TO XMLSCHEMA URI 'http://abis.be/'
                  LOCATION 'http://abis.be/courses.xsd'
               ) )
      ```
  - impossible to more generally “link” XML documents within Db2

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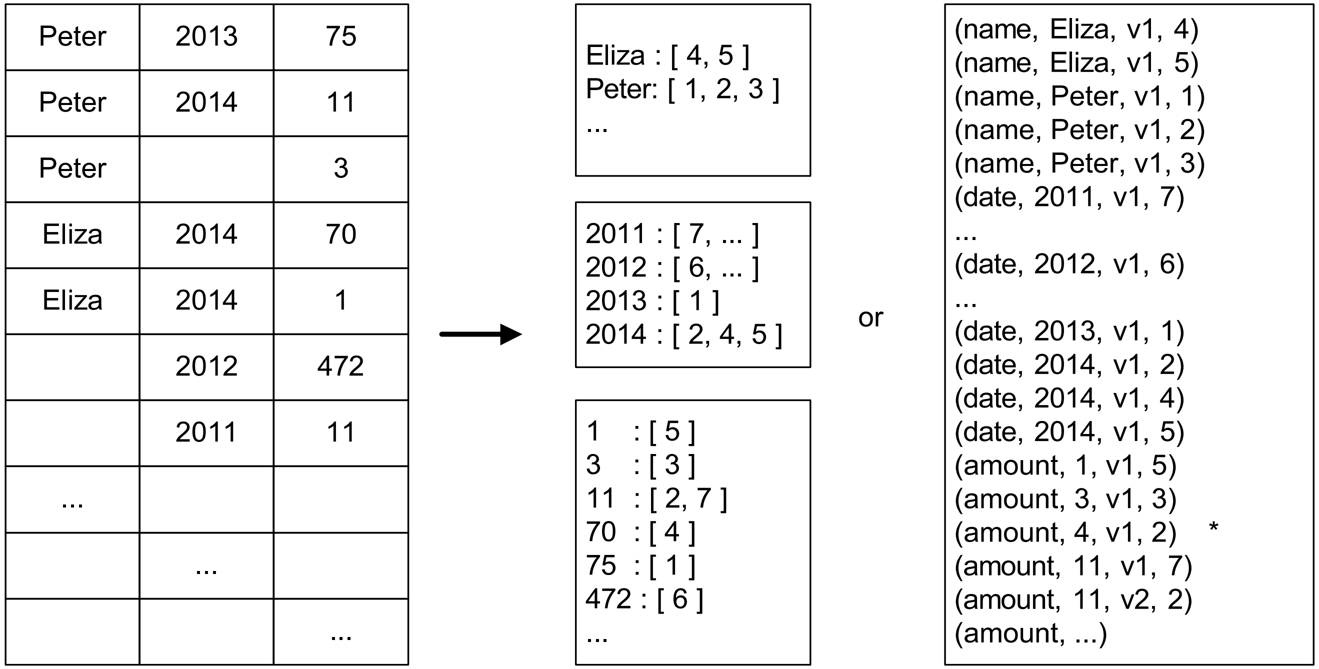
Intermezzo: NoSQL database types (cont'd)

Columnar Database

- stores tables as sections of columns of data
- data stored together with meta-data ('a map')

  [typically including row id, attribute name & value, timestamp]



Peter	2013	75
Peter	2014	11
Peter		3
Eliza	2014	70
Eliza	2014	1
	2012	472
	2011	11
...		
	...	
		...

```
Eliza : [ 4, 5 ]
Peter: [ 1, 2, 3 ]
...
```

```
2011 : [ 7, ... ]
2012 : [ 6, ... ]
2013 : [ 1 ]
2014 : [ 2, 4, 5 ]
```

```
1    : [ 5 ]
3    : [ 3 ]
11   : [ 2, 7 ]
70   : [ 4 ]
75   : [ 1 ]
472 : [ 6 ]
...
```

or

```
(name, Eliza, v1, 4)
(name, Eliza, v1, 5)
(name, Peter, v1, 1)
(name, Peter, v1, 2)
(name, Peter, v1, 3)
(date, 2011, v1, 7)
...
(date, 2012, v1, 6)
...
(date, 2013, v1, 1)
(date, 2014, v1, 2)
(date, 2014, v1, 4)
(date, 2014, v1, 5)
(amount, 1, v1, 5)
(amount, 3, v1, 3)
(amount, 4, v1, 2)    *
(amount, 11, v1, 7)
(amount, 11, v2, 2)
(amount, ...)
```

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Intermezzo: NoSQL database types (cont'd)

Columnar Database - Db2's answer: "**BLU acceleration**" (since Db2 10.5):

- in-memory tables
- stored in a columnar fashion

  table dll: `ORGANIZE BY COLUMN` keyword

  => better compression (similar data) & "sparse" (data skipping)
- is essentially an **indexes-only** table!

  (one per column; sorted on timestamp)

Related Db2 technology:

`alter table` ddl:

`APPEND ON` keyword

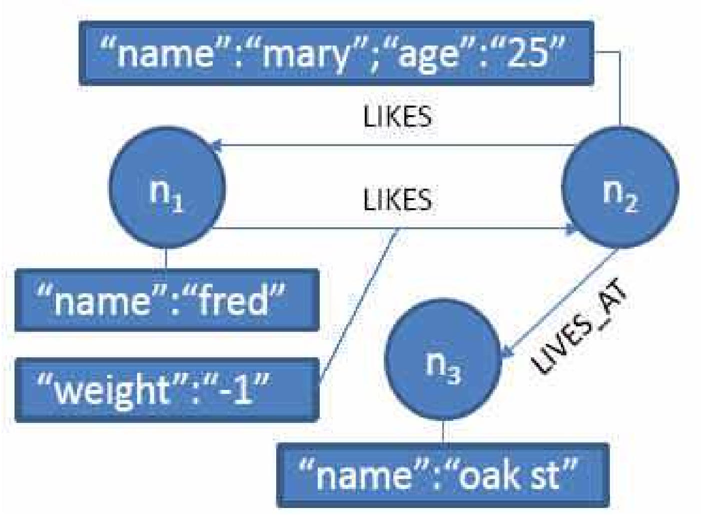
`COMPRESS YES` keyword

`PREFETCHSIZE` keyword of the `ALTER TABLESPACE` statement

Intermezzo: NoSQL database types (cont'd)

Graph (navigational) Data Model

- data stored as *nodes* & *links*, both with (arbitrary) attributes
- requests through *system id's* (or through indexes)



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Intermezzo: NoSQL database types (cont'd)

Graph (navigational) Data Model - Db2's implementation:

- This is *exactly* the internal data representation of Db2 !
  - RIDs
  - index is a hierarchy with internal & external pointers
  - z/OS: page sets (including space map pages)
  - fan sets (both for indexes and for foreign keys)
  - log records, log range info in the directory
- Is even used *exclusively* in the runtime environment
  - static SQL
  - packages & access paths

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Problem #3 - table joins are heavy

Statement: “table joins: too often needed, too heavy, unnatural”

Db2’s response:

- normalisation (hence joins) avoids **redundancy**; one may *denormalize*
- use VIEWs to hide the “complexity” of joins
- use **MQTs** to additionally make join views “lighter” (**performance**)
  - but .. beware of **refresh** issues!   (*consistency* (ACID) jeopardised..)
- **aggregate concatenation** (since Db2 10.1):

```
SELECT   coname, LISTAGG(pname, ', ')
                     WITHIN GROUP (ORDER BY pname) AS employees
FROM     companies JOIN persons ON cono = p_cono
GROUP BY   p_cono
;
SELECT   coname, (SELECT  LISTAGG(pname, ', ')
                  FROM    persons WHERE p_cono=c.cono)
FROM     companies c
```

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Problem #4 - scalability, parallelism, sharding

NoSQL wants:

- to use a *distributed* storage model   (autonomous "nodes"; TCP/IP)
- with data partitioning ("sharding"), i.e.: *horizontally* splitting
- with *replication* for fault-tolerance   (redundancy across nodes)

  ==> hence can afford "commodity hardware"

  ==> scales linearly: e.g. 10x more nodes for 10x more data or users
  => same response times promised ...
- sharding & replication allow for parallelism:

  serve multiple clients in parallel (from different data copies),

  and/or divide the work for 1 client over multiple workers

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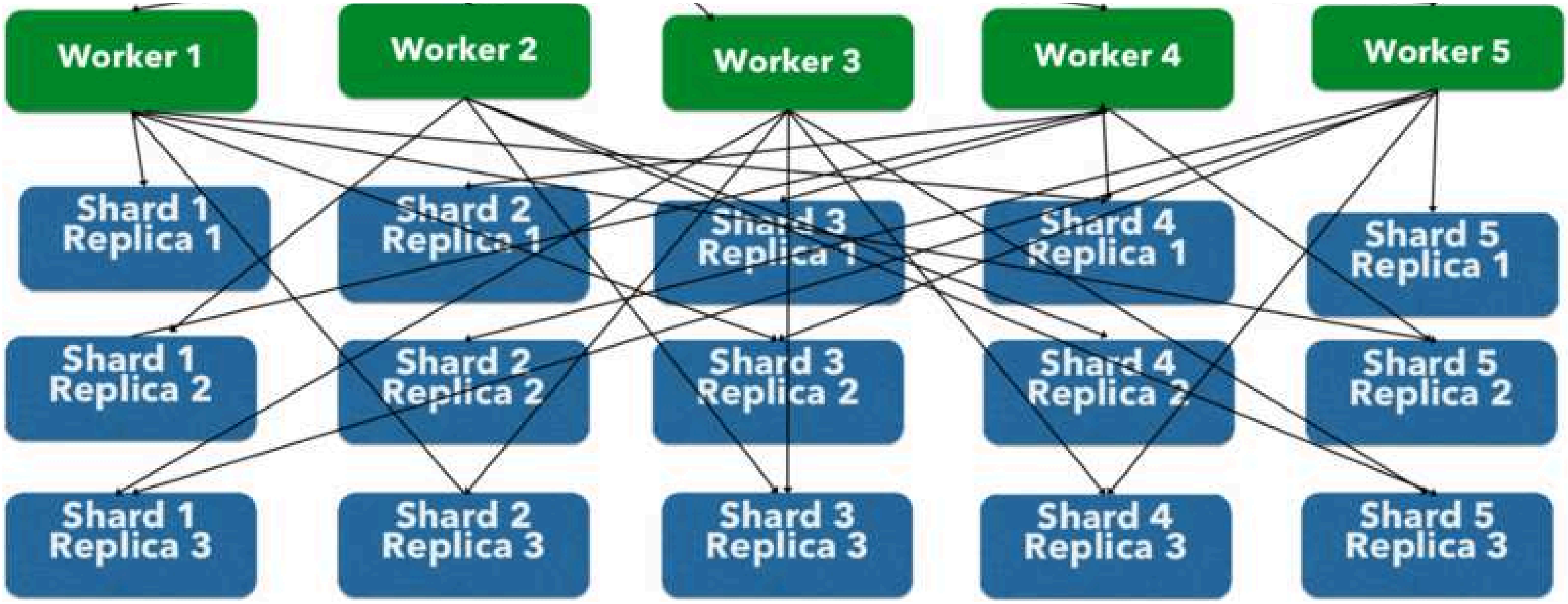
Scalability, parallelism, sharding, replication



Data node = Worker **(Worker 1 may e.g. need data from Data node 2, though ...)**

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Sharding with Db2 ?

Db2's implementation of "sharding" ?

- **Partitioning** => either PBG or PBR
  - can imply (if wanted) that partitions are on different disks

    => no shared **disks**; no *replication* though (except for backups+logs)
  - but partitions *cannot* be in different buffer pools

    (shared **real memory**)
  - **indexes** can be partitioned or not

    => note Db2 *does not require any indexes*!
- **HADR**
  - High Availability Disaster Recovery => data **replication**
  - primary vs standby database => will *take over* when needed ...
  - *not sharding*: e.g. clients cannot connect to the standby server

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Sharding with Db2 ? (cont'd)

- **Clone tables ? (atypical use case to implement 2-fold replication ...)**

  ==> Always a shared something solution ...

- **pureScale**
  - **since 2009, on AIX**
  - **several machines (members) together forming a *cluster***
  - **no shared processor, no shared memory (buffer pools)**
  - **easily scales (more members => more parallel clients)**
  - **"easy" recovery from failing member**
  - **but shared disks! => so *not* sharding!**
  - **also a shared lock manager & a shared group buffer pool**
- **Data sharing:**
  - **available on Db2 for z/OS:**

    different LPARs, different Db2 instances
  - **very similar to pureScale**

Transactions, consistency and availability

- In a ‘shared something’ environment, ACID is wanted:
  - Pessimistic behaviour: force consistency at *end of transaction*!
  - **A**tomicity: all or nothing (of the *n* actions): commit or rollback
  - **C**onsistency: transactions *never* observe or cause inconsistent data
  - **I**solation: transactions are not aware of concurrent transactions
  - **D**urability: acknowledged transactions persist in all events (even in case of *disaster*)
- In a ‘shared nothing’ environment, BASE is implemented:
  - Optimistic behaviour: accept *temporary* database *inconsistencies*
  - **B**asically **A**vailable [guaranteed thanks to replication - no wait times]
  - **S**oft state [it’s user’s (application’s) task to guarantee consistency]
  - **E**ventually consistent (weakly consistent) [‘stale’ data is OK]

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Distributed data & processing

Why not have the best of both worlds?

=> Consistency (ACID): all clients see same data at same moment

=> Availability (through N-fold replication): no server timeouts

=> speed (through sharding) => Partition tolerance

CAP theorem:

- Brewer's Conjecture (2000; proved in 2002; refined in 2012):

  in any environment (shared-nothing or not)
  it is only possible to satisfy ***at most two*** *of these requirements*

- C + A => *ACID*;
  A + P => *BASE*;
  C + P => write N read 1 / write 1 read N

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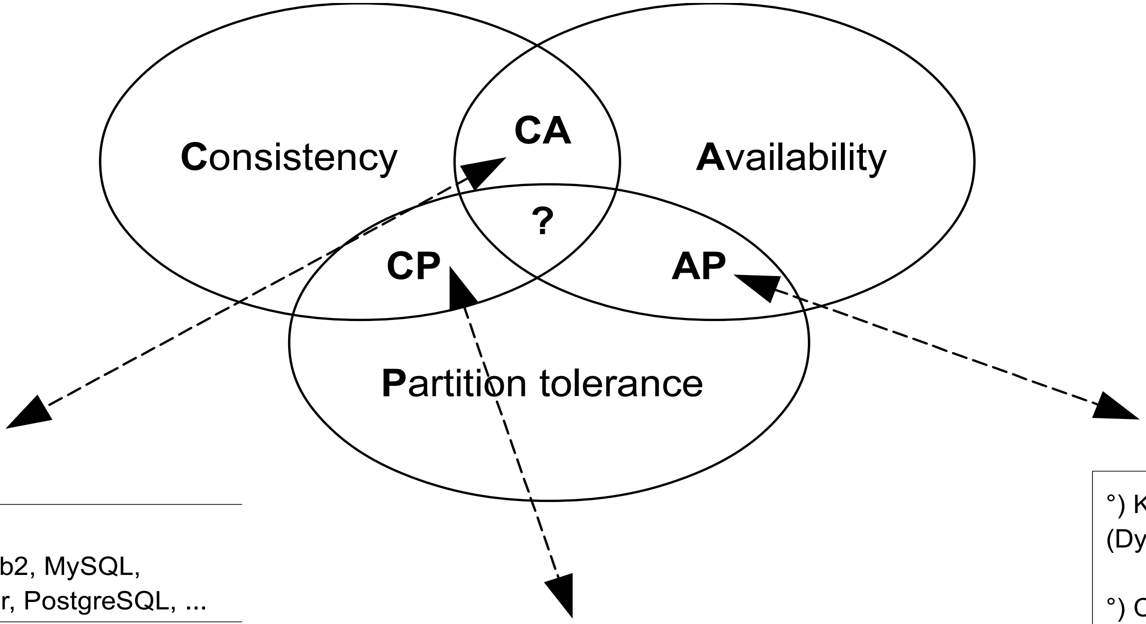
CAP theorem



RDBMS
(Oracle, Db2, MySQL,
SQLServer, PostgreSQL, ...

°) KEY VALUE
(Berkley DB, Redis)

°) COLUMN/TABULAR
(BigTable, Hypertable,
Hbase)

°) DOCUMENT
(MongoDB, Terrastore)

°) KEY VALUE
(Dynamo, Voldemort, KAI)

°) COLUMN/TABULAR
(Cassandra)

°) DOCUMENT
(SimpleDB, CouchDB, Riak)

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Weakening ACID in Db2

- **Atomicity: transaction (consisting of the *n* actions): all or nothing**
  - **long-running transactions => might be problematic!**
    - **logs** span multiple log data sets => active log (& log buffers) too large
    - **locks** of long duration -- either SHARED or EXCLUSIVE
  - **2 "old" solutions:**
    - *regularly commit* (say every 5 seconds)=>breaks atomicity: a bit *BASE* !
    - use ISOLATION=UR for long running reads => see also Consistency ...
      or use `WITH UR` keyword with `SELECT`
  - **and a "newer" one:**
    - **optimistic locking**, lock avoidance, ...
    - idea: don't place exclusive locks, but verify "last modified" time on read
      => data page timestamp, row change timestamp column, ...

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Weakening ACID in Db2 (cont'd)

- **Consistency: transactions *never* observe or cause inconsistent data**
  - ***READ* locks should last at least until effective read**

    => SET ISOLATION = CS (or WITH CS)
  - **what about e.g. phantom reads?**

    => ACID would require ISOLATION=RR !!
  - ***WRITE* inconsistency:**
    - use NOT ENFORCED foreign key constraints (or no FKs at all ...)
    - not using cursor `FOR UPDATE` yet update (without `CURRENT OF`): *evil!*
    - after LOAD:

      Integrity Pending state

      => SET INTEGRITY FOR table IMMEDIATE UNCHECKED

      (might make sense for e.g. a test environment)
- **Isolation: transactions are not aware of concurrent other transactions**
  - **weakened through (again) ISOLATION=UR, or regular commits**
  - **NoSQL would use *replication* though ... => mimic with MQTs ?**

NoSQL features of Db2 revisited

1. NoSQL, BigData, analytics
   - XML / JSON
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2. Parallelism and sharding
   - cluster-based model:
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Weakening ACID in Db2 (cont'd)

- **Durability: acknowledged transactions persist in all events**
  - **also in case of a disaster (e.g. disk crash)**
  - **Db2 guarantees this through Backups & transaction/archive logs**
  - **"circumventing" the Db2 default behaviour:**
    - ALTER TABLESPACE ... NOT LOGGED (only for LOB data)
    - LOAD ... COPY NO

      => BACKUP PENDING state => *Db2 does* ***not*** *allow data changes*
    - LOAD ... NONRECOVERABLE
    - not making backups
    - set database to *circular logging* only (logarchmeth1&2 set to OFF)

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“NoSQL” application scenario’s with Db2

Some typically considered “application design” scenario’s

which contain aspects which are not 100% “ACID”:

- **Long running applications (typically: batch jobs)**
  - **need to “commit regularly”**
  - **should also apply to *read-only* applications! (often forgotten ...)**
- **Risk of inconsistent data, when application ends abnormally !**
  - **incomplete updates/inserts**
  - **duplicate updates/inserts on restart of job! => even worse ...**
- **Solution: make application restartable => programming skill!**

“NoSQL” application scenario’s with Db2 (cont’d)

- **Long running *interactive* applications**
  - **graphical front-end, e.g. “paging” application: one screen at a time**
  - **cursor locks must be kept ... => unacceptable**
  - **solution: pseudo-conversation**
    - application retrieves data for just 1 screen from Db2
    - application closes connection with Db2 after each screen
    - application reconnects to Db2 on “page down” or “page up” request
  - **This requires `ORDER BY` and additional `WHERE key > :last_seen`**
    - note the (Db2 10) handy “paging” syntax for when key is multi-column!

WHERE (key1, key2) > (:last_seen_1, :last_seen_2)

“syntactic sugar” for:

```
WHERE  key1 > :last_seen_1
   OR  key1 = :last_seen_1 AND key2 > :last_seen_2
```

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Restartability

- **Not a new issue:**
  - **has been used for "batch" application development since "ages"**
  - **non-restartable programs are often rewritten to become restartable**
- ***but* typical for a "NoSQL" approach: because it's a client decision**
- ***What is restartability?***
  - **When a batch application returns normally => RC=0, no problem**
  - **When a batch application returns *abnormally* (crashes, or RC > 0):**
    - Could e.g. be a "disk full" problem, or an "unavailable file" issue
    - Can the operator safely restart the program, after fixing the cause?
    - In general, **no**: risk of e.g. **partial duplicate updates** in Db2 ...
    - Unless either *no intermediate commits*, or program is restartable!

Restartability - Example

```
SELECT STATUS  INTO :ExecutionStatus FROM SYNCTable ;
if (ExecutionStatus == NormalEnd) { NormalStart(); } else { PrepareProgramRestart(); }

NormalStart() :
    ProdNo <- 0; OrdNo <- 0; Totals <- 0;
    UPDATE SYNCTable SET STATUS = :Running ;
PrepareProgramRestart() :
    SELECT  PRNO,ORDNO,TOTALS  INTO :ProdNo, :OrdNo, :Totals
    FROM    SYNCTable ;

DECLARE prod CURSOR WITH HOLD FOR
    SELECT ... FROM ... WHERE ... AND  (PRODNO,ORDNO) > (:ProdNo, :OrdNo)
    ORDER BY     PRODNO, ORDNO ;
```

- **Note: restart info is saved in Db2 “syncpoint” table !!**

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Restartability - Example (cont'd)

```
NormalProgramEnd():
    UPDATE SYNCTable SET PRNO=0, ORDNO=0, STATUS= :NormalEnd ;
    COMMIT ;
```

- **If the batch program modifies data,**
  COMMIT processing (e.g. every 5 seconds) might already be in place;
  modify it as follows:

```
SyncpointProcessing() :
    UPDATE SYNCTable SET PRNO=:ProdNo, ORDNO=:OrdNo, Totals = :Totals ;
    COMMIT ;   -- of both the data modifications and the synpoint info
```

Pseudo-conversational programs

- Not a new issue -- *but* typical for a “NoSQL” approach: **client decision**
- Typical situation:
  - User wants to scroll through a Db2 result set
  - The program shows only (say) 10 results (one screenful) at a time
  - Programs might allow for updates/inserts or might be read-only
  - Scroll-forward “next screen” & scroll-backward “previous screen”
- Pseudo-conversational approach:
  - Program reads just 10 rows from cursor, then **disconnects** from Db2
  - On “next screen”, it reconnects, runs cursor *with additional WHERE*
  - Program needs to remember “last entry seen”

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Pseudo-conversational programs (cont'd)

- **Example:**

```
-- “data-dependent pagination”:
DECLARE nextscreen CURSOR FOR
    SELECT ... FROM ... WHERE  ... AND (PRODNO,ORDNO) > (:ProdNo, :OrdNo)
    ORDER BY      PRODNO, ORDNO
    FETCH FIRST 10 ROWS ONLY ;

OPEN nextscreen ;
FETCH nextscreen INTO :ProdNo, :OrdNo, ... ;
while (SQLCODE == 0) :
    Display_data() ;
    FETCH nextscreen INTO :ProdNo, :OrdNo, ... ;
CLOSE nextscreen ;
-- at this point, ProdNo and OrdNo are ready for the next “OPEN CURSOR”
```

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Pseudo-conversational programs (cont'd)

- **Scrolling backwards:**

```
DECLARE prevscreen CURSOR FOR
    SELECT ... FROM ... WHERE  ... AND (PRODNO,ORDNO) < (:FirstProdNo, :FirstOrdNo)
    ORDER BY      PRODNO DESC, ORDNO DESC
    FETCH FIRST 10 ROWS ONLY ;

OPEN prevscreen ;
FETCH prevscreen INTO :LastProdNo, :LastOrdNo, ... ;
FirstProdNo <- LastProdNo; FirstOrdNo <- LastOrdNo;
while (SQLCODE == 0) :
    Display_data_backward() ;
    FETCH prevscreen INTO :FirstProdNo, :FirstOrdNo, ... ;
CLOSE prevscreen ;
```

(will also need FirstProdNo&FirstOrdNo on forward cursor traversal)

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In summary ...

- NoSQL, BigData, analytics
  - Db2 supports non-flat data: **XML** (and JSON)
  - more Db2 flexibility: BLOB, **hash** access, APPEND ON, MQTs, ...
- Parallelism and sharding
  - **pureScale** cluster: comes close to a NoSQL setup
  - **CAP** theorem: cannot be 100% ACID and 100% sharded ...
  - Db2 features for “mimicing” some NoSQL functionality:

    clone tables, no indexes, columnar tables, HADR replication
- Weakening ACID in Db2
  - SET ISOLATION = UR; NOT ENFORCED; LOG NO
  - how to make Db2 batch programs **restartable**
  - how to make interactive programs **pseudo-conversational**

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Questions, remarks, feedback, ... ?

NoSQL features of Db2 (LUW) revisited

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TRAINING & CONSULTING

Thank you!

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