Going Native: Leveraging DB2 for z/OS SQL Procedures and UDFs

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For starters, a prediction

SQL Procedure Language (SQL PL) will come to be the dominant language for development of DB2 for z/OS stored procedures and user-defined functions (UDFs).

You should know about SQL PL, and your organization should use it.

Agenda

- Where we've been, and where we're going
- Native SQL procedures and UDFs – performance
- Native SQL procedures and UDFs – scalability and security
- Native SQL procedure and UDF development and management
- Managing the shift to SQL PL

Where we've been, and where we're going

SQL Procedure Language

- Initially delivered with DB2 for z/OS Version 7
- A way to code DB2 stored procedures using only SQL
  - Enabled via introduction of a new category of SQL statements, called control statements (referring to logic flow control)
    - Examples: IF, WHILE, ITERATE, LOOP, GOTO

```
CREATE PROCEDURE divide2
   (IN numerator INTEGER, IN denominator INTEGER,
    OUT divide_result INTEGER)
   LANGUAGE SQL
   BEGIN
     DECLARE overflow CONDITION FOR SQLSTATE '22003';
     DECLARE CONTINUE HANDLER FOR overflow
       RESIGNAL SQLSTATE '22375';
     IF denominator = 0 THEN
       SIGNAL overflow;
     ELSE
       SET divide_result = numerator / denominator;
     END IF;
   END
```

This is a compound SQL statement

From the DB2 V8 SQL Reference

DB2 V7 SQL procedures – pro and con

- Pro:
  - Expanded the pool of people who could develop DB2 for z/OS stored procedures
- Con:
  - As part of program preparation, SQL PL routine was converted into a C language program with embedded SQL DML statements
    - C language programs are generally not as CPU-efficient as programs written in COBOL
    - The CPU cost of the C language executable discouraged some organizations from using SQL procedures

Big breakthrough: native SQL procedures

- Introduced with DB2 9 for z/OS in new-function mode (or DB2 10 NFM for organizations that migrated to DB2 10 from DB2 V8)
- Key differences (vs. original SQL procedures, which are now known as external SQL procedures):
  - No external-to-DB2 executable (no object or load module) – a native SQL procedure's package is that procedure's one and only executable
  - Executes in DBM1, the DB2 database services address space (as do all packages) – not in a WLM-managed stored procedure address space
  - Runs under caller's task (vs. TCB in a stored procedure address space)
  - Provides superior functionality (example: nested compound SQL statements – great for multi-statement condition handlers)
  - And, native SQL procedures – not external SQL procedures – are where you will see advances in SQL PL functionality (more on this to come)

NFM

DB2 10: “native” SQL user-defined functions

Official term is compiled SQL scalar function
(or non-inlined SQL scalar function)

- They allow coding a compound statement in the RETURNS part of CREATE FUNCTION for a SQL UDF (in other words, you can code a UDF in SQL PL)
  - Previously, “logic” in a SQL UDF was very limited
  - As is true for a native SQL procedure, a “native” SQL UDF’s package is its one and only executable
  - Also like a native SQL procedure, a “native” UDF executes in the DB2 DBM1 address space, and under the invoker’s task
- Alternatively, DB2 10 compiled SQL scalar function can contain a scalar fullselect in the RETURN part of CREAT FUNCTION
  - Previously, couldn’t even reference a column in RETURN

More on DB2 10 SQL UDFs

- Starting with DB2 10 NFM, there are three types of CREATE FUNCTION statements for SQL UDFs (versus one with DB2 9)
  - *Compiled SQL scalar functions*, aka non-inlined SQL scalar functions (new – what I've called "native" SQL UDFs)
  - *Inlined SQL scalar functions*
  - *SQL table functions* (new)

Has its own package

Don't have their own packages – incorporated into package of invoker

- A SQL table UDF returns a set of rows to an invoker
  - Table UDFs formerly had to be external
- **Bottom line**: starting with DB2 10 NFM, you can code high-function UDFs using only SQL

What a pre-DB2 10 SQL UDF had to look like

(and still can, in the form of a DB2 10 or 11 inlined SQL scalar function)

```
CREATE FUNCTION KM_MILES(X DECIMAL(7,2))
RETURNS DECIMAL(7,2)
LANGUAGE SQL
CONTAINS SQL
NO EXTERNAL ACTION
DETERMINISTIC
RETURN X*0.62;
```

Here's your logic

What a DB2 10 “native” SQL UDF can look like

```
CREATE FUNCTION REVERSE(INSTR VARCHAR(4000))
  RETURNS VARCHAR(4000)
  DETERMINISTIC NO EXTERNAL ACTION CONTAINS SQL
  BEGIN
    DECLARE REVSTR, RESTSTR VARCHAR(4000) DEFAULT '';
    DECLARE LEN INT;
    IF INSTR IS NULL THEN
     RETURN NULL;
    END IF;
    SET (RESTSTR, LEN) = (INSTR, LENGTH(INSTR));
    WHILE LEN > 0 DO
     SET (REVSTR, RESTSTR, LEN)
       = (SUBSTR(RESTSTR, 1, 1) CONCAT REVSTR,
       SUBSTR(RESTSTR, 2, LEN - 1),
       LEN - 1);
    END WHILE;
    RETURN REVSTR;
  END#
```

From the DB2 10 SQL Reference

Here's your logic

And here's a SQL UDF with a scalar fullselect

```
CREATE FUNCTION UNIT_SALES_COUNT(X CHARACTER(6))
RETURNS INTEGER
LANGUAGE SQL
CONTAINS SQL
NO EXTERNAL ACTION
DETERMINISTIC
RETURN
 (SELECT SUM(UNIT_SALES)
  FROM PRODUCT_SALES
  WHERE PRODUCT_ID = X);
```

Couldn't have this in RETURN statement before DB2 10

DB2 10 new functionality for native SQL procedures

Not applicable to external stored procedures – SQL or otherwise

- XML data type valid for SQL procedure input and output parameters, and for variables declared in a SQL procedure
  - Also, XML data type can be passed to or received from, and/or be used in a variable declaration in, a SQL UDF
  - Benefit: you no longer have to serialize an XML value into a character string or a CLOB in order to work with it in a SQL procedure or UDF

DB2 11: new native SQL procedure functionality

- Array parameters can be passed to and/or received from, and array variables can be declared in, native SQL procedures (and the same is true for compiled SQL scalar UDFs)
  - Call to SQL procedure with array input or output parameter can come from SQL PL routine, from Java program, or from .NET client (for latter two, via IBM Data Server Driver type 4 driver)
    - .NET client can call native SQL procedure with array input parameter
  - An array in this context is a form of a DB2 for z/OS user-defined data type (i.e., a UDT) – you create it, then you use it
  - Two array types: ordinary (elements are addressed by their ordinal position in the array) and associative (elements ordered and referenced by array index values)

This is an ordinary array

Max number of elements in array (defaults to about 2 billion)

```
CREATE TYPE PHONENUMBERS AS DECIMAL(10,0) ARRAY[50];
```

Data type of values in the array

DB2 11 new native SQL procedure functionality

- A SQL procedure can function as an autonomous transaction
  - How it's done: AUTONOMOUS option specified in CREATE PROCEDURE (or ALTER PROCEDURE) statement
    - Specified instead of COMMIT ON RETURN YES/NO
  - What it means:
    - The autonomous SQL procedure commits on returning to the calling program, but (unlike the case when COMMIT ON RETURN YES is in effect) that commit does NOT affect the calling program's unit of work
    - Autonomous SQL procedure's unit of work (UOW) is independent of calling program's UOW – if calling program's UOW rolled back, data changes made by autonomous SQL procedure will not be rolled back
    - An autonomous SQL procedure does not share locks with caller, and could conceivably get into a lock contention situation with its caller
    - An autonomous SQL procedure can be cancelled by cancelling caller
    - One autonomous SQL procedure can't call another

Native SQL procedures and UDFs – performance

Native SQL procedures (and UDFs): zIIP offload

- Some people think that native SQL procedures are zIIP eligible, period – that is NOT the case
- A native SQL procedure is zIIP-eligible ONLY when called by a DRDA requester (i.e., when the call comes through DDF)
  - A native SQL procedure runs under the task of its caller – if caller is a DRDA requester, task is an enclave SRB in the DDF address space, and that makes the SQL procedure zIIP-eligible
- An external DB2 stored procedure (SQL or otherwise) runs under a TCB in a stored procedure address space, and for that reason it's not zIIP-eligible, regardless of the caller
- So, *when DRDA requesters call external DB2 stored procedures*, switching to native SQL procedures will boost zIIP utilization

Eliminating task switch delays

- When an external DB2 stored procedure is called (or an external UDF invoked), the caller's thread has to be switched from the caller's task to the stored procedure's task
- Not so important for a stored procedure, but a UDF could be driven many times in the execution of 1 query, if (for example) the UDF appears in the SELECT of a correlated subquery
  - In that case, all the thread switching from the application's task to an external UDF's task (and back) could really add up
  - At one site (DB2 10 NFM), a given query drove over 1,000 invocations of an external UDF in a single execution, and a query monitor showed a large amount of "UDF TCB wait" time
  - The external UDF was changed to a SQL UDF, and the query's elapsed time decreased substantially

DB2 10: better SQL PL performance

(a package)

- The compiled form of a native SQL procedure executes with improved CPU efficiency in a DB2 10 environment vs. DB2 9 (when SQL procedure is regenerated in the DB2 10 system)
- A couple of reasons why this is so:
  - The path length for execution of IF statements (very common in SQL PL routines) is reduced
  - SET statements that reference built-in functions (e.g., the CHAR function) are more CPU-efficient
- You can get additional CPU savings by leveraging the new (with DB2 10 NFM) support for “chained” SET statements:

```
SET x=1;
SET y=2;
```

```
SET x=1, y=2;
```

REGENERATE versus REBIND PACKAGE

- Referring to REBIND PACKAGE vs. ALTER PROCEDURE (or FUNCTION) with REGENERATE for a SQL PL routine
- Key difference:
  - REBIND PACKAGE affects only the non-control statements in a routine (e.g., SQL DML statements like SELECT), while REGENERATE reworks a package in its entirety
    - To get improved CPU efficiency for IF statements, and for SET statements that reference built-in functions, you need to REGENERATE SQL PL routines in a DB2 10 (or later) environment – REBIND PACKAGE won't do it
    - Plus, if you want the bulk of the control statement section of a SQL PL routine's package to go above 2 GB bar in DBM1 when the package is allocated to a thread, you'll need to REGENERATE the routine

More on REGENERATE vs. REBIND PACKAGE

- Like REBIND PACKAGE, REGENERATE can lead to access path changes for SQL DML statements in a SQL PL routine
  - APREUSE (reuse access paths) not an option for REGENERATE
  - Also, plan management (reactivate previous instance of package via REBIND SWITCH) not applicable to REGENERATE
  - So, use REBIND PACKAGE instead of REGENERATE if there's not a need to rework control section of SQL PL routine's package
  - If you do want to REGENERATE a SQL PL routine's package, consider doing a REBIND PACKAGE first
    - After the REBIND PACKAGE, check to see if access paths changed (APCOMPARE on REBIND can help here)
    - If access paths didn't change (or changed for the better), you should be safe with a REGENERATE (access paths likely to stay the same if the REGENERATE closely follows the REBIND PACKAGE)

Other performance boosters

- These are things that can improve the CPU efficiency of DB2 stored procedures in general – both native SQL and external
  - RELEASE(DEALLOCATE) for packages of frequently executed stored procedures (saves CPU when used with persistent threads)
    - DB2 10 provides more “head room” for RELEASE(DEALLOCATE) by shifting thread-related virtual storage above the 2 GB bar in DBM1 (for packages bound or rebound in DB2 10 system)
    - More DB2 10: RELEASE(DEALLOCATE) respected for packages executed via DDF threads – these become high-performance DBATs
    - DB2 11: relief for BIND/REBIND, DDL, utility concurrency issues related to RELEASE(DEALLOCATE) + persistent threads (DB2 10: can use MODIFY DDF command to turn high-performance DBATs off/on)
  - DB2 10 NFM: DECLARE CURSOR WITH RETURN TO CLIENT
    - Especially for larger result sets, a more CPU-efficient way to make result set rows available to a “top-level” calling program from a nested stored procedure, versus temporary table approach

Performance benefits of stored procedures

- From a performance perspective, the "sweet spot" for stored procedure usage is for a DB2 client-server (i.e., DDF) workload
- Stored procedures provide a means of packaging static SQL in a form that can be dynamically invoked

For optimal CPU efficiency

Client-side developers may want to call stored procedures via JDBC or ODBC

- Stored procedures also help to loosen coupling between client-side programs and database design
  - Consider a logical database design change (visible to data-accessing programs) that would improve application performance
  - If affected data is accessed via stored procedures, client-side code likely won't need changes – just change stored procedures as needed

Native SQL procedures and UDFs – scalability and security

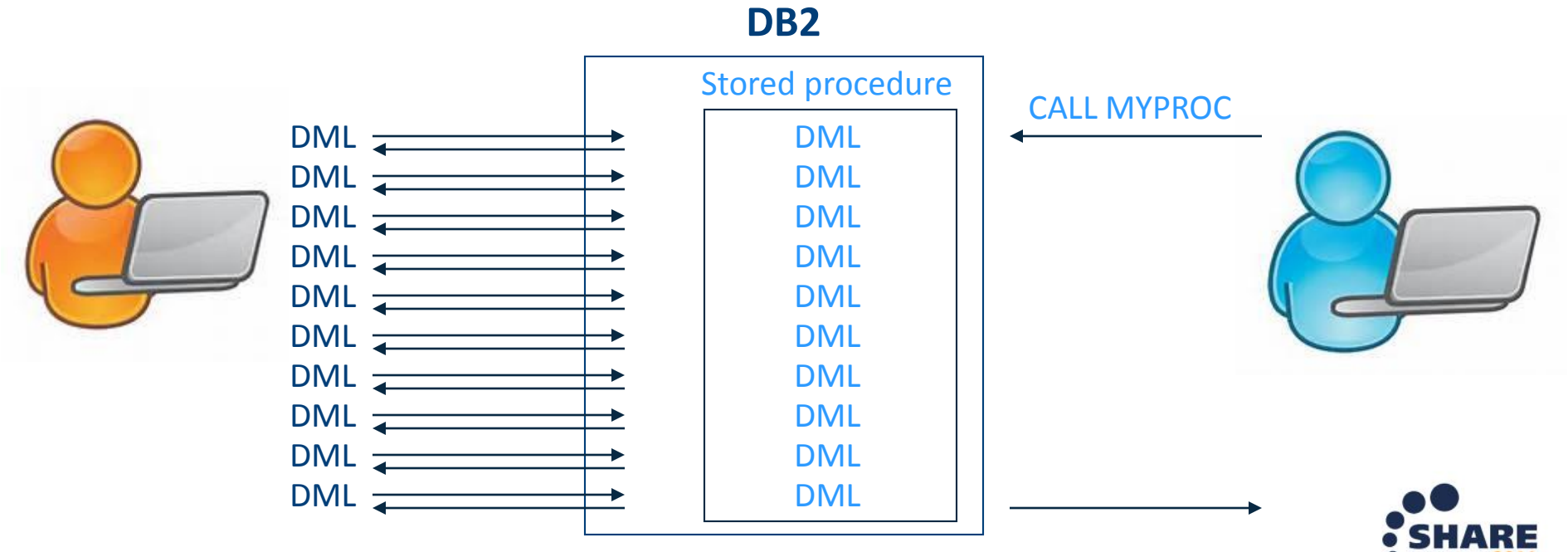
About this section of the presentation…

- As I see it, the scalability and security advantages of DB2 stored procedures pertain to stored procedures in general – external as well as native SQL
- That being the case, the particular advantages of native SQL procedures (and UDFs) versus external stored procedures in this area can be described as follows:

> *Native SQL procedures provide the security and scalability advantages that pertain to DB2 stored procedures in general, with these added advantages:*
>
> - They can be developed by SQL-knowledgeable people who aren't COBOL or Java programmers
> - They provide server-side CPU cost savings for DB2 client-server (DDF) applications, thanks to significant zIIP offload

Scalability: reduced network “chattiness”

- For a DDF transaction that involves issuance of, say, 10 SQL DML statements, packaging those statements in a stored procedure replaces 10 network request/response pairs with 1



Scalability: the DB2 MQListener

- If some of your transactional work can drive asynchronous vs. synchronous DB2 processing, peak workloads can be spread out, time-wise, smoothing out mainframe utilization profiles
  - Input data could be placed on a WebSphere MQ queue, at which point a transaction, from the client perspective, is done
  - The DB2 MQListener ships with DB2 for z/OS, and enables you to associate an MQ queue with a DB2 stored procedure
    - When message arrives on queue, associated stored procedure is automatically invoked – message is passed as input
    - You could set up several queues for different message types, and each queue could be associated with a particular stored procedure
  - With this approach, transaction surge would increase a queue's message depth, vs. increasing server utilization
  - Added bonus: a less-brittle application infrastructure (if the database is unavailable, messages build up on queues)

Security: static SQL

- Recall that stored procedures provide a means of packaging static SQL in a form that can be dynamically invoked
- Sometimes, the contribution of static SQL toward more-robust security is more attractive than the performance advantage
  - When SQL DML statements are static and issued by way of a stored procedure, invoking application's auth ID does not require table access privileges (SELECT, INSERT, UPDATE, DELETE)
    - Instead, the application's ID requires only the EXECUTE privilege on the stored procedure
    - Even more secure: create role, grant execute on stored procedure to role, and create trusted context that restricts use of role's privileges to a particular application ID connecting from a particular IP address

Security: database schema abstraction

- If someone wants to hack into your database, he'll have an easier time of it if he knows names of tables and columns
- When "table-touching" SQL statements are packaged in stored procedures, stored procedure developers require knowledge of database details but coders of calling programs do not
  - Data security is boosted by limiting the number of people with detailed knowledge of the database schema

Native SQL procedure and UDF development and management

IBM Data Studio

- A great tool for developing and debugging SQL PL routines
  - Free, and downloadable – current release is Version 4.1 (http://www-03.ibm.com/software/products/en/data-studio/)
  - Eclipse-based, GUI client that runs under Windows or Linux
  - Among other things, the Data Studio Debug view enables you to:
    - Set breakpoints (on both a line and variable basis)
    - Step into or over a line of code
    - Inspect variables, and change variable values
  - Also, beats the tar out of SPUFI when it comes to testing individual SQL statements, especially in these categories:
    - XML data access (even formats it for you on retrieval)
    - LOB data access
    - Stored procedure calls

What about SQL PL source code management?

- There are vendor solutions available for management of SQL PL source code
- Another option: “roll-your-own”
  - This approach can be aided by some sample REXX routines provided via the fix for APAR PM29226 (DB2 9 and 10 for z/OS)
  - DB2 sample job DSNTEJ67 illustrates use of these routines
    - One service extracts the source for a SQL PL routine from the DB2 catalog and places it in a file (or into a string)
    - Another invokes SQL PL precompiler, generates a listing of a routine
    - Another can be used to change elements of SQL PL source for a routine (e.g., schema, version ID, CREATE PROCEDURE options)
    - Another can be used to deploy SQL PL source code

Another free SCM option for SQL PL

- Use the open-source Apache Subversion software versioning and revision control system, in conjunction with Data Studio (http://subversion.apache.org/)
- Data Studio is built on Eclipse, and Subversion (also known as SVN) integrates with Eclipse
  - SQL PL routines developed using Data Studio are Eclipse resources
  - These resources can be managed by an Eclipse “Team” component plug-in such as Subversion
    - Subversion can be installed into Data Studio

Native SQL procedure deployment

- With the procedure's package being the only executable, deployment is different versus external procedures
- To get native SQL procedure from test system into production, you can use BIND PACKAGE with the DEPLOY option
  - Non-control section of procedure's package will be reoptimized on production system, but the control section will not be changed
- If previous version of the SQL procedure is already running in production, control when the new version becomes active via ACTIVATE VERSION option of ALTER PROCEDURE
  - Selective use of the new version before then can be enabled via the CURRENT ROUTINE VERSION special register
- ***Get comfortable with these deployment mechanisms before making major use of native SQL procedures and UDFs***

ALTER vs. drop/re-create for native SQL procs

- Sometimes – especially early in an organization's use of SQL procedures – DBAs will use drop and re-create versus ALTER PROCEDURE to make changes to a procedure
- That approach can be problematic when you get into nested procedure calls (i.e., one stored procedure calls another)
  - If PROC_A calls PROC_B, *and PROC_A is a native SQL procedure*, an attempt to drop PROC_B will fail
    - You can check SYSPACKDEP catalog table to see if any native SQL procedures are dependent on a given stored procedure (DTYPE = 'N')
  - You could try dropping PROC_A, then dropping PROC_B, then changing PROC_B via re-create, then re-create PROC_A, but what if PROC_A is called by a native SQL procedure?
  - Bottom line: if you can accomplish a needed change with ALTER PROCEDURE, do that versus drop and re-create

Managing the shift to SQL PL

About existing external stored procedures…

- Some organizations have hundreds, even thousands, of DB2 for z/OS stored procedures written in COBOL
  - It would probably be counter productive to try to change these to native SQL procedures en masse
  - On top of that, some of those COBOL stored procedures might access non-DB2 data (VSAM data, for example)
  - Low-hanging fruit for replacement with native SQL procedures: simple, frequently executed COBOL procedures that access DB2 data and are mostly called by DRDA requesters (want zIIP offload)
- As for external SQL procedures, converting those to native SQL procedures may be very straightforward – or not
  - Lots of useful information in this IBM “technote” (just a few pages):

    http://www-01.ibm.com/support/docview.wss?uid=swg21297948

Question: who writes SQL PL routines?

- One might think DB2 DBAs, but you could have a bandwidth problem with that approach
  - DB2 for z/OS DBA teams are often pretty lean and mean, and they're usually pretty busy managing the database system
- Maybe application developers – organizations usually have more of these folks than DB2 DBAs
  - But SQL PL, and all kinds of aspects of the CREATE and ALTER PROCEDURE (and FUNCTION) statements, may be unfamiliar to these people
- There's another way…

What about creating a new role?

- Might be called something like “procedural DBA”
  - DB2 database-centric, but with an emphasis on developing and managing stored procedures (and functions)
  - With such a position available, you could get a mix of applicants
    - Some who have been traditional DB2 DBAs and want more of an application focus
    - Some who have been traditional application programmers and want a more data-oriented role
    - In either case, could be an appealing new career challenge
- Something to keep in mind: SQL PL is virtually identical in DB2 for z/OS and DB2 for LUW systems
  - So, people writing SQL procedures and UDFs could create routines for both platforms

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