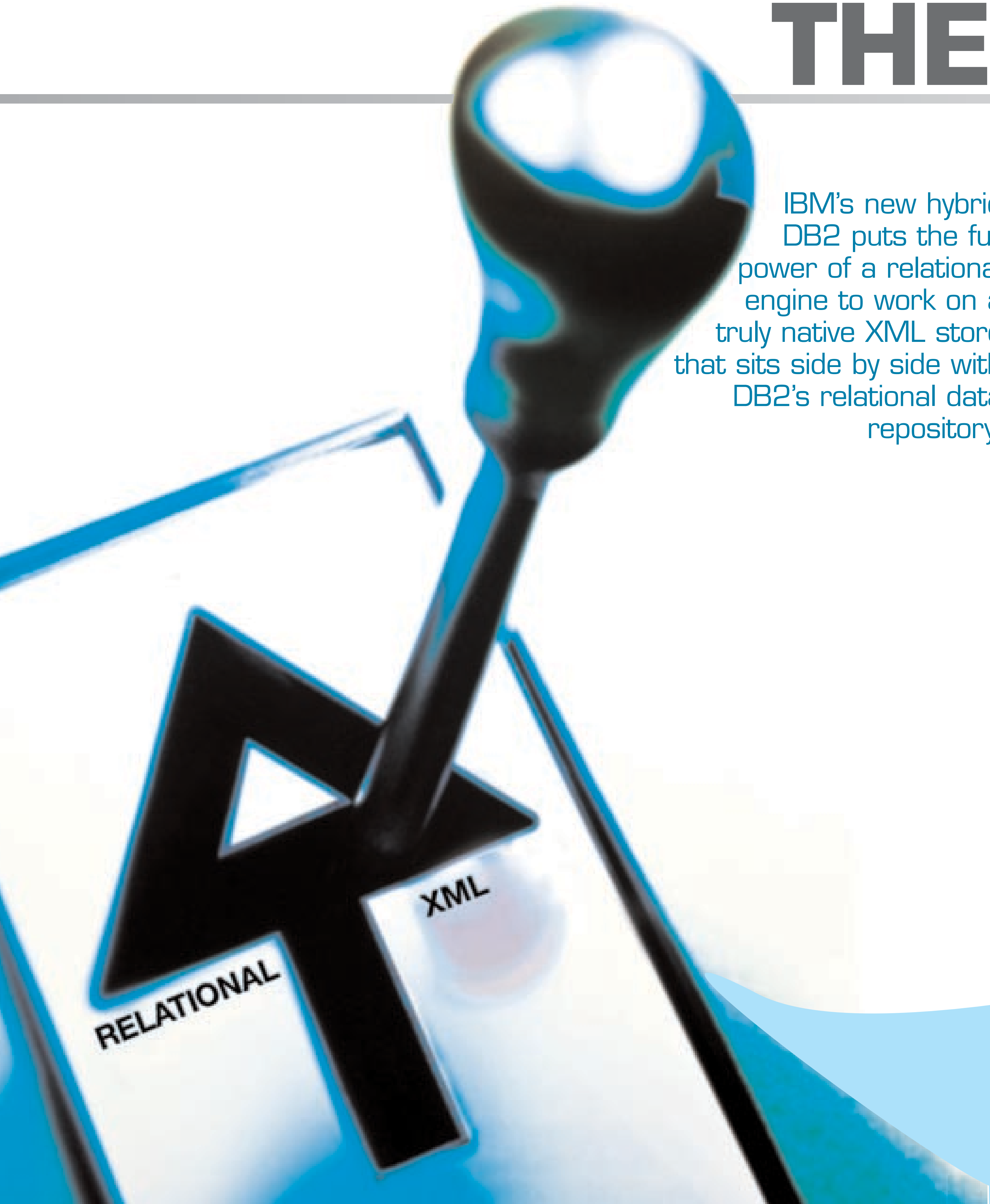
FIRING UP THE

IBM's new hybrid DB2 puts the full power of a relational engine to work on a truly native XML store that sits side by side with DB2's relational data repository.



HYBRID ENGINE

Relational databases drive most businesses of any size today. Popular and important as these databases are, they're simply not a great match for semi-structured (and hierarchical) content represented in XML. Because enterprises have, in aggregate, trillions of dollars invested in relational data and relational database management systems (RDBMSs), simply replacing RDBMSs with a pure XML store isn't an option. Adding an XML-only database into the infrastructure adds yet another integration and complexity challenge.

IBM is about to introduce true-native support for both XML and relational data. This evolutionary technology, now in beta tests with a small group of IBM customers, provides hybrid relational/XML storage from the ground up. That means DB2 will no longer need the XML Extender (just as it doesn't need an SQL Extender). DB2 will simply handle XML natively. (There are varying definitions of "native" XML support. To clear up the confusion about what's typically called "native" today, see the sidebar on page 45.)

In the hybrid version, XML is handled as a new data type. Nearly every DB2 component, tool, and utility has been enhanced to recognize and handle this new data type. The new storage paradigm retains XML in a parsed, annotated tree form—similar to the XML Document Object Model (DOM)—that's separate from the relational data store (see Figure 1, page 44).

On top of both data stores (relational and XML) sits one hybrid database engine. That single engine can process XQuery, XPath, SQL, and SQL/XML. The engine features a bilingual query compiler with parsers for both SQL and XQuery. So developers can access information using either language (or both together) according to what makes the most sense in specific situations. A hybrid DB2 provides the flexibility to shift (between XML and SQL) paradigms as information management needs change.

Storing relational and XML data in a database management system that understands and supports both models at every level (from the client, through the engine, down to the disk) provides flexibility and consistently fast performance. The XML data inherits the same backup and recovery, optimization, scalability, and high availability DB2 offers for relational data. Ultimately, a unified XML/relational database keeps things simple by avoiding the need to integrate XML and relational data from separate stores.

NATIVE BENEFITS

The first generation of XML support in relational databases was based on either shredding (or decomposing) documents to fit into relational tables or storing documents intact as character or binary large objects (CLOBs or BLOBs). Each of these choices attempts to force XML into a relational model. However, these approaches have serious limitations in capability and performance. The hybrid model stores XML in a model similar to the DOM. The XML data is formatted to buffered data pages for faster navigation and query execution as well as simpler indexing.

When DB2's true-native XML support debuts with the next major release, existing support for storing XML documents shredded in relational tables or intact as CLOBs and BLOBs will continue. Support for shredding is important because XML can be used to feed existing relational schemas. However, true-native storage offers significant advantages in these areas:

Storage. DB2's native XML technology will store XML with node-level granularity instead of document-level. While interacting with IBM's native XML support, the abstraction shown is a column of type XML in a relational table. This column has no maximum length and no mandatory constraining XML schema. Any well-formed XML statement can be inserted into that column. Therefore, the following statement is a valid table definition:

```
Create table dept (deptID int, deptdoc xml)
```

A table isn't limited to a single column of any given type, so the following statement is equally valid:

```
Create table dept2 (deptID int, deptinfo xml,
 orgchart xml, employees xml)
```

In the physical storage layer, the primary storage unit in the IBM implementation is a node. A node exists on a page along with other nodes from the same or different documents. Each node is linked not only to its parent, but also to its children. As a result, navigating to a node's

BY ANJUL BHAMBHRI

parent, siblings, or children is highly efficient, operating at little more than pointer traversal speeds as long as the next referenced node is on the same page. Nodes can grow or shrink in size, or they can be relocated to other pages without rewriting the entire document.

Indexing. XML applications that manage millions of XML documents aren't uncommon; indexing these large collections of XML data is required to provide high query performance. DB2 supports path-specific indexes on XML columns so that elements and attributes frequently used in predicates and cross-document joins can be indexed.

The new XML values index can provide efficient evaluation of XML pattern expressions to improve performance during queries on XML documents. In contrast to traditional relational indexes, in which index keys are composed of one or more table columns specified by the user, the XML values index uses a particular XML pattern expression (subset of XPath that doesn't contain predicates, among other things) to index paths and values in XML documents stored in a single XML column. The index can also fill in default attribute and element values from the schema at insertion time if the values aren't specified in the document. When creating an index, you can specify what paths to index and as what type. Any nodes that match the path expression or the set of path expressions in the XML documents stored in that column are indexed, and the index points directly to the node in storage that's linked to its parent and children for fast navigation.

Instead of providing index-access to the beginning of a document, index entries contain actual document node position information. As a result, the index can quickly provide direct access to the nodes within a document and avoid a document traversal. In addition, because the index has this document node position information, it understands the document hierarchy and can perform containment tests. The index knows which child nodes belong to the same ancestor and can do appropriate filtering.

For example, here's how to define an index on all employee names in all documents in the XML column deptdoc:

```
create index idx1 on dept(deptdoc) generate
 key using xmlpattern '/dept/employee/name'
 as sql varchar(35);
```

The xmlpattern is a path that identifies the XML nodes to be indexed.

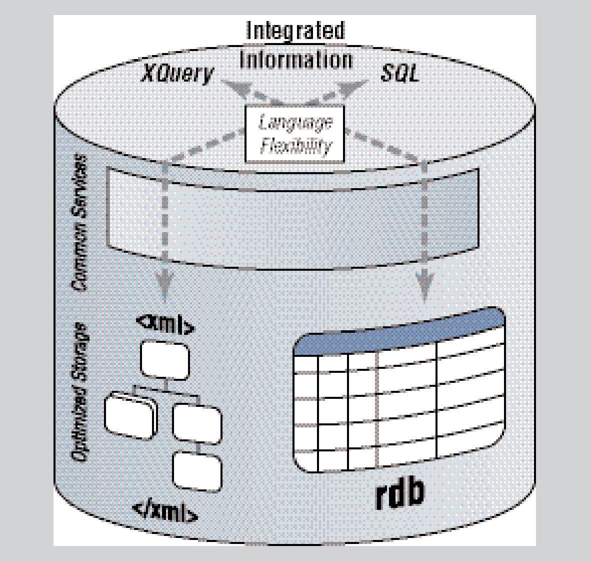


FIGURE 1. DB2's new XML-relational storage model.

Because DB2 doesn't require a single XML schema for all documents in an XML column, it may not know which data type to use in the index for a given xmlpattern. The user must specify the datatype explicitly in the as sql <type> clause.

If a node matches the xmlpattern but fails to cast to the specified index type, then no index entry is created for the node without raising an error. A single document may contain zero, one, or multiple nodes that match the xmlpattern. Thus there may be zero, one, or multiple index entries for a single row in a table (which is significantly different from indexes on relational columns).

You can create indexes on multiple path expressions on any given column of type XML. Therefore, the following statements are also valid:

```
create index idx1 on dept(deptdoc) generate
 keyusing xmlpattern '/dept/employee/name'
 as sql varchar(35);
create index idx2 on dept(deptdoc) generate
 key using xmlpattern '/dept/employee/@id as
 sql int;
```

Furthermore, path expressions can include both wildcards and descendant-or-self axis traversal, so the following statements are also valid:

```
Create Index IX3 on dept(deptdoc) generate
 keys using xmlpattern '/dept/*/name' as sql
 varchar(20)
Create Index IX4 on dept(deptdoc) generate
 keys using xmlpattern '//office' as sql double
Create Index IX5 on dept(deptdoc) generate
 keys using xmlpattern '/dept/employee/*' as
 sql varchar(20)
```

Query. XQuery, the new language for querying XML data, is designed to handle diverse schemas, including constructs such as sequences (instead of sets, as in SQL), multiple nested sequences, and sparse attributes. XQuery can also support heterogeneous schemas and dynamic schema changes.

The IBM implementation has no stand-alone XQuery or XPath processor. The basic XQuery and XPath primitives are built directly into the query engine. The query compiler itself is bilingual, having two interoperating query language parsers—one for SQL and the other for XQuery—to generate a new variation of the Query Graph Model designed to process relational and XML data. Because the intermediate query representation is language-neutral, XQuery, SQL and combinations of XQuery and SQL compile into the same

WHAT IS TRUE NATIVE?

Each of the currently available (non-native) methods for managing XML in relational databases attempts to make XML conform to the relational model in some way. These approaches include:

Shredding. Most major RDBMSs (including DB2) support shredding. Shredding involves defining a relational schema that corresponds to the XML (for example, representing parent/child relationships in the XML as one or more child tables in a referential integrity constraint with its parent) and defining a mapping from the XML data to the relational schema.

Shredding is a good fit in existing relational environments. However, mapping can be complex and fragile, and you must define a mapping for each XML document you want to store. If the XML schema changes, the mapping may no longer be valid or may require a complex change process. Once decomposed, the data ceases to be XML, loses any digital signature, and becomes difficult and expensive to reconstruct (often requiring many joins).

Storing XML as a CLOB. All major vendors support storing entire XML documents in a variable length character type (VARCHAR) or as CLOBs. If XML documents are inserted into CLOB or VARCHAR columns, they are typically inserted as unparsed text objects. CLOBs preserve the original document and provide uniform handling of any XML, including highly volatile schemas.

Avoiding XML parsing at insert time guarantees high insert performance. However, without XML parsing, XML document structure is entirely ignored. This precludes the database from doing intelligent and efficient search and sub-document level extract operations on the stored text objects. The only remedy is to invoke the XML parser at query execution time to “look into” the XML documents so that search conditions can be evaluated. The high insert performance comes at the cost of low search and extract performance.

BLOB (pseudo native). BLOB-based storage is conceptually similar to CLOB storage; however, instead of storing the XML data as a preparsed string, BLOBs store it in a proprietary post-parse binary representation. This approach is sometimes called pseudo native, because the data representation remains in XML within the BLOB.

However, the underlying storage for a document is virtualized as a single contiguous byte range, which can cause performance problems. Updating can require the entire document to be rewritten (and locked). Access to portions of the document might require the entire document to be read from disk.

True native. True native storage holds the post-parsed data on disk, enabling individual nodes of the data model to be stored independently—that is, not as a stream—and then interconnected. True native storage provides the advantages of BLOB and CLOB, but resolves the remaining performance issues because the document storage isn’t virtualized as a single contiguous byte range. The storage for the entire set of documents is virtualized as a contiguous byte range; however, individual nodes can be relocated in this range with minimal impact on other nodes and indexing.

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intermediate representation, go through the same rewrites and transformation, are optimized in a similar manner, and generate similar executable code. This process results in optimal and interoperating query plans regardless of the language used to specify them.

Because the two parsers interoperate, you can mix SQL and XQuery in the same statement, making the searches more powerful by providing the ability to query within the XML document and returning fragments of it from SQL:

```
select deptID, xmlquery(‘for $d in
  $deptdoc/dept
  where $d/@bldg = 101
return $d/name' passing d.deptdoc as
  "deptdoc")
from dept d
where deptID <> "PR27";
```

The query first filters the rows where deptID is not PR27. After that, it returns deptID and the department name as XML fragments if the building is 101.

In DB2, XQuery can operate on XML documents in XML columns. However, if you want to restrict the input to an XQuery based on conditions placed on relational columns you can do so via db2-fn:sqlquery, which accepts any select statement that returns a single XML column.

```
For $e in db2-fn:sqlquery('select deptdoc from
  dept where deptid = "pr27"')/dept/employee
Where $e/office = 344
Return $e/name
```

Deeper levels of nesting (SQL within XQuery in which SQL itself contains nested XQuery) is supported.

Flexibility and performance. With IBM’s hybrid approach, there’s no need to predefine XML schema, limit documents to a given schema, or provide any mapping between XML and relational models.

The hybrid approach offers an important advantage over shredding: It eliminates the cost of joins and other processing necessary to reconstitute XML documents. In the case of complex documents, these costs can be very significant.

When compared to CLOB approaches, truly native storage eliminates the need to parse XML documents at query time. Given XML parsing costs, CLOB-based approaches are impractical if any form of search into the document—that is, parsing—is necessary. CLOB should be considered only when the usage models are expected to be full document insertion, search by purely relational attributes, and full document retrieval.

Native storage improves on the BLOB approach because it provides more consistent behavior as the size of documents increases or when the amount of data to access is a small percentage of the total document size.

RIGHT MODEL, RIGHT TASK

A true-native XML data store does more than expose XML to its clients—it represents the XML as XML throughout the entire data engine stack (from client to disk and back out again).

Hybrid systems don’t mandate that all data be represented as relational data, nor do they require that all data be in XML; instead, they provide the choice of the right model for the right task. ■

Anjul Bhambhri [bhambhri@us.ibm.com] is the senior development manager for XML support in DB2 and heads the XML effort across DB2 UDB.