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Oracle XML DB: Choosing the Best XMLType Storage Option for Your Use Case

ORACLE

Introduction

XMLType is an abstract data type that provides different storage and indexing models to best fit your data and your use of it. As an abstract data type, your applications and database queries gain in flexibility: the same interface is available for all XMLType operations.

XML is being used in a variety of ways – e.g., sometimes XML is constructed from relational data sources, so it is relatively structured, sometimes it is used in the ETL scenario, which is also very structured, sometimes it is used for storing free-form documents like resumes, etc. In addition, the retrieval pattern is different for different kinds of data. The data-centric users usually have a fixed set of queries, whereas the document-centric users issue more ad-hoc queries.

Because the XML usage falls in a broad spectrum, there is no one-size-fits-all storage to offer the best performance and flexibility for each of these use cases. Hence Oracle offers three different storage models for XMLType. Because different storage (persistence) models are available, you can tailor performance and functionality to best fit the kind of XML data you have and the pattern of its use. Therefore, one key decision to make when using Oracle XML DB for persisting XML data as XMLType is which storage model to use for which kind of XML data. This paper guides you on how to choose the best storage option, given your use case.

Storage Options

XMLType tables and columns can be stored in the following ways:

- **Binary XML storage** – This is the default storage for Oracle XML Database. XMLType data is stored in a post-parsed binary format specifically designed for XML data. Binary XML is compact, post-parsed, and XML schema-aware XML. The biggest advantage of Binary XML storage is its flexibility – you can use it for schemaless documents, or when the schema allows for high variability. The format also provides efficient partial update and stream-able query execution.
- **Structured storage** – XMLType data is stored relationally. The biggest advantage of structured storage is the performance. This provides the best performance in structured cases – the query performance matches that of relational tables, and updates can be performed in-place. It also provides relational-like schema evolution capability.
- **Unstructured storage** – This storage form, also known as XMLType CLOB storage, is deprecated in Oracle 12cR1. Despite ability to store document byte for byte in original form and providing "document fidelity", this storage is extremely inefficient for partial document updates retrieval. If XMLType as CLOB format is already used for storage, customers should consider moving their data to Binary XML storage format using Oracle Golden Gate. If "Document Fidelity" is important for your usecase, you could store a copy of XML document in a relational CLOB column.

In addition, Oracle supports the following kinds of indexes on XMLType:

- B-Tree index on Structured storage
- XMLIndex with Structured and Unstructured components on Binary XML and Unstructured storage
- Secondary B-Tree indexes on the secondary tables created by XMLIndex (for both Structured and Unstructured components)
- XML Full Text Index on Binary XML.

Each of these storage models and index combinations has its own advantages and disadvantages in different dimensions, such as performance and flexibility. No single storage or index is right for every use case. The advantages and disadvantages of different storage options are summarized in Appendix 1.

XMLType Use Cases

Most XMLType use cases fall into well defined categories listed below. If your use case falls into any of these categories, you could start by using the recommended solution for that use case. If the recommended solution doesn't satisfy your needs, then look at the remaining sections to fine-tune the storage/indexing model.

Note that this whitepaper is about the use cases where the data is persisted as XMLType. Although a common XML use case is "XML generation from relational data". This use case is not discussed here, because the storage is relational and the user is using XML generation functions to generate XML which is not persisted.

Use Case 1: An XML store with very little query requirements

There are several reasons why an application will want to store XML data and perhaps retrieve the full XML. In this use case, there is no requirement to update or query XML fragments. If in case XML fragments do need to be queried or updated, such operations are done in the application-tier, so the database is unaware of them. In such cases, the user has 2 options:

Option 1 is to store the XML into the XMLType Binary XML storage.

Option 2 is to just store the XML into a relational BLOB or CLOB column, preferably as SecureFile.

However, when using option 2, Oracle will not parse the XML, so we cannot guarantee the validity of the XML data. In addition, in option 2, users cannot perform XMLType operations on this column.

Use Case 2: ETL: XML used only as a staging area

ETL stands for "extract-transform-load" and refers to XML use cases where customers need to store XML in the database before transforming it into their operational systems (mainly relational). The XML data is highly structured and conforms to an XML schema. Producing relational values from XML as well as generating XML from relational data is covered under this category. The storage we recommend for ETL is XMLType Structured Storage, also known as Object Relational storage.

Use Case 3: XML persistence requiring interoperability with relational systems (including updates)

This use case is similar to use case 2 above, except that the XMLType data require updates. These updates could update partial XML data (known as "piecewise updates"). The storage

we recommend for this use case is the XMLType Structured Storage, also known as the Object Relational storage, since it has excellent support for piecewise updates.

Use Case 4: Semi-structured XML persistence that includes updates

In this use case, either the schema is variable, or large portions of schema are not well defined. Hence the use of XMLType Structured Storage is not feasible. Binary XML is the ideal storage option for this use case. For value searches, use structured XMLIndex when paths are known, and use path-subsetted unstructured XMLIndex when paths are not known beforehand.

Use Case 5: Business intelligence

SQL constructs such as order-by, group-by, and window enable powerful business intelligence (BI) queries over relational data. The XMLTable function allows values in XML to be projected out as a virtual table. Order-by, group-by, and window constructs can operate on columns of the virtual table. Structured XMLIndex internally organizes its storage tables in a manner that reflects the virtual table(s) exposed by XMLTable. Therefore, structured XMLIndex is well suited for indexing XML data in a way that makes such XMLTable-based queries very efficient. A query that uses the XMLTable function can be rewritten to simple access of the relational tables of a structured XMLIndex. This means that order-by, group-by, and window constructs operating on columns of the virtual table are translated to order-by, group-by, and window constructs operating on the corresponding physical columns of the structured XMLIndex tables.

For BI-style queries, we recommend that the user store their data as binary XML, with structured XMLIndex on it. Furthermore, the user should create relational views over XML using XMLTable, where the views project all columns of interest to the BI application. Application queries should be written against these relational views. If structured XMLIndex is created in one-to-one correspondence to these views, Oracle RDBMS will make sure that queries over the views are seamlessly translated into queries over the relational tables of the structured XMLIndex, thereby providing relational performance.

Use Case 6: XML content store with full text searches

If your application needs to do full text searches on XML data, you should use binary XML with XML Full Text index on it.

Use Case 7: Data integration from diverse data sources to allow a uniform query interface

If your XML data comes from several different data sources, each having its own schema, then you should store it in the binary XML format.

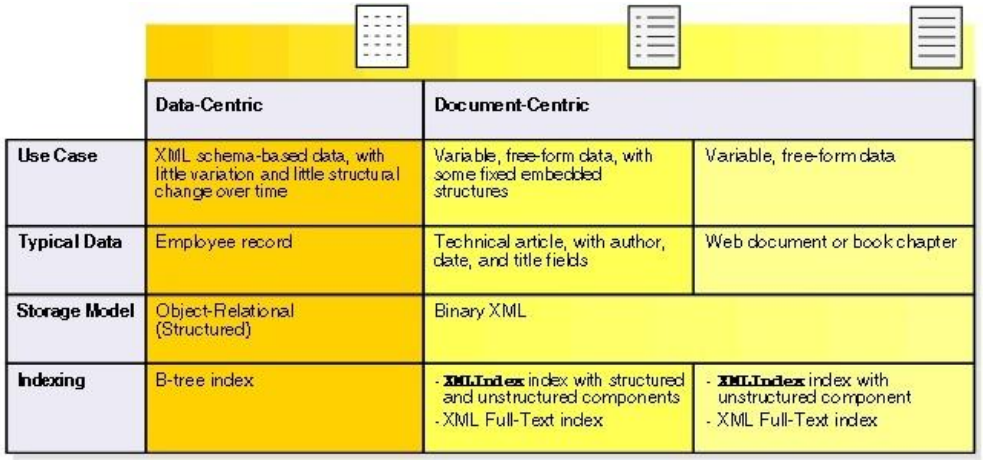
There are two different flavors of this use case:

1. If data from different data sources share some structured islands that can be normalized, XMLIndex structured component can be created over these structured islands. An RSS news aggregator is a good example of such use case.
2. If there are no common structured islands from different data sources, Unstructured XMLIndex can be created.

If your use case doesn't fit into one of the buckets described above, you need to take additional considerations detailed in the following sections on how to choose your storage.

The Rule of Thumb – Data Centric vs. Document Centric

The first thing to consider when choosing an XMLType storage model is the nature of your XML data and the ways you use it. A spectrum of XML use cases has data-centric use of highly structured data at one end and document-centric use of highly unstructured data at the other. The first question to ask yourself is whether your use case primarily data-centric or document-centric. These considerations are summarized in Figure 1 followed by detailed descriptions.



	Data-Centric	Document-Centric	
Use Case	XML schema-based data, with little variation and little structural change over time	Variable, free-form data, with some fixed embedded structures	Variable, free-form data
Typical Data	Employee record	Technical article, with author, date, and title fields	Web document or book chapter
Storage Model	Object-Relational (Structured)	Binary XML	
Indexing	B-tree index	- **XMLIndex** index with structured and unstructured components - XML Full-Text index	- **XMLIndex** index with unstructured component - XML Full-Text index

FIGURE 1: XML USE CASES AND XMLTYPE STORAGE MODELS

- Data-centric – Your data is, in general, highly structured, with relatively static and predictable structure, and your applications take advantage of this structure. Your data also

conforms to an XML schema. This kind of data typically follows an entity relation (ER) model.

- Document-centric – there are two cases:
  - Your data is relatively structured, but your applications do not take advantage of that structure: they treat the data as if it were without structure.
  - Your data is generally without structure or with a variable structure. Document structure can vary over time (evolution) and the content is mixed (semi-structured) with many elements contain both text nodes and child elements. Furthermore, many XML elements can be absent or can appear in different orders. Finally, documents might or might not conform to an XML schema.
- Semi-structured – Your data has structured (data-centric) and unstructured (document-centric) parts. The primary document could be structured, with islands of unstructured content, or the primary document could be unstructured, with structured islands.

Once you have determined the data-centric or document-centric half of the spectrum appropriate for your use case and data, consider whether your case is at an end of the spectrum or closer to the middle. That is, just how data-centric or document-centric is your case?

- Employ structured storage for purely data-centric uses. A typical example of this use case would be an employee record (fields' employee number, name, address, and so on). The structured storage is an entity-relationship decomposition of the XML. Use B-tree indexing with structured storage. This storage model gives the best performance for data-centric cases as the metadata (i.e., tags) is pulled out into column level, and hence queries can do a metadata lookup, which is extremely fast.
- Employ binary XML storage for all document-centric use cases. This option gives the storage flexibility because the metadata (i.e, tags) is stored with the data, so schema changes are easily handled. XMLIndex is the indexing method of choice here.
  - For general indexing of document-centric XML data, use Unstructured XMLIndex. A typical example of this use case would be an XML Web document or a book chapter.
  - If your data contains some predictable, fixed structures that you query frequently, then you can use XMLIndex indexes with structured components on those parts. A typical example of this use case would be a free-form specification, with author, date, and title fields.
  - To handle islands of structure within generally unstructured content, please create a structured XMLIndex and as well as unstructured XMLIndex. A use case where you might use both components would be to support queries that extract an XML fragment from a document whenever some structured data is present. The unstructured XMLindex is used for the fragment extraction; the structured component is used for the predicate that checks for the structured data (e.g., the SQL WHERE clause).

These considerations are summarized in Figure 1 above. The figure shows the spectrum of use cases, from most data-centric, at the left, to most document-centric, at the right. The table in the figure classifies use cases and shows the corresponding storage models and indexing methods.

Query Pattern

Another important consideration in choosing your storage and indexing option is your query patterns. The question to ask yourself is whether you have a single root hierarchy or a multi-root hierarchy.

- Single root hierarchy – This happens when you have purely content data, and you always query from the root down the tree to the leaves. For example, your XML instance is a book, and you always query from the root down to the text.
- Multi-root-hierarchy – This happens when your query can originate from different elements in the schema. For example, you have a Department-Employee-Project schema, and sometimes your query searches using the "department id", sometimes using "project id", and sometimes using "employee id". This case frequently happens when XML is used as a data-exchange vehicle.

If you have a multi-root hierarchy, then structured storage will give you the best performance because it will perform relational-style lookups starting from any storage table to the parent/child tables. If, for some reason, you are unable to use the structured storage, the next best choice is to use Binary XML with structured XML Index. Single root hierarchy case is amenable to different storage options, as specified in the "Advanced considerations" section below.

If your use case is primarily structured, when do you choose Structured storage or Binary storage with Structured XMLIndex? Structured XMLIndex lets you leverage the flexibility of Binary XML while maintaining relational performance. One way to determine if Structured XMLIndex is right for you, is to ask yourself – are your queries known ahead of time? If the queries are known ahead of time, and the list of Xpaths queried is known, you can create a structured XMLIndex on those paths. Note that the queries can change over time, in which case you can ALTER your structured XMLIndex. However, if the queries are not known ahead of time, you are better off choosing the object-relational storage.

Advanced considerations

Of course, not all use cases are easy to classify into the spectrum outlined in the above sections. Even when they are, other constructs of the schema may dictate the storage model.

Three storage solutions are described below. Following that, we give a flowchart guiding you on how to choose a storage model.

The storage solutions

Here are the three storage options Oracle XMLDB provides. Please see "The flowchart" in the next subsection to decide which solution is right for you.

Solution Binary: Choose Binary XML storage. Choose your indexing options:

- Does your data have predictable structured islands in it?
  - Yes Choose Structured XML Index for the structured islands.
- Do you need to support full text queries?
  - Yes Create XML Full Text index.
- Does your need to support ad-hoc XML queries involving predicates ?
  - Yes Create Unstructured XMLIndex.

Solution Object Relational: Choose Structured storage.

- Create B-tree and bitmap indexes just like you would for relational storage.

Solution Clob: Choose relational CLOB column storage. Choose your indexing options:

- Do you need to support full-text queries?
  - Yes Create XML Full Text index.

The Flowchart

This flowchart guides you on how to choose the storage.

1. Do you need Document Fidelity for your XMLType? In other words, do you want to maintain the original XML data, byte for byte, with all original white spaces preserved?

   Yes Use "Solution Clob" for storing 1 copy of your data, and optionally also storing your data using Solution Binary for XMLType operations. Note that it will be your responsibility to keep the 2 copies in sync.

2. Do you usually just insert and select the entire XML data? In other words, do you rarely select or update part of the XML?

   Yes Use "Solution Binary" for storage.

3. Do you want to store XMLType instances conforming to multiple schemas in 1 table/column? (Note: This kind of usage is not recommended because your queries will not be able to take advantage of the schema to make optimizations.)

Yes Stop. Choose "Solution Binary"

4. Do you have a schema for your XMLType?

   Yes Go to Step 6.

5. (You do not have a schema.) Perhaps your XMLType is data-centric. Is it possible for you to generate a schema using a schema generation tool?

   No Stop. Choose "Solution Binary"

6. If you came here, it means that your data conforms to a single schema, so you may be able to get the best performance out of using the Structured storage. However, there are several schema constructs that are incompatible with structured storage. You will need to massage your schema and/or use case to make it structured-storage-friendly. Here are some factors that may affect your choice.

   6.1. **Schema evolution:**

   Note: It is conceivable that your use case during product development may be different from that of a production product. For example, it is conceivable that your data is structured, and your schema may evolve frequently during product development. However, once your product is released, it may evolve infrequently. In this case, it is important to consider the production time schema evolution (as opposed to development time schema evolution).

   6.1.1. Will the XML Schema be evolved very frequently?

   No Go to 6.2

   6.1.2. Can you take advantage of in-place evolve, or will you need to do copy-evolve?

   In-place evolve Go to 6.2

   Copy-evolve → Stop. Choose "Solution Binary".

   6.2. **Sparseness of data:** Is your data extremely sparse (like HL7, XBRL)?

   Yes Stop. Choose "Solution Binary".

   6.3. **Use of ANY, Choice:** A lot of automatic schema generators add constructs like ANY, Choice in the schema to make it more flexible. Many times, these are not strictly needed. These constructs make it hard to register the schema as Object Relational.

   6.3.1. Does your schema use constructs that make it hard to register as Object Relational, e.g., ANY, Choice etc?

   No Go to 6.4

6.3.2. Is it possible to modify your schema to remove these constructs?

Yes Modify the schema to remove such constructs and go to 6.4

No Stop. Choose "Solution Binary".

6.4. Stop. Choose "Solution Object Relational".

7. If you are still unable to decide what storage / indexing option is right for you, try out both Solutions Binary & Object Relational and run performance experiments with your workload to see what works best for you.

Conclusion

XML has diverse use cases ranging from data-centric to document-centric, so there is no one-size-fits-all storage model to give the best performance and flexibility for each of these cases. XMLType is an abstract data type that provides different storage and indexing models to best fit your data and your use of it. One key decision to make when using Oracle XML DB for persisting XML data as XMLType is which storage model to use for which kind of XML data. In general, default Binary XML storage provides a good option for most of the use cases. In specialized scenario of extremely structured document with an XML schema, object relational storage can be used. This paper has guided you in looking at various properties of your XML data to decide the best storage and indexing option, given your specific use case.

Appendix 1: Storage options relative advantages

The advantages and disadvantages of different storage options are summarized in Table-1 below:

QUALITY	BINARY XML STORAGE	STRUCTURED STORAGE
Throughput	+ High throughput. Fast DOM loading. There is a slight overhead from the binary encoder / decoder.	– XML decomposition can result in reduced throughput when ingesting or retrieving the entire content of an XML document.
Indexing support	+ XMLIndex, function-based, and Oracle Text indexes.	++ B-tree, Bitmap, Oracle Text, XMLIndex, and function-based indexes.
Queries	+. Fast when using XMLIndex. User queries which cannot use the index use streaming Xpath evaluation, which is reasonably fast as well.	++ Extremely Fast. Relational query performance. Users can create B-tree indexes on the exploded columns.
Update operations (DML)	+ In-place, piecewise update for SecureFile LOB storage.	++ Extremely fast. Relational column gets updated in-place.
Space efficiency (disk)	+ Extremely space-efficient because of encoded representation	++ Space-efficient.
Data flexibility	+ Flexibility in the structure of the XML documents that can be stored in an XMLType column or table.	– Limited flexibility. Only documents that conform to the XML schema can be stored in the XMLType table or column.
XML schema flexibility	++ Can store schemaless or schema based documents. An XMLType table can store documents conforming to any of the registered schemas.	– One XMLType table can only store documents conforming to one schema. Also provides relational-like in-place schema evolution capability.
XML fidelity	+ DOM fidelity (see structured storage description).	+ DOM fidelity: A DOM created from an XML document that has been stored in the database will be identical to a DOM created from the original document. However, insignificant white space may be discarded.

QUALITY	BINARY XML STORAGE	STRUCTURED STORAGE
Optimized memory management	+ XML operations can be optimized to reduce memory requirements.	+ XML operations can be optimized to reduce memory requirements.
Validation upon insert	++ XML schema-based data can be fully validated when it is inserted, though this is an expensive operation.	+ XML data is partially validated when it is inserted.
Partitioning	++ Partition based on relational or virtual columns.	++ Available
Streams based replication	++ Available	++ Available
Compression and Encryption	Binary XML with SecureFile storage can be compressed / encrypted	Each element/attribute can be compressed / encrypted individually

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