Modeling the Enterprise Data Architecture

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Unlike the simplistic models in books and training courses, a real enterprise has a very complicated data architecture. Most of the data will be held in large legacy or package systems, for which the details of data structure may be unknown. Other data will be held in spreadsheets and personal databases (such as Microsoft Access), and may be invisible to the IT department or senior business data administrators. Some key data may reside in external systems maintained by service providers or business partners. As you explore your own complex data architecture, you will come to accept two realities:

1. You have little control over the way high-level business data concepts are realized. Data is likely to be highly dispersed, often without adequate controls on quality.

2. Most data is duplicated across a number of systems, with significant variations in quality, format, and meaning. Some of the copies, maintained by Enterprise Application Integration (EAI) technology or careful business processes, may be good (but probably not perfect). Most are very poor, maintained only by occasional batch transfers and stressed or broken manual processes. Organizational and business process conflicts, or simple failures of trust, may get in the way of common sense improvements.
These conditions have several important consequences. For instance, poor copies may cause business or technical problems that become exacerbated when initiatives such as Customer Relationship Management (CRM) and Business Intelligence need to merge data from various sources. Some organizations work to harness various legacy systems in end-to-end processes. Either the business or IT may be driving changes to simplify business processes, streamline data flows, and reduce duplication. Although modeling can be of great benefit in meeting these challenges, most traditional modeling approaches cannot address them. They produce models that are either too detailed to be of use or not detailed enough, and they typically fail to focus on the difficult issues of the enterprise data architecture and the integration of its various components.

We believe it is important to create powerful, simple, and effective models of the data structure from an enterprise viewpoint -- a set of models known as the "enterprise data architecture." This article describes a new approach, based on the Unified Modeling Language (UML), which we believe meets the real requirements for modeling an enterprise data architecture.

Note: Some of the later steps of this approach introduce techniques that may at first seem a little complicated. Don't worry! You don't need to use all the techniques every time, and the earlier stages deliver benefit in their own right. The important thing is to develop models that help solve your problems.

What Is a Data Architecture?

An enterprise's information systems architecture has many interrelated aspects, including applications, hardware, networks, business processes, technology choices, and data. As shown in Figure 1, the data architecture is a layered set of models that provides a solid foundation for strategic initiatives such as:

- A Data Strategy, outlining the business's aims and objectives for improved collection and use of data.
- Business process improvements.
- Decisions on the future of new and changed systems.
- Integration, data warehousing, and reporting initiatives.
Before describing what a data architecture is, it is helpful to consider first what it is not. As shown in Figure 2, the data architecture is not the set of detailed models of individual systems, because they cannot convey the "big picture" information required to meet the above needs. And it is not just the top-level models of business processes and system scopes, since they don't include enough detail to answer the real questions.

Figure 2 is a "data architecture map," which shows the scope and context of the data architecture. The idea is to map the major data areas in the enterprise on one axis, and the various types of models on the other axis, ranging from highly business-focused models to very detailed system structures. The scope of a complete data architecture is shown as a band across the middle of the chart.

The models that comprise the data architecture are described in more
In addition to using this model for explaining the scope of data architecture work, you can use it to build a map of the current state of knowledge, and the scope of ongoing or planned activities. Simply plot existing or planned modeling efforts at the appropriate intersection. You can also use color to indicate the status or validity of a model, which may be useful.

The data architecture map describes "what" comprises the data architecture. The data strategy and initiatives supporting it explain "why." The individual models describe what the data is, where it is held, and how, when, and by whom it is changed.

**Which Models Constitute the Data Architecture?**

The data architecture is defined primarily by models at four levels, described in the following sections. As a general rule, the high-level data model will change only when there is a significant change in business processes, but the other models will exist in various versions representing the "as is" structure and one or more "to be" evolutions.

**High-Level Data Models**

The top level is a group of high-level data models describing the business data from a conceptual viewpoint, independent of any current realization by actual systems. Each high-level data model (HLDM) comprises:

- A common (canonical) UML class model of the main data items (the business entities) and their relationships.
- A superset of business attributes, including descriptions of their meaning (semantics), standardized formatting (syntax), and universal constraints.

Since these are data models, they will typically exclude class methods, although it may be appropriate to summarize these if one business object has responsibility to manage the structure of others.

The model should include all attributes of business significance, and any that define the data structure (for example, inputs to a business rule that controls multiplicity).

Consider a hypothetical car rental company. Figure 3 shows part of an example HLDM, showing how the business entity "vehicle" has two variants -- cars and vans -- and how any vehicle may be the subject of one or more rentals.
Figure 3: Partial High-level Data Model -- for a hypothetical car rental business.

For the purposes of this article, our examples have been dramatically simplified, but they still show how the techniques could apply to examples with real-world complexity. We have also relaxed UML conventions on naming classes and attributes to aid in readability -- e.g., "Registration Mark" includes a space.

Realization Overviews

The next step is to model the relationships between the conceptual entities of the HLDM and the real key data objects of current or planned systems, showing how the conceptual entities are realized by the real objects. Relationships between different realizations of the same data item, and the ways in which changes are propagated across the various systems, are modeled at a later stage.

The key here is to focus on the "visible" data structure of the systems -- i.e., the data structure exposed by the user interface, reports, and data interfaces. This may not be the same as the physical data structure, but that is unimportant. Highly customizable packages may have a complex meta-model internally, but what is of interest is the system's instantiation in terms of your business. An ancient legacy system may have an arcane physical structure for historical reasons, and the implementation details of an external service may be completely hidden behind an interface façade, but in both cases your focus will be on the visible structure -- the logical system entities and their attributes.

Figure 4 shows how our simple car rental HLDM is realized by three systems: CarFleet (an in-house fleet management system), VanCare (an external system used to support outsourced maintenance of the van fleet), and RentalSystem (the main rental control system).
UML realization relationships are key to this model. Color and physical layout can be used to good effect, and a consistent naming scheme such as the one shown should identify both the logical system entities and their host systems.

Where the conceptual and real entities have a different structure or meaning, then generalization and aggregation relationships are used to break down the class structures until the realizations can be mapped directly, as shown in Figure 4. This approach can be used even when the HLDM is a meta-model and implementation models are concrete, or vice-versa.

Source and Consumer Models

The next layer of models shows the relationships between different realizations of the same data item, how changes are propagated across the various systems, and the organizational custodians of different data elements.

The models are similar to the realization overviews, except that the focus is on identifying the role, provenance, and evolution of each data item, using the following stereotypes:

- <<Master>> identifies an agreed master source of data.
- <<Use in place>> and <<Update in place>> identify where one system is able to use another system's data directly via existing interfaces. Notes should explain how this works.
- <<Copy>> and <<Updates Copy>> identify where one system takes a regular or irregular copy of another system's data (or list of updates), and whether this copy is used unmodified, or is modified by the receiving system. Notes should describe timing and similar issues.
- <<Independent master>> identifies where a system is not the master, and should theoretically have a copy of the master data,
but because the processes are insufficiently established, the second data set has diverged.

- **<<Custodian>>** identifies a custodial relationship between a data item and an organization or role (shown as a Business Actor, with dependency relationships to appropriate data classes).

- **<<Uses>>** identifies a significant cross-organizational usage of data.

Where different attributes are handled in different ways (e.g., one realization is master for some attributes of a class, and another realization is master for others), the high-level data model should model those attributes using two or more separate classes. The Source and Consumer model (Figure 5) can then clearly show the different responsibilities and their origins.

![Figure 5: Source and Consumer Model -- adds information (in green) that describes how different realizations are related, and how they relate to different organizational roles.](image)

**Transportation and Transformation Models**

The last layer of models describes how the data in implementation systems is transformed as it moves between systems. They show:

- Physical class and attribute structure of system interfaces (which will equate to database structures where direct data access is the best or only option). This model will also show realization of the HLDM within interface mechanisms such as an EAI hub or backbone.

- Realization relationships between the different physical data structures.
- Transformation rules at the attribute level, documented using Object Constraint Language (OCL).
- Interface driver, constraint, and timing rules, modeled using interaction or sequence diagrams.

If this looks a bit complex, remember that you don't have to use this technique all the time, and you can use simple textual notes rather than OCL if you prefer.

Extending our car rental example, suppose we want to use EAI to keep the Hire Unit list in RentalSystem up to date, extracting, merging, and transforming the two source lists. The "to be" model in Figure 6 describes the physical interfaces and transformation rules required, including the canonical structure of data in the EAI messages.
CarFleet has a data-based interface consisting of two main tables; Vancare has a programatic interface (e.g., an object model or Web service), as does Rental System, which includes an `Insert()` function to receive the updates.

**Public Standards**

Public or industry standards may have two roles:

- They may form the basis for either the HLDM, or realization of the HLDM within the EAI backbone and external interfaces.
- They may determine the data structure of external interfaces or some physical systems, and therefore represent physical data structures to be transformed within interfaces.

**Meta-Model**

To sum up, the meta-model in Figure 7 shows how the various models in our scheme and their components relate to one another:

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**Figure 6:** Transformation Model -- adds detail showing how data is transformed as it moves between systems.

**Figure 7:** Meta-Model -- shows relationships among various models and model elements in the data architecture.
Using and Developing the Data Architecture

The data architecture has many uses. It helps you to get a handle on data as it is really used by the business, and it is a key artifact if you want to develop and implement governance supporting a data strategy. It should also be used to guide cross-system developments such as Enterprise Application Integration (EAI), common reporting, and data warehousing initiatives.

Although our explanation of the data architecture proceeded from the "top down," the data architecture is usually developed from the "middle-out," working from the data requirements of specific system interfaces and rationalization exercises, and not based on an exhaustive top-down process and information requirement analysis. This allows it to develop to address specific tactical and strategic requirements without unmanageable dependencies, and provides a cross-check to data analysis originated on the basis of separate top-down and bottom-up modeling exercises.

The data architecture may never be "complete" for the whole enterprise. Even so, it provides a consistent approach and context for modeling activities. However, as the data architecture matures, it may be appropriate to undertake some work to "fill in the gaps."

The models, in particular the Source and Consumer models, will support validation of target business processes, by identifying whether target data is contained within a single system, maintained by well-defined interfaces and processes, or spread across several (potentially inconsistent) sources.¹

Improving the Data Architecture: A Data Strategy

Modeling the "as is" data architecture can be extremely useful, and it can certainly show where things are sub-optimal. However, if you want to make future improvements, you will need more than just good models. Most of the issues around improving data collection, usage, and governance are non-technical. The IT department, together with business managers, will need to develop several things:

1. Principles establishing how the enterprise aims to collect, manage, and use data.
2. The data architecture, including both "as is" and "to be" models.
3. Governance rules and change control processes for the data architecture, managed jointly by IT and appropriate business representatives.
4. Policies for data management in each business area:
   - What data is stored.
   - Who is responsible for its collection and quality.
   - Who controls it, and who administers it.
How long it must be stored, and how it will be disposed of or archived afterwards.

Who may have access to it, and how it should be disclosed to parties outside the normal user groups.

5. A scheme for classifying information and associated risks so that appropriate security measures can be defined.

You may also need to help improve and document business processes to improve data management.

This data strategy needs to be founded on clear, agreed-upon principles, such as the following:

- Wherever possible, data must be simple to enter and must accurately reflect the situation; it must also be in a useful, usable form for both input and output.
- Data should only be collected if it has known and documented use(s) and value.
- Data should be readily available to those with a legitimate business need for it.
- Processes for data capture, validation, and processing should be automated wherever possible. Data should only be entered once.
- Processes that update a given data item should be standard across the enterprise.
- Data should be recorded as accurately and completely as possible, by the most informed source, as close as possible to its point of creation, in an electronic form at the earliest opportunity, and in an auditable and traceable manner.
- The cost of data collection and sharing should be minimized.
- The enterprise, rather than any individual or business unit, owns all data.
- Every data source must have a defined custodian (a business role) responsible for the accuracy, integrity, and security of that data.
- Data must be protected from unauthorized access and modification.
- Data should not be duplicated unless duplication is essential for practical reasons. In such cases, one source must be clearly identified as the master, there must be a robust process to keep the copies in step, and copies must not be modified.
- Data structures must be under strict change control, so that the various business and system implications of any change can be properly managed.
- Whenever possible, adopt international, national, or industry standards for common data models. When this is not possible, develop organizational standards instead.
Conclusion

A documented understanding of the enterprise data architecture is an essential pre-requisite to many common IS and business improvement initiatives. The appropriate models are quite distinct from both detailed system models and high-level business models. This article outlines a set of UML models and techniques that should help to meet these needs.

References

The use of UML for enterprise modeling is an emerging field. The techniques described here are new, and this is the first time they have been described publicly. However, we have found the following very useful introductions to the wider problem of modeling with UML at an architectural or business level, including:


Notes

1 We plan a future article to discuss how the various models relate to the process of establishing an integration "backbone" or "hub" between systems, and using this to create interfaces and populate a data warehouse.

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