Multidatabase Interdependencies in Industry

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Abstract

In this paper we address the problem of data consistency between interrelated data. In industrial environments, lack of consistent data creates difficulties in interoperation between systems and often requires manual interventions to restart operations that fail due to inconsistent data. We report the results of a study to understand applicability, adequacy and advantages of a framework we had proposed earlier to specify interdatabase dependencies in multidatabase environments. We studied several existing Bellcore systems and identified examples of interdependent data. The examples demonstrate that the framework allows precise and detailed specification of complex interdependencies that lead to efficient strategies to enforce the consistency requirements among the corporate data managed in multiple databases. We believe that our specification framework can help in the maintenance of data that meet a business’s consistency needs, reduce time consuming and costly manual operations, and provide data of better quality to end users.

1 Introduction

Poor specification and maintenance of consistency between related data may hamper interoperability and result in wasted operations, leading to manual intervention or system patches that incur higher expense. Consistency of corporate data requires managing interdependent data which are logically related data maintained by multiple databases. Previously, we proposed a framework for specifying interdependent data [RSK91][SR90]. In this framework, the interdependency between multiple systems is represented using Data Dependency Descriptors ($D^3$). A $D^3$ is a 5-tuple:

$$D^3 = \langle S, U, P, C, A \rangle$$

- $S$ is the set of source data objects,
- $U$ is the target data object,
- $P$ is a boolean-valued predicate called interdatabase dependency predicate which specifies the relationship between the source and target data objects, and evaluates to true if satisfied. For relational databases, $P$ can be specified, using operators of relational algebra (selection, projection, join, union, difference, intersection, etc.). Together with the basic operators, we also use the aggregate operator $\xi$ and the transitive closure operator $\alpha$.
- $C$ is a boolean-valued predicate, called mutual consistency predicate. It defines consistency requirements involving time and state of data, and specifies when $P$ must be satisfied.
- $A$ is a collection of consistency restoration procedures that specify actions to be taken to restore consistency. The execution mode of the action component specifies the way by which a restoration procedure (child) is related to its parent transaction. Non-vital specification allows relaxation of atomicity, and decoupled specification is used to relax isolation.

The dependencies are specified in a declarative fashion and will be viewed as separate schema entities, collectively referred to as interdependency schema ($IDS$). In other words, the $IDS$ is a set of all $D^3$s to be enforced in the multidatabase system for managing consistency of the corporate data. They can be used to perform updates in a way that allows us to overcome the limitations imposed by traditional transaction management systems (e.g., two-phase

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commit). For example, we may allow data to be temporarily inconsistent, within specified limits.

In this paper we report the results of a case study to understand applicability, adequacy and advantages of our framework. We studied several systems (existing or currently under development) at Bell Communications Research, Inc. (Bellcore) and we identified examples of actual and realistic interdependencies among them. This empirical study shows that the $D^3$ framework allows precise and detailed specification of complex interdependencies that may lead to more sophisticated and efficient enforcement of strategies and better support of business rules related to consistency of corporate data. We believe that our framework provides both information system developers and users with many advantages, such as: specification of development requirements of products that meet a business’s data consistency needs, enforcement of interoperability of application systems, elimination of time consuming and costly manual operations, and better quality of data to end users. Lack of data consistency is one of the most important problems in today’s industries. We hope our work can motivate researchers and vendors to develop solutions to this important problem within the constraints of existing environments.

2 Example Specification of $D^3$s

The study included many meetings, with product requirements analysts and system developers who provided information relevant to the study, and a consideration of ten systems. Most of the discussions involved systems from the Planning and Engineering area of Bellcore, and their interactions with the source or fundamental data systems (i.e., provisioning and unit inventory systems) and reference data systems. Due to space limitation, we give examples of only two of the interdependencies we studied and documented. Additional examples and detailed discussion can be found in [KS92]. Figure 1 shows a high level view of the systems that featured in the discussions.

Example 1

The relation $DMD_{CAP}$ in PVI (Planning View of Inventory) contains various counts of demand and capacity for an instance of a Planning Unit. The attribute $spare$ in table $DMD_{CAP}$ contains the spare capacity of an inventory item, based on some measurement unit. This information is also kept in the LEIS System, in table $CSA_{SPARE}$ under the $pots_{spr_{ipl}}$ attribute. The $D^3$ specifies the consistency requirement (discussed in detail below) between the spare capacity of an inventory item in LEIS and the spare capacity of the same item in PVI. The relevant schema of $PVI.DMD_{CAP}$ is:

$DMD_{CAP}$

$(pln_{unit_{id}}, dmd/cap_{meas_{unit}}, load_{time_{period}}, location_{id}, total, assigned, spare, tradeable)$ and $LEIS.CSA_{SPARE}$ is defined as:

$LEIS.CSA_{SPARE}$ $(csa_{flag}, dss_{flag}, dss_{spr_{pl}}, pots_{spr_{ipl}}, avl_{pg_{cap}}, spr_{fibers})$

The attribute $pots_{spr_{ipl}}$ in table $CSA_{SPARE}$ is the
source of PVI, under the conditions on
The related objects, we can allow the target object to diverge with respect to the source object (a) by up to 6 months (defined by $c_1$), or (b) until a planner explicitly requests an Inquiry of the most recent data for a particular carrier service area – $csa$ (defined by $c_2$). In usual circumstances, a restoration procedure $Update_PVI.DMD.DCAP$ will be executed once every six months to restore the dependency as required by $c_1$. It will involve data for all $csa$ the LEIS system maintains. Today, this restoration involves a bulk upload. When a planner wants most recent data for a specific $csa$ of interest that is supported by $c_1$ before s/he begins the planning activity, s/he issues the Planning Inquiry. This is particularly useful when a planner knows or suspects that a particular $csa$ has seen much higher than usual recent provisioning activity. Procedure $Update_PVI.DMD.DCAP.csasonly(csa)$ will involve consistency restoration for interdependent data extensions related to the $csa$ specified in the Planning Inquiry($csa$) only. This restoration should be done in a coupled and vital mode since the planning activity can proceed only after its successful execution.

$D_3^3 ::= $ 
$S : LEIS.CSA.SPARE.potsSpr.npl$ 
$U : PVI.DMD.DCAP.spares$ 
$P : \Pi_{csa,potsSpr.npl}(LEIS.CSA.SPARE) =$ 
\begin{align*} 
& Location \downarrow d,spare \\
& \sigma_{planUnitType=\\"all\ d\line\"} \\
& \quad dm/dcapMeasUnit=npl\ channel\ (PVI.DMD.DCAP) \\
C : c_1 \lor c_2 \text{ where} \\
& c_1 := \epsilon(6\ months) \\
& c_2 := !\text{Planning}\ Inquiry(csa) \\
A : when c_1 \text{ Update_PVI.DMD.DCAP as non-coupled} \\
\quad otherwise Update_PVI.DMD.csasonly(csa) \text{ as coupled and vital}$

### Example 2

<table>
<thead>
<tr>
<th>ENTITYJOB</th>
<th>(entity, entityCut, entityInCap, eqType, jobNum, lnCapInNat, lnCapInIns)</th>
</tr>
</thead>
</table>
| LSD&F     | contains detailed information about line capacity in network access lines (lnCapInNat) for every equipment connected to a particular switch, identified by its CLLI-code. On the other hand, PVI contains a total of the line capacity for all switches. The dependency constraint identified above may not hold after an update to the LSD&F database, such as a recent job that connected more cables to a switch with a specific CLLI-code, e.g. 12345678. Still PVI can tolerate such updates in LSD&F up to a point specified in the consistency predicate $C$ before it must be made consistent with the related data in LSD&F. Assuming that LSD&F keeps versions of the ENTITYJOB table, PVI can lag behind, up to 3 versions. In addition, if 15% or more of the tuples of the particular switch in ENTITYJOB have been updated, then the consistency should be restored immediately. We can formulate the above interdependency as follows:

$D_2^3 ::=$ 
$S : LSD&F.ENTITYJOB.lncap_innal$ 
$U : PVI.DMD.DCAP.total$ 
$P : \Pi_{DMD.DCAP.total}$ 
\begin{align*} 
\sigma_{DMD.DCAP.planUnitId=\\"\&CLLI-code\"} \\
(dM.DCAP) = \\
\xi_{\text{sum}(lncapInNat)}(\sigma_{\text{entity}=\\"\&CLLI-code\"}(ENTITYJOB)) \\
C : c_1 \lor c_2 \text{ where} \\
& c_1 := 3\ versions(ENTITYJOB) \text{ and} \\
& c_2 := 15\%\Pi_{\text{lnCapInnal}}(\sigma_{\text{entity}=\\"\&CLLI-code\"}(ENTITYJOB)) \\
A : when c_1 \text{ Update_PVI.DMD.DCAP as non-coupled} \\
\quad otherwise Update_SwitchOnly as coupled and vital$
heterogeneous multi-system environments.

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References

