MAPPING TEMPORAL DATA WAREHOUSE CONCEPTS TO SAP BW COMPONENTS

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Abstract: SAP Business Information Warehouse (BW) today is a suitable and viable option for enterprise data warehousing and one of the few data warehouse products that offer an integrated user interface for administering and monitoring data. In previous works we introduced design and modeling techniques for representing time and temporal information in enterprise data warehouses and discussed generic problems linked to the design and implementation of the Time dimension, which have to be considered for global business processes, such as handling different time zones and representing holidays and daylight saving time (DST). This paper investigates supporting the global exchange of time-dependent business information by mapping those temporal data warehouse concepts to SAP BW components, such as InfoCubes and master data tables.

1 INTRODUCTION

The amount of data flowing into and through organizations is growing exponentially. This data comes from many different sources and locations, and the ability to put this data to work is critical to an organization's success. To exploit the large amount of data moving through their organizations, many companies have developed data warehouse systems.

SAP Business Information Warehouse (BW) today is a suitable and viable option for enterprise data warehousing. It is equipped with preconfigured information models and reports as well as automated data extraction and loading methods to provide a common view of enterprise data, which facilitates analysis and interpretation of information. It also enables Online Analytical Processing (OLAP) to format the information of large amounts of operative and historical data.

In (Hezzah, 2004a) we introduced design and modeling techniques for representing temporal information in the data warehouse and solved common problems related to the implementation of the Time dimension in business data warehouses, such as representing holidays, seasons and fiscal periods, considering the observation of daylight saving time (DST) and handling different time zones.

We addressed Time dimension updates in (Hezzah, 2004b) and introduced an approach to handle structural and instance updates to the Time dimension, and showed how they differ from updates to other slowly changing dimensions. We investigated the information model of SAP BW in (Hezzah, 2004c) and discussed the role of temporal characteristics as a time reference to business events.

This paper investigates how the global exchange of time-dependent information can be supported by using SAP BW as an enterprise data warehouse. It provides an overview on the information model of SAP BW with focus on the storage architectural layer. It addresses the time characteristics of SAP BW and introduces a mapping of temporal concepts introduced in previous works to SAP BW components. This includes handling different time zones and local time conversion, as well as modeling relevant real-world business issues such as holidays, seasons and daylight saving time (DST).

2 THE SAP BW INFORMATION MODEL

Before we actually start addressing the options, methods and tools available in SAP BW to implement a solution for modeling temporal information, let's first focus on the architectural

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layers of the SAP BW implementation consisting of the layered architecture of SAP BW accompanied by two administrative architectural components.

SAP BW is built on a relational OLAP (ROLAP) model. The main structures used for multidimensional analysis in SAP BW are called InfoCubes. The InfoCube Manager generates the InfoCube infrastructure consisting of a fact table and a set of dimension tables, as well as the update and retrieval routines according to the definition stored in the meta data repository.

Master data is stored in master data attribute tables, language-dependent text tables, and hierarchy tables. Master data attributes and texts can be defined as time dependent, and hierarchies can be defined as version or time dependent. Generally speaking, master data is data that remains unchanged over a long period of time, e.g. customer, product, etc.

The characteristics determine the granularity at which the key figures are kept in the InfoCube. The key figures, also known as facts, provide the values that are reported on in a query, e.g. quantity, amount or number of items. These values must have units to give them meaning. Time characteristics are characteristics such as date, month, fiscal year, etc.

Slowly changing dimensions (e.g. customer or product) are stored in SAP BW master data tables. The master data table can have a time-dependent and a time-independent part.

Attributes are InfoObjects that exist already, and that are assigned logically to the new characteristic. It is possible to decide for each attribute individually, whether it is time-dependent or not. If only one attribute is time-dependent, a master data table is created. However, there can still be attributes for this characteristic that are not time-dependent.

The Time dimension can be customized by assigning time characteristics. It could be given using the characteristics 'day' (in the form YYYYMMDD), 'week' (in the form YYYY.WW), 'month' (in the form YYYY.MM), 'year' (in the form YYYY) and 'period' (in the form YYYY.PPP).

3 TIME CHARACTERISTICS IN SAP BW

Time characteristics are used in the obligatory Time dimension of InfoCubes to express the time reference to business events. As time characteristics in SAP BW are internally treated in a special way, it is not possible to create client-specific time characteristics.

The time reference characteristic for an InfoCube, when there are several time characteristics in the InfoCube, is always the "most refined", since all other times in the InfoCube are derived from this. An InfoCube might contain warehouse key figures that should be evaluated for the calendar month and calendar year. In this case, the calendar month is the most refined common time reference characteristic.

There is a difference between complete and incomplete time characteristics: The complete time characteristics are the SAP BW time characteristics calendar day (0CALDAY), calendar week (0CALWEEK), calendar month (0CALMONTH), calendar quarter (0CALQUARTER), calendar year (0CALYEAR), fiscal year (0FISCYEAR) and fiscal period (0FISCPER). They are clearly assigned to a point in time.

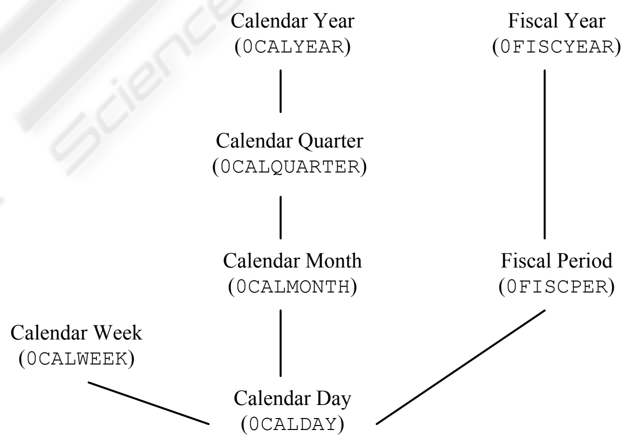


Figure 1: Hierarchy of SAP BW time characteristics

Time zone	Time zone text	TimeZnRule	Difference from UTC	DST rule	Daylight saving rule	Activ
BRZLWE	Brasil West	M0400	- 4 hours	BRAZIL	Brazil	☑
CAT	Central Africa	P0200	+ 2 hours	NONE	NO daylight saving	☑
CET	Central Europe	P0100	+ 1 hour	EUROPE	Europe	☑
CHILE	Chile	M0400	- 4 hours	CHILE	Chile	☑
CHILEE	Chile Easter Island	M0600	- 6 hours	CHILE	Chile	☑
CST	Central Time (Dallas)	M0600	- 6 hours	USA	USA	☑
CSTNO	Central Time No DST	M0600	- 6 hours	NONE	NO daylight saving	☑
CYPRUS	Cyprus	P0200	+ 2 hours	CYPRUS	Cyprus	☑
EET	Eastern Europe	P0200	+ 2 hours	EUROPE	Europe	☑
EGYPT	Egypt	P0200	+ 2 hours	EGYPT	Egypt	☑
EST	Eastern Time (New York)	M0500	- 5 hours	USA	USA	☑
ESTNO	Eastern Time (Indianapo..	M0500	- 5 hours	NONE	NO daylight saving	☑

Figure 2: Time zones in SAP BW

Only these time characteristics can be used as time reference characteristics, since it must be possible to derive time characteristics automatically from the most detailed time characteristic with the non-cumulative folder.

Incomplete time characteristics, such as `0CALMONTH2`, `0CALQUART1`, `0HALFYEAR1`, `0WEEKDAY1` or `0FISCPER3` can be used in a non-cumulative InfoCube but cannot be a time reference characteristic, since they are not assigned to a specific point in time. Figure 1 gives an overview of the hierarchy of SAP BW time characteristics.

4 MAPPING TEMPORAL CHARACTERISTICS TO SAP BW COMPONENTS

4.1 Consideration of Time Zones

Local dates and times can only be compared with each other and exchanged if they are in the same time zone. Many global companies, however, work in different time zones, but still need to exchange their data across regional boundaries.

Processes which cover more than one time zone primarily affect logistics functions such as availability checks, production planning, delivery scheduling, statistics and service provision, but they also affect financial accounting in areas such as inter-company transactions, etc.

In (Hezzah, 2004a) we introduced an approach to modeling time zones in the data warehouse, which uses multiple Time dimensions for local and universal time. We showed that splitting the time-of-day from the date gives us the capability to navigate sales facts by date and time of both local and universal time and saves us implementing the time calculation based on time zones into the application logic.

We also extended the Time dimension by additional attributes and flags to solve the issue of daylight saving time DST in different time zones. Then in (Hezzah, 2004b) we solved the issue of Time dimension updates, and showed how changes to the DST rules can affect the structure as well as single instances of the Time dimension.

SAP BW uses a similar approach, which supports the conversion of local dates and times via the time zone function. This function supports using dates and times that are comparable and exchangeable in applications that are implemented worldwide. The only difference is that it integrates DST rules into the time zone configuration and not directly into the Time dimension, and the universal time is not additionally stored in a separate dimension, but is calculated based on the time zone via a conversion function (see 4.1.1).

All available time zones are maintained in a central table, and are assigned rules for DST observation as shown in Figure 2. Rules for time zones, such as the difference from Universal Time Coordinated (UTC), are maintained in a separate table and also assigned to the time zones.

4.1.1 Time Conversion in SAP BW

Generally, users think and act in terms of their local time, and they also expect to use their local time in business transactions. When the SAP BW system is used for global transactions that span time zones, business partners and systems will have different local times. These differences in local times can lead to problems such as late postings and missed batch runs.

For example, a company with its headquarters and database server in Paris requires that all billing documents be posted by 4:00 p.m. Users in the company's office in London might expect that to mean 4:00 p.m. in London, which is 1 hour behind Paris time. Thus any users in London posting billing documents after 3:00 p.m. would be posting their documents too late.For business processes spanning

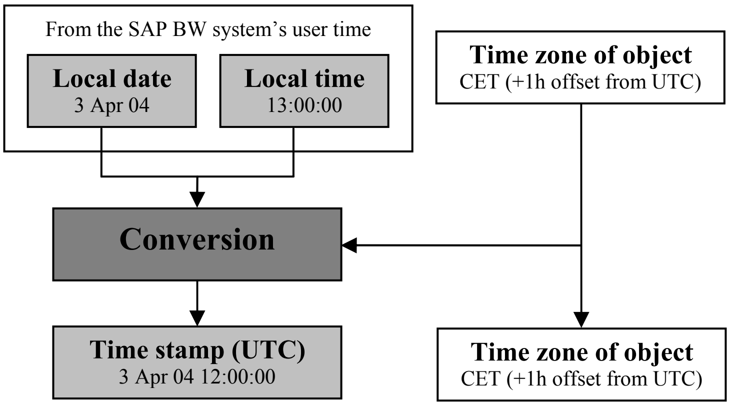


Figure 3: Time conversion function of SAP BW

time zones, inaccuracies of up to 24 hours could occur. To compare the local times of users in different time zones, the SAP BW system represents time differently externally and internally. The external representation of the time corresponds to a context-dependent local time. For example, in Germany, the time is represented in Central European Time (CET) and in New York in Eastern Standard Time (EST).

Internally, the system normalizes the internal system time to UTC, which serves as a reference time. By normalizing date and time internally, the time zone function eliminates problems that can arise from users working in different local time zones. For some transactions, the system normalizes dates and times by storing a time zone and a time stamp, which consists of the time and date of an event converted from local time to UTC.

Figure 3 shows how the Conversion function of SAP BW uses time zone information to transform the local time into universal time. Here, the requested delivery date of 3 Apr 2004 13:00:00 CET for a ship-to address in Germany receives the time stamp of 3 Apr 2004 12:00:00 UTC.

To determine the time zone of an object in SAP BW, the system uses a series of decision rules. By determining an object's time zone, the system can display a time stamp of the object in any local time.

To ensure consistent determination of time zones and efficient performance, this process is performed by a central function depending on the location of the object.

The SAP BW system uses a 24-hour clock with the local date and local time of the object (here the ship-to address) from the user interface with the object's time zone to calculate the time stamp. To display the object's local date and time, SAP BW uses the object's time zone, which is stored with the time stamp, and goes through the process backwards. For application programs, a time stamp accurate to the second is generally sufficient.

The time stamp's external representation corresponds to the date and time representation. The same user options exist for displaying the time stamp as for the date and time:

- `DD.MM.YYYY hh:mm:ss (03.04.2004 14:36:25)`
- `MM/DD/YYYY hh:mm:ss (04/03/2004 14:36:25)`
- `MM-DD-YYYY hh:mm:ss (04-03-2004 14:36:25)`
- `YYYY.MM-DD hh:mm:ss (2004.04-03 14:36:25)`
- `YYYY/MM/DD hh:mm:ss (2004/04/03 14:36:25)`

The total output length is 19 characters. The system supports displaying times without seconds, but it does not support displaying times as 'AM' or 'PM'.

Internally, the system combines the data types for date and time to create the 14-character time stamp (8 characters for the date and 6 for the time). Combining date and time allows the system to sort time stamps correctly based on date (year-month-day) or time (hour-minute-second). The allowed range of values for the time stamp is `'01.01.0001 00:00:00'` to `'31.12.9999 23:59:59'`. To avoid confusion with a.m. and p.m. time designations, the system always uses a 24-hour clock, and the system's initial value for the time stamp is zero or `00:00:00`, which corresponds to midnight instead of `24:00:00`.

The following example describes dates and times on inter-company documents between two companies located in different time zones. The local date is different for the two companies:

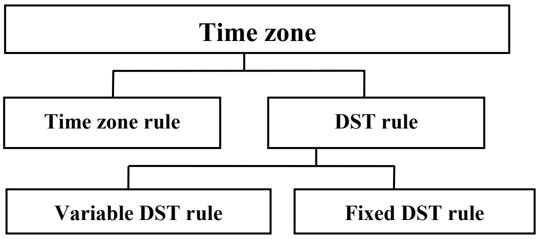


Figure 4: Structure for DST rules

Company code A: 2000, Location: Los Angeles, Date: 15.04.04, Time: 19:36:03
Company code B: 5200, Location: Melbourne, Date: 16.04.04, Time: 10:36:03
System Date: 15.04.04

The document is associated with a single day, and therefore, the document date, posting date and entry date have the same value for both companies, although they may differ from each other. The determination of the posting date depends on the type of transaction. The system records this transaction for both companies with the date of the system at the time of issue. Once the document has been received in the receiving company, the time zone function will propose a posting date based on the local date and time zone of the user who entered the document.

However, considering dates alone is not sufficient to ensure exact time calculations. For time-critical processes, dates with times replace dates without times. A date standing alone, could easily result in a one day inaccuracy (for example, depending on the time of day, 3 April in Melbourne may still be 2 April in Los Angeles). For a date without a time, an inaccuracy related to time zones can be as long as 48 hours in some extreme cases. For time calculations, an accurate duration (for example, hours and minutes instead of days) must be used. Otherwise, chain calculations could be inaccurate by several days.

4.1.2 Daylight Saving Time

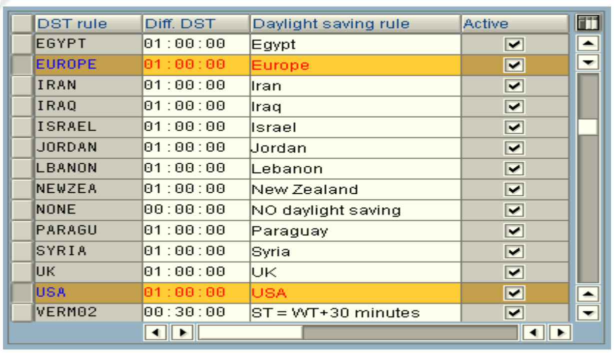
Some time zones observe daylight saving time (DST) and use a “DST rule” for calculation purposes. For these time zones, clocks are normally set forward one hour to make better use of the longer daylight hours in the late spring, summer and early fall.

SAP BW uses a structure for DST observation, which is slightly different from the one we introduced in (Hezzah, 2004a) and (Hezzah, 2004b). This structure integrates the rules for DST into the time zone rules, which makes maintenance and updating easier, but otherwise doesn’t have any comparative functional advantage over the approach we previously presented. However, for global companies using data in different time zones, the calculation of DST offsets is this way integrated into the application logic and doesn’t need to be considered on database level.

SAP BW introduces rules to maintain DST start and end dates as well as the time shifts caused by DST. These rules result in the following structure for a time zone in the system (Figure 4):

DST rules (Figure 5) define the offset of DST relative to the time zone’s standard time (for Europe and USA +1 hour). It does not define the start and end dates of DST. These rules are assigned to the different time zones as already shown in Figure 2.

Variable DST rules (Figure 6) define how the system calculates the start and end dates of DST. These rules can always be changed, so there is no



DST rule	Diff. DST	Daylight saving rule	Active
EGYPT	01:00:00	Egypt	✔
EUROPE	01:00:00	Europe	✔
IRAN	01:00:00	Iran	✔
IRAQ	01:00:00	Iraq	✔
ISRAEL	01:00:00	Israel	✔
JORDAN	01:00:00	Jordan	✔
LBANON	01:00:00	Lebanon	✔
NEWZEA	01:00:00	New Zealand	✔
NONE	00:00:00	NO daylight saving	✔
PARAGU	01:00:00	Paraguay	✔
SYRIA	01:00:00	Syria	✔
UK	01:00:00	UK	✔
USA	01:00:00	USA	✔
VERM02	00:30:00	ST = WT+30 minutes	✔

Figure 5: DST rules

DST rule	Valid from	Start mon.	Start day	StrtDayMo.	Strt. time	End month	End day	EndDay/Mo.	End time	D
CHILE	1998	10	1	2	02:00:00	3	1	2	02:00:00	C
CYPRUS	1998	3	1	5	02:00:00	9	1	5	02:00:00	C
EGYPT	1998	4	6	5	02:00:00	9	6	5	02:00:00	E
EUROPE	1990	3	1	5	02:00:00	9	1	5	03:00:00	E
EUROPE	1996	3	1	5	02:00:00	10	1	5	03:00:00	E
ISRAEL	1998	3	6	3	02:00:00	9	6	3	02:00:00	I
LBANON	1999	3	1	5	02:00:00	9	1	5	03:00:00	L
NEWZEA	1998	10	1	1	02:00:00	3	1	3	02:00:00	N
UK	1990	4	1	1	02:00:00	10	1	1	03:00:00	U
USA	1990	4	1	1	02:00:00	10	5	1	03:00:00	U
VERM10	2222	10	1	1	02:00:00	3	1	5	03:00:00	S

Figure 6: Variable DST rule

need to maintain DST start and end dates for every year. For cases in which DST is not defined by variable rules, fixed DST rules define the start and end dates for a specific year.

Rather than distinguishing between two separate time zones (one for winter and one for summer), only one time zone indicator is used in SAP BW which includes the DST rule when applicable. The geographical assignment of DST rules and time zone rules can be performed at country, region, or even postal code level.

The switch backwards from DST to "winter time" can cause problems because the clocks are set back by one hour, which means that an hour is repeated. For applications that use time stamps, this can cause the following problems:

- Time stamps from different real times can have the same value
- The time stamps do not necessarily reflect the sequence in which system events really occurred

In (Hezzah 2004a) we solved this problem by introducing the 23-hour and 25-hour day, which simply deletes one hour from all days on which time is switched to DST, and inserts an additional hour on all days on which the time is switched backwards. Applications that use time stamps based on UTC are not affected by this problem.

Since not all time stamps in the SAP BW system are based on UTC, SAP has until recently recommended shutting down the system during this time to avoid the problem described above. The new solution to this problem is the DST Safe Kernel, which makes time during the "repeated hour" run at half the usual speed. This means that the system can rely on time stamps in the correct sequence without duplicates, even if it is not using UTC, which solves many issues related to the system availability of SAP applications.

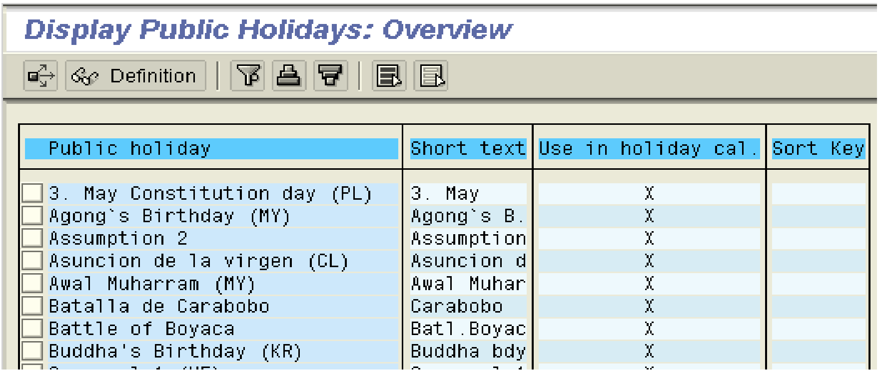
4.2 Holidays in SAP BW

In (Hezzah, 2004a) we introduced among other things a practical approach, which models relevant real-world business issues, such as holidays, seasons, and fiscal periods, by extending the Time dimension with new attributes and flags. In order to consider holidays in different countries or in different time zones we used multiple holiday flags (`holiday_flag_1` …… `holiday_flag_n`), one for each country we needed to consider. Integrating these attributes into the Time dimension effectively reduces query execution time and provides more functionality than using conventional RDBMS tables, for instance, navigating data by holidays and non-holidays. Here we investigate how this issue is handled in the current implementation of SAP BW.

While SAP BW integrates seasons and fiscal periods into the Time dimension, it still stores holiday data in a separate table called public holidays. This table is used by two other tables, public holiday calendar and factory calendar, to define holiday rules. The public holiday and factory calendar is a central module in the SAP BW system. It is used in many areas, such as logistics and human resources. The calendar system consists of the following components:

Public holidays: Contains the definition of public holidays, calculations rules for date, religious denominations, etc. (Figure 7). It consists of the following attributes: public holiday type, date or calculation rule, public holiday text (short or long), and (if required) sort criterion, religious denomination or public holiday class. If other public holidays are needed, it is possible to add them by maintaining the public holiday definition and copying them to new or existing public holiday rules.

Public holiday calendar: Contains any composition of public holiday rules. Here it is possible to assign any public holiday required to a public holiday rule, which has the following attributes: calendar ID, calendar description, period of validity (From year, To year).



Display Public Holidays: Overview

Definition

Public holiday	Short text	Use in holiday cal.	Sort Key
3. May Constitution day (PL)	3. May	X	
Agong`s Birthday (MY)	Agong`s B.	X	
Assumption 2	Assumption	X	
Asuncion de la virgen (CL)	Asuncion d	X	
Awal Muharram (MY)	Awal Muhar	X	
Batalla de Carabobo	Carabobo	X	
Battle of Boyaca	Batl.Boyac	X	
Buddha's Birthday (KR)	Buddha bdy	X	

Figure 7: Public holidays

Factory calendar: Contains a definition of workdays including special regulations, under the assignment of a particular public holiday calendar. The following attributes are maintained: factory calendar ID, factory calendar description, period of validity (From year, To year), start no. factory date incremented for each workday, default value is 0).

The main drawback of this structure is that it doesn't support navigating data efficiently by holidays or non-holidays. Also separating the holiday definition from the Time dimension increases query execution time and decreases overall performance. Besides, it will be too complex if we want to look at data, not just on holidays, but also on different seasons, fiscal periods or weekdays. These attributes are stored in different tables and must be joined with the fact table.

However, using the public holidays and factory calendar automatically eliminates irrelevant holidays since only holidays assigned to a holiday rule are considered in the executed query. This way, not all entries in the public holidays table need to be examined by the query. Moreover, for global organizations, which are the main target group of SAP BW, it is a big advantage being able to store all holidays of all countries and regions in a single database table and assign holiday rules to time zones to include only a subset in any query.

5 CONCLUSIONS

This paper has addressed representing temporal information by using SAP BW as an enterprise data warehouse. It investigated the information model of SAP with focus on the storage architectural layer and gave an overview on the time characteristics provided by SAP BW. To improve the global exchange of time-dependent business information, we introduced a mapping of temporal concepts presented in previous works to SAP BW components like InfoCubes and master data tables, and showed how common business-related temporal issues, such as handling different time zones, representing holidays, fiscal periods and daylight saving time (DST) can be modeled using functions of SAP BW.

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