Temporal Data

CAP provides out-of-the-box support for declaring and serving date-effective entities with application-controlled validity, in particular to serve as-of-now and time-travel queries.

Temporal data allows you to maintain information relating to past, present, and future application time. Built-in support for temporal data follows the general principle of CDS to capture intent with models while staying conceptual, concise, and comprehensive, and minimizing pollution by technical artifacts.

> For an introduction to this topic, see Temporal database (Wikipedia) and Temporal features in SQL:2011 .

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Starting with 'Timeless' Models

For the following explanation, let's start with a base model to manage employees and their work assignments, which is free of any traces of temporal data management.

Timeless Model

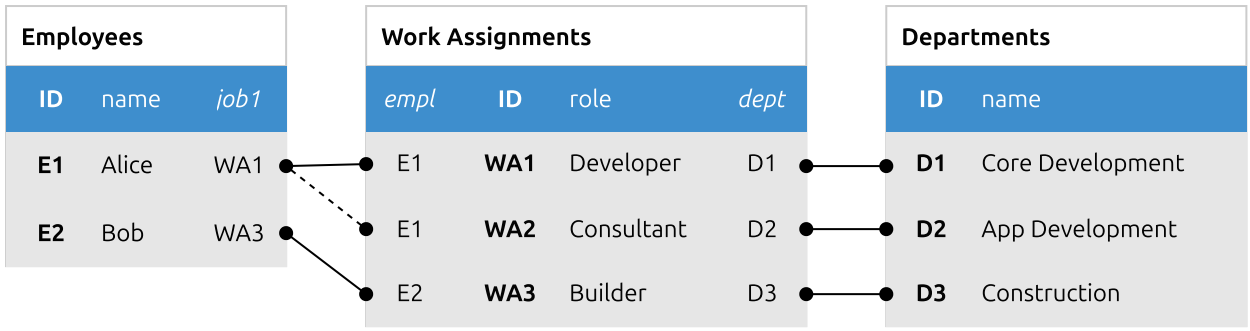
timeless-model.cds

```cds
namespace com.acme.hr;
using { com.acme.common.Persons } from './common';

entity Employees : Persons {
  jobs : Composition of many WorkAssignments on jobs.empl=$self;
  job1 : Association to one /*of*/ WorkAssignments;
}

entity WorkAssignments {
  key ID  : UUID;
  role    : String(111);
  empl    : Association to Employees;
  dept    : Association to Departments;
}

entity Departments {
  key ID  : UUID;
  name    : String(111);
  head    : Association to Employees;
  members : Association to many Employees on members.jobs.dept = $self;
}
```

> An employee can have several work assignments at the same time. Each work assignment links to one department.

Timeless Data

A set of sample data entries for this model, which only captures the latest state, can look like this:



> Italic titles indicate to-one associations; actual names of the respective foreign key columns in SQL are `job1_ID`, `empl_ID`, and `dept_ID`.

Declaring Temporal Entities

Temporal Entities represent *logical* records of information for which we track changes over time by recording each change as individual *time slices* in the database with valid from/to boundaries. For example, we could track the changes of Alice's primary work assignment *WA1* over time:

Work Assignments

empl	ID	validFrom	validTo	role	*dept*
E1	**WA1**	**2014-01-01**	2017-01-01	Developer	D2
E1	**WA1**	**2017-01-01**	2017-04-01	Developer	D1
E1	**WA1**	**2017-04-01**	2018-09-15	Senior Developer	D1
E1	**WA1**	**2018-09-15**	9999-12-31	Architect	D1
...	**...**	**...**	...	...	...

> **TIP**
>
> Validity periods are expected to be **non-overlapping** and **closed-open** intervals; same as in SQL:2011.

Using Annotations `@cds.valid.from/to`

To track temporal data, just add a pair of date/time elements to the respective entities annotated with `@cds.valid.from/to` , as follows:

```cds
entity WorkAssignments { //...
  start : Date @cds.valid.from;
  end   : Date @cds.valid.to;
}
```

> **TIP**
>
> The annotation pair `@cds.valid.from/to` actually triggers the built-in mechanisms for serving temporal data. It specifies which elements form the **application-time** period, similar to SQL:2011.

Using Common Aspect `temporal`

Alternatively, use the predefined aspect `temporal` to declare temporal entities:

```cds
using { temporal } from '@sap/cds/common';
entity WorkAssignments : temporal {/*...*/}
```

Aspect `temporal` is defined in *@sap/cds/common* as follows:

```cds
aspect temporal {
  validFrom : Timestamp @cds.valid.from;
  validTo   : Timestamp @cds.valid.to;
}
```

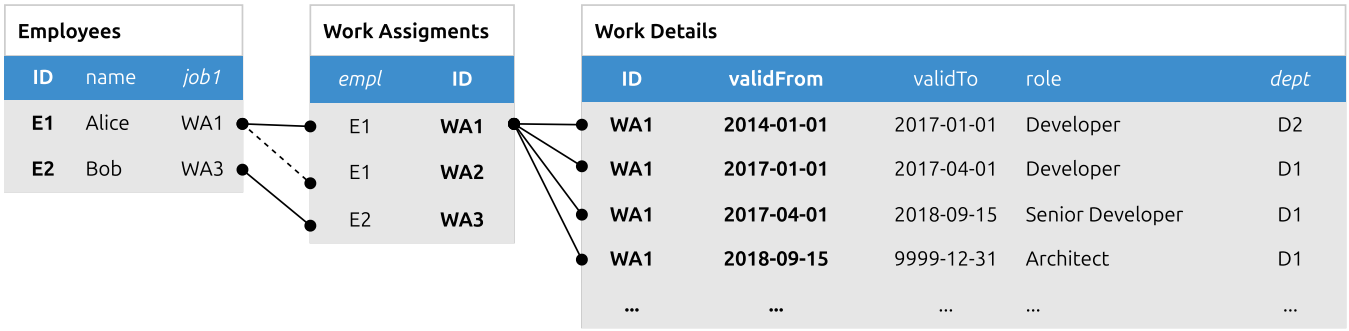
Separate Temporal Details

The previous samples would turn the whole *WorkAssignment* entity into a temporal one. Frequently though, only some parts of an entity are temporal, while others stay timeless. You can reflect this by separating temporal elements from non-temporal ones:

```cds
entity WorkAssignments {          // non-temporal head entity
  key ID  : UUID;
  empl    : Association to Employees;
```

```
  details : Composition of WorkDetails on details.ID = $self.ID;
}
entity WorkDetails : temporal {   // temporal details entity
  key ID  : UUID;                 // logical record ID
  role    : String(111);
  dept    : Association to Departments;
}
```

The data situation would change as follows:



Employees

ID	name	*job1*
E1	Alice	WA1
E2	Bob	WA3

Work Assigments

empl	ID
E1	**WA1**
E1	**WA2**
E2	**WA3**

Work Details

ID	validFrom	validTo	role	*dept*
WA1	**2014-01-01**	2017-01-01	Developer	D2
WA1	**2017-01-01**	2017-04-01	Developer	D1
WA1	**2017-04-01**	2018-09-15	Senior Developer	D1
WA1	**2018-09-15**	9999-12-31	Architect	D1
...	...	...	...	...

Serving Temporal Data

We expose the entities from the following timeless model in a service as follows:

service.cds

```cds
using { com.acme.hr } from './temporal-model';
service HRService {
  entity Employees as projection on hr.Employees;
  entity WorkAssignments as projection on hr.WorkAssignments;
  entity Departments as projection on hr.Departments;
}
```

> You can omit composed entities like *WorkAssignments* from the service, as they would get auto-exposed automatically.

Reading Temporal Data

As-of-now Queries

READ requests without specifying any temporal query parameter will automatically return data valid *as of now*.

For example, assumed the following OData query to read all employees with their current work assignments is processed on March 2019:

```http
GET Employees?
$expand=jobs($select=role&$expand=dept($select=name))
```

The values of `$at`, and so also the respective session variables, would be set to, for example:

$at.from =	*session_context('valid-from')=*	*2019-03-08T22:11:00Z*
$at.to =	*session_context('valid-to') =*	*2019-03-08T22:11:00.001Z*

The result set would be:

```json
[
  { "ID": "E1", "name": "Alice", "jobs": [
    { "role": "Architect", "dept": {"name": "Core Development"}},
    { "role": "Consultant", "dept": {"name": "App Development"}}
  ]},
  { "ID": "E2", "name": "Bob", "jobs": [
    { "role": "Builder", "dept": {"name": "Construction"}}
  ]}
]
```

Time-Travel Queries

We can run the same OData query as in the previous sample to read a snapshot data as valid on January 1, 2017 using the `sap-valid-at` query parameter:

```http
GET Employees?sap-valid-at=date'2017-01-01'
$expand=jobs($select=role&$expand=dept($select=name))
```

The values of `$at` and hence the respective session variables would be set to, for example:

`$at.from` =	session_context('valid-from')=	2017-01-01T00:00:00Z
`$at.to` =	session_context('valid-to') =	2017-01-01T00:00:00.001Z

The result set would be:

```json
[
    { "ID": "E1", "name": "Alice", "jobs": [
      { "role": "Developer", "dept": {"name": "Core Development"}},
      { "role": "Consultant", "dept": {"name": "App Development"}}
    ]}, ...
]
```

> **WARNING**
>
> Time-travel queries aren't supported on SQLite due to the lack of *session_context* variables.

Time-Period Queries

We can run the same OData query as in the previous sample to read all history of data as valid since 2016 using the `sap-valid-from` query parameter:

```http
GET Employees?sap-valid-from=date'2016-01-01'
$expand=jobs($select=role&$expand=dept($select=name))
```

The result set would be:

```json
[
  { "ID": "E1", "name": "Alice", "jobs": [
    { "role": "Developer", "dept": {"name": "App Development"}},
    { "role": "Developer", "dept": {"name": "Core Development"}},
    { "role": "Senior Developer", "dept": {"name": "Core Development"}},
```

```
    { "role": "Consultant", "dept": {"name": "App Development"}}
  ]}, ...
]
```

> You would add *validFrom* in such time-period queries, for example:

```http
GET Employees?sap-valid-from=date'2016-01-01'
$expand=jobs($select=validFrom,role,dept/name)
```

> **WARNING**
>
> Time-series queries aren't supported on SQLite due to the lack of *session_context* variables.

> **TIP**
>
> Writing temporal data must be done in custom handlers.

Transitive Temporal Data

The basic techniques and built-in support for reading temporal data serves all possible use cases with respect to as-of-now and time-travel queries. Special care has to be taken though if time-period queries transitively expand across two or more temporal data entities.

As an example, assume that both, *WorkAssignments* and *Departments* are temporal:

```cds
using { temporal } from '@sap/cds/common';
entity WorkAssignments : temporal {/*...*/
  dept : Association to Departments;
}
entity Departments : temporal {/*...*/}
```

When reading employees with all history since 2016, for example:

```http
GET Employees?sap-valid-from=date'2016-01-01'
$expand=jobs(
  $select=validFrom,role&$expand=dept(
    $select=validFrom,name
```

```
  )
)
```

The results for *`Alice`* would be:

```json
[
  { "ID": "E1", "name": "Alice", "jobs": [
    { "validFrom":"2014-01-01", "role": "Developer", "dept": [
      {"validFrom":"2013-04-01", "name": "App Development"}
    ]},
    { "validFrom":"2017-01-01", "role": "Consultant", "dept": [
      {"validFrom":"2013-04-01", "name": "App Development"}
    ]},
    { "validFrom":"2017-01-01", "role": "Developer", "dept": [
      {"validFrom":"2014-01-01", "name": "Tech Platform Dev"},
      {"validFrom":"2017-07-01", "name": "Core Development"}
    ]},
    { "validFrom":"2017-04-01", "role": "Senior Developer", "dept": [
      {"validFrom":"2014-01-01", "name": "Tech Platform Dev"},
      {"validFrom":"2017-07-01", "name": "Core Development"}
    ]},
    { "validFrom":"2018-09-15", "role": "Architect", "dept": [
      {"validFrom":"2014-01-01", "name": "Tech Platform Dev"},
      {"validFrom":"2017-07-01", "name": "Core Development"}
    ]}
  ]}, ...
]
```

That is, all-time slices for changes to departments since 2016 are repeated for each time slice of work assignments in that time frame, which is a confusing and redundant piece of information. You can fix this by adding an alternative association to departments as follows:

```cds
using { temporal } from '@sap/cds/common';
entity WorkAssignments : temporal {/*...*/
  dept : Association to Departments;
  dept1 : Association to Departments on dept1.id = dept.id
    and dept1.validFrom <= validFrom and validFrom < dept1.validTo;
}
entity Departments : temporal {/*...*/}
```

Primary Keys of Time Slices

While timeless entities are uniquely identified by the declared primary *key* — we call that the *conceptual* key in CDS — time slices are uniquely identified by *the conceptual key + validFrom*.

In effect the SQL DDL statement for the *WorkAssignments* would look like this:

```sql
CREATE TABLE com_acme_hr_WorkAssignments (
    ID : nvarchar(36),
    validFrom : timestamp,
    validTo : timestamp,
    -- ...
    PRIMARY KEY ( ID, validFrom )
)
```

In contrast to that, the exposed API preserves the timeless view, to easily serve as-of-now and time-travel queries out of the box as described above:

```xml
<EntityType Name="WorkAssignments">
  <Key>
    <PropertyRef Name="ID"/>
  </Key>
  ...
</EntityType>
```

Reading an explicit time slice can look like this:

```sql
SELECT from WorkAssignments WHERE ID='WA1' and validFrom='2017-01-01'
```

Similarly, referring to individual time slices by an association:

```cds
entity SomeSnapshotEntity {
  //...
  workAssignment : Association to WorkAssignments { ID, validFrom }
}
```

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