A 3D data modeling approach for integrated management of below and above ground utility network features

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TU Delft

Content

A 3D data modeling approach for integrated management of below ground utility network features and related above ground city objects

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A way of handling/storing three-dimensional data

A 3D data modeling approach for **integrated management** of below ground utility network features and related above ground city objects

Management of different data in a (cooperative) system/environment

Asset management

[**as**-et **man**-ij-m*uh* nt]

noun

1. An integrated framework for the maintenance of the assets, above and below ground, in public space. In order to spend the maintenance budget as wisely as possible and better decision making an optimum balance is needed between costs, performance and risk.

A 3D data modeling approach for integrated management of below ground utility network features and related above ground city objects

Any components that are part of the below ground utility network e.g. a pipe or cable.

City objects that are visible above ground and have a relationship or dependency with the below ground utility network e.g. a streetlight

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Problem statement and motivation

Substantial work has already been done in the modelling and representation of above ground features in the context of 3D city modelling

BUT the below ground part of the real world, of which utility networks form a big part, is often neglected in 3D city models

At the same time…

Several utility network data models exist.

BUT these are commonly tailored to a specific domain

A comprehensive 3D standard data model which provides a common basis for the integration of the different utility networks and 3D city objects in order to facilitate analyses, visualization and management tasks, lacks.

Research question and Scope

How to efficiently model below ground utility networks and related above ground 3D city objects in order to facilitate integrated asset management?

Sub-research questions:

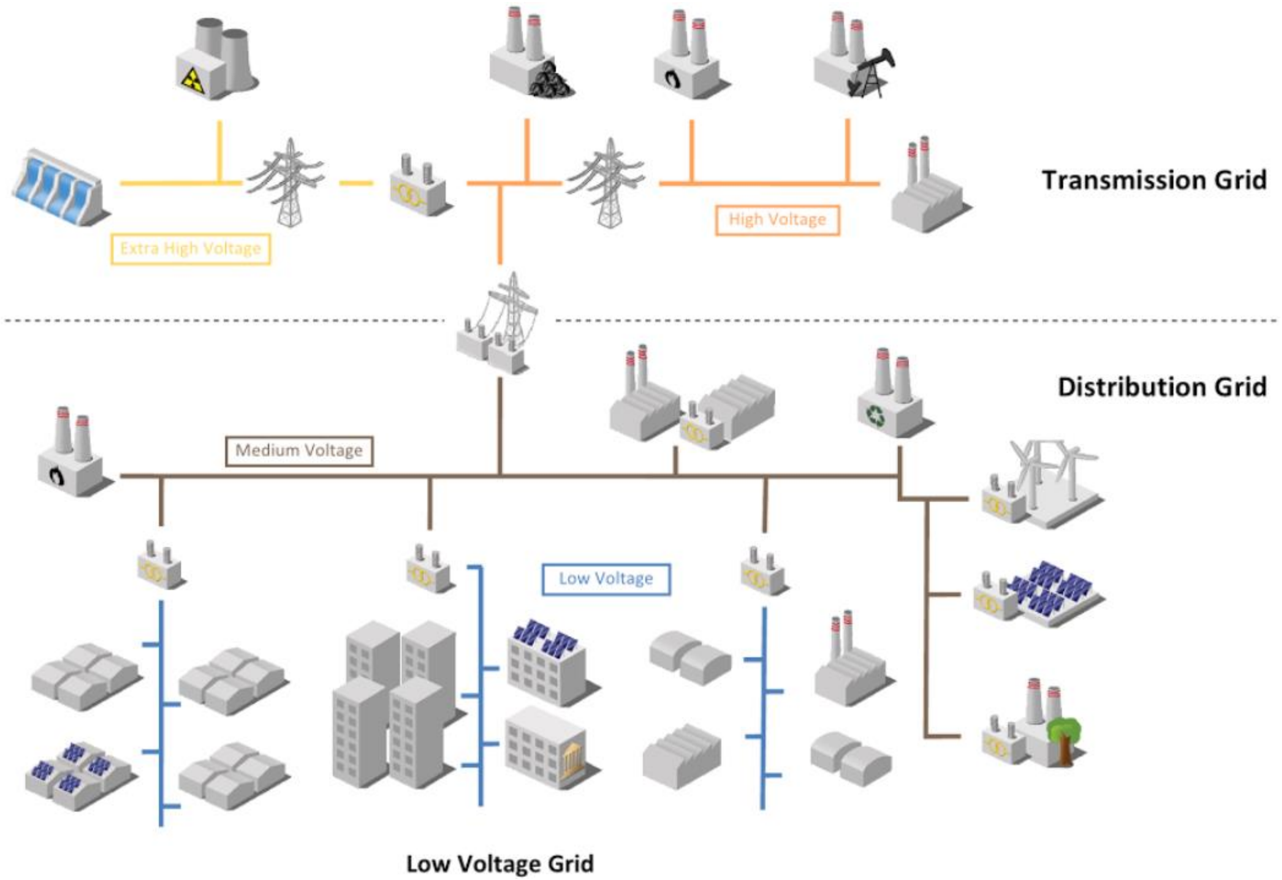
- *What dependencies and relations between below and above ground utility network features are of importance for the municipality of Rotterdam in order to facilitate asset management?*
- *To what extent can the current state of an existing utility network data model such as the CityGML Utility Network ADE fulfil the needs of the municipality of Rotterdam?*
- *Is the proposed data modeling approach suitable for implementation of existing utility network data and city objects in 3D city models?*
- *Which mapping methods are required to derive a relational database from the designed data model?*
- *Can the designed relational database be used to perform essential (spatial) operations?*
- *How to visualize the modeled data and (spatial) operations on the designed relational database?*

Scope:

- Two different types of utility networks and related city objects
- Only actual physical relationship (nothing like proximity)
- Representation in a low LoD
- Other types of data, e.g. financial data, will not be considered

Background: Electricity network

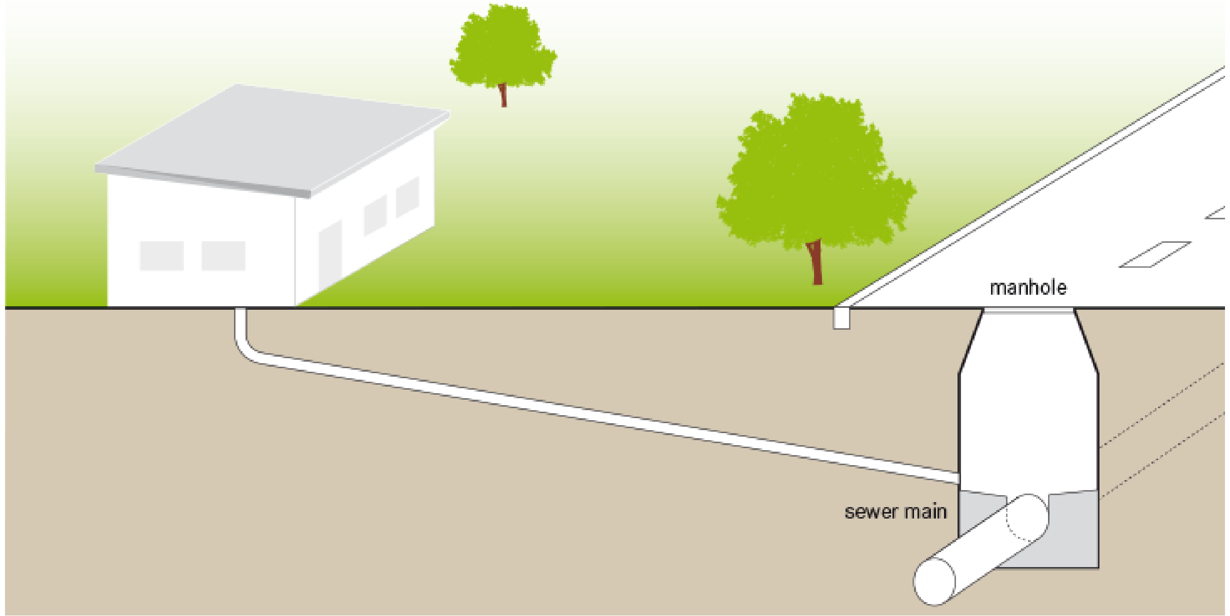
Most above ground city objects relate to the Low-Voltage Grid, e.g. streetlights

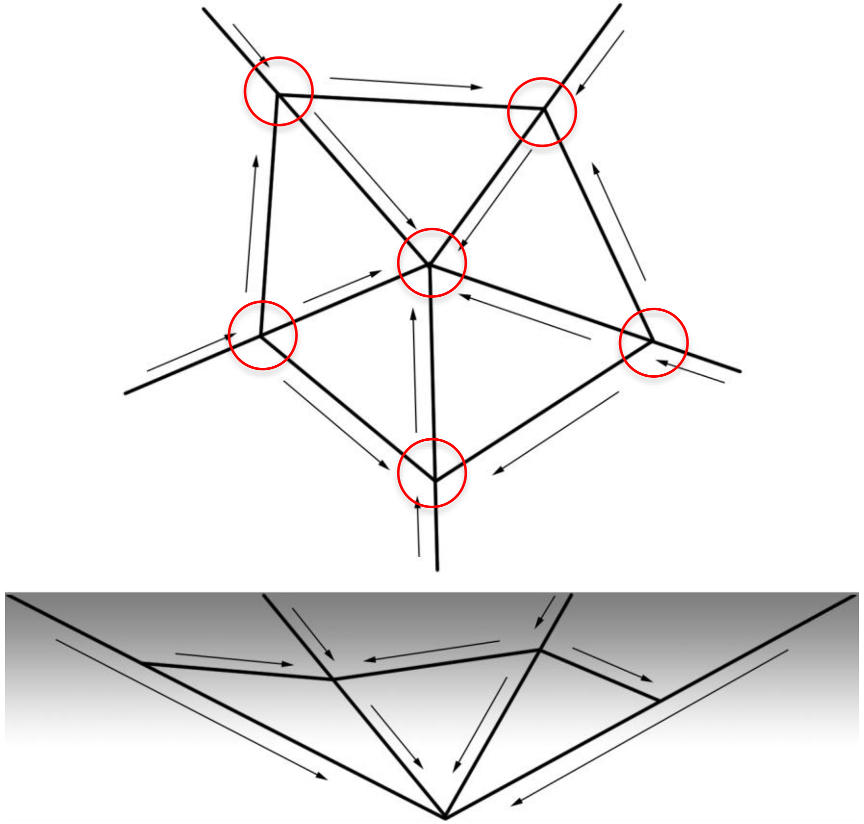


Background: Sewer network

In a standard sewer system, water is transported from higher to lower elevation due gravity

Manholes are mainly used for inspection and put at points of intersection or change of direction/material





Background: Existing utility network data models

Why the CityGML Utility Network ADE?

Data model	2D/3D	Scale	Topological relationships		Utility type
			network features	network features and city objects	
INSPIRE Utility Networks	2D	Urban	Yes	No	Any
IFC Utility model	2D+3D	Building	Yes	Yes*	Any
ESRI Utility Network	2D**	Urban	Yes	No	Any
PipelineML	2D	Urban	Yes	No	Oil and gas
CIM	-	Urban	Yes	No	Electricity
IMKL	2D+3D	Urban	Yes	No	Any
CityGML Utility Network ADE	2D+3D	Urban	Yes	Yes	Any***

Table 3.1: A comparison between the different utility network data models

*Only inside a building
**Only in 3D for just pure visualization purposes
***A single model is used for any type of utility network

The CityGML Utility Network ADE is capable of:

- Relating utility network features as well as utility network features and above ground city objects
- Modeling relationships and dependencies between network features of **different** types of networks
- Embedding into 3D urban space (since it is part of the matured CityGML standard)

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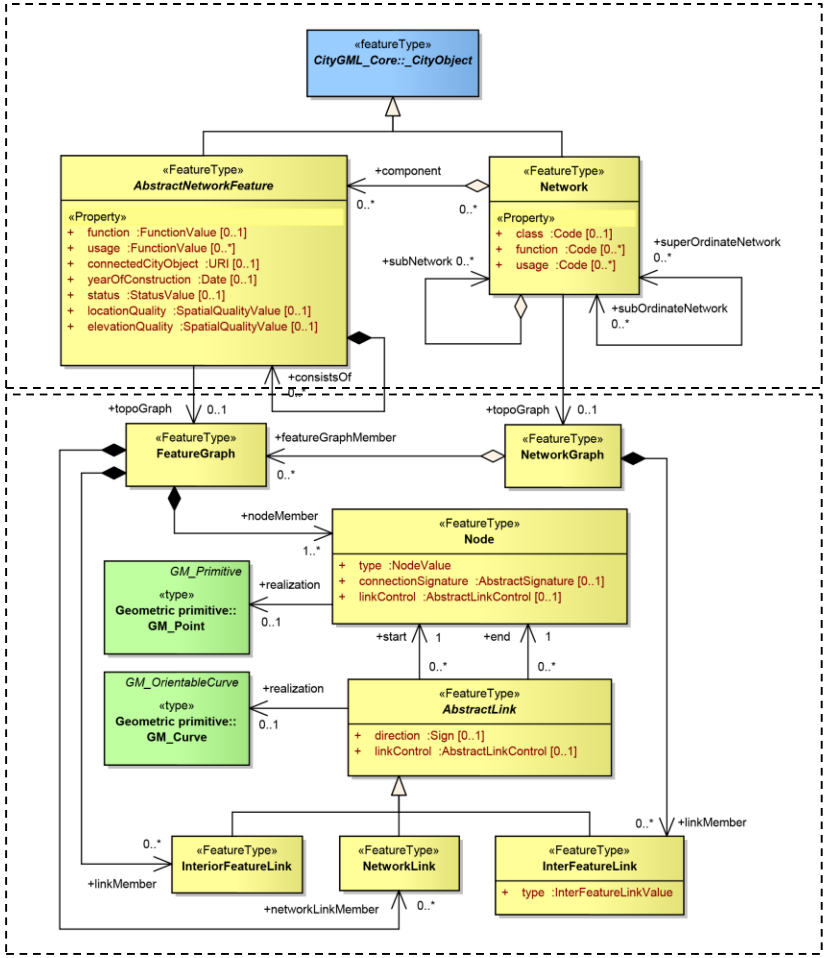
CityGML Utility Network ADE

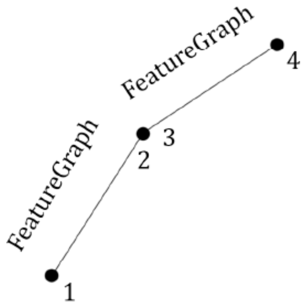
Topograph →

Graph →



- Currently consisting of:
  - the Core module
  - 5 additional modules to add more detail
    - Feature Material
    - Functional Characteristics
    - Hollow Space
    - Network Components
    - Network Properties
- This data model is continuously under development!

→



InteriorFeatureLinks

id	start	end	geom
1	1	2	0 0 0, 2 3 1
2	3	4	2 3 1, 5 5 2

InterFeatureLinks

id	start	end
1	2	3

Nodes

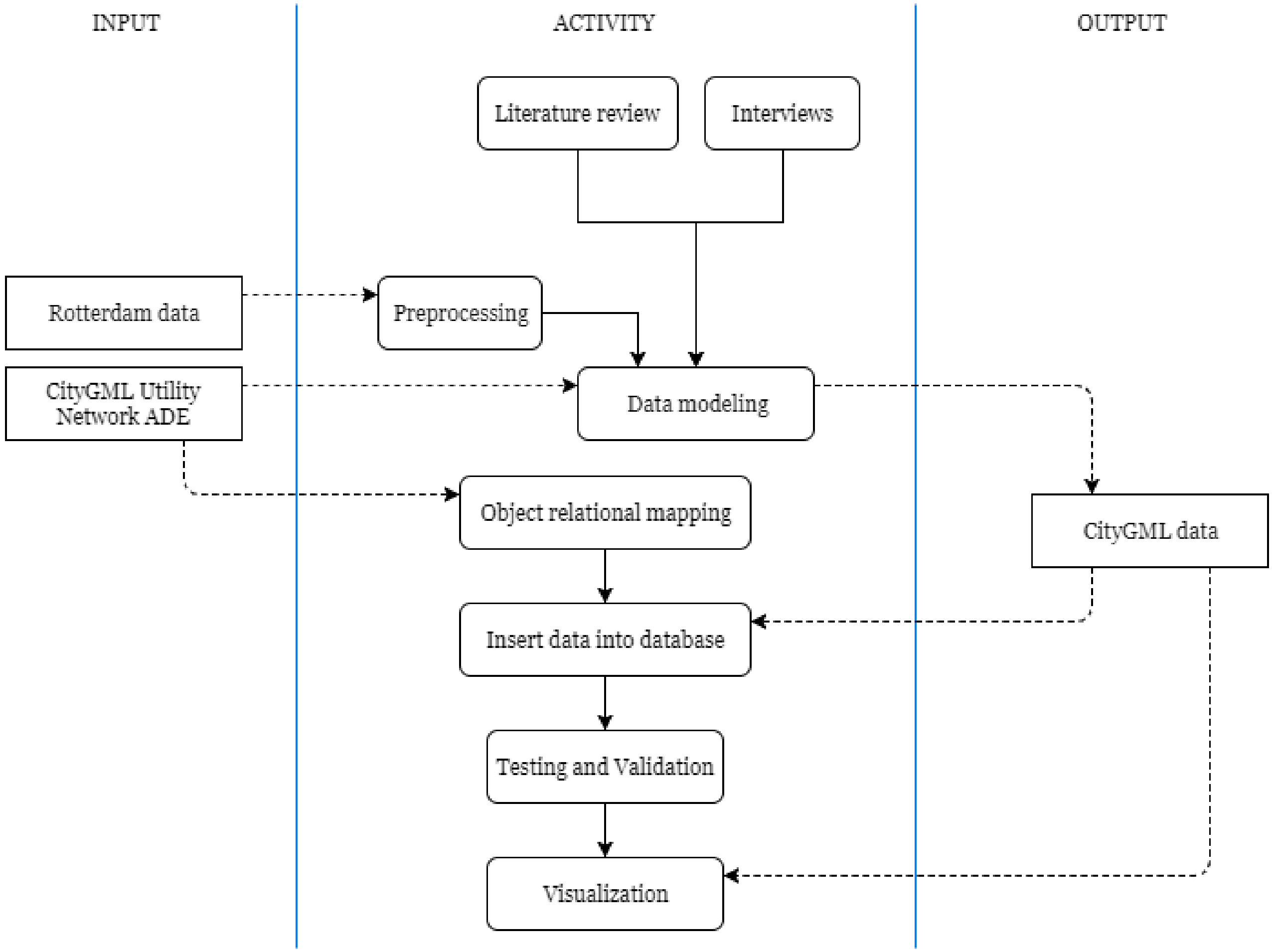
id	geom
1	0 0 0
2	2 3 1
3	2 3 1
4	5 5 2

FeatureGraphs

id
1
2

Figure 4.7: Utility Network ADE topology principle

Conceptual design



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What are we working with?

- Lines representing a pipe or cable

Depending on the use, different types of utility networks are measured differently.
For example, the inner bottom of standard sewer pipes is measured.
For other types mostly the outer top is measured.

- Points representing the location of a city object, e.g. a streetlight

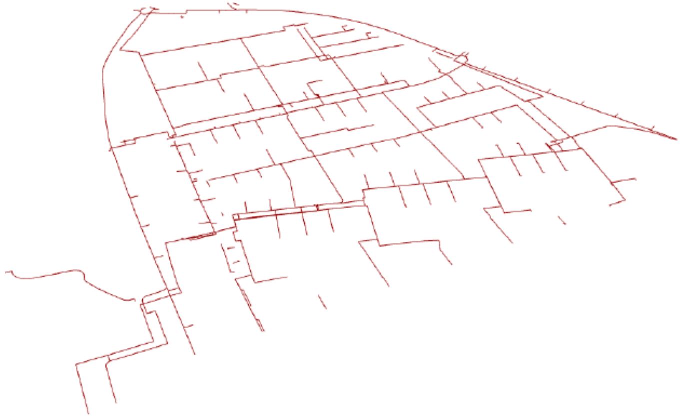
Often these are in 2D

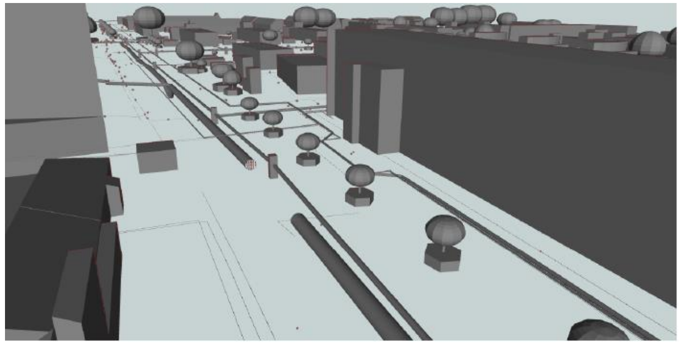
Both lines and points are in ESRI Shapefile format!

- A 3D model of the city of Rotterdam

The 3D model includes buildings, trees, ground level, design and building information. Pipes and cables are modeled as generic city objects.

The 3D model is in CityGML format





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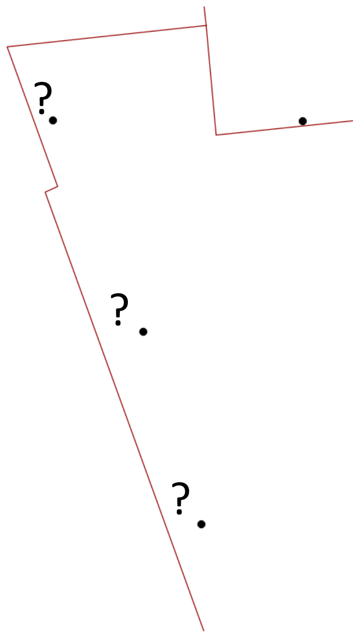
Preprocessing

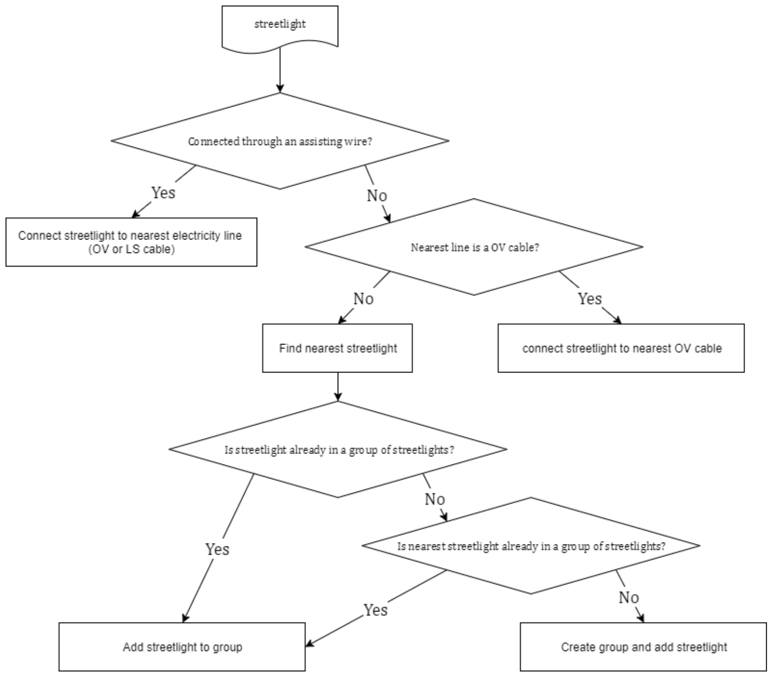
Problem

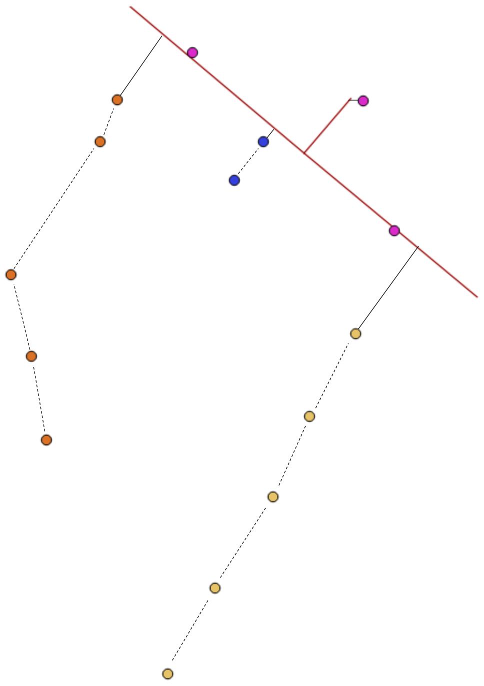
The connection line to streetlights is not registered
→ it is unknown how the streetlights are connected to the below ground electricity lines.

Solution

An algorithm that computes a best estimate of what streetlights are connected to what streetlights and what streetlights are connected to what electricity line

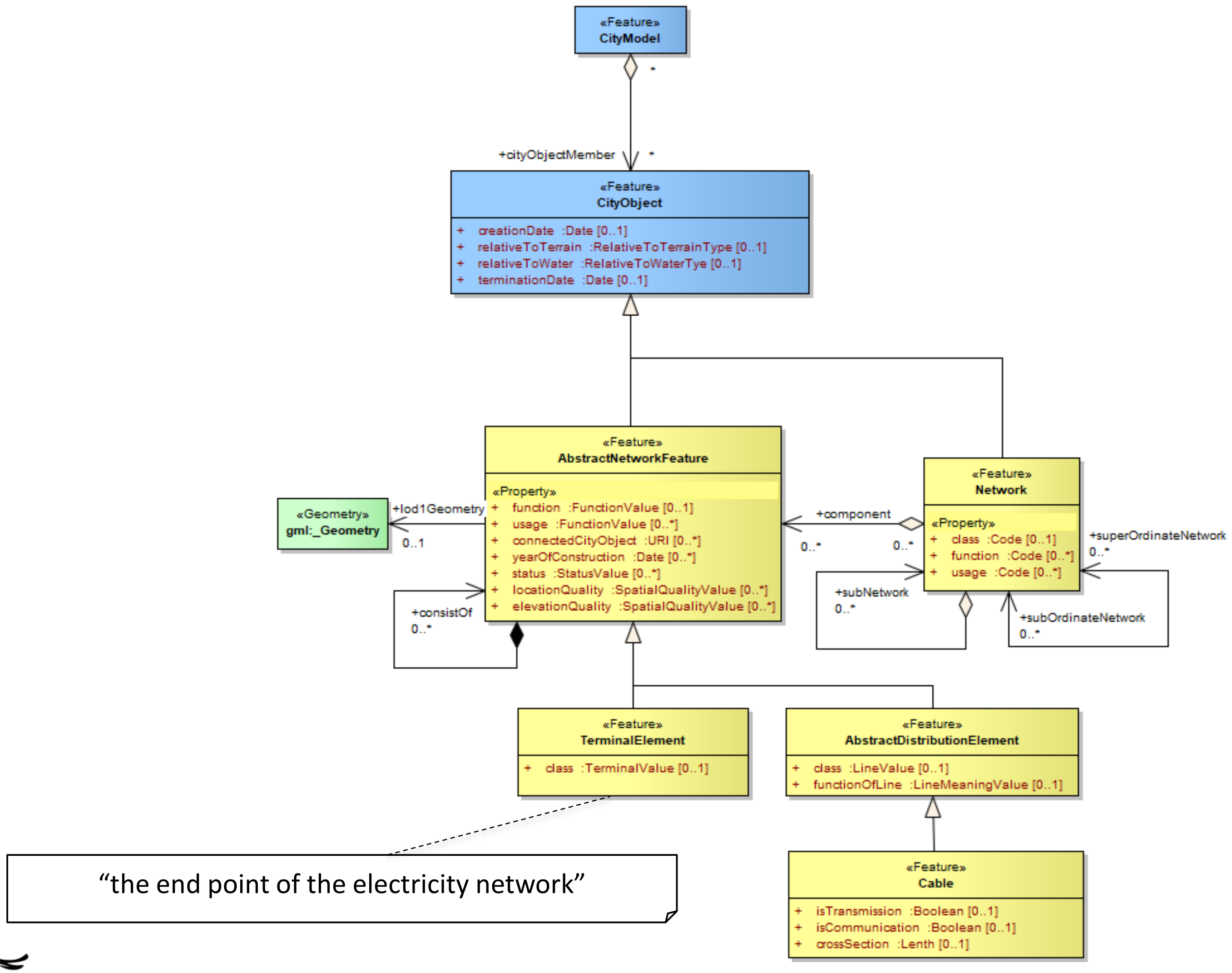






Utility network data mapping

Electricity network



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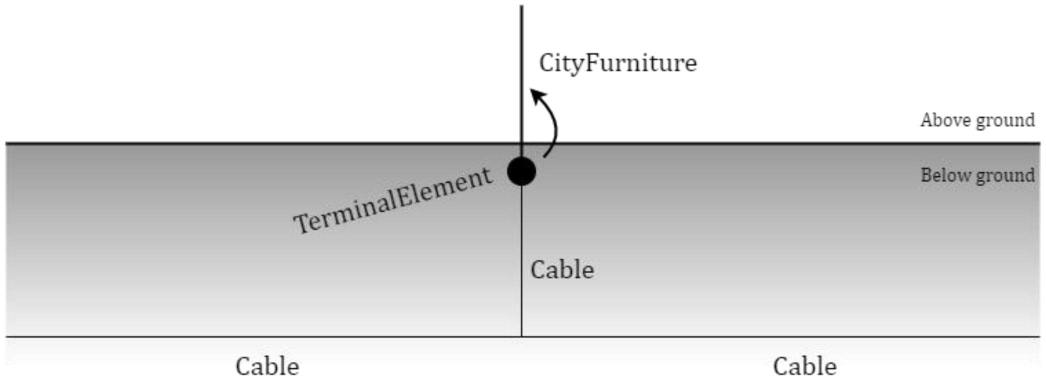
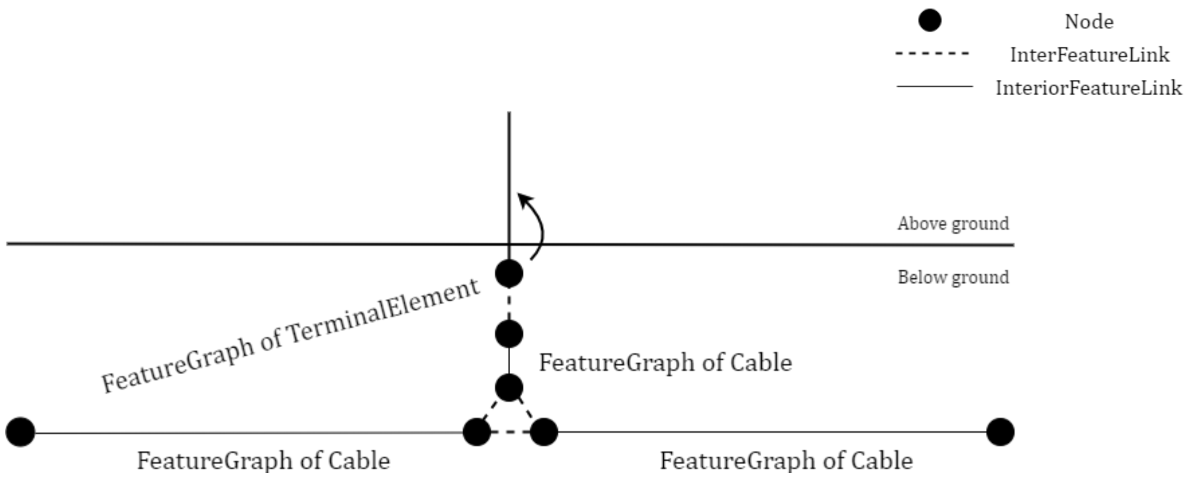
Utility network data modelling

Electricity network

Topography

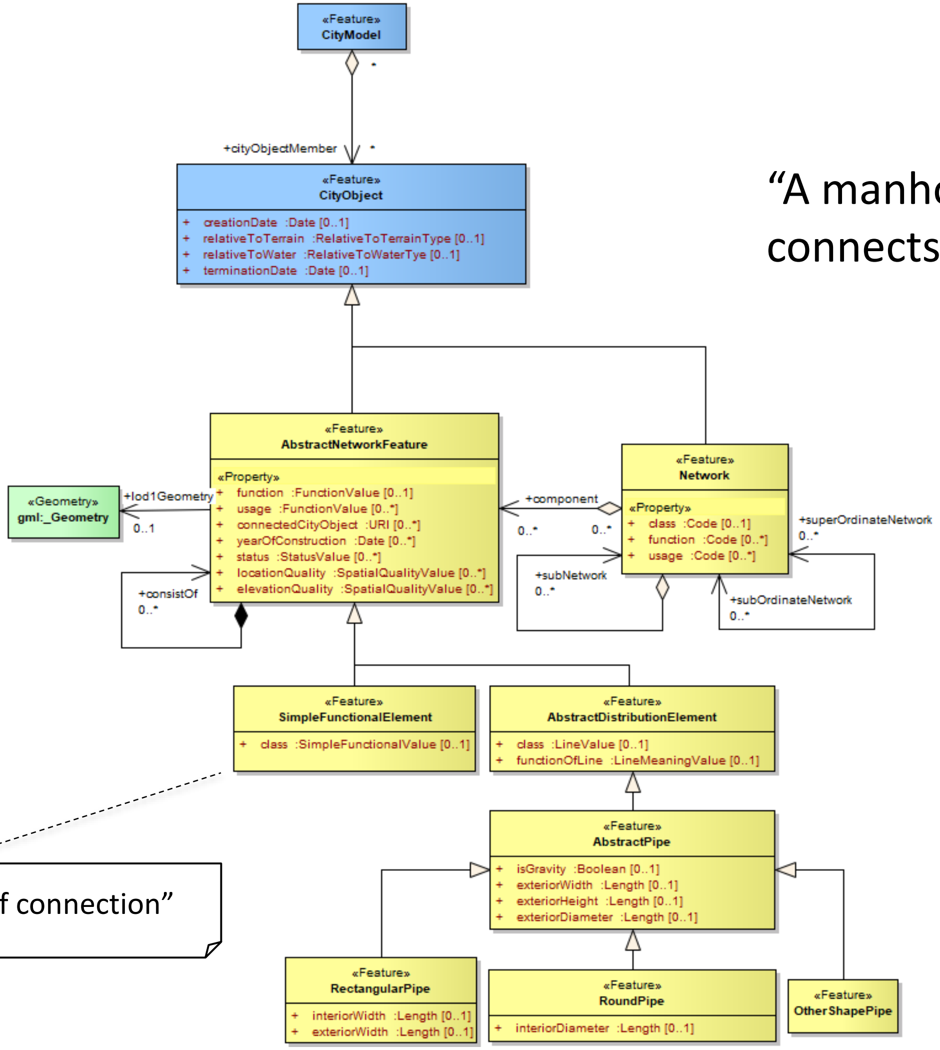


Graph



Utility network data modelling

Sewer network



“A manhole is a vertical pipe, usually made of concrete, that connects the below ground sewer network to the surface”

“a manhole is a point of connection”

These are manholes! →

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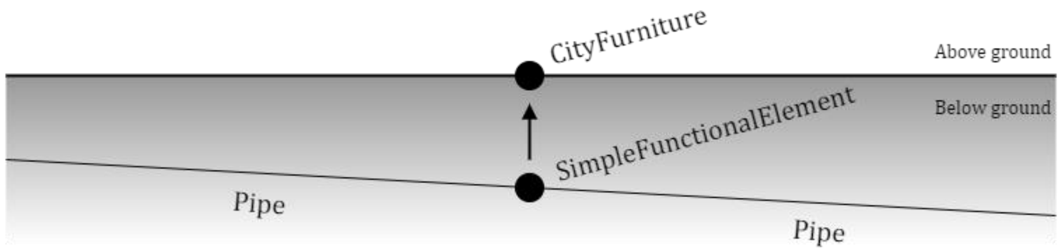
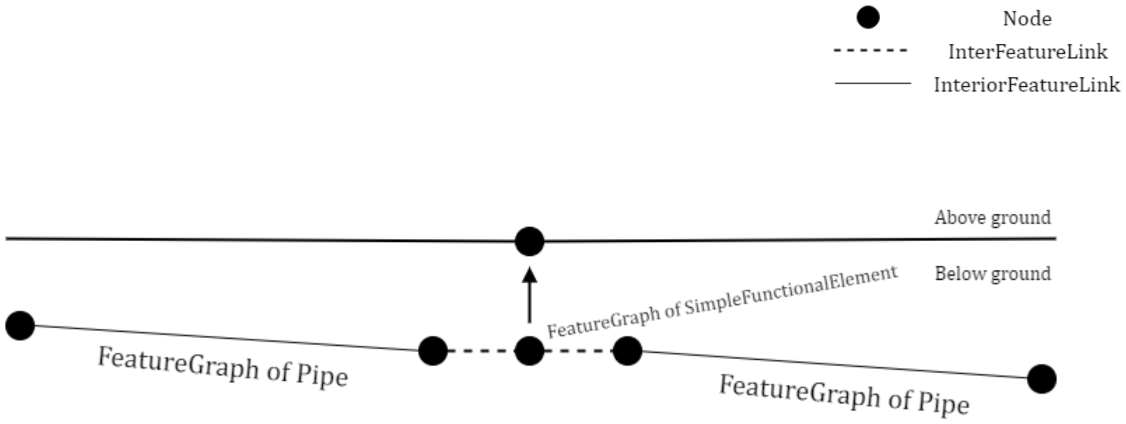
Utility network data modeling

Sewer network

Topography



Graph



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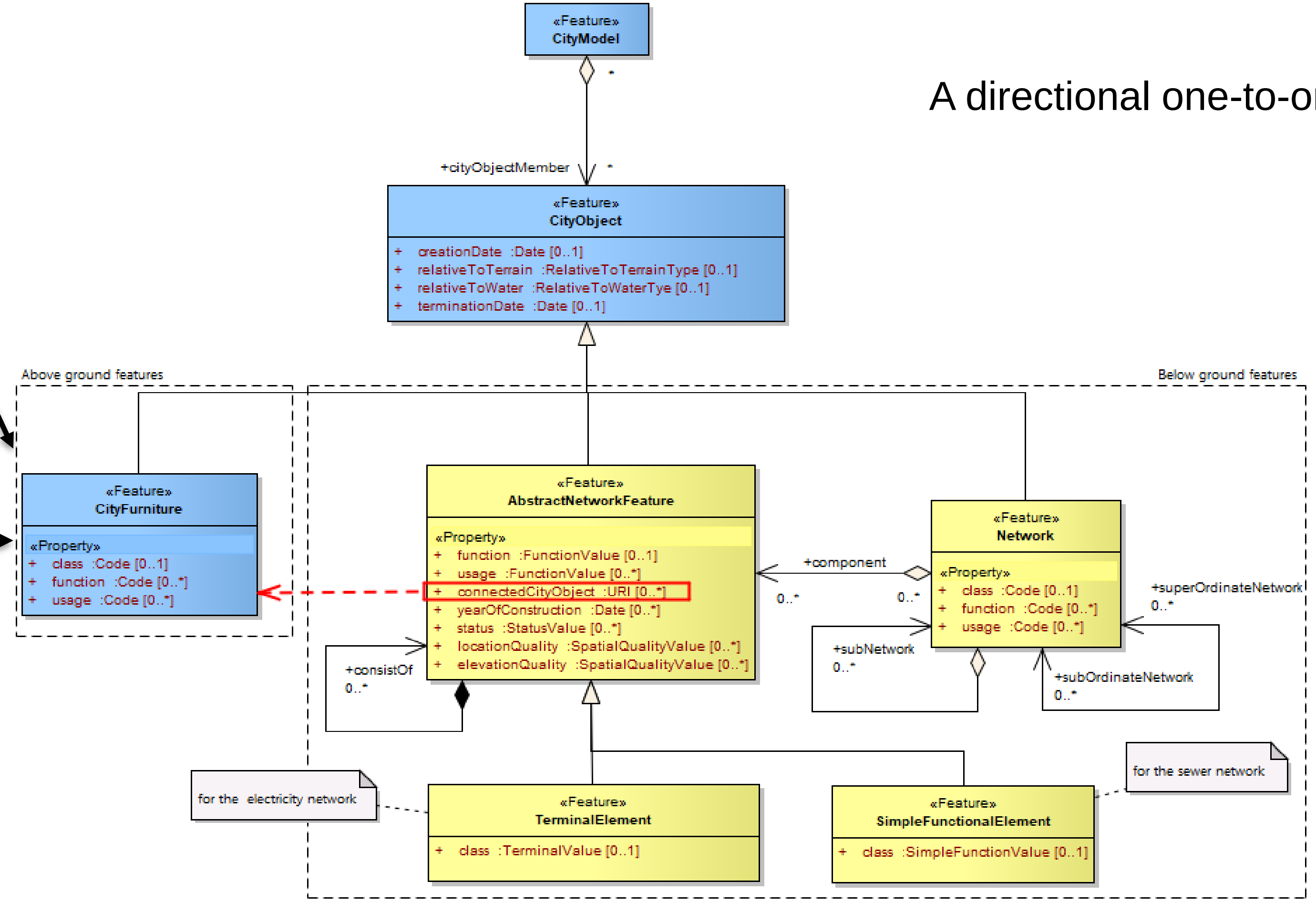
Linking below and above ground utility network features



A directional one-to-one relationship!

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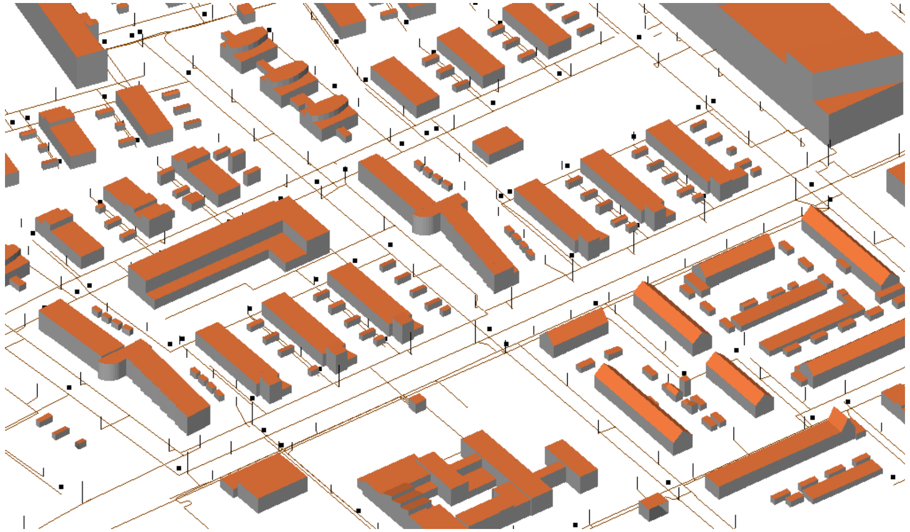
This is completely done in FME!

- This is a complex translation (over a 100 transformers are used and lots of relationships)
- The workspace is particularly designed for the Rotterdam data in vector file format

- Building the topology is an important step. Its success relies on the type and quality of the input data

→ a .gml file is output

And can be visualized in the FZKViewer or the FME Data Inspector



BUT the support and possibilities are limited

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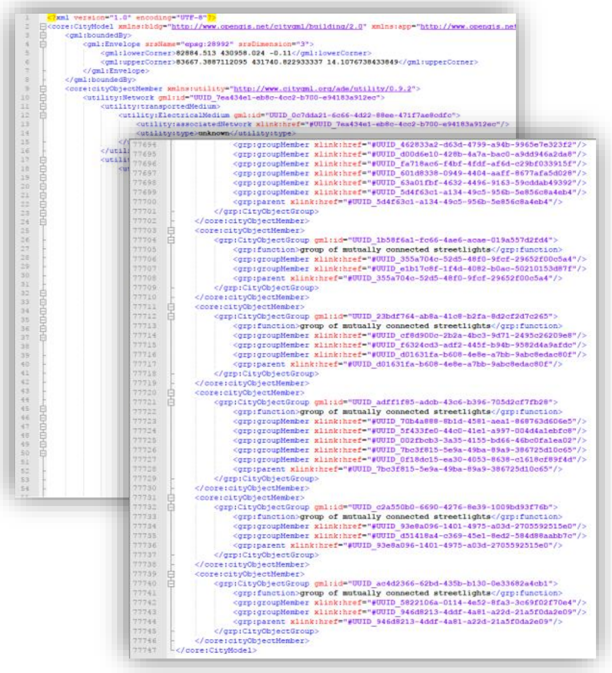
Derivation of the relational database



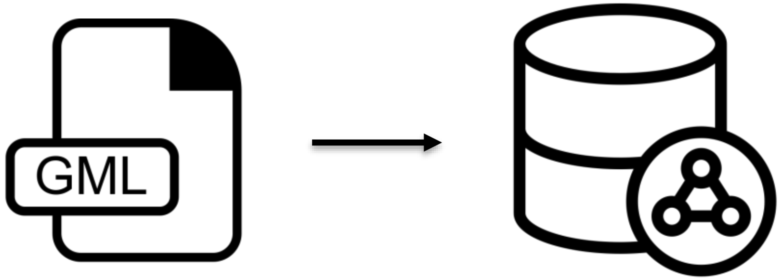
Why?

- CityGML datasets may become very large and objects may be arbitrarily nested leading to complex data structures
- Efficient storage and management of CityGML data requires carefully optimized database schemas
- To ensure interoperable data access and detailed (network) operations

How?

- Mapping the CityGML Core
- Extend the database by mapping the CityGML Utility Network ADE

All by means of 3DCityDB!



3DCityDB can be used to store, represent, and manage virtual 3D city models in a relational database that implements the CityGML standard.

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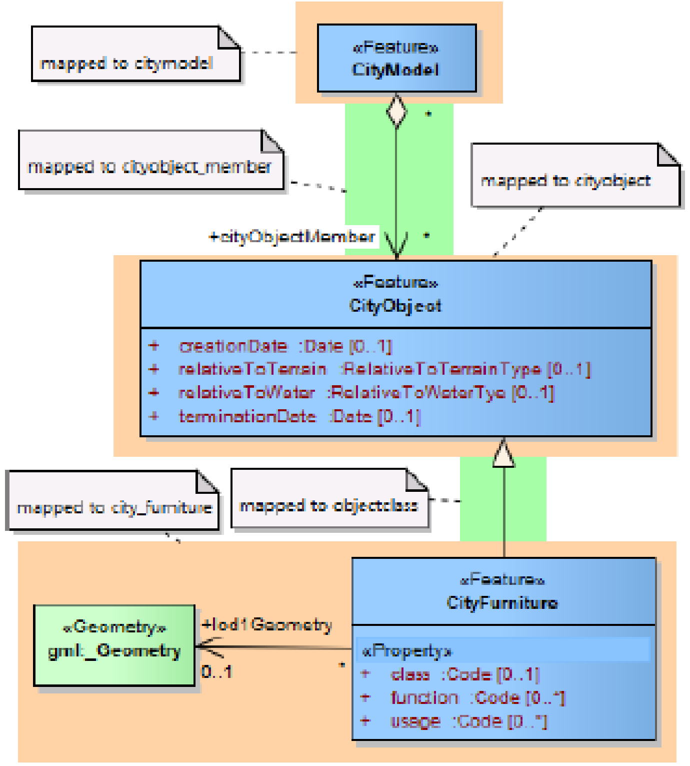
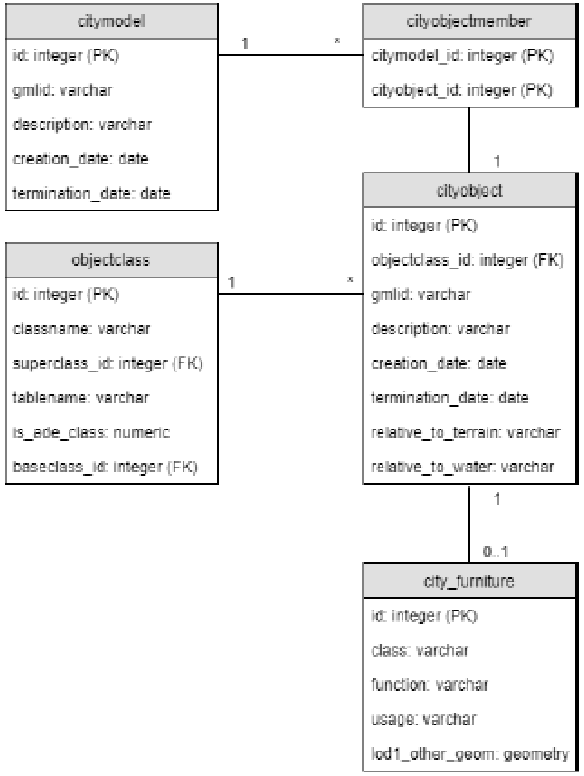
Derivation of the relational database

Mapping the relevant classes of the CityGML Core → 5 tables



(a)

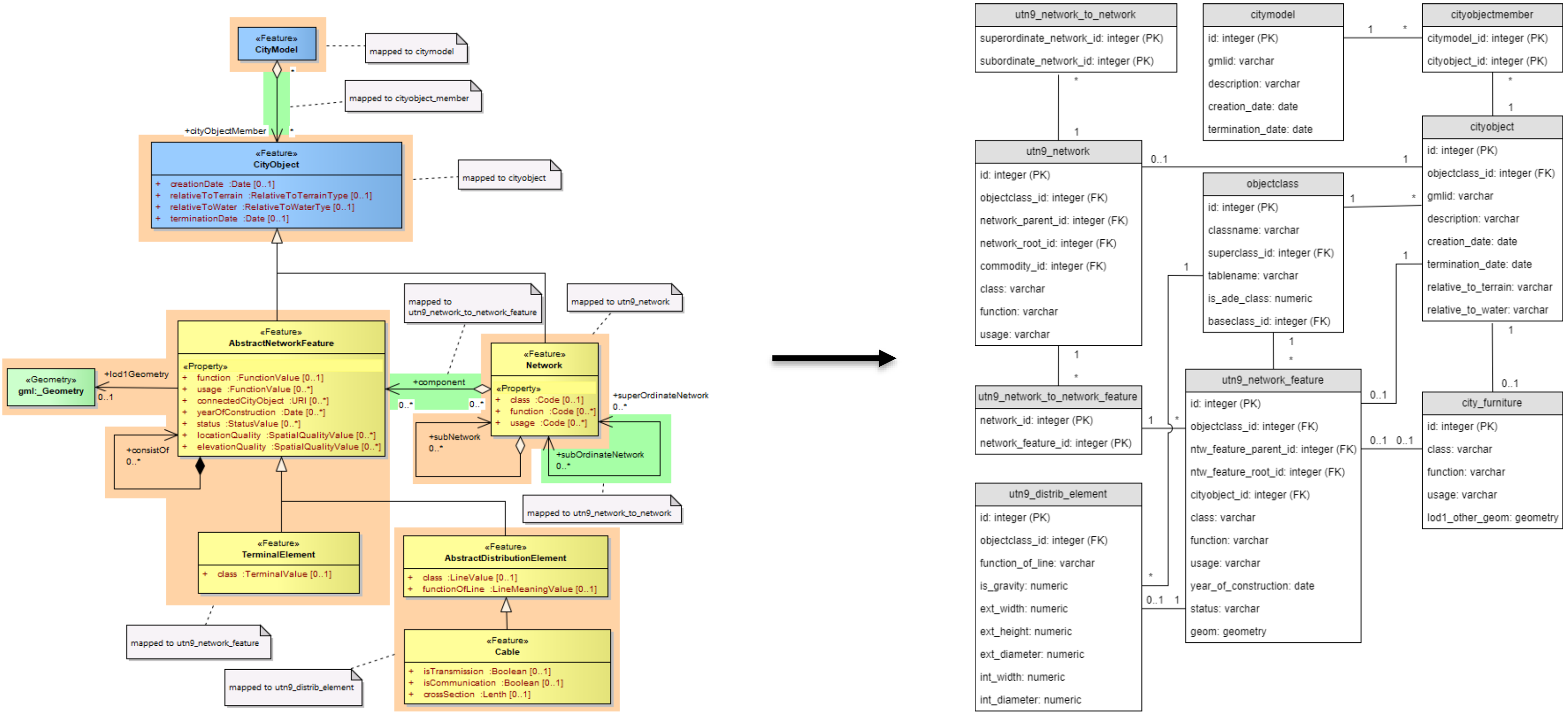


(b)

← What kind of cityobject

Derivation of the relational database

Mapping the relevant classes of the CityGML Utility Network ADE → 5 more tables!



← What kind of cityobject

Generally, most abstract classes are mapped to a single table with an additional field used to specify the object class.
Additional tables had to be created for establishing the one-to-many, many-to-one or many-to-many relationships.

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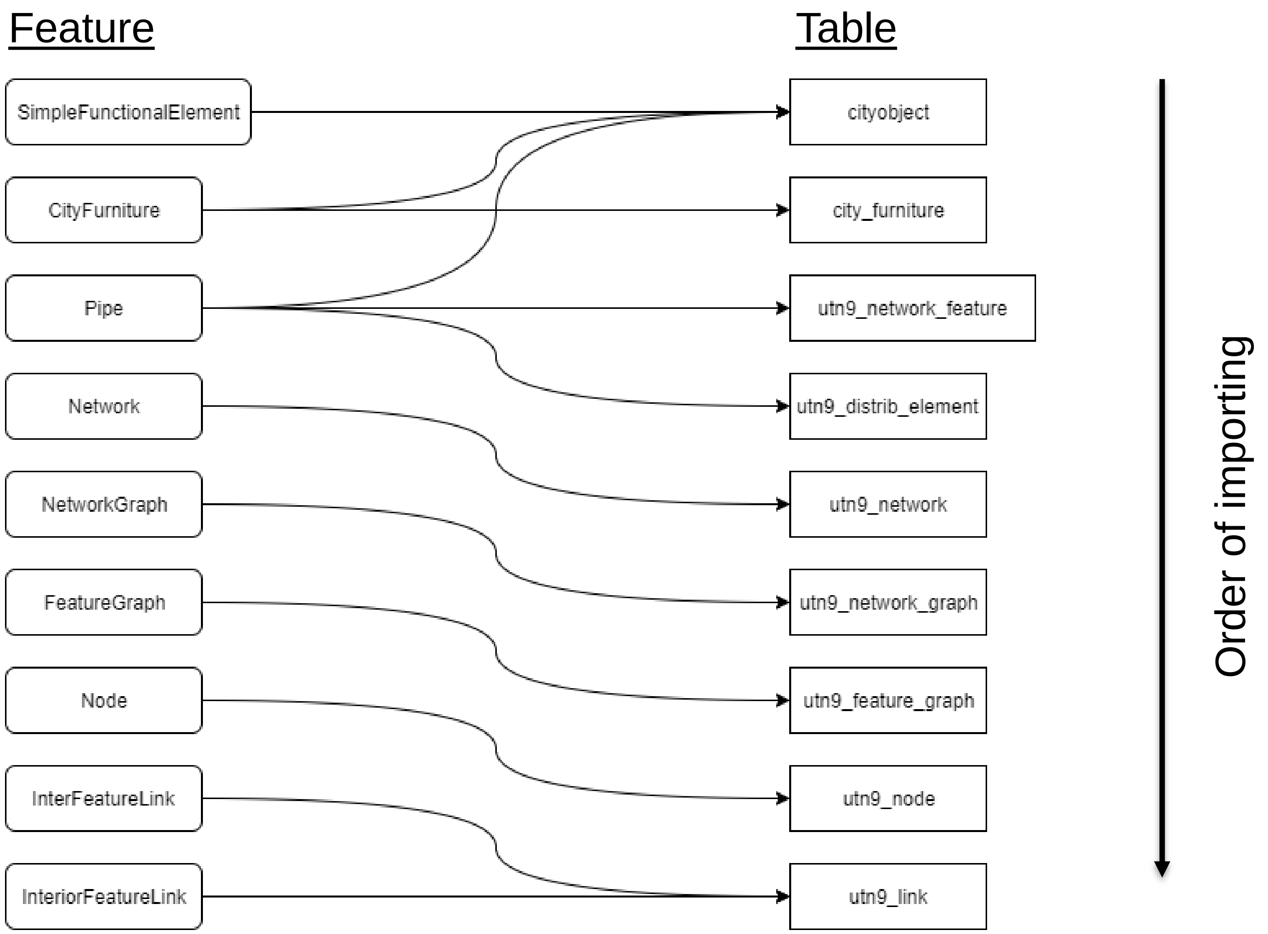
Importing the CityGML data

- Importing the data is a task that must be handled with care
- Parallel importing of all feature types into the tables in a single workspace might cause an error due to referencing to not existing id’s

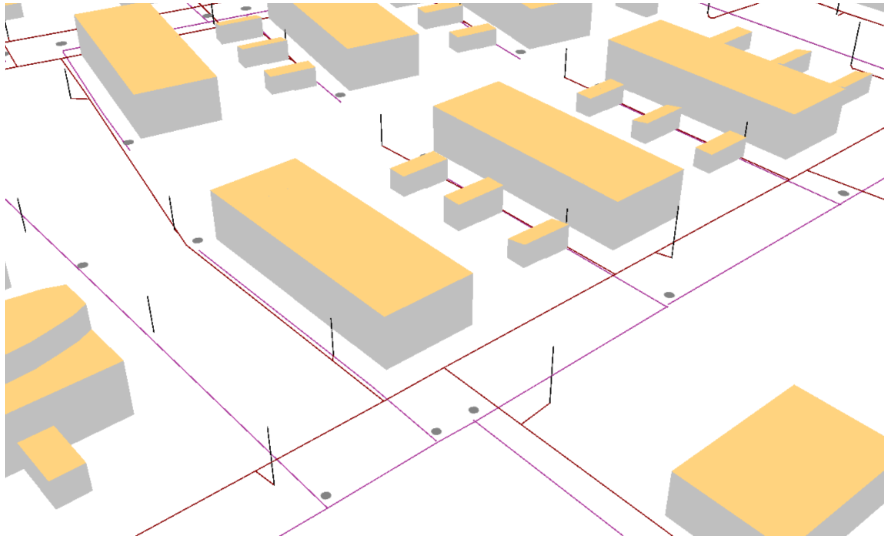


*Depending on the utility network type, the features differ slightly

Importing the CityGML data

- The inserting of the CityGML Utility Network ADE data is done in FME (again)
- A command line batch file is created that runs the different workspaces, used to populate the different tables with the CityGML data, after each other

And connecting to a GIS e.g. ArcGIS



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Testing and Validation; querying the database

SQL scripts are written in order to conduct (network) analyses on the spatial data in the relational database

Scenario: What streetlights are affected in case of a utility strike?

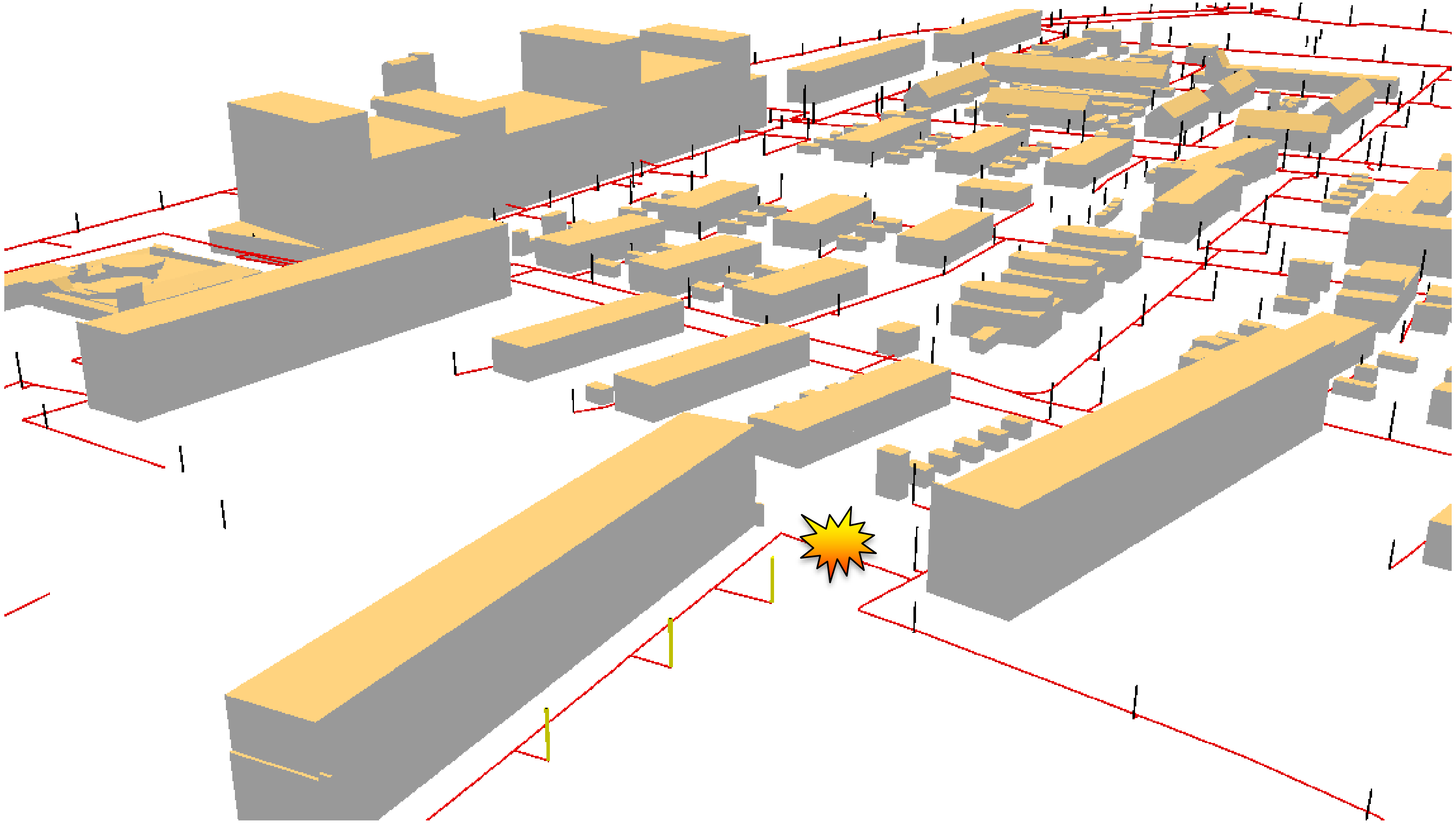
1. Knowing the location, what geometries are affected?
2. What FeatureGraphs and corresponding nodes are affected?
3. What nodes can (not) be reached? (PgRouting)
4. What city furniture objects (streetlights) are affected?

id	classname	cityobject_id	lod1_other_geom
142	TerminalElement	1560	01020000A040...
151	TerminalElement	1569	01020000A040...
159	TerminalElement	1577	01020000A040...
1037	Cable	null	null
1038	Cable	null	null
1039	Cable	null	null
1235	Cable	null	null
1291	Cable	null	null
1326	Cable	null	null

```
SELECT ntw_feature_id, classname, cityobject_id, lod1_other_geom
FROM(
    SELECT ntw_features.id as ntw_feature_id, classname, cityobject_id
    FROM(
        SELECT id, objectclass_id, cityobject_id
        FROM(
            SELECT utn9_feature_graph.ntw_feature_id
            FROM(
                SELECT feat_graph_id
                FROM(
                    SELECT sum(cost) AS sum_cost, end_vid as node_id
                    FROM pgr_dijkstra(
                        'SELECT id, start_node_id::int4 AS source,
                        end_node_id::int4 AS target, cost::double precision
                        FROM utn9_link
                        WHERE id != 2440',
                        1647, array[1,2,3...], false)
                    GROUP BY node_id
                    ORDER BY sum_cost ASC) as nodes_in_reach
                JOIN utn9_node ON nodes_in_reach.node_id = utn9_node.id
                GROUP BY feat_graph_id) as feat_graph_ids
            JOIN utn9_feature_graph ON feat_graph_ids.feat_graph_id =
            utn9_feature_graph.ntw_feature_id) as ntw_feature_ids
        JOIN utn9_network_feature ON ntw_feature_ids.ntw_feature_id =
        utn9_network_feature.id) as ntw_features
    JOIN objectclass ON ntw_features.objectclass_id = objectclass.id)
    as terminalelement_ids
LEFT OUTER JOIN city_furniture ON terminalelement_ids.cityobject_id =
city_furniture.id
```

A tabular output is not so sexy

Affected streetlights in ArcGIS



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Conclusion

How to efficiently model below ground utility networks and related above ground 3D city objects in order to facilitate integrated asset management?

This research has shown the suitability of the CityGML Utility Network ADE by the implementation of two types of below ground utility networks (viz. Low-Voltage electricity and standard sewer)

And is successfully examined by implementing relationships between:

1) the below ground electricity network and above ground streetlights and
2) between the sewer network and the above ground manhole covers

The object-oriented CityGML model is successfully mapped to a relational database which has proven to be efficient for storing, management and analyses by means of the performed (network) operations.

Future work

- Implementation of more different utility networks and city objects
- Modeling in a higher Level of Detail (LoD)
- Detailing the CityGML Utility Network ADE classes and use
- Better investigating on more types of analyses
- Implementing larger datasets
- Implementing datasets with a different accuracy
- Exporting a CityGML file from the relational database
- Better investigating on visualization of the data
- Investigation on how to model different types of relationships

Thank you!

AD

Nieuws Regio Sport Show Video Koken & Eten Abonneren

Alphen Amersfoort Amsterdam Apeldoorn Arnhem Bergen op Zoom Breda Delft Den Bosch Den Haag Dordrecht Meer...

Alleen in het centrum brandde nog licht. Het grootste deel van Rotterdam-Noord zat zonder stroom. © J3lte / Twitter

Stroomstoring Rotterdam-Noord na anderhalf uur voorbij

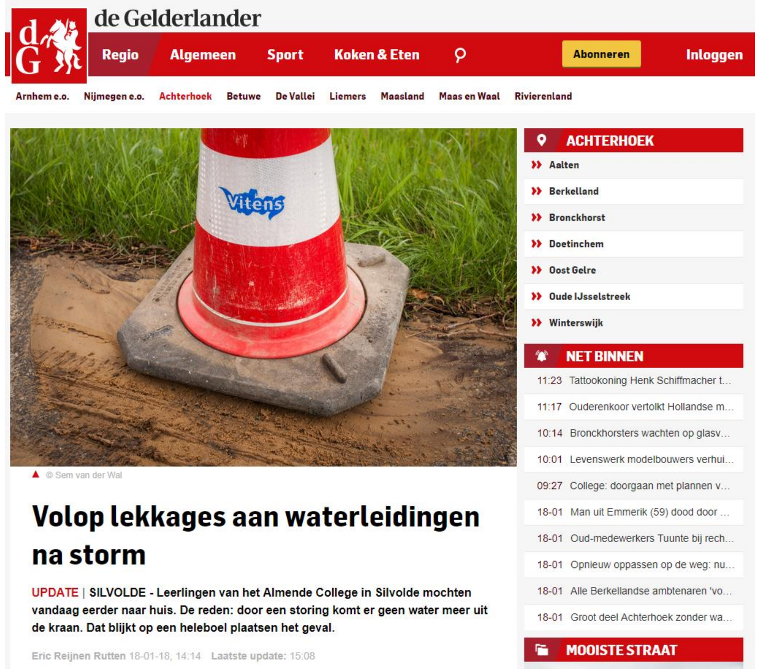
Door een grote stroomstoring is het pikkedonker geweest in grote delen van Rotterdam-Noord. In onder meer Bergpolder, Blijdorp en het Oude Noorden zaten 29.645 huishoudens anderhalf uur zonder stroom.

Adrianne de Koning 13-12-17, 19:09 Laatste update: 21:48

NET BINNEN

09:12 Stroomstoring in klein deel Baren…
08:38 Jongens krijgen wijkverbod na ov…
07:31 Forse vertraging Hoekse Lijn: reizi…
06:52 'Bakkie? What do you mean?'
06:40 Slachtoffer is benieuwd naar verh…
06:17 D66 wil rem op sis-boetes
13-12 Roxeanne Hazes en Lakshmi tred…
13-12 Radioprijs voor Rijnmond-duo
13-12 Arabisch restaurant Bab Tuma wil…
13-12 Stroomstoring Rotterdam-Noord n…

Elke dag op de hoogte van



de Gelderlander

Regio Algemeen Sport Koken & Eten Abonneren Inloggen

Arnhem e.o. Nijmegen e.o. Achterhoek Betuwe De Vallei Liemers Maasland Maas en Waal Rivierenland

© Sem van der Wal

Volop lekkages aan waterleidingen na storm

UPDATE | SILVOLDE - Leerlingen van het Almende College in Silvolde mochten vandaag eerder naar huis. De reden: door een storing komt er geen water meer uit de kraan. Dat blijkt op een heleboel plaatsen het geval.

Eric Reijnen Rutten 18-01-18, 14:14 Laatste update: 15:08

ACHTERHOEK

- Aalten
- Berkelland
- Bronckhorst
- Doetinchem
- Oost Gelre
- Oude IJsselstreek
- Winterswijk

NET BINNEN

11:23 Tattookoning Henk Schiffmacher t…
11:17 Ouderenkoor vertolkt Hollandse m…
10:14 Bronckhorsters wachten op glasv…
10:01 Levenswerk modelbouwers verhui…
09:27 College: doorgaan met plannen v…
18-01 Man uit Emmerik (59) dood door …
18-01 Oud-medewerkers Tuunte bij rech…
18-01 Opnieuw oppassen op de weg: nu…
18-01 Alle Berkellandse ambtenaren 'vo…
18-01 Groot deel Achterhoek zonder wa…

MOOISTE STRAAT

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